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DIET OF THE GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*) AT THE JUODKRANTĖ COLONY, LITHUANIA

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Abstract. Substantial population increases in the Great Cormorant (*Phalacrocorax carbo sinensis*) in Lithuania since the mid 1980s have given rise to complaints by fishermen and fish farmers that the stocks of fish that they target or cultivate are being depleted. In order to test the veracity of these claims, we investigated the dietary composition of the Great Cormorant breeding colony at Juodkrantė on the Curonian Spit, Lithuania, through the analysis of 220 pellets, collected during the breeding seasons in 2005–2007. At least 25 fish taxa were identified in the sample, but only three dominated by both abundance (82.9%) and biomass (73.6%), namely Ruffe (*Gymnocephalus cernuus*), Perch (*Perca fluviatilis*) and Roach (*Rutilus rutilus*). The mean total length of fish prey caught was 9.5 cm and the mean weight was 16.8 g. Commercial fish species comprised a large proportion of the Great Cormorant diet (83% by biomass), predominately small, low commercial value fish, mostly Roach. Despite the proximity of the Baltic Sea to the colony, marine fish species contributed only low proportions to the overall diet (5.7% abundance, 6.5% biomass). Evidence from our study supports the contention that the Curonian Lagoon is the main feeding area for the Great Cormorant.
Key words: Curonian Lagoon, Baltic Sea, diet composition, pellet analysis

INTRODUCTION

Great Cormorants (*Phalacrocorax carbo sinensis*) are widespread fish-eating waterbirds, whose populations increased rapidly in Europe during the second part of the 20th century. After their local extinction in Lithuania during the 19th century (Ivanauskas 1938), Great Cormorants returned in 1986 and recommenced breeding (Jusys 1997; Stanevičius & Paltanavičius 1997). Great Cormorant numbers increased rapidly until 2003, before their population levelled-off at about 4,000 breeding pairs, 3,000 of which now nest at the Juodkrantė colony (Dagys 2007; Ložys 2008). This rapid increase caused many conflicts with fishermen and fish farmers who believed that the increased numbers of Great Cormorants were depleting stocks in their fishery and farms. Although Great Cormorants can take a large number of fish, there is no clear evidence that quantifies the size of their impact on the abundance and size structure of natural fish communities, especially in large and highly productive water bodies (Mous 2000; Engstrom 2001; Stempniewicz *et al.* 2003a; Čech *et al.* 2008). A comprehensive investigation of the Great Cormorant's diet is necessary for the assessment of scale of impact on fish populations, mainly in terms of dietary composition and its variation over time and with prey fish size and its implications for stock assessment.

There is not much pre-existing quantitative information or data about Great Cormorant diets in Lithuania. However, Žydelis *et al.* (2002) analysed regurgitated fish samples from the Juodkrantė colony in 2001. The present study was also carried out within the same colony near Juodkrantė, Lithuania's largest, during the breeding periods in 2005–2007. Diet composition was investigated through the analysis of regurgitated pellets. Prey composition, abundance and size, and temporal variation in diet were estimated and analysed.

MATERIAL AND METHODS

The study of the Great Cormorant diet took place in the colony located on the Curonian Spit near Juodkrantė settlement (Fig. 1). The Curonian Spit is narrow (approx. 2 km wide at the position of the colony) and separates the freshwater Curonian Lagoon from the brackish Baltic Sea. The total area of the Curonian Lagoon is 1,584 km^2, 413 km^2 of which belongs to Lithuania. The Lagoon is a shallow, highly productive freshwater body with some occasional brackish water influxes from the sea into its northern part, via the Klaipėda Strait, that temporarily (up to two months per year) raises water salinity over 5‰ (up to 7‰) in the area near Juodkrantė (Center of Marine Research 2009). The fish stocks of the

Curonian Lagoon are under intense exploitation by the commercial fishery. Great Cormorants nest in an old pine tree forest mixed with a colony of Grey Herons (*Ardea cinerea*). Breeding populations varied from 2,700 to 2,900 pairs during the study period.

Despite some biases (Carss *et al.* 1997; McKay *et al.* 2003), pellet analysis is a relatively cheap and simple method to obtain dietary information. Pellets were collected during the breeding season in 2005, 2006 and 2007, twice per month from April to July inclusive. Only fresh, complete pellets were collected from the ground at the colony, placed into plastic bags and stored at -20°C. In laboratory each sample was soaked in a 2% solution of neutral biological wash booster (Farmos L 5002) for 2–3 days. After the mucus dissolved, pellets were rinsed with cold water through a sieve (mesh size 0.3 mm). Undigested bones and other hard remains (otoliths (*sagittea*), pharyngeal teeth, jaws, chewing pads and vertebra) were retrieved from the sample and dried at. Fish species were identified by comparison with a reference collection of fish bones as well as published

