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POPULATION DEVELOPMENT OF THE GREAT CORMORANT (*PHALACROCORAX CARBO*) IN ESTONIA

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Abstract. In the 1960s the number of great cormorants in the Baltic Sea region was estimated at approximately 3,100 breeding pairs. The numbers remained low until the mid-1970s. In the 1980s the population began rapidly to increase and expand its range towards the eastern and northern parts of the Baltic Sea. In Estonia, great cormorants re-established breeding in 1983. During the first seven years (1983-1989) the number of breeding pairs remained below 100, yet in 1994 the population consisted of more than 1,000 pairs. In 1999 the estimated number of breeding pairs was 5,000 and in 2005, even 10,000 pairs. The maximum number of 14,000 breeding pairs was reached in 2008, however, in subsequent years the numbers have declined. Initial population growth resulted mainly from immigration from other parts of the Baltic Sea. Until 1992, the Estonian population consisted almost entirely of the breeders in the Moonsund Archipelago, whose relative importance has presently declined to 22%. Subsequently, cormorants inhabited islands in the Gulf of Riga, where at present the numbers have more or less stabilized at around 5,500 pairs, which accounts for 42% of all breeders. The number of breeding pairs is still increasing on the islands of the Gulf of Finland, forming 26% of the Estonian breeding population. The breeding sites in the Baltic Proper, together with the inland water bodies of Estonia host only a minor proportion of the population, 7% and 3%, respectively. Such rapid population growth of the Great Cormorant probably results from protection measures, as well as from enhanced breeding success after the banning of poisons such as DDT and PCBs but also from changes in the Baltic Sea fish stocks. However, the harsh winters of the past few years are expected to decrease population size in near future due to the reduced number of recruits and diminishing immigration.

Introduction

There are two* subspecies of the great cormorant breeding in Europe, *Phalacrocorax carbo carbo* and *Phalacrocorax carbo sinensis*. The main difference lies in their habitat preference. The subspecies *carbo* mainly breeds on rocky coasts in more exposed marine habitats in northern France, Great Britain, Ireland, Iceland and Norway. The continental subspecies *sinensis* is widespread in the rest of Europe (Hagemeijer & Blair 1997), including Estonia. The numbers of both subspecies are increasing, but this trend is slower and regionally variable in the case of *carbo* subspecies. In 2006, during the Pan-European census of breeding great cormorants, the numbers of the subspecies *sinensis* and *carbo* were estimated at 232,300 and 52,100 pairs, respectively. As for January 2007, the numbers of the continental subspecies (including the young of the year, the non-breeders and the breeding birds) in Europe were estimated at 755,300 individuals (Wetlands International Cormorant Research Group, 2008).

The first data, indicating cormorant presence in Estonia come from the findings of fossil cormorant bones from Stone Age human settlement sites in Kunda Lammasmäe and in Kõpu. Bones from the Iron Age have been found at hillfort of Iru (Sits 1934, Kriiska & Lõugas 1999). However, direct evidence indicating the existence of a breeding population (e.g. bones of nestlings or juveniles) in Estonia from this period is missing.

At the end of the 18th century, cormorants were rare visitors at the Baltic Sea. First breeding was registered around 1775 in Denmark and thereafter at the beginning of the 19th century in coastal areas of Germany. The first large colonies were established on the southern coast of the Rügen Island and in the middle of the 19th century also on the islands Usedom and Wollin (Herrmann 2011). However, A.W. Hupel (1777) stated that in the 18th century, cormorant colonies at the former Livonian coast were established in trees. Similarly, at the beginning of the 20th century, P. Wasmuth (1909) and O. Koch (1911) affirmed that in the past decades, cormorant colonies were found in the forest in some parts of Estonia, including Kolga (*Kolk*) ja Purdi (*Noistfer*). Moreover,

* Marion & Gentil (2006) distinguish also the subspecies *P. c. norvegicus*

written reports from the same period reveal that cormorants were breeding in the downstream area of the River Nemunas and on the Curonian Spit, in Lithuania (Jusys, 1997) but also in Poland (Tomialojc, 1976). Due to systematic persecution, cormorants almost entirely disappeared from the Baltic Sea by the end of the 19th century, only a small number endured in a few provinces in Prussia. Cormorants re-established breeding in Denmark and Sweden in 1938 and 1948, respectively. From the 1960s until the mid-1970s the Baltic Sea cormorant population was estimated at 2,500 to 3,500 breeding pairs (Herrmann 2011), whereby the entire European population of the continental subspecies *sinensis* had been estimated in the beginning of the 1960s at about 4,000 pairs (Herrmann *et al* 2012). Due to the more efficient protection since 1965, the population started to gradually recover in the western part of the Baltic Sea, and from 1980 began rapidly to increase and expand its range towards the east (Bregnballe 1996).

To date the Baltic Sea is considered as the core area of the European cormorant population, hosting approximately 70% of the European continental subspecies *sinensis*. Cormorant numbers in the Baltic Sea region have been constantly increasing up to 2010. The number of breeding pairs reached up to 4,900 in 1980 and 51,000 in 1991, however, during the Pan-European census in 2006, already 157,000 breeding pairs were registered, increasing even to 166,000 in 2009 (Herrmann *et al*. 2012). Back then, there were clear regional differences in the development of the local populations. Since 1994, the population size in the SW part of the Baltic Sea (Denmark and Mecklenburg-Vorpommern, in Germany) has more or less stabilized at around 50,000 pairs. The numbers in the southern Sweden were either stable or decreasing. The population size in the central part of the Baltic Sea (the island of Gotland) was increasing, yet the increase was even three times faster in the eastern and northern parts of the Baltic Sea. Cormorant numbers rose rapidly also in the Russian part of the Gulf of Finland (Gaginskaja & Rychkova 2010). As a result of such regional disparities, the proportion of the westward breeding cormorants has declined in the Baltic Sea region: as in 2006, the breeding population in the western countries (Sweden 44,000, Denmark 38,000, coastal areas of Germany 15,200 and Poland 25,800 pairs) made up 79% of the total Baltic Sea population, then in 2009, the proportion had already declined to 72% (Figure 1; Herrmann *et al*. 2012).

The entire Baltic Sea population suffered a setback in consequence of a harsh winter of 2009/2010. The number of breeding pairs decreased in all monitoring areas at the Baltic Sea – in Gotland, in Sweden (21%), in Mecklenburg-Vorpommern and Schleswig-Holstein, in Germany (20% and 4%, respectively), on the Vistula Spit in Poland (20%), in Denmark (15%), in Finland (10%) and in Estonia (5%). Altogether, cormorant numbers in these areas declined by 14.5%, i.e. by 14,350 breeding pairs (Herrmann *et al*. 2012). However, a decline of the breeding population in the Baltic Sea was not likely to be as extensive as it could be concluded on the basis of the nest counts. A decline in the number of breeding pairs can, besides the increased mortality rate, also be explained by an increased number of individuals skipping breeding due to their worsened health condition. Additionally, the winter 2010/2011 was harsh, but not as severe as the previous one, particularly for the eastward populations of the Baltic Sea. Differences in the weather conditions in the western and eastern wintering grounds were reflected in the number of breeders – numbers were declining in the western part of the Baltic Sea (Denmark 10% and Mecklenburg-Vorpommern in Germany 18%), but remained stable in the central part (the island of Gotland) and in Baltic states, and even increased in Finland (23%; Herrmann *et al*. 2012). Altogether, these two cold winters escalated the downward trend of the cormorant numbers at the SW Baltic Sea.

