Annex 1: Threatened European fish species affected by the Great Cormorant

Summary

Out of 228 threatened fish species in Europe, predation by the Great Cormorant has been recorded for only 13 species according to the IUCN. Of these 13 species, three occur in Lake Constance, two in the Lake District in the UK, and three in Italy. This indicates that most of the threatened species affected by the Great Cormorant, apart from the Danube Salmon (*Hucho hucho*) and the European Eel (*Anguilla anguilla*), have limited ranges. The Great Cormorant was not identified as the primary threat to any of these species. In most cases, both the extent and severity of predation by the Great Cormorant are unknown, and the decline of these species is mainly attributed to other factors such as river regulation and pollution. Hence, the European threat assessments of European freshwater fish do not confirm the argument of the CMP that the Great Cormorant is the main threat to Europe's freshwater fish and the primary driver of their extinction.

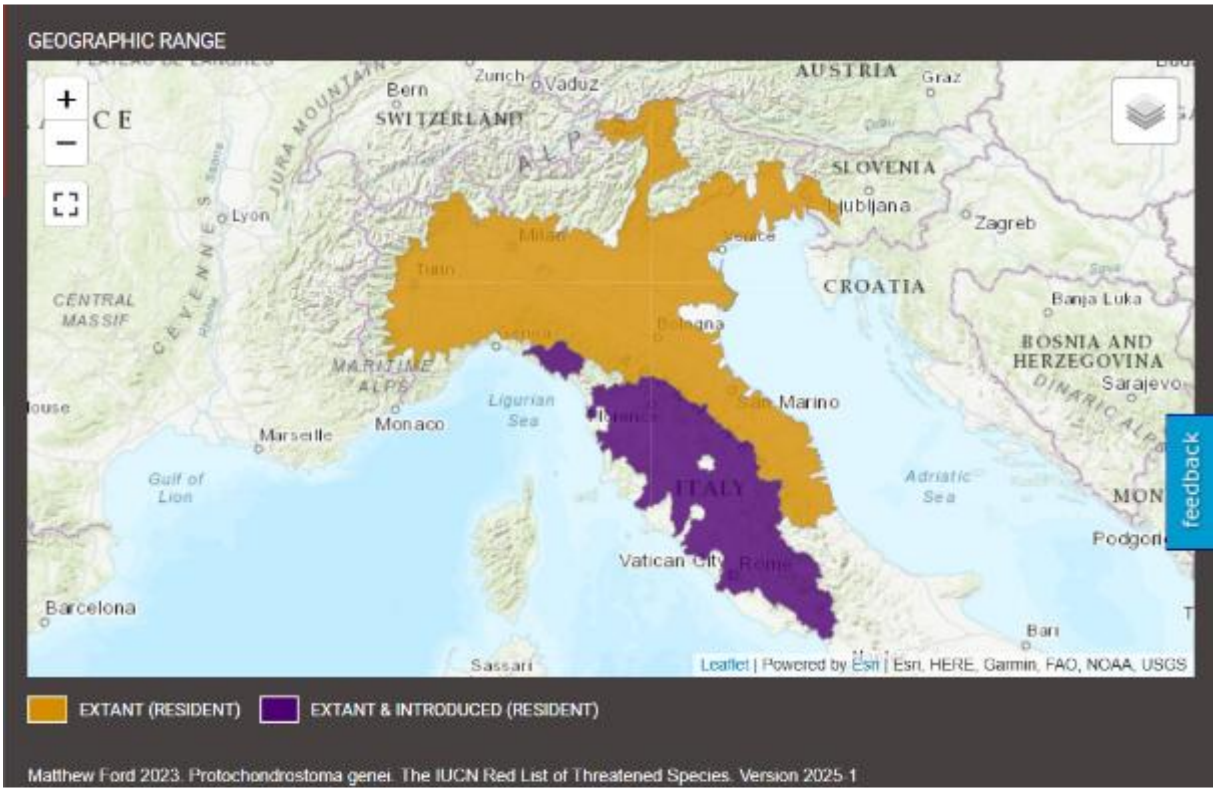
This overview refutes the argument that a Pan-European Cormorant Management Plan would be necessary to address the predation of threatened species by the Great Cormorant.

In the interest of transparency and facilitating the verification of information, the relevant maps and threat assessments are reproduced without alteration. Text concerning the threat by Great Cormorant is highlighted in **bold**.

Threatened species affected by the Great Cormorant

South European Nase (*Protochondrostoma genei*)

Distribution



Threats

This species' decline is understood to have been driven by river regulation and other forms of anthropogenic habitat degradation, which have resulted in widespread loss of the heterogeneous, interconnected fluvial habitats required to complete its life-cycle. The construction of dams, sills, weirs and other barriers throughout its range has severely altered natural flow and sedimentation regimes, blocked migration routes, fragmented subpopulations, and reduced the extent of suitable habitat for all life stages. Hydroelectric dams have created unnatural fluctuations in discharge and water temperature (hydropeaking and thermopeaking) which bring about artificial dewatering of downstream river stretches and loss of stable nursery habitat for juveniles. Furthermore, the combined effect of hydropeaking, dam flushing operations, changes in land use, and the removal of riparian vegetation has increased accumulation of fine sediments at some spawning sites, plausibly impairing the hatching and survival rates of eggs and larvae.

The quality of habitat has been further diminished by bank stabilisation, channelisation and other efforts to enhance flood protection or exploit water resources for irrigated agriculture. Unregulated water abstraction may constitute a particular threat in smaller tributaries, and at some upstream spawning and nursery sites. Some habitats have also been damaged by the industrial extraction of riverine gravel and other sediments for urban development, removal of riparian vegetation and/or maintenance procedures such as dredging or the removal of fallen branches and other debris which provide both cover and surfaces on which this species grazes.

This species is further threatened by diffuse and point source agricultural, domestic and industrial pollution, which has at some locations reduced the extent and quality of habitat due to eutrophication or discharge of toxic substances. Pollution can be particularly impactful in minor river systems when discharge is reduced during the summer.

Its decline in the Soča River is believed to have been at least partially driven by competitive interactions with the non-native Common Nase (Chondrostoma nasus), which was introduced for recreational fisheries purposes during the mid-20th century.

Other non-native fish taxa established within this species' range include Pumpkinseed (Lepomis gibbosus), Largemouth Bass (Micropterus salmoides), Eurasian Perch (Perca fluviatilis), Common Bream (Abramis brama), Common Roach (Rutilus rutilus), Common Barbel (Barbus barbus), Goldfish (Carassius auratus), Crucian Carp (Carassius carassius), Common Carp (Cyprinus domestic strain), Grass Carp (Ctenopharyngodon idella), Topmouth Gudgeon (Pseudorasbora parva), Black Bullhead (Ameiurus melas), Wels Catfish (Silurus glanis), Brown Trout (Salmo trutta) and Rainbow Trout (Onchorhyncus mykiss), all of which are considered invasive and can exert detrimental pressures on native freshwater fauna through increased competition, predation, habitat degradation or parasite transmission. Native fish species have been completely displaced by non-native communities in some parts of the Po River system.

Predation pressure from increasingly abundant piscivorous birds, particularly Great Cormorant (Phalacrocorax carbo), has also been suggested to represent a significant threat in the Po River catchment.

The negative impact of some threats could plausibly be exacerbated by increasingly rapid climate change in the northern Adriatic region, which is already driving extended periods of drought. During the summer of 2022, a severe drought in Slovenia resulted in the dewatering of some streams to which this species had been introduced within the framework of a conservation project (see 'Conservation'). As a result, numerous individuals were manually translocated to perennial downstream habitats.

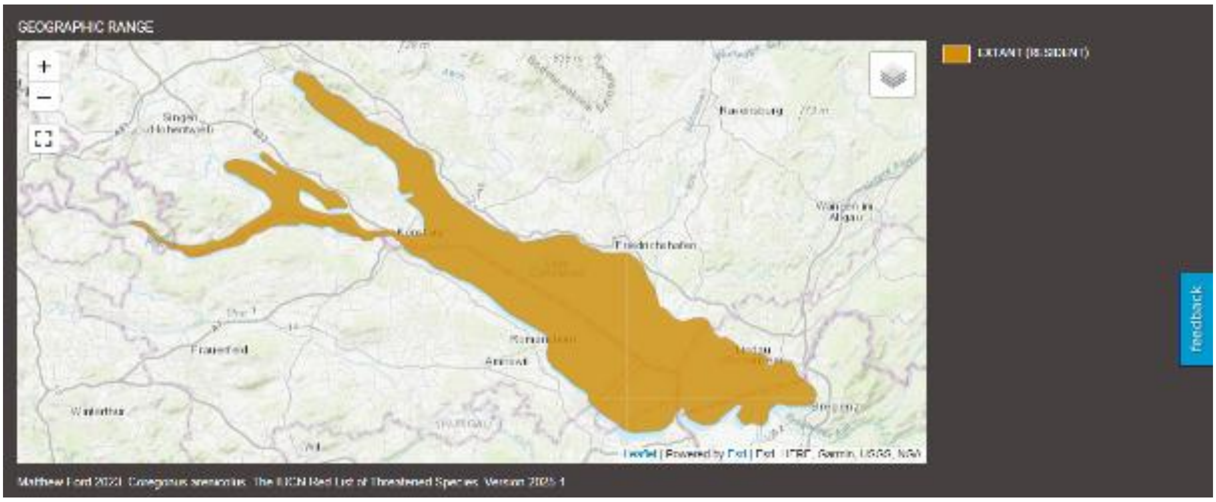
Impact of Great Cormorant

Scope: Unknown

Severity: Unknown

Sandfelchen (Coregonus arenicolus) – Endangered

Distribution



Main threats

A rising human population in the Lake Constance catchment after 1900 drove the development of industry and agriculture, which led to increasing pollution from domestic wastewater and runoff. The lake subsequently entered a phase of eutrophication, which peaked in 1979 and led to periodic stratification and anoxia in the hypolimnion. The natural reproduction of native whitefishes was reportedly inhibited during this period, since their eggs could no longer develop in the oxygen-depleted substrata.

The development of anoxic conditions in the profundal zone probably led to the extinction of the sympatric Bodensee Kilch. A hypothesised secondary outcome of this stratification is the potential for overlap and increased gene flow between different whitefish species that were formerly segregated along depth gradients, which raises the possibility of speciation reversal and extinction events due to introgressive hybridisation. However, increased gene flow between whitefish taxa might also be driven by intensive stocking and artificial breeding in hatcheries (see below). Unregulated stocking of Lake Constance with non-native whitefishes from other central Alpine lakes, Eastern Europe and North America also occurred around the end of the 19th century, but there is no evidence of any long-term negative impact on the native taxa.

An increase in zooplankton abundance during the eutrophication process triggered significant interannual variation in whitefish biomass. These discrepancies were characterised by rapid growth rates, leading to an increased proportion of sexually immature individuals being captured by commercial fisheries and a loss of older age classes in the standing stock.

The supplementary stocking of hatchery-reared native whitefishes, whereby gametes are stripped from wild individuals and larvae reared under hatchery conditions before being released as fingerlings, may represent a further threat. These procedures are carried out in many perialpine lakes, although there is little evidence that they improve yield when ecological conditions are suitable for natural whitefish reproduction. Furthermore, studies focusing on other fish species have demonstrated that the influx of juvenile individuals can impair natural recruitment, impose artificial sexual selection on target species, and increase hybridisation rates due to the inadvertent crossing of similar-looking sympatric taxa.

However, DNA analyses published to date suggest that the above factors have caused no significant loss of genetic diversity in the extant Lake Constance whitefish community.

The observed decline in whitefish commercial landings since 2005 has been inconclusively attributed to the re-oligotrophication of the lake (see 'Conservation'), which has driven a reduction in food availability due to declining zooplankton abundance. Growth rates have also reduced considerably, although both of these outcomes are likely to represent a partial return to natural conditions.

The non-native Three-Spined Stickleback (Gasterosteus aculeatus) is currently viewed as a major threat due to its rapid expansion in the pelagic zone of the lake since around 2012-2013. This species not only competes with native whitefishes for zooplankton resources, but preys on their eggs and fry. Further study is required in order to establish the precise extent of its impact.

The invasive Quagga Mussel (Dreissena bugensis) has also spread throughout Lake Constance since it was first recorded in 2016. This filter-feeding mollusc appears to be driving significant food web alterations, including energy sources and pathways for native fishes, due to its propensity to alter zooplankton abundance, community structure and composition. On the other hand, it has been hypothesised that the mussel might provide an additional food source for the zoobenthivorous Sandfelchen and therefore benefit the species.

The piscivorous Great Cormorant (Phalacrocorax carbo) is estimated to consume c. 450 tonnes of mixed fish species per year and may be contributing to native

whitefish declines.

Warming of the lake due to climate change constitutes a plausible ongoing and future threat, since it may result in habitat shifting.

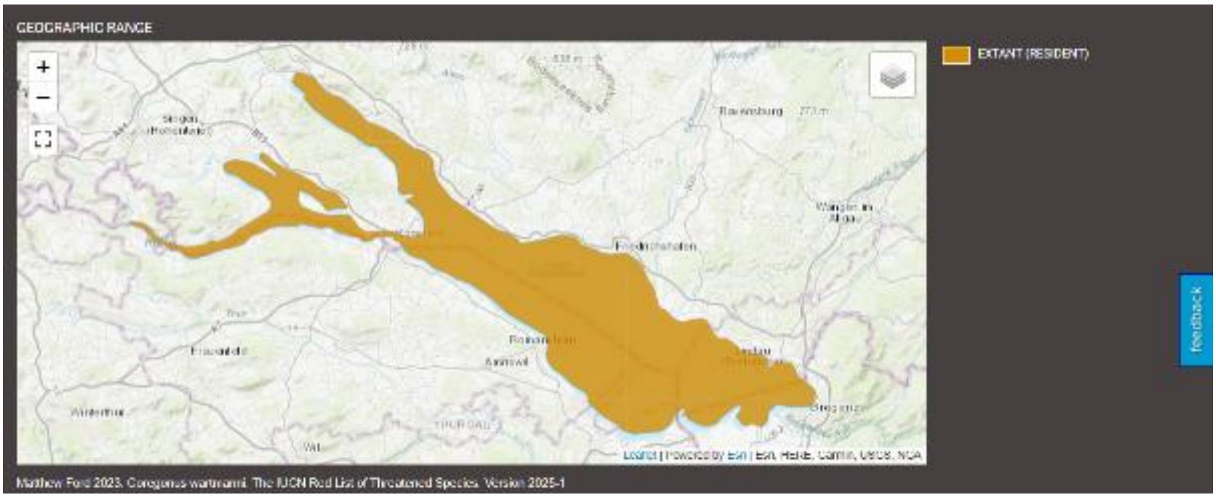
Assessment of the impact of Great Cormorant

Scope: Unknown

Severity: Unknown

Blaufelchen (*Coregonus wartmanni*) – Endangered

Distribution



Threats

A rising human population in the Lake Constance catchment drove the development of industry and agriculture after 1900, which led to increasing pollution from domestic wastewater and runoff. The lake subsequently entered a phase of eutrophication which peaked in 1979 and led to periodic stratification and anoxia in the hypolimnion. The natural reproduction of native whitefishes was reportedly inhibited during this period since their eggs could no longer develop in the oxygen-depleted substrata.

The development of anoxic conditions in the profundal zone probably led to the extinction of the sympatric Bodensee Kilch. A hypothesised secondary outcome of this stratification is the potential for overlap and increased gene flow between different whitefish species that were formerly segregated along depth gradients, which raises the possibility of speciation reversal and extinction events due to introgressive hybridisation. However, increased gene flow between whitefish taxa might also be driven by intensive stocking and artificial breeding in hatcheries (see below). Unregulated stocking of Lake Constance with non-native whitefishes from other central Alpine lakes, Eastern Europe and North America also occurred for a period from the end of the

19th century, but there is no evidence of any long-term negative impact.

An increase in zooplankton abundance during the eutrophication process also triggered significant inter-annual variation in whitefish biomass. These discrepancies were characterised by rapid growth rates, leading to an increased proportion of sexually immature individuals being captured by commercial fisheries and a loss of older age classes in the standing stock.

The supplementary stocking of hatchery-reared native whitefishes, whereby gametes are stripped from wild individuals and larvae reared under hatchery conditions before being released as fingerlings, may represent a further threat. These procedures are carried out in many perialpine lakes, although there is little evidence that they improve yield when ecological conditions are suitable for natural whitefish reproduction. Furthermore, studies focusing on other fish species have demonstrated that the influx of juvenile individuals can impair natural recruitment, impose artificial sexual selection on target species and increase hybridisation rates due to the inadvertent crossing of similar-looking sympatric taxa in hatcheries.

DNA analyses published to date suggest that the above factors have caused no significant loss of genetic diversity in the extant Lake Constance whitefish community.

The observed decline in Blaufelchen commercial landings since 2005 has been inconclusively attributed to the re-oligotrophication of the lake (see 'Conservation'), which has driven a natural reduction in food availability due to declining zooplankton abundance. Growth rates have also reduced considerably, although both of these outcomes are likely to represent a partial return to normal conditions.

The non-native Three-Spined Stickleback (Gasterosteus aculeatus) is currently viewed as a major threat due to its rapid expansion in the pelagic zone of the lake since around 2012-2013. This species not only competes with native whitefishes for zooplankton resources but preys on their eggs and fry. Further study is required in order to establish the precise extent of its impact.

The invasive Quagga Mussel (Dreissena bugensis) has also spread throughout Lake Constance since it was first recorded in 2016. This filter-feeding mollusc appears to be driving significant food web alterations, including energy sources and pathways for pelagic fishes due to its propensity to alter zooplankton abundance, community structure and composition.

The piscivorous Great Cormorant (Phalacrocorax carbo) is estimated to consume c. 450 tonnes of mixed fish species per year and may be contributing to native

whitefish declines.

Warming of the lake due to climate change constitutes a plausible ongoing and future threat, since it may result in habitat shifting.

Assessment of the impact of Great Cormorant

Scope: Unknown

Severity: Unknown

Gangfisch (Coregonus macrophthalmus) – Endangered

Distribution

Threats

A rising human population in the Lake Constance catchment after 1900 drove the development of industry and agriculture, which led to increasing pollution from domestic wastewater and runoff. The lake subsequently entered a phase of eutrophication, which peaked in 1979 and led to periodic stratification and anoxia in the hypolimnion. The natural reproduction of native whitefishes was reportedly inhibited during this period, since their eggs could no longer develop in the oxygen-depleted substrata.

The development of anoxic conditions in the profundal zone probably led to the extinction of the sympatric Bodensee Kilch. A hypothesised secondary outcome of this stratification is the potential for overlap and increased gene flow between different whitefish species that were formerly segregated along depth gradients, which raises the possibility of speciation reversal and extinction events due to introgressive hybridisation. However, increased gene flow between whitefish taxa might also be driven by intensive stocking and artificial breeding in hatcheries (see below). Unregulated stocking of Lake Constance with non-native whitefishes from other central Alpine lakes, Eastern Europe and North America also occurred around the end of the 19th century, but there is no evidence of any long-term negative impact on the native taxa.

An increase in zooplankton abundance during the eutrophication process triggered significant interannual variation in whitefish biomass. These discrepancies were characterised by rapid growth rates, leading to an increased proportion of sexually immature individuals being captured by commercial fisheries and a loss of older age classes in the standing stock.

The supplementary stocking of hatchery-reared native whitefishes, whereby gametes are stripped from wild individuals and larvae reared under hatchery conditions before being released as fingerlings, may represent a further threat. These procedures are carried out in many perialpine lakes, although there is little evidence that they improve yield when ecological conditions are suitable for natural whitefish reproduction. Furthermore, studies focusing on other fish species have demonstrated that the influx of juvenile individuals can impair natural recruitment, impose artificial sexual selection on target species, and increase hybridisation rates due to the inadvertent crossing of similar-looking sympatric taxa.

However, DNA analyses published to date suggest that the above factors have caused no significant loss of genetic diversity in the extant Lake Constance whitefish community.

The observed decline in whitefish commercial landings since 2005 has been inconclusively attributed to the re-oligotrophication of the lake (see 'Conservation'), which has driven a reduction in food availability due to declining zooplankton abundance. Growth rates have also reduced considerably, although both of these outcomes are likely to represent a partial return to natural conditions.

The non-native Three-Spined Stickleback (Gasterosteus aculeatus) is currently viewed as a major threat due to its rapid expansion in the pelagic zone of the lake since around 2012-2013, which corresponds to the recent Gangfisch decline (see 'Population'). This species not only competes with native whitefishes for zooplankton resources, but preys on their eggs and fry. Further study is required in order to establish the precise extent of its impact.

The invasive Quagga Mussel (Dreissena bugensis) has also spread throughout Lake Constance since it was first recorded in 2016. This filter-feeding mollusc appears to be driving significant food web alterations, including energy sources and pathways for native fishes, due to its propensity to alter zooplankton abundance, community structure and composition. On the other hand, it has been hypothesised that the mussel might provide an additional food source for the zoobenthivorous Gangfisch and therefore benefit the species.

The piscivorous Great Cormorant (Phalacrocorax carbo) is estimated to consume c. 450 tonnes of mixed fish species per year and may be contributing to native whitefish declines.

Warming of the lake due to climate change constitutes a plausible ongoing and future threat, since it may result in habitat shifting.

Impact of Great Cormorant

Scope: Unknown

Severity: Unknown

Schelly (Coregonus stigmaticus) – Vulnerable

Distribution

Threats

The water level of Haweswater fluctuated significantly between the 1970s-1990s due to water abstraction for domestic supply (see 'Habitats and Ecology'). This is believed to have driven the decline of the resident Schelly subpopulation through dewatering of breeding sites during the spawning and incubation period. More recently, prolonged periods of drought have led to the water level being temporarily reduced by up to c. 60%.

Predation by a Great Cormorant (Phalacrocorax carbo) breeding colony that settled at Haweswater during the early 1990s may have prevented subpopulation recovery despite attempted measures to mitigate the water level. The birds were themselves managed for a period but these efforts were discontinued in 2008, with perceived predation pressure increasing to c. 45% of its former level by 2010 (see

'Conservation').

The Ullswater subpopulation may be locally threatened by the deposition of fine sediments contaminated with ore from a former lead mine on spawning sites in the southern part of the lake. This issue may be compounded during periods of high flow, e.g., in the wake of storms. High levels of tourism and amenity use, especially during summer, have also been proposed as a plausible threat.

Non-native fish species established in Ullswater include the Common Roach (Rutilus rutilus), which was first recorded in 2013 and is known to compete with planktivorous fishes for food resources.

Presence of the Eurasian Ruffe (Gymnocephalus cernua) in some nearby lakes is an additional cause for concern since it is an opportunistic, largely benthivorous predator that has been strongly linked to the purported decline of the Powan (Coregonus clupeoides) in Loch Lomond, Scotland. The Swamp Stonecrop (Crassula helmsii) is also established at those sites, and if translocated this invasive plant could reduce the quality of Schelly spawning habitat through encroachment, since it tends to grow densely in sublittoral zones and does not die back in winter.

At Brothers Water, the primary identified threat is decreasing oxygen in the hypolimnion leading to a reduction in profundal refuge areas. This phenomenon may be caused by nutrient enrichment and could be exacerbated by warming temperatures.

Warming of the lakes due to climate change constitutes a major ongoing and future threat for this cold-water adapted species.

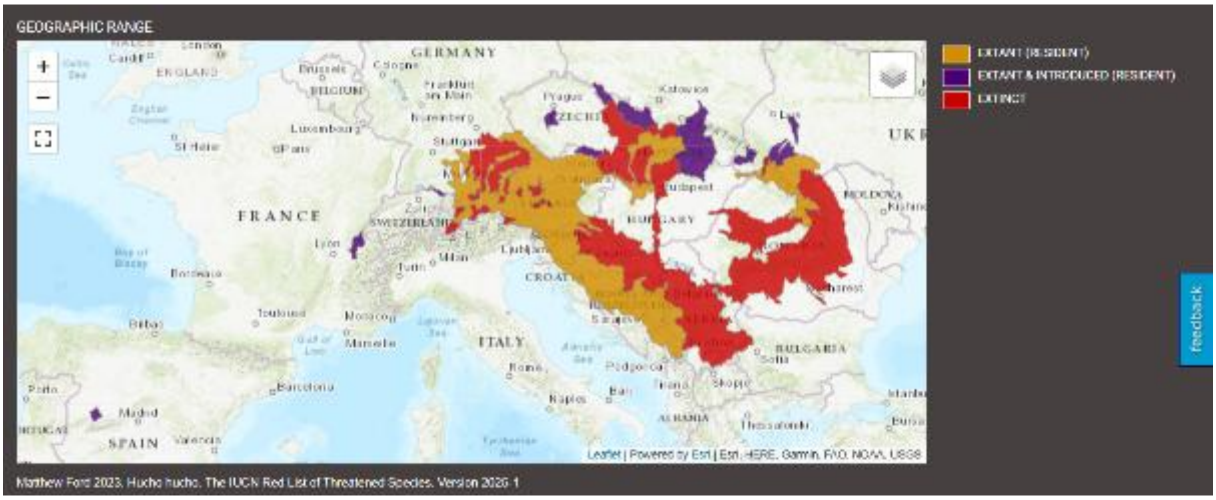
Impact of Great Cormorant

Scope: Minority (<50%)

Severity: Unknown

Danube Salmon (*Hucho hucho*) – Vulnerable

Distribution



Threats

This species' decline has largely been driven by river regulation and other hydromorphological alterations, which have resulted in the widespread loss of the heterogeneous, interconnected fluvial habitats required to complete its life cycle. In particular, the widespread construction of dams, weirs and other barriers has altered natural flow and sedimentation regimes, blocked seasonal migration routes and access to spawning sites, fragmented subpopulations (which leads to reduced genetic diversity due to the naturally low abundance of mature individuals), and generally reduced the extent of suitable habitat for all life stages. Moreover, the majority of existing fishways do not favour the passage of large-bodied fish taxa such as Danube Salmon (Freyhof et al. 2015, 2020; Hanfland et al. 2015; Schöffmann and Marić 2024).

Hydroelectric dams have also created unnatural fluctuations in discharge and water temperature (hydropeaking and thermopeaking) which cause dewatering of foraging and spawning sites, the loss of stable nursery habitat for juveniles, and downstream displacement. The combined effect of hydropeaking, dam flushing operations, changes in land use, and the removal of riparian vegetation is also likely to have increased the accumulation of fine sediments at spawning sites, thus impairing the hatching and survival rates of eggs and larvae. Extensive dam construction is ongoing and/or planned for the future in some parts of the Danube Salmon's range, particularly in Austria, Slovenia and the Western Balkans (Freyhof et al. 2015, 2020; Snoj et al. 2022; Pliberšek and Tavčar 2024; Schöffmann and Marić 2024).

The quality of habitat has been further diminished by bank stabilisation, channelisation and other efforts to enhance flood protection or exploit water for human development. The industrial extraction of riverine gravel and other sediments for urban development has contributed to an observed reduction in the extent and quality of available spawning sites (Curtean-Bănăduc et al. 2019, Hanfland et al. 2015, Schöffmann and Marić 2024).

This species is also susceptible to declining water quality caused by diffuse and point source agricultural, domestic and industrial pollution, which has resulted in eutrophication or discharge of toxic substances at some locations, e.g., the Váh River downstream of Ružomberok and Hron River downstream of Dubová in Slovakia, the Bosna River in Bosnia and Herzegovina, the Vișeu River in Romania (Holčík et al. 1988, Muhamedagić and Habibović 2013, Curtean-Bănăduc et al. 2019, Jakšić et al. 2024).

In some cases, the threats described above have also driven declines in its prey species, which may have further exacerbated local declines (Schmutz et al. 2023, Pinter et al. 2024).

Some of this species' biological traits, such as large body size, relatively low abundance and late sexual maturity, render it susceptible to recruitment overfishing. Licensed and unregulated harvesting and angling have thus contributed to its decline, with the negative impact in some cases exacerbated by insufficient fisheries regulations (e.g., a lack of catch and release practices, minimum size limits which permit the removal of sexually immature individuals, continued offtake of adults during the annual reproductive period) and/or a reduction in the size of local subpopulations due to habitat fragmentation and other factors. Licensed angling is no longer considered to represent a widespread threat due to the implementation of fisheries' regulations and an ongoing increase in catch-and-release policies (see 'Conservation'), but unregulated harvesting using nets, spears, poisons and even explosives continues to occur in the Western Balkans, Romania and Ukraine (Holčík et al. 1988, Witkowski et al. 2013, Didenko et al. 2011, 2018, Curtean-Bănăduc et al. 2019).

The impact of supportive breeding and stocking with hatchery-reared individuals derived either from captive broodstocks or through the stripping of wild adults is increasingly viewed as a threat to the integrity of natural gene pools. Individuals continue to be translocated between different river systems (see 'Population'), stocking is often not precisely-documented, and widespread admixture between different genetic clusters has occurred. For example, in Austria, all rivers which retain extant subpopulations are regularly stocked with individuals derived from the Mur River, and it is believed that the original wild gene pools have been completely lost. In addition, the repeated use of captive, semi-domesticated broodstocks for the production of gametes, plus the practice of mixing gametes obtained from multiple male and female individuals within a single container ("mixed milt fertilisation") may be creating artificial selection processes which are likely to drive genetic drift, reduce the scale of differentiation between locally-adapted subpopulations, and lead to a loss of hereditary behaviours such as spawning site fidelity. Stocking with hatchery-reared individuals may also lead to increased competition, predation pressure and the transfer of parasites and pathogens (Kuciński and Fopp-Bayat 2021, Snoj et al. 2022, Jakšić et al. 2024).

Rising water temperatures due to climate change also represent a plausible threat, since they may interfere with food availability, lifespan, and the timing of reproductive processes (Jakšić et al. 2024, Pinter et al. 2024).

Subpopulations inhabiting some rivers draining the Alps may also be threatened by increasing abundance of the piscivorous Eurasian Otter (Lutra lutra), Great Cormorant (Phalacrocorax carbo) and Goosander (Mergus merganser), which consume both Danube Salmon individuals and its prey species (Hanfland et al. 2015, Schmutz et al. 2023).

Impact of Great Cormorant

Scope: Unknown

Severity: Unknown

Lonsdale's Charr (Salvelinus lonsdalii) – Vulnerable

Distribution

Threats

The water level at Haweswater fluctuated significantly between the 1970s-1990s due to water abstraction for domestic supply (see 'Habitats and Ecology'). This is believed to have driven a decline in the resident subpopulation through dewatering of key sites during the spawning and egg incubation period. More recently, prolonged periods of drought have led to the water level being temporarily reduced by up to c. 60%.

In addition, predation by a Great Cormorant (Phalacrocorax carbo) breeding colony

that settled at Haweswater during the early 1990s may have interfered with population recovery. The birds were managed for a period but these efforts were discontinued in 2008 (see 'Conservation').

Increasing water temperatures due to climate change represents an ongoing and future threat.

Impact of Great Cormorant

Scope: Whole (>90%)

Severity: Unknown

Fibreno Trout (*Salmo fibreni*) – Critically Endangered

Distribution

Threats

During the mid-2000s, Lake Posta Fibreno basin had reportedly suffered from habitat degradation including a significant reduction in macrophyte coverage, unregulated water abstraction, and sedimentation of an extensive reedbed which borders the southern part of the lake. Pollution due to runoff from adjacent agricultural land and discharge of untreated domestic wastewater was also observed, but the high turnover of the lake was assumed to to maintain water quality through the constant flushing of excess nutrients.

Non-native and potentially threatening species recorded at the time included Coypu (Myocastor coypus), Goldfish (Carassius auratus) and Eastern Mosquitofish (Gambusia holbrooki), among which the former was considered to be damaging both squatic and riparian vegetation. A number of native fish species, including Apennine Roach (Sarmarutilus rubilio) and Italian Chub (Squalius squalus) were also observed in the lake for the first time, the presence of which may plausibly have resulted in increased competition for resources in the system.

The increasing winter presence of Eurasian Coot (*Fulica atra*) and the piscivorous Great Cormorant (*Phalacrocorax carbo*) was also noted as a potential threat.

Impact of Great Cormorant

Scope: Not assessed

Severity: Not assessed

Cisalpine Pike (*Esox cisalpinus*)

Distribution

Threats

This species is threatened by hybridisation with the congeneric Northern Pike (Esox lucius), which has been widely introduced throughout its range. This process was initiated to address the decline in commercially-important native subpopulations, and largely occurred before the Cisalpine Pike was recognised as a distinct taxon.

The introduction of other non-native fish species, particularly Largemouth Bass (Micropterus salmoides), Wels Catfish (Silurus glanis) and Goldfish (Carassius auratus) has also been linked with Cisalpine Pike declines due to increased predation, resource competition or habitat degradation, e.g., increased turbidity or macrophyte loss (see below).

The depletion of marginal, temporarily-inundated wetlands, e.g., reedbeds in Lake Trasimeno, has in some cases severely reduced the extent of suitable spawning and nursery habitats.

Increased eutrophication and turbidity driven by pollution from agricultural, domestic and industrial sources negatively affect feeding and reduce the growth of macrophytes which provide cover for Cisalpine Pike and their prey.

In northern Italy, the ongoing expansion of the piscivorous Great Cormorant (Phalacrocorax carbo) is believed to represent a growing threat, particularly when their numbers increase during winter.

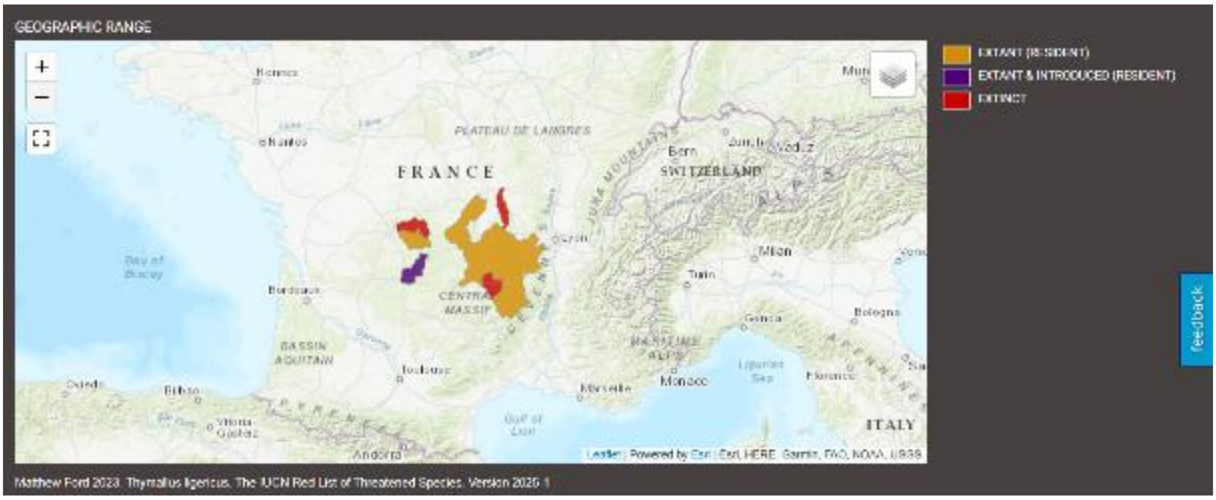
Impact of Great Cormorant

Scope: Unknown

Severity: Unknown

Loire Grayling (*Thymallus ligericus*)

Distribution



Threats

This species' decline has primarily been driven by river regulation and other forms of habitat degradation, which have resulted in widespread loss of the heterogeneous, interconnected fluvial habitats required to complete its life-cycle.

In particular, the construction of dams, weirs and other barriers has altered natural flow and sedimentation regimes, blocked access to spawning and seasonal foraging sites, fragmented subpopulations, interfered with the distinctive habitat shifts required during early ontogenetic development, and generally reduced the extent of suitable habitat for all life stages. The quality of available habitat has been further diminished by bank stabilisation, channelisation and other efforts to enhance flood protection or river transportation links.

Hydroelectric dams have created regular fluctuations in discharge and water temperature (hydropeaking and thermopeaking) which cause dewatering of spawning sites and loss of stable nursery habitat for juveniles, plus downstream displacement and stranding of individual fish.

Furthermore, the combined effect of hydropeaking, dam flushing operations, changes in land use, and the removal of riparian vegetation has increased accumulation of fine sediments at spawning sites, impairing the hatching and survival rates of eggs and larvae.

The industrial extraction of riverine gravel and other sediments for urban development has further reduced the extent of available spawning sites.

This species is also likely to have declined due to widespread agricultural, domestic and industrial pollution during the 20th century, some of which persists today.

Predation pressure from increasingly abundant piscivorous birds, particularly Great Cormorant (Phalacrocorax carbo), is believed to represent a significant threat at some locations.

Although there is currently no evidence that introgressive hybridisation with stocked individuals of non-native origin represents a threat (see 'Habitat and Ecology'), stocking may nevertheless impair natural recruitment and fitness through increased resource competition, introduction of parasites and pathogens, and by favouring the local abundance of predators.

The extent of habitat is likely to be impacted by climate change, due to increased water temperatures and diminishing river discharge.

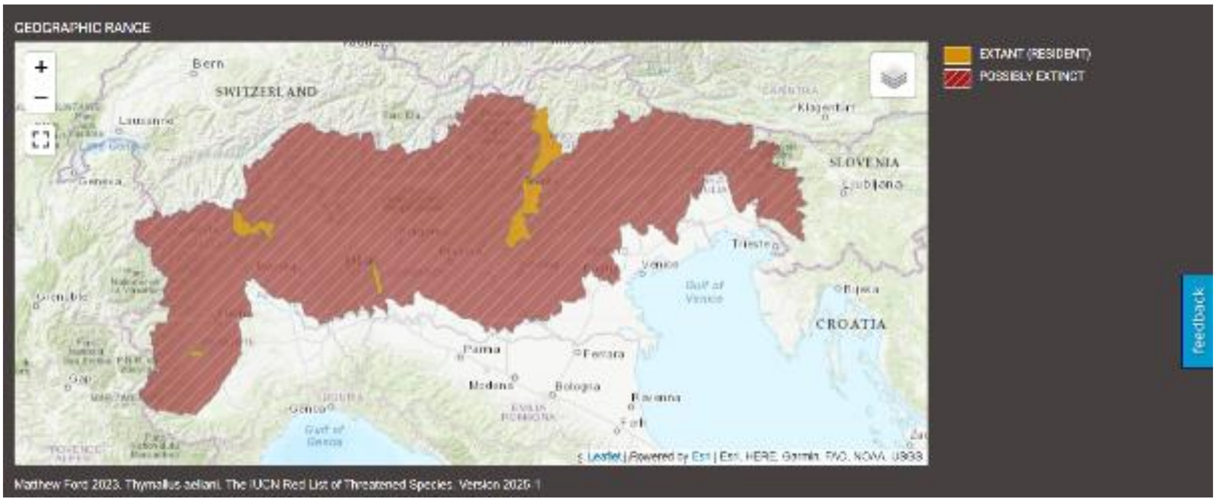
Impact of Great Cormorant

Scope: Unknown

Severity: Unknown

Adriatic Grayling (*Thymallus aeliani*) - Endangered

Distribution



Threats

This species' decline was initially driven by river regulation and other forms of habitat degradation, which resulted in widespread loss of the heterogeneous, interconnected fluvial habitats required to complete its life-cycle.

In particular, the construction of dams, weirs and other barriers has altered natural flow and sedimentation regimes, blocked access to spawning and seasonal foraging sites, fragmented subpopulations, interfered with the distinctive habitat shifts required during early ontogenetic development, and generally reduced the extent of suitable habitat for all life stages. The quality of habitat has been further diminished by bank stabilisation, channelisation and other efforts to enhance flood protection or river transportation links.

Hydroelectric dams have created regular fluctuations in discharge and water temperature (hydropeaking and thermopeaking) which cause dewatering of spawning sites and loss of stable nursery habitat for juveniles, plus downstream displacement and stranding of individuals.

Furthermore, the combined effect of hydropeaking, dam flushing operations, changes in land use, and the removal of riparian vegetation has increased accumulation of fine sediments at spawning sites, impairing the hatching and survival rates of eggs and larvae.

The industrial extraction of riverine gravel and other sediments for urban development has further reduced the extent of available spawning sites.

This species is also likely to have declined due to widespread agricultural, domestic and industrial pollution during the 20th century, some of which persists today.

Predation pressure from piscivorous birds, particularly Great Cormorant (Phalacrocorax carbo), has been suggested to represent a significant threat in the Po River system.

In response to declining abundance driven by these factors, restocking with hatchery-reared domesticated and/or non-native individuals originating from the Danube River system and elsewhere in Europe has taken place throughout the Adriatic Grayling's range since the 1960s.

As a result, hybridisation and introgression with these lineages has occurred on an extensive but variable basis, ranging from considerable persistence of native genetic profiles to comprehensive admixture (see 'Population').

The stocking of hatchery-reared individuals also increases the risk of introducing novel pathogens or parasites to native fish communities.

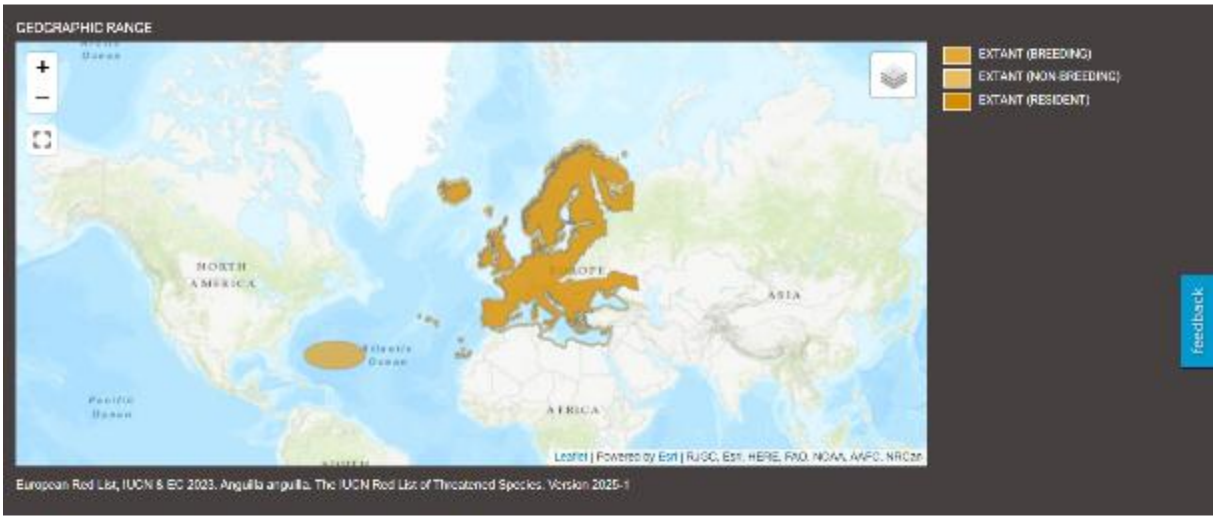
The extent of suitable habitat is likely to be impacted by climate change, due to increased water temperatures and diminishing river discharge.

