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Trophic peculiarities of the Great Cormorant, Grey Heron and Long-tailed Duck on the Baltic Sea Lithuanian coast: a stable isotope approach

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The stable isotopes of nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) were analysed in the feathers of the Great Cormorant (*Phalacrocorax carbo*), Grey Heron (*Ardea cinerea*) and Long-tailed Duck (*Clangula hyemalis*) staying in the different seasons at the Lithuanian Baltic Sea coast. Stable isotope ratios in bird feathers represented dietary variations and foraging habitats during the feather growth period. Adult Great Cormorants fed juveniles by smaller fish at the beginning of fledging, switching later to larger prey. The stable isotope analysis indicated that the Grey Heron diet did not change significantly during the fledging period of their juveniles. The calculated trophic levels of Great Cormorants and Grey Herons were similar (3.55 ± 0.12 and 3.57 ± 0.41, respectively). The isotopic values in Grey Herons and Great Cormorants were 14.6–16.0‰ for $\delta^{15}N$ and –27.3–(–24.9)‰ for $\delta^{13}C$. These values are typical of piscivorous bird species mostly feeding in freshwater bodies, i. e. in the Curonian Lagoon. The $\delta^{15}N$ values found in the feathers of Long-tailed Ducks ranged from 7.7 to 13.9‰ and the $\delta^{13}C$ values ranged from –33.6 to –24.9‰ showing high variation of feeding habitats during the moulting period: from freshwater to marine environment.

Key words: stable isotopes analysis, water birds, trophic relationships

INTRODUCTION

Food web studies usually concentrate on the most abundant species in an area. Colonially breeding birds are often tackled for this because they constitute an important link within a food web as well as for the reason they stay in big numbers during the whole breeding season.

The Great Cormorant (*Phalacrocorax carbo*) is an abundant piscivorous bird species that receives much public, political and scientific attention for its assumed competition with fishermen, economic damage as well as for species protection approaches on the Lithuanian Baltic Sea coast. In the west of Lithuania, the species breeds in a colony at the Curonian Spit, 1 km from the sea and 0.3 km from the Curonian Lagoon. The colony grew to 2700–2900 pairs in 2005–2007. In addition, about 290 pairs of Grey Herons (*Ardea cinerea*) bred at the same colony with Great Cormorants in 2005–2007 (Putys, Zarankaitė, 2010; Žydelis, Kontautas, 2008).

Not only birds present during the breeding season may have an important role in a food web, but wintering species as well, however their foraging behaviour is more difficult to observe. The Long-tailed Duck (*Clangula hyemalis*) is the most abundant wintering species in the Baltic Sea and the second abundant on the Lithuanian near-shore zone (after Velvet Scoter, *Melanitta fusca*) where 300–500 individuals were estimated in 2009/2010 (Europos ..., 2011). In addition, the Long-tailed Duck was the most often recorded water bird species during beach bird surveys on the Lithuanian coastline.

To evaluate the diet, traditional methods, like stomach analysis, can be used. However, the stable

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isotope analysis is very often more suitable, as the method allows to reveal integrative information on a diet. The method is based on predictable variations of stable nitrogen ($^{15}N/^{14}N$) and carbon ($^{13}C/^{12}C$) isotope ratios in tissues. The ratio of stable nitrogen isotopes increases at a rate of ~3–5 parts per thousand during transition from a lower to a higher trophic level. The carbon isotope ratio changes less between trophic levels than that of nitrogen; however, both of the indicators strongly differ in marine and terrestrial / freshwater food webs, thus provide extra information on the type of the feeding habitat (Barret et al., 2007).

The stable isotope values obtained while analysing feathers allows to reveal the diet of a bird during the feather growth period and enables to recognize the bird's diet during past or present seasons. The stable isotope analysis of a single feather reflects the diet of an individual bird. In addition, feathers are preferable in various studies, as do not need to sacrifice birds (Mizutani et al., 1990).

The objective of this study is to verify some trophic patterns of common water bird species from the Baltic Sea Lithuanian coast by means of the stable isotope analyses of feathers.

MATERIALS AND METHODS

The feathers of birds of the three species, Great Cormorant, Grey Heron and Long-tailed Duck, collected from the Lithuanian Baltic Sea coast (south-eastern part of the Baltic Sea) were analysed. The samples were taken for $\delta^{15}N$ and $\delta^{13}C$ stable isotope analysis as indicated in Table.