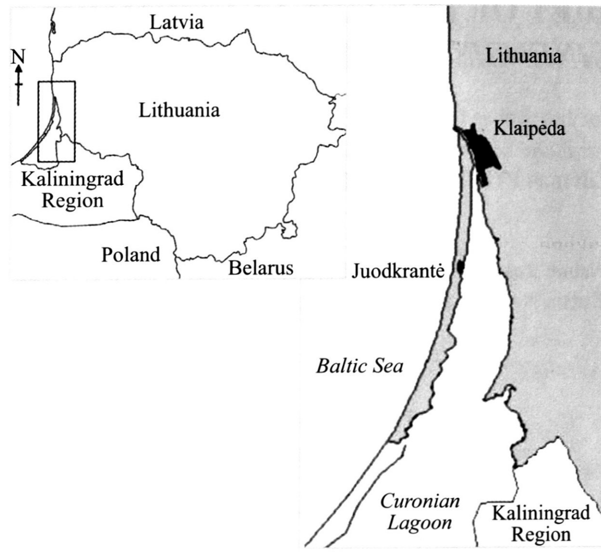

Figure 1. The location of the Curonian Lagoon and study site at Juodkrantė (inset) on the Curonian Spit, Lithuania. The narrow entrance to the Curonian Lagoon is at Klaipėda.

Table 1. Relationships between fish total length (TL) (fork length (FL) for Sea Trout and fish bones length (otolith length OL, otolith width OW, chewing pad length CL, *maxillae* length ML). Published equations are taken from: * – Leopold *et al.* 2001, ** – Härkönen 1986.

Species	Relationship
Baltic Herring (*Clupea harengus*)	TL = 6.29 OL – 1.93*
Twaite Shad (*Alosa fallax*)	TL = 13.898 OL – 12.315
Baltic Sprat (*Sprattus sprattus*)	TL = 6.87OL*
Sea Trout (*Salmo trutta*)	FL = 107.9 OL – 87.7**
Smelt (*Osmerus eperlanus*)	TL = 3.9959 OL – 1.3209
Roach (*Rutilus rutilus*)	TL = 6.22578 OL + 0.66165 $TL = 0.53592 + 4.02638\ CL - 0.1525CL^2$
White bream (*Blicca bjoerkna*)	TL = 8.26743 OL – 3.8389
Bream (*Abramis brama*)	TL = 7.64615 OL – 2.6987
Vimba (*Vimba vimba*)	TL = 11.329 OL – 8.9157
Goldfish (*Carassius auratus gibelio*)	TL = 4.9288 OL – 0.1164
Ide (*Leuciscus idus*)	TL = 7.55 OL - 2.02*
Rudd (*Scardinius erythrophthalmus*)	TL = 2.79 CL + 3.48*
Gudgeon (*Gobio gobio*)	TL = 7.4445 OL + 0.852
Tench (*Tinca tinca*)	TL = 8.06 OL*
Razorfish (*Pelecus cultratus*)	TL = 7.877 OL + 3.8408
Burbot (*Lota lota*)	TL = 30.313 OL + 18.969
Viviparous Blenny (*Zoarces viviparus*)	TL = 23.706 OW – 7.7824
Bullhead Scorpion (*Myoxocephalus scorpius*)	TL = 3.49 OL – 1.37*
Ruffe (*Gymnocephalus cernuus*)	TL = 2.21448 OL – 0.5978
Perch (*Perca fluviatilis*)	TL = 3.24109 OL – 1.4643
Pikeperch (*Sander lucioperca*)	TL = 4.49447 OL – 4.2245 TL = 1.1383 ML + 3.2127
Lesser Sandeel (*Ammodytes tobianus*)	TL = 7.2503 OL – 4.2884
Round Goby (*Neogobius melanostomus*)	TL = 4.1145 O – 2.6571
Pomatoschistus sp.	TL = 3.35 OL*
Flounder (*Platychthis flesus*)	TL = 4.5389 OL – 1.1836
Turbot (*Psetta maxima*)	TL = 4.8777 OL + 0.4728

morphometry data and images (Härkönen 1986; Veldkamp 1995a; Harvey *et al.* 2000; Leopold *et al.* 2001; Čech *et al.* 2008). Fish abundance was calculated as the largest number of the left or right side bones (otoliths, pharyngeal teeth) or other unpaired hard remains (e.g. chewing pads) for each prey species. Otoliths and chewing pads were measured to the nearest 0.1 mm, Pikeperch (*Sander lucioperca*) *maxillae* to 1 mm. Fish total length (TL) was determined from the relationship between bone size and fish length. The TL of cyprinid fish was calculated from otolith or chewing pad length, TL of Pikeperch from otolith or *maxillae* length, Eelpout (*Zoarces viviparous*) from otolith width, and TL of other prey was calculated from otolith length. Fish weight was calculated using published weight-length equations (Härkönen 1986; Leopold *et al.* 2001; Martyniak *et al.* 2003; Trella 2003) as well as estimated from our reference collection (Table 1). Although a quantitative correction factor for the erosion of otoliths and other bony structures was not applied in this study, a visual correction to compensate for the erosion of otoliths was applied by comparing with otoliths of similar size from our reference collection. Digestion most heavily affects the prolonged thin part of otoliths, such as the rostrum, whereas the width is less affected. A Chi-square test was used to detect annual differences in Cormorant diet composition (by number and by weight). The four most abundant fish species by numbers and five most important by biomass prey species were used in this analysis.