Problems arising from such a rapid increase and spreading of the cormorant population urged the European Commission to launch an initiative called CorMan* (2011-2013). The aim of the project, among other things, is to perform a count of cormorant breeding colonies in the Western Palearctic in the summer of 2012 and of wintering cormorants in January 2013. Summer and winter counts are being carried out one after the other, so that the results are directly comparable. The entire Europe, along with important border areas as regards the cormorants, is divided into four regions. Estonia belongs to the region North, together with Iceland, Norway, Sweden, Finland, Denmark, Latvia, Lithuania and Kaliningrad Oblast of the Russian Federation. Such a Pan-European census enables to obtain a more complete and consistent overview of the European cormorant population.

*See http://ec.europa.eu/environment/nature/cormorants/home_en.htm

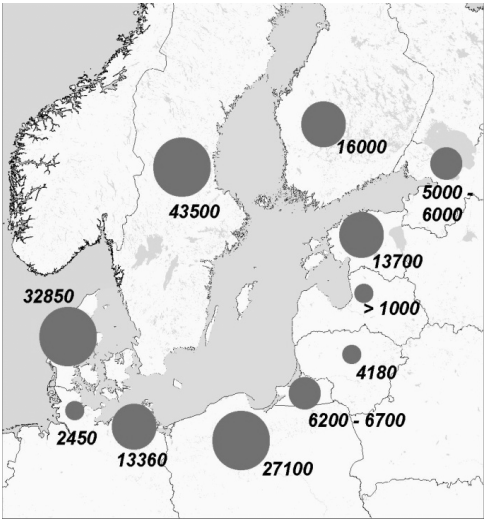

Figure 1. The number of breeding pairs of the great cormorant in the Baltic Sea area in 2009. [Herrmann *et al*. 2012]

A fast spread and a rapid population growth of the cormorants in Estonia, together with the resulting environmental problems, have attracted the attention of researchers. Eve Mägi, Urve Ratas and Elle Puurmann (1995) have studied the changes in the landscape in cormorant colony on Tondirahu islet. Jeroen Nienhuis (1997) has analysed the interspecies food competition between cormorants and smews (*Mergellus albellus*) in Matsalu Bay. Ichthyologists have studied the impact of cormorants on the local fish stocks and on the coastal fishery (Eschbaum *et al.* 2003; Vetemaa *et al.* 2010). Also a master's thesis (Veber 2001) and a bachelor thesis (Salutamm 2009) are expanding on the foregoing subject. Recently an overview of the recoveries of cormorants ringed in Estonia has been published (Leola 2011). Changes occurring in the cormorant population have been briefed in popular-scientific publications, where often the harmfulness of this species has been under debate (e.g. Eschbaum 2004; Lilleleht 2004a, 2011).

The cormorant is one of a few bird species in Estonia with an existing data set of an absolute census. This species has been monitored annually in Matsalu National Park ever since it established breeding, and in the past ten years several reports on the status of the Estonian population have been written (Lilleleht 1995, 2002, 2004a, 2004b, 2007,

2008a, 2008b; Rattiste & Saks 2010; Rattiste 2011a, 2011b). The aforementioned records are sufficient in order to describe the development of the Estonian cormorant breeding population. Hereby, the current article provides a comprehensive overview of the development of the Estonian cormorant population until 2011.

Material and methods

Monitoring of the cormorant population has been carried out since the species re-established breeding in Estonia, in 1983. The aim of the monitoring has been to obtain an exact overview of the distribution, numbers and breeding success of the cormorants. In order to obtain information on the number and distribution of breeding pairs, already known colonies have been visited. Additionally, potentially suitable breeding sites have been checked to discover newly established colonies (in particular, the areas at Lake Peipus and the islands in the Gulf of Finland). Data on colonies was received as follows:

- colonies within protected areas were annually checked during breeding bird censuses (e.g. Vilsandi and Matsalu National Parks and Hiiumaa Islets' Landscape Reserve);
- colonies visited during the national census of breeding birds on small islands (since 2008);
- information on the number of nests and birds in colonies, obtained from aerial photographs;
- random information on the location of newly established colonies.

If information on cormorant colonies was not obtained from the first two aforementioned sources, special counts were carried out.

It is important to point out that the number of breeding pairs is assessed on the basis of the number of counted nests. Therefore, the actual number of breeding pairs in a particular colony may be somewhat higher. For example, by the time of the counts, some nests might either not exist anymore (the shortage of nest material urges other cormorants to remove and re-use the nest material of predated and flooded nests) or some birds might skip breeding because of poor body condition.

In the current article, the following geographical distribution of breeding areas has been used: the Gulf of Finland, the Moonsund

Archipelago, the Gulf of Riga, Baltic Proper and the inland water bodies of Estonia. The Baltic Proper is considered as an area that lies west of Saaremaa, and west and north of Hiiumaa.

Results

Estonia as a whole

In Estonia, cormorants first re-established breeding in 1983, on Lõuna-Malusi Island, in the Gulf of Finland, where one nest was found (Lilleleht & Leibak 1991). In 1984, a colony was discovered on the islet of Sipelgarahu, in the Matsalu National Park (Moonsund Archipelago). While cormorant breeding assembly in the Moonsund Archipelago persisted (Paakspuu & Mägi 1988), yet in the Gulf of Finland the next nest was found only in 1987, on Lõuna- Malusi Island. The first colony there was established on Lõuna-Uhtju Island in 1994, that is 11 years after the first nest registration (table 1). In the Gulf of Riga, breeding was first recorded in 1989, on the small islet of Kerjurahu (Lilleleht & Leibak 1991), and the first colony was established in 1992 on Väike-Allirahu (Lilleleht 1999). In the Baltic Proper, cormorants bred for the first time in 1994, when two nests were found on Kakralaid Islet, NE from the island of Hiiumaa (Leito & Leito 2011). A more or less permanent colony formed there in 1998. On the Estonian mainland, similarly to the Baltic Proper, the first breeding was registered in 1994, on the Tondisaar Island, in Lake Võrtsjärv, yet a permanent colony developed there in 1999.

During the first decade (1983-1992), when the very first nests were found in the Gulf of Finland and the Gulf of Riga, and the first permanent colony in the Moonsund Archipelago was established, the number of concurrently used breeding sites in Estonia was up to three. In the following years, the number of colonies grew steadily, reaching 30 by the end of 2007, and has not increased since (Figure 2).

In favourable breeding sites, cormorant colonies may endure over a long period of time. So, in the Matsalu National Park cormorants had been breeding on Tondirahu for 25 years (until 2010) and on Sipelgarahu for 19 years; in the Gulf of Finland, on Lõuna-Uhtju for 18 years, on Põhja-Uhtju and Põhja-Malus for 14 years, and in the Käina Bay (Moonsund Archipelago), on Männaklaid for 16 years. Colonies of at

Table 1. The number of great cormorant nests in different regions of Estonia and the breeding population estimate. + indicates breeding, but the number of pairs is unknown.