Impact of Great Cormorant

Scope: Unknown

Severity: Unknown

European Eel (*Anguilla anguilla*) – Critically Endangered



Threats

Anguilla anguilla is susceptible to a number of natural and anthropogenic threats. These threats include but are not limited to; barriers to migration, climate change, habitat loss/degradation, invasive species, parasitism, pollution, predation and unsustainable exploitation (Drouineau et al. 2018, Righton et al. 2021). The occurrence and significance of these threats varies considerably from area to area across the species range. The significance of any single threat, or the synergy it may have with other threats is still poorly understood (Dekker 2004, Jacoby et al. 2015, Miller et al. 2016). It is therefore important to highlight that management measures focusing on a single threat, in isolation of other identified pressures (listed below), are less likely to have a significant positive effect on the stock than a combined approach. There is a significant body of information including a great deal of contradiction in peer-reviewed and grey literature, and in expert opinion, relating to these threats. The assessment process and accompanying external review indicated that a comprehensive discussion of these threats and their impacts was significantly beyond the scope of this assessment. Below, all suspected threats are listed (in alphabetical order), with some (but not all) key references and a very brief synopsis of these threats. This is by no means comprehensive and does not attempt to fully dissect the wide range of views and data on these pressures. As such, a robust and comprehensive analysis of the existing data and opinion on factors linked to the decline in abundance of the European Eel would be extremely timely. Barriers to migration – including damage by hydropower turbines (Winter et al. 2006, Acou et al. 2008, Azeroual 2010, van der Meer 2012, Clavero and Hermoso 2015, Wright et al. 2015, Besson et al. 2016, Mota et al. 2016, Bernaś et al. 2016, Dainys et al. 2017, Piper et al. 2018, Verhelst et al. 2018a,b, Hanel et al. 2019). Climate change and/or changes in oceanic currents (including the influence of the North Atlantic Oscillation (NAO)), climate-related hydrological changes (reduced precipitation, drought), and other oceanic factors (Castonguay et al. 1994, Dekker 2004, Kim et al. 2004, Minegishi et al. 2005, Bonhommeau et al. 2008, Miller et al. 2009, Durif et al. 2011, Kettle et al. 2011, Pacariz et al. 2014, Miller and Tsukamoto 2016, Politis et al. 2017, ICES 2018c, Westerberg et al. 2018). Disease and parasites (particularly Anguillicola crassus) (De Charleroy et al. 1990, Würtz and Taraschewski 2000, Vettier et al. 2003, van Ginneken et al. 2004, Gollock et al. 2005, Palstra et al. 2007, Sjöberg et al. 2009, Haenen et al. 2012, Becerra-Jurado et al. 2014, Kempter et al. 2014, Weclawski et al. 2014, Wysujack et al. 2014, Muñoz et al. 2015, Barry et al. 2017, Hafir-Mansouri et al. 2018).

Legal and illegal exploitation and trade of eels (ICES 2012, 2013, 2018c; Crook 2010, 2014; Shiraishi and Crook 2015, Dekker and Beaulaton 2016, Stein et al. 2016, Gollock et al. 2018, Musing et al. 2018, Dekker 2019, Kaifu et al. 2019).

Habitat loss (and associated resource decline) (Boëtius and Boëtius 1980, Svedäng and

Wickström 1997, van Ginneken and van den Thillart 2000, Feunteun 2002, Kettle et al. 2011).

Pollutants (Robinet and Feunteun 2002, Maes et al. 2005, Palstra et al. 2006, Geeraerts and Belpaire 2010, Sühring et al. 2013, 2014, 2015, Kammann et al. 2014, Szlinder-Richert et al. 2014, Belpaire et al. 2015, 2016, 2019, Claveau et al. 2015, Fernández-Vega et al. 2015, Jürgens et al. 2015, Rosabel et al. 2015, Rudovica and Bartkevics 2015, Caron et al. 2016, Freese et al. 2016, 2017, 2019, Maes et al. 2008, Michel et al. 2016, Polak-Juszczak and Nermer 2016, Castro et al. 2018, De Meyer et al. 2018, Nowosad et al. 2018, Rakocevic et al. 2018). Predation (Carpentier et al. 2009, DEFRA 2010, Simpson et al. 2015, Wahlberg et al. 2014, Wysujack et al. 2015, Amilhat et al. 2016, Hansson et al. 2018, Ovegård 2017, Lennox et al. 2018).

Summary

Barriers to upstream and downstream migration are a threat to the European Eel through the reduction of available habitat - pumps or hydropower turbines and their associated screens and water management systems can also cause mortality or sub-lethal injury (ICES, 2019a). In the AMBER (Adaptive Management of Barriers in European Rivers) project has begun tracking barriers across Europe, compiling them into a 'Barrier Atlas' to better inform management and conservation (AMBER International 2019). The project is ongoing, but so far around 415,000 barriers - complete or partial, with degree of obstruction not often fully quantified - have been recorded within this tool (AMBER International 2019). Relating in particular to hydropower, 21,387 plants are recorded currently in existence in Europe, with a further 278 under construction, and 8,507 planned (Schwarz et al. 2019). In the Iberian Peninsula, 80% of eel habitat had been lost when compared to a 19th century baseline, as a result of dams causing fragmentation (Clavero and Hermoso 2015). A full life cycle model developed by Bevacqua et al. (2015) suggested the decline of the European Eel between 1975 and 1985 may be somewhat attributed to habitat loss. The model projected a reduction in suitable eel habitat, by 16% in the Mediterranean and 71% in the North and Baltic seas (Bevacqua et al. 2015). Degradation and loss of available habitat is also exacerbated by development, flood control, water-level management and the abstraction of surface and groundwater for both domestic and commercial use (Drouineau et al. 2018). For example, Portugal and Spain have been impacted by dam construction and/or drought in recent decades (Kettle et al. 2011). Further, it has been hypothesised, that the decline in good quality habitat and associated resources may be causing a decline in body condition of escaping silver eels in parts of the range which may have effects on the success of migration and/or spawning due this species', particularly the female's, reliance on fat stores for reproductive success (van Ginneken and van den Thillart 2000). Climate change has been proposed to play a role in fluctuations of abundance in A. anguilla – particularly larval transport and glass eel recruitment - through its impact on the suspected breeding area (Sargasso Sea) and on changing oceanic conditions that can influence the recruitment of glass eels to near shore and freshwater environments. An important consideration in this discussion is the time scale over which changes are thought to occur as a result of oceanic conditions. The North Atlantic Oscillation (NAO) and the associated climate variability that this brings to the North Atlantic have been dated as far back as the Holocene (Kim et al. 2004). As such, fluctuations in climate do occur naturally and have been influencing eel populations for millions of years (Minegishi et al. 2005). The NAO has been studied as a driver of recruitment in both the European and American Eel, with published literature arguing for and against this hypothesis. Durif et al. (2011) indicated that periods of high NAO appear to negatively correlate with recruitment to freshwater habitats due to larval metamorphosis being impeded due to the larvae being driven into colder water, slowing the process considerably. Further, changing ocean climate might potentially be responsible for fluctuations in productivity and thus food availability for leptocephali (Miller et al. 2009, Miller and Tsukamoto 2016). Using a high-resolution ocean model, Baltazar-Soares et al. (2014) found ocean current variations to be a major driver in the onset of the decline in European Eel recruitment that occurred in the early 1980s. Although after this period, the correlation between oceanic fluctuations and eel recruitment was lost, and lack of recovery was likely a result of other pressures (Baltazar-Soares et al. 2014). Pacariz et al. (2014), however, found that the overall success of larval drift from the spawning ground to the East Atlantic was not affected by changes in climate between 1958–2008, suggesting that trends in recruitment are attributable to factors other than changing currents, a theory also supported by Henderson et al. (2012). Politis et al. (2017) found 18°C to be optimum temperature for spawning of A. anguilla under experimental conditions. The results suggested A. anguilla may inhabit a deeper layer of the Sargasso Sea during early life stages and may be vulnerable to changes in temperature as a result of ocean warming. A recent ICES WGEEL report described climate change and increasing ocean temperature under “new and emerging threats”, due to unusually warm and dry periods occurring throughout European countries (ICES 2018c). This warm and dry period resulted in higher water temperatures, reduced levels of dissolved oxygen, and in some cases habitat loss through drought, creating stressful conditions for eels and other freshwater biota (ICES 2018c). There were several reports of eel mortalities from European countries, connected to warmer water, increased instances of disease, or deaths that could not be explained (ICES 2018c). Westerberg et al. (2018) examined the abundance and distribution of leptocephali using historic and recent sampling expeditions conducted in the Sargasso Sea covering the period of 1920-2014. Decreases in leptocephali density (20-35% of pre-1980’s) were compared with spawning stock (using commercial landings as a proxy) and recruitment declines. Declines in leptocephali density and spawning stock follow a similar rate, however, were an order of magnitude less than that of recruitment (1-2% of pre-1980’s). This supports that a major cause of recruitment decline may be due to changing oceanic conditions, either as a result of increased leptocephali mortality following spawning, during the drifting oceanic phase, or a shift in geographical glass eel arrival, to outside areas currently monitored. The parasite nematode (Anguillicola crassus), introduced when the Japanese Eel (A. japonica) was imported to Europe for culture in the early 1980s, is also thought to impact the ability of the European Eel to reach its spawning ground. There multiple proposed impacts which include a negative effect on silver stage physiology (Fazio et al. 2012); swimbladder damage which impairs swimming performance (Palstra et al. 2007); and a reduced ability to cope with high pressure during their reproductive migration (Vettier et al. 2003, Sjöberg et al. 2009). Prevalence of A. crassus has been found to be higher in smaller eels (Barry et al. 2017, Hafir-Mansouri et al. 2018), with the proposal that smaller eels feeding mainly on invertebrates have a greater infection intensity than larger, piscivorous eels, because of increased chance of encounter with infected invertebrate hosts (Barry et al. 2017). Lipophilic pollutant contaminants and metals act as stressors within the continental stage of the European Eel life cycle (Drouineau et al. 2018, Belpaire et al. 2019). This can result in damage to the respiratory system, tissues and organs, alter the regular function of endocrine processes, osmoregulation, and haematological dynamics, as well as decreasing protein content, reducing the ability of an eel to cope with physiological stress (Geeraerts and Belpaire 2010, Belpaire et al. 2016, 2019, De Meyer et al. 2018). Lipids are essential for allowing normal migration and reproduction (Belpaire et al. 2019). As pollutants impair lipid metabolism and storage, it may reduce the ability of silver eels to migration (Belpaire et al. 2019). Chemicals stored by eels and released when fat stores are broken down during migration, could subsequently limit the capacity of the silver eels to complete their spawning migrations due to metabolic disruption (Robinet and Feunteun 2002, Palstra et al. 2006, Drouineau et al. 2018, Belpaire et al. 2019). Further, there is concern that even if the spawning migration is completed that lipid stores containing xenobiotics may result in disrupted gonadogenesis and/or low-quality gametes, as well as transmission of pollutants to the larvae (Robinet and Feunteun 2002, Sühring et al. 2015, Belpaire et al. 2016, Freese et al. 2017, 2019, Drouineau et al. 2018, Nowosad et al. 2018). Ultimately, pollutants may be affecting eels at molecular and individual levels, but also scaling to population and community-wide effects (Belpaire et al. 2016, 2019). Lipophilic chemical pollutants have been identified as a cause of recruitment failure, although current policies focusing on increasing escapement from continental waters do not consider eel quality (Belpaire et al. 2019). To mitigate impacts of contaminants, it may be valuable for management to integrate methods to improve the condition and quality of both habitats and escaping eels (Freese et al. 2016, Belpaire et al. 2019). This may also be considered in relation to stocking activities, by ensuring eels have suitable, unpolluted rearing habitat (Freese et al. 2016, Belpaire et al. 2019). Predation also represents a threat to A. anguilla and is increasingly being discussed in relation to competition with commercial and recreational fisheries. **Cormorants in particular have been a focus of recent**

research, which has found eel consumption by cormorants to be of a similar quantity to that of fishery landings in both the Baltic Sea (Hansson et al. 2018) and some lakes in Sweden (Ovegård 2017). Human factors may exacerbate the threat. Under experimental conditions, acoustic disturbance has been found to reduce anti-predation behaviour in eels, affecting likelihood of survival (Simpson et al. 2015). Unsustainable exploitation is a threat to the species. Fishing for the European Eel began with small-scale fisheries up to the late 1800s, before shifting during the mid-1900s to larger scale, commercial exploitation, with production peaking between 1960–70 (Dekker and Beaulaton 2016, Dekker 2019, Kaifu et al. 2019). Across its distribution, all continental stages of the European Eel are currently exploited although data from different regions varies in quality and period of collection. Trade of European Eel continues within the European Union (EU) for consumption, culture and stocking, although export from the EU has been banned since 2010 although over this time period commercial landings of yellow and silver eels have remained relatively consistent (around 2000–3000 tonnes) (ICES 2019a) (see Conservation). Indeed, it seems that yellow/silver eels are declining while glass eel catches increase (European Commission 2020a). Despite the ban on trade outside of the EU, under-reporting, illegal fishing (poaching) and illegal trade are believed to occur throughout the range of the European Eel fisheries (Musing et al. 2018). There is little information regarding illegal exploitation of the European Eel, which is thought to be driven mainly by demand from East Asia for use as a substitute for Anguilla japonica, due to the reduced abundance of glass eels of this species (Kaifu et al. 2019). Assessment of the impact of this component of fishery exploitation is therefore extremely difficult. Export of European Eel outside of EU borders is visible through trade statistics, and enforcement agencies report the tonnage of successful operations where shipments have been intercepted, and seizures made (Musing et al. 2018, Kaifu et al. 2019). A review of exploitation, including an attempt to understand the scale of eel trafficking for the European Eel was conducted by Stein and Dekker in Kaifu et al. (2019).

Impact of Great Cormorant

Scope: Not assessed

Severity: Not assessed

Marble Trout (Salmo marmoratus) – Vulnerable

Distribution

Distribution is not mapped for this species.

This species has a somewhat discontinuous distribution in rivers draining to the Adriatic Sea. In the northern part of the Adriatic basin, its range extends from the Po River and its present and historical orographic left-bank tributaries in Italy and Switzerland eastward to the Rižana River in Slovenia. It is restricted to systems draining the southern slopes of the Alps, and is thus absent from most right-bank tributaries of the Po. In the southeastern Adriatic, it is present in the Neretva River and Lake Skadar watersheds but is absent from some sinking affluents that are isolated by karstic landscape features, e.g., the Trebižat and Trebišnjica rivers in the Neretva River watershed and Nikšić Polje in the upper Zeta River catchment.

It has been introduced to several European river systems outside of this range in the past, but is not understood to have become established in any of them.

Threats

This species is primarily threatened by introgressive hybridisation with non-native Brown Trout (Salmo domestic strain), which has been widely introduced throughout most of its range for the creation or restocking of recreational fisheries. These activities may have taken place for several centuries at some locations, especially in Italy, but underwent a dramatic expansion with the development of aquaculture techniques during the late 19th century. The non-native individuals produced in hatcheries today are of mixed origin, but are typically derived from the Atlantic Brown Trout mitochondrial lineage (see 'Taxonomic Notes'). The negative impact of stocking with non-native individuals is widely-documented in the northern Adriatic basin, but has not been extensively-investigated in the Neretva River or Lake Skadar catchments.

This species' decline has also been driven by river regulation and other forms of habitat degradation, which have resulted in widespread loss of the heterogeneous, interconnected fluvial habitats required to complete its life cycle. In particular, the construction of dams, weirs and other barriers has altered natural flow and sedimentation regimes, blocked access to spawning sites, fragmented subpopulations, increased stranding rates, and generally reduced the extent of suitable habitat for all life stages. The quality of habitat has been further diminished by bank stabilisation, channelisation and other efforts to enhance flood protection or exploit water for human development. Furthermore, the increase in habitat homogeneity associated with these modifications is understood to reduce reproductive isolation between native and introduced trouts.

Hydroelectric dams have created unnatural fluctuations in discharge and water temperature (hydropeaking and thermopeaking) which cause dewatering of spawning sites, the loss of stable nursery habitat for juveniles, and downstream displacement, while unstable flow and temperature regimes may also increase hybridisation rates. The combined effect of hydropeaking, dam flushing operations, changes in land use, and the removal of riparian vegetation has also increased accumulation of fine sediments at spawning sites, thus impairing the hatching and survival rates of eggs and larvae. The middle reaches of the Neretva River system have been particularly impacted by hydropower projects, and the proposed construction of around 70 additional schemes in the upper part of the catchment plus the ongoing "Upper Horizons" expansion scheme in the lower basin together represent a plausible threat to the entire ecosystem.

The industrial extraction of riverine gravel and other sediments for urban development is likely to have further reduced the extent and quality of available spawning sites. In the Neretva River, removal of sediments from the main stem has deepened the river bed and hampered the transport of heavy sediments.

This species is also understood to be threatened by diffuse and point source agricultural, domestic and industrial pollution, which has resulted in eutrophication or discharge of toxic substances at some locations. For example, the lower reaches of the Morača River, which provides more than 60% of Lake Skadar's water, are polluted due to long-term discharge of agricultural and industrial contaminants plus insufficiently-treated municipal wastewater from the city of Podgorica and other urban centres. As a result, the lake has become increasingly eutrophic since the 1970s, which has led to bottom-up changes in food web structure. Most perialpine lakes in the Po River system also suffered from anthropogenic eutrophication during the 20th century.

Periodic major floods and associated debris flows driven by stochastic environmental processes comprise the principal threats to the pure subpopulations inhabiting small upland streams in Slovenia. In 2000, one of these was extirpated following a landslide caused by tectonic activity in the Predelica River watershed.

Northern Adriatic subpopulations are plausibly threatened by increasing abundance of the piscivorous Great Cormorant (Phalacrocorax carbo), particularly during the winter.

Rising water temperatures due to climate change represent a plausible future threat, since they may interfere with food availability, lifespan, and the timing of reproductive processes, with the latter potentially leading to greater overlap with non-native Brown Trout.

Impact of Great Cormorant

Scope: Unknown

Severity: Unknown

Food and Agriculture Organization of the United Nations

Framework for a European Management Plan for the Great Cormorant

Version July 2025

European Inland Fisheries and Aquaculture Advisory Commission

Co-funded by the European Union

Preparation of this document

The preparation of this Framework for a European Management Plan for the Great Cormorant received financial support from the European Maritime, Fisheries and Aquaculture Fund (EMFAF) within its work programme for 2024–2025, under the FAO-European Commission Trust Fund project on 'Developing Europe-wide management advice to protect vulnerable and endangered fish species from unsustainable predation by cormorants" (GCP/RER/069/EC).

The membership of the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) and the European Parliament requested the preparation of a European management plan for the great cormorant various times since 2008.

This document has been written by Ian G. Cowx (University of Hull, United Kingdom), Niels Jepsen (Danish Technical University, Denmark) and Raymon Van Anrooy (EIFAAC secretary).

The preparation of the document involved hundreds of stakeholders, representing governments, research and management institutions, intergovernmental organizations, non-governmental organizations (NGOs) and Civil society organizations (CSOs) active in bird conservation, fish and biodiversity conservation, water management, fisheries and aquaculture. Draft versions of this document were shared by the EIFAAC Secretariat with all key stakeholders in April and May 2025 for comments and suggestions.

Contributions, information and comments were received from Government officials from ministries responsible for environment and fisheries of nearly all 37 EIFAAC member countries.

The European Commission Directorate General for Maritime Affairs and Fisheries (DG MARE) and European Commission Directorate General for the Environment (DG ENV), and various Members of the European Parliament participated in the stakeholder meetings and contributed to the draft framework management plan, as well as scientists on bird- and fish conservation, fisheries and aquaculture from more than 30 European universities.

Organizations which participated in and contributed to the development of this framework management plan included, amongst others: Angling Trust (United Kingdom), Alienor, Aquaculture Advisory Council (AAC), Association of Marine Aquaculture Companies of Andalusia (ASEMA, Spain), Association Française des Professionnels de la Pisciculture d'Etangs (France), Asociatia Nationala a Producatorilor din Pescarie (ROMFISH, Romania), Baltic Sea Advisory Council (BSAC), Birdlife Europe, Centro Tecnológico de la Acuicultura (CTAQUA, Spain), Brancheorganisationen Dansk Lystfiskeri (Denmark), Danmarks Sportsfiskerforbund (Denmark), Deutscher Fischerei Verband e. V.(Germany), Deutscher Angelfischerverband e.V. (Germany), Eurogroup for Animals, European Anglers Alliance (EAA), European Federation for Hunting and Conservation (FACE), Federation of European Aquaculture Producers (FEAP), Fédération Française d'Aquaculture (France), Fishprotection contra Cormorant re. association (FPcC, Germany), Lystfisker Danmark (Denmark), Maison Wallonne de la Pêche (Belgium), Natural Resources Institute Finland (LUKE), North Sea Advisory Council (NSAC), Organizacja Producentów Polski Karp (Poland), Polskie Towarzystwo Rybackie (Poland), Polski Związek Wędkarski (Poland), Seas at Risk, Sportvisserij Nederland (Netherlands), Svenska Jägareforbündet (Sweden), Wetlands International, and Związek Producentów Ryb (Poland).

The preparatory process included a range of regional workshops, meetings and consultations in 2024 and 2025, such as:

- An EIFAAC workshop on management advice for reducing the impact of cormorant predation on fish and fisheries, Pula/online, Croatia, 8 October 2024. (78 participants from 24 countries)
- A Baltic Sea Advisory Council Workshop on predators in the Baltic (seals, cormorants), second edition, Helsinki/online, Finland, 30 October 2024 (71 participants)
- A North Sea Advisory Council/BSAC Workshop on predators (seals & cormorants), Lulea, Sweden, 20 March 2025 (41 participants)
- An EIFAAC Stakeholder consultation on the draft European Cormorant Management Plan, Rome/online, 25 April 2025 (114 participants from 27 countries)
- A Polish Presidency to the Council of the EU/EIFAAC Conference on management advice to reduce cormorant predation impacts, Brussels/online, Belgium, 3 June 2025 (230 participants from 27 countries).

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Executive summary

Cormorants are protected in the European Union under the Birds Directive (2009/147/EC), which has contributed to a dramatic increase in their populations since the 1980s. This conservation success has brought cormorants into conflict with inland and coastal fisheries and aquaculture in Europe. The increasing population size and expanding range of the great cormorant in Europe have contributed to threats to aquatic biodiversity, declining fish stocks and loss of aquaculture production in both fresh and coastal waters, leading to economic losses for commercial and recreational fisheries and aquaculture enterprises.

To address the problems caused by the increasing European great cormorant population size, numerous mitigation measures have been undertaken at the national level. However, great cormorant population numbers and their distribution range across Europe continue to increase and mitigation measures have been largely unsuccessful. The limited success of ongoing national management interventions has highlighted the need for a pan-European management plan, as previously requested by the European Parliament.

This document provides a framework for a European Management Plan for the great cormorant (CMP framework) to manage the adverse impacts of an expanding great cormorant population on inland and coastal fish, fisheries and aquaculture across its European distribution range. It provides a balanced, science-based, and inclusive roadmap for managing the complex interactions between cormorants, fisheries, aquaculture and fish conservation in Europe. It is designed to compensate, mitigate and, where possible, reconcile cormorant-fish conflicts. It focusses on maintaining the great cormorant's good conservation status, but also recognises the social and economic dimensions, especially related to fish and fisheries and aquaculture, along with consequences of cormorant-fish-human interactions.

The CMP framework contains a review of the biology and development of great cormorants in Europe, a section on impact on fish resources and associated socio-economic impacts, a section on legislative, policy and management issues of relevance and provides a structured framework for its implementation and evaluation.

The CMP framework involves a series of steps: 1) assessment of the system of cormorant fish interactions, related economics, and the underpinning policy drivers, objectives and target end points; 2) formulating management measures; 3) choosing a course of action; 4) implementing management actions, monitoring changes in cormorant, fish, aquaculture and ecosystem characteristics, region-wide cooperation, and compensation for damages to fisheries and aquaculture; and 5) re-evaluation and adjustment of the endpoints and objectives of the plan into the future.

The CMP framework provides a process for stakeholder engagement and enables structured decision-making and adaptive management through the Evaluate-Adjust-Adapt processes. The outcomes of the CMP target a significant decrease in cormorant-related conflicts in Europe, maintenance of the favourable conservation status of the great cormorant across its European distribution range, improvement of the conservation status of vulnerable fish species, and, in part, address reasons for failure to achieve good ecological status in rivers, lakes and transitional waters under the EU Water Framework Directive. It will also contribute towards sustainable freshwater aquaculture and inland fisheries business development and food security for Europe.

Contents

1. The need for a European Cormorant Management Plan

Recovery of the great cormorant (*Phalacrocorax carbo carbo* and *Phalacrocorax carbo sinensis*) in Europe symbolises a highly successful conservation story. From very low abundance in the 1950s due to persecution and toxic pollution, its population has grown and expanded its range across Europe (van Eerden and Gregersen, 1995; Bregnballe, 1996; Bregnballe et al., 2011a; Bregnballe et al., 2014). This has brought the great cormorant into direct conflict with fisheries, and has been the subject of intense debate since the 1990s regarding its impact on inland and coastal fisheries in Europe. This is reflected by the various interventions by the European Parliament (EP) over the past three decades (see section 2.5.3 and Annex 2), including calls for a European Management Plan and a call for support for various projects to address the conflict. Support has also been given by the European Commission (EC) to projects to attempt to address the problem (REDCAFE[1], INTERCAFE[2], CORMAN[3] and FRAP[4] projects). The increasing population size and expanding range of the great cormorant have contributed to low levels of fish stocks and problems with their recovery, and loss of aquaculture production in both inland and coastal waters. This has led to economic losses for commercial and recreational fisheries and aquaculture enterprises (Section 2.3).

This perspective is countered by arguments that the current poor status of fish stocks is the result of commercial and recreational overfishing, including considerable bycatch, and general environmental degradation (Klenke et al., 2013). It is suggested that fish stocks should be helped in their recovery by managing fishing pressure and strategically removing the barriers to fish migration and restoring their habitats, thus meeting the EU´s nature restoration goal to restore 25 000 km free flowing rivers by 2030. Whilst considerable attention has been paid to these measures through the Common Fisheries Policy (updated in 2013[5]), including measures introduced in 2023 to improve the sustainability and resilience of the EU fisheries and aquaculture sectors, and under the Water Framework Directive (WFD)[6] (including estuarine (transitional) and coastal waters) and the Marine Strategy Framework Directive (MSFD)[7], fish populations continue to decline. Freshwater fish are amongst those with the highest proportion of species in poor conservation status of any biota (EEA, 2020). Within Europe, 37% of the 531 native freshwater fishes assessed for the IUCN European Red List are threatened (Freyhof and Brooks, 2011).

One factor that has persisted throughout this period, since first raised in the 1990s and including removal of *P. c. sinensis* from Annex 1 of the Birds Directive in 1997[8], is predation

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[1] https://www.ceh.ac.uk/our-science/projects/intercafe-information#:~:text=REDCAFE,European%20Union's%20Framework%20Five%20Programme
[2] https://www.ceh.ac.uk/our-science/projects/intercafe#:~:text=The%20main%20objective%20of%20INTERCAFE,Europe%20and%20to%20deliver%20a
[3] EU Project: Sustainable Management of Cormorant Populations: https://tinyurl.com/y7vpcy6p; http://cormorants.freehostia.com/
[4] https://www.ufz.de/index.php?en=36309
[5] Common fisheries policy (CFP) - European Commission
[6] Water Framework Directive - European Commission[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32008L0056
[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32008L0056
[8] https://ec.europa.eu/commission/presscorner/detail/ro/ip_97_718

and damage by cormorants. This is not only directly affecting fish populations themselves but also constraining recovery of threatened species and depleted stocks after environmental conditions have been improved.

To date it has not been possible to reconcile the increased pressure from cormorants in rivers, lakes and coastal waters or on aquaculture facilities using traditional mitigation measures (restoration, barrier removal, stocking, reducing fishing pressure and shifting capture methods), and alternative strategies are required. This includes managing the cormorant population size proportionate to the damage caused, and recognising localised actions have failed to resolve ongoing conflicts because the problem is pan-European (Kindermann, 2008; Cowx, 2013).

A precedent for such a multi-country approach has been successfully adopted for other problem bird species, e.g. the barnacle goose (Jensen et al., 2018), greylag goose (Powolny et al., 2018) and the Svalbard pink-footed goose, where a management plan has been put in place to control its feeding on field crops (Madsen et al., 2012), which was evaluated in 2017 (Madsen et al., 2017).

While cormorants may constitute a vital component of biodiversity, fisheries managers, fisheries organizations, fish farming organizations and fish farmers, and those engaged in management and rehabilitation of endangered fish species have raised concerns about critical declines in fish conservation status and fish farming. In the case of fish farming, pond-based aquaculture is becoming economically unviable in various places because of predation losses and damage (FAO, 2024b, 2025a; FDAAPPMA, 2024; Parlier, 2024). Pond farm closures could also have considerable indirect impact on conservation of aquatic biota as they act as critical habitat for many threatened aquatic biota.

Although much attention has to be paid to the impact of fishing on the status of fish stocks, this predominantly refers to marine waters and diadromous species such as salmon, shad, lamprey and eel. Fishing for eel is now heavily regulated to protect the species (Council Regulation (EC) No 1100/2007). Inland waters in Europe are rarely impacted by fishing, because it is mostly recreational catch and release fishing (Cowx, 2015).Especially in rivers where the stocks are notably in decline, predation by cormorants is often a major contributor to the decline or failure to recover (e.g. Conrad et al., 2002; Guthörl, 2006; Jepsen et al., 2018; Jepsen and Rasmussen, 2023; Kallö et al., 2020; Kallö et al., 2023; Kennedy & Greer, 1988; Steffens, 2010), but see Suter (1995) who found no effect of cormorants.

Fish populations in many water bodies are now in poor condition and many stocks are threatened, including fish species of high conservation value (e.g. IUCN, 2015, 2019; Pradhl, 1996; Sayer et al., 2025). A high proportion of freshwater and marine fish species are currently in poor or bad conservation status (around 80%) based on Habitats Directive assessments, a proportion that is higher than any other species group. Loss of large freshwater fish that are top predators of smaller fish may result in higher biomass of small fish, lower biomass of invertebrates and therefore more algae, impacting the ecological status of water bodies (European Environment Agency, 2024).

To address issues arising from increasing abundance and range of cormorant populations in Europe, numerous national and European collaborative projects have been undertaken to manage and mitigate the conflict between cormorants and fisheries and aquaculture, including the EU REDCAFE, INTERCAFE, CORMAN and FRAP projects and the development of a cormorant management toolbox (Russell et al., 2013), There has, however, been no discernible reduction in cormorant population numbers across Europe or mitigation of the problems encountered by their increasing presence. More projects have been initiated, including the Horizon 2020 ProtectFish[9] and national management plans were developed in some countries to address the problem (Gerdaux, 2005; Cowx, 2013). These actions, however, do not address one of the fundamental issues - lack of a coherent regional management plan for this migratory bird species, despite numerous calls for such a plan from the European Parliament, EIFAAC, fisheries and aquaculture agencies and NGOs such as the European Anglers Alliance and Aquaculture Advisory Council (see Annex 2). Consequently, fish populations continue to deteriorate, with many fish stocks and associate businesses threatened in their survival. Further, many aquaculture businesses have become unviable and gone out of business as a result of unsustainable cormorant predation (e.g. Musil, 2002; Kortan et. al., 2008; Donati et al., 1997; Adamek and Kaigrova, 2022; FAO, 2025a).

The aim of this document is to:

- outline the nature of the conflict arising from the recovery and expansion of great cormorant in Europe, the ways they have been addressed, and the effectiveness of adopted measures;
- review the main economic effects of the conflict, and attempts to define the major problems preventing resolution;
- review the legislative and policy framework relevant to the cormorant-fish conflict; and
- present a framework for a European management plan to reduce damages caused by great cormorants to fish biodiversity, fisheries and aquaculture.

[9] Homepage - Protectfish

2. Cormorant-fish conflict

2.1 Description of the cormorant population

Two subspecies of great cormorant occur across Europe, the smaller *Phalacrocorax carbo sinensis* inhabits coastal as well as inland waters, whereas the other subspecies, the larger *Phalacrocorax carbo carbo* is mainly found around the open coast of Norway, Ireland, British Isles and Iceland (Nelson, 2005; Bregnballe et al., 2014). The subspecies *P. c. sinensis* has increased strongly in both numbers and geographical range and causes many conflicts throughout Europe. The subspecies *P. c. carbo* has maintained a stable population and distribution in recent decades (although declining in Norway), and, as such, does not cause as many conflicts. Thus, when the term cormorant is used in this document, it refers mainly to *P. c. sinensis* in mainland Europe and *P. c. carbo* in north-western Atlantic coastal countries.

2.1.1 Breeding biology

Cormorants are colonial waterbirds that breed in relatively large colonies. They are flexible with regards to where they establish colonies. Cormorants build their nests in trees, shrubs and/or on the ground. They breed directly on the ground on small islands if these are safe against predators (primarily foxes). However, if there are trees and shrubs on the island where they settle, they usually choose to build the nests in them. When cormorants breed by lakes, the nests are often found in trees next to the lakeshore. Colonies can occur in diverse locations, including shipwrecks, electrical transmission towers (decommissioned) and even old light houses. The breeding season extends from March to July. The eggs are white to slightly blue. Cormorants start breeding from ages 2 - 6 years and will usually lay 2 – 5 eggs each year. The reproductive time of most cormorants starts from an age of 3 years (Frederiksen and Bregnballe, 2001). Nesting success increases with age and experience (Bregnballe, 2006). The cormorants are rather long-lived and can reach ages of 15-20 years (Frederiksen and Bregnballe, 2000; Fransson and Pettersson, 2001) and adult cormorants are estimated to have a mean annual survival rate of 88 percent. The mortality rate can range between 5% and 26%, depending on factors like winter severity and population size (Frederiksen and Bregnballe, 2000). The egg incubation period is approximately 30 days. About 7 weeks after hatching, the young are ready to fly. Breeding success depends primarily on food availability and amount of disturbance during the breeding season. In favourable years, ≈2.5 young can be produced per nest, but in years with little food as few as 0.5 young are produced per nest. Some studies from Germany and Czechia reported the number of young per breeding pair was 2.1 - 3.8 per nest (Zimmerman and Rutschke, 1991). The young will typically leave the nests between late June and the end of July, depending on latitude.

2.1.2 Foraging and diet

Cormorants live almost exclusively on fish. The cormorant's individual food intake fluctuates throughout the season from 200 to 700 g/day, with a mean of 500 g/day (Grémillet et al., 1996; Keller & Visser, 1999; Ridgway, 2010). The need is greatest in May-June, when cormorants have young. The cormorant is an efficient underwater hunter that forages in virtually all water bodies, even the smallest fresh waters (running and still), shallow coasts and brackish habitats in depths up to 50 m, but normally only down to 20 m (Bregnballe, 2009) Cormorants usually seek food alone, but also forage in groups of up to several hundreds in fjords, lakes, rivers and in shallow marine areas. During the breeding period, they will normally utilise water bodies in a radius of about 30 km from the colonies, but foraging trips of up to

50 km are known. Cormorants are good at locating areas with many fish that are relatively easy to catch, such as in ponds and small open lakes (van Eerden et al., 2012). Cormorants also forage in very small water bodies like garden-ponds, small streams of 1-2 m width and even in underground concrete channels. Cormorants can survive on shrimps, sticklebacks and tiny sand goby if other prey is absent, but they can also eat fish of up to 2 kg (±50 cm in length) (Klenke et al., 2013; Kallö et al., 2023).

2.1.3 Migration and overwintering

Cormorants have established breeding colonies in most European countries, but most of the breeding takes place in northern Europe, especially around the Baltic Sea (van Eerden et al., 2012). From late summer to autumn, there is a shift in the distribution of cormorants away from the Baltic/Nordic fjords and freshwater areas and out to the more open coasts and remote small islands. Around September-October they begin their autumn migration. Some migrate along the Atlantic coast and others migrate over land, usually along rivers (Figure 1) (Frederiksen, et al., 2018). Important wintering areas include The Netherlands, France, Spain, southern Germany, Switzerland and northern Italy (Bregnballe and Rasmussen, 2000). Some cormorants choose to stay in northern areas, including the British Isles and the Baltic Sea region in winter, and do well in mild winters. The number of cormorants that overwinter in the north has increased as winters have become milder, linked to increasing air temperatures and less ice-cover.

Figure 1. Example of recoveries of ringed cormorants from The Eurasian African Bird Migration Atlas (https://migrationatlas.org/node/1773#section1)

The population of cormorants in Southern European countries like Italy, Croatia, Spain and Portugal has continued to increase in recent decades (Regione del Veneto, 2024; Opacak et al., 2004; Junta de Andalucia, 2025), as well as in Central and Eastern Europe (Bregnballe et al., 2014). Cormorants in Central and Eastern Europe tend to stay year-round, so they are moving from obligatory migratory birds towards more diverse strategies (including resident birds).

2.1.4 Development in Europe

In Europe, standardized comprehensive cormorant surveys have only been conducted a few times. The last comprehensive survey was in 2013 (van Eerden 2021), thus the numbers given below are estimates. The European Breeding Birds Atlas[10] shows trends in distribution and abundance of cormorants and their breeding status up to and including 2017 (Figure 2), and it is widely recognised that the distribution range and abundance have increased further in recent years (T. Bregnballe, unpublished data).

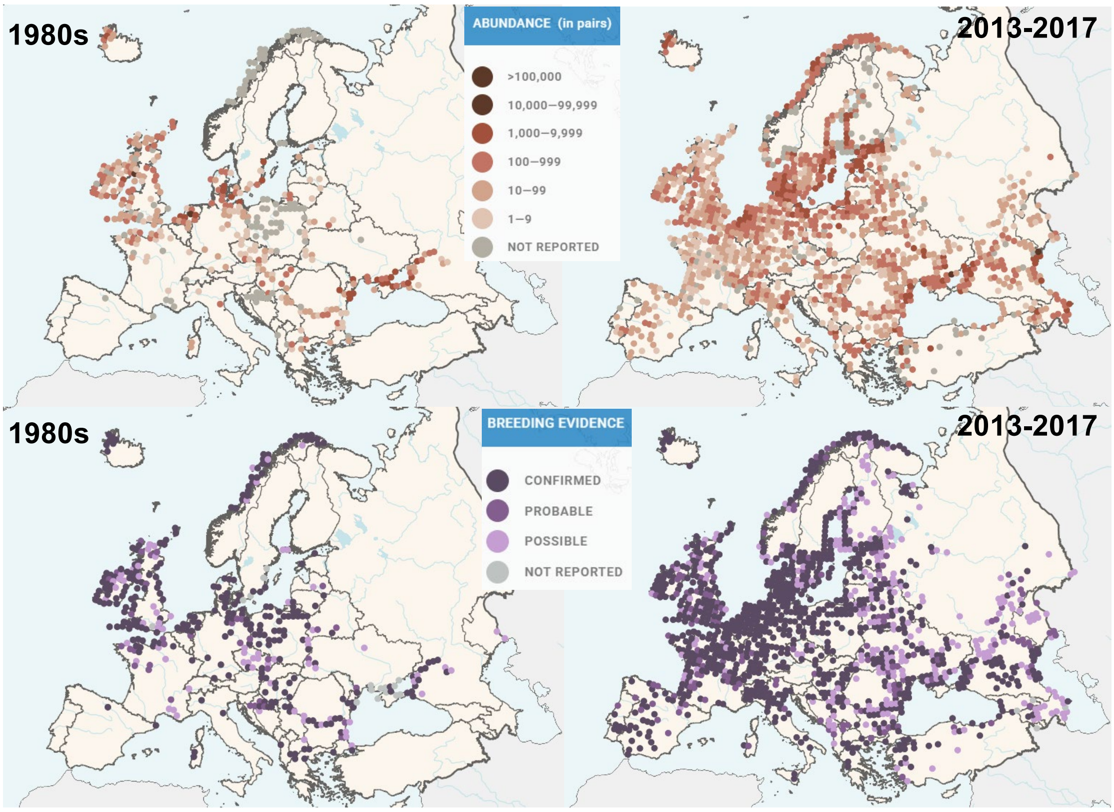

Figure 2. Abundance (upper panels) and distribution of breeding cormorants in the Western Palearctic in 2012 presented in 50 x 50 km grid cells between the 1980s and 2013-2017. (source: European Breeding Birds Atlas 2 - https://ebba2.info/maps/species/Phalacrocorax-carbo/ebba2/abundance/)

In the first half of the 20th Century, the great cormorant was close to extinction in Europe. In the early 1960s, the northwest European population numbered about 5 000 breeding pairs. In the 1970s, the population began to grow in The Netherlands, Denmark and Sweden, and numbers increased to ≈13 500 pairs in 1981. The increase in numbers reflects that the abundance of cormorants was negatively impacted in the past by human activities or side

[10] https://ebba2.info/maps/species/Phalacrocorax-carbo/ebba2/abundance/

effects of societal development (e.g. persecution, toxic pollution such as DDT and PCBs) (Dirksen et al., 1995; van Eerden and Gregersen, 1995). Adoption of the EU Birds Directive in 1979 resulted in markedly increased protection of cormorants, and cormorant population abundance and their distribution increased greatly (van Eerden and Gregersen, 1995). The implementation of the Birds Directive was not followed by plans for management of the species, and the population of *P. c. sinensis* grew rapidly and spread over Europe (van Eerden and Gregersen, 1995; Lindell et al., 1995; Keller and Muller, 2015; Bregnballe, 1996; Bregnballe et al., 2011; Bregnballe et al., 2014).