Results

Overall, 6,304 prey items belonging to at least 26 fish taxa from 12 families were identified in the sample of 220 pellets (74, 56 and 90 in years 2005, 2006 and 2007 respectively) (Table 2). The remains of a crustacean species (*Crangon crangon*) were also found in some pellets, possibly as a result of secondary consumption. Numbers of prey per pellet varied from 1 to 116 (mean 28.7). The frequency of occurrence of the three dominant species in the Great Cormorant diet species exceeded 70%: Roach (*Rutilus rutilus*) 86.8%, Ruffe (*Gymnocephalus cernuus*) 83.2%, and Perch (*Perca fluviatilis*) 75.5% (Fig. 2). The frequency of occurrence of five other prey species exceeded 10%: White Bream (*Blicca bjoerkna*) 37.3%, Smelt (*Osmerus eperlanus*) 31.4%, Pikeperch 24.1%, Bream (*Abramis brama*) 17.3% and Flounder (*Platichthys flesus*) 10.5%. Although unimportant in terms of proportion (0.2% by number and 0.3% by weight), the occurrence of the Round Goby (*Neogobius melanostomus*) was noteworthy because it is an invasive species. Remains of marine fish species (Table 2) were found in 19.5% of the analysed pellets.

Percid fish (Percidae) were the most abundant in the Great Cormorant diet and comprised 65.2% by numbers (Table 2). Cyprinids' (Cyprinidae) share was 23.5% by number. The total contribution of these two fish families was 88.8%. Among the other families, the more abundant numerically was Smelt (Osmeridae, 5%). Three species were the most abundant by numbers (Fig. 3): Ruffe (39.3%), Perch (24.4%) and Roach (19.2%). Only Smelt was the more abundant among the other prey, contributing 5% by numbers. Smelt was more abundant in the diet (9.3%) during the spring spawning migration (April–May). The contribution of marine fish species in the diet was 5.7% by numbers.

The total weight of identified prey was 105 kg. Cyprinids (53.1%) and percids (37.2%) were the most important fish in the Great Cormorant diet by biomass comprising 90.3% (Table 2). None of the other families exceeded 3% in the diet. Three fish species were the most important by biomass (Fig. 3), Roach

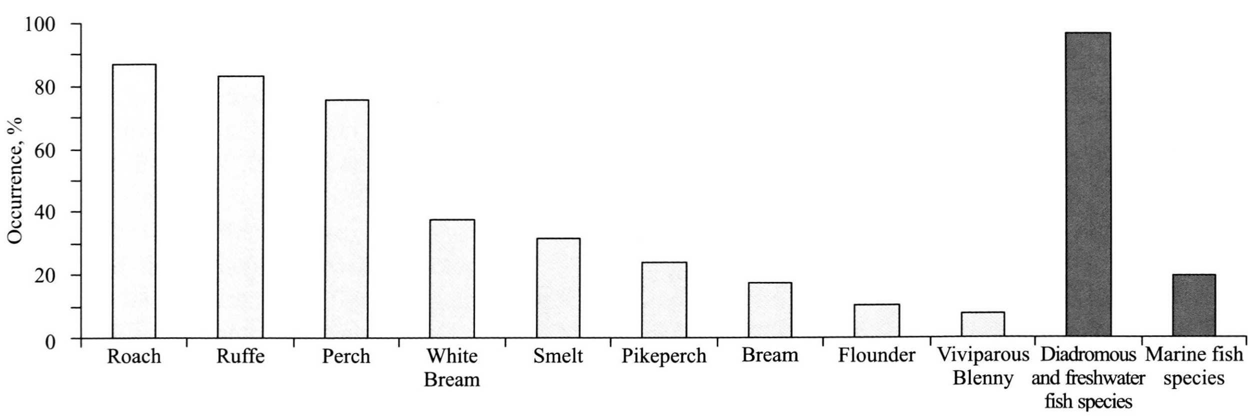

Figure 2. Frequency of occurrence (%) of the most important and of different ecological groups of Great Cormorant prey found in pellets at the Juodkrantė colony in 2005–2007.