Year	Region					Nests (total)	Breeding population
	Gulf of Finland	Moonsund Archipelago	Gulf of Riga	Baltic Proper	Continental Estonia		
1983	1	0	0	0		1	1
1984	+	5	0	0		5	6
1985	+	16	0	0		16	17
1986	+	21	0	0		21	22
1987	1	21	0	0		22	22
1988	+	36	0	0		36	37
1989		75	1	0		76	77
1990		139	0	0		139	140
1991		262	0	0		262	265
1992		467	17	0		484	490
1993		770	193	0		963	970
1994	20	960	436	2	8	1426	1430
1995	30	1539	810	7		2386	2390
1996	30	1411	924	0		2365	2370
1997	52	1907	1276	0		3235	3240
1998	302	2672	904	20		3898	3905
1999	323	3410	1208	48	16	5005	5015
2000	419	3705	1111	14	15	5264	5275
2001	654	4188	1452	13	23	6330	6350
2002	975	3100	3824	180	15	8094	8100
2003	942	3418	3822	274	15	8471	8500
2004	1187	3533	4110	709	20	9559	9600
2005	1188	4498	3484	861	20	10051	10100
2006	1521	4565	4538	1091	30	11745	11750
2007	2419	4185	5377	673	79	12733	12750
2008	2788	4533	6062	490	110	13983	14000
2009	3204	4618	5735	107	25	13689	13700
2010	3511	3404	5025	805	236	12981	13100
2011	3389	2812	5445	901	380	12927	13050

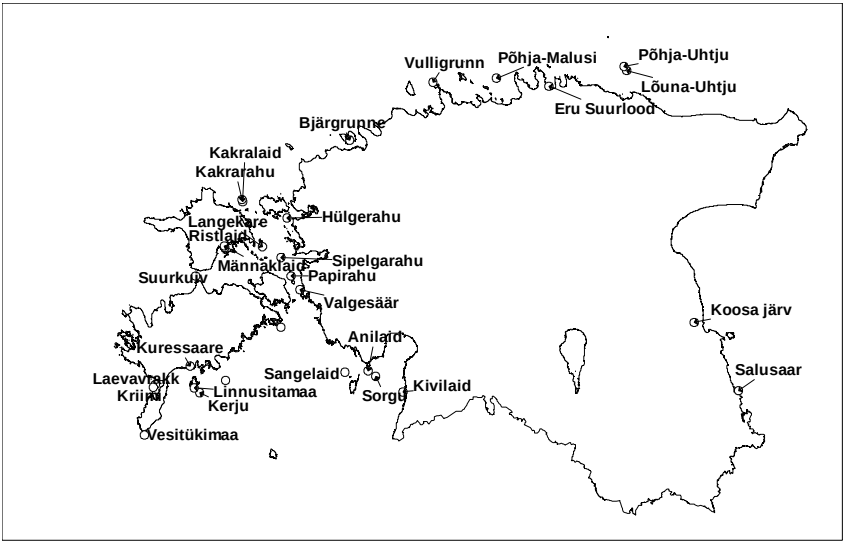

Figure 2. The breeding sites of great cormorants in Estonia in 2011.

least 16 years old have been registered on Häädemeeste Kivilaid, in the Gulf of Riga and on the small islet of Kerjurahu, close to Abruka.

In the first seven years (1983-1989), the number of cormorant breeding pairs remained below 100, but increased to more than 1,400 pairs in the following 5 years (1990-1994) (table 1, Figure 3). By 1999, the numbers were estimated at up to 5,000 pairs and even up to 10,000 in 2005. The record number of 14,000 breeding pairs was reached in 2008. The highest increase in population size has been observed in 2002 and 2006 (1,764 and 1,694 pairs, respectively). Such a rapid population growth was followed by a remarkable decline (table 2), especially following the cold winter in 2009/2010. In addition to lower survival, harsh wintering conditions probably resulted also in poor body condition, which urged many cormorants to skip breeding. On account of this, our breeding population estimates of 2010 and 2011 are about 100 pairs higher than the actual number of counted nests (table 1). Due to the rapid population growth, the relative proportion of the Estonian population in the whole Baltic Sea population has increased from 0.5 % in 1991 to 8.2 % in 2009.

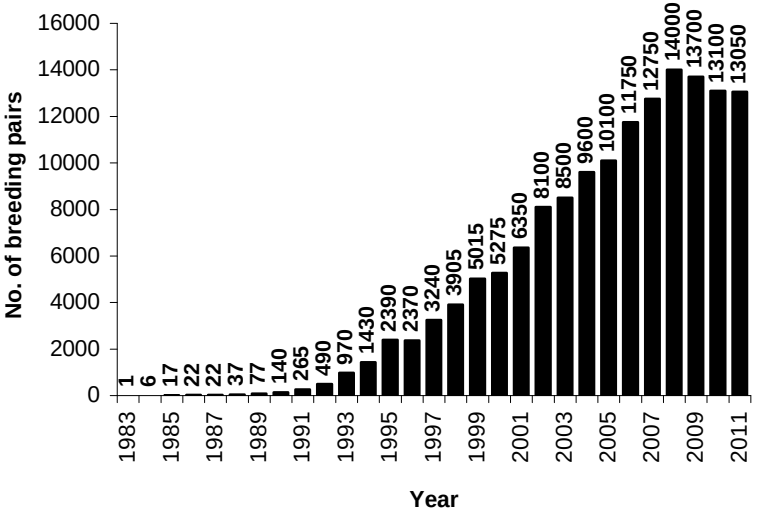

Figure 3. The development of the Estonian great cormorant population.

Table 2. The development of the breeding population of the great cormorant.

Period	Annual increase	
	pairs	%
1983–1988	7	105,9
1989–1994	271	79,4
1995–2000	577	17,2
2001–2006	1080	13,1
2007	1000	8,5
2008	1250	9,8
2009	-300	-2,1
2010	-600	-4,4
2011	-50	-0,4

Cormorants re-established breeding in Estonia by inhabiting first suitable nesting sites in the Moonsund Archipelago where the majority of Estonian breeding population situated until 1992 (table 1, Figure 4). Subsequently, as the cormorants inhabited the islets in the Gulf of Riga and in the Gulf of Finland, the proportion of the breeders of the Moonsund Archipelago began steadily to decline, and by 2011, it had declined

to only 22% of the breeding population. The Gulf of Riga was inhabited in an especially short period, with the only setback occurring in 1998 to 2001, when part of the breeders moved to the Moonsund Archipelago, probably due to persecution (Figure 4). Since 2007, the population size in the Gulf of Riga has stayed more or less stable, and accounts for 42% of the total breeders of Estonia. However, the number of breeding pairs is still increasing on the islands in the Gulf of Finland. Since 2001, the breeding population there has annually increased on average by 275 pairs, and accounts for 26% of the whole Estonian breeding population. The Baltic Proper and the inland water bodies of Estonia host 7% and 3% of the Estonian breeding population, respectively.