Other reasons for the successful expansion of the great cormorant are increased nutrient input into lakes and coastal waters leading to eutrophication, boosting fish populations and thereby providing more abundant food sources for cormorants (de Nie, 1995; van Eerden and Gregersen, 1995; Suter, 1997). The growth of fish farming in various European countries, particularly in areas frequented during cormorant migration, provide additional foraging opportunities, especially in fishponds (Moerbeek et al., 1987).

The global population in 2014 was estimated to number ≈1 400 000-2 100 000 individuals (Wetlands International, 2015). The European population was estimated at 401 000-512 000 breeding pairs, which equates to 828 000-1 030 000 mature individuals (Birdlife International 2015; 2018). The total number of breeding pairs in Europe is estimated to have increased since 2014, but has not been counted recently. This recent, substantial, increase in numbers has coincided with an extension in geographical range, with cormorants moving north, especially along the Baltic coasts of Sweden and Finland, resulting in a build-up of breeding colonies as far north as the Bothnian Bay (Figure 1). However, there have also been marked increases in numbers of (smaller) breeding colonies on the European mainland and British Isles. Knowledge of the size of the cormorant population in Europe prior to modern times, is limited, but it has been concluded, based on archaeological finds and ancient literature dating back a thousand years that the cormorant was never very abundant in Europe (Beike et al., 2013), thus “*the current distribution and abundance of the cormorant cannot be seen as a recovery of the species to historically existing conditions*”.

Even the best counts (2006, 2012/13) carry some uncertainty, both because some colonies may have been overlooked and because some nests inside some of the colonies are likely to have been missed (Bregnballe et al., 2013).

The dynamic nature of the cormorant population, as well as variation in the counting effort from country to country, makes robust estimates of total population size in Europe challenging. The conversion from counted nests/pairs to total number of individuals is not trivial and will vary with population age-structure. This has given rise to much discussion regarding the “true” size of the population, but overall, it is often assumed that each counted nest equates to 4.5 birds in the autumn (Bregnballe, 2009; Wetlands International, 2025), although another study used as a simplified method for population estimation a conversion factor as low as 3 birds for waterbirds in general (Meininger et al., 1995). Based on the nest counts and the conversion factor of 4.5 it is valid to approximate that there are currently more than 2 million cormorants spending all or most of their time in European waters. The future development of the cormorant population will primarily be determined by: a) the food supply; b) opportunities for cormorants to establish new colonies; c) regulatory measures, especially culling of juveniles and adults; and d) expansion of the population of white-tailed sea eagles and other predators like foxes and racoons, and weather conditions (Hermann et al., 2021).

2.2 Impact of cormorants on aquatic resources

Discussions regarding cormorant predation on wild fish, and thus commercial fishing, recreational fishing, fisheries and fish conservation, have been intense for decades and continue to date (e.g. Kindermann, 2008; Cowx, 2013; Carss, 2022; Saarikoski et al. 2025). Impacts from cormorant predation on wild fish populations are, however, difficult to measure. Consequently, most information is gained from single site assessments carried out as part of targeted studies (see Kindermann, 2008; Seiche et al., 2012; Cowx, 2013; EU Cormorant Platform[11]). These are supplemented by information in various national and regional cormorant management plans (e.g. Sweden, Denmark, Finland, Veneto region in Italy; see Gerdaux, 2005 and Cowx, 2013 for overviews) and information being compiled as part of the ProtectFish project. These studies provide clear and compelling evidence for predation impact on fish species and populations in specific areas. There are many common recurrent results from different places that show the impact of cormorant predation of fish stocks, especially salmon and sea trout [smolts] and grayling in rivers, pike in lakes, and cod and juvenile flatfishes in coastal waters, but not all results can be readily used or seen as valid for other areas or species. Consequently, the transferability of scientific results is central to providing evidence for the conflict. The impact on farmed fish, on the other hand, is relatively easier to evaluate, as the input (fry/fingerlings, feed), growth and mortality rates, and output (expected harvest without predation) are known. In this section, definitive evidence of impact is described, whereas it is acknowledged that evidence of no- or low impact can also be found in the scientific literature. A more thorough discussion of this dichotomy can be found in Cowx (2013) and Marzano et al. (2013).

Nevertheless, ample evidence shows that predation from cormorants can have substantial adverse impacts on aquaculture and inland and coastal fishing, and on aquatic biodiversity in general. Considering a total population of 2 million cormorants in Europe (Geographic Europe, not EU) and the fact that they each must consume a mean of 500 g of fish/day (Grémillet et al., 1996, Keller and Visser, 1999, Ridgway, 2010), equates to ≈ 365 000 tonnes of fish consumed each year, assuming they all forage within European waters the whole year. If this number is compared with high sea commercial fishing landings, it is only a fraction, but if compared with coastal and freshwater fish harvest, it is a very high proportion. So, the impact from cormorant predation is very dependent on the foraging habitat. In the open sea it represents less direct impact. In coastal areas and fjords the predation impact will only be a major when fish stocks are low, but in rivers and lakes with a naturally lower fish biomass the impact can be very high.

Rivers

In rivers and streams, even rare visits by cormorants have serious consequences for wild river fish populations, like salmon, marble trout, brown trout, grayling, barbel and nase (e.g. Harris, et al., 2008; Jepsen et al., 2018, 2018b; Kennedy and Greer, 1998; Kohl, 2005; Steffens, 2010; Kainz, 1994; NASCO, 2025). Trout and salmon smolts are particularly vulnerable to cormorant predation, especially stocked hatchery reared trout and other commonly stocked species (Boström et al., 2009; Boström et al., 2012; Cech and Vejrik, 2011; Jepsen et al, 2019, Källo et al., 2023; Säterberg et al., 2023). Some studies argue that cormorant predation may pose an

[11]https://circabc.europa.eu/ui/group/e21159fc-a026-4045-a47f-9ff1a319e1c5/library/b592c4bf-acd4-41e4-aba1-e6d3d5d9a0b0/details

extinction risk to some fish populations (Koed et al., 2006; Jepsen et al., 2010; Steffens, 2010). Cyprinid fishes (e.g. roach, bleak and bream), European pike and perch-like fish (pike-perch, perch and gizzard shad) are also at great risk of being adversely affected by cormorants (Evrard, et al., 2005; Ovegård et al., 2021; Delmastro et al., 2015; FDAAPPMA 47, 2024).

Lakes

Depletion of fish stocks in lakes as a result of predation by cormorants has been documented in Sweden, Germany, Denmark and the United Kingdom of Great Britain and Northern Ireland (e.g. Britton et al., 2002, 2003; Boel, 2012; Boström et al., 2012; Carpenter et al., 2005; Dirksen, et al. 1995; Ovegaard, et al., 2017; Rudstam et al., 2004; Skov et al., 2014; Winfield, et al., 2007; Wright, 2003), but see Engström, (2001) for no impact. These impacts are particularly severe in small shallow lakes (e.g. Britton et al., 2002, 2003; Wright, 2003).

Marine

In coastal (and fjord) waters, there is considerable evidence that cormorants can consume a high proportion of the fish stocks (Birt et al., 1987; Bax, 1998; Delingard, et al., 2021; Dieperink, 1995; Vetemaa et al., 2010): and for some species in the Baltic Sea cormorants eat more fish than are caught by commercial fisheries (Hansson et al., 2017), although the results of this modelling study have been disputed (Heikinheimo et al., 2018). Nevertheless, predation impacts on cod, eel, flounder and perch in the Baltic Sea area are now well-documented:

- perch (e.g. Vetemaa et al., 2010; Östman et al., 2012, 2013; Gagnon et al., 2015, Veneranta et al.,2020; Arlinghaus et al., 2021; Bergström et al., 2022);
- pikeperch (e.g. Eschbaum et al., ,2003; Mustamäki et al., 2014; Heikinheimo et al., 2016; Salmi et al., 2015);
- pike (e.g. Östman et al., 2013; Hansson et al., 2017; Bergström et al., ,2022);
- flounder (e.g. Florin et al., 2013; Östman et al., 2013; Jepsen et al., 2010; Nielsen et al., 2008; Jepsen et al., in prep);
- eel (e.g. Jepsen et al., 2010; Dauster, 1987);
- cod (Jepsen et al., in prep).

However, there are also studies that did not find severe impacts of cormorant predation on marine fish stocks (e.g. Lehikoinen et al., 2017; Heikinheimo et al., 2018; Heikinheimo et al., 2022).

Information on cormorant predation of threatened eel populations—once the foundation of historically important fisheries—is scattered (Carpentier et al., 2009). However, research indicates that cormorants can consume 40–44% of small eels in a single summer in coastal areas (Jepsen et al., 2010; Danish Eel MP, 2008). Estimates suggest that cormorants are the leading cause of eel mortality, exerting a far greater impact than both fishing and hydropower/water pumping stations combined.

Fishing

Inland (freshwater) capture fisheries production in the European area has declined from 192 000 tonnes in 1980 to 110 000 tonnes in 2023, a reduction of 43 % (FAO, 2025c). The increase in predation by cormorants cannot be solely blamed for this reduction in freshwater fish production, but has certainly contributed to the decline. Increased predation from cormorants also constrains depleted fish populations from recovering, despite measures being taken to address other influencing factors, as has been observed in Denmark (Jepsen et al., 2018). The reduced stocks of freshwater fish have caused most EU Member States to introduce catch and release practices (Arlinghaus et al., 2002; 2015; Ferter et al., 2013; Arthur, 2025) and resort to intensive stocking of fish in inland waters for recreational fisheries (Cowx, 2025). For comparison, non-EU, eastern European countries that have lower prevalence of cormorants, have exhibited an increase in inland fisheries production over the same period, although production has been relatively stable in recent years (FAO, 2025c). These countries have generally less problems with cormorant predation on fish, as the cormorant population is smaller, not protected, actively managed and hunted (FAO, 2025a, forthcoming).

Fish farming

Despite considerable emphasis on promoting aquaculture production in the EU (EC, 2020b, 2021, 2022), freshwater aquaculture production has declined in the European area between 1990 and 2023 from 340 000 tonnes to 300 000 tonnes - a reduction of 14% (FAO, 2025d). Pond aquaculture in France, Germany, Czechia and Romania saw declines in production, where an increase would have been expected based on improved aquaculture techniques and management (FAO, 2025d). Whilst economic and marketing factors may contribute this decline, the reduction in production is partly attributable to the increase in cormorant numbers and related predation on freshwater fishponds (Opacak et al., 2004; Seiche et al., 2012; Volponi, 1997; Halasi-Kovács et al., 2023). Most freshwater fish aquaculture production in Europe takes place in ponds, and cormorants have caused farm closures and reduced profitability in many countries (FAO, 2025a forthcoming).

General decline in fish and fisheries

Against the backdrop of increasing cormorant population abundance and range, is the recognition that fish stocks and fisheries are in decline because of other factors, including fishing pressure, predation pressure from other piscivores, climate change, habitat degradation and environmental change. These other factors do, of course, play a role, but there are many studies where other causes for declining fish can be ruled out, leaving only cormorant predation (e.g. Koed at al. 2006; Jepsen et al., 2010, 2018, 2019; Klenke et al., 2012). Arguments that fisheries themselves are largely responsible are unsubstantiated for most areas, because fishing activities have declined drastically in freshwater and coastal areas, and fish stocks had responded positively until cormorant numbers increased (e.g. Anon, 2022; Boel, 2012; Jepsen et al., 2014; Jepsen et al., 2018; Jepsen and Rasmussen, 2023). Fishing, as a single factor, is not accountable for the poor state of many fish stocks in inland and coastal waters (whereas fishing is often responsible for open seas fisheries). However, in some southern Member States, there is still some commercial inland fishing, which may have a significant impact on populations. Fishing pressure in coastal waters has reduced tremendously in the last decades (Pascual-Fernandez et al., 2020; Guyader et al., 2013), but fisheries are still in decline. As an example, the traditional coastal cod fishing in the western Baltic has almost ceased to exist (Figure 3), while tagging studies show that cormorants are now eating 70% of the tagged cod in just one season (Jepsen et al. unpublished). With such predation pressure, rebuilding of the stock is unlikely, despite closure of the fisheries.

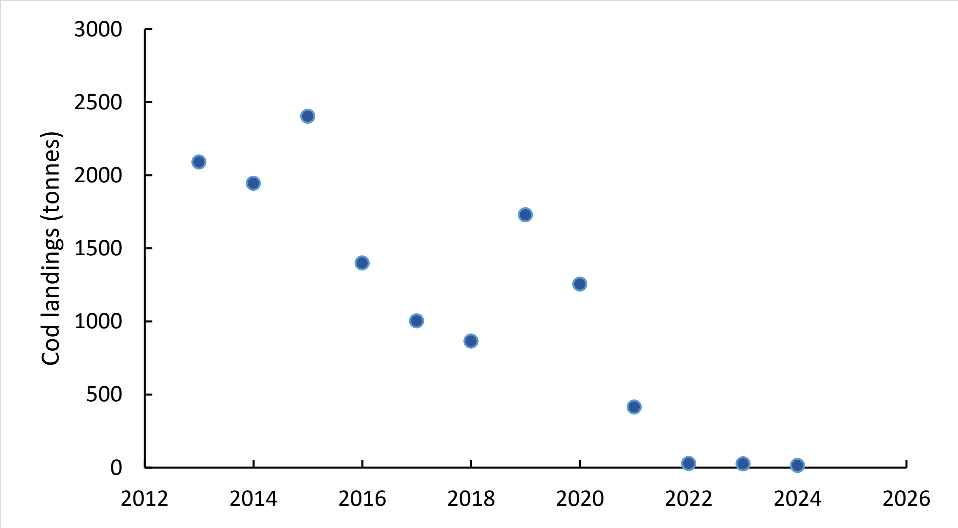

Figure 3. Danish landings of cod in the Western Baltic (source: subdivision 22, Fiskeristatistik.dk)

In inland waters, catch and release is widely practiced by recreational fishers (Arthur, 2025; EAA, pers. comm.) so has little impact of stock status. In addition, populations of many freshwater fish species that are not subjected to any fisheries exploitation, and where habitat quality has improved, because of considerable investment in removing barriers to reconnect rivers (see European Centre for River Restoration[12]), river habitat and water quality improvement activities, still have not recovered. Tagging studies document the direct impact of cormorants on several freshwater fish populations (e.g. Jepsen and Rasmussen, 2023; Skov et al., 2014). Cormorants appear to be a common denominator in the failure to meet recovery benchmark targets of Good Ecological Status or Potential for fish under the EU Water Framework Directive (e.g. Steffens 2010; Görner, 2019; Jepsen et al., 2014), but bird predation, not being formally recognised as a pressure, inadvertently overlooks this problem. The failure to meet good ecological status affects not only fish but also apex predators like otters and other fish-eating birds (e.g. herons, mergansers, ospreys, kingfishers), the prey base of which has become unstable.

While predation remains the primary impact of cormorants on fish populations, there are additional concerns regarding the effects of wounding and disturbance on fish stocks. Studies (e.g. Gremillet et al., 2003, 2006) revealed that although cormorants are considered highly efficient predators, they abandon nearly half of their hunting attempts due to prey escaping their grasp or being too large to swallow. Many of these escaped fish sustain injuries, which can lead to infections and increased mortality rates (Adamek et al., 2007).

In natural fisheries, the proportion of fish injured by cormorants is generally low (less than 5%). However, in aquaculture settings, such as farm ponds, injury rates can be higher—up to 18% (Kortan and Adamek, 2011). Further, Kortan et al., (2008) found that as many as 47% of two-year-old mirror carp (*Cyprinus carpio*) measuring 200–300 mm in total length and weighing 200–300 g showed signs of injury. Such additional damage can result in considerable economic losses in both stillwater and commercial fisheries, rendering fish unmarketable or undesirable for harvest (Callaghan et al., 1998; Engstrom 1998).

[12] https://www.ecrr.org/

Additionally, cormorants can cause fish to seek refuge in inaccessible habitats, such as small streams, in reed, or under complex overhanging structures. This displacement makes the fish unavailable to fisheries (Feltham et al., 1999). In some cases, fish become so densely packed in these refuge areas that they face the risk of oxygen depletion, which can lead to further mortality.

Dietary studies consistently show that cormorants forage on a broad spectrum of fish species. However, Doucette et al. (2011) suggested that cormorants may, in fact, exhibit specific and relatively narrow dietary niche preferences. These preferences can influence food web dynamics, particularly in ecosystems with low prey diversity. In diverse systems with abundant prey, cormorants are less likely to exert significant pressure. Conversely, in ecosystems with limited prey options, their predation has more pronounced ecological or economic impacts. Therefore, it is important not to assume universally negative effects of cormorants on fisheries, but instead to evaluate impacts in the context of local food web structure and the niches occupied by both cormorants and ecologically and economically valuable fish species.

Because cormorants are able to feed on a wide range of fish species and are highly mobile, simple predator prey relationships are unlikely to regulate population grow naturally making concerted action necessary. It seems to have become a classic “predator-pit” situation for many fish stocks. A predator pit occurs when two alternative equilibria (Holling 1973; May 1977) exist and prey is held at a low density equilibrium, unable to pass a critical threshold (‘the pit’) needed to reach the higher density equilibrium (Messier 1994; Sinclair and Pech 1996).

Habitat effects

An often-overlooked aspect of cormorant ecology is the dramatic transformation of forest ecosystems associated with dense breeding colonies (Goc et al., 2005). The accumulation of guano in these areas can lead to canopy loss of up to 90% in riparian forests, triggering cascading effects on other organisms, including amphibians. Additionally, nutrient enrichment of adjacent water bodies from guano runoff can disrupt ecological processes, resulting in reduced biodiversity and biomass of aquatic invertebrates and plants.

The growing numbers of cormorants, particularly large nesting and overwintering colonies have further amplified their ecological footprint. For example, in forested areas, cormorants can inflict substantial damage. In extreme cases, such as the Kąty Rybackie colony in Poland, which spans approximately 100 ha of pine forest, entire forest stands have been killed, leading to conflicts with forest managers (Goc et al., 2005). In the Swedish archipelago, losses in value of summerhouses have been reported and discussed in the public media, due to the establishment of cormorant colonies on small islands (e.g. Svenska Dagbladet, 2021).

Cormorant colonies also alter soil chemistry. Eggshell fragments and pellet contents can neutralize soil acidity, while high concentrations of faecal matter enrich the soil with nitrogen and phosphorus. This process can exceed the soil’s phosphate absorption capacity (Breuning-Madsen et al., 2008), increasing the risk of nutrient leaching into nearby watercourses and potentially triggering eutrophication. Such nutrient loading has implications for water quality and may affect the classification of water bodies under the Water Framework Directive.

The physical presence of carcasses from dead chicks and adults attracts scavengers and predators further alters the local ecological community. Overall, the establishment of a cormorant colony induces widespread habitat changes, initiates succession processes, and contributes to a substantial transfer of energy and nutrients from aquatic to terrestrial systems. By shortening food chains and accelerating biogeochemical cycles, cormorants can alter both aquatic and terrestrial environments. Indeed, by predating on larger piscivorous fish, cormorants modify the food chain leaving small pelagic species to proliferate (Olin et al., 2022) and deplete the larger zooplankton that regulate algal growth (Gerke et al., 2021). Ultimately this can accelerate eutrophication processes (Donadi et al., 2017; Eklöf et al., 2020), with algal blooms causing oxygen depletion, and negatively impacting on water quality and aquatic biodiversity (Alves Amorim and Do Nascimento Moura, 2021). The consequences of this indirect impact of cormorant predation on fish on the ecological status of water bodies under the EU WFD can be significant (Ovegård et al., 2021).

2.3 Socio-economic impact of cormorant predation of fish

The social and economic impact of cormorant predation on recreational fishing and aquaculture facilities is substantial. A study by EIFAAC, the Federation of European Aquaculture Producers (FEAP) and European Angling Alliance (EAA) estimated that the costs of cormorant predation to aquaculture and fisheries in Europe were more than 350 million euros per year in 2023 and 2024 (FAO, 2025a forthcoming). Government research institutions and ministries from 25 countries contributed to the study. More than 250 angling clubs and 160 fish farmers submitted information on cormorant counts, preventive actions taken and damage and losses due to predation by cormorants[13].

There are approximately 7 000 freshwater (pond and raceway) aquaculture farms in the EU, with a total annual turnover of around 1 billion euros (EC, 2023). The total freshwater aquaculture pond area in the EU is nearly 360 000 hectares. The freshwater fish output from pond production in the EU was around 100 000 tonnes per year in recent years, plus some tens of thousands of tonnes of trout that are mainly produced in raceways (FAO, 2025a; Cai et al., 2024).

Box 1: Losses to aquaculture farms. A total of 118 aquaculture farmers from seven EU countries, which produce on average 11 000 tonnes of trout, carp, pikeperch and tench per year, reported for 2023 a combined loss of more than 10 million euros due to fish predation by cormorants. Reported losses per farm ranged from 500 euros to more than one million euros per farm, with a median figure of 30 000 euros per farm. Losses reported by pond farmers ranged from 100 euro/ha to 662 euro/ha. Annual losses of trout in raceways to cormorant predation were around 2%, increasing to 40% of the stock in large-sized pond production systems. The average annual fish stock loss due to cormorant predation in carp and tench ponds was 19%, ranging between 3% and 70% of the stock.

National level aquaculture studies, strategies and plans of European countries, such as in France, Germany and Poland, frequently refer to the economic losses and impact of cormorant predation on aquaculture farm production and incomes (e.g. Ministère de la Transition écologique, 2025; MAPA, 2014; AG NASTAQ, 2020) Annual losses from fish predation by cormorants to pond aquaculture farmers throughout Europe are estimated to be higher than 250 million euros . Recreational fishing clubs reported losses of stocked fish in the order of 100 million euros annually due to cormorant predation. In comparison, heron

[13] Detailed information will be published in FAO 2025a (forthcoming).

predation losses to aquaculture and recreational fisheries were estimated at 48 million euros annually (FAO, 2025a forthcoming).

Reported income losses in pond aquaculture due to predation by cormorants are often the difference between a profitable and loss-making business (Halasi-Kovács et al., 2023; FAO, 2024a, b; FAO, 2025a forthcoming; Engle et al., 2021). Tens of aquaculture farms have closed due to cormorant predation, as farms were no longer economically viable. Moreover, many pond aquaculture farmers, and some cage culture farmers, indicated they were disinvesting in aquaculture, shifting towards more extensive production practices, as the risks from predation by great cormorants and other protected species (e.g. herons, pygmy cormorants and otters) become too large (FAO, 2025a forthcoming).

This generally happened after fish farmers tried a wide variety of measures to reduce predation on their fish stocks. It is estimated that employment in freshwater aquaculture in Europe has declined by 20 % in the last 20 years (FAO, 2025b), partly due to increasing cormorant predation and lack of compensation for lost fish. New investments in freshwater pond aquaculture have stalled as they are considered not viable (Parlier, 2024; Ministère de la Transition écologique, 2025; FAO, 2025a forthcoming), causing a further reduction in rural employment opportunities. The European Commission's campaign to promote aquaculture across the region through the "Aquaculture in the EU: We work for you with passion[14]", which aims to bring aquaculture closer to citizens across the continent, with a strong focus on sustainability, food security, and regional development, cannot succeed without addressing the cormorant issue.

Recreational fishing organizations are widely acknowledged as providing stewardship to the nature resources under their management (Shephard et al., 2023). Many of these organizations reported that river restoration to maintain and rehabilitate aquatic biodiversity is failing because of predation of fish by cormorants. To reintroduce endangered species such as Atlantic salmon and North Sea houting, to support declining stocks of species such as grayling and to sustain angling, many lakes and rivers need restocking, a labour-intensive and expensive process. The level of predation by cormorants has reached the point where fishing organizations can no longer bear the costs of river restoration and re-stocking. Reduced catches by recreational fishers lead to less participation and reduced income for angling clubs and rural communities, and consequently less expenses and effort towards stewardship of the inland aquatic resources. Loss of members, loss of tourists, reduction in license fee income for recreational and commercial fishing are negative effects associated with the high level of cormorant predation. Some commercial fisheries are also reporting reduced profitability and losses due to conflicts with cormorants, such as in Greece (Katselis et al., 2023) and the Baltic Sea (Svels et al., 2019).

The costs for aquaculture businesses and angling clubs to try to reduce predation and mitigate the effects of predation on their fish stocks are high. Costs include scaring and hunting/culling cormorants, costs of covering ponds/water by nets, restocking costs, and volunteer hours for guarding the ponds and rivers, adding millions of euros annually (FAO, 2025a forthcoming; Ministère de la Transition écologique, 2025). Moreover, stressed fish and fish that are seeking shelter from predation do not eat well, causing suppressed growth rates and reduced income for farmers (FAO, 2024b).

[14] https://eu-aquaculture.campaign.europa.eu/index_en

Fish farmers reported stress, depression and health problems due to the need to continuously guard their ponds against cormorants and not being allowed to take timely action.

The loss of fish production due to cormorant predation also has an impact on the availability of food that provides high quality protein and micronutrients (EIFAC, 1988; Engle et al., 2021; Golden et al., 2021) in Europe. A substantial part of the estimated 365 000 tonnes of fish consumed annually by the great cormorant population in Europe could have been high quality nutritious food for people (FEAP, 2022; FAO, 2025a forthcoming). Given that the average fish and seafood consumption per capita in Europe is some 22 kg per year, the cormorant population in Europe consumes as much fish as 16 million people. The total value of fish consumed by the cormorant population in Europe is estimated at more than 1 billion euro per year (FAO, 2025a forthcoming).

The import of fish and seafood continues to increase in the EU and was around 5.9 million tonnes in 2023 (EC, 2024a): and the EU trade balance on these products is negative (approximately 23 billion euro/year). Food sovereignty of Europe is on the political agenda, to reduce dependence on food imports and improve food systems and the fisheries and aquaculture sectors have an important role to play, according to the European Ocean Pact (EC, 2025). The large cormorant population presents a barrier to increasing aquatic food systems (aquaculture and fisheries) production in freshwater and coastal environments throughout Europe.

Ecosystem services are negatively affected by the growing cormorant population, as aquatic biodiversity and natural recruitment of fish are compromised. The services provided by aquatic and wetlands ecosystems (including 360 000 ha of man-made fishpond ecosystems) have been attributable high values. Pond farms contribute greatly to preserving biodiversity of numerous wetland-related plant and animal species, most of them with NATURA 2000 importance. Operating fishponds contributes to climate resilience through carbon sequestration, and retention of water as well as assisting in a circular approach of water management. The loss of pond aquaculture causes a reduction in natural values and biodiversity and excludes a measure to attain climate goals (FAO, 2024a). The monetary damage done by cormorants to aquatic ecosystems has not been investigated sufficiently for making an estimate here.

2.4 Measures to prevent and avoid serious harm

Numerous reviews have been undertaken of measures to prevent and avoid serious harm by fish-eating birds to inland fisheries and aquaculture enterprises, most of which have been synthesised under the EU REDCAFE and INTERCAFE projects, and specifically in the Cormorant Toolbox (Russell et al., 2012). The main measures can be broken down as follows:

- Non-lethal
  - Scaring cormorants away from fishery or aquaculture unit;
  - Exclusion techniques;
  - Habitat modification techniques to reduce availability of fish to cormorants.
  - Fish stock management techniques to reduce availability of fish to cormorants;
- Lethal measures
  - Lethal measures to reduce cormorant number directly;
  - Reducing reproductive success through egg destruction;

The various measures are deployed in different European countries to different extents, and with varying degrees of success (Russel et al., 1996, 2003, 2008; Russell and Carss, 2022). The choice of measures depends on the scale of the cormorant-fisheries conflict, the type of water body or fishery operation impacted, and the potential economic losses incurred.

2.4.1 *Non-lethal control measures*

Scaring is a well-established method that is applied across Europe with varying degrees of success. Scaring devices cover a range of visual and auditory tools from shooting, gas cannons, fireworks, green lasers, reflectors, bells and the presence of people during daylight hours. To be effective scaring methods need to be continuous, varied, and require considerable manpower and coordinated effort. Scaring, however, moves the predation problem from one fishery or fish farm to another, increasing the food requirement of birds, so is unlikely to be regionally effective. Novel technologies like automated optical recognition combined with artificial intelligence for detection of foraging cormorants, drones to scare or to oil eggs, shotguns and rifles with silencers, subsonic ammunition, and thermal aiming devices, are being tested by stakeholders and may contribute to the available toolbox.

Scaring methods can, and often are, coupled with other exclusion and habitat modification methods that control access of cormorants to the fish and fisheries. These include wires and netting that prevent cormorants from landing on the water and foraging, or habitat modifications and increasing habitat complexity that may act as refugia for fish from cormorants. Such measures are only relevant for artificial settings like aquaculture ponds and raceways, stocked ponds, and around fixed fishing gears. Whilst they may be effective at the local level in small water bodies or small fish farm ponds, they are largely impractical for large water bodies, especially where they are utilized for angling, navigation or other conservation species, including birds.

These exclusion actions can be supported by modification to the fish stocking protocols, such that larger fish, outside the normal foraging size of cormorants, are stocked and at times when cormorant numbers are lowest.

2.4.2 *Lethal actions against cormorants in Europe*

As with most wild bird species, their deliberate capture and killing, disturbance, destruction of its nest or taking of its eggs can only be allowed by EU Member States in accordance with the derogation system of the EU Birds Directive (Article 9). Large scale shooting of cormorants, under Article 9 derogation of the Birds Directive, takes place in the France, Hungary, Sweden, Denmark and parts of Germany, as well as non-EU countries such as Norway and the United Kingdom, (Figure 4). The effectiveness of these measures appear to be limited, both locally (conflicts continue) (FAO, 2024b) and at a pan-EU level (population increasing). Similarly, oiling and egg pricking are used in several countries with limited effect on controlling cormorant numbers at a European scale. This is in part because some countries, such as the Netherlands, do not apply the derogation and lethal control is not permitted. Other countries apply the derogation options but insufficiently to make a difference. As a consequence, these countries potentially act as a source for replenishment of birds in countries where lethal control measures are carried out.

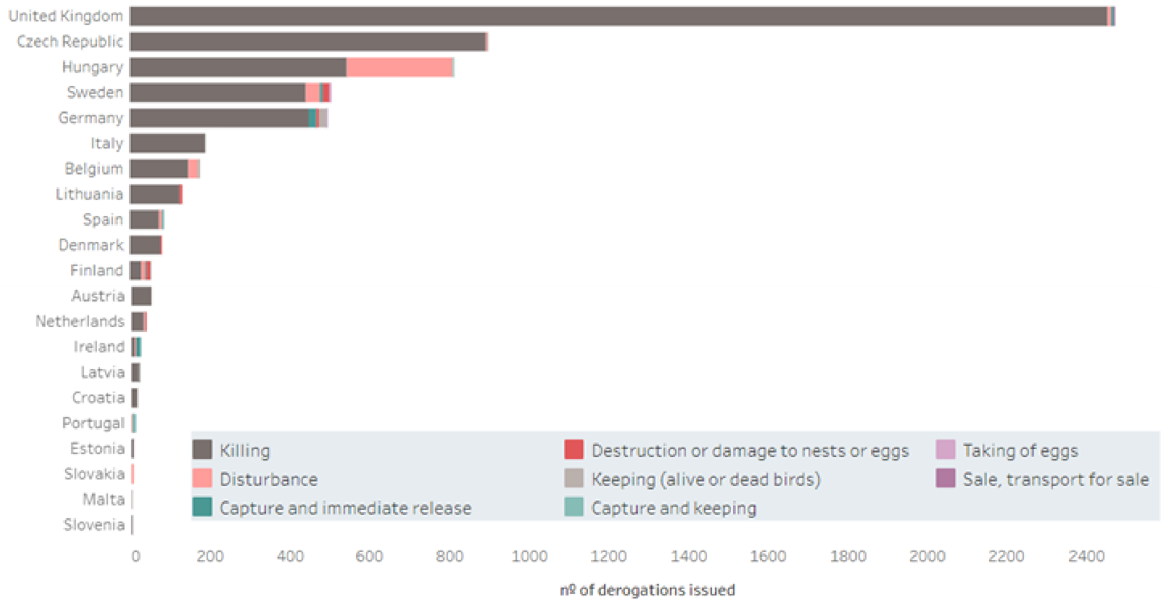

Figure 4 Number of derogations issued under Article 9 of the Birds Directive to control cormorants in Europe: 2015-2023 (Source: https://www.eea.europa.eu/en/analysis/maps-and-charts/overview-of-derogations-and-exceptions-dashboards)[15]. Note: Poland and France do not report here.

Eastern European countries outside of the EU, where cormorants are not protected, and actively managed and hunted, generally experience less problems with cormorant predation and some fish stocks and inland fisheries populations have even improved in recent years (FAO, 2025a forthcoming).

These results suggest, that to be effective, lethal control measures need to be applied in a coordinated, well planned and executed manner and include most European countries.

It should be recognised that some management organizations and stakeholders do not endorse culling cormorants under Article 9. BirdLife International and FACE produced a joint statement in 2008 on the derogation under Article 9 opposing any proposal of listing the cormorant as huntable species in Annex II of the Birds Directive[16]. It is argued that there is no legal possibility under the Birds Directive for a binding EU-wide framework obliging Member States to reduce cormorant populations. BirdLife International and FACE stress that it is the right of each EU Member State to decide on the application of derogations of Article 9, and suggest management efforts should focus on following up and promotion of the work undertaken by the REDCAFE and INTERCAFE projects. However, as already shown, these measures are ineffective at the pan-European scale.

2.4.3 Compensation

Many national authorities take the view that the cost of managing cormorant conflicts should be borne by the stakeholder. Nevertheless, some countries or regions apply or have applied

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[15] This figure does not include France, as the country did not report on its derogations to the EU. Information on the national system of derogations can be found here: https://www.isere.gouv.fr/Actions-de-l-Etat/Animaux/Faune-sauvage/Les-especes-protegees/Le-Grand-Cormoran

[16] Joint Statement of BirdLife International and FACE on Cormorants *June 2008:* https://circabc.europa.eu/ui/group/3f466d71-92a7-49eb-9c63-6cb0fadf29dc/library/df4389c7-8e4b-44cf-87e9-dba40a27e1ec?p=1&n=10&sort=modified_DESC

compensation schemes to offset the consequences of cormorant predation for certain stakeholders. These include Czechia, Finland, Lithuania, Romania, Saxony (Germany), Slovakia, and Wallonia (Belgium). Such measures are largely, but not exclusively, restricted to fish farms and hatcheries, with losses of fish consumed covered (though not always fully) by compensatory payments. The calculation of compensation payments is seldom rigorous and often simply an approximation related to the farm system and visualization of cormorant presence. In some countries it is also possible to apply for financial aid for the construction of netting enclosures or scaring programmes. It should also be recognised that compensation payments are not necessarily related to financial losses but more to encourage fish farmers to maintain the heritage value of cultural landscapes.

2.4.4 Management plans

Management plans to address the cormorant-fisheries conflict exist in a number of European countries (including, Austria, Denmark, France, Germany, Ireland, Italy, Slovakia and Sweden within the EU, and Norway, Switzerland and parts of the United Kingdom outside the European Union) (Gerdeaux, 2005; Cowx, 2015), but these are not coordinated between countries. The plans are generally related to control of bird depredation on open water bodies, and in Switzerland and Austria the management plans target control (mostly scaring with culling as a last option) of birds exploiting river fisheries. This lack of coordinated planning coupled with inconsistency over culling populations between countries has implications for managing the cormorant fisheries conflict. Although transnational cormorant management plans are generally lacking in Europe, the feasibility of such an approach to address the conflict is possible, as can be seen from implementation of cormorant management in North America on lakes Huron and Ontario (U.S. Fish and Wildlife Service, 2003; Fielder, 2008, 2010). Here multi-faceted large-scale plans have proven successful to reduce the predation pressure from cormorants. The plans are often structured with alternatives, which are introduced progressively and only implemented if the previous stage remained unsuccessful: 1) no intervention; 2) scaring birds (without shooting); 3) limiting local damage at commercial fish ponds; 4) strictly monitored reduction of resources; 5) reduction of regional populations; and 6) opening up lethal control as a last alternative.

2.4.5 Conclusions

The main conclusion is that no single management intervention is effective at mitigating the problems created by great cormorants. Shooting (on a large scale) does not appear to be a viable option unless the numbers are reduced across the European distribution range. Continuous dispersal and turnover of birds is a result of incoherent action from countries that do not adopt intervention measures. Controlling local bird population density by destroying nesting areas and oiling eggs is again only likely to have a limited and short-term effect, if not carried out in a coordinated at a regional scale, especially targeting the main breeding colonies in northern Europe. Similarly, scaring methods (human disturbance, laser guns, and sound and taste aversion) do not appear to be effective because they must be carried out on a continuous basis, birds become accustomed to the methods employed, and the problem is potentially dissipated to other fisheries. Exclusion devices are only viable on some aquaculture facilities, and are not feasible in open fisheries because they restrict or prohibit fishing activities. Some success has been achieved with fish refuge devices (McKay *et al.,* 1999; Russell *et al.,* 2003, 2008; Orpwood *et al.,* 2010), but again only at a local scale. These features included artificial reefs or underwater fenced off zones that constrain access to fish-eating birds, but are not suitable for rivers where they can cause localised flooding problems.

The solution to the problem of bird depredation is thus complex and multi-facetted. It is unlikely that legislation to protect birds will be changed in the short term and scientific evidence/advice seems unable to provide easy solutions. Furthermore, irrespective of the physical measures necessary to reduce the problems, the conflicts that now exist are deep-rooted, societal issues and will not be resolved unless all stakeholders are involved in the debate and solution.

2.5 Policies and legislation relevant for management

There is a range of international and regional instruments, EU directives, EU policies and national legislation that affect the management and conservation of the great cormorant and the most important of these are discussed below.

2.5.1 International instruments

The **Convention on the Conservation of Migratory Species of Wild Animals (CMS)** of 1979 entered into force in 1983. The CMS (also called Bonn Convention) contains appendices for endangered migratory species (Appendix 1) and migratory species conserved through Agreements (Appendix 2). The great cormorant does not appear in these appendixes.

Nevertheless, the Fourth Conference of the parties (1994) issued Recommendation 4.1 on "Conservation and management of cormorants in the African Eurasian region", which recognized the strong increase in the great cormorant population and requested to maintain a favourable conservation status for this species. The same recommendation requested the members to carry out research on the assessment of damage caused by cormorants to fishers' interests, and on the effectiveness of scaring techniques and the development of other techniques to protect fisheries. However, implementation was limited to some projects. At the 12th Conference of the parties (2017) it was proposed to develop an Action Plan for the Great Cormorant in the African-Eurasian Region, but the parties did not agree to this proposal.

The **Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA,** 1995) entered into force in 1999. Most European countries have ratified this Agreement. The great cormorant (*P. c. carbo*) is included in the list of waterbird species to which the Agreement applies. In development of action and/or management plans under AEWA, species that get priority are listed in Appendix I of the CMS, as threatened species according to the IUCN Red List, and with populations of less than 10 000 individuals. The large population sizes of great cormorant would not justify an AEWA action plan, as plans are made for population recovery purposes.

Under the AEWA the great cormorant (*P. c. carbo* and *P. c. sinensis*) has three populations listed with distribution in Europe. Currently all three have the status: Populations numbering more than around 100 000 individuals which could benefit from international cooperation. The AEWA has provisions to address the management of overabundant and-conflict raising species. This has been applied with the implementation of International Single Species Management Plans for the Svalbard pink-footed goose, greylag goose, and barnacle goose. The first two are huntable under the EU Birds Directive, while the last one is not. AEWA has not been given mandate by the parties to the Agreement to work on the great cormorant.

Nevertheless, this cormorant management plan framework largely complies with the AEWA international single and multi-species management plans format and guidelines[17].

2.5.2 *European and EU legal and policy instruments*

The **Convention on the Conservation of European Wildlife and Natural Habitats** (Bern Convention, 1979), of the Council of Europe, entered into force in 1982. All members of the Council of Europe have ratified the Bern Convention. It governs the conservation of fauna in Europe, including the great cormorant. Article 2 of the Convention text states: "The Contracting Parties shall take requisite to maintain the population of wild flora and fauna at, or adapt it to, a level which corresponds in particular to ecological, scientific and cultural requirements, while taking account of economic and recreational requirements and the needs of sub-species, varieties or forms at risk locally."

Phalacrocorax carbo carbo and *P. c. sinensis* are not included in Appendix II of the Bern Convention concerning special protection of the wild fauna species specified. The species is covered under the Convention's Appendix III protection regime. This implies that:

> Article 7.1. Each Contracting Party shall take appropriate and necessary legislative and administrative measures to ensure the protection of the wild fauna species specified in Appendix III.
>
> Article 7.2. Any exploitation of wild fauna specified in Appendix III shall be regulated in order to keep the populations out of danger, taking into account the requirements of Article 2.

The EU Directive on the Conservation of Wild Birds (Birds Directive, 2009) relates to the conservation of all species of naturally occurring birds in the wild state in the European territory of the EU Member States. It covers the protection, management and control of these species, and lays down rules for their exploitation. The Directive covers birds, their eggs, nests and habitats. The current Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds, is an amendment of the 1979 Directive 79/409/EEC.

Like the Bern Convention, the Birds Directive requires EU Member States take measures to maintain the population of the species at a level that corresponds to ecological, scientific and cultural requirements, while taking account of economic and recreational requirements, or to adapt the population of these species to that level (Article 2).