			N				Number, %	weight, %	of occurrence, %	Mean length (TL), cm (SD)	Mean weight, g (SD)	Maximum Length, cm	Maximum Weight, g
			45				0.7	2.3					
	…pea harengus)	M	39	+	+	+	0.6	1.4	5.5	17.5 (3.6)	38.5 (19)	23.2	81.5
	…waite Shad (*Alosa fallax*)	D	3	+	+	+	0.05	0.9	1.4	32.6 (0.8)	311 (24)	33.5	338.7
3	Baltic Sprat (*Sprattus sprattus*)	M	3	+		+	0.05	0.02	1.4	9.3 (2.3)	7 (5.7)	11.7	13.5
	Salmonidae		3				0.05	0.02					
4	Sea Trout (*Salmo trutta*)	D	3			+	0.05	0.02	1.4	6.3 (1)	6.6 (3.1)	7.4	10.1
	Osmeridae		313				5	1.5					
5	Smelt (*Osmerus eperlanus*)	D	313	+	+	+	5	1.5	31.4	8.8 (3.4)	5.2 (6.1)	18.7	35.1
	Cyprinidae		1,483				23.6	53.1					
6	Roach (*Rutilus rutilus*)	F	1,209	+	+	+	19.2	42.3	86.8	13.5 (4.7)	37.3 (41.6)	28.7	305.1
7	White bream (*Blicca bjoerkna*)	F	167	+	+	+	2.7	5.2	37.3	13 (4.3)	32.6 (37.5)	25.9	212.4
8	Bream (*Abramis brama*)	F	44	+	+	+	0.7	1.8	17.3	15.1 (4.1)	43.5 (37.3)	24.7	167.9
9	Vimba (*Vimba vimba*)	D	14	+	+	+	0.2	1.3	3.2	19.8 (6.8)	99.4 (100.3)	31.9	326.7
10	Goldfish (*Carassius auratus gibelio*)	F	2			+	0.03	0.2	0.9	17.1 (0.4)	93.9 (7.8)	17.4	99.3
11	Ide (*Leuciscus idus*)	F	12	+	+	+	0.2	0.7	4.5	14.2 (5.8)	58.7 (87.2)	26.7	308.4
12	Rudd (*Scardinius erythrophthalmus*)	F	3			+	0.05	0.01	0.5	7.5 (0.9)	4.1 (1.7)	8.5	6.1
13	Gudgeon (*Gobio gobio*)	F	24	+	+		0.4	0.2	0.9	8.6 (1.9)	7.3 (7.8)	16.5	43
14	Tench (*Tinca tinca*)	F	1	+			0.02	0.2	0.5	199.5	23.4	23.4	199.5
15	Razorfish (*Pelecus cultratus*)	F	7	+	+		0.1	1.2	3.2	29.4 (5.7)	182.9 (98.4)	34.6	293.9
	Lotidae		15				0.2	0.5					
16	Burbot (*Lota lota*)	F	15	+	+		0.2	0.5	2.3	13.3 (6.5)	33.3 (33)	22.3	93
	Zoarcidae		151				2.4	2.2					
17	Viviparous Blenny (*Zoarces viviparus*)	M	151	+	+	+	2.4	2.2	7.7	12.8 (4)	15.2 (16.7)	24.8	105.5
	Cottidae		7				0.1	0.3					
18	Bullhead Scorpion (*Myoxocephalus scorpius*)	M	7	+	+		0.1	0.3	1.4	12.2 (5.6)	44.2 (50.3)	19.9	128.4
	Percidae		4,109				65.2	37.2					
19	Ruffe (*Gymnocephalus cernuus*)	F	2,478	+	+	+	39.3	14.2	83.2	7.1 (2.5)	6 (6.1)	15.3	44.8
20	Perch (*Perca fluviatilis*)	F	1,536	+	+	+	24.4	17.1	75.5	8.2 (3.9)	11.7 (20.7)	27.7	289.7
21	Pikeperch (*Sander lucioperca*)	F	95	+	+	+	1.5	5.9	24.1	17.3 (6.7)	65.5 (84.8)	36.2	435.6
	Ammodytidae		5				0.1	0.01					
22	Lesser Sandeel (*Ammodytes tobianus*)	M	5		+	+	0.1	0.01	2.3	8.8 (2.6)	2.3 (1.3)	10.9	3.8
	Gobiidae		23				0.4	0.3					
23	Round Goby (*Neogobius melanostomus*)	M (F)	12			+	0.2	0.3	2.7	11.3 (1.4)	27.7 (3.5)	13.2	
24	*Pomatoschistus* sp.	M	11	+	+	+	0.2	0.01	2.7				
	Pleuronectidae		136				2.2						
25	Flounder (*Platichthys flesus*)	M	136	+	+								
	Scophthalmidae												
	Turbot (*Psetta maxima*)												

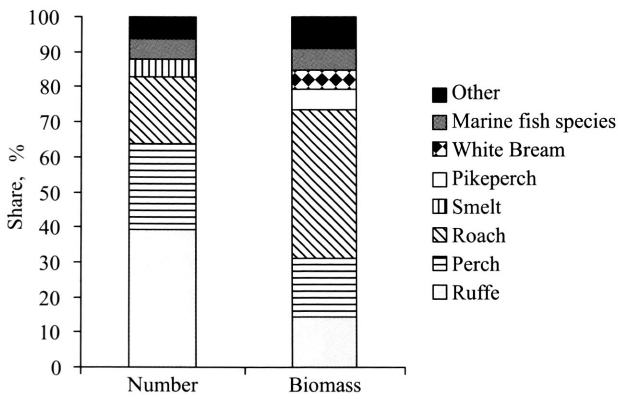

Figure 3. Diet composition of the Great Cormorant by numbers and biomass at the Juodkrantė colony in 2005–2007 (for marine fish species see Table 2).

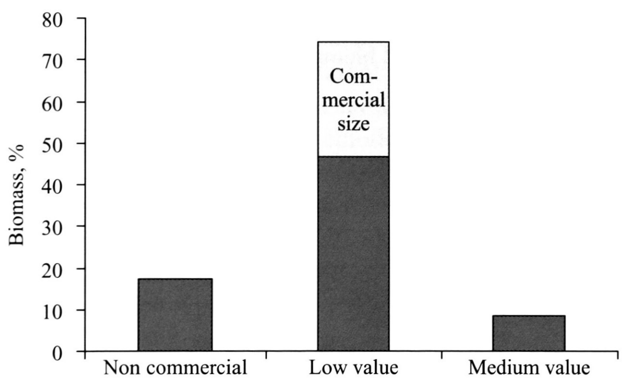

Figure 4. Percentage of different commercial value fish in the Great Cormorant diet by biomass at the Juodkrantė colony during 2005–2007 (non-commercial fish: Ruffe, Viviparous Blenny, Lesser Sand Eel, Bullhead Scorpion, Gudgeon and Gobiids; medium value fish: Pikeperch, Burbot and Turbot).