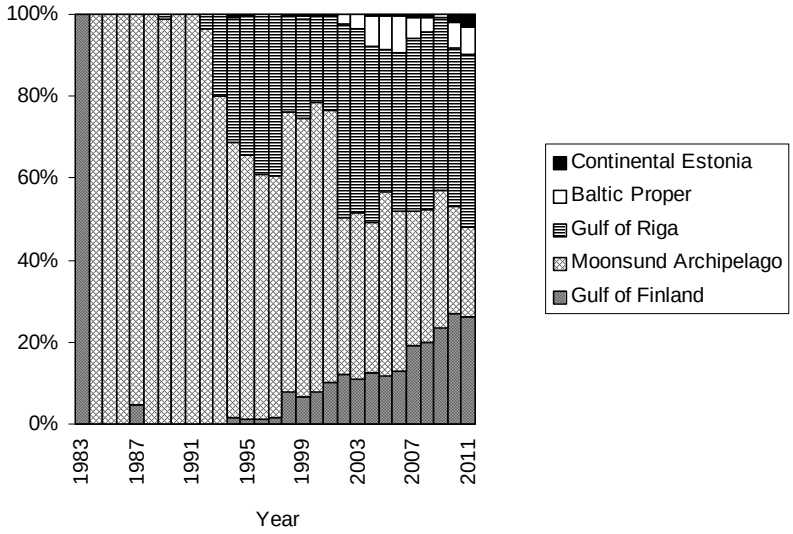

Figure 4. The geographical distribution of breeding great cormorants.

Gulf of Finland

The first cormorant colony in the Gulf of Finland consisted of 20 nests and was established on Lõuna-Uhtju in 1994, 11 years after the first reported nest (table 3). Two years later, cormorants inhabited Põhja-Malusi, and another two years later Põhja-Uhtju. In 1999, four nests

were found west from Suur-Pakri, on Krassi islet (Krässgrund) (Veber 2001), which is also so far the only nesting attempt reported on this lowland islet. The next colony in the Gulf of Finland was reported in 2006, on a small islet of Bjärgrunne, which is located between the islands Suur-Pakri and Väike-Pakri. In the subsequent year, 2007, during the aerial waterbird census, a new colony was reported on Vullikrunn that lies north from Aegna Island. However, the colony size (452 nests) indicates that this islet had already been inhabited some time ago. On the islets of Eru Bay, cormorants were first reported breeding in 1997, on Eru (Kasispea) Keskmine Lood. The next breeding attempt on the islets occurred on Eru Suurlood) and Eru Väikelood in 2007, and on Eru Keskmine Lood in 2008 (Metsaorg *et al*. 2007; Lilleleht 2008b). In the following years, cormorants inhabited only the Eru Suurlood (table 3).

Even though cormorants have been breeding on 10 different islands in the Gulf of Finland, only 6 have permanent colonies – Põhja-Malusi, Lõuna-Uhtju, Põhja-Uhtju, Bjärgrunne, Vullikrunn and the Eru Suurlood. Breeding attempts on the rest of the four islands have been mostly occasional.

The cormorant population in the Gulf of Finland has been increased at accelerating rate (Figure 5). During six years (1994-1999) after the establishment of the very first colony, the breeding population has grown by 61 pairs per year, and in the consecutive six years, by an average of 154 pairs. The mean annual growth rate of the past six years (2006-2011) has been 374 pairs. The fastest growing cormorant colonies are located on the islands Põhja-Malusi and Põhja-Uhtju (table 3).

Moonsund Archipelago

Moonsund Archipelago was inhabited by cormorants in 1984 – a colony of 5 nests and approximately 20 adult birds were reported on Sipelgarahu, in the Matsalu National Park. The colony was flooded during a storm, which forced the birds to move to Valgerahu. In the succeeding year cormorants did not re-inhabit Sipelgarahu, yet the colony on Valgerahu already consisted of 16 nests (Paakspuu & Mägi 1986). In 1986,

Table 3. The number of great cormorant nests on the islands of the Gulf of Finland. Expected number of nests given in parentheses.

Year	Breeding site									
	Lõuna-Malusi	Põhja-Malusi	Lõuna-Uhtju	Põhja-Uhtju	Krässgrund	Bjärgrunne	Eru Suurlood	Eru Keskmine Lood	Eru Väikelood	Vullikrunn
1983	1									
1984	(<5)									
1985	(<5)									
1986	(<5)									
1987	1									
1988	(<5)									
1989										
1990										
1991										
1992										
1993										
1994			(20)							
1995			(30)							
1996			(30)							
1997			(50)							
1998		5	296	1						
1999		41	264	14	4					
2000		(40)	364	(15)						
2001		266	323	65						
2002		345	505	125						
2003		(260	387	295						
2004		519	375	293						
2005		564	383	241						
2006	0	728	512	271	0	10				
2007	0	653	513	482		190	123		6	452
2008	27	937	540	490		334	52	4	0	404
2009	109	988	723	537		170	118	0	0	559
2010	2	1343	571	636		285	120	0	0	554
2011	0	1280	331	933		244	38	0	0	563

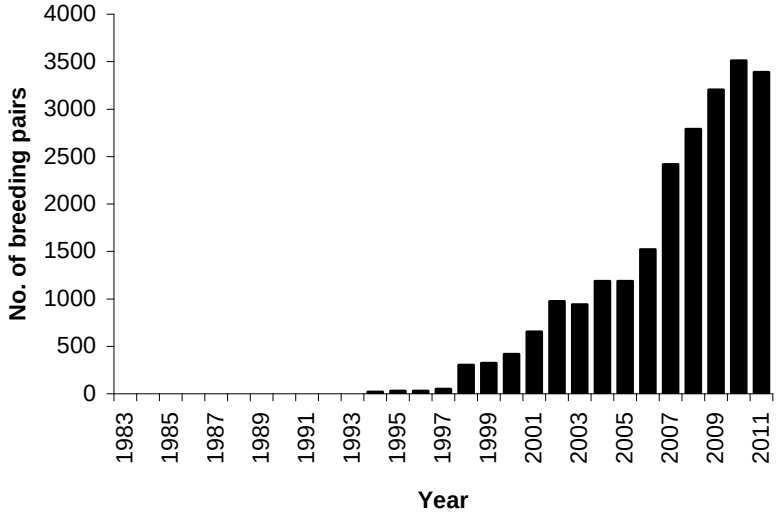

Figure 5. The numbers of breeding pairs of the great cormorant on the islands of the Gulf of Finland.

cormorants remained on Valgerahu and an additional colony was established on Tondirahu (Paakspuu & Mägi 1988). Over the next seven years (1987-1993) the colony on Tondirahu increased to 739 nests and was basically the only breeding site in the Moonsund Archipelago (table 4). Since 1993, cormorants have inhabited numerous breeding sites in the Moonsund Archipelago: re-inhabited Sipelgarahu, in 1993; Hanerahu in the Hiiumaa Islets' Landscape Reserve, in 1994 (Leito & Leito 2011); and Männaklaid, in the Käina Bay in 1995. In 1999, cormorants established a colony on the Langekare Island, near Hiiumaa; in 2000, on Anemaa, in the Matsalu National Park; in 2001, on Ristlaid, in the Käina Bay; and in 2002, on Papirahu, in the Matsalu National Park. In 2003, cormorants were first breeding on the Suurkuiv Islet, in Soela Strait. In 2004, an attempt to establish a colony on one of the islets in Saunja Bay was noted. In 2006, cormorants inhabited Hülgerahu, near Hobulaid. Breeding attempts were also reported on two of the Kõbaja Islets - on Valkare and Valgesäär, in 2007 and 2009, respectively. On the latter islet, a breeding colony exists since 2011. In 2008, a breeding attempt was reported on Papilaid, in the

Table 4. The number of great cormorant nests in the Moonsund Archipelago. Expected number of nests given in parentheses, * indicates that only repeat clutches were laid on island.