Species listed in Annex I of the Birds Directive are subject to special conservation measures concerning their habitat to ensure their survival and reproduction in their area of distribution (Art. 4: Birds Directive). *Phalacrocorax carbo carbo* and *P. c. sinensis* have not been listed in Annex I to the Birds Directive since 1997[18]. This means the obligation to classify special protection areas does not apply to these species; however, they do fall under the general protection regime provided by the Birds Directive.

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[17] https://egmp.aewa.info/sites/default/files/download/population_status_reports/aewa_mop8_24_species_management_plan_format.pdf

[18] See https://ec.europa.eu/commission/presscorner/detail/en/ip_97_718 and https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:91997E003084

This general protection regime can be found in Article 5 (without prejudice to Articles 7 and 9) setting out the required measures to be taken by the Member States:

Article 5: Without prejudice to Articles 7 and 9, Member States shall take the requisite measures to establish a general system of protection for all species of birds referred to in Article 1, prohibiting in particular:

a) deliberate killing or capture by any method;
b) deliberate destruction of, or damage to, their nests and eggs or removal of their nests;
c) taking their eggs in the wild and keeping these eggs even if empty;
d) deliberate disturbance of these birds particularly during the period of breeding and rearing, in so far as disturbance would be significant having regard to the objectives of this Directive;
e) keeping birds of species for which the hunting and capture of which is prohibited.

Article 7 applies to species listed under Annex II to the Directive (species that may be hunted under national legislation). Paragraphs 2 and 3 under Article 7 state that "The species referred to in Annex II, Part A may be hunted in the geographical sea and land area where this Directive applies" and "The species referred to in Annex II, Part B may be hunted only in the Member States in respect of which they are indicated." Neither of the two parts under Annex II currently list *P. c. carbo* and *P. c. sinensis* and therefore this annex does not apply for this species.

Article 9 allows Member States to derogate (in other words, *to suspend under certain circumstances*) from the basic prohibitions in Articles 5-8 as follows:

1. Member States **may derogate** from the provisions of Articles 5 to 8, where there is **no other satisfactory solution**, for the following reasons:
   a) in the interests of public health and safety, — in the interests of air safety — **to prevent serious damage to crops, livestock, forests, fisheries and water** — for the protection of flora and fauna;
   b) for the purposes of research and teaching, of re-population, of re-introduction and for the breeding necessary for these purposes;
   c) to permit, under strictly supervised conditions and on a selective basis, the capture, keeping or other judicious use of certain birds in small numbers.
2. The derogations referred to in paragraph 1 **must specify:**
   a) the species which are subject to the derogations;
   b) the means, arrangements or methods authorised for capture or killing;
   c) the conditions of risk and the circumstances of time and place under which such derogations may be granted;
   d) the authority empowered to declare that the required conditions obtain and to decide what means, arrangements or methods may be used, within what limits and by whom;
   e) the controls which will be carried out.
3. Each year the Member States shall send a **report to the Commission** on the implementation of paragraphs 1 and 2.
4. On the basis of the information available to it, and in particular the information communicated to it pursuant to paragraph 3, the Commission shall at all times ensure that the consequences of the derogations referred to in paragraph 1 are not incompatible with this Directive. It shall take appropriate steps to this end.

Over the period 2015 – 2023, the great cormorant was the species with the second highest number of derogations under Article 9, after the house sparrow (*Passer domesticus*). In terms of the type of derogations, *P. carbo* (both subspecies included) is the species for which most derogations for deliberate killing were made; 86% of the total number of derogations related to the great cormorant (Figure 4). Moreover, 22 EU Member States (23 including the United Kingdom) made derogations for killing cormorants, largely with the purpose of preventing serious damage. The nearly 10 000 derogations made for great cormorants over the period 2015 – 2023 (Figure 4) indicate the considerable problems caused by the species.

The European Commission has repeatedly stated that the tools made available by the current interpretation of Article 9, as laid out in a guidance report from 2013 (EC, 2013b), are sufficient to manage the cormorant population and mitigate the local conflicts. Nevertheless, many of the requests by fisheries and aquaculture sector stakeholders for permissions for killing, egg oiling or nest destruction of great cormorants do not obtain approval from national environment agencies as their internal policies aim to limit derogations, or approvals are only given after large scale damage has been done. The very different way the Article 9 is used in the different countries gives rise to additional conflicts and cases regarding permission to regulate cormorants often end in national courtrooms.

The **EU Directive on the conservation of natural habitats and of wild fauna and flora (Habitats Directive, 1992)** aims to contribute towards ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the Member States (Council Directive 92/43/EEC). Article 12 [protection of species] of this directive is similar as Article 5 of the Birds Directive.

Article 16 of the Habitats Directive provides the possibility to derogate if "there is no satisfactory alternative, and the derogation is not detrimental to the maintenance of the populations of the species concerned at a favourable conservation status in their natural range":

a) in the interest of protecting wild fauna and flora and conserving natural habitats;
b) to prevent serious damage, in particular to crops, livestock, forests, fisheries and water and other types of property;
c) in the interests of public health and public safety, or for other imperative reasons of overriding public interest, including those of a social or economic nature and beneficial consequences;

Great cormorants are not mentioned in the Habitats Directive. Derogations under Article 9 of the Birds Directive should be used when cormorant predation is impacting "natural habitat areas" (Annex I), "species requiring special areas of conservation" (Annex II) and "Strictly protected species" (Annex IV). There are 65 fish species listed under the annexes of the Habitats Directive. A number of these, such as Atlantic salmon, Danube salmon, houting, marble trout, grayling, barbel and nase, are negatively impacted by predation from cormorants (see Section 2.2).

The **EU framework for community action in the field of water policy (Water Framework Directive, 2000)** (Directive 2000/60/EC) is also a relevant piece of legislation in relation to the problems caused by great cormorants. The Water Framework Directive requires EU Member States to protect and, where necessary, restore water bodies to reach good status, and to prevent deterioration. Good status means both good chemical and good ecological status. Native fish are foundational to aquatic food web stability. Predation by cormorants can have significantly impact on the fish fauna, species composition, fish population abundance and changes the age structure in fish communities, as well as the reproductive capacities of protected fish species throughout Europe. Impacts like predation by cormorants must be (but is not presently) considered when assessing the WFD-waterbody status based on the biological quality element “Fish fauna”.

The cormorant – fish, fisheries and aquaculture conflict also has an impact on the implementation and outcomes of a range of other elements of EU policy and legal frameworks, such as:

- The **European Green Deal** (EC, 2019), which states that “European farmers and fishermen are key to managing the transition”, and that it “is essential to preserve and restore biodiversity in lakes, rivers, wetlands and estuaries, and to prevent and limit damage from floods.” Fishers and fish farmers have thus a key role to play.
- **EU Biodiversity Strategy for 2030: Bringing nature back into our lives** (EC, 2020a), regarding restoring the good environmental status of marine ecosystems and restoration of freshwater ecosystems.
- **EU Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system** (EC, 2020b), aims (among others), to “ensure food security in the face of climate change and biodiversity loss”, and gives emphasis to economic return creation and a shift to sustainable fish and seafood production which must be accelerated.
- **Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030** (EC, 2021), which recognizes that “For freshwater aquaculture in particular, predators and drought pose also a challenge in terms of profitability.” The strategy also states that *”the* environmental performance of the EU aquaculture sector can be further improved by the management of predators*”.*
- **Common Fisheries Policy** (EC, 2013a) which aims to “ensure that fishing and aquaculture activities are environmentally sustainable in the long-term and are managed in a way that is consistent with the objectives of achieving economic, social and employment benefits, and of contributing to the availability of food supplies”.
- The Communication of the Commission on **Safeguarding food security and reinforcing the resilience of food systems** (EC, 2022) recognizes the importance of long-term availability of affordable food (including fish) for the European population, sustainable management of fish stocks and reducing the dependence on imports.
- **Nature Restoration Regulation** (EC, 2024b), which aims to contribute to “(a) the long-term and sustained recovery of biodiverse and resilient ecosystems across the Member States’ land and sea areas through the restoration of degraded ecosystems; (b) achieving the Union’s overarching objectives concerning climate change mitigation, climate change adaptation and land degradation neutrality; (c) enhancing food security; and (d) meeting the Union’s international commitments.

2.5.3 European Parliament and international resolutions

The **European Parliament resolution** of 4 December 2008 on the adoption of a **European Cormorant Management Plan** [aims] to minimise the increasing impact of cormorants on fish stocks, fishing and aquaculture (2008/2177(INI)). In this resolution the European Parliament called (amongst others) on the European Commission to submit a cormorant population management plan in several stages, coordinated at the European level and seeking to integrate cormorant populations into the environment as developed and cultivated by man in the long term, without jeopardising the objectives of the EU Birds Directive or Natura 2000 with regards fish species and marine and freshwater ecosystems (paragraph 7).

The **European Parliament resolution** of 12 June 2018 **towards a sustainable and competitive European aquaculture sector: current status and future challenges** (2017/2118(INI)), reiterated “the views it has already expressed in its resolution on the adoption of a European Cormorant Management Plan, and points out that reducing the harm caused by cormorants and other birds of prey to aquaculture farms is a major factor in production costs, and thus for their survival and competitiveness; calls on the Member States to apply the current exceptions in the case of herons and cormorants and to the Commission to review the state of conservation of the otter”(paragraph 90).

The **European Parliament resolution** of 4 October 2022 on **striving for a sustainable and competitive EU aquaculture: the way forward** (2021/2189(INI)) acknowledged that the population of cormorants has seen a massive increase, and that this increase is causing serious damage to many marine sectors, including aquaculture. The resolution “Calls on the Commission to prepare a proposal for an EU great cormorant management plan that could properly and definitively address the problem the aquaculture sector has been facing for many years, based on the best available scientific advice and experiences and practices already tested in Member States; urges that the plan be designed for the effective mitigation and control of their effect on aquaculture farms, with a view to reducing their economic, environmental and social impact on production and biodiversity; highlights that the plan should include a list of eligible measures on preventive coexistence solutions and adequate compensation for losses and measures, financed with EU or national funds; insists that financial support for tailor-made research aimed at finding and testing preventive measures is key, but also for allowing proper monitoring, including recording and analysing the effects of the measures undertaken; calls on the Member States to implement those measures on a local case-by-case basis and report to the Commission every year on the implementation of the plan, including the effectiveness of the measures chosen; calls on the Commission to evaluate the EU great cormorant management plan every five years and report to Parliament; urges the Commission to prepare, as an immediate action, a guidance document on how to apply derogations provided for in Article 9 of the Birds Directive, and to assess the need to modify the current legislation where preventive measures have proven insufficient and the financial and social impact does not allow for coexistence solutions, according to the best scientific advice”(paragraph 56).

The **IUCN/Wetlands International Cormorant Research Group** responded in an Open letter to the Members of European Parliament about the initiative report (2021/2189(INI)), and in particular its paragraph 56 on cormorant management[19]. IUCN/Wetlands International asked to promote the implementation of existing solutions and to ensure follow up of scientific research to solve conflicts. The **European Inland Fisheries and Aquaculture Advisory Commission** (EIFAAC), through an advisory note[20], welcomed the European Parliament resolution of 4 October 2022 on striving for a sustainable and competitive EU aquaculture: the

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[19] https://www.birdlife.org/wp-content/uploads/2022/09/Open_Letter_MEP_Cormorant_Research_Group.pdf

[20] https://www.fao.org/fishery/services/storage/fs/fishery/images/organization/EIFAAC_advisorynotes.pdf

way forward (2021/2189(INI)) and offered its expertise to coordinate the development of a European-wide great cormorant management plan to harmonize measures and regulations aiming to reduce the population of cormorants in Europe to a sustainable and manageable level.

In 2022, EIFAAC also issued a Resolution on measures to support the protection of vulnerable and endangered fish species from unsustainable predation from cormorants (EIFAAC/31/2022/3), which *inter alia* called for the preparation of a European-wide cormorant management plan to harmonize measures and regulations aiming to reduce the damage to fish stocks in Europe.

In addition to the above mentioned international and regional instruments, various European countries have adopted national level measures to reduce the impact of cormorant predation on fish, fisheries and aquaculture (including also the establishment of damage reporting and compensation schemes). These national measures have not been as successful as hoped, due to the migratory nature of the cormorants, where super abundance of the predators, results in a "sink-situation" with new birds coming in as an area becomes "vacant" due to local restrictive regulations in controlling great cormorants in adjacent areas.

2.5.4 Predation risk management

To prevent cormorant predation on fish and mitigate the consequences of predation, various European countries have applied a range of measures, with limited success (see Section 2.4).

Preventive measures include UV-resistant netting of hatchery/nursery tanks, raceways and small ponds in aquaculture, as well as netting of small stretches of rivers. Other farms, where ponds are too large to cover with nets, have installed fishing lines across these ponds, with limited success. Many angling clubs have increased their pond depth, introduced more water plants (to reduce sighting and accessibility of fish by cormorants), floating covers, or "fish forests", which provide shelter against predation. Others have introduced fenced areas in their waters, also covered by nets, with mesh sizes that are too small for cormorants, but large enough for small fish.

Bird scaring devices with predator decoys, sudden noises, kites, balloons, aluminium strips, moving objects and laser lights are used by fish farmers and angling clubs. These are short-term solutions, as birds seem to get used to them. Watch-keeping and chasing cormorants away from ponds and angling areas and stocking are now common practices, but require lots of time from fish farmers and volunteers.

Preventive measures applied under Article 9 (derogations) of the EU Birds Directive, include culling (shooting), destruction of nests, oiling of eggs and disturbance of nests during breeding season. Due to the application and review processes involved, approvals for such measures often come too late, when the damage is done. There is apparently a high degree of variation in the way each Member State reads Article §9, from strict "no implementation" to easy and fast provision of permissions to regulate.

Frequently applied risk mitigation strategies include an increase in stocking of fry and fingerlings, stocking with larger fish, stocking in spring instead of autumn, or just stop stocking and maintain a fish density that is very low, making a water area less attractive for cormorants.

Aquaculture crop insurance, including cover of damage caused by predators, is available in most European countries. Many marine cage culture operations are also insured. However, the insurance premiums are often too high for freshwater pond farmers (van Anrooy et al., 2022). Aquaculture crop insurance premium subsidies are not provided by European governments.

Financial compensation for damage caused by cormorants to fish stocks in aquaculture exists in a few European countries, such as Belgium, Czechia, Latvia, Slovakia, and some regions in Germany. However, the compensation paid is partial and some countries that paid compensation in the past no longer do so. There is no financial compensation for angling clubs for lost fish due to predation by cormorants. In a few countries, some limited compensation was paid in the past to commercial (inland) fisheries, but this seems to have stopped. A few angling clubs involved in aquatic biodiversity protection have received financial support for preventive measures such as netting and construction of fish forests/shelters. The existing financial compensation and prevention systems for predation of fish by cormorants are few, inadequate in scope and insufficient in terms of funds available.

2.6 Management issues

Interactions between birds and fish/fisheries have long been prevalent within both marine and freshwater ecosystems (see Annex 2). In recent years, however, there has been increasing concern and accountability of the impact of expanding populations of fish-eating birds on wild fish populations and aquaculture enterprises. This has led to growing concerns about, on the one hand conservation of birds and on the other hand sustainability of fisheries resources for both commercial and recreational exploitation and aquaculture development, alongside protection of native aquatic biodiversity.

Conflicts involving cormorants have been studied in detail in Europe through the EU REDCAFE/INTERCAFE COST Action projects[21] and FRAP[22], but also at a national level, where multiple scientific projects have sought to resolve or mitigate the conflicts (see Sections 2.2 and 2.4). The conflicts primarily arise from competition for the same resources, but the conservation of fish populations has become increasingly important, especially as many fish stocks have declined, and, critically, non-fished species have become vulnerable. The effects of predation are amplified in areas where fish stocks are already under pressure from deteriorating habitats. Summaries of these conflicts and actions are highlighted below.

Coastal and lake fisheries: Cormorants are directly catching fish in nets, removing valuable catch, damaging other (large) fish and nets. Solutions have been to use of cover-nets in pound net fisheries and regulating/killing cormorants in proximity of the nets. Cover nets have, however, been of limited effect because cormorants learn to swim under the nets (the same way as fish enter), plus the nets are expensive and laborious to use.

Aquaculture: Modern, recirculation aquaculture systems (RAS) and raceway systems can be protected by nets, strings or by moving indoors, but traditional pond-aquaculture remains open to cormorants and the problem cannot be solved by covering ponds with nets as cormorants learn to walk in under the nets. The same is true for the many put and take lakes/ponds, where cormorants can cause great damage to the stocked fish by eating the smaller fish and injuring the large fish. Aquaculture producers that use cages in coastal areas,

[21] http://cormorants.freehostia.com/

[22] Behrens et al 2008; Managing international 'problem' species: why pan-European cormorant management is so difficult. Environmental Conservation 35, 55-63.

lakes and reservoirs, have often covered their cages with nets against fish escapes and predation by cormorants. However, at maintenance and harvest times many cage fish farmers encounter predation by groups of cormorants.

Recreational fishing: When cormorants forage in rivers, the main target fish species are often eaten in very high numbers, leaving rivers with very little fish to catch. Grayling and salmonid (trout and salmon) populations can be diminished, even when only relatively few birds have been hunting. In many rivers, the total biomass of fish has dropped from around 500 - 150 kg/ha to 10-15 kg/ha (Jepsen et al., 2018; Görlach and Müller, 2005; Görner, 2006; Steffens, 2010). This means that fishing in such "fish-empty" rivers is no longer attractive and feels ethically wrong. Even a few cormorants can eat a substantial part of the total fish stock. Management measures include to stock more and larger fish and to organize "hunting/scaring patrols" along rivers. In larger lakes, the situation is less pronounced, but cormorants have been shown to remove a high proportion of large perch, mid-sized pike, trout and zander in lakes in Denmark, France, the Netherlands and Sweden, making recreational fishing less attractive.

Conservation: Some fish species that used to be very abundant, like the grayling, salmon and eel, are now in a very bad conservation status, with generally negative trends, and some populations are locally extinct. When investigating the causes, cormorant predation remains a key contributory factor that precludes the capacity for some fish populations to recover when other stressors are addressed. Thus, species of freshwater fish protected under the Habitats Directive and listed as vulnerable or threatened in the IUCN Red List are under increasing pressure from cormorant predation and, to date, management responses have been very limited. Further, many species are now vulnerable and contribute towards many water bodies failing good ecological status or potential under the EU Water Framework Directive. It is clear that many local or generic factors other than predation can cause fish populations to decline. Most of these factors are described by the IUCN/SSC specialist freshwater fish group (https://freshwaterfish.org/), but with little documentation about the size of impact and cormorant predation is largely overlooked.

Although the most frequently reported problems with cormorants are related to fisheries, guano (faeces) produced by birds at breeding and roosting sites is known to eventually kill trees — which, when alive, may have commercial or amenity value. Guano production can also alter the local fauna and flora communities, which can have conservation consequences for some rare or localised plant and animal species, especially amphibians and other bird species dependent of fish for their food. In some places the presence of relatively large aggregations of cormorants in colonies or roosts, and the associated noise and smell are degrading the local land/waterscapes.

The conflicts involving fish protection and cormorants have been intense in most member states and across the rest of Europe for decades and remain that way despite many protective and responsive measures, including culling (according to EU Birds Directive's Article 9-derogation). There are only a few well-documented examples of successful attempts to reduce avian predation pressure (e.g. Lake Neuchâtel in Switzerland [Vogel et al., 2010]; Lake Ontario, USA; [Johnson et al., 2001]). Since completion of the EU-funded REDCAFE and INTERCAFE COST-Action projects (2008), conflicts have further escalated and numerous new reports of damage to wild fish populations have been published (see Sections 2.2 and 2.3), thereby changing the nature of the conflicts, at least partly from commercial and recreational fisheries perspectives, to species conservation, i.e. balancing the need of how best to meet conservation requirements for species regarded as being in conflict. The existing tools to mitigate conflicts (i.e. INTERCAFE TOOLBOX [Russell et al., 2012]) have not proved effective under current application to reduce the ongoing levels of conflicts.

A recent EIFAAC survey (FAO, 2024a), with responses from 26 European countries, revealed a continued high level of conflict between cormorants and biodiversity conservation, recreational fisheries, commercial fisheries and aquaculture. The number of conflicts between cormorants and recreational fisheries and biodiversity conservation have increased rapidly. Seventy percent of the respondents agreed that a European-wide cormorant management plan is needed to control the increasing cormorant population.

3. Plan principles, overall goal and specific objectives

3.1 Nature of the conflict

In the past 30 years the number of breeding and overwintering great cormorants has increased dramatically across Europe, creating conflict between bird conservation and fisheries and aquaculture. In many European countries, great cormorant populations negatively impact fish stocks and reduce catches, putting pressure on fisheries and aquaculture activities and thus creating socioeconomic conflicts. Although the great cormorant is protected under Directive 2009/147/EC (Birds Directive), there is an urgent need to resolve the cormorant-fish conflict in a manner proportionate to the damage caused, recognising localised actions have failed to resolve the ongoing conflict and the problem is pan-European.

3.2 Overall goal

The overall goal of the *European Management Plan for the Great Cormorant* is:

> ***To achieve a fair balance between pan-European conservation of the great cormorant, with the sustainable use and protection of aquatic biodiversity, fish populations, fisheries and aquaculture interests, including the socio-economic well-being of communities dependent on fisheries and aquaculture***.

3.3 Guiding principles

The management plan is guided by the following principles.

Sustainability	Ensure the long-term coexistence of cormorants, fish populations, and human livelihoods by maintaining both an ecological balance and economic viability of fisheries and aquaculture.
Evidence-based management	Where possible, decisions will be based on robust scientific data, including population dynamics, migration patterns, ecological and socio-economic data and information.
Recognising alternative issues	Due consideration is given for all environmental, social and economic pressures constraining fish and fisheries recovery.
Adaptive management	Use flexible and dynamic approaches to address evolving challenges, incorporating regular monitoring and stakeholder feedback.
Collaboration and coordination	Promote cooperation and continuous dialogue among European countries, bird, fisheries, conservation and animal welfare organizations and other stakeholders.
Compliance with policies and legal frameworks	Align management actions with EU directives (e.g. Birds Directive, Habitats Directive, Water Framework Directive), international treaties (e.g. Bern Convention) and national legislation and policies of European countries.
Minimization of conflicts	Balance the needs of fisheries, aquaculture, biodiversity conservation, including fish and birds, and societal interests to reduce conflicts between stakeholders.
Ethical considerations	Apply management measures with lowest adverse animal welfare impacts.

Precautionary approach	Address potential risks proactively, ensuring that management measures do not cause unintended ecological or economic harm.
Environmental stewardship	Conduct management interventions in a responsible manner with care for the environment and in accordance with key stakeholder interests.

3.4 Objectives

This pan-European management planning framework aims to mitigate, compensate and, where possible, reconcile cormorant-fish conflicts. It focusses on the biological dimension of maintaining the great cormorant's conservation status[23], while recognising the social and economic consequences of cormorant-fish interactions. The plan is also expected to contribute to the long-term viability of inland and coastal recreational and commercial fisheries and aquaculture enterprises in Europe, and the implementation of European and national food security and rural development policies and strategies.

The objectives of the framework plan, based on consultation with national authorities and key stakeholders in 2024 and 2025, are to:

1. Maintain up-to-date status and trend data on distribution and abundance of great cormorants (breeding and overwintering), and inland and coastal fish populations and aquaculture, and understand reasons for changes in population abundance of both cormorants and fish stocks.
2. Improve understanding, documentation and quantification of ecological, economic and social impacts of cormorants on inland and coastal waters and their associated aquatic biodiversity, and fisheries and aquaculture.
3. Provide a plan of action to protect vulnerable fish species against predation by great cormorants, contributing to achievement of EU Water Framework Directive, Habitats Directive, and the European biodiversity targets.
4. Adapt, update and provide a framework to implement preventative measures to reduce and mitigate impact of cormorant predation on fisheries and aquaculture, and harmonise compensation schemes.
5. Provide a framework to facilitate the use of derogations to authorise controlled culling of great cormorants, whilst maintaining the good population status of great cormorants across its distribution range in Europe.
6. Promote cross-border collaboration and harmonisation of monitoring, management and policy frameworks.
7. Provide a central, open-access, fully moderated platform for engagement with all key stakeholders.

[23] AEWA and the EU Habitats Directive apply the term "Favourable Conservation Status", while the EU Birds Directive uses "Good Population Status". The Bern Convention under its Article 7 makes reference to restoring 'satisfactory population levels'.

4. European Management Planning framework for the Great Cormorant

4.1 Management planning framework

The European Management Planning framework for the Great Cormorant (CMP) adopts an adaptive approach and involves a series of steps: 1) assessment of the status of cormorant-fish interactions, related economics, and the underpinning policy drivers, objectives and target end points; 2) formulating management measures; 3) choosing a course of action; 4) implementing management actions, monitoring changes in cormorant, fish, aquaculture and ecosystem characteristics, region-wide cooperation, and compensation for damages to fisheries and aquaculture; and 5) evaluation and adjustment of endpoints and goals of the plan into the future (Figure 5). Explicit specifications and documentation are required at each step, supported by stakeholder participation and consultation.

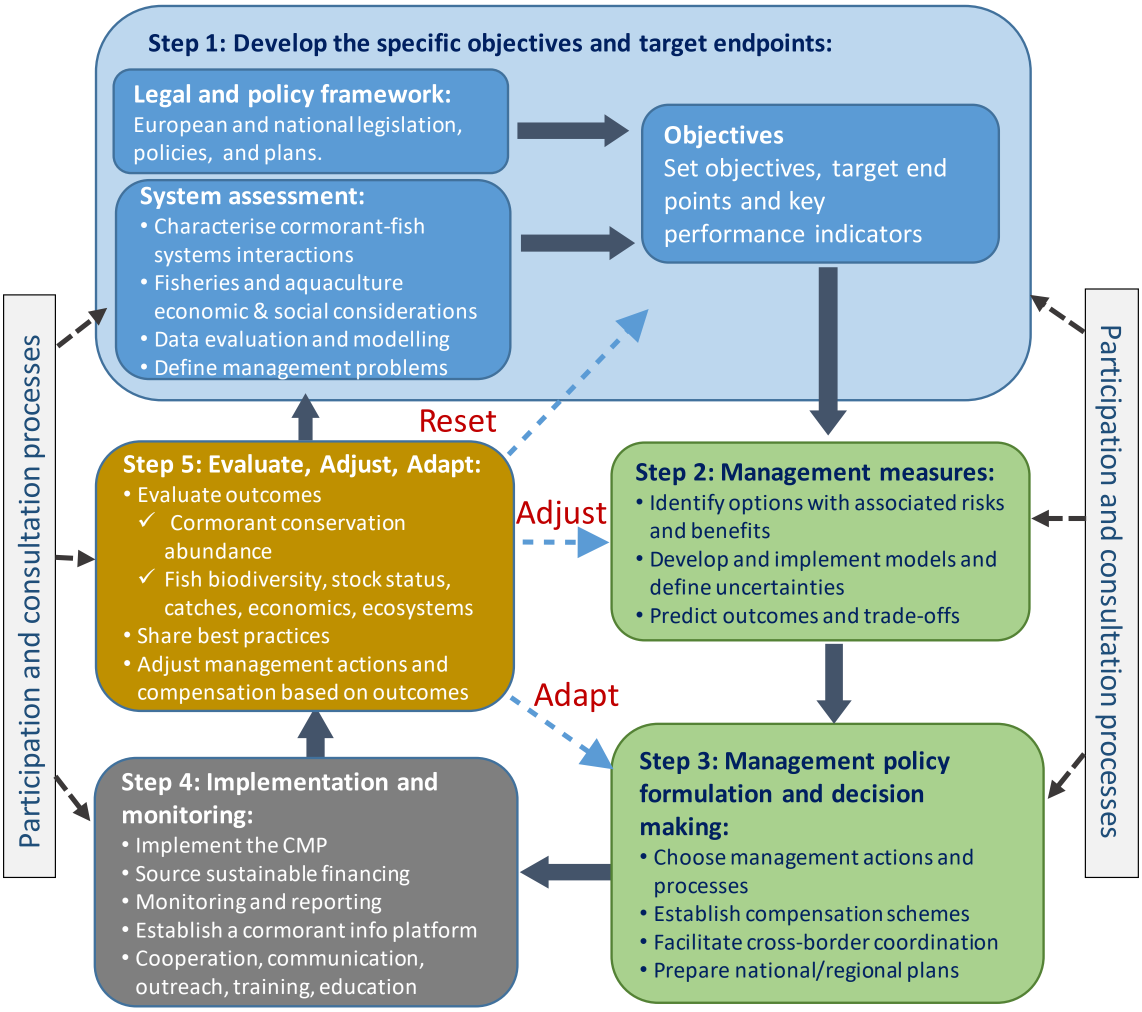

Figure 5. Framework for the European Management Plan for the Great Cormorant

The framework for the CMP provides a process to quantify the problems, stakeholder motives and desires, goals and objectives, and enables structured decision-making and adaptive management through the Evaluate-Adjust-Adapt-processes.

4.2 Step 1: Develop the specific objectives and target endpoints of the management plan

4.2.1 Characterise cormorant, fisheries and aquaculture systems

The first step is to formally characterise cormorant-fish systems interactions and define the management problems and conflicts. Sufficient information exists to define and quantify these problems (see Section 2), and develop an appropriate action plan, but the information should be continuously updated and used accordingly to revise any proposed actions. Data collection methods, data evaluation and modelling processes should be agreed on by key stakeholders and, where necessary, approved by the proposed Cormorant Management Advisory Group (see Section 4.5.2 and Annex 4).

The following actions are needed to reinforce the information and account for changing conditions as the CMP is enacted.

- Establish and operate an open-access, **pan-European system for monitoring** and updating cormorant population trends in distribution and abundance, breeding sites, and migration routes, and factors contributing to their range expansion.
- **Build on and standardise data collection and monitoring protocols** for cormorants and fish and fisheries across European countries and agencies for consistency and comparability. (This action would build on the ongoing ProtectFish project)
- **Review the status and trends in fish populations across Europe** related to achieving WFD and HD objectives in the face of cormorant predation. (This action would expand the ProtectFish work to more European countries)
- **Establish scientifically informed favourable reference value and range for defining good population status of great cormorant across its European range, and thresholds** that trigger implementation of non-lethal deterrents and lethal control measures (in compliance with the Birds Directive and national legal protections).
- Continue data collection and **monitoring of ecological, economic and social impacts** of cormorant predation and other pressures on fish stocks in inland and coastal waters and fish farms, and provide evaluation against other threats to fish biodiversity and population status.
- **Establish a central database** of cormorant abundance, breeding colonies, population dynamics, migratory patterns and predation impacts. This input should engage with existing databases that hold appropriate data such as the European Breeding Birds Atlas. The cormorant data will be complemented by national fish monitoring data collated under the WFD and HD or other non-EU national monitoring requirements.

4.2.2 Setting objectives

The objectives for the plan, as defined in Section 3.4, should be aligned to quantitative targeted end points for the size of the European great cormorant population. There is a need to **establish scientifically derived reference and end points for the abundance and distribution of the European cormorant population** that maintain good population status for the species, but also aligns with attaining favourable conservation status of fish species across Europe where cormorant predation is a known pressure, thus improving the status of fish populations and viable fish farming enterprises (see Section 4.3). These end points will be developed and agreed upon by the Cormorant Management Advisory Group in collaboration with key stakeholders, and reviewed and endorsed by competent authorities in European countries and at the regional level (as needed).

4.2.3 Legal and policy framework

The distribution and abundance of great cormorants in Europe are largely regulated under the EU Birds Directive and national wildlife protection legislation (see Section 2.5). Where conflicts arise, people can request to control population size through lethal measures, generally targeting the adult birds or eggs (oiling). These requests are evaluated, approved or denied, by environment ministries or competent authorities. In EU Member States, environment ministries, as the competent authorities, submit annual reports to the European Commission on derogations granted under Article 9 of the Birds Directive and this will continue, but it is recommended that the actual numbers of birds culled, not just the numbers approved, should be reported.

Local control measures have so far proved inadequate to reduce the impact of cormorant depredation at a European level. There is a clear need to assess the population status of cormorants in each European country and align national and regional policies and management measures within Europe to ensure consistency and effectiveness of control measures. Such an-assessment should occur as a priority during implementation of the CMP. Where countries abstain for control, due account should be made of the contribution of these countries to replenishment of the overall European great cormorant population abundance.

Management options for consideration are:

- Clarify requirements and the procedure to apply derogations under Article 9 and introduce a standardized, fast-track, stream-lined protocol to apply for derogation for common use by stakeholders and competent authorities in all countries;
- Consider a change in the protection status of the great cormorant under the Bern Convention from a non-named species in Appendix III to a species listed as an exception (similar to the house sparrow, jackdaw, rook and great black-backed gull);
- Consider development of legislation that establishes spatial (zonal) management plans with zones where great cormorant abundance is actively managed to protect fish populations (e.g. around aquaculture farms and fish populations in both coastal and inland waters), i.e. where lethal measures are granted and documented, and matched with "exclusive protection zones" for cormorants.
- Depending on the mid-term evaluation, and progress made towards resolving the cormorant-fish conflict, consider preparation of a definitive great cormorant International Single Species Action Plan under the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA), applicable to countries in its European distribution range.

4.3 Step 2: Determine management measures

An array of management tools has already been developed to address the cormorant fish conflict. These are described in detail in the INTERCAFE Toolbox (Russell et al., 2012). They cover both non-lethal and lethal control measures (see Section 2.4). The main non-lethal measures include use of visual and acoustic deterrents, barriers, and habitat modification; promoting fish refuges (e.g. submerged structures) to shelter vulnerable species, and support for stocking programmes for at-risk fish populations, where ecologically appropriate.

In high-conflict areas, lethal control of the cormorant population is carried out following a licensing/permit system according to Article 9 derogation criteria underpinned by strict ecological justification and in line with local management plans. As such, lethal control tends to be a local or national measure and there has been a lack of coordinated control to manage the population of cormorant at a European scale.

To meet the desired objectives to reduce cormorant depredation to sustainable levels across its European range, this step identifies innovative and sustainable methods, with associated risks and benefits, for managing long-term sustainability of the great cormorant population whilst minimizing the negative impacts of cormorants on fish stocks, aquaculture, aquatic biodiversity and ecosystem health proportionate to the scale of the impact.

The following options, which are not mutually exclusive, should be considered:

- **Status quo/do nothing:** This option will lead to continued impacts on the viability of fisheries and aquaculture throughout Europe, as seen by a continued history of conflict since the protection of great cormorant (Annex 2), and further jeopardising conservation of fish. If the population continues to expand the likelihood is that the cormorant population will eventually become food limited as is already the case in some areas where numbers are in decline (e.g. in Denmark). There is a greater risk that the great cormorant population in Europe will continue to grow and further expand its distribution range, which will increase pressure on fish stocks, fisheries and aquaculture.
- Develop **national and/or region-specific strategies** that recognise varying levels of cormorant population density, habitat type, and human interventions across Europe and implement adaptive interventions that allow for adjustments based on new data, research findings, and evolving cormorant and fish population status and dynamics.
- Develop, test and promote **non-lethal deterrent methods** to prevent or reduce predation rates. This should build on the **INTERCAFE Toolbox** where existing and novel measures are tested, updated, including in combination, and advice made available to all stakeholders**.** Nevertheless, it should be recognised that many of the non-lethal methods have inherent problems with application (see Annex 3), and do not address the underlying problem of reducing predation pressure across the European landscape. Support for **stocking programmes** for at-risk fish populations should also be considered where ecologically appropriate (Cowx et al., 2025).
- Targeted **lethal control,** when justified under Article 9 of the Birds Directive and without compromising the favourable conservation status of the great cormorant, to manage the cormorant population size proportionate to damage caused. The justification will be to protect, and conserve threatened and endangered fish populations and improve population status of impacted fish populations. This will require coordinated culling and egg oiling across the great cormorant European distribution range, especially in primary breeding areas, and will require engagement with countries that currently do not control cormorant numbers and are acting as reservoirs for replenishing cormorant numbers. The culling needed and rate of intervention will level off as the population reaches a manageable level, and thus make spatial management a more viable and effective option.
- **Establish spatial management** to reduce cormorant predation impact on fish, by assigning zones where cormorant abundance is actively managed to protect fish populations and aquaculture and "no-regulation protection-zones" for cormorants. As such, there will be a need to develop **zonal management plans** where lethal control is

tied to documented impact of predation on fish populations, especially in high-conflict areas.

Throughout the formulation of management options, attention is paid to ensure compliance with the EU Directives and national laws and regulations.

4.4 Step 3: Management policy formulation and decision making

4.4.1 Choose management actions and processes, including monitoring and evaluation plans

The following actions are recommended to achieve a balance between pan-European conservation of cormorants, and the sustainable use and protection of fish populations, fisheries and aquaculture interests.

- Review information on cormorant-fish systems interactions and define the management problems and conflicts. This should also include identifying issues that constrain reaching consensus of the status of both great cormorant and fish population status.
- Develop and use models to predict outcomes and trade-offs, and define uncertainties, with proposed actions.
- Carry out regular assessments of the conservation status of aquatic biodiversity, including fish populations, and of habitat quality affected by cormorant presence and management.
- Develop models on the target population size of breeding pairs of cormorants within the European distribution range based on information collected in Step 1 and modelling carried out as part of the management decision-making process. This will build on a reference value for favourable conservation status for cormorant established in Step 1 and scale of impact determined in Step 2.
- Propose an appropriate mix of short and long-term management measures to reach the defined goal - i.e.:
  - ➢ Immediate and continuous: support non-lethal measures, including deterrents, barriers, habitat modifications and fish stocking, where measurable impact is achieved.
  - ➢ Short term: coordinated culling where impact of cormorant predation is established and until regionally agreed targets of breeding pairs are reached, based on triennial monitoring and adaptive management procedures (see Step 5). This will build on the existing country-specific actions but coordinated across regions and the great cormorant European distribution rage to enable cross-border management of cormorant depredation.
  - ➢ Long term: oiling of eggs in a defined percentage of nests annually based on triennial monitoring and adaptive management procedures (see Step 5). The practice of egg oiling has been used for cormorants for many years and is widely applied for managing seagull colonies.

Recovery of inland and coastal fish populations and aquatic biodiversity proven to be impacted by cormorant depredation (e.g. grayling, trout, salmon, chub, nase, eel) to good ecological status or potential, as well as a reduction in losses at aquaculture ponds should be attained. If not, the regional target should be adjusted following review of cormorant abundance and status of fish populations and impacts on aquaculture and fisheries, after an initial interim period of three years and every three years thereafter.

The measures will be applied in accordance with legal requirements of Article 9, where and when damage is predicted or preventive measures have been implemented and proven ineffective. The application for derogations needs to be standardised, including appropriate justification for each case, and coordinated across the European distribution range, enabling actions to be taken immediately to avoid further damages.

Linked to this, is the need to establish an effective system for damage reporting, assessment and applying for compensation for fisheries and aquaculture facilities affected by great cormorant predation. The procedure for determining compensation payments, including damage reporting, criteria for payment and payment for damages, needs to be equitable and standardised across all European countries.

Each European country needs to prepare and submit a 6-year national plan of management measures and monitoring to the CMAG, which will enable the preparation of a regional overview of actions that will be used to formulate actions for the next implementation period.

4.4.2 Facilitate cross-border coordination and decision making

One of the barriers to effective management of the migratory and expanding cormorant population is the limited cross-border coordination of management interventions. Each country operates its own management activities. Some countries, however, choose not to use Article 9 derogations to reduce the cormorant population size, compromising measures by other countries to effectively address depredation from this transboundary, highly migratory, shared population of birds. Consequently, it appears that much of the effort by individual countries or regions is ineffective at the pan-European level, as it is not addressing the cause - the ever-expanding cormorant population.

To overcome this issue of lack of coordination between countries and authorities the following mechanisms are proposed:

- **Review and adoption of the European management plan for the great cormorant** by the competent authorities and relevant stakeholders within its European distribution range, the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) and possibly by AEWA. It is important to ensure coordination and joint implementation of the CMP with non-EU countries in Europe.
- Review and **endorsement of the European management plan for the great cormorant** by the European Parliament through a dedicated resolution.
- **Preparation and adoption of one or more regional plans,** e.g. one each for the Baltic Sea and North Sea areas, Eastern Europe and Southern Europe.
- **Facilitate coordination between countries** to share responsibility for data collection, monitoring, management, control and evaluation. This will require a structure in which the CMAG and a secretariat have major roles to play (see also Section 4.5.5 and Annex 4).

4.5 Step 4: Implementation and monitoring

4.5.1 Implementation of the framework for European Management Plan for the Great Cormorant

The proposed framework for the CMP should act as a catalyst towards implementation, and requires a roadmap of interventions. A tentative timeline for action towards implementation is as follows:

Year	*Key milestones*
October 2025	Formal submission of the 3rd draft framework CMP to the European Parliament, EIFAAC and European Commission.
Year 1	Formal review of the draft framework CMP by EIFAAC, the European Parliament and possibly the European Commission, through Expert Group on the Nature Directives (NADEG), and national governments to discuss the CMP framework.
Year 1	CMP forerunners: Regional working groups established by some countries.
Year 2	Establish the Cormorant Management Advisory Group (CMAG) with representatives from the European countries and key stakeholders, including scientists, bird, fisheries, aquaculture, fish conservation and animal welfare NGOs.
Year 2	Determine and agree European cormorant population abundance thresholds and management targets through multi-stakeholder fora.
Year 2	Prepare and submit a single species management plan, based on the CMP, for review and adoption by AEWA.
Year 2	European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) adopts the CMP, increasing its application to non-EU countries in Europe.
Year 2-3	Set-up of the Secretariat and a Compliance Committee, composed of country representatives, with clear terms of reference (using Annex 4 as basis).
Year 3	Implementation of the CMP, and development of regional and national level management plans (as required).
Year 3-8	Annual reporting by countries to the Secretariat and CMAG.
Year 8	Mid-term review, evaluation and adaptation of CMP

Following start-up, the outcomes of new research findings and ecological shifts (e.g. climate change effects on fish migration and bird distribution) will be evaluated and the actions adapted every 3 years.