(42.3%), Perch (17.1%), Ruffe (14.2%). The less numerous Pikeperch and White Bream were important by biomass, contributing 5.9% and 5.2% respectively. The proportion of marine fish species in the diet was 6.5%.

Commercially targeted fish species comprised 82.8% by biomass in Great Cormorant diet (Fig. 4). However, only 27.8% were of commercial size (Table 3), mostly Roach (22%) and Perch (2.7%). Medium-priced fish species (1–3 €/kg according to prices in 2007) comprised 8.4%, whereas the rest of the commercial fish in the diet were low-priced, dominated by Roach and Perch.

The mean total length of fish found in pellets was 9.5 ± 4.7 cm (TL) and the mean weight 16.8 ± 31 g. Most of the identified fish (74.5%) were less than 12 cm long (Fig. 5). However, 10–22 cm long fish comprised 68.8% of the Great Cormorant diet by biomass. The largest identified fish was a Pikeperch of 36.2 cm and 436 g.

Table 3. Commercial length limits (TL) of Great Cormorant prey fish, according to Lithuania commercial fishery regulation (* – Baltic Sea).

Fish species	Fish total length (TL), cm
Burbot	49
Pikeperch	46
Ide	45
Bream	35
Razorfish	32
Vimba*	28
Goldfish	22
Flounder	21
Roach	18
Rudd	18
Perch	18
Smelt*	16

Among the identified fish species in the Great Cormorant diet, 14 occurred during all three of the study years (Table 2). The rest of the fish species were relatively unimportant in the diet, comprising 1.5% by numbers and 2.7% by biomass. Perch, Ruffe and Roach were the most important in the Great Cormorant diet over the entire study period. Their total proportion increased annually by both numbers (77.2% in 2005, 84% in 2006 and 86.5% in 2007) and biomass (68.7% in 2005, 71.1% in 2006, and 78.1% in 2007 respectively). Differences in diet composition between years were significant by both numbers and biomass, except between 2006 and 2007 by numbers and 2005 and 2006 by biomass (Table 4).

The proportion of the main fish species in the Great Cormorant diet varied significantly by both numbers and biomass during the study period (Figs 6 and 7). The proportion of Ruffe decreased from 50.5% to 31.3% by numbers during the study period (statistically significant differences between 2005–2006 and 2005–2007 years), and ranged from 22.3% in 2006 to 9.6% in 2007 by biomass (significant differences between 2006–2007). The perch proportion increased more than three times by numbers, from 8.7% in 2005 to more than 30% in 2006 and 2007 (significant differences between 2005–2006 and 2005–2007 years). The proportion by biomass was gradually increasing from 10.1% to 22.3% (significant difference between 2005–2007).

The proportion of marine fish decreased significantly during the study period, being 10.4% in 2005, 4.7% in 2006, and 2.9% in 2007 by numbers (significant difference between 2005–2006 and 2005–2007) and 8.8% in 2005 and 2006, and 3.6% in 2007 by biomass. The frequency of occurrence of marine fish in Great Cormorant pellets differed more than two-fold: 20.3% in 2005, 28.6% in 2006, 13.3% in 2007 (Fig. 2). The frequency in 2007 was significantly lower than in 2005 and 2006.

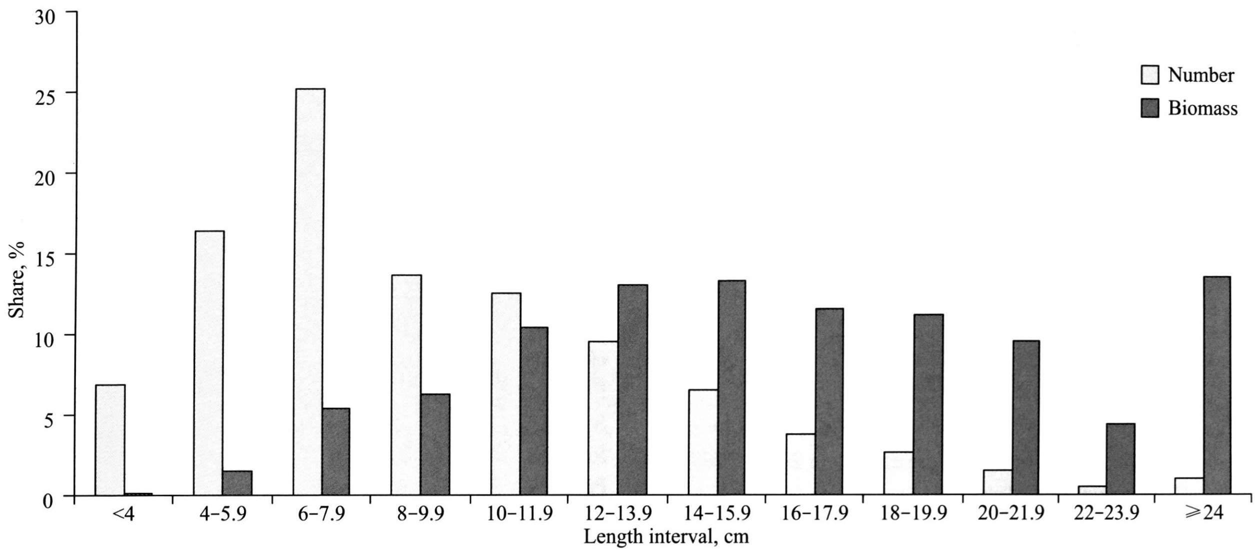

Figure 5. Distribution by length class (TL) of Great Cormorant prey fish numbers and biomass at the Juodkrantė colony in 2005–2007.