Year	Breeding site															
	Sipelgarahu	Valgerahu	Tondirahu	Anemaa	Papirahu	Papilaid	Kõbaja Valkare	Kõbaja Valgesäär	Männaklaid	Ristlaid	Kadaklaid	Hanerahu	Langekare	Hülgerahu	Suurkuiv	Saunja Bay
1984	5	*	0	0	0	0			0	0	0	0	0			
1985	0	16	0	0	0	0			0	0	0	0	0			
1986	0	15	6	0	0	0			0	0	0	0	0			
1987	0	0	21	0	0	0			0	0	0	0	0			
1988	0	2	34	0	0	0			0	0	0	0	0			
1989	0	0	75	0	0	0			0	0	0	0	0			
1990	0	0	139	0	0	0			0	0	0	0	0			
1991	0	0	262	0	0	0			0	0	0	0	0			
1992	0	0	467	0	0	0			0	0	0	0	0			0
1993	31	0	739	0	0	0			0	0	0	0	0			0
1994	94	0	856	0	0	0			0	0	0	10	0			0
1995	84	0	1400	0	0	0			18	0	0	37	0			0
1996	125	0	1286	0	0	0			0	0	0	0	0			0
1997	69	0	1795	0	0	0			18	0	0	25	0		0	0
1998	409	0	2113	0	0	0			150	0	0	0	0			0
1999	608	0	2335	0	0	0			335	0	0	0	132			0
2000	348	0	2911	*	0	0			(300)	0	0	0	146			0
2001	932	0	2816	0	0	0			(350)	(40)	0	0	50			0
2002	187	67	668	382	785	0			482	129	0	0	400			0
2003	221	0	2046	0	526	0			(450)	(100)	0	0			75	0
2004	331	0	1857	0	617	0			562	162	0	0	0			4
2005	522	0	1770	0	805	0			1065	336	0	0	0			0
2006	148	0	1999	0	1014	0			913	353	0	0	0	30	108	0
2007	65	0	1771	430	622	0	70	0	750	350	0	0	0	55	0	72
2008	0	0	1518	56	1015	(200)	0	0	1240	350	0	0	0	0	154	0
2009	100	0	1815	0	1006	0	0	14	1169	404	31	0	0		79	0
2010	150	0	512	0	1156	0	0	0	907	380	0	0	0	13	286	0
2011	729	0	0	0	140	0	0	302	691	495	0	0	110	230	115	0

Matsalu National Park. In the succeeding year another breeding attempt was registered on Kadaklaid, in Käina Bay.

The maximum number of breeding colonies in the Moonsund Archipelago was registered in 2007, and comprised 9 different sites. Cormorants have been breeding on 16 different islets in the Moonsund Archipelago, yet on only 6 of them more or less permanent colonies have been established - Sipelgarahu, Tondirahu and Papirahu, in the Matsalu National Park; Männaklaid and Ristlaid, in the Käina Bay; and Suurkuiv, in the Soela Strait (table 4). The oldest cormorant colony so far has existed on Tondirahu, which endured for 25 years but was abandoned in 2011.

For the time being, the reason for abandonment is believed to be the presence of the white-tailed eagles (*Haliaeetus albicilla*) on the islet, feeding on young cormorants. Breeding colonies have also endured for many years on several other islets: Sipelgarahu 18, Männaklaid 16, Ristlaid 11, Papirahu 10 and Suurkuiv 6 years. On the remaining 10 islets, breeding has been more occasional and lasted only up to four years. These breeding sites have not been suitable enough and have often been inhabited

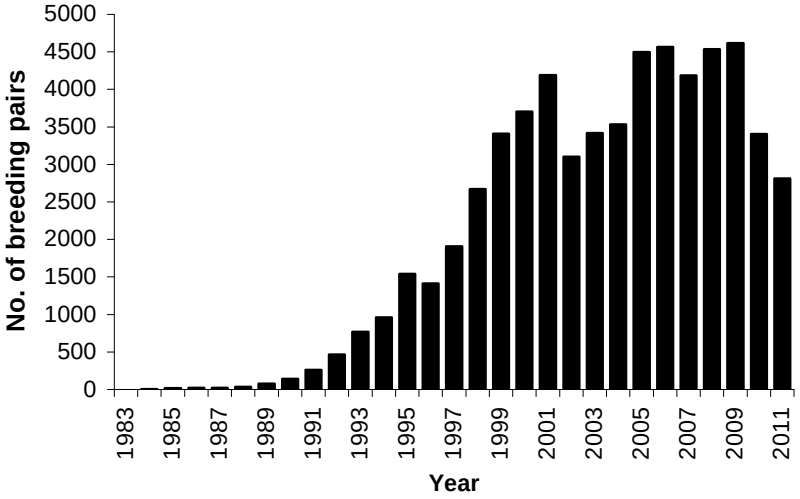

Figure 6. The numbers of breeding pairs of the great cormorant in the Moonsund Archipelago.

after extensive predation has occurred or after a large number of nests had been flooded elsewhere. For example, Anemaa is an islet that has been inhabited perforce. By now, also Valgerahu has lost its importance as a breeding site - in the past years, this low islet with no vegetation has been reshaped by storms and birds do not breed there any more.

It took seven years (1984–1990) for the cormorant population on the Moonsund Archipelago to exceed the limit of 100 breeding pairs. In the succeeding seven years (1991-1997), the population grew rapidly, the average annual increase being 274 pairs. This was followed by an exponential growth, probably due to individuals immigrating from the Gulf of Riga, as in only four years (1998-2001), the number of breeding pairs increased from 1,907 to 4,188 (table 1, Figure 4 and 6). Such a rapid growth, however, was followed by a quick decline. In 2002, the largest cormorant colony on Tondirahu, in Matsalu National Park, was depredated by a red fox, as a result of which the island was abandoned and the majority of the birds moved to the nearby islands and to the Gulf of Riga (where the number of breeding pairs increased by 2,372 in 2002; table 1). In the Moonsund Archipelago, however, the number of breeding cormorants declined to 3,100 pairs. This setback was followed by a new growth in numbers (on average 217 pairs per year), and in 2009, the population of the Moonsund Archipelago exceeded 4,600 breeding pairs. However, the population growth has not been steady, as depending on breeding conditions birds moved between the Gulf of Riga and the Moonsund Archipelago. So in 2005, the Moonsund population grew by 965 breeding pairs, whereby the population at the Gulf of Riga declined by 626 pairs. Within the last two years, the number of breeders has declined by 1,806 pairs and Moonsund population consists of 2,800 pairs (table 4, Figure 6).

Gulf of Riga

The first nest in the Gulf of Riga was reported in 1989, i.e. five years after cormorants established breeding in the Moonsund Archipelago. The nest was located on the small islet of Kerju, south of Abruka Island. Yet it took another three years, before a colony was established on Väike-Allirahu, in 1992 (table 5). The species rapidly expanded its range within the entire Gulf of Riga, and in the next ten years, 11 new breed-

ing sites were occupied: in 1993, a colony was established on Sorgu Island; in 1995, cormorants inhabited Kivilaid and Linnusitamaa; and in 1996, the species inhabited Sangelaid, near Kihnu Island. In 1997, the cormorants inhabited the islets Sillalaid and Anilaid for the first time.

Table 5. The number of great cormorant nests on the islands of the Gulf of Riga. Expected number of nests is given in parentheses, + indicates breeding, but the number of pairs is unknown.