4.5.2 CMP management structure

Implementation of a European Management Plan for the Great Cormorant (CMP) will require an organizational structure. The following structure, which is largely similar to the structure used by most Regional Fisheries Management Organizations (RFMOs), is proposed:

a) Cormorant Management Advisory Group – supporting assessment/research and data collection.
b) Compliance Committee – monitoring compliance with the implementation of the Plan.
c) Secretariat – coordinating, facilitating and reporting on the implementation of activities in support of the Plan.

Further details on the management structure are provided in Annex 4, including draft Terms of Reference for each entity.

As part of the organization, each European country should report activities and outcomes to the Secretariat annually. The Secretariat will compile the reports and provide a regional overview for the countries, European Parliament, European Commission and EIFAAC and other appropriate stakeholders, after review by the Compliance Committee.

The proposed structure for CMP implementation, monitoring and reporting is presented in Figure 6.

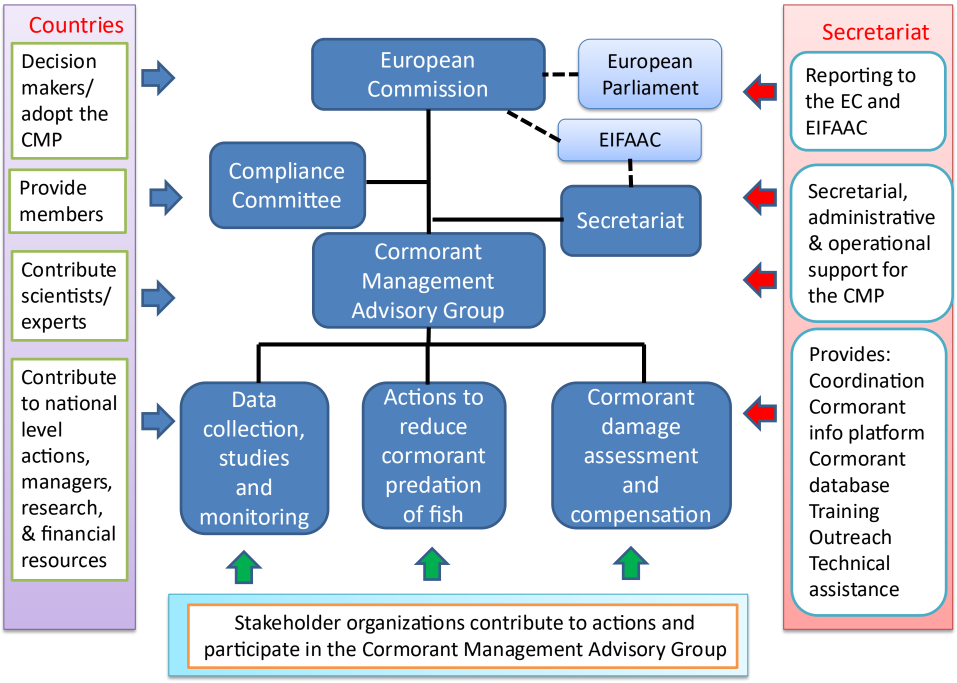

Figure 6: Framework for CMP implementation

4.5.3 Financing the implementation of the CMP

Sustainable financing is fundamental to successful endorsement and implementation of the management plan. Without funding from national budgets, the European Maritime, Fisheries and Aquaculture Fund (EMFAF), and possibly the EU LIFE Programme or Horizon Europe, for establishing the key elements of the plan, such as data collection and collation, model development and supporting initial stakeholder collaboration, any plan will be difficult to implement.

The funds will be required to:

- Develop, promote and implement conflict prevention and mitigation measures, including **non-lethal deterrents**, **predation thresholds** and **fish stock resilience**;
- Establish and operationalize damage/loss reporting systems, damage assessment and **compensation schemes** for affected fisheries and aquaculture entrepreneurs;
- Establish and operate **joint data collection and monitoring initiatives**, reporting and dissemination;
- Establish and maintain a Secretariat that will support a **Cormorant Management Platform,** including a data hub, coordinate actions between countries, support awareness raising and capacity building, and reporting to the competent bodies and regional bodies;
- Facilitate meetings of the **Cormorant Management Advisory Group** (CMAG) and **Compliance Committee** (CC);

- Provide technical support to European countries for developing national plans, capacity building, awareness raising, and legislation review and amendment (as required).
- Support scientific studies leading to documentation of impact or not, where a consensus has not been reached.

Co-financing from individual European countries is required to implement local measures for mitigating and compensating damages caused by great cormorants along with central financing from the EMFAF and LIFE Programmes.

The running costs for the secretariat (salaries and running costs) and meetings of the CMAG, CC and secretariat will need to be covered centrally from EU and national resources. The more substantial costs for the field measures (shooting and oiling), populations monitoring (cormorants and fish) and compensation payment for damages caused by cormorants should be largely covered nationally, but include EMFAF and LIFE programme assistance.

Shooting of adult cormorants already takes place in most countries and is mainly carried out by volunteers, so the extra costs will mainly be on monitoring and egg-oiling. However, where needed, consideration should be given to reimburse the costs for non-lethal and lethal control measures from national and EMFAF sources. For instance, the ammunition costs could be claimed and reimbursed, as is done in some countries for pest control measures (e.g. for rodents). Fish monitoring in rivers and lakes is taking place under the Water Framework and Habitats Directives, usually on a six-year cycle, although routine monitoring of fish populations occurs in most countries on a more regular basis. Efforts must be made to adjust monitoring needs to help contributing to reporting for the CMP, including establishing ***index rivers*** and assigning vulnerable fish populations for more intensive annual (indicator) monitoring. This would need changes in monitoring programmes to become operational, but if infrastructure and expertise are present and available, this should not result in significantly higher costs. The oiling of eggs will be quite labour intensive for short periods every spring; the main effort will likely be greater for countries around the Baltic, with most nests to oil. Nevertheless, these countries are also the ones likely to benefit the most from a reduction in cormorant predation.

4.5.4 Monitoring and data hub

An open-access, pan-European system for storage of cormorant population monitoring data and evaluation of trends, breeding sites, and migration routes is required to support the implementation of the CMP. This needs to be coupled with fisheries and aquaculture data. This data storage and associated platform will need to be maintained by the proposed Secretariat but should fully engage with the European Bird Census Council and other bird and fish conservation NGOs to benefit from going actions. This information can be used to develop scientifically informed population thresholds to prevent overpopulation, mitigate negative impacts and implement effective population control methods, such as habitat modification, non-lethal deterrents, or regulated culling. Such a data hub will also allow transparency of information and establishment of management targets. It is recognised, however, that data sharing is a complex undertaking because of ownership and intellectual property rights issues, but the hub will provide links to all open access data to support this action.

Each year national reports will be submitted to the CMAG to prepare a European overview of numbers of birds culled and eggs oiled against the status of fisheries and aquaculture and impacts of cormorant predation.

4.5.5 *Cooperation and participation*

It is recognised that the great cormorant is a highly mobile species, therefore management requires collaboration between European countries to address the migratory nature of cormorants and their shared impacts. Therefore a participatory stakeholder approach similar to the ecosystem approach to fisheries management will be applied. Actions to redress the balance of cormorant and fish population needs, must involve all countries and key stakeholders working in harmony to attain the same desired end points. To achieve this, the establishment of a Cormorant Management Advisory Committee (CMAG) is needed. The CMAG will include representatives of competent authorities, natural resource managers, scientists, and other key stakeholders (e.g. representatives of bird conservation, aquaculture, recreational fisheries, commercial fisheries, biodiversity conservation and other organizations). The involvement of these stakeholder organizations and institutions in the data collection and monitoring, management actions, and damage assessments is critical to the success of the CMP.

To oversee compliance with the plan and implementation of the agreed actions, a Compliance Committee (CC) will be required, comprising representatives of the European countries and key stakeholders. The structure and terms of reference of the committees are described in Annex 4. The CC will work in close collaboration with the European Commission concerning the Birds Directive and possibly with the AEWA Secretariat.

Embedded within this international cooperation is the need to develop mechanisms for sharing successful strategies and lessons learned among European countries. This can be achieved by establishing a **Cormorant Information Platform** (including cormorants' info as was presented by the IUCN Wetlands International Cormorant Research Group platform[24], but also containing data and information on fish, fisheries and aquaculture), which will be actively maintained and updated by the secretariat. The platform will be used to share up-to-date information on cormorant distribution and abundance, fish population monitoring results, discussions and decisions on policies/legislation, and appropriate training materials.

4.5.6 *Public awareness, communication and education*

Informing the public about interactions between fisheries and cormorant ecology, cormorants and fishes roles in the ecosystem and delivery of ecosystem services, preventive measures and the need to foster coexistence, are essential. Local community involvement in decision-making processes to foster ownership and compliance with the plan is key. A communication strategy will be developed, and **public information campaigns will be carried out on a regular basis** to improve awareness of the complexity of the conflict.

Legitimate and inclusive stakeholder engagement is fundamental to the plan and must consider the motives and drivers of the main stakeholder groups. Whilst conservation of biodiversity, in line with European biodiversity targets, is central to the plan, due consideration must also be given to wider environmental and biodiversity protection, economic development, food security and livelihoods objectives.

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[24] http://cormorants.freehostia.com/

Stakeholders will become literate in all aspects of the cormorant fish conflicts, issues and potential solutions in the CMP through training and communication. Information will be balanced and clear to ensure consensus and avoid misrepresentation and misinterpretation.

4.6 Step 5: Evaluate, Adjust, Adapt

Continuous monitoring and data collection on the status and distribution of the great cormorant population and its impacts, and keeping track of management actions and results will allow evaluation of the CMP. Information on fish biodiversity, fish stock status, catches, economics, ecosystems and fish farming enterprises is also essential for the evaluation and adaptation of the CMP. It is essential that environmental changes and non-target effects are tracked. Information should include feedback from stakeholders and field operators.

Information collated during the first 6-year period will be analysed against a reference year established at the onset of the implementation period when the threshold levels for good conservation status are established and agreed to:

- Evaluate whether the management actions are achieving desired outcomes;
- Assess outcomes of different management actions;
- Integrate new scientific research, technologies and or policy updates;
- Identify unintended consequences, including ecosystem changes and proliferation of pest species;
- Redefine management objectives and targets based on the updated information.

Where necessary, management actions will be adjusted in the following ways:

- ***Modify control techniques:*** if a method (scaring, exclusion, culling and egg oiling) is ineffective or causing unintended harm, switch to alternative methods.
- ***Optimize resource allocation***: redirect efforts to the most affected areas or most effective actions.
- ***Increase or decrease intervention intensity:*** if the cormorant population abundance falls below the threshold that threatens their conservation status, any actions should be suspended until the numbers have recovered; conversely where cormorant numbers are increasing and found to have adverse impacts, efforts should be intensified.
- ***Introduce new technologies***: use innovations, such as drones, to increase capacity to count birds and nests, to oil eggs in remote nests and in tree-based colonies, or use drones to scare birds. Where such methods are implemented on Natura 2000 sites, permissions from the competent authorities should be obtained.
- ***Compensation:*** Adjust compensation levels based on CMP outcomes, preventive measures taken, and social and economic performance of the affected aquaculture and fisheries enterprises and angling clubs. Re-allocate void compensation money to support the CMP.

The adjustment of actions may require an update of the objectives and key performance indicators (KPIs), including:

- Revising goals if needed - e.g. shift from long-term suppression to targeted control to maintain equitable balance of bird and fish populations;
- Define new success metrics based on updated knowledge;
- Adjust timelines and expectations based on outcomes.

It is also necessary to communicate new findings to policymakers, managers, and the public. There may also be a need to adapt engagement strategies to increase compliance and participation.

There is also a need to incorporate lessons learned and plan for future adaptation by documenting successes, failures and best practices, and develop contingency plans for unforeseen challenges (e.g. climate change impacts, other piscivorous species). Maintaining flexibility in decision-making to adapt quickly to emerging threats is fundamental to this requirement.

5. Logical framework approach

The European Great Cormorant Management Plan needs clear priority actions and a timeframe for implementation of these actions. Table 1 gives an overview of actions that should be targeted in the short to medium term to manage the adverse impacts of an expanding great cormorant population on inland and coastal fish, fisheries and aquaculture across its European distribution range. It should be noted Table 1 is not a definitive logical project framework because the current document is a framework for a management plan an quantifiable goals have not been determined, thus indicators cannot be defined. It does, however, follow the structure of an AEWA single species action plan and can easily be adapted for comprehensive cormorant management plan.

Implementation of the actions will largely depend on availability of funding.

The CMP is deliberately not a blue-print plan, but guides coordinated action throughout Europe. It is designed to enable change in policies, legislation and cormorant management approaches in line with achieving the joint objectives. The outcomes of actions will be reviewed every 6 years and adaptation of the CMP and associated management measures is foreseen.

The budget required for implementation of the CMP will be prepared at a later stage in the drafting process, based on agreed structure and actions. Key elements to ensure successful implementation of the CMP will be:

- Allocation of adequate financial resources from the EU, country environmental budgets and other internal and external sources.
- Availability and motivation of personnel, including support from bird, environmental, fisheries and aquaculture agencies, NGOs and CSOs.
- Necessary logistical resources and equipment available to apply management measures and fund appropriate compensation.

Table 1. Implementation activities, priorities and timeframe for delivery of the cormorant management plan

Goal / Action	Objectives addressed	Timeframe	Outputs	Indicators	Responsibility
Step 1: Develop the specific objectives and target endpoints of the management plan					
Characterise cormorant, fisheries and aquaculture systems					
1) Establish and operate a standardised pan-European **system for monitoring cormorant population trends** and breeding sites.	1, 2, 4	Triennial	• Triennial monitoring of breeding and overwintering cormorant population abundance and distribution in European countries. • Monitoring of cormorant breeding success at nesting sites in protected areas. • Regular assessment of conservation status of aquatic biodiversity, including fish populations, and habitat quality affected by cormorant presence and management. • Protocol for stomach analysis of culled cormorants applied. • Access and update European Fisheries Data Framework information. • Empirical information on economic impacts of cormorants on fisheries and other ecosystems services in freshwater and coastal water bodies taking into account also other pressures on fish and fisheries. • Updated studies on the impact of cormorants on the economic viability of fish farms.	• Regular updates of status and trends in cormorant population distribution and abundance, including breeding and overwintering population sizes. • Open access European monitoring information system updated on biennial basis. • Review of the cormorant population distribution and abundance in Europe. • Regular updates of conservation status of aquatic biodiversity, including fish populations, and habitat quality affected by cormorant presence and management. • Updated information on economic impacts of cormorants on fisheries, aquaculture and other ecosystems services in freshwater and coastal water bodies.	• National bird monitoring organizations, CSOs, NGOs and volunteers. • EIFAAC. • National and regional fisheries and environment agencies and fisheries and aquaculture organizations in each country.
2) **Establish standardise data collection and monitoring protocols** for assessing status of fish populations cross European countries in line with HD and WFD needs.	1, 2, 6	Triennial. Minimum compliance with HD and WFD reporting			
3) Conduct, in a coordinated and standardised manner, studies and report on **ecological and economic impacts of cormorant predation** on fish populations, freshwater and coastal ecosystems, and fish farms, whilst accounting for other pressures on fish and fisheries.	1, 2, 6	Initially to establish reference state and periodically to assess impact of measures			

Goal / Action	Objectives addressed	Timeframe	Outputs	Indicators	Responsibility
Setting objectives					
4) Agree on the **objectives for the Cormorant Management Plan**.	3, 4, 5	Year 1-2	• Objectives prepared and disseminated. • Predictive modelling tools developed, maintained and results communicated. • Evaluation of actions on cormorant distribution and population size through coordinated monitoring and modelling. • Established regional population abundance thresholds to maintain cormorant conservation status across its distribution range.	• Objectives and KPIs of the CMP agreed. • Local, national and regional cormorant population thresholds established and agreed by key stakeholders.	• National and regional competent authorities. • CMAG, Compliance Committee.
5) Develop scientifically informed cormorant favourable reference value for good population status and thresholds that trigger implementation of non-lethal, deterrents, such as scaring, exclusion devices or habitat modification, or targeted humane population control methods.	1, 2, 3, 4, 5, 6	Year 2			
6) Establish **key performance indicators (KPIs)** to measure the success of management actions, such as changes in cormorant populations and fish stock recovery.	3, 4, 5, 6	Year 1-2			
Legal and policy framework					
7) **Introduce standardized, stream-lined procedures to apply for derogations under Article 9, including universal or regional justifications,** for common use by stakeholders and competent authorities in all countries	4, 5	Years 1-2	• Standardised, fast-track systems developed and applied by most European countries. • Report of legal review published.	• Annual country reports indicate the average time between application and approval. • An increase in the number of article 9 derogations commensurate with scale of cormorant impact.	• National and regional competent authorities. • CMAG • Stakeholder organizations.

Goal / Action	Objectives addressed	Timeframe	Outputs	Indicators	Responsibility
8) **Legal review** of the options for re-evaluating the status of the great cormorant under the Bern Convention.	3, 5, 6	Year 1-2		• Legal advice shared online.	• Bern Convention Secretariat. • AEWA. • EIFAAC.
Step 2: Determine management measures					
9) **Mitigation measures**: Explore innovative and sustainable methods for managing cormorant populations and mitigating their impacts.	3, 4, 5	Years 1-5	• Updated studies on the ecological damage to wild fish stocks, including virtual population analysis and fish population modelling, and assessment of well-being of fish species of conservation importance. • Empirical information on economic impacts of cormorants on fisheries and other ecosystems services in freshwater and coastal water bodies. • Updated studies on economic and livelihoods impact of predation by cormorants at aquaculture enterprises. • Update and promote the INTERCAFE Toolbox for non-lethal deterrents to reduce depredation by cormorants on wild fish stocks and at aquaculture facilities, with indicators of likely success and options, including use of multiple deterrents, to improve likelihood of success.	• Scientific monitoring programme in place to determine and agree on acceptable levels of cormorant depredation. • Ecological and impact data updated and made available online. • Population monitoring data published, and data incorporated into predictive models. • Updated INTERCAFE cormorant mitigation and population management toolbox published online. • Zonal management plans available online.	• Relevant monitoring and research organizations. • CMAG and Compliance Committee. • EIFAAC. • Relevant national and regional competent authorities. • Stakeholder organizations.
10) **Non-lethal deterrents to protect fish and fisheries**: Determine non-lethal deterrent methods, such as nets, acoustic devices and visual deterrents, to safeguard fish stocks and keep cormorants away from sensitive areas.	3, 4,5, 6	Year 1-2			
11) **Non-lethal deterrents to protect aquaculture**: Determine non-lethal deterrent methods, such as nets and acoustic devices, to reduce economic losses in fish farms.	3,4, 5, 6	Year 1-2			
12) **Systematic lethal control measures:** Establish clear regionally agreed criteria to justify for when and where lethal	2, 3, 4, 5, 6	Years 1-5			

Goal / Action	Objectives addressed	Timeframe	Outputs	Indicators	Responsibility
control (such as culling) can be used.			• Thresholds of cormorant population abundance at local and region scales established, where lethal control becomes a justifiable option to manage population abundance where serious damage has been established. • High conflict areas selected where zonal management could be applied. • Zonal management plans developed.		
13) **Spatial management**: Establish spatial management, including zonal management plans where appropriate, to increase effectiveness of management actions in high-conflict areas.	3, 4, 5, 6	Years 3-5			
Step 3: Management policy formulation and decision making					
14) European management plan for the great cormorant: Finalize and agree on the actions and KPIs of the plan.	all	Year 1-2	• Pan-European adaptive management plan for cormorants agreed along with its goal, objectives and key actions and KPIs. • National plans developed and 'Best practice' guidelines for organization of coordinated control of cormorant numbers at regional and national levels established. • Clear criteria established for when and where lethal control (such as culling) can be employed, under what conditions permits can be granted, and how this aligns with EU and national legislation. • Guidelines to facilitate Article 9 derogations under the Birds Directive	• Management Plan agreed by all parties and published. • Thresholds for lethal control established and agreed. • Population target confirmed and communicated to relevant national authorities. • Number of derogations submitted. • National / regional management plans published and shared. • National/local management plans produced including development of activities benefitting local communities. • Funds made available for research and monitoring	• Relevant monitoring and research organizations. • National environment agencies. • CMAG and Compliance Committee. • Relevant national and regional competent authorities, CSOs, NGOs in dealing with
15) **National plans:** Develop national or region-specific plans that recognise varying levels of cormorant population density, habitat type, and human interventions across Europe.	3, 4, 5, 6, 7	Years 1-2			
16) Evaluate efficacy of non-lethal (e.g. scaring, habitat modification netting) and lethal **control measures** such as oiling eggs or regulated culling (in compliance with legal protections).	3, 4, 5	Years 1-5			

Goal / Action	Objectives addressed	Timeframe	Outputs	Indicators	Responsibility
17) **Derogations:** Use the derogations system under the Birds Directive to report on controlled culling in areas where cormorants cause serious damage to aid decision making on appropriate measures.	4, 5, 6	Continuous	available and linked to requirements to control cormorant depredation pressures. • Damage assessment method developed and agreed. • Damage compensation system established, based on best practices and lessons learnt from other bird damage compensation systems used for agriculture. • Relevant authorities (national or regional) responsible for implementation and enforcement engaged. • Existing structures/capacity or new structures in place. • Appropriate funding secured and dispersed to appropriate research and monitoring programmes. • Platform for communication and feedback established and operational under guidance of CMAG and the Secretariat.	programmes and for damage compensation. • Compensation system for cormorant damage to aquaculture and fisheries enterprises established in most countries. • Communication and data platform established.	wildlife and cormorant issues. • EIFAAC. • Secretariat.
18) **Compensation system:** Establish an effective system for damage reporting, assessment and compensation for predation by cormorants.	3,4, 5 6	Years 1-2			
19) **Assign responsibilities** to authorities and organizations at national level for implementation of management plan and support targeted activities.	5, 6, 7	Years 1-2			
20) **Funding:** Ensure financial resources available to implement CMP, including funding from national, EMFAF and LIFE programme sources.	all	Continuous			
21) **Promote dialogue:** Create platforms for dialogue among fishers, aquaculture farmers , conservationists, and policymakers to build trust and consensus.	5, 6, 7	Years 1-3 Continuous			

<table>
<tr><th>Goal / Action</th><th>Objectives addressed</th><th>Timeframe</th><th>Outputs</th><th>Indicators</th><th>Responsibility</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Step 4: Implementation and monitoring</td></tr>
<tr><td>22) Protect fish and fisheries using non-lethal deterrents: Implement non-lethal deterrent methods, such as nets, acoustic devices and visual deterrents, to safeguard fish stocks and aquaculture facilities and keep cormorants away from sensitive areas.</td><td>3, 4, 5, 6</td><td></td><td rowspan="5">• Cormorant depredation rates reduced to socially, ecologically, economically and environmentally acceptable levels by regulated intervention mechanisms.
• Population monitoring to ensure population size remains within established threshold for several consecutive years, and the CMAG agrees to take necessary action where appropriate.
• Coordination to ensure cormorant management does not compromise protection of key biodiversity areas and protects conservation species, including fish.
• Countries support and actively facilitate rehabilitation of key habitats for fish.
• Dispersion of damage compensation funds to offset economic losses to fisheries and aquaculture enterprises, and possibly angling organizations.</td><td rowspan="5">• Population monitoring data published, and data incorporated in predictive models.
• Annual reporting and publication of data.
• Review the status of the great cormorant under the Birds Directive and Bern Convention.
• Countries support and actively facilitate the rehabilitation of fish habitats.
• Annual report on damages and dispersal of compensation funds.</td><td rowspan="5">• Monitoring and research organizations.
• CMAG and Compliance Committee.
• EIFAAC.
• Secretariat
• Relevant national and regional competent authorities.</td></tr>
<tr><td>23) Habitat modification: Implement habitat modifications where necessary to reduce conflicts with fisheries and aquaculture.</td><td>3, 4, 5, 6</td><td>Years 3-10</td></tr>
<tr><td>24) Restore habitats: Rehabilitate ecosystems affected by cormorant colonies, such as areas of deforestation or degraded soils.</td><td>3, 4, 5, 6</td><td>Years 3-10</td></tr>
<tr><td>25) Control measures: Implement targeted population control methods where necessary, such as oiling eggs or culling.</td><td>3, 4, 5, 6</td><td>Continuous</td></tr>
<tr><td>26) Compensation mechanisms: Implement equitable damage compensation schemes for</td><td>3, 4, 5, 6</td><td>Years 1-3</td></tr>
</table>

Goal / Action	Objectives addressed	Timeframe	Outputs	Indicators	Responsibility
fisheries and aquaculture enterprises affected by cormorant predation across countries.					
Cooperation and participation					
27) **Cross-border coordination:** Facilitate collaboration between European countries to address the migratory nature of cormorants and their shared impacts.	4, 5, 6, 7	Years 2-5	• A Cormorant Management Advisory Group (CMAG) ~~and Compliance Committee (CC)~~ established, along with review and feedback system at the regional level. • European countries and stakeholder representatives participate actively in research and monitoring activities. • Authorities (national or regional) responsible for CMP implementation and enforcement within each country share data and information at regional level with the CMAG, CC and secretariat. • Reporting of annual culling and egg-oiling statistics by countries to the Secretariat. • Wise use and 'best practices' for the control of cormorants at national and local levels promoted.	• European Cormorant Management Advisory Group and ~~Compliance Committee~~ formally established. • Annual meeting reports of the CMAG and CC. • Monitoring data published and reported to relevant authorities and organizations. • Publication of Article 9 derogation statistics, with the number of culled cormorants. • Best practices shared and dialogue between stakeholders active.	• CMAG and ~~Compliance Committee~~. • Monitoring and research organizations. • Relevant national and regional competent authorities, CSOs, and NGOs. • EIFAAC. • Secretariat.
28) **Cormorant Information Platform:** Establish a centralized database to share cormorant population data, fishery impact reports, and best management practices between European countries, agencies and other stakeholders.	4, 5, 6, 7	Years 2, continuous.			
29) **Share best practices**: Develop mechanisms for sharing successful strategies and lessons learned among European countries.	3, 4, 5, 6, 7	Years 3-6, continuous.			
Public awareness, communication and education					
30) **Awareness campaigns:** Conduct awareness campaigns to inform	4, 5, 6, 7	Years 2-6 - ongoing	• A communication strategy on the CMP developed and implemented.	• CMP communication strategy available online.	• CMAG. • EIFAAC.

Goal / Action	Objectives addressed	Timeframe	Outputs	Indicators	Responsibility
the public about cormorant conservation, cormorant impact on biodiversity, and the costs to fisheries and aquaculture.			• Awareness raising campaigns and knowledge systems implemented and freely available. • Stakeholders and communities actively engaged in CMP development, implementation and evaluation. • Educational programmes designed and presented periodically in European countries and online.	• Statistics on stakeholder engagement in the CMP development and implementation compiled by the CMAG. • Publication of guidelines, training programmes and local codes of conduct. • Education programmes available nationally and online in various languages.	• Secretariat. • Monitoring and research organizations. • Relevant national and regional competent authorities, CSOs, and NGOs.
31) **Stakeholder involvement:** Engage stakeholders, including fisheries and aquaculture organizations, conservation organizations, managers and policymakers, in the development and implementation of management measures.	4, 5, 6, 7	Ongoing			
32) **Educational programmes:** Enhance understanding and education about cormorants, fish and their role in the environment, economy and food security to gain broader public support for management actions.	6, 7	Years 2-6 - ongoing			
Step 5: Evaluate, Adjust, Adapt					
33) **Evaluate & Adjust:** review outcomes of measures and adjust CMP actions based on new data, research findings, and evolving cormorant-fish population dynamics.	all	Year 6-8	• European countries and key stakeholders participate in the CMP evaluation. • CMP evaluated along with its goal, objectives, key actions and KPIs. • CMP adaptations or adjustments proposed based on the evaluation recommendations, new data,	• ~~Reports of the compliance committee.~~ • Annual reports compiled by Secretariat. • CMP evaluation report published. • Proposals for adjustment and adaptation of the CMP submitted	• CMAG and ~~Compliance Committee.~~ • Relevant national and regional competent authorities.
34) **Evaluate breeding sites:** Key cormorant breeding colonies in	1, 2, 3, 5	Year 6-8			

Goal / Action	Objectives addressed	Timeframe	Outputs	Indicators	Responsibility
Nature 200 sites are protected and control measures managed in other main breeding colonies to maintain population status.			research findings, and evolving cormorant and fish population dynamics. • Status of cormorant breeding sites, aquatic biodiversity and fish habitat outcomes evaluated. • CMP adapted to changes in the European policy and legislative framework. • European countries evaluate the outcomes of the CMP at national level and adjust their national plans and management actions.	to relevant national and regional competent authorities. • CMP amendments take in consideration relevant changes in the European policy and legislative environment. • Reports of national level evaluations of national and regional cormorant management plans and damage compensation schemes.	• Secretariat.
35) **Evaluate biodiversity and habitat outcomes**: Ensure cormorant management measures have positive biodiversity and habitat outcomes.	1, 2, 5	Year 6-8			
36) **Adapt to changes in the management environment**: Coordinate with EU Natura 2000 sites, WFD and HD programmes and other relevant policies and programmes to ensure that cormorant management contributes to the protection of biodiversity.	all	Year 6-8			
37) **Harmonize policies and legislation:** Align the CMP with other regional policies and legislative changes within Europe (such as the Bern Convention, AEWA, Birds Directive, HD, and WFD) and national policies to ensure consistent and effective management measures.	4, 6, 7	Year 6-8			

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Annex 1: Acronyms and abbreviations

AEWA	Agreement on the Conservation of African-Eurasian Migratory Waterbirds
CC	Compliance Committee
CMP	Cormorant Management Plan
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CMAG	Cormorant Management Advisory Group
CORMAN	EU Project: Sustainable Management of Cormorant Populations https://tinyurl.com/y7vpcy6p http://cormorants.freehostia.com/
CSO	Civil Society Organization
EAA	European Angling Alliance
EBBA	European Breeding Birds Atlas
EC	European Commission
EIFAAC	European Inland Fisheries and Aquaculture Advisory Commission
EMFAF	European Maritime, Fisheries and Aquaculture Fund
EP	European Parliament
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FEAP	Federation of European Aquaculture Producers
FRAP	Development of a procedural framework for action plans to reconcile the conflict between large vertebrate conservation and the use of biological resources: fisheries and fish-eating vertebrates as a model case. https://www.ufz.de/index.php?en=36309
HD	Habitats Directive (EU Directive on the conservation of natural habitats and of wild fauna and flora)
INTERCAFE	EU COST Action Project: Interdisciplinary Initiative to Reduce pan-European Cormorant-Fisheries Conflicts. https://www.ceh.ac.uk/our-science/projects/intercafe#:~:text=The%20main%20objective%20of%20INTERCAFE,Europe%20and%20to%20deliver%20a (http://cormorants.freehostia.com/)
INTERCAFE TOOLBOX	Russell, I., Broughton, B., Keller, T. and Carss, D.N. (2012). The INTERCAFE Cormorant Management Toolbox: methods for reducing cormorant problems at European fisheries. INTERCAFE COST Action 635 Final Report III (ISBN 978-1-906698-09-6).
IUCN	International Union for Nature Conservation
MS	Member State
NGO	Non-Government Organization
REDCAFE	EU FP5 Concerted Action Project: Reducing the conflict between cormorants and fisheries on a pan-European scale https://www.ceh.ac.uk/our-science/projects/intercafe-information#:~:text=REDCAFE,European%20Union's%20Framework%20Five%20Programme.
WFD	Water Framework Directive (EU framework for community action in the field of water policy)

Annex 2: Timeline of interventions on the cormorant-fish conflict

Year	Event	Responsible / Reference
1979	Birds Directive	European Commission
1994	Development of an Action Plan for the Great Cormorant in the African-Eurasian Region. Recommendation 04.01. ADOPTED	UNEP/CMS https://www.cms.int/en/meeting/fourth-meeting-conference-parties-cms
1994/95	EU Directives on the protection of cormorants and herons ;MEP question & COM answer,	https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C:1995:024:FULL
1996	Cormorants And Human Interests Workshop towards an International Conservation and Management Plan for the Great Cormorant (*Phalacrocorax carbo*)	van Dam C. and Asbirk S. (Eds.). 1997 - National Reference Centre for Nature Management, Wageningen, The Netherlands. 152 pp.
1996	Demonstration in Strasbourg 5-10,000 people. Le Monde « Les pêcheurs déclarent la guerre aux cormorans sur les bords du Rhin »	Fishing and aquaculture interests
1997	Development of an Action Plan for the Great Cormorant in the African-Eurasian Region. Denmark and the Netherlands declared they were willing to take the initiative for the preparation of an action plan for the great cormorant	UNEP/CMS https://www.cms.int/en/document/development-action-plan-great-cormorant-african-eurasian-region
1997	Opinion of the Committee of the Regions on 'The immediate measures which need to be taken to counter the damage caused by cormorants in the European regions'	Committee of the Regions https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:51997IR0028&from=FR
1997	Removal of cormorant from Annex I	EU-Commission https://ec.europa.eu/commission/presscorner/detail/ro/ip_97_718
2001	REDCAFE: EU FP5 Concerted Action Project: Reducing the conflict between cormorants and fisheries on a pan-European scale.	DG Environment https://www.ceh.ac.uk/our-science/projects/intercafe-information#:~:text=REDCAFE,European%20Union's%20Framework%20Five%20Programme
2001	International Symposium on Interaction between fish and birds: implications for management. (3 - 6 April 2001)	Organized by the Hull International Fisheries Institute, University of Hull, in collaboration with EIFAC. Cowx I.G. (2003) *Interactions between Birds and Fish: Implications for Management*. Oxford: Fishing News Books Blackwell Science, 374 pp.
2002	GRAND CORMORAN conference (12-13 March 2002)	France
2002	Cormorant event/meeting	Hunting Intergroup EU-Parliament
2003	A statement on cormorants	EU Council of Ministers (fisheries),

2003	INTERCAFE -project EU COST Action Project: Interdisciplinary Initiative to Reduce pan-European Cormorant-Fisheries Conflicts. INTERCAFE - Interdisciplinary Initiative to Reduce pan-European Cormorant-Fishery Conflicts, (2004-2008, 60 partners, 2012). European Science Foundation/EU RTD Framework Programme, COST Action (635).	https://www.ceh.ac.uk/our-science/projects/intercafe#:~:text=The%20main%20objective%20of%20INTERCAFE,Europe%20and%20to%20deliver%20a (http://cormorants.freehostia.com/
2003	FRAP project: Development of a Procedural Framework for Action Plans to Reconcile Conflicts between Large Vertebrate Conservation and the Use of Biological Resources: Fisheries and Fish-eating Vertebrates as a Model Case	DG-Research https://www.ufz.de/index.php?en=36309
2004	"Review of international policy and practice for the management of native species conflicts"	DG-Environment
2007	Cormorant event (23 May 2007)	Hunting Intergroup EU-Parliament
2007	EIFAC Workshop on a European Cormorant Management Plan. Bonn, Germany, (20-21 November, 2007	EIFAC Occasional Paper No. 41. https://www.fao.org/4/i0210e/i0210e00.htm
2008	European Parliament resolution of 4 December 2008 on the adoption of a European Cormorant Management Plan to minimise the increasing impact of cormorants on fish stocks, fishing and aquaculture (2008/2177(INI))	EU-Parliament: EUR-Lex - 52008IP0583 - EN - EUR-Lex
2008	Resolution on a Pan-European management plan for the control of cormorants – 2 July	Advisory Committee on Fisheries and Aquaculture (ACFA) https://maritime-forum.ec.europa.eu/document/download/f64d062c-1ed1-4f57-ab48-7ce8b2444f49_en?filename=Answ%20DG%20ENV%20187956.pdf
2008	Kindermann report adopted 4 December	Report on the adoption of a European Cormorant Management Plan to minimise increasing impact of cormorants on fish stocks, fishing and aquaculture (2008/2177(INI)) Committee on Fisheries, European Parliament (A6-0434/2008
2009	17-18 January Cormorant count	Wetlands Cormorant Research Group
2009	Follow-up to the European Parliament resolution on the adoption of a European Cormorant Management Plan to minimise the increasing impact of cormorants on fish stocks, fishing and aquaculture	EU-Commission
2009	Cormorant seminar – Commission and stakeholders, 31 March	EU-Commission

2009	Speech by Commissioner Joe Borg at the Fisheries Council, Luxembourg, 23 June	Commissioner Joe Borg
2009	EU-guide for use of §9-derogation (final version in 2010)	EU-Commission
2010	CORMAN: EU project "Sustainable Management of Cormorant Populations" (2011-2014)	Consortium Partnership Aarhus University – DCE Danish Centre for Environment and Energy with UK Centre for Ecology & Hydrology. https://tinyurl.com/y7vpcy6p
2011	France presented a note demanding that the Commission establish a management plan for cormorant populations	France http://register.consilium.europa.eu/pdf/en/11/st11/st11532.en11.pdf
2013	Between Fisheries and Bird Conservation: The Cormorant Conflict Report to European Parliament Directorate General for Internal Policies Policy Department B: Structural and Cohesion Policies, Fisheries	Cowx I.G. 2013 https://www.europarl.europa.eu/RegData/etudes/note/join/2013/495845/IPOL-PECH_NT(2013)495845_EN.pdf
2013	EU guide for applying great cormorant derogations under article 9 of the birds directive 2009/147/EC.	European Commission: Directorate-General for Environment and N2K Group EEIG, *Great cormorant – Applying derogations under article 9 of the birds directive 2009/147/EC*, Publications Office,2013, https://data.europa.eu/doi/10.2779/56719
2016	Answer on cormorant plan given by Mr Vella on behalf of the Commission:	EU-Commission https://www.europarl.europa.eu/doceo/document/E-8-2016-004736-ASW_EN.html
2018	European Parliament resolution of 12 June 2018 on towards a sustainable and competitive European aquaculture sector: current status and future challenges (2017/2118(INI))	EU-Parliament: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=oj:JOC_2020_028_R_0004
2021	Aquaculture Advisory Council: Recommendation on Freshwater Aquaculture and Wildlife	https://aac-europe.org/wp-content/uploads/2021/06/AAC_Recommendation_-_Ecosystem_Services_2021_08_revised2.pdf
2021	Commissioner Sinkevičius' answer on the European great cormorant population	EU-Commission https://www.europarl.europa.eu/doceo/document/E-9-2021-001534-ASW_EN.html
2022	European Parliament resolution of 4 October 2022 on striving for a sustainable and competitive EU aquaculture: the way forward (2021/2189(INI))	EU-Parliament: https://www.europarl.europa.eu/doceo/document/TA-9-2022-0334_EN.html
2022	**EU Council** approved Conclusions on aquaculture strategic guidelines state in Point 10 that "*cormorants…have become a considerable challenge*" and urge "*the*	https://data.consilium.europa.eu/doc/document/ST-11496-2022-INIT/en/pdf

	Commission to timely identify effective and efficient EU-wide management measures to prevent or reduce the damage caused by predators".	
2022	EIFAAC Resolution EIFAAC/31/2022/3 "On the protection of vulnerable and endangered fish species from unsustainable predation from cormorants" including the need for a CMP	FAO/EIFAAC https://openknowledge.fao.org/handle/20.500.14283/cd2886en
2022	Aquaculture Advisory Council: Recommendation on predation by birds in relation with shellfish farming.	https://aac-europe.org/wp-content/uploads/2022/03/10.AAC_Recommendation_-_Freshwater_aquaculture_and_wildlife_2022_10.pdf
2024	FAO-European Commission Trust Fund project on 'Developing Europe-wide management advice to protect vulnerable and endangered fish species from unsustainable predation by cormorants" (GCP/RER/069/EC).	DG Mare/EIFAAC European Maritime, Fisheries and Aquaculture Fund (EMFAF) financed within its work programme for 2024–2025. Projects - Ongoing projects | EIFAAC | FAO
2024	ProtectFish EU Horizon Project: Researching management solutions for fish, birds and people.	DG Research https://protectfish.eu/
2024	EIFAAC Workshop on management advice for reducing the impact of cormorant predation on fish and fisheries. Pula, Croatia, 8 October 2024	EIFAAC: https://www.fao.org/fishery/en/meeting/41469. Report available at: https://openknowledge.fao.org/items/9a7bd657-f7a4-4c86-a372-bfdf55f726ba
2024	BSAC Workshop on predators in the Baltic (seals, cormorants) second edition, Helsinki, Finland, 30 October 2024	BSAC: https://www.bsac.dk/wp-content/uploads/2024/06/BSACworkshoponpredators_Helsinki_30102024_final-report.pdf
2025	NSAC/BSAC Workshop on predators (seals & cormorants) – Lulea, Sweden, 20 March 2025	NSAC/BSAC: https://www.nsrac.org/projects/nsac-bsac-workshop-on-predators-seals-cormorants-20-march-2025-lulea-sweden/
2025	Stakeholder consultation on the draft European cormorant management plan, Rome, virtual, 25 April 2025	EIFAAC https://www.fao.org/fishery/en/meeting/41503
2025	Conference on management advice to reduce cormorant predation impacts, Brussels/virtual, 3 June 2025	Polish Presidency to the European Council & EIFAAC https://www.fao.org/fishery/en/meeting/41505
2025	Letter to the European Commission by Members of the European Parliament: Call for an EU-wide management strategy for the Great Cormorant while maintaining its favourable conservation status – a long overdue necessity. 3 July 2025	The letter is available at the EAA website: https://www.eaa-europe.org/news/18452/10-meps-call-in-open-letter-to-eu-commission-for-a-coordinated-eu-strategy-on-cormorant-predation-management.html

Annex 3: Overview of measures to reduce impact of cormorants on fisheries and aquaculture

Measure and objective	Efficacy and acceptability
Lethal measures to reduce cormorant numbers directly	
• Active removal of adult breeding birds or overwintering birds from the population. • Shooting at site-specific or local levels under Article 9 derogation. • Coordinated culling for population control at a national level at a national level.	• Response to localised culling short-lived and bird numbers recover to pre-treatment levels over a period of a few weeks. • Shooting adults also helps reduce cormorant predation pressure through harassment of remaining birds. • To be effective in the longer term, culling needs to be repeated at frequent intervals and coordinated across European distribution range. • Culling birds at roosts near aquaculture ponds or on the ponds is likely to create only short-term respite and push birds into other areas where they might become a problem. • Local reductions on the non-breeding grounds have marginal impact at a continental scale, and the problem will recur in the next season when new wintering birds appear.
Reducing reproductive success	
• Egg destruction, for example by oiling [*spraying eggs with inert mineral or vegetable oil*] and egg pricking.	• The benefits of egg oiling over destroying eggs are that cormorants continue to incubate the eggs and are less likely to attempt to re-nest. • Reduces the number of hatchlings. • Takes a minimum of two years before there is noticeable reduction in population numbers. • Expensive and time consuming to carry out and difficult to access many roosts, especially in trees. Drones can improve effectiveness.
• Destruction of nests and breeding habitat.	• Nests or trees used for nesting can be removed or physically broken up with the hope that adult birds will either leave the area, or fail to rebuild or re-nest successfully that season. • Nest destruction is labour intensive, although can be practical on smaller colony sites. • Requires more than one visit per colony as birds are known to re-nest and lay additional eggs if nests and eggs are destroyed (time consuming). • Constrained by factors such as adverse environmental or amenity impacts and influenced by the availability of alternative roosting sites.