Table 4. Annual comparison of Great Cormorant diet composition by numbers and biomass. Chi-square test results are shown. Significant differences are in bold font.

		2005/2006		2006/2007		2005/2007	
		χ^2	P	χ^2	p	χ^2	P
Composition by numbers (df = 4)		**24.6**	**<0.001**	8.1	0.088	**36.8**	**<0.001**
Composition by biomass (df = 5)		10.3	0.068	**32**	**<0.001**	**21.3**	**<0.001**
Proportion of Ruffe (df = 1)	numbers	**6.6**	**0.01**	1.9	0.76	**21.8**	**<0.0001**
	biomass	3.8	0.052	**18.6**	**<0.0001**	2.4	0.118
Proportion of Perch (df = 1)	numbers	**24.1**	**<0.0001**	0.09	0.76	**21.8**	**<0.0001**
	biomass	2.7	0.098	1.7	0.189	**7.8**	**< 0.005**
Proportion of Roach (df = 1)	numbers	2.1	0.147	**5.9**	**0.015**	1.2	0.265
	biomass	**6.4**	**0.011**	0.2	0.63	**8.2**	**<0.004**
Proportion of marine fish (df = 1)	numbers	**7.3**	**<0.007**	1.2	0.283	**20**	**<0.0001**
	biomass	0	1	**12.4**	**0.0004**	**12.4**	**0.0004**
Frequency of occurrence of marine fish		3.4	0.0066	**20.3**	**<0.0001**	**4.2**	**0.039**

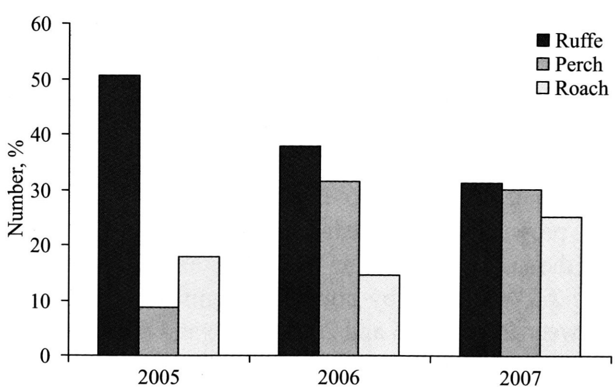

Figure 6. Percentage of dominating fish species by numbers in the Great Cormorant diet at the Juodkrantė colony in 2005–2007.

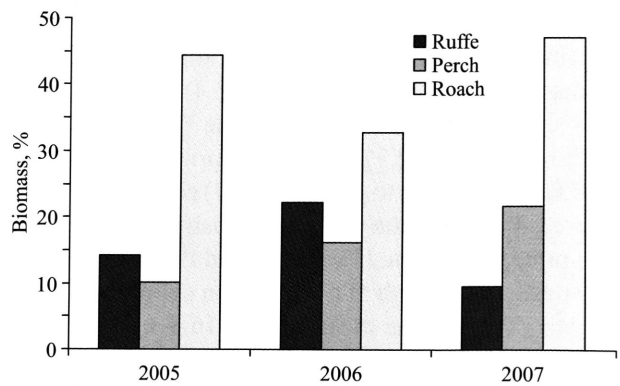

Figure 7. Percentage dominance by biomass of fish species in the Great Cormorant diet at the Juodkrantė colony during 2005–2007.

Discussion

Pellets can be collected easily and rapidly, with little or no disturbance to the birds, yet they provide good information about the species of fish eaten. On the other hand, several sources of error are involved in the analysis; erosion of fish remains that leads to underestimation of fish size, under-representation of small species due to complete weathering of otoliths and other remains (Martucci *et al.* 1993; Zijlstra & Van Eerden 1995; Carss *et al.* 1997; McKay *et al.* 2003), and secondary consumption of prey by the birds (Blackwell & Sinclair 1995). Nevertheless, pellet analysis is considered an appropriate method for the qualitative analysis of avian diets, but should not be used for the calculation of daily food intake rates because its disadvantages lead to underestimation of total prey biomass consumed (Carss *et al.* 1997). The pursuit of an appropriate quantitative correction requires an additional comprehensive investigation, including a methodological evaluation.