Year	Breeding site													
	Sorgu	Kivilaid	Pikla laiud	Kerju rahu	Linnusitamaa	Väike-Allirahu	Allirahu	Tombamaa	Vesitükimaa	Tuudinasv	Sangelaid	Sillalaid	Anilaid	Kuressaare fairway
1989				1										
1990														
1991														
1992						17								
1993	(80)			50	0	63								
1994	(40)			390	0	≥6				0				
1995	0	50		716	4	40	0	0						
1996	0	108		798	0						18	0	0	
1997	0	121		866	263	1			1		18	1	5	
1998	0	125		378	246	(25)					130			
1999	60	4	106	805	76						(150)			
2000		+		961	138		12	0						
2001	(100)	120		894	96		+		0		242			
2002	146	940	20	1527	792	74	0	212	13	0	0	(100)		
2003		974	0	+	(800)			(1000)	15		640	393		
2004	515	1536	10	0	353	0		1385	123		0	188		0
2005	175	1012	269	0	388	90		601	666		260	23		0
2006	352	1305	196	0	0	0		1645	811	81	67	58	23	0
2007	195	1465	208	855	0	0		479	1966		0	0	209	0
2008	0	1095	0	1664	113	7	0	120	1355	0	468	0	1240	0
2009	0	1447	176	2063	88	0	0	0	956	70	0	0	935	0
2010	213	903	0	2133	247			0	1204	(65)	0	0	260	0
2011	880	234	0	1956	3	0	0	229	1213	63	1	0	865	1

Pikla islets were first occupied by cormorants in 1999, and a year later so far the only breeding attempt on Allirahul occurred. In 2002, a colony was reported on the islet of Tombamaa, in the immediate vicinity of Allirahu. That same year also first nests on the islet of Vesitükimaa were established. The next breeding site in the Gulf of Riga was the small islet of Kübassaare Tuudinasv that was occupied four years later, in 2006. In 2011, an empty nest was reported on a ridge of Kuressaare Bay fairway (table 5).

Ever since the cormorants inhabited the Gulf of Riga in 1989, they have occupied 14 different breeding sites. The highest number of concurrently occupied breeding sites is 10 (table 5). Such high fluctuation in numbers as well as in mobility is specific to the cormorant colonies of the Gulf of Riga, and is probably related to frequent human persecution, but also natural conditions. Thus, for a number of times, cormorants had to leave colonies on Sorgu and Sangelaid, due to persecution, and the small islets of Tombamaa and Pikla, due to the destruction of nests by storm. Regardless, cormorants have returned to these islands and other such sites, probably due to a lack of suitable breeding sites elsewhere. The most enduring cormorant colonies were located on the islets Kerju and Häädemeeste Kivilaid (at least for 16 years), Linnusitamaa (14 years), Sorgu (11 years), Vesitükimaa and Sangelaid (10 years; table 5).

Of all the Estonian cormorant sub-populations, the one in the Gulf of Riga stands out for its initial rapid growth: in 1992 there were 17 breeding pairs, and only in five years this number grew to 1,275 pairs (the average annual growth being 252 pairs; table 1, Figure 7). In the following four years (1998-2001) the numbers were declining, which probably resulted from birds moving to the Moonsund Archipelago (Figure 4). Yet, at the end of 2002, a large number of cormorants breeding in the Moonsund Archipelago moved to the islets in the Gulf of Riga, boosting the numbers by 2,372 pairs. The further development occurred with slight ups and downs (mean annual increase of 448 pairs) until 2008, when the size of the local breeding population reached its maximum of 6,062 pairs. Harsh winters caused the population growth to cease and by 2011 the number of nests in the Gulf of Riga had declined to 5,230.

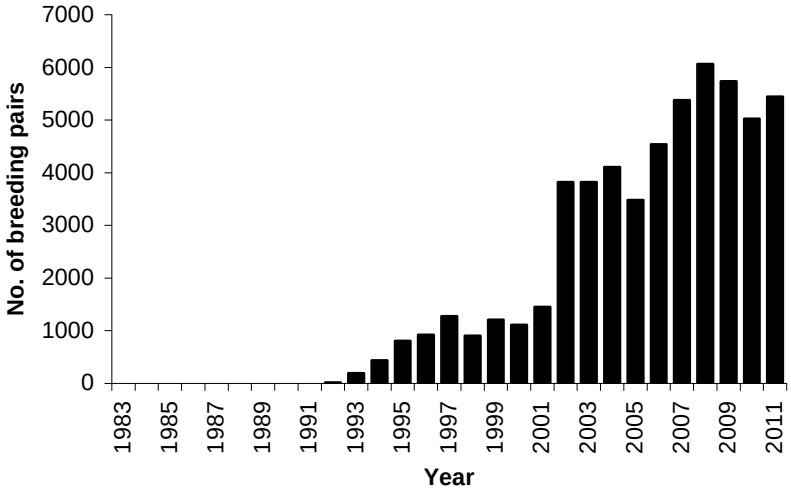

Figure 7. The numbers of breeding pairs of the great cormorant on the islands of the Gulf of Riga.

Baltic Proper

The breeding areas in the Baltic Proper may be divided into three sub-regions – northeast (Strait of Hari Kurk) and north from Hiiumaa, the western coast of Saaremaa, and the areas in the south-western coast of Saaremaa (Figure 2). The first breeding attempt in the Strait of Hari Kurk was reported in 1994, as two nests were found on the islet of Kakralaid (Leito & Leito 2011). In 2008, colonies were established on Kakrarahu nearby Kakralaid and on Selgrahu, another 8 km northwest from Kakrarahu. These two small islets were probably inhabited by cormorants, which had previously bred on Kakralaid (table 6). In 2003, cormorants inhabited the Vilsandi National Park, in the western coast of Saaremaa. First they settled on the islet Keskmine Vaika and two years later on the islet Alumine Vaika, however, the latter only has been occupied occasionally. The only breeding attempts on Telve Island and on the islet Telve Kuivarahu were reported in 2007. One breeding attempt of seven cormorant pairs at Lake Nonni (1.9 km off the coast), in 1995,

may also be numbered among the breeders of the western Saaremaa (Mänd 1996). The latter breeding attempt is also the only one known so far occurring in the coastal area, and several ornithologists of Saaremaa remain sceptical about this report. In the southwestern coast of Saaremaa, cormorants were first breeding on the islet Kriimi, located in the Lõu Bay, in 1999. Since 2002, a shipwreck (also called "The Greek ship") became the most important breeding site for this region. By now the topside of this wreckage has been scrapped and the majority of the cormorants have returned to Kriimilaid. The third cormorant colony in the Lõu Bay was established on Ooslamaa, in 2007.

Table 6. The number of Great Cormorant nests in Baltic Proper. Expected number of nests given in parentheses.

Year	Breeding site										
	Kakralaid	Kakrarahu	Selgrahu	Keskmine Vaika	Alumine Vaika	Telve	Telve Kuivarahu	Nonni järv	Shipwreck at Lõu Bay	Kriimi	Ooslamaa
1994	2			0	0		0				
1995				0	0		0	7			
1996				0	0		0				
1997				0	0		0			0	0
1998	20			0	0		0		0	0	0
1999	43			0	0		0			5	0
2000	0			0	0		0			14	0
2001	13			0	0		0				
2002	(100)			0	0		0		80	0	0
2003	(100)			74	0		0		(100)		
2004	(240)			105	0		0		364		
2005	170			209	82		0		(400)		
2006	125			355	1		0		610	0	
2007	110			221	0	30	45		205	0	62
2008	118	68	110	59	0		0		135	0	0
2009	0	0	90	0	0		0		17	0	0
2010	41	461	53	0	22		0		(20)	208	
2011	305	317	0	0	0		0		20	259	0

In the Baltic Proper, cormorants have occupied 10 breeding sites, of which up to 6 have been concurrently in use (table 6). More or less permanent colonies have been established on Kakralaid and in the wreckage in Lõu Bay. Keskmine Vaika was inhabited for 6 consecutive years, but has been abandoned to date. The main colonies in the Baltic Proper are in the strait of Hari Kurk and in Lõu Bay, whereas the Vilsandi National Park seems to be more an occasional breeding area for the cormorants.