The feathers of Great Cormorants and Grey Herons were taken during their breeding season in 2010 at the colony situated between the Baltic Sea and Curonian Lagoon. The samples of Grey Herons and the first samples of Great Cormorants were collected from the carcasses of flightless juveniles found at the colony. The flying Great Cormorant juveniles were caught by the bird ringers, and coverts were taken from live birds. The Long-tailed Ducks were obtained as a by-catch of the artisanal fishery in March 2010. The birds drowned in nets were collected with the cooperation of fishermen at the coastal waters of the northern part of the Lithuanian Baltic Sea coast. The wing coverts were taken from drowned ducks. All feathers were preserved in the fridge till analysis.

Prior to analysis the feathers were cleaned of surface contaminants, dried and cut by scissors into small pieces. Tips and the middle part of each feather were analysed separately. Approximately 0.5 mg of each dried feather was loaded into a tin capsule and analysed for $\delta^{15}N$ and $\delta^{13}C$ with the Carlo-Erba elemental analyser coupled to an isotope ratio mass spectrometer at the Leibniz Institute for Baltic Sea Research, Germany.

Isotope ratio was expressed as a parts-per-thousand difference (‰) of the heavier to the lighter isotope, compared with an international standard:

$$\delta X = \left(\frac{R_{\text{sample}}}{R_{\text{standard}}} - 1 \right) \times 1000, \quad (1)$$

where X is ^{13}C, ^{15}N and R is the corresponding ratio $^{13}C/^{12}C$ or $^{15}N/^{14}N$. R_{standard} for ^{13}C is Pee Dee Belemnite and R_{standard} for ^{15}N is atmospheric N_2.

Table. **List of analysed samples from water birds from the Baltic Sea Lithuanian coast**

Species	Date	Sampling point	Number of individuals of analysed feathers	Analysed parts of feathers
Great Cormorant	10.06.2010	A colony at Juodkrantė	3 juveniles	3 tips and 3 middle parts
	08.07.2010	On the coast of the Curonian Lagoon, 0.5 km from the colony at Juodkrantė	3 juveniles	3 tips and 3 middle parts
Grey Heron	01.07.2010	A colony at Juodkrantė	3 juveniles	3 tips and 3 middle parts
Long-tailed Duck	29.03.2010	At the seacoast of Palanga	3 adults (2 ♂ and 1♀)	3 tips

The results were also expressed as means with standard deviations (SD). The signed rank test was applied to compare $\delta^{15}N$ values for Great Cormorants.

Trophic levels were calculated for Great Cormorants and Grey Herons by the equation:

$$TL = (\delta^{15}N_{\text{secondary consumer}} - \delta^{15}N_{\text{baseline}}) / 3.4 + 2 \text{ (Post, 2002)}, \quad (2)$$

where $\delta^{15}N$ values of *Valvata* sp. were used for isotopic signature of primary consumer ($\delta^{15}N_{\text{baseline}}$) (May–August signatures; Lesutiene, 2009).

RESULTS

The results of bird feather analysis are presented in Figure. The isotopic signatures of $\delta^{15}N$ and $\delta^{13}C$ in the feathers of Great Cormorants and Grey Herons represent dietary variation during the feather growth period. Statistically significant differences were found in $\delta^{15}N$ of tips and middle part portions sampled from the same cormorant feathers (Signed rank test, $p < 0.05$). Analysis of Grey Heron feathers did not show an isotopic shift in $\delta^{15}N$. The calculated trophic level was 3.55 ± 0.12 for Great Cormorants and 3.57 ± 0.41 for Grey Herons.

Each sample reflects the diet of an individual Long-tailed Duck (Figure). The $\delta^{15}N$ and $\delta^{13}C$ indicate that ducks fed on organisms with different $\delta^{15}N$ and $\delta^{13}C$ values. Males were more depleted of $\delta^{13}C$ than females, but there was also an isotopic difference between males.

DISCUSSION

There are a few published studies covering the trophology aspects of the Great Cormorant colony at the Curonian Spit. In late February about 3 000 pairs of Great Cormorants arrives to Juodkrantė colony for breeding and stay there until the middle of October. In addition, there are quite high numbers of non-breeding cormorant birds that stay on the Curonian Lagoon area, which account for 20–25% of the nesting bird number. In winter, the species is considered rare; however, each year they are observed on the Baltic Sea coast (Žydelis et al., 2002). Therefore, Great Cormorants are present for half a year on the Baltic Sea coast and Curonian Lagoon and during this pe-