Situated on a narrow spit that separates the Curonian Lagoon from the Baltic Sea, the Great Cormorant colony near Juodkrantė settlement is located close to both water bodies (approx. 1 km from the sea and less than 0.3 km from the lagoon). Among the 79 fish and lamprey species (47 of them defined as common) registered in the Baltic Sea Lithuanian Economic Zone and in the Curonian Lagoon (Repečka 2003), 31 are marine species (11 of them are also found in the lagoon), 37 freshwater species (20 also occur in the sea) and 11 diadromous species. Overall, 25 fish species were identified in the Great Cormorant diet. The remains of unidentified *Pomatoschistus* spp. gobiids were also found, of which two species inhabit the Lithuanian Baltic Sea coastal waters (namely *P. minutus* and *P. microps*). Although the proportion of marine fish in the diet was found low, the bird's favourite feeding grounds cannot be determined with certainty since both marine and freshwater fish coexist in both the lagoon and the sea. More observations and research on fish populations in the sea and the lagoon are needed to resolve this question. However, drawing from the prey types and sizes consumed, the most likely feeding grounds can be proposed. At least Roach and Ruffe, contributing more than half of Great Cormorant diet by biomass, just occasionally occur in the sea. Perch, the other important prey fish, is much more abundant in the lagoon as well, especially small individuals which dominate in the diet. The Curonian Lagoon is shallow and highly productive, with abundant small shoaling fish and low water transparency (Secchi depth often does not exceed 0.3–0.4 m in summer). When a colony size reaches about one thousand breeding pairs (Van Eerden & Voslamber 1995; Suter 1997; Van Eerden *et al.* 2003) these conditions (turbid water, optimally 0.5–0.8 m Secchi depth) allow Great Cormorants to prey in groups on shoals of small fish, much more effectively than if they fed solitarily. This fact, combined with the high proportion of small fish found in the pellets of the Great Cormorants, indicate a potential for mass feeding in the Lagoon. One of the largest Great Cormorant colonies in Europe, the Polish Kąty Rybackie, is located near the sea and the brackish Vistula Lagoon in a manner similar to the Juodkrantė colony. The proportion of sea fish in the diet of Great Cormorants at Kąty Rybackie was estimated to be approximately 30% by biomass, with significant seasonal differences (Bzoma *et al.* 2003; Martyniak *et al.* 2003; Bzoma 2004).

The biomass proportions of fish species in the diet of Cormorants breeding at the Juodkrantė colony did not concur with proportions estimated from Curonian Lagoon fish stock evaluation data (Repečka 1997). The three main fish species, Roach, Perch and Ruffe, were also dominant in the Lithuanian part of the Lagoon, but in lower proportions (60.9%; Repečka 1997) than in Great Cormorant's diet (Table 2). The Bream and White Bream, two other important Lagoon species, comprised 31.7% by biomass, a proportion much higher than that in the Cormorant's diet. Great Cormorants may find these fish hard to swallow because of their laterally flattened body (Veldkamp 1995b; Čech *et al.* 2008). Large fish, usually too big as prey for Great Cormorants, share a fair amount of biomass in the Curonian Lagoon as well, e.g. large Bream comprised 19.2% by biomass (Repečka 1997).

Great Cormorants breeding at the Juodkrantė colony mostly fed on small shoaling fish, namely Ruffe and Perch (Table 2, Fig. 5). A similar diet composition was observed at the Kąty Rybackie colony in Poland, where the majority of fish were less than 10 cm length (Martyniak *et al.* 2003; Stempniewicz *et al.* 2003a). Less abundant larger fish were more important at the Juodkrantė colony: 10–22 cm long fish contributed 68.8% by biomass to the Great Cormorant diet, while their share by numbers was 36.4%. The abundance of small fish might be increasing due to the decline of predatory fish because of commercial overfishing, especially of Pikeperch, in the Curonian Lagoon (Van Eerden & Voslamber 1995; Stempniewicz *et al.* 2003b). Another important factor that may be responsible for the dominance of cyprinid fish, comprising more than half of the Great Cormorant's diet, is the increasing eutrophication of the Lagoon waters. Eutrophication and intensive commercial fishing are considered generally responsible for the expansion of the Great Cormorant in Europe (De Nie 1995).

The three main Great Cormorant prey species (Roach, Ruffe and Perch) were the most important during all study periods of our investigation, with an increasing temporal trend. A similar diet pattern was observed for the Great Cormorant in the Vistula Lagoon during 1995–1997. The proportion of Ruffe, Roach and Perch in the diet varied from 77% to 84% by biomass; the biomass of these fish species also exceeded 50% in scientific catches (Stempniewicz *et al.* 2003b). In the Great Cormorant diet study conducted at the Juodkrantė colony in 2001 by the analysis of regurgitated fish (Žydelis *et al.* 2002), the contribution of Roach was similarly important to the present study. However, other important prey included relatively large Pikeperch and Bream (mean total length 25.1 cm and 22.5 cm respectively). Different study methods might have contributed to these differences because when analysing diets from regurgitated fish, the mean fish size is more accurately estimated in comparison to stomach content than from pellet analysis (Martyniak *et al.* 2003). The Curonian Lagoon is a complex system with substantial fluctuations in abundance of different fish species over a long time scale that may also be reflected in the Great Cormorant diet. The Great Cormorant is a piscivorous opportunistic predator and although it is size and species selective, its diet reflects fish community structure (De Nie 1995; Dirksen *et al.* 1995; Veldkamp 1995b; Engstrom & Jonsson 2003; Čech *et al.* 2008). Our results revealed that the most abundant fish in the Curonian Lagoon dominated the diet, confirming the Cormorant's opportunistic behaviour.