Until 2001, the number of breeders nesting northeast and north from Hiiumaa, remained low, up to a maximum of 43 pairs. The numbers increased to 100 pairs in 2002, and remained between 100 to 125 pairs until 2007 (with the only exceptions in 2004 and 2005, when the numbers reached 240 and 170 pairs, respectively). In the following years, the number of breeding pairs increased from 296 in 2008 to 622 in 2011. Yet, nest predation reduced the numbers to only 90 pairs in 2009 (table 6). The number of breeding pairs in the Vilsandi National Park increased rapidly from 74 in 2003 to 355 in 2006. Thereafter the numbers declined to 59 pairs in only two years. 22 cormorant pairs made the last breeding attempt in this region in 2010. The breeding population of the southwestern coast of Saaremaa remained low until 2001, but began rapidly to grow in 2002 (average annual increase of 133 pairs), and reached the record number of 610 breeding pairs in 2006. In the subsequent years, the population size in this region has greatly fluctuated, and was estimated at 279 pairs in 2011 (table 6).

Continental Estonia

The first known breeding attempt on an inland water body dates back to 1994, when a colony of 8 nests was reported on the Tondisaar Island, in Lake Võrtsjärv. Due to the frequent human disturbance, which made the colony susceptible to predation by herring gulls *Larus argentatus*, it never grew large, remaining at around 15 to 30 nests (table 7). Only in 2007 and 2008, the number of nests counted in the trees was 79 and 90, respectively. This colony existed until the end of 2010. Subsequently, in 2005, cormorants occupied the Salusaar Island, in Lake Lämmijärv. In

spring, cormorants were engaged in nest building there, yet, in July, no birds were sighted any more. In 2008, although there were 20 nests in the trees, no sound proof of any breeding activity was recorded. In 2010, a total of 196 breeding pairs were registered on the island, and in 2011, the numbers grew to 360 pairs. The third cormorant colony in the inland was registered in 2011, in the northern part of Lake Koosa, and was estimated at 20 breeding pairs. At present, there are two cormorant colonies at the inland water bodies of Estonia.

Table 7. The number of great cormorant nests in continental Estonia. Expected number of nests is given in parentheses.

Year	Breeding site		
	Tondisaar, Võrtsjärv	Salusaar, Lämmijärv	Lake Koosa
1994	8		
1995			
1996			
1997			
1998			
1999	16		
2000	(15)		
2001	23		
2002	15		
2003	15		
2004	20		
2005	20		
2006	30		
2007	79		
2008	90	20	
2009	25		
2010	40	196	
2011	0	360	20

Discussion

In the early 1960s, the European population of the continental subspecies *P. carbo sinensis* had declined to 4,000 pairs. On the Baltic Sea only a few colonies existed in Denmark, Sweden, Germany and Poland, with the numbers reaching to approximately 3,100 pairs. The numbers remained low until the mid-1970s. In the 1980s, however, the population

started rapidly to grow and expand towards the eastern and northern parts of the Baltic Sea, and this increase ceased only as a result of the past two harsh winters (2009/2010 and 2010/2011; Herrmann *et al.* 2012). Such an increase in the breeding population could occur only provided that the number of recruits was higher than the number of non-surviving breeders, i.e. in case of an overproduction. Thus, the increase in the numbers could be caused by any circumstances that reduced offspring mortality and/or enhanced the survival of the breeders.

A major factor contributing to the increase of the cormorant population is believed to be the more effective protection measures applied in the European Union (Van Eerden & Gregersen 1995). The first European country to take cormorants under strict protection was the Netherlands, in 1965. The Birds Directive (Council Directive 79/409/EEC) of 1979 on the conservation of wild birds included the Great Cormorant to the list of protected species as a subject to special conservation measures (Annex I). In 1997, the population status was no longer critical and cormorants were removed from that list. Another important factor affecting the population growth is considered to be an enhanced breeding success since the 1980s, following a reduced exposure to environmental poisons such as DDT and PCBs (Hermann *et al.* 2012). Boudewijn & Dirksen (1995) found that in cormorant colonies located in areas of higher exposure of organochlorine contaminants, the eggs as well as the fish caught by the adults had a higher DDE and PCB content, which resulted in a lower hatching success and a higher nestling mortality compared to other colonies in the Netherlands. At the same time, the assessment of hazardous substances in the Baltic Sea shows that the level of PCBs and several pesticides (DDT and its breakdown products, DDE and DDD) has significantly declined during the recent decades (HELCOM 2010). Also, it is believed that changes in the marine ecosystems (Ådjers *et al.* 2006) arising from human activity (eutrophication, overfishing) have changed the local fish stocks favourable for cormorants (many small-sized fish).

Research on establishing new breeding grounds and breeding area expansion has been carried out in several countries. Studies in Denmark have demonstrated that newly established colonies resulted mainly

from the immigration of first-time breeders originating from denser colonies. Dispersal decisions were based on comparing conditions in their natal colony with conditions in colonies that were visited during the pre-breeding years. First-time breeders preferred to settle in colonies where they could expect better breeding success (Hénaux *et al.* 2007). Thus, first of all, poor breeding conditions prevailing in natal colony induce expanding to new breeding areas. Long-term monitoring of the colonies in Denmark has demonstrated that the breeding success declines within the old colonies and the number of breeders stops growing (Bregnballe 2010a). Since the 1990s, the cormorant populations in Denmark, Germany, the Netherlands and Sweden have reached their carrying capacity, forcing the offspring to settle in new breeding areas elsewhere (Bregnballe *et al.* 2003). For example, in Vorsø cormorant colony, in Denmark, the proportion of 1-year-olds observed in the colony has declined, and this can partly be explained by an increased emigration (Frederiksen & Bregnballe 2000a). Analysis on ringed birds also showed that first-time breeders dispersed longer distances than older breeders, the latter preferred to settle in neighbouring colonies in order to benefit from their experience with foraging areas (Hénaux *et al.* 2007).

At least during the first years, the number of breeders in newly established breeding areas increases only due to immigration, as the cormorants reach sexual maturity and start to breed usually at the age of three or four years (Frederiksen & Bregnballe 2001). Based on the demographic parameters of the cormorant colonies in Denmark (age at the first breeding, survival of different age groups) and the breeding success in Finnish colonies, Lehikoinen (2006) concluded that the average proportion of immigrants among first-time breeders has been 84% in early stage (1996–2004) of the population development in Finland, whereas since 1999, the proportion of local offspring among newly established breeders started gradually to increase. The highest recorded population growth rates in entire Baltic Sea area are found in Finland and Estonia, indicating very high immigration intensity from other parts of the Baltic Sea (Lehikoinen 2006).