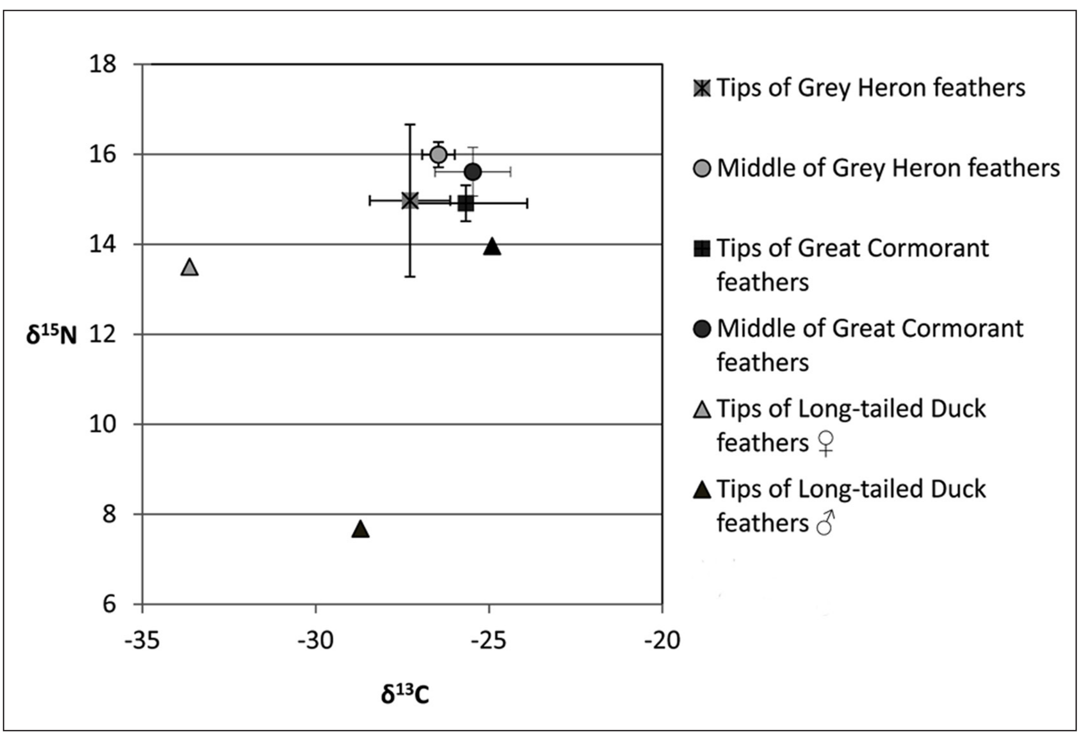

Figure. **Mean isotopic values of tip and middle parts of bird feather** riod consume the largest biomass of fish. Žydelis, Kontautas (2008) proved that the direct competition between piscivorous birds and fishermen for fish recourses is low. The estimated consumption by common piscivorous bird species is equal to about 9% of the total fish resources in the lagoon and two-thirds of the amount of fish landed by commercial fishermen. In addition, there is a size difference between fish consumed by cormorants and commercially valuable fish size (Žydelis, Kontautas, 2008).

At least 25 fish taxa were identified by Pūtys, Zarankaitė (2010) as prey of Great Cormorants. The Curonian Lagoon was the main feeding area for Great Cormorants. They mainly fed on the most common and abundant species in the lagoon (Repečka, 2003; Žydelis, Kontautas, 2008) and gregarious fish species (Suter, 1997). Marine fish contributed only a low portion to the overall diet (6.5% of biomass; Pūtys, Zarankaitė, 2010).

The isotopic signature in the feathers of juveniles of Grey Herons and Great Cormorants collected in June and July represented species diets at the area. It can be suggested that the measured isotopic signatures 14.6–16.0 for δ^{15}N and –27.3–(–24.9) for δ^{13}C are typical values for piscivorous bird species feeding mainly in the Curonian Lagoon.

This study also indicated the existence of a dietary shift in Great Cormorant juveniles. The tips of analysed feathers were synthesized earlier than the middle part, so isotopic difference between these two parts showed diet changes during the fledging period. Lehikoinen (2005) proved that Great Cormorants breeding in the Gulf of Finland switched size and species of prey fish: when the juveniles were small, cormorants fed them by smaller and slimmer fish specimens; larger juveniles were fed by bigger fish (Lehikoinen, 2005). The ability by Great Cormorants to select the most valuable prey has been proved by Čech et al. (2008) as well.

The calculated trophic level for Great Cormorants was 3.6, what is quite low for the top predator. However, Great Cormorants mainly fed on small percids and cyprinids with the mean length of 9.5 cm (Putys and Zarankaite, 2010), so the diet peculiarities estimated by traditional methods explain the results obtained by the stable isotope analysis.