Scaring cormorants away from fisheries or aquaculture units	
• Auditory deterrents: automatic exploders, pop-up scarecrows with exploders, pyrotechnics, alarm or distress calls. • Visual deterrents: laser guns, reflecting tapes, eyespot balloons, scarecrows, lights, water spray devices. • Aerial harassment with ultralight aircraft, radio-controlled model airplanes; ground harassment with vehicle patrols. • Chemical [conditioned taste aversion] deterrents.	• Can discourage cormorants from using specific sites. • For harassment to be effective, a variety of techniques should be used in combination, and the location and combination of devices should be changed frequently for best results. • Roost dispersal may move predating birds from the target area but pass on the problem to other fisheries and aquaculture units. • Measures only have an effective range up to 200 m so of little use on river systems or larger sites. • Cormorants learn quickly and these methods often do not deter the birds for extended periods of time. • Use of scaring devices may be constrained where there are risks of disturbing other wildlife or human habituation.
Exclusion techniques	
• Netting enclosures using nets, wires, floating plastic balls. • Facility design and construction.	• Nets provide a physical barrier and are effective if the edges of the nets extend to the ground surrounding the pond. • Difficult to implement over large pond areas and rivers. • Costs may be prohibitive for large ponds. • Overhead wire systems function by making it difficult for cormorants to land on, and take off from, ponds. Although these systems are effective at preventing large flocks from landing, individual birds often learn to fly between the lines, or land on levies and walk into the pond despite the wires. • Success of both wire systems and floating ropes depends on the availability of alternative foraging areas nearby. • Construction of pond margins and bottom profile, location of fingerling ponds, and feeding techniques may lessen damage marginally.
Habitat modification techniques to reduce availability of fish to cormorants	
• Elimination of resting or roosting places. • Elimination of nests. • Improving habitat quality for fish. • Construction of artificial fish refuges.	• Fish refuges can reduce fish losses, foraging efficiency of cormorants and incidence of damage to fish. • Practical constraints regarding the use of refuge structures in rivers and larger still-waters

	(especially those that are also used for water sports). • Causes obstructions and snagging to anglers but also increases flooding risk in large rivers.
Fish stock management techniques to reduce availability of fish to cormorants	
• Increase the size of individuals stocked, regulation of stocking density. • Alter stocking strategy [timing of stocking, frequency and location of stocking]. • Use of buffer species to divert cormorants from predating on valuable species.	• Reduces depredation on small-sized individuals but can increase scarring and wounding of larger individuals. • Not always feasible because of availability of stock. • Increases cost of stocking.
No control	
• Allows species abundance and interrelationships to become regulated based on predator prey interactions.	• Cormorant population will continue to expand and exacerbate conflict. • Outcry from stakeholders and businesses affected by cormorant predation. • May not be acceptable where survival of endangered fish and other aquatic species are at risk, especially from cormorant damage.

Source: table adapted from Cowx, 2013.

Annex 4: Cormorant management framework structure

Cormorant Management Advisory Group (CMAG)

1. The Cormorant Management Advisory group (CMAG) will be responsible for providing scientific, ecological, social and economic advice relating to the management of cormorants in Europe, as well as support the implementation of the adaptive (multiannual) European Management Plan for the Great Cormorant.

2. The CMAG Terms of Reference are to:

a) Develop standardized methods and guidelines to assist European countries in their data collection and reporting in relation to the implementation of the CMP;
b) Collect and assess information provided by European countries, relevant organizations, institutions or programmes on cormorant management efforts, and other data relevant to measuring the impact of the cormorants on aquatic biodiversity, fisheries and aquaculture;
c) Collate and assess information on the status and trends of the great cormorant population, ecosystems and fisheries-related human components, using the appropriate indicators and in relation to agreed management, biological, and/or conservation reference points;
d) Provide independent advice on a technical and scientific basis to facilitate the adoption and implementation of measures concerning the sustainable management of great cormorants and the assessment of biological, ecological, social and economic implications under different management scenarios;
e) Report annually, through the secretariat, to the European Commission and EIFAAC on recommendations concerning conservation, management and research on cormorants, including consensus, majority and minority views.

3. Composition of the CMAG

The CMAG will be composed of scientists officially nominated by the European countries, and observers from international and European stakeholder organizations.

Each European country shall have the right to appoint a representative and an alternate, if needed, both with suitable scientific qualifications, who may be accompanied by experts and advisers.

Members and the Secretariat may invite experts, in their individual capacity, to enhance and broaden the expertise of the CMAG.

The European countries and observers shall finance the participation of their representatives, alternates, experts and advisers to the CMAG meetings.

~~Compliance Committee~~

~~1. The Compliance Committee (CC) will be responsible for reviewing the individual compliance by European countries with the European Management Plan for the Great Cormorant, and its agreed management measures.~~

~~2. The Compliance Committee Terms of Reference are:~~

a) assess, based on all available information, compliance by European countries, and relevant institutions with the measures of the CMP;
b) request clarifications and express concern to European countries and relevant institutions in cases of non-compliance with the agreed measures in the CMP;
c) submit, through the secretariat, to the attention of the European Commission cases in which countries and relevant institutions are not compliant with the agreed measures of the plan, cases in which activities undermine the effectiveness of the CMP;
d) provide additional information, as it considers appropriate or as may be requested by the European Commission and EIFAAC, relating to the implementation and compliance with measures in the CMP;
e) monitor and evaluate the CMP, and formally propose adaptations to the CMP for consideration by the European Commission and EIFAAC;
f) provide independent institutional and legal advice and submit bi-annual reports to the Commission to facilitate the adoption of adaptations to the CMP.

3. Composition of the Compliance Committee

The Compliance Committee shall be composed of one representative and one alternate of each European country. Experts and stakeholder organizations can be invited as observers.

The European countries shall finance the participation of their representatives and/or alternates to the Compliance Committee meetings.

Secretariat

1. The Secretariat will be responsible for the official communications related to the implementation, review, evaluation and adaptation of the European Management Plan for the Great Cormorant, coordination with countries, international and regional stakeholders, and reporting to the European Parliament, European Commission and EIFAAC.

2. The Secretariat Terms of Reference are:

a) receive and transmit the official communications regarding the CMP;
b) maintain contacts with government officials, international and regional organizations concerned with the conservation and management of cormorants and fish and other aquatic species that are impacted by cormorant predations, to facilitate consultation and cooperation on all matters pertaining to the objectives of the CMP,
c) facilitate the preparation and implementation of the CMP, prepare budgets and ensure timely reporting to the European Commission, EP and EIFAAC;
d) participate in the formulation of proposals regarding the budget, the CMP and related activities;
e) stimulate interest among European countries and potential donors in the implementation of the CMP and in possible financing or in implementing cooperative projects and complementary activities;
f) promote, facilitate, and monitor the development and maintain the Cormorant Information Platform and regional databases on ecological, social

and economic information related to the population of cormorants and impacts on fish, fisheries and aquaculture;

g) coordinate and technically support the research, awareness raising and capacity building programmes in support of implementation of the CMP, when required;
h) organize meetings of the CMAG and Compliance Committee and other related ad hoc meetings;
i) prepare, or arrange for the preparation of, background documents and papers and report annually on the implementation of the CMP to the European Commission, EP and EIFAAC, and arrange for the subsequent publication of the annual reports;
j) perform any other function, as may be required by the European Commission, EP and/or EIFAAC.

3. The Secretariat shall be composed of:

1. An Executive Secretary – responsible for implementation of policies and activities related to the CMP and reporting to the European Commission, EP and EIFAAC.
2. A Research and Capacity building officer – responsible for database maintenance and management and facilitation of research, awareness raising and capacity building on the CMP.
3. An administrative assistant – responsible for administrative and operational support related to implementation of the CMP.

Appendix 3. Effectiveness of the North American cormorant management plans

1. Introduction

Cormorant management plans in North America have been implemented to address conflicts between Double-crested Cormorants (*Phalacrocorax auritus*) and human interests, particularly fisheries, aquaculture, and habitat conservation. The effectiveness of these plans is highly context-dependent, varying by management method, ecological setting, and stakeholder objectives. Non-lethal spatial management in urban areas, such as Toronto, has successfully reduced tree damage while maintaining cormorant populations (McDonald et al., 2018). Lethal controls, including culling and egg oiling, have shown local effectiveness in reducing population growth and mitigating specific resource impacts, but their long-term and large-scale efficacy is limited by density-dependent factors and immigration from unmanaged colonies (Guillaumet et al., 2014; Coleman, 2008; Bédard et al., 1995; Strickland et al., 2011). Modeling studies suggest that coordinated, early, and targeted management can improve efficiency, but such optimization is rarely achieved in practice (Guillaumet et al., 2012). There is ongoing debate about the ecological justification for widespread cormorant control, with some studies highlighting a lack of robust evidence linking cormorant abundance to major fishery declines, especially in large systems like the Great Lakes (Ludwig et al., 2023; Wires & Cuthbert, 2006; Ovegård et al., 2021; Cooke, 2021). Additionally, management actions can have unintended consequences for co-nesting waterbirds and broader ecosystem dynamics (Wyman et al., 2018; Seefelt, 2018). Overall, while cormorant management can achieve specific local objectives, its broader effectiveness and ecological justification remain contested, underscoring the need for adaptive, evidence-based, and multi-species approaches (Guillaumet et al., 2014; Ludwig et al., 2023; Dorr et al., 2022; Cooke, 2021).

2. Methods

A comprehensive literature review was conducted using Consensus, which aggregates over 170 million research papers from sources including Semantic Scholar and PubMed. The search strategy involved 20 targeted queries across 8 search groups, focusing on management effectiveness, ecological impacts, stakeholder perspectives, and modelling approaches. In total, 1,024 papers were identified, 558 were screened, 268 were deemed eligible, and 50 were included in this review.

Eight unique search groups were used to capture the breadth of research on cormorant management effectiveness in North America.

The results were reviewed for accuracy by the staff of Wetlands International Europe.

3. Results

3.1 Management Approaches and Local Effectiveness

Non-lethal management, such as spatial deterrence and habitat modification, has been effective in specific contexts. For example, in Toronto, targeted deterrence prevented the expansion of tree-nesting colonies and shifted birds to less damaging ground-nesting, reducing tree mortality while supporting a thriving cormorant population (McDonald et al., 2018; Taylor et al., 2011). Lethal controls (culling, egg oiling, nest destruction) have reduced local population growth rates and resource impacts, especially when combined, but their effects are often temporary and can be offset by immigration from nearby colonies or density-dependent population responses (Guillaumet et al., 2014; Coleman, 2008; Bédard et al., 1995; Strickland et al., 2011).

3.2 Population Dynamics and Modelling

Long-term studies and modelling indicate that management actions can have cumulative effects on local population growth, particularly when applied early and in central colonies. However, lack of coordination and optimisation across regions limits overall effectiveness (Guillaumet et al., 2014; Guillaumet et al., 2012). Density-dependent factors and high mobility of cormorants often undermine sustained population reductions, and metapopulation dynamics play a significant role in recolonisation and recruitment (Guillaumet et al., 2014; Guillaumet et al., 2012; Kimble et al., 2020).

3.3 Ecological and Multi-Species Impacts

The impact of cormorant management on fisheries is complex and often overstated. Meta-analyses and regional studies show limited evidence that cormorant predation is a primary driver of fish population declines in large systems like the Great Lakes, where other factors (e.g., invasive species, habitat change) are more influential (Ludwig et al., 2023; Wires & Cuthbert, 2006; Ovegård et al., 2021; Cooke, 2021). Management actions can also affect co-nesting waterbirds, with some species declining in managed areas and others remaining unaffected or benefiting, highlighting the need for multi-species management considerations (Wyman et al., 2018; Seefelt, 2018).

3.4 Social, Economic, and Policy Considerations

Stakeholder conflicts and social perceptions strongly influence management decisions. Some management plans are driven more by social and political pressures than by ecological necessity, and there is a disconnect between science-based recommendations and actual policy implementation in some regions (Wires, 2017; Ludwig et al., 2023; Dorr et al., 2022; Cooke, 2021). Economic analyses suggest that the costs and benefits of management actions are not always rigorously assessed, and long-term data on population dynamics and ecosystem impacts are often lacking (Ludwig et al., 2023; Cooke, 2021).

4. Discussion

The research on cormorant management in North America reveals a nuanced picture. Localised management—both lethal and non-lethal—can be effective in achieving specific objectives, such as reducing tree damage or temporarily lowering cormorant numbers at targeted sites (McDonald et al., 2018; Guillaumet et al., 2014; Coleman, 2008; Farquhar et al., 2012; Strickland et al., 2011). However, the broader effectiveness of these plans is limited by ecological complexity, density-dependent population dynamics, and the high mobility of cormorants, which often lead to recolonisation and population rebounds (Guillaumet et al., 2014; Guillaumet et al., 2012; Kimble et al., 2020).

There is a significant disconnect between the perceived need for widespread cormorant control and the actual ecological evidence supporting such actions. Many studies and reviews argue that cormorant predation is not the primary driver of fish population declines in large systems, and that management actions are often justified more by social and political pressures than by robust scientific evidence (Ludwig et al., 2023; Wires & Cuthbert, 2006; Ovegård et al., 2021; Cooke, 2021). Furthermore, management can have unintended negative impacts on co-nesting waterbirds and broader ecosystem processes, underscoring the need for multi-species and adaptive management frameworks (Wyman et al., 2018; Seefelt, 2018).

The quality of research varies, with some long-term, multi-site studies and modelling efforts providing strong evidence for the limited and context-dependent effectiveness of management, while other studies highlight significant knowledge gaps, especially regarding long-term population dynamics and ecosystem impacts (Guillaumet et al., 2014; Guillaumet et al., 2012; Ludwig et al., 2023; Dorr et al., 2022; Cooke, 2021). Adaptive management, improved coordination, and evidence-based policy are recommended to enhance the effectiveness and ecological justification of future cormorant management plans.

5. Conclusion

In summary, cormorant management plans in North America can be effective for specific, localized objectives, but their broader ecological effectiveness and justification are limited by complex population dynamics, ecological interactions, and social factors. Adaptive, evidence-based, and multi-species approaches are needed to improve future management outcomes.

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DYNAMICS OF GREAT CORMORANT POPULATION IN EUROPE

Final report

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Conducted for DG Environment,
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Under Service Contract
N° 070307/2013/657707/ETU/B3

CormoDist

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DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

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Conducted for DG Environment, European Commission
Under Service Contract N° 070307/2013/6577079/ETU/B3

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Content

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Within the project itself, we would like to express our gratitude to all those who were involved at various stages of this work, in particular K. T. Pedersen, S. Volponi, J. Sterup, A. D. Fox, F. Korner-Nievergelt, E. Køhler, J. Kotzerka and J. Lynch. We thank EURING, the European ringing centres and the key ringers of cormorants in the various countries who allowed us to use the data on ringing recoveries. We would also like to acknowledge the contribution of the ringing centres who found the time to collaborate with us in preparing the country-by-country data sets.

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In relation to estimating the compositions of the wintering populations, this work would not have been possible without access to the results of counts of breeding populations. This information was provided by individual countries and with the help from the IUCN/Wetlands International Cormorant Research Group.

We thank the CorMan Project Stakeholder Liaison Group for their hard work in agreeing and writing ‘A review of the issues relating to control of cormorant populations at the pan-European level’ (available on the EC Cormorant Platform) and from which text was lifted for chapter 7 of this report.

Ultimately though, the success of our ability in describing the migration and distribution patterns of the cormorants in Europe was entirely dependent on an army of highly motivated professionals and volunteers in the field who were willing to ring more than 200,000 cormorant chicks. Finally, we hope that, like us, they can appreciate their invaluable contribution as they contemplate the results of this project and what must be the best overall picture to date of European cormorant migration and distribution patterns that they helped us to produce. We look forward to making some of the many results publical available through various publications.

1 Introduction

1.1 Background

In most European regions, increasing 'populations' of the Great Cormorant, particularly the continental race or sub-species *Phalacrocorax carbo sinensis*, are creating human-wildlife conflicts across the European community. A variety of fishery stakeholders throughout Europe have experienced adverse effects of the species' fish consumption and its ability to quickly locate fish that are easily accessible. The repeated occurrence of conflicts between cormorants and commercial fisheries, aquaculture and angling interests necessitates strategic guidance on how to reduce the perceived damage caused by these birds.

In the process of developing appropriate management approaches, it has become evident that knowledge about the migration patterns and population dynamics of the *sinensis* sub-species is essential for the process of developing sound strategies to reduce conflicts. It has, for example, become clear that a firmer knowledge base is needed to assess the likelihood of reducing damage by implementing local or regional regulation of cormorant numbers, or whether controls on even larger geographical scales could at all be effective in reducing damage to various types of fisheries. The scientific basis for such decision making would be improved by identifying how cormorants distribute themselves outside the breeding season and how external factors influence their distributional patterns.

The European Commission takes the issue seriously and took the initiative with the following pair of actions:

- It developed a non-binding guidance document that explores the possibilities provided by Article 9 of the EU Birds Directive regarding its application.
- It hired Aarhus University and the NERC Centre for Ecology & Hydrology as a contractor to (a) disseminate relevant information about cormorants through a website hosted by DG Environment under the European Commission (the so-called 'EU Cormorant Platform'), and (b) organise counts of cormorants in Europe during the breeding season and in winter.

The second of these tasks was undertaken within a DG-Environment Service Contract project entitled 'Sustainable Management of Cormorant Populations' – which was later given the acronym 'CorMan'.

It became evident during the CorMan project that there was a need for more knowledge about the migration patterns of the *sinensis* sub-species of Great Cormorants in Europe. Such knowledge was judged essential for better understanding migratory connectivity and of relevance for future evaluation of the pros and cons of various management options for dealing with the conflicts. As a consequence this issue was mentioned during discussions between the CorMan project coordinators and DG-Environment.

Building on these gaps in knowledge, a tender for a project dealing with this and other issues was announced by DG-Environment in March 2013. The project was entitled 'Dynamics of the Great Cormorant population in Europe'. Following an evaluation of applications the bid from Aarhus University in Denmark was chosen and after a contract was signed in August 2013, the project started in the end of September 2013.

Initially the project was planned to last for one year but after the first 6 months of the project we realized that far more time was needed in order to collate all relevant data and conduct quality checks of recoveries. This process was both very time consuming and involved a lot of communication and waiting time to give ringing centres and key cormorant ringers time to assist us with the required clearing of various data issues. As a result, DG-Environment allowed the project to be extended until late 2015.

As contractors we decided to give the project the acronym 'CormoDist'.

1.2 The CormoDist project and its aims

The CormoDist project has been led by Aarhus University but other institutions, researchers and key cormorant ringers have been involved to varying extents.

The major focus of the CormoDist project has been on using recoveries of dead ringed Great Cormorants in order (1) to identify where cormorants from specific breeding areas spend their winter, (2) to quantify the composition of wintering populations in terms of their breeding origin and (3) to explore whether there have been changes over time in migration patterns and in the geographical origin of the cormorants present in the different wintering areas.

The project has only dealt with the continental sub-species *Ph. c. sinensis* mainly because the majority of the conflicts with cormorants in Europe are with this sub-species .

More specifically the tender material specified that the contractor should:

1. Provide an overview of where cormorants from different breeding populations occur in Europe during autumn and in winter (see '1' in Fig. 1.2.1).
2. Determine the geographical origin of the cormorants occurring in the various Member States by quantifying the proportion originating from the different sections of the northern breeding range (see '2' in Fig. 1.2.1).
3. Estimate the proportions of autumn staging and wintering cormorants that rely for foraging on natural wetlands and in artificial commercial fisheries (i.e. aquaculture).
4. Formulate the most likely viable strategic options to deal with the often highly conflict-ridden cormorant-fisheries interactions at local, regional, and European levels.
5. Present results, disseminate information and provide advice in the form of reports and participation in meetings.

The above description of tasks represents a summarised version of the tasks listed in the Tender Specifications.

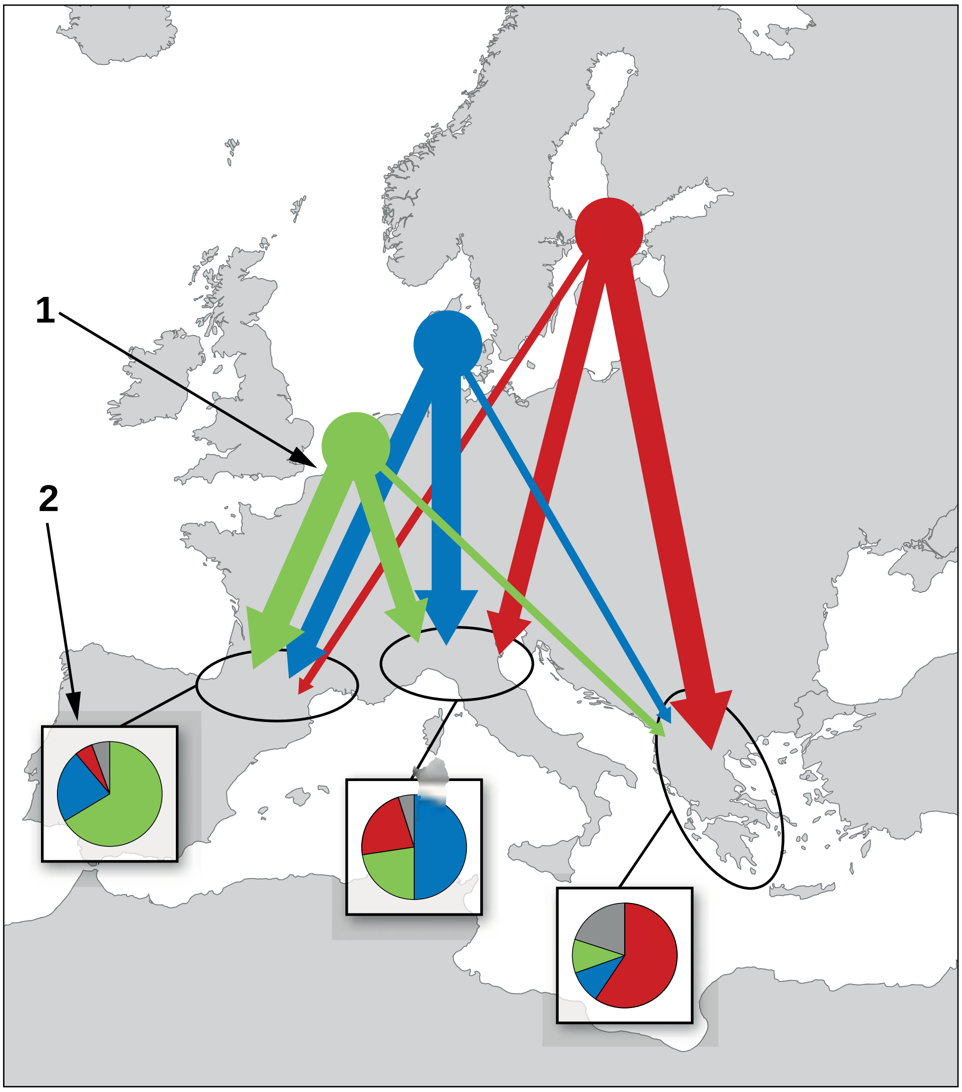


Fig. 1.2.1. Schematic figure illustrating a theoretical example of migratory connectivity between breeding and wintering areas. The number '1' refers to the estimation of the proportion of birds migrating from specific breeding areas to various wintering areas, and the number '2' refers to the estimation of the composition of the winter population in different parts of Europe with respect to the geographical origin of the birds present in winter.

1.3 The current report

This report is the final report to DG Environment within the European Commission. It describes the material used, the methods applied, the main results and discusses some of the implications of the results for future management of cormorant-fisheries conflicts in the European Union.

More specifically this report focuses on:

- Project management and activities
- Descriptions of migration patterns of cormorants from different sectors of the European breeding range including documentation of how the cormorants are distributed during post-breeding and in autumn and winter.

- Descriptions of changes in migration patterns and identification of some of the factors affecting where individual cormorants are wintering.
- Presentations of outputs from a newly developed model which has been used for estimating the proportion of birds migrating to different wintering areas and to quantify the composition of the various wintering populations with respect to their breeding origin.
- Discussions of pros and cons of various strategies for management of conflicts and cormorant numbers at different geographical levels.

A short discussion and a few concluding remarks are given at the end of the report before offering a list of references cited in this text.

Cormorants roosting below the Alps in Austria, March 2015. The Alps constitute a barrier for the cormorants during autumn and spring migration. Photo: C. Noebauer©.

2 Project organisation and management

2.1 Organisation of project

The project was managed by the National Centre for Environment and Energy and the Department of Bioscience, Aarhus University, Denmark.

The project team consisted of three employees from Aarhus University and four sub-contractors being D. N. Carss (NERC, Centre for Ecology & Hydrology, United Kingdom), K. T. Pedersen (Bird IT, Denmark), S. Volponi (Istituto Superiore per la Protezione e la Ricerca Ambientale, Italy), J. Lynch (JL Nature, Denmark) and J. Sterup (Denmark). A. D. Fox was involved in the project as a controller of the quality of the research on behalf of the Department of Bioscience at Aarhus University. The project's major collaborators from outside the project were F. Korner-Nievergelt (Swiss Ornithological Institute), EURING and several national ringing centres.

For the purposes of increasing the quality of the interpretation of the results from the project, Aarhus University established a working group consisting of relevant cormorant researchers from IUCN/Wetlands International Cormorant Research Group. These researchers contributed to the project by participating in four meetings as well as through direct contact with the project leader. The cormorant experts from the IUCN/Wetlands International Cormorant Research Group were M. R. van Eerden, S. Rijn, L. Marion, R. Parz-Gollner and J.-Y. Paquet.

The overall management of the project was handled by the project leader, Thomas Bregnballe. The collation of data and the quality checks were handled by K. T. Pedersen, T. Bregnballe, J. Lynch, S. Volponi, J. Sterup and M. Frederiksen. The descriptive handling of migration patterns and factors affecting this was carried out by T. Bregnballe and E. Køhler. The development and use of the model applied for the work on migratory connectivity and quantification of the compositions of wintering populations was carried out by M. Frederiksen, F. Korner-Nievergelt and T. Bregnballe. The discussions of the implications of the projects results for future management options were led by D. Carss, T. Bregnballe, M. Frederiksen and involved input from the cormorant experts from the IUCN/Wetlands International Cormorant Research Group.

2.2 Management and communication

The overall management of the project was handled by the project leader Thomas Bregnballe but Morten Frederiksen and later on also Dave Carss participated in discussions of various issues related to decisions that had to be taken.

Careful management effort was invested to ensure engagement by all team members from the start of the project, to make sure all were aware of their roles and the expectations placed upon them, why they were undertaking the tasks assigned, how they fitted into the overall project (and its expected outcomes) and their specific goals and deadlines. Particular emphasis was placed on managing the inevitable changes and delays that occurred during the course of the project. The team and DG Environment were kept informed to ensure that all were aware of these changes, their causes and their consequences for the work plans.

Participants in the meeting between some of the team members and researchers from the IUCN/Wetlands International Cormorant Research Group at Sandbjerg in October 2015. The persons are from left to rigth: M. R. van Eerden (representative of the IUCN/ Wetlands International Cormorant Research Group), S. Volponi (subcontractor), D. N. Carss, T. Bregnballe (project leader), M. Frederiksen (behind; ..), J. Y. Paquet (middle; ..), L. Marion (behind; ..) and Stef van Rijn (in front; ..). The photographer Rosemarie Parz-Gollner is missing from the photo.

The project leader administrated the project through direct contact with the team members and the individual subcontractors.

During the project the team members communicated with each other at meetings and by e-mail, telephone and Skype.

Specific management was required when dealing with the ringing centres and the key cormorant ringers in Europe. Thus there were several important issues to deal with in relation to such issues as data ownership, handling of mistakes, analysis and publication.

2.3 Publicising of the project and its results

The publicising of the project, its aims and results was mainly through:

- Hundreds of e-mails to persons, institutions and organisations known to have an interest in cormorants and ringing.
- A description of the project on the IUCN/Wetlands International Cormorant Research Group home page which is used by persons interested in cormorants.
- A description of the project published in the Cormorant Research Newsletter, February 2015.
- Two oral presentations in April 2014 at the 9th International Conference on Cormorants and at the 7th Meeting of IUCN/Wetlands International, Osijek, Croatia.
- An oral presentation in October 2014 for the ORNIS Commitee, Brussels, Belgium.

- An oral presentation in October 2015 for the NADEG Commitee, Brussels, Belgium.
- Articles presenting preliminary results from the CormoDist project in the Cormorant Research Group Bulletin, May 2015: "Migration patterns and distribution outside the breeding season of Great Cormorants" and "Movements, distribution and ecology of cormorants outside the breeding season: Gaps in current knowledge".

Work on publishing the results from the project in the form of reports and scientific papers is currently in progress.

Ringing of cormorant chicks is particularly demanding in tree-nesting colonies.
Photo: F. Möllers.

3 Material and methods

3.1 Collation of data and current knowledge

The outcomes of this project depended to a very large extent on the analysis and interpretation of data that had already been collected but not collated and analysed. The collation of recovery data and subsequent organisation and quality control of these constituted a major task for the project. The building of the best possible data set was given extremely high priority and took more than a year partly due to extensive variation in how data were originally organised and due to the demand associated with detecting and correcting mistakes in the information connected to each recovery.

In our working towards answering the focal questions, we not only worked with raw data, but also with an extensive amount of information that has been produced over the last 30 years about spatiotemporal variation in cormorant numbers throughout Europe, the species' behaviour and the species' ecology. We initiated collation of existing knowledge about cormorants and their population dynamics early in the project to ensure that the relevant knowledge would be available to us when analysing data, interpreting results and writing up conclusions.

We contacted the European Union for Bird Ringing (EURING), national ringing centres and selected key cormorant ringers in order:

- to inform them about the project
- to invite them to collaborate and maybe co-author scientific papers
- to request delivery of their data on the numbers of cormorants ringed and the recoveries that had been generated.

We established connections with IUCN-Wetlands International and their Cormorant Research Group and the EC project 'CorMan' as well as with national key institutions and researchers in order:

- to inform them about the project
- to ensure access to the best possible data that exist on annual numbers of cormorants breeding
- to benefit from existing knowledge about the behaviour and ecology of cormorants.

We informed ringing centres in all European countries and the key cormorant researchers about the purpose of the project, and we asked for permission to use information from the recovery data gathered through their ringing activities.

Collating all the relevant information and conducting quality checks of data required time and resources. To reduce the risk of delays with these tasks, we used three subcontractors, all of which had experience in handling data and communicating with data owners.

The following sections describe the types of data and information we collated and how we procured and organised these.

3.2 Organisation of ringing and recovery data

For the description of the migration patterns and winter distribution and for the quantification of migratory connectivity we collated recovery information for cormorants of the sub-species *Ph. c. sinensis* ringed as chicks in Europe, including the Russian part of the Gulf of Finland.

We gained access to data on recoveries in two ways. Firstly we wrote to all relevant ringing centres and key cormorant ringers in Europe, Ukraine and parts of Russia. Secondly we wrote to the European Union for Bird Ringing (EURING). In line with the standard procedure for EURING they also contacted the relevant countries that had provided data for the EURING database and asked these for permission to pass on extracts from their database to the CormoDist project.

In the project we constructed our own database containing recovery information. For each recovery we stored information about:

- location of ringing and recovery site (names of location/colony, EURING province code, geographical coordinates etc.)
- date of ringing and date of recovery
- exact or approximate age when ringed
- condition of the bird when found (e.g. whether the bird had died recently or had been long dead)
- finding circumstances and/or cause of death (e.g. drowned in fishing gear, shot, unknown etc.)
- whether or not the bird was ringed with a colour-ring besides a metal-ring (this may influence the probability of recording the presence of rings on cormorants found dead).

The recovery data were then subject to quality control, including checks for mistakes in the dates given for ringing and recoveries and in the recovery location coordinates.

The European Union for Bird Ringing (EURING) does not store information about the number of cormorant chicks ringed in any one colony in a given year. We therefore needed to go back to the individual ringing centres and in some cases to the original ringers to get this information.

The database we constructed was updated whenever we received new information. For most countries we were only able to procure information on numbers ringed at the national level and not at the level of individual colonies.

3.3 The study area and its division into breeding and wintering areas

Priority was given to assess the patterns of migration of breeding populations in countries from where Great Cormorants migrate to EU Member States. Furthermore it was decided to focus on cormorants belonging to the continental sub-species *Ph. c. sinensis* breeding in northern and western Europe. Thus based on published material and a preliminary analysis of migration routes from different parts of the breeding range we found that:

- Great Cormorants of the Atlantic sub-species *Ph. c. carbo* breeding in United Kingdom and Norway constitute a very small proportion of the cormorants wintering in inland areas on the mainland of Europe (e.g. Coulson & Brazendale 1968, Mogstad & Røv 1997, Fonteneau & Marion 2005). Furthermore, it turned out to be difficult to get access to the recovery data of cormorants ringed in United Kingdom.

- A very low number of cormorants had been ringed in the southeastern countries in Europe such as Albania, Romania, Bulgaria and Greece.
- Only a small proportion of the cormorants breeding in Ukraine migrated to the EU Member States Romania, Bulgaria and Greece (Koshelev et al. 1997, Kostiushyn et al. 2011).

As a consequence of the above decisions on how to define the outer borders of the study area, we excluded the breeding populations in Ireland, United Kingdom, central and northern Norway, the Russian Federation (except Kaliningrad and the Russian part of the Gulf of Finland), southeastern Europe and Ukraine.

We further divided the breeding range of the *sinensis* sub-species within the study area into a sub-set of 12 areas (Fig. 3.3.1, Table 3.3.1). Most breeding areas were defined as individual countries but some countries were allocated to the same group as one or more of their neighbours. Countries were grouped for one or more of the following reasons: 1) the cormorants from the neighbouring countries were likely to have the same migration pattern, 2) a fairly low number of cormorants had been ringed in the individual countries, 3) the breeding population in one or more of the countries was fairly small.

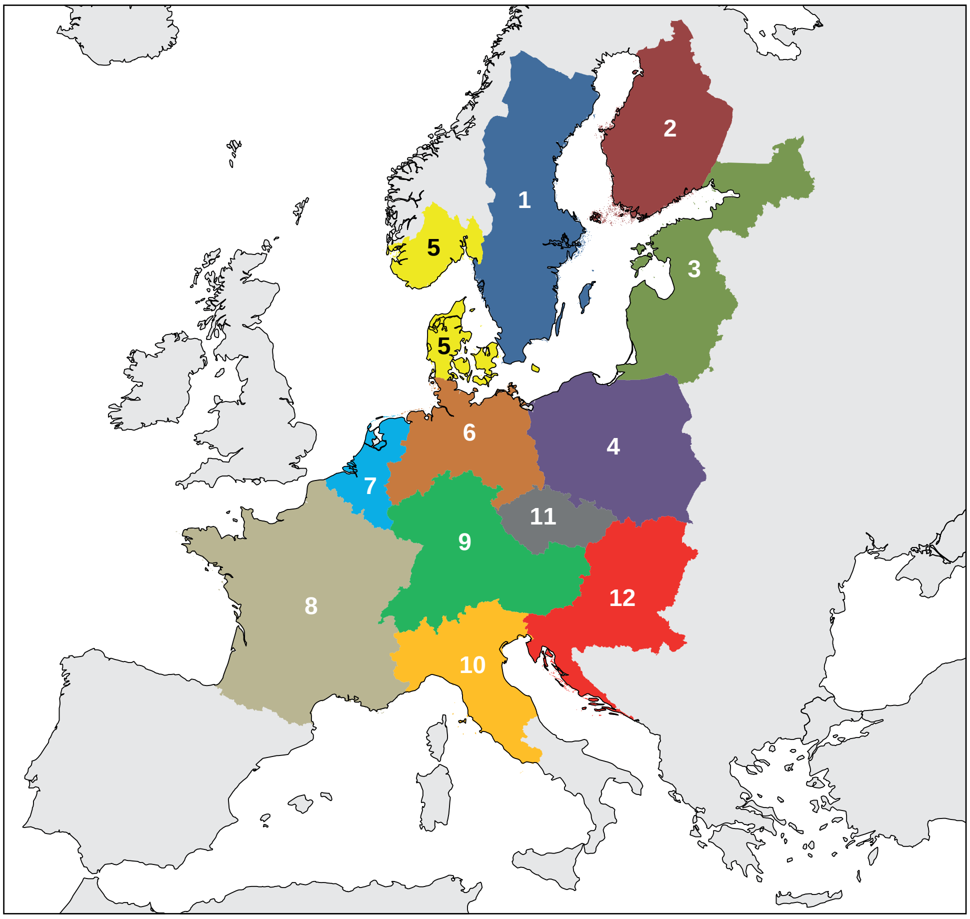


Figure 3.3.1. Delineation of the 12 defined breeding areas in Europe. The countries and areas included in each of the defined breeding areas are listed in Table 3.3.1.

Table 3.3.1. The countries and areas included in each of the defined breeding areas. See also Fig. 3.3.1.

Area No.	Name of area used in the report	Countries and areas included
1	Sweden	Sweden
2	Finland	Finland
3	East Baltic	Russian part of the Gulf of Finland, Estonia, Latvia, Lithuania and Kaliningrad
4	Poland	Poland
5	Denmark	Denmark and Norway (only south Norway where the breeders belong to the *sinensis* sub-species)
6	Germany	Germany
7	The Netherlands and Belgium	The Netherlands and Belgium
8	France	France
9	Switzerland	Switzerland and Austria
10	Italy	Italy
11	Czech Republic	Czech Republic
12	Croatia and Hungary	Croatia, Hungary and a small part of Serbia

We also divided the wintering area used by the European breeding population of *sinensis* into 11 wintering areas (Fig. 3.3.2, Table 3.3.2). In our definition of the wintering areas we attempted to take the following circumstances into account:

- For the reporting of results it would be useful to define staging and wintering areas as individual countries as far as this seemed reasonable.
- The number of cormorants occurring in the area in winter should not be too small compared with the other wintering areas.
- The composition of the wintering population with respect to the geographical origin of the individuals present in the area should not vary extensively within the defined wintering area. Since the cormorants from the northern breeding areas tend to migrate in a southwestern direction (see chapter 4), we found it wise to split Germany and Austria and lump individual provinces in these countries with neighbouring countries.

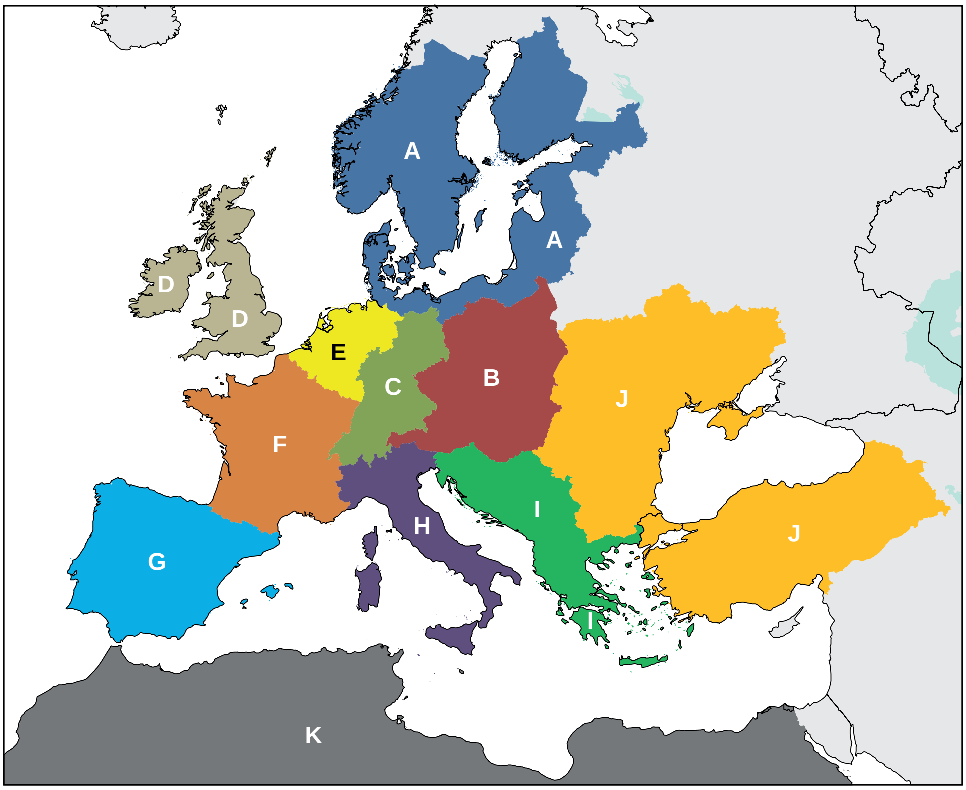


Figure 3.3.2. Delineation of the 11 defined wintering areas in Europe. The countries and areas included in each of the defined wintering areas are listed in Table 3.3.2.