Recoveries of marked nestlings indicate that all breeding cormorants of northern Europe (not only of the Baltic Sea) belong to one

integrated population. So have cormorants hatched in Germany, Sweden and the Netherlands been reported breeding in Denmark (Bregnballe 2000). Likewise, during spring and summer, young adult cormorants born in Sweden, Germany or Denmark have been observed in Estonia. And vice versa, nestlings ringed in Estonia have been recovered in Finland, Poland, Sweden and Germany (data from Matsalu Ringing Centre) and probably they have settled to breed there as well. Whereas the coastal colonies of Estonia have probably been formed on the basis of Baltic Sea population, the breeders of inland colonies might originate from Latvian and/or Russian inland colonies. In the last decade cormorants have inhabited the Pskov Oblast, also including Lake Lämmijärv (Борисов и др. 2009).

Not all the newly established (but also already existing) breeding sites persist. Some of them are permanently abandoned while others are only temporarily deserted. Nest site fidelity of the cormorants primarily depends on the breeding conditions in the colony. Recent studies in Denmark have demonstrated that the dispersal from a colony increased with decreasing mean number of fledglings in the colony, in both first-time and experienced breeders. However, nest site fidelity was higher in experienced breeders compared with first-time breeders (Hénaux *et al.* 2007). A small brood size at fledging may result from several reasons, e.g. from habitat characteristics (poor foraging conditions and high predation pressure by natural predators) and human persecution. During storms, colonies that are established on small and flat islets are often flooded, resulting in complete or partial breeding failure (as a rule, repeat clutches are smaller and have a lower survival of nestlings). For this reason, there have been no permanent colonies established on the small islets of Pikla, Sillalaid and Tuudinasv. An important factor of the colony persistence is also the nearby fish resources. Studies in Denmark have shown that lower nest site fidelity coincided with the decline in food resources and breeding success (Frederiksen & Bregnballe 2000b). The main natural predators of the cormorant in Estonia are red foxes, raccoon dogs, large gulls and white-tailed eagles. In 2002, cormorants had to abandon Tondirahu islet due to the predation by the red fox, and in 2009, Allirahu colony was abandoned as a response to predation by

the raccoon dog. In June 2009, after spending twenty-four hours in a hide in Tondirahu colony, Arne Ader stated a high predation pressure. He estimated the number of cormorant nestlings killed during this time by herring gulls, great black-backed gulls and white-tailed eagles to be at least 30. By now the cormorants have abandoned this islet. In many cormorant colonies, especially in those at the Gulf of Riga, people have systematically destroyed cormorant nests and killed nestlings. This is the main reason for a particularly high mobility of colonies in this region.

The white-tailed eagle is basically the only natural predator feeding on adult cormorants. Simultaneously with a rapid increase in cormorant numbers, an increase in the white-tailed eagle population has occurred. The breeding population of white-tailed eagle at the Baltic Sea has grown from 670–680 pairs in 1991, to 1,150–1,200 pairs in 1998, and to 2,070–2,200 pairs in 2007 (Herrmann *et al.* 2011). In Estonia, the breeding population of white-tailed eagle was estimated at 200-220 pairs in 2010 (Nellis 2010). Assuming that there is no significant difference between age composition of the white-tailed eagle population in summer and winter, and taking into account that the ratio of adult birds visiting supplementary feeding sites during winter is about 35 to 45% (Renno Nellis, pers. comm.), the number of white-tailed eagles (breeders and non-breeders together) in Estonia might reach 900–1,250 individuals. As cormorant is a relatively easy prey for the white-tailed eagles, the latter are often seen in the cormorant colonies. So, for example, 18 white-tailed eagles were observed to leave a cormorant colony on Tondirahu islet on June 30, in 2008 (data by Triin Paakspuu), and 43 eagles were present in cormorant colonies in Käina Bay on June 29, in 2012 (observation by Vello Tarning and Leho Aaslaid).

People have been trying to control the growing population of the cormorants, both legally and illegally. For example, in Denmark, up to 18% of the cormorant nests are being oiled (on average, 6,000 nests were oiled annually in 2004–2009), in order to restrict colonisation of new sites and reduce hatching success in existing colonies (Bregnballe 2010b). Along with other factors (e.g. low breeding success due to poor feeding conditions, higher mortality rate of adults and juveniles, delay

of first breeding attempt), suppression of breeding success also seems to affect the population – an increase in the number of colonies has stopped, and since 2006 also the number of breeders is declining. When in 2006 the cormorant population in Denmark, which is little bit smaller than Estonia, was estimated at 38,000 breeding pairs, then in 2009 the population has declined to 32,850 pairs, and in 2011 even to 25,200 pairs (Bregnballe 2010a; Herrmann *et al.* 2012). However, besides consistent management, the population decline during the past two years can also be explained by higher mortality rates due to very harsh winters. In addition to oiling of the eggs, population management also includes controlling cormorant numbers by hunting. In Europe up to 60,000 cormorants of both subspecies are being shot every year, mostly during winter (Carss 2003). In the Baltic Sea region 10,000–20,000 cormorants are hunted every year (Herrmann *et al.* 2012). In Estonia law permits hunting of cormorants since 1997. Supposedly, the management of cormorant population in Western Europe and within the wintering grounds have reduced immigration pressure to the eastern part of the Baltic Sea. In almost all the Baltic Sea countries, including Estonia, cormorant nests have been destroyed and nestlings killed illegally (Carss 2003, Lehikoinen 2006). However, there is no consistent and reliable data about such activity.

Also climatic factors can affect population size (Engen *et al.* 2005). The annual survival rate of the cormorants varies greatly from year to year. For example, the mean annual survival rate in Denmark is 88%, whereas a combination of population size in Europe and winter temperatures explains 52–64% of the year-to-year variation in survival. The larger population is, the more severely survival is affected by winter severity. While during a series of cold winters in the mid-1980s the density of the cormorant population in Europe was not high enough to affect adult survival, then harsh winter 1995/1996 resulted already in unusually high mortality rate in Danish cormorants (Frederiksen & Bregnballe 2000b). This particular winter also affected Estonian population. Since the start of rapid population growth in 1989 until 2009, the only year in which the cormorant population in Estonia did not grow was 1996 (Table 1).

It is highly likely that the cormorant population in Estonia is soon going to face a setback. The severe winter of 2009/2010 has a long-term impact on the cormorant population of the Baltic Sea region. First, harsh wintering conditions reduced the survival of juveniles, in particular, and therefore (despite the usual hatching success in 2009) a significant reduction in the number of first-time breeders could be expected in 2012 and 2013, when the cohort of 2009 starts to breed for the first time. Second, the number of breeders in 2010 was low not only on account of higher adult winter mortality, but also due to birds skipping breeding because of poor body condition. In Estonia, the number of breeders declined by 700 breeding pairs. Also, the average clutch size following the harsh winter was smaller than usual (Rattiste 2011a). As a consequence, in 2010 the number of fledglings was lower than in previous years. Moreover, the cohort of 2010 also suffered from the severe winter of 2010/2011, especially on western wintering grounds. Thus, the cohort of 2010 is smaller than in the previous years, not only owing to a smaller number of breeders and a smaller brood size but also due to a higher winter mortality of juveniles. These birds reach sexual maturity and start breeding mainly in 2013 and 2014, and in these two years even further reduction in the number of first-time breeders, compared to 2012, can be expected. In addition, a decline in the breeding population of the great cormorant is to be expected not only as a result from a decreased local offspring but also from a lower immigration pressure.

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