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Perch (*Perca fluviatilis*) and pikeperch (*Sander lucioperca*) in the diet of the great cormorant (*Phalacrocorax carbo*) and effects on catches in the Archipelago Sea, Southwest coast of Finland

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ABSTRACT

We investigated cormorant diet in the Archipelago Sea, Southwest coast of Finland. Samples of cormorant pellets, regurgitates and stomachs were collected in 2010–2011. During these years, pikeperch and perch were found to make up 0.04–10% and 21–43% of the diet respectively, by mass. The length distribution of perch eaten by cormorants was more similar to the length distribution in purse seine samples rather than to that in commercial catches. The size structure of pikeperch in the cormorants' diet was intermediate between those in purse seine samples and commercial catches. Combined commercial and recreational catches have varied between 500–2000 t for perch and 225–525 t for pikeperch in the 2000s. Potential yield losses to fisheries caused by cormorant feeding in 2010 were 340–420 t for perch and 110–140 t for pikeperch, thus cormorant predation may affect catches and the profitability of fishing.

1. Introduction

Some studies in Europe and North America indicate that cormorants can have an impact on fish stocks and fisheries (e.g. Rudstam et al., 2004; Fielder, 2010; Jepsen et al., 2010; Vetemaa et al., 2010; Östman et al., 2012; Mustamäki et al., 2013) while in other studies no impact has been found (e.g. Engström, 2001; Liordos and Goutner, 2007; Lehikoinen et al., 2011). The differences in the results depend on differences in the fish species studied, cormorant predation pressure, fishing pressure, fish community structure and research methods. Especially percids (*Percidae*) seem to be particularly vulnerable to cormorant predation (Rudstam et al., 2004; Fielder, 2010; Vetemaa et al., 2010; Östman et al., 2012; Mustamäki et al., 2013; Skov et al., 2014, but see Lehikoinen et al., 2011).

The great cormorant (*Phalacrocorax carbo*) started to breed on the southern coast of Finland in 1996 (Rusanen et al., 1998). Cormorants had colonized the Archipelago Sea by the turn of the millennium; the number of nesting pairs was over 4000 in 2011.

Temperature during the summer is the main factor affecting the year-class strength of percids (Böhling et al., 1991; Pekcan-Hekim et al., 2011). The mean water temperature in the Archipelago Sea during July-August has been favorable to pikeperch (*Sander lucioperca*) reproduction (Pekcan-Hekim et al., 2011) in several years during the first decade of the millennium (Heikinheimo et al., 2014). The eutrophication and turbidity levels have been fairly stable during the past decade (Anonymous, 2011a). Despite these favorable conditions for percids, commercial catches of pikeperch and perch (*Perca fluviatilis*) have diminished during the first decade of the millennium (Fig. 1). Recreational catches of perch and pikeperch in the Archipelago Sea reached their lowest level since 1986 in 2010 (Anonymous, 2004, 2011b). Commercial fishermen argue that cormorants are contributing to the reduced catches in traditional fishing areas (Salmi et al., 2010). So far, research on the spatial variation in the diet of cormorants and their effects on fisheries have been scarce in the Baltic Sea region.

In this paper we studied the diet of cormorants in the Finnish Archipelago Sea. We examined both spatial variation and inter-annual variation between 2010 and 2011 in the proportions of perch and pikeperch in the diet. We compared length distributions of perch and pikeperch from cormorant diet samples with distributions from test fishing and commercial fishing samples. We collected these data in order to estimate the amount of perch and

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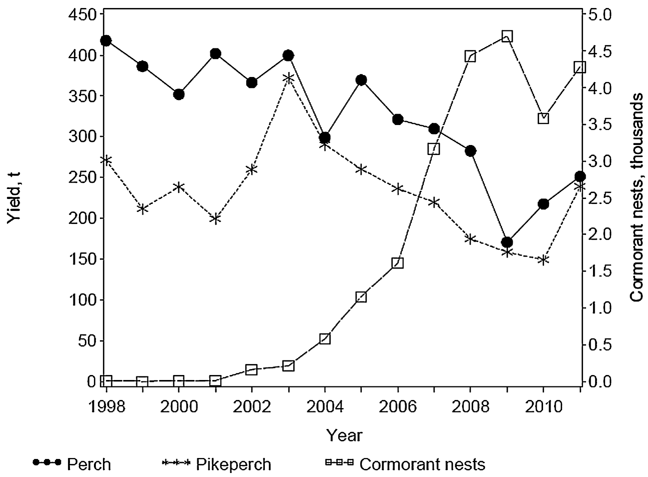

Fig. 1. Commercial yield of perch and pikeperch and the number of cormorant nests in the Archipelago Sea from 1998–2011.

pikeperch in the cormorants' diet and cormorants' effect on commercial and recreational fishery catches in the Archipelago Sea.