Table 3.3.2. The countries and provinces included in each of the defined wintering areas.

Area No.	Name of area used in the report	Countries and areas included
A	Baltic Sea	Norway (central and south), Sweden (central and south), Finland (central and south), Russia (Gulf of Finland), Estonia, Latvia, Lithuania, Kaliningrad, Poland (along Baltic Sea), Germany (Schleswig-Holstein, Mecklenburg-Vorpommern) and Denmark
B	Central East	Poland (central and south), Czech Republic, Slovakia, Hungary, Austria (central and east)
C	Switzerland and Germany	Switzerland, Germany (except N and NW Germany), Austria west and Liechtenstein
D	United Kingdom	United Kingdom and Ireland
E	The Netherlands and Belgium	The Netherlands, Belgium, Germany (Niedersachsen, Nordrhein-Westfalen, Rheinland-Pfalz and Saarland) and Luxembourg
F	France	France
G	Spain and Portugal	Spain and Portugal
H	Italy	Italy including Corsica
I	Balkan	Slovenia, Croatia, Bosnia, Serbia, Montenegro, Macedonia, Albania and Greece
J	Black Sea	Ukraine, Romania, Bulgaria and Turkey
K	North Africa	North Africa and Malta

3.4 Ringing activity

For the description of migration patterns and distribution during late summer, autumn and winter, we included recoveries made between 1983 and 2013 of birds ringed between 1974 and 2013. Only in a few countries had ringing been undertaken place during the 1970s. The birds ringed during 1974-1979 contributed only 65 of all 11,062 recoveries included, and 56 of these recoveries were of cormorants ringed in Denmark. The birds ringed during 1980-1982 comprised 175 of all 11,062 recoveries, of which 165 had been ringed in Denmark. The remaining birds for which we have recoveries were ringed during 1983-2013.

For the analyses of migratory connectivity, we only included recoveries of birds ringed between 1983 and 2013.

There were large differences among the countries in the number of Great Cormorants ringed, and the effort invested in ringing varied among years in all countries. The annual number of cormorant chicks ringed in the 12 defined breeding areas is shown in Fig. 3.4.1. In none of the countries did the number of chicks ringed follow the development of the breeding populations.

Within the breeding areas the ringing activity was not limited to one, or just a few, breeding colonies but took place in several or many different colonies. Nonetheless, in most of the breeding areas the effort invested in ringing was particularly high in a rather limited number of colonies. An example of such variation is given in Table 3.4.1.

Great Cormorants are able to save energy during migration and foraging flights by gliding on thermal wind. Photo: C. M. Olsen.

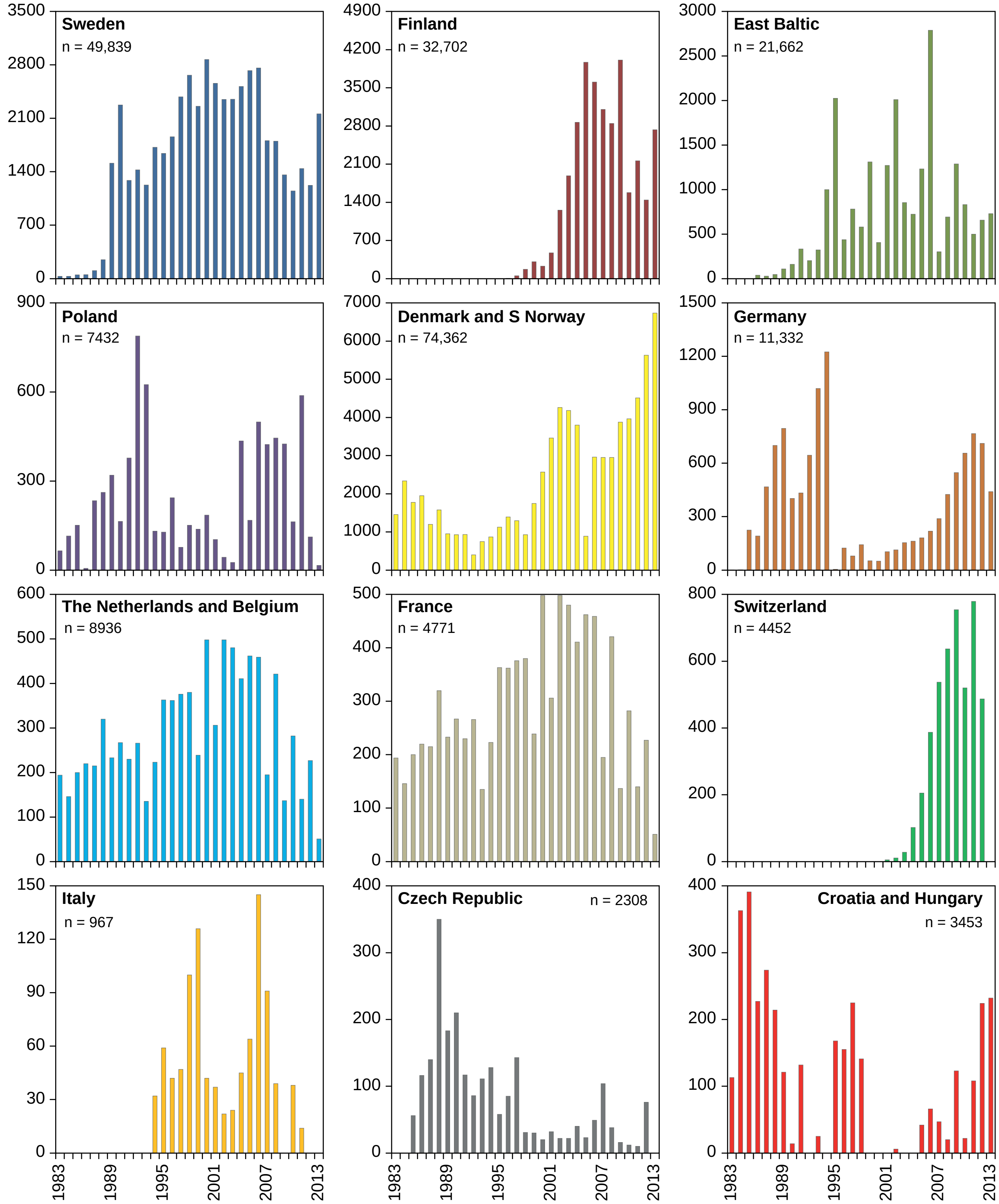


Figure 3.4.1. The annual number of cormorant chicks ringed in the 12 breeding areas. Note that the y-axes have been drawn to different scales.

Table 3.4.1. The number of cormorant chicks ringed in 31 breeding colonies in Denmark during 1974-2013. The colonies are listed in order of declining numbers of chicks ringed within each of the six regions in Denmark.

Region within Denmark	Colony	Numbers
West Jutland and Limfjorden	Rønland Sandø	2667
	Havrvig Polde	1206
	Agger Tange	1056
	Rotholmene	645
	Melsig	635
	Fjandø	357
	Klægbanken	18
	Vårholm	13
Northern Kattegat	Hirsholmene	5752
	Toftesø	2174
	Rønholm	101
	Havnø	72
SW Kattegat	Vorsø	13,903
	Mågeøerne	7666
	Stavns Fjord	4315
	Hindsholm	221
	Svanegrund	171
Little Belt and South Funen	Brændegård Sø	6471
	Bastholm	159
	Kidholmene	131
	Bågø	27
Northern Zealand	Saltbækvig	451
	Øer ved Orø	403
SE Denmark	Tyreholm	11,808
	Malurtholm	3621
	Rågø	2872
	Vensholm	2556
	Nakskov Fjord	1929
	Dyrefod	1469
	Ormø	478

3.5 Recoveries: seasons, sample sizes and finding circumstances

3.5.1 Seasons and sample sizes

The migration patterns and the distributions during late summer, autumn and winter was described by including recoveries made between 1st July and 28th February. For this work we defined the seasons as follows:

- Late summer/post-breeding: 1st July – 31st August.
- Autumn: 1st September – 30th November
- Winter: 1st December – 28th February

The number of recoveries that were available from the different time periods between late summer and winter are given in Table 3.5.1 for each of the 12 breeding areas. For some of the breeding areas the recoveries extended from the first season 1983/84 to the last season 2013/14 whereas for others, recoveries were only available from 10 of the seasons (Table 3.5.2 and 3.5.3).

For the analyses of migratory connectivity, we only included recoveries made in the winters between 1983/84 and 2013/14, and for these analyses the winter was defined as extending from 15th November to 28th February. The sample sizes for the analyses of migratory connectivity are given in Appendix 5.1.

Table 3.5.1. The number of ringed Great Cormorants from the 12 breeding areas recovered in total during post-breeding (July-August), autumn (September-November) and in winter (December-February) over the seasons between 1983/84-2013/14. This data set was used for the preparation of the Kernel plots presented in chapter 4.

No.	Breeding area	Jul.-Aug.	Sep.	Oct.	Nov.	Dec.-Feb.	Total
1	Sweden	473	337	348	316	980	2454
2	Finland	116	102	170	145	479	1012
3	East Baltic	117	118	156	127	296	814
4	Poland	132	55	54	34	75	350
5	Denmark and South Norway	1225	619	619	538	1720	4721
6	Germany	195	103	72	52	184	606
7	The Netherlands and Belgium	222	71	47	56	169	565
8	France	28	10	13	11	42	104
9	Switzerland and Austria	5	6	15	14	62	102
10	Italy	3		2	7	9	21
11	Czech Republic	52	24	44	18	19	157
12	Croatia, Hungary and Slovakia	61	21	27	12	35	156

Table 3.5.2. Numbers of ringed Great Cormorants from the six breeding areas along the Baltic Sea recovered dead during each of the seasons (July-February) between 1983/84 and 2013/14.

Season	Sweden	Finland	East Baltic	Poland	Denmark	Germany
1983/84	3	0	0	8	161	1
1984/85	6	0	0	12	271	2
1985/86	7	0	0	16	199	10
1986/87	1	0	0	4	244	22
1987/88	9	0	0	23	160	28
1988/89	18	0	0	35	192	44
1989/90	81	0	5	24	148	50
1990/91	103	0	3	9	84	32
1991/92	70	0	3	15	77	30
1992/93	80	0	4	16	61	22
1993/94	83	0	14	20	97	52
1994/95	79	0	49	13	56	44
1995/96	76	0	86	8	80	10
1996/97	126	0	23	14	145	22
1997/98	118	3	25	7	64	11
1998/99	114	6	20	5	49	14
1999/00	109	6	18	4	96	12
2000/01	134	6	14	5	179	7
2001/02	121	12	25	6	202	5
2002/03	135	35	63	2	211	12
2003/04	102	43	31	3	247	5
2004/05	130	88	59	19	187	7
2005/06	112	116	41	6	92	8
2006/07	115	96	91	20	127	4
2007/08	88	102	32	11	150	4
2008/09	109	104	34	14	142	21
2009/10	83	151	48	10	192	27
2010/11	81	68	32	5	144	30
2011/12	56	73	39	10	162	28
2012/13	50	58	24	4	228	25
2013/14	51	44	24	2	208	15

Table 3.5.3. Numbers of ringed Great Cormorants from the two breeding areas along the Atlantic coast (the Netherlands/Belgium and France) and the four breeding areas in central Europe and the Adriatic recovered dead during each of the seasons (July-February) between 1983/84 and 2013/14.

Season	The Netherlands	France	Switzerland	Italy	Czech Republic	Croatia & Hungary
1983/84	14	0	0	0	0	6
1984/85	11	1	0	0	0	6
1985/86	13	0	0	0	3	20
1986/87	9	0	0	0	2	14
1987/88	21	0	0	0	4	13
1988/89	26	0	0	0	13	22
1989/90	10	1	0	0	15	11
1990/91	22	9	0	0	18	3
1991/92	21	2	0	0	6	3
1992/93	23	2	0	0	5	1
1993/94	18	3	0	0	13	1
1994/95	20	3	0	0	3	0
1995/96	24	7	0	0	5	3
1996/97	24	1	0	1	3	7
1997/98	20	2	0	0	3	18
1998/99	25	0	0	1	7	4
1999/00	21	4	0	4	4	1
2000/01	21	5	0	1	2	2
2001/02	17	0	0	0	2	0
2002/03	35	7	0	0	7	0
2003/04	17	4	0	0	2	0
2004/05	31	6	2	0	4	8
2005/06	19	7	3	1	4	1
2006/07	21	7	8	2	9	2
2007/08	10	6	10	3	10	1
2008/09	23	8	12	4	7	0
2009/10	9	5	11	0	1	0
2010/11	11	3	13	3	1	3
2011/12	12	4	23	1	0	1
2012/13	12	5	17	0	4	3
2013/14	5	2	3	0	0	1

3.5.2 Geographical origin of the individuals recovered

In all the defined breeding areas ringing has been carried out in several or even in many different colonies. This meant that the birds recovered in late summer, autumn or winter where not just birds originating from one or a few breeding colonies. The geographical spread of the ringed cormorants that were later recovered during late summer, autumn or winter is illustrated in Figs 3.5.1-3.5.4.

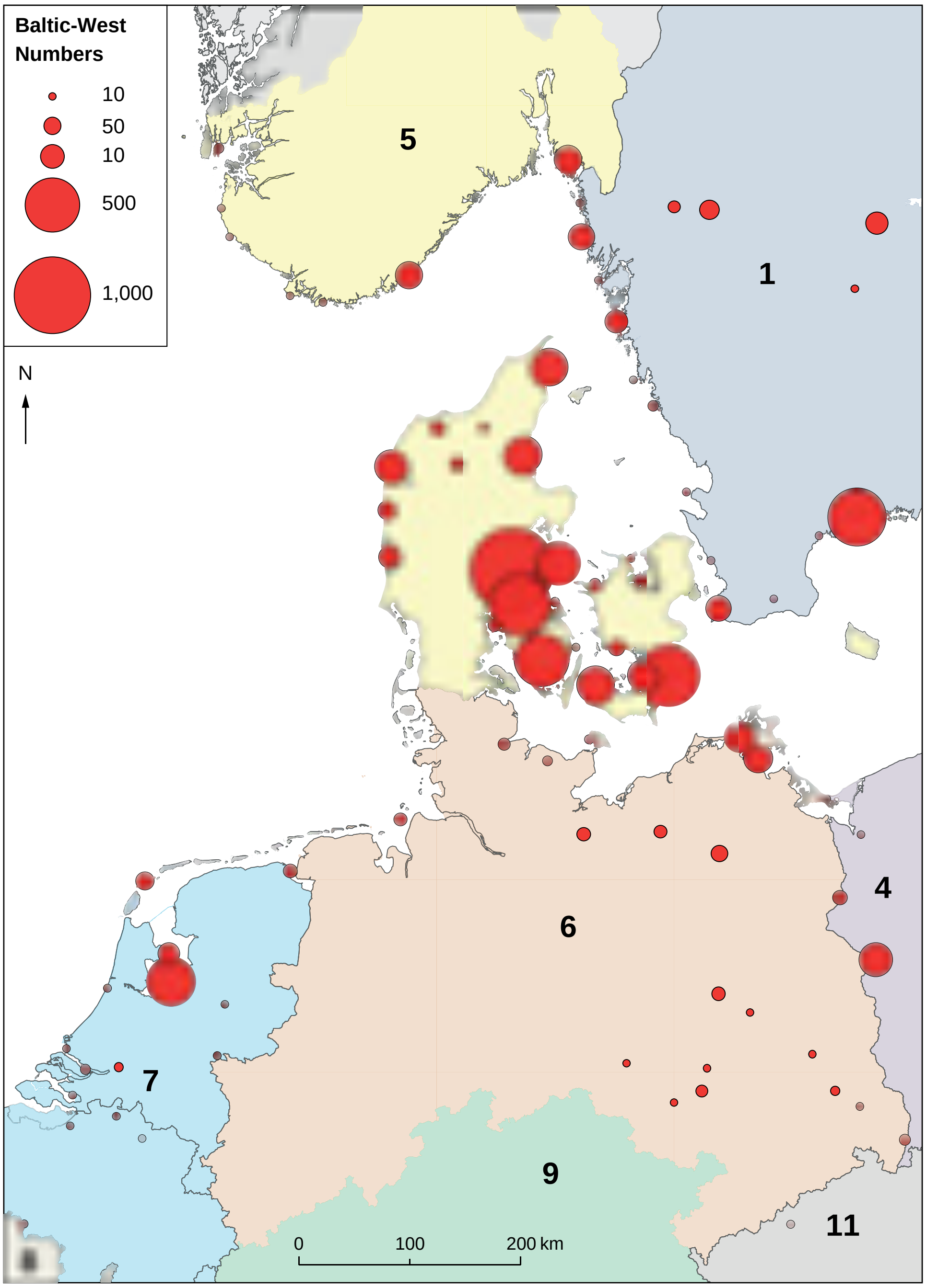


Figure 3.5.1. Location of the sites where Great Cormorants were ringed as chicks in the western part of the Baltic Sea and for which recoveries have been included in the present analysis. The size of each circle reflects the number of recovered birds that originated from the sites shown. Data from ringing sites located within 10 km distance were pooled.

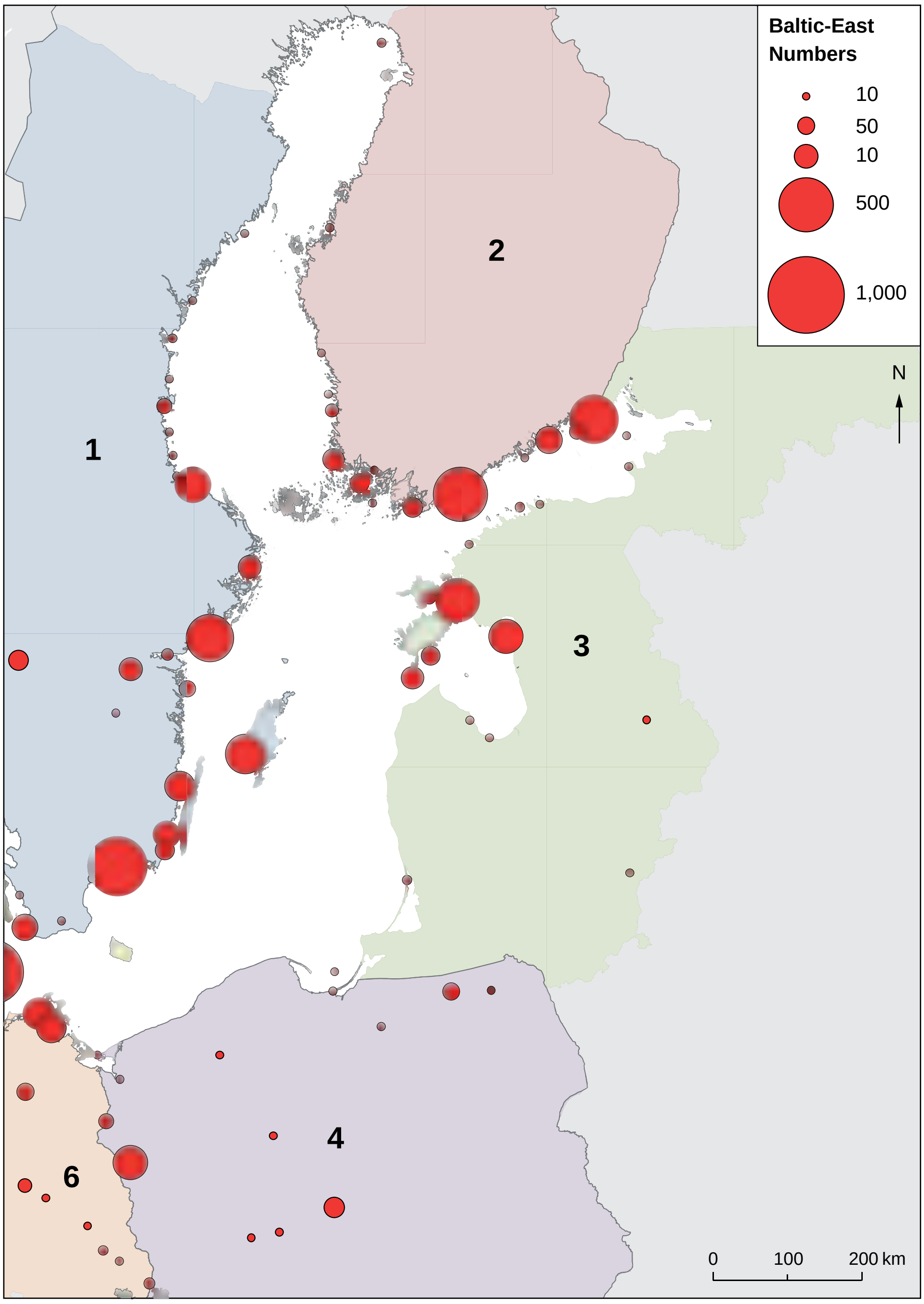


Figure 3.5.2. Location of the sites where Great Cormorants were ringed as chicks in the eastern part of the Baltic Sea and for which recoveries have been included in the present analysis. The size of each circle reflects the number of recovered birds that originated from the sites shown. Data from ringing sites located within 10 km distance were pooled.

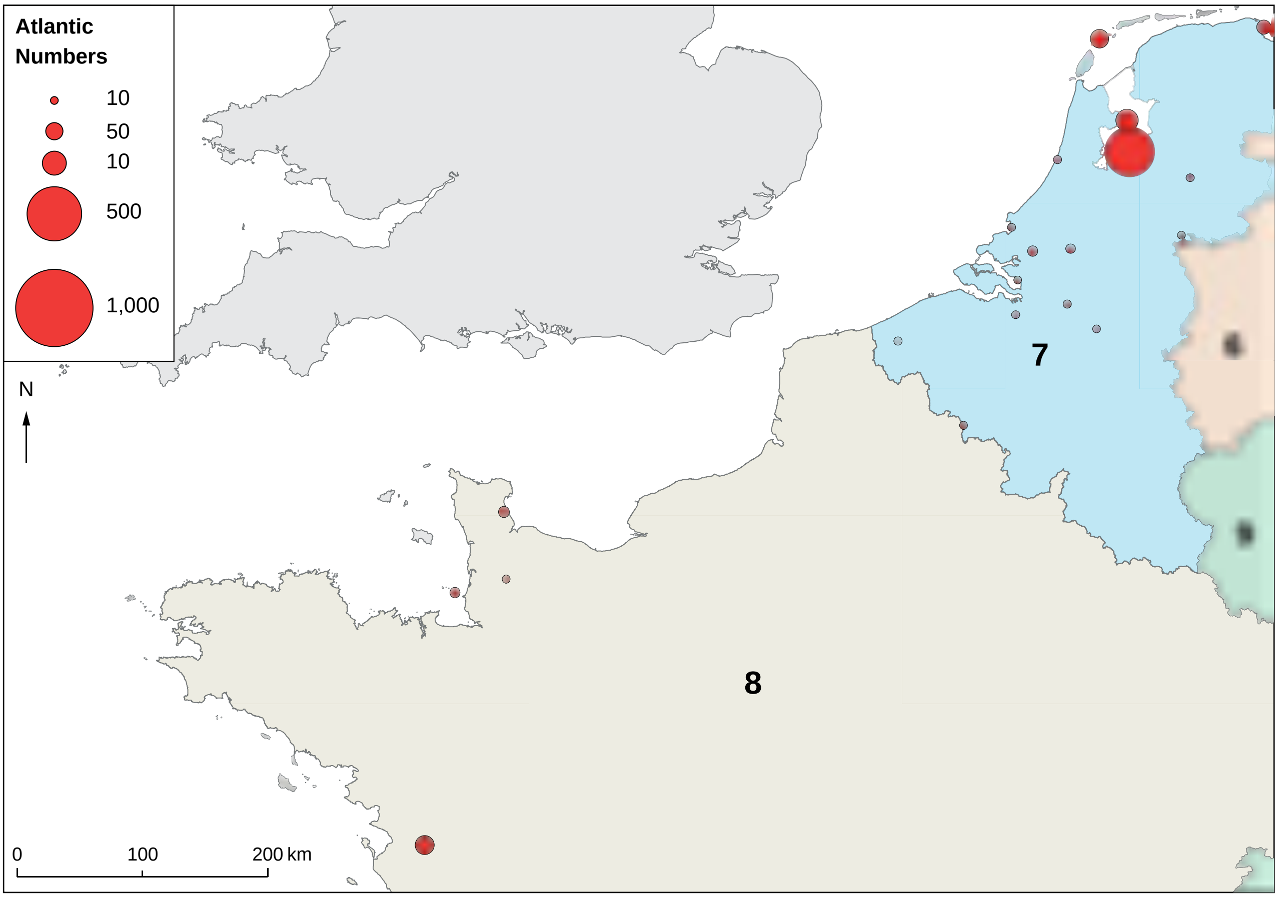


Figure 3.5.3. Location of the sites where Great Cormorants were ringed as chicks in the Netherlands, Belgium and France for which recoveries have been included in the present analysis. The size of each circle reflects the number of recovered birds that originated from the sites shown. Data from ringing sites located within 10 km distance were pooled.

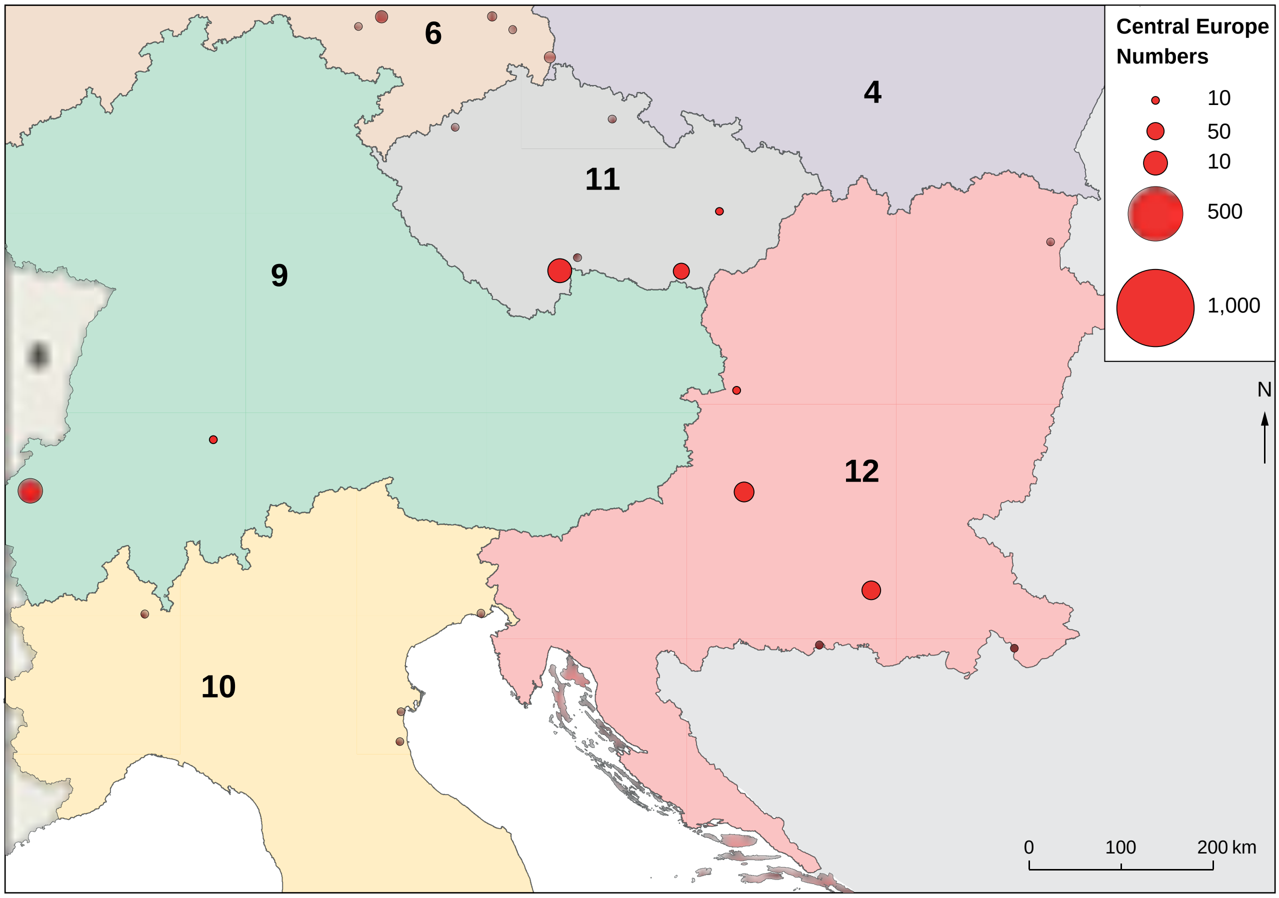


Figure 3.5.4. Location of the sites where Great Cormorants were ringed as chicks in Switzerland, Austria, northern Italy, Czech Republic, Slovakia, Hungary and Croatia for which recoveries have been included in the present analysis. The size of each circle reflects the number of recovered birds that originated from the sites shown. Data from ringing sites located within 10 km distance were pooled.

3.5.3 Recovery circumstances

There were many different circumstances under which ringed cormorants were recovered but some types of circumstances were far more common than others. There was fairly large variation among staging and wintering areas in the probability that a ringed cormorant would be recovered and reported because it had been shot, had drowned in fishing gear or had died for other reasons (Tables 3.5.4-3.5.6).

This variation affected the frequency with which birds from different breeding areas were reported dead due to for example shooting or drowning in fishing gear (Table 3.5.7, see also Bregnballe 1999). Thus birds from different breeding areas used – to some extent – different staging and wintering areas where the risks of dying for various reasons were unequal (Tables 3.5.4-3.5.6).

Table 3.5.4. The circumstances at which individuals ringed were found, given as the percentage of those recovered during the post-breeding period (July-August) for four regions in Europe. Only including regions where the number of recoveries exceeded 100. 'N' denotes the total number of recoveries included from the region.

	Proportion (%) of recoveries				
Area	**Shot**	**Drowned**	**Other**	**Unknown**	**N**
A Baltic Sea and S Norway	10	44.1	9.9	35.9	1971
B Central East	65.6	8.1	2.5	23.8	160
C Switzerland and Germany	51.1	11.3	9.0	28.6	133
E The Netherlands, Belgium, Germany	1.6	8.0	24.0	66.4	250

Table 3.5.5. The circumstances at which individuals ringed were found, given as the percentage of those recovered during Autumn (1 September-15 November) for six regions in Europe. Only including regions where the number of recoveries exceeded 100. 'N' denotes the total number of recoveries included from the region.

	Proportion (%) of recoveries				
Area	**Shot**	**Drowned**	**Other**	**Unknown**	**N**
A Baltic Sea and S Norway	21.5	43.7	4.8	30	2093
B Central East	80	3.1	3.1	13.8	420
C Switzerland and Germany	56.9	11.5	7.3	24.2	260
E The Netherlands, Belgium, Germany	6.0	21.1	15.9	56.9	232
F France	55.1	3.5	6.6	34.8	423
H Italy	25.6	7.7	7.7	59.0	117

Table 3.5.6. The circumstances at which individuals ringed were found, given as the percentage of those recovered during winter (16 November–28 February) for nine regions in Europe. Only including regions where the number of recoveries exceeded 100. 'N' denotes the total number of recoveries included from the region.

	Proportion (%) of recoveries				
Area	**Shot**	**Drowned**	**Other**	**Unknown**	**N**
A Baltic Sea and S Norway	14.0	28.4	13.1	44.5	764
B Central East	61.0	5.3	6.0	27.7	282
C Switzerland and Germany	62.7	12.8	4.3	20.3	611
E The Netherlands, Belgium, Germany	10.9	8.7	19.9	60.5	357
F France	66.8	2.8	4.3	26.1	1317
G Spain and Portugal	22.1	19.9	12.5	45.4	271
H Italy	42.9	9.1	4.3	43.7	462
I Balkan	46.2	14.2	3.2	36.4	253
K North Africa	27.2	9.7	16.0	47.0	268

Table 3.5.7. Circumstances at which ringed Great Cormorants were reported dead given as the proportion (%) of all recoveries of cormorants coming from the different breeding areas. Proportions are given for each of the following three time-periods of the year: post-breeding period (July-August), autumn (1 September–15 November) and winter (16 November-28 February). Breeding areas and seasons are only included if the number of recoveries exceeded 40.

			Proportion (%) of recoveries			
Breeding area		**Number of recoveries**	**Shot**	**Drowned**	**Other**	**Unknown**
Sweden						
	Post-breeding	473	15.4	41.4	11.2	31.9
	Autumn	874	33.4	32.8	5.9	27.8
	Winter	1107	46.3	11.4	8.9	33.4
Finland						
	Post-breeding	116	16.4	25.9	18.1	39.7
	Autumn	362	42.3	25.4	5.5	26.8
	Winter	534	54.1	8.8	5.2	31.8
East Baltic						
	Post-breeding	117	27.4	34.2	6.8	31.6
	Autumn	336	42.3	22.9	5.1	29.8
	Winter	361	46.5	16.1	5.3	32.1
Poland						
	Post-breeding	132	59.1	22.0	3.8	15.2
	Autumn	133	71.4	17.3	0.8	10.5
	Winter	85	47.1	18.8	11.8	22.4
Denmark and South Norway						
	Post-breeding	1225	7.3	42.6	9.8	40.2
	Autumn	1531	29.5	30.7	5.9	33.9
	Winter	1965	40.7	12.2	9.0	38.2
Germany						
	Post-breeding	195	19.5	36.9	3.1	40.5
	Autumn	206	22.3	33.0	5.8	38.8
	Winter	205	41.5	11.7	6.3	40.5
The Netherlands and Belgium						
	Post-breeding	222	3.2	13.1	24.3	59.5
	Autumn	148	20.3	21.6	12.8	45.3
	Winter	195	36.9	5.6	12.3	45.1
France						
	Winter	47	29.8	2.1	12.8	55.3
Switzerland						
	Winter	68	38.2	25.0	5.9	30.9
Czech Republic						
	Post-breeding	52	90.4	1.9	3.8	3.8
	Autumn	84	82.1	1.2	6.0	10.7
Croatia and Hungary						
	Post-breeding	61	36.1	3.3	4.9	55.7
	Autumn	51	51.0	2.0	5.9	41.2
	Winter	44	43.2	2.3	2.3	52.3

3.5.4 Recoveries as a reflection of distribution of cormorants

The recoveries used in the present project give information about where individual cormorants from a certain breeding area have been present at least once. But the number of individuals that are recovered and reported from a certain area is not only related to the number of ringed individuals that have been present in that area. It is also related to the probability a) that a cormorant present in the area will die before leaving, b) that it will be found by a human if it dies and c) that the person(s) finding the dead bird will report this to a ringing centre. For example, the probability that a ringed cormorant will be recovered is likely to be highest in areas where cormorants are exposed to shooting, are at risk of drowning in fishing gear and/or occur in areas where humans occur regularly.

For these reasons the distribution of recoveries at different times of the year will not precisely reflect the distribution of the birds belonging to a certain breeding population. This is important to bear in mind, for example when looking at maps that show distributions of recoveries.

3.6 Describing patterns in migration behaviour and distribution

3.6.1 Migration behaviour and patterns in distribution

To visualise how birds from specific breeding areas were distributed outside the breeding season, we plotted all recoveries on maps. We used Kernel plots in order to better illustrate the spatial variation in the density of recoveries. We used the R-package 'birdring' to produce the Kernel plots (Korner-Nievergelt & Robinson 2014). For these plots we pooled recoveries made over many autumns and winters. Hence, we describe patterns of distribution that represents 10-40 years of data depending on when ringing took place and recoveries were retrieved.

In order to illustrate how far from the breeding areas the birds were recovered during different times of the year, we measured the distance between the ringing site and the site of recovery. Subsequently we extracted the median distance for different time periods between late summer and winter for first-year birds and adults separately.

3.6.2 Factors affecting migration routes and winter distribution

In an attempt to explore to what extent different types of internal and external factors affected migration patterns of cormorants in Europe we use the recovery data to answer such questions as:

- Do cormorants in their first year of life overwinter in the same areas as older cormorants?
- Do males and females overwinter in the same areas?
- Are there indications that characteristics of the geographical location of the individual breeding colony influences migration routes and the distribution of these birds outside the breeding season?
- Have cormorants changed their migration behaviour and choice of wintering area over the years?
- Can recovery data be used to explore how year-to-year variation in winter temperature affects the winter distribution of cormorants?

The relationship between the age of cormorants and their winter distribution was explored by comparing the distance between the ringing site and the recovery site. These comparisons were only made for ringing areas where a large number of cormorants had been ringed.

To explore the possible differences between males and females in their distribution outside breeding, we used a data set from Denmark where a large number of breeders had been sexed from their behaviour at the breeding sites and from observed morphological characteristics. We compared the distance between the ringing site and the recovery site for different periods between later summer and winter and we compared the frequency occurrence of males and females in the different wintering areas defined in Fig. 3.3.2.

To explore whether characteristics of the geographical location of individual breeding colonies affected where cormorants occurred outside the breeding season, we compared distributions of birds ringed in different regions of Denmark.

The following methods were applied in the attempt to identify whether and how cormorants had changed their choice of wintering area over time:

- Maps of distributions of winter recoveries from different series of years were compared.
- The median coordinates of recovery sites were calculated for different series of winters and compared. This was done for birds originating from breeding areas where cormorants had been ringed for a number of years.
- The median distance between the ringing site and the recovery site was calculated for each winter for cormorants originating from countries where ringing had been fairly intensive over many years.
- The model developed for the study of migratory connectivity was applied to estimate the proportion of birds that had migrated from specific breeding areas to the different wintering areas. These estimates were made over 5-year periods and for some of the breeding areas the sample sizes allowed us to explore whether changes had taken place over time. One of the advantages of this method was that the model allowed us to correct for the spatiotemporal variation in recovery probabilities whereas this was not possible in the simple study of distributions of recoveries (see chapter 5 and Appendix 5.2).

The possible relationship between the choice of wintering area and weather conditions in single winters was studied by relating year-to-year variation in the distance between the ringing site and the recovery site of Danish-ringed cormorants and the climatic conditions in the main wintering areas. Information about winter-to-winter variation in climatic conditions in various areas of Europe was extracted from other ongoing work at Aarhus University.

3.7 Migratory connectivity and composition of wintering populations

By combining data on recoveries of ringed cormorants found dead with other types of data and the use of a newly developed model we conducted a series of calculations that enabled us to answer such questions as:

- how many birds from each breeding area winter where? (see '1' in Fig. 1.2.1).
- how large a proportion of the wintering birds present in for example wintering area C originate from the breeding area no. 3 etc.? (see '2' in Fig. 1.2.1).
- to what extent do birds from different breeding areas mix in winter, and are there any indications that they stay separate according to their breeding origin?

- are there indications that birds from certain breeding areas change their migratory behaviour, i.e. that there are changes in where they spent the winter?
- what are the consequences for the composition of the wintering populations with respect to geographical origin that some breeding populations increase in size whereas others decline and that cormorants may change their migratory behaviour?

For the quantification of migratory connectivity and for the estimates of the composition of the wintering populations we not only needed the recovery data, but also additional information to convert the numbers of recoveries to an estimate of the relative numbers of individuals involved. For this conversion we collated data and knowledge about:

- Numbers of cormorant chicks ringed per year, country and (if available) colony.
- The number of breeding pairs per year, country and (if available) colony.
- Mean breeding productivity per year, country and (if available) colony.
- Information on all recoveries of dead ringed cormorants in winter (location, origin, age etc.).

We developed a database with information about the annual number of cormorants breeding in European countries, including some of the states in the western part of the former USSR. Some of the relevant information on breeding numbers was retrieved from reports etc. and some was delivered through personal contact with the national coordinators of breeding counts of cormorants. Consequently some of the information used was unpublished data supplied by individual countries.

For our conversion of numbers of recoveries to relative numbers of cormorants, we needed to estimate the number of fledged young produced per colony per year in all the breeding areas in Europe. The reproductive output from cormorant colonies has been studied in breeding colonies throughout most of the breeding range of the *Ph. c. sinensis* sub-species in Europe. However, these studies have usually lasted for only a single or a few years and only covered years when the specific breeding colony was either growing, stable or in decline. Nonetheless, we assessed that the number of published studies was sufficient to allow reasonable estimates of the number of fledglings produced per year in the European cormorant colonies during their respective phases of population development.

Having collated and organised these data, we identified the areas and years for which we had to make assumptions about the precise sizes of breeding populations and numbers of fledglings produced. These assumptions were developed on the basis of results published by cormorant researchers in Europe. We also discussed the validity of our assumptions with other European cormorant researchers as well as with our scientific quality controller.

It was not straightforward to convert the collated data into a quantitative overview of migratory connectivity. This is partly because there is substantial geographical and temporal variation both in the proportion of cormorants that have been ringed in the breeding areas, and in the probability that a dead ringed bird is recovered. Thus, the absence of records of birds from a specific breeding origin in a wintering area may simply reflect that few or no birds were ringed in that country, and similarly the absence of dead recoveries in a specific wintering area may reflect that dead birds were not recorded, perhaps because no shooting of cormorants took place in the area. These examples are extreme (and unrealistic), but even a lower and more realistic level of variation in ringing and recovery effort makes the estimation of migratory connectivity complicated.

The approach and model developed and applied for quantifying the migratory connectivity and estimate the composition of the wintering populations is described in chapter 5 and Appendix 5.1.

Most Great Cormorants moult into breeding plumage already during late winter. Adults and one immature bird roosting at a spring staging site in March 2011. Photo: R. Parz-Gollner©.

3.8 Other issues

3.8.1 Modelling spatial effects of changes in population size and management

The original plan was to use modelling approaches in an attempt to try to predict how cormorant numbers will develop in different parts of central and southern Europe as a consequence of natural and/or management-induced changes in numbers in the breeding areas, and vice versa. However, as discussed with DG Environment during the work of the present project there is now clear evidence that cormorants are highly dynamic in their choice of staging sites and wintering areas, and this made it very difficult to model future scenarios with a reasonable certainty within the time and resources available for the CormoDist project.