The study did not indicate a diet shift of Grey Heron juveniles while growing. As Grey Herons forage on food regurgitated by Great Cormorants (Wojczslanis et al., 2005, and personal observations at the studied colony) this behaviour explains the proximity of the Grey Heron isotope signature to that of the Great Cormorant. The calculated trophic levels for these two piscivorous species were also similar. Although Grey Heron feeds on fish found under Great Cormorant nests, the stable isotope analysis did not reveal any significant difference in diet change during juvenile fledging. The Grey Heron is known as a more opportunistic species and can feed on a broader range of prey compared to Great Cormorants. The most important component of the Grey Heron diet during the breeding season is fish; however, insects, frogs, small mammals, molluscs, insects, small birds or their juveniles are also consumed as food (Jakubas, Mioduszewska, 2005; Navasaitis, 1983). The exploitation of other food sources by the Grey Heron compared to those of the Great Cormorant could explain the results of δ^{15}N and δ^{13}C values obtained.

The studies on Long-tailed Ducks in Europe are quite rare. The diet of wintering Long-tailed Ducks studied along the coasts of the Baltic Sea indicated that the species feeds on the most common benthic animals or animals living close to the bottom depending on the habitat type and season (Stempniewicz, 1995, Žydelis, Ruškytė, 2005). The measurements both of δ^{15}N and δ^{13}C in feathers do not reflect the diet of wintering specimens in the area of the Lithuanian Baltic Sea coastal waters, because it is related to the food consumed during the moulting period in northern post-breeding habitats (NatureServe, 2011; Petersen et al., 2003).

The δ^{15}N values for the feathers of Long-tailed Ducks from the Lithuanian Baltic Sea coastal zone ranged from 7.7 to 13.9‰. A very similar range of these signatures have been published by Braune et al. (2005) who measured stable isotopes in bone collagen of Long-tailed Ducks in their breeding grounds. Bone collagen is low metabolic rate tissues which represent lifetime average values (Braune et al., 2005) while feathers represent bird diet of their growth period (Mizutani et al., 1990).

The $\delta^{13}C$ values of Long-tailed Ducks ranged from –33.6 to –24.9‰ showing variation of feeding habitats – from freshwater to marine environment. The species nests on freshwater habitats where only females and ducklings stay whereas moulting males and non-breeding females appear in coastal lagoons (NatureServe, 2011; Petersen et al., 2003). In ducks, an isotopic difference registered in birds of different sex represented their different habitats and prey.

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DIDŽIOJO KORMORANO, PILKOJO GARNIO IR LEDINĖS ANTIES MITYBA BALTIJOS JŪROS LIETUVOS PRIEKRANTĖJE REMIANTIS STABILIŲJŲ IZOTOPŲ ANALIZE

Santrauka

Stabiliųjų azoto ($\delta^{15}N$) ir anglies ($\delta^{13}C$) izotopų metodas buvo panaudotas didžiojo kormorano (*Phalacrocorax carbo*), pilkojo garnio (*Ardea cinerea*) ir ledinės anties (*Clangula hyemalis*), paplitusių Lietuvos Baltijos jūros priekrantės zonoje, plunksnų analizei. Stabiliųjų izotopų santykis plunksnose atspindi dietos ypatumus bei mitybos vietų, kuriose laikosi paukščiai plunksnų augimo periodu, ypatybes. Suaugę didieji kormoranai jauniklius maitino smulkesnėmis žuvimis jauniklių plasnojamųjų plunksnų augimo pradžioje, palyginti su jų dieta vėlesniu plunksnų augimo laikotarpiu. Remiantis analizės rezultatais, pilkojo garnio jauniklių mityba statistiškai reikšmingai nekito plunksnų augimo laiku, apskaičiuoti didžiojo kormorano ir pilkojo garnio trofiniai lygmenys buvo panašūs (atitinkamai 3,55 ± 0,12 ir 3,57 ± 0,41). Išmatuotos didžiojo kormorano ir pilkojo garnio stabiliųjų azoto (14,6–16,0 ‰) ir anglies (–27,3 – (–24,9) ‰) izotopų žymės rodo, kad abi šios rūšys galėtų būti laikomos tipinėmis žuvlesių paukščių rūšimis, kurios maitinasi daugiausia Kuršių mariose. Stabiliųjų azoto izotopų santykis ledinių ančių plunksnose kito nuo 7,7 iki 13,9 ‰, o anglies reikšmės – nuo –33,6 iki –24,9 ‰, ir tai rodo jų dietos ir maitinimosi buveinių įvairovę plasnojamųjų plunksnų keitimo laiku – nuo gėlo vandens telkinių iki jūrinės aplinkos.

Raktažodžiai: stabiliųjų izotopų analizė, vandens paukščiai, mitybos ryšiai