2. Materials and methods

Cormorant diet samples were collected at three of the eight cormorant breeding colonies in the study area in 2010–2011. Study colonies were Kluppi, Kustavi (60.6° N, 21.1° E); Kalmanhohde, Taivassalo (60.5° N, 21.7° E) and Äggskär, Parainen (60.3° N, 21.8° E) in the Archipelago Sea on the southwest coast of Finland (Fig. 2). These colonies were selected because they are situated in habitats that differ from each other in e.g. openness, depth, and turbidity, and are representative of the different habitat types of the Archipelago Sea (Kangas et al., 2003). Kalmanhohde is located in an inner bay with closed shoreline, and turbid and shallow water. Äggskär is situated in the central part of the Archipelago Sea, where the water area is greater than the land area, and waters are deeper and more transparent. Kluppi is in the outer Archipelago Sea and characterized by open shores with deep and cool water. Colonies Kluppi and Äggskär were populated by cormorants in 2003 and Kalmanhohde in 2009 (P. Rusanen, pers. comm.). The numbers of breeding pairs in 2010 and 2011 were, by area: 717 and 417 in Kluppi, 1436 and 2000 in Äggskär, and 325 and 241 in Kalmanhohde (P. Rusanen, pers. comm.).

We consider the presence of cormorants during two periods of the year; the breeding season (April–July) and the non-breeding season (August–November). The first cormorants start to migrate southwards after the breeding season. Breeding season diet samples were collected from 1 May to 31 July and non-breeding season samples from 1 August to 15 November. Samples collected during the breeding season primarily represent the diet of subspecies *P. c. sinensis*, which inhabits the study colony area during that period. Samples collected outside the breeding season represent the diet of migrating birds from both subspecies, *sinensis* and *carbo*, which are present in the study area for a period of variable length during their migration.

We collected cormorant pellets ($n = 647$), regurgitates ($n = 101$) and culled birds ($n = 44$). The samples contained remains from 8494 fish. Samples were collected with the permission of Southwest Finland Centre for Economic Development, Transport and the Environment (Southwest Finland ELY Centre).

During the breeding season, diet samples were collected in the nesting colonies. After the breeding season, samples were collected from resting places located up to nine km from the colonies. Pellets were collected at intervals of three weeks from May to October in 2010 and from May to November in 2011. 20 individual samples were taken from each colony per visit; only fresh and complete pellets were collected. Samples of regurgitates of nestlings were also collected. In 2010, bulk samples from each study colony were collected over three weeks in June and July. In 2011, we collected samples of regurgitated fish of 20 nestlings from each colony per visit. Samples were collected at intervals of three weeks in June and July. Stomach contents of culled birds were gathered from hunters from the 20th August to the 31st October in 2010 and 2011.

All samples were frozen for at least 24 h. Pellets were washed before analysis. Fish from the defrosted sample were identified to species level (or if that was not possible, to the genus level). Total length (TL) was measured (whole fish) or calculated (bones) to the nearest mm and fish were weighed or calculated to the nearest gram. The lengths of partly digested fish were estimated and masses were calculated using the length–mass formulae. Remnants of cyprinid species in pellets and stomachs were identified using pharyngeal teeth and chewing pads, while other fish species were identified using otoliths and vomer bones (Wheeler, 1978; Härkönen, 1986; Veldkamp, 1995; Radu, 2005; Čech, 2006; Svetocheva et al., 2007). Fish lengths were calculated from otoliths with Härkönen's (1986) formula, from pharyngeal teeth with Čech's (2006) formula and from chewing pads with Veldkamp's (1995) formula. Only non-eroded bones were used for length–mass calculations. Fish mass was calculated by using length–mass relation formula (Le Cren, 1951):

$$W = aL^b \quad (1)$$

where W is the wet mass in g, L is the total length in cm, a is a coefficient and b an exponent (Table 1). The values used in the length–mass relation formulae were based on measurements from fish caught in test fishing, surveys and commercial fishing (EU Data Collection Framework on fisheries) of the Finnish coast of the Baltic Sea. For fourhorned sculpin we used values from Swedish test fishing (Institute of Coastal Research, Department of Aquatic Resources, Swedish University of Agricultural sciences). We calculated mass for black goby and small sandeel (*Ammodytes tobianus*) using Härkönen's (1986) formula. For three-spined stickleback we used a mean mass of two grams and for common goby (*Pomatoschitus microps*) and sand goby (*Pomatoschitus minutus*) a mean mass of one gram.

We used pellets as primary samples and supplemented the pellet data with regurgitates and samples from culled birds. We calculated proportions of different prey species in the diet by combining individual samples from the time frame and area of interest. Samples of different types were treated equally when calculating proportions of different prey species in the diet.

Purse seine (cod end stretched mesh size 6 mm) test fishing samples, cormorant diet samples and commercial catch samples for perch and pikeperch were collected in the Mynälahti Bay area in summer 2011 (Fig. 2). The size structures of perch and pikeperch in the samples were compared. The size distributions of gill net (GN) and fyke net (FN) commercial catches were combined and the ratio (GN/FN) in the total catch was used as a weighting factor.

The total fish mass consumed by cormorants was calculated separately for the eight colonies in the study area. The number of nests in each colony in 2010–2011 was provided by Finnish Environment Institute (P. Rusanen, pers. comm.). For colonies from which we lacked diet data, we used values from the nearest colony situated in similar habitat.

The total fish mass consumed by cormorants in each colony was calculated using two methods, which differ from each other in the estimation of the total number of birds and in the daily consumption assumed for one bird. Method 1 was adopted from Vetemaa et al. (2010). They obtained the total number of birds in a colony of increasing size by multiplying the number of nests by a factor of