The remains of the invasive Round Goby (*Neogobius melanostomus*), spreading in the Curonian Lagoon and in the Baltic Sea coastal waters (Rakauskas *et al.* 2008), were found in Great Cormorant pellets in 2007 for the first time. Although its proportion in the diet was very low (Table 2), further population increases of this slow moving, bottom living fish in the aquatic ecosystems could render it an important prey item for the Cormorant in the future. The Round Goby comprised about 70% by biomass (more than 90% during the breeding season) of the Great Cormorant diet in the gulf of Gdansk (Bzoma & Meissner 2005), where its abundance is high; from a few to 30 individuals per 1 m^2 (Sapota 2004). A similar change was observed in the diet of the Double-crested Cormorant (*Phalacrocorax auritus)* in North America's Great Lakes, where the Round Goby was introduced during the last decade of the 20^{th} century (Johnson & McCullough 2008). The increasing abundance of the Round Goby in the Curonian Lagoon might affect Great Cormorant populations in the future, like in the Gulf of Gdansk, where the increase in abundance of wintering Great Cormorants is considered to be related to Round Goby invasion. On the other hand, the Great Cormorant as a predator might also regulate Round Goby populations to limit their expansion.

Commercial fish species, mostly low-valued, comprise a large proportion in Great Cormorant diet (Fig. 4). We found a substantial proportion of commercial size fish in the diet, but of low commercial value only, mostly Roach. They were remarkably smaller then fish caught in 40–45 mm mesh size gillnets, the most important commercial gear in the Curonian Lagoon (Žydelis & Kontautas 2008). Among the more valuable commercial fish in the Curonian Lagoon, only Pikeperch had a substantial proportion in the Great Cormorant diet (5.9% by biomass), but no one individual was of commercial size. Thus we found only a minor direct competition with the commercial fishery. The most valuable Curonian Lagoon fish, the European Eel (*Anguilla anguilla*), was not found in the Great Cormorant pellets. Most studies have demonstrated a low proportion of the European Eel in the Great Cormorant diet (De Nie 1995; Dirksen *et al.* 1995; Carpentier *et al.* 2003; Engstrom & Jonsson 2003; Martyniak *et al.* 2003; Stempniewicz *et al.* 2003a). However, when natural or stocked populations are abundant, the European Eel may comprise 30% or more by biomass in the Cormorant's diet in mid-summer (Van Dobben 1952; Knoesche 2003). Mass fishing, when Great Cormorants mostly prey on small pelagic shoaling fish in turbid environments, has become common during the last few decades and it is one of the reasons why Eels are not usually important in the diet (De Nie 1995; Van Dobben 1995; Van Eerden & Voslamber 1995). Furthermore, European Eel stock and recruitment has been declining throughout its range during the last few decades (Dekker 2004).

The present study revealed that Great Cormorants breeding at the Juodkrantė colony were mainly feeding on small percids and cyprinids, most likely in the Curonian Lagoon. This dietary compostion is typical for Great Cormorants preying socially in shallow turbid waters. Commercial fish species comprised a large proportion of the diet, but the most of them were low-valued Roach and consequently, direct competition with the commercial fishery was only minor. A previous study on the impact of piscivorous birds fish stock size and community composition in the Curonian Lagoon, based on commercial landing statistics and fish community monitoring data during 1993–2002 that coincided with the period of steep growth of Great Cormorant colony at Juodkrantė, did no show any changes that could be attributed to an increase in bird numbers (Žydelis & Kontautas 2008). More detailed studies on fish population size and structure in the Curonian Lagoon are required for a definitive assessment of the impact of Great Cormorants, especially on the most important prey species. Moreover, the role of Great Cormorants in the Curonian Lagoon and the coastal waters of the Baltic Sea may change in the future due to expansion of Round Goby populations.

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DIDŽIOJO KORMORANO (*PHALACROCORAX CARBO SINENSIS*) MITYBA JUODKRANTĖS KOLONIJOJE LIETUVOJE

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SANTRAUKA

Nuo praėjusio amžiaus 9-ojo dešimtmečio vidurio Lietuvoje išplitusius didžiuosius kormoranus (*Phalacrocorax carbo sinensis*) žvejai dažnai kaltina dėl žuvų išteklių mažėjimo. Poveikio ištekliams įvertinimui buvo atlikti didžiųjų kormoranų mitybos tyrimai kolonijoje Kuršių nerijoje ties Juodkrante, analizuojant atrajas. 2005–2007 m. perėjimo ir jauniklių maitinimo metu buvo surinkta 220 atrajų. Identifikuotos 25 žuvų rūšys. Pūgžlys (*Gymnocephalus cernuus*), ešerys (*Perca fluviatilis*) ir kuoja (*Rutilus rutilus*) vyravo mityboje tiek pagal skaičių (82,9%), tiek pagal masę (73,6%). Vidutinis žuvies ilgis racione buvo 9,5 cm, vidutinis svoris – 16,8 g. Nors verslinės žuvys pagal biomasę sudarė 83% kormoranų mitybos, dauguma jų buvo smulkios, nedidelės vertės žuvys, ypač kuojos. Nežiūrint to, kad paukščių kolonija yra netoli Baltijos jūros, jūrinės žuvys sudarė tik nedidelę mitybos dalį (5,7% pagal skaičių ir 6,5% pagal masę). Galima daryti prielaidą, kad Kuršių marios yra pagrindinė Juodkrantės kolonijoje perinčių didžiųjų kormoranų maitinimosi akvatorija.

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