Although knowledge of migratory connectivity provides some of the necessary information to assess how changes in population size (management-induced or natural) in specific wintering areas affect specific breeding areas, or vice versa, it is not recommended to make such predictions in a dynamic system where the birds in unpredictable ways change their migratory behaviour as observed in the present study. So even though we currently have reliable estimates of the proportional composition of wintering populations in specific areas, we do not feel confident that we can predict how changes in one (breeding or wintering) area affect numbers in other areas. Likewise we have not attempted to develop scenarios where we simulate the immediate impact of population changes in one area on numbers of birds in other areas. Such estimates of how the impact of a population increase (or decrease) in a specific breeding area is distributed among wintering areas rely on very strict (and often unrealistic) assumptions, including that the change in population size does not affect the demography and behaviour of the birds. A more realistic assessment requires a tool that can evaluate the outcome if these assumptions do not hold.

The ideal way to explore potential impacts of population change in a spatially explicit setting is an individual-based (or agent-based) model (Grimm 1999, Bousquet & Le Page 2004), where each individual is modelled and followed explicitly. However, such models are difficult to construct and parameterise, and the time and resources available within CormoDist did not allow the adoption of this approach.

A potentially useful alternative to direct calculations based on migratory connectivity or using individual-based modelling would be to apply matrix population modelling (Caswell 2001). The use of matrix population modelling can – under some conditions – ensure more realistic predictions than the direct calculations based on migratory connectivity. A matrix population model represents the size and composition (in terms of age classes and spatial structure) at a given time and projects this to a later time step using information on demography (survival and reproduction) and movements. Assumptions about compensatory density-dependent changes in demography (e.g. improved breeding success when population size is reduced) and adaptive behaviour (e.g. attraction to 'empty' areas, or adverse reaction to disturbance or culling) can be built into the model, and various scenarios explored. Previous work has included construction of matrix population models for cormorants in Europe, without (Frederiksen et al. 2001) or with a very simple spatial structure (Frederiksen et al. 2003). These models were used to explore various scenarios for population control.

In CormoDist, we ended up deciding not to extend these models to include a more detailed spatial structure and estimates of migratory connectivity. This decision was taken after seeing the outcomes of the analyses of recoveries and after discussions with the IUCN/Cormorant Research Group and our scientific quality controller who followed the project.

3.8.2 Use of artificial versus natural feeding areas

Providing an estimate of the proportion of autumn staging and wintering cormorants that rely for foraging on natural wetlands and in artificial commercial fisheries such as aquaculture is far from easy. For such considerations, "artificial commercial fisheries" were assumed to simply refer to the extensive carp *Cyprinus carpio* aquaculture ponds to be found across Europe. In practice, it was known that the ringing data used in the CormoDist project would not offer an insight into the proportions of cormorants relying on natural versus artificial commercial fisheries. Similarly, it would be very difficult to quantify (or even predict) the number (and, hence, proportions) of cormorants that permanently or temporarily forage in artificially developed commercial fisheries (i.e. aquaculture ponds) outside the breeding season.

Two further options were:

1. that knowledge about the number of cormorants counted in coastal wetlands and in inland wetlands without fish farms might give a rough idea about the minimum number of cormorants that cover their daily food requirements without foraging at fish farms.
2. that by estimating the number of fish farms for certain countries or parts of Europe, and combining these numbers with assumptions and knowledge about the number of cormorants that on a daily basis forage at different types of fish farms, and by scaling-up these estimates, a rough (if highly uncertain) overall estimate could be derived. However, on further consideration, neither was found to be useful or to offer meaningful biological insight.

After careful consideration (including discussions with the IUCN/Wetlands International Cormorant Research Group), it was thus decided that the most biologically meaningful way of explore the proportions of autumn staging and wintering cormorants that rely for foraging on natural wetlands and in artificial commercial fisheries (i.e. aquaculture) was to refer to published material on the relationships between cormorants and their use of feeding habitats at specific water bodies throughout Europe.

The plumage of first-year cormorants differs from that of older birds. First-year birds tend to have more white feathers on the breast. Photo: F. Möllers.

4 Migration and winter distribution

4.1 Cormorants from the Baltic Sea

4.1.1 Breeding population

The shallow waters and coasts along the Baltic Sea constitute the most important breeding area for the *sinensis* sub-species of the Great Cormorant in Europe (Bregnballe et al. 2014). In 2012 the countries around the Baltic Sea had 74% of the breeding population found in Europe west of Russia-Belarus-Ukraine (including Kaliningrad and the Russian part of the Gulf of Finland but excluding countries around the Black Sea; Bregnballe et al. 2014). It is therefore of particular interest to understand the migration patterns of the birds belonging to this part of the European breeding population of cormorants.

The development of the breeding population in the countries around the Baltic Sea is shown in Fig. 4.1.1. It is evident that the total number of breeding Great Cormorants increased steadily from ca. 10,000 pairs in 1983 to ca. 160-170,000 pairs during 2006-2013. The initial population increase occurred in the western parts of the Baltic Sea (Denmark, Germany, Sweden and Poland) and later on the 'wave of expansion' spread eastwards. Numbers continued to increase during the 1990s in Germany, Sweden, Poland and Estonia whereas stabilization in breeding numbers was observed in Denmark. In the early 2000s further eastward expansion was observed as breeding numbers increased in the eastern Baltic regions, primarily in Finland and Estonia, while declines were observed in Denmark and numbers stabilized in Germany, Sweden and Poland. Combined with marginal increases in some of the eastern Baltic states (Latvia, Lithuania and Russia) this resulted in a stabilisation of the population across the region.

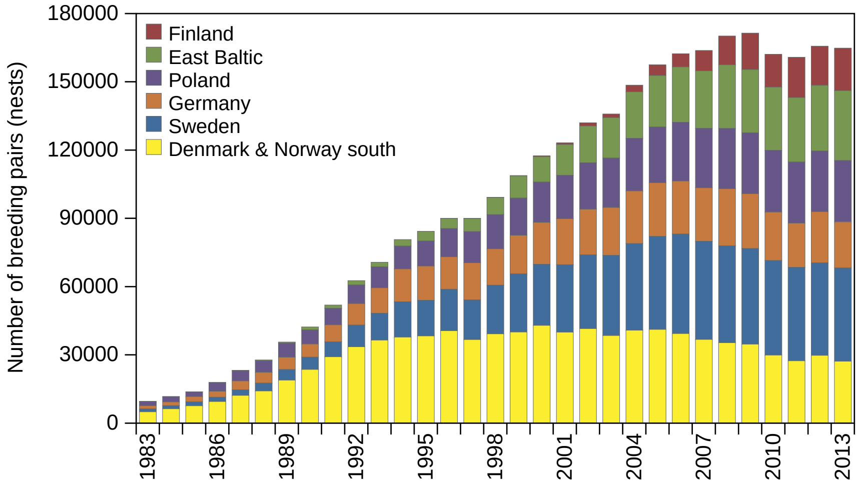


Figure 4.1.1. Development of the number of Great Cormorants breeding in the countries around the Baltic Sea, 1983-2013. The region 'East Baltic' includes the countries/areas: Russian part of the Gulf of Finland, Estonia, Latvia, Lithuania and Kaliningrad. For the following countries breeding numbers were estimated for some of the years by interpolation based on counts in previous and subsequent years: Norway, Sweden, Poland, Russian part of the Gulf of Finland, Latvia, Lithuania and Kaliningrad.

4.1.2 Overall patterns of distribution

The overall distribution patterns in late summer, during autumn and in winter of the cormorants originating from breeding areas around the Baltic Sea are shown in Fig. 4.1.2. It is evident from these maps and Table 4.1.1 that a large proportion of the Great Cormorants breeding around the Baltic Sea migrated in southerly and south-westerly directions in autumn. It is also clear that the Baltic cormorants were found wintering over most of Europe ranging from Portugal in the west to Romania in the east and from Bergen (Norway) in the north to southern Tunisia in the south, i.e. covering distances of more than 3000 km in both directions.

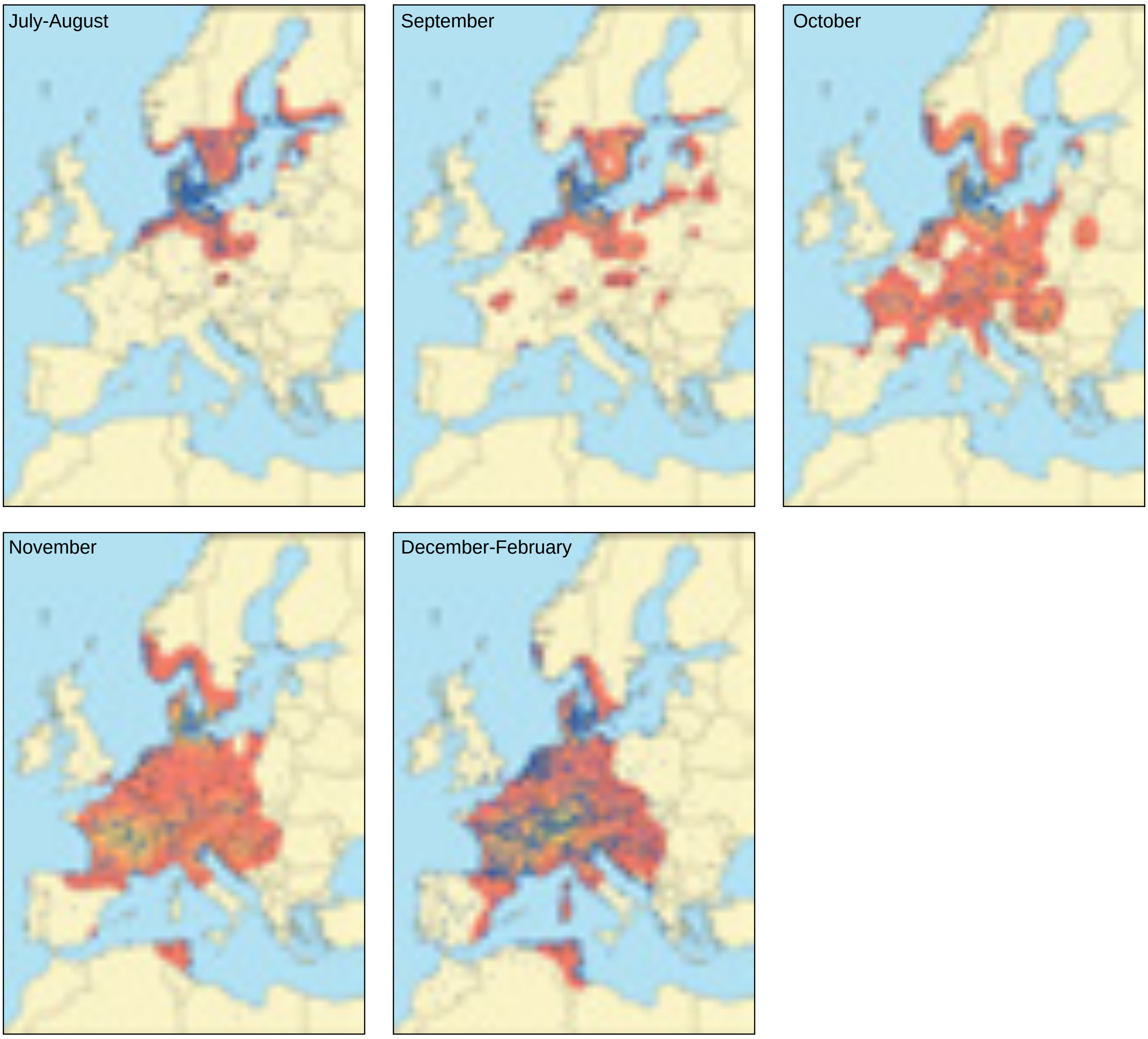
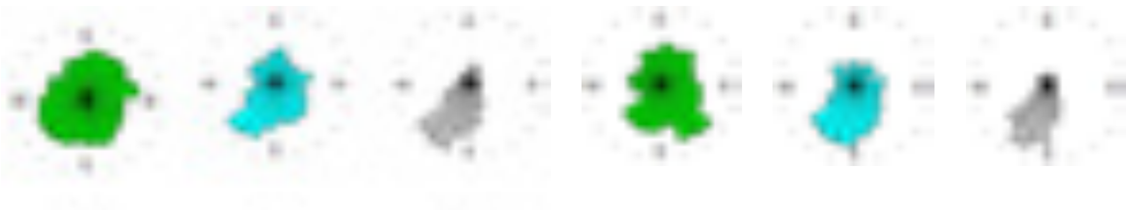
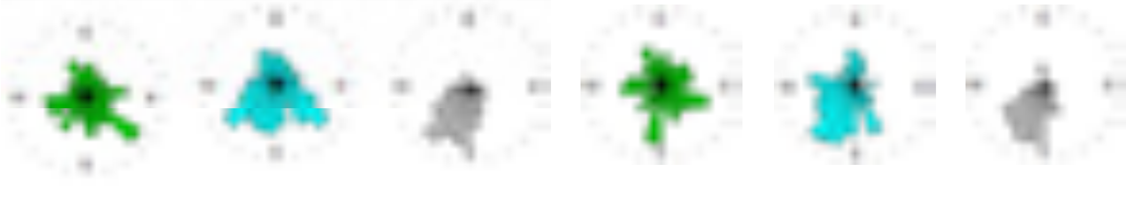


Figure 4.1.2. Recovery sites of Great Cormorants ringed in countries around the Baltic Sea (breeding areas no. 1-6) and recovered as dead in July-August (post-breeding period), September, October, November and December-February, 1983/84-2013/14. The coloured areas indicate higher recovery density, with yellow identifying areas with the highest densities.

Table 4.1.1. Dispersal directions from ringing site to recovery site in first-year birds and older birds given for three time-periods for Great Cormorants originating from the Baltic Sea region. The length of each segment relates to relative frequency.

	1-year-birds			Older birds		
	Jul.-Aug.	Sep.-Nov.	Dec.-Feb.	Jul.-Aug.	Sep.-Nov.	Dec.-Feb.
Denmark 	[illegible]	[illegible]	[illegible]	311	435	942
Germany 	[illegible]	[illegible]	[illegible]	49	50	104
Sweden 	[illegible]	[illegible]	[illegible]	205	264	569
Poland 	[illegible]	[illegible]	[illegible]	34	43	49
Finland 	[illegible]	[illegible]	[illegible]	52	87	231
East Baltic Sea 	74	239	183	43	97	178

4.1.3 Denmark

The vast majority of the ringed cormorants from this breeding area were of Danish origin. Thus 95.5% of the 4721 recovered cormorants originating from this breeding area had been ringed in Denmark whereas 4.5% had been ringed in the *sinensis* colonies in southern Norway. To make it easier, we therefore refer to the cormorants from this breeding area as being of Danish origin.

The cormorants from this breeding area dispersed in all directions immediately after the breeding season (Table 4.1.1). Older birds displayed a tendency to disperse in a more southerly and southeasterly direction in the post-breeding period, whereas this tendency was not seen among first-year birds. During the post-breeding period (defined as July-August) over 90% of the recovered birds, originally ringed in Denmark, were found inside the region covering the Baltic Sea and southern Norway (Table 4.1.2; see Fig. 3.3.2 for the definition of this area). Furthermore 50% of both first-year birds and older birds recovered during the post-breeding period were found within 200 km of the original colony where they were ringed (Fig. 4.1.3). A small percentage of birds migrated to more distant locations already in the post-breeding period, e.g. to the Netherlands, Belgium, Germany, Switzerland and France (Fig. 4.1.3, Table 4.1.2).

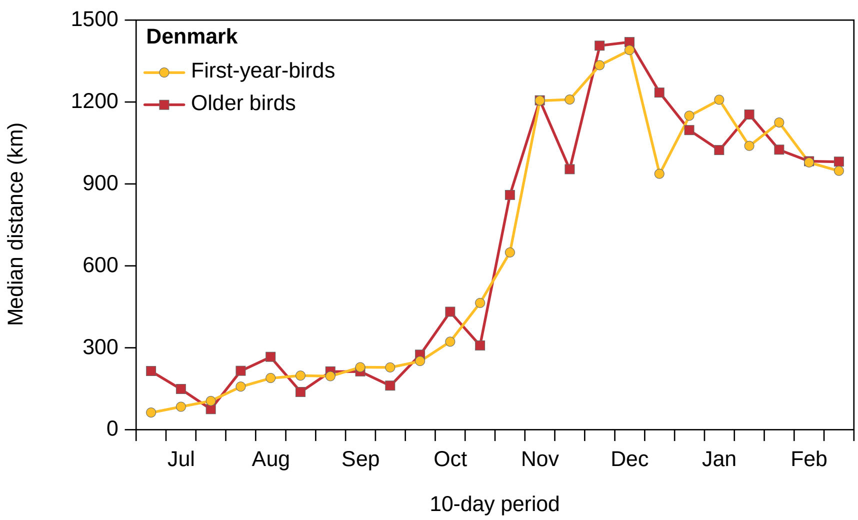


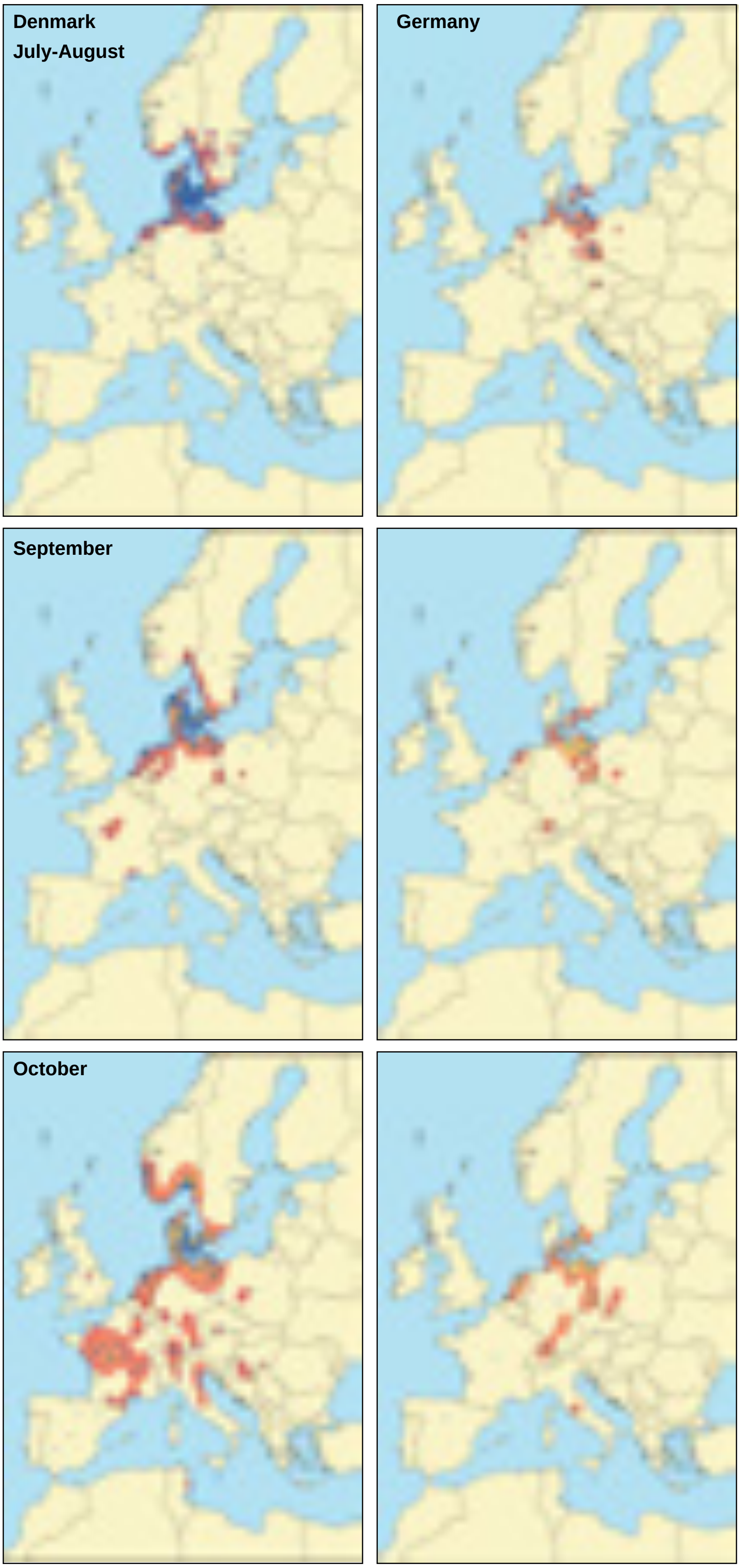
Figure 4.1.3. Median distance from ringing site to recovery site for first-year and older Great Cormorants ringed in Denmark during 1974-2013 and recovered in 1983/84-2013/14 presented for each 10-day period during July-February.

Table 4.1.2. Distribution of recoveries of Great Cormorants originating from different parts of the Baltic Sea region, given for the post-breeding period (July-August), the autumn (September-November) and the winter (December-February), 1983/84-2013/14. Sample sizes are given in the last column. The delineation of the staging and wintering areas is shown in Fig. 3.3.2.

	Breeding area number	Breeding area	A Baltic Sea and S Norway	B Central East	C Switzerland and Germany	D United Kingdom	E The Netherlands, Belgium, Germany	F France	G Spain and Portugal	H Italy	I Balkan	J Black Sea	K North Africa	Outside study area	N
Post-breeding	1	Sweden	91.3	2.3	0.6	0	2.5	1.1	0.6	0.2	0.2	0	0.6	0.4	473
	2	Finland	81.9	6.0	1.7	0	1.7	2.6	2.6	0.9	0.9	0	0	1.7	116
	3	East Baltic	72.6	12.8	2.6	0	0	0.9	0	0.9	1.7	0	0	8.5	117
	4	Poland	36.4	27.3	29.5	0	0.8	0	0	1.5	0.8	0	0.8	3.0	132
	5	Denmark	92.9	0.7	1.4	0	3.4	1.1	0.2	0.1	0.2	0	0.2	0	1225
	6	Germany	66.2	3.6	20.5	0	7.2	1.0	0.5	0.5	0.5	0	0	0	195
Autumn	1	Sweden	64.2	6.8	7.1	0.9	4.5	9.3	1.8	3.1	0.6	0	1.4	0.5	874
	2	Finland	40.9	20.4	12.2	0.6	2.2	12.4	1.9	3.9	1.4	0	1.7	2.5	362
	3	East Baltic	51.8	24.7	4.2	0	0.6	3.6	0.3	3.6	3.0	1.5	0.3	6.5	336
	4	Poland	20.3	48.1	18.8	0	0	1.5	0	2.3	4.5	0	0	4.5	133
	5	Denmark	68.5	1.8	3.1	1.1	6.5	12.4	1.5	2.8	0.5	0.1	1.7	0	1531
	6	Germany	47.6	6.8	23.8	0	8.3	6.3	1.0	3.9	0.5	0	1.9	0	206
Winter	1	Sweden	20.7	4.3	14.9	0.5	5.8	28.5	3.5	11.1	4.7	0.2	5.9	0	1107
	2	Finland	10.1	16.9	19.1	0.4	5.1	24.7	4.7	9.7	7.1	0.4	1.9	0	534
	3	East Baltic	12.2	22.2	13.3	0	1.7	10.2	1.4	15.2	19.9	1.7	2.2	0	361
	4	Poland	1.2	16.5	15.3	0	3.5	3.5	4.7	18.8	25.9	0	10.6	0	85
	5	Denmark	21.5	1.1	10.3	1.4	9.8	33.1	6.4	7.8	1.5	0	7.0	0	1965
	6	Germany	4.9	5.9	31.2	0	6.8	20.5	5.4	13.7	5.9	0	5.9	0	205

During the autumn months, over two thirds of recoveries of cormorants of Danish origin were from the Baltic Sea area (Table 4.1.2). Both age groups displayed a tendency to migrate in a southwesterly direction (Table 4.1.1). Dispersal distance, determined by the median distance between ringing location and recovery location, increased noticeably from mid-October (ca. 400 km) to mid-November (ca. 1200-1400 km; Fig. 4.1.3). This indicates that a large percentage of cormorants did not begin to leave the post-breeding areas before mid-October. The dispersal distance suggested that many birds had arrived at the overwintering areas around mid-November (Fig. 4.1.3).

During the winter months cormorants of Danish origin were widely distributed across western and central Europe. This is also evident from Fig. 4.1.4 and Appendix 5.2. In winter large proportions of the ringed birds were recovered in France, the western part of the Baltic Sea, Switzerland and Germany and in the Netherlands and Belgium (Table 4.1.2).


Denmark
July-August
Germany
September
October

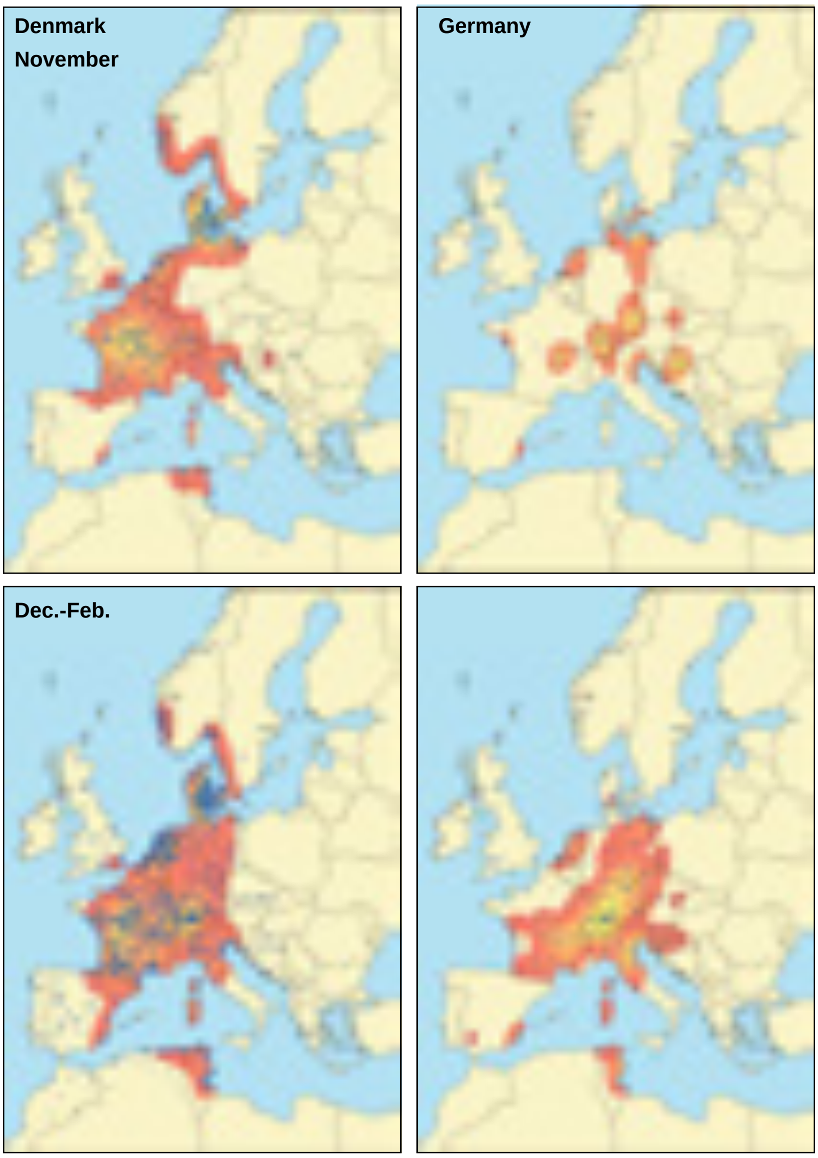


Figure 4.1.4. Recovery sites of Great Cormorants ringed in Denmark (left) and Germany (right) and recovered as dead in July-August (post-breeding period), September, October, November and December-February, 1983/84-2013/14. The coloured areas indicate higher recovery density, with yellow identifying areas with the highest densities.

A smaller percentage of birds were recovered in Spain and Portugal and in North Africa. Very few birds were recovered on the Balkan Peninsula, especially after the mid-1990s. The corrected estimate of the winter distribution of Danish cormorants among the 11 defined staging and wintering areas is given in Appendix 5.2 with three 5(6)-year periods as examples.

The median dispersal distance peaked in early December at ca. 1400 km (Fig. 4.1.3). The apparent decrease in dispersal distance observed during the winter months in both age groups (Fig. 4.1.3) may have occurred because of higher mortality in the northern areas in mid-winter and late in winter and/or because some of the birds departed from the wintering grounds already in mid- and late winter.

The winter distribution of cormorants of Danish origin has changed markedly over the years. The main tendency has been towards a decline in the use of the wintering areas in Spain-Portugal, Italy and on the Balkan Peninsula and an increase in the use of wintering areas in the Netherlands, Belgium and France. Some of these changes are described in Appendix 5.2.

Further descriptions of migration patterns in cormorants of Danish origin can be found in Bregnballe et al. (1997) and Bregnballe & Rasmussen (2000).

4.1.4 Germany

Great Cormorants of German origin displayed a similar dispersal pattern to Danish cormorants in the post-breeding season. However a greater proportion of first-year birds travelled in a south-easterly direction, with older birds dispersing in a more southerly direction (Table 4.1.1). Similar to the Danish cormorants, during the post-breeding period more than 50 % of both age groups were found within 200 km of the ringing colony (Fig. 4.1.5). The majority of birds were recovered in the Baltic Sea area (66%) and in Switzerland and Germany (21%) at this time of the year (Table 4.1.2). Smaller proportions were recovered in the Netherlands and Belgium (7%), the Central East area (4%) and France (1%); see also Fig. 4.1.4.

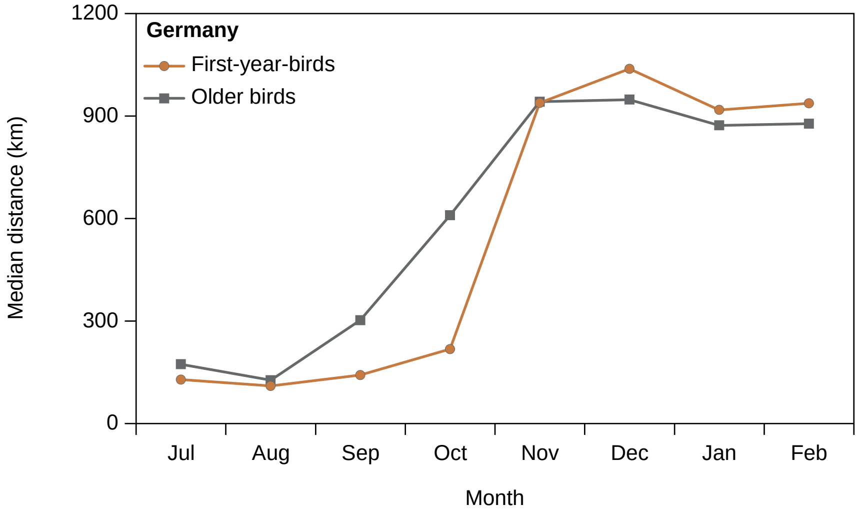


Figure 4.1.5. Median distance from ringing site to recovery site for first-year and older Great Cormorants ringed in Germany during 1974-2013 and recovered in 1983/84-2013/14 presented for each 10-day period during July-February.

During the autumn months almost 50% of the cormorants of German origin were found in the Baltic Sea area (Table 4.1.1). Similar to cormorants of Danish origin, the dispersal distance increased noticeably in October, especially among first-year birds (Fig. 4.1.5). Older birds tended to show an increase in dispersal distance already in September (Fig. 4.1.5), maybe suggesting an age related difference in timing of departure for the wintering grounds. Similar to cormorants of Danish origin, the stabilisation in the median dispersal distance observed in November suggests arrival at the wintering grounds of a large proportion of German birds already by mid-November.

Cormorants of German origin overwintered mainly in central Europe with the majority of birds recovered in Switzerland and Germany (31%), France (21%) and Italy (14%; see also Fig. 4.1.4 and Appendix 5.2). Compared to birds of Danish origin, German cormorants dispersed over a smaller area and fewer birds overwintered in the northern and most western parts of Europe. The median dispersal distance peaked at 900-1000 km in December and remained relatively constant during the winter months (Fig. 4.1.5).

See also Herrmann et al. (2015) and references herein for a more detailed description of migration patterns of cormorants of German origin. The paper by Herrmann et al. (2015) also describes the marked changes that have taken place in where German cormorants stay in Europe during winter. Some of these changes can also be seen from the pie charts in Appendix 5.2.

4.1.5 Sweden

During the post-breeding period Great Cormorants of Swedish origin dispersed primarily in southerly and westerly directions. First-year birds dispersed in more westerly directions, while older birds were more widely dispersed (Table 4.1.1). Older cormorants of Swedish origin travelled apparently further from the ringing site in the post-breeding period than either Danish or German birds (Fig. 4.1.6). Similar to birds of Danish origin more than 90% of the Swedish population remained in the Baltic Sea area during the post-breeding period, with the majority of birds recovered in Denmark and Sweden (Fig. 4.1.7). A small number of birds had apparently migrated as far as France and Spain already during post-breeding (Table 4.1.2, Fig. 4.1.7).

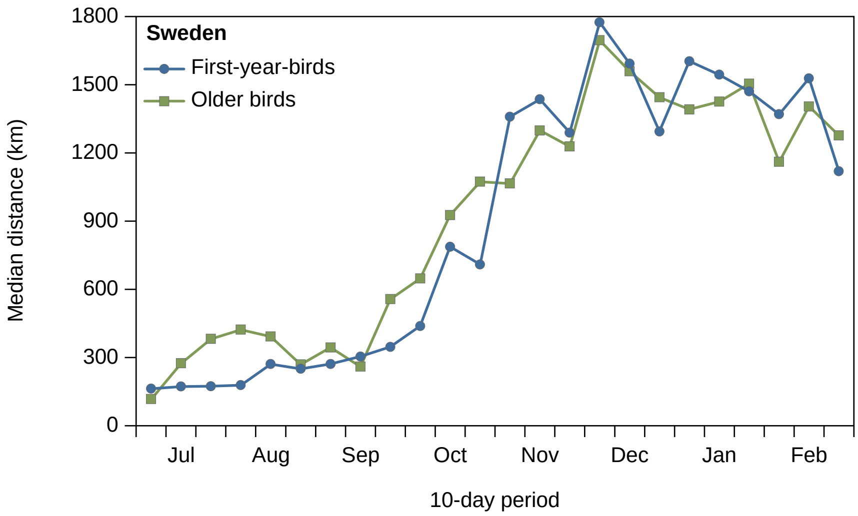
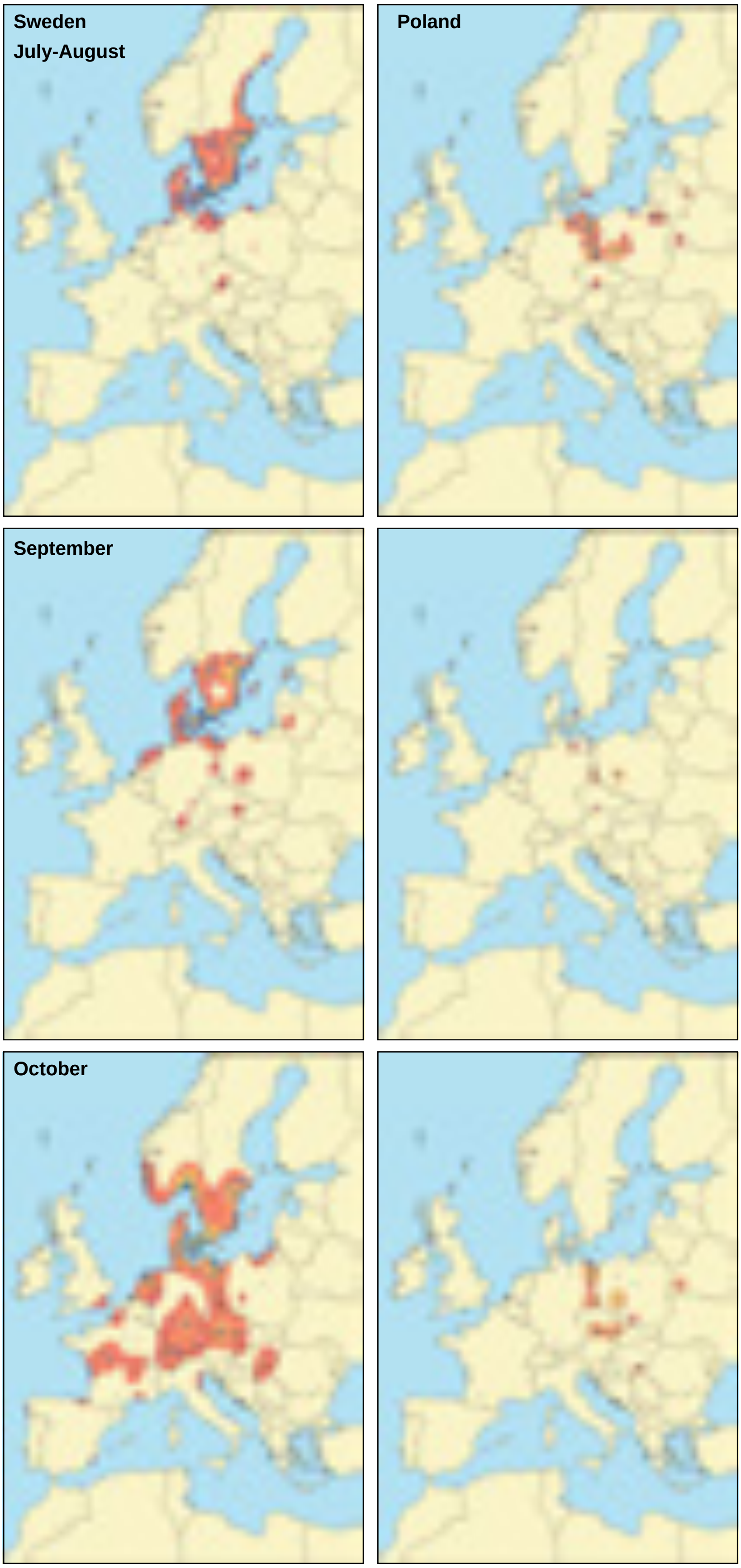


Figure 4.1.6. Median distance from ringing site to recovery site for first-year and older Great Cormorants ringed in Sweden during 1982-2013 and recovered in 1983/84-2013/14 presented for each 10-day period during July-February.


Sweden
July-August
Poland
September
October

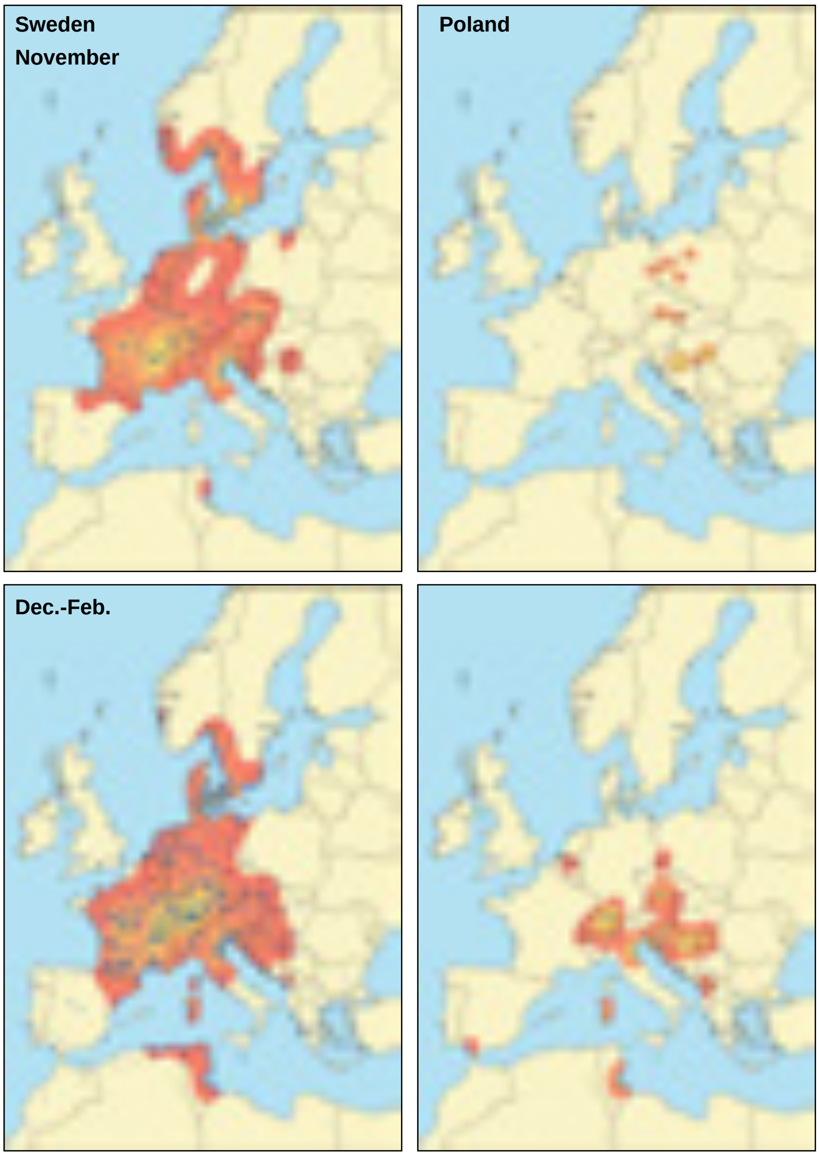


Figure 4.1.7. Recovery sites of Great Cormorants ringed in Sweden (left) and Poland (right) and recovered as dead in July-August (post-breeding period), September, October, November and December-February, 1983/84-2013/14. The coloured areas indicate higher recovery density, with yellow identifying areas with the highest densities.

Similar to cormorants of Danish origin, during the autumn months almost two thirds (64%) of the Swedish population were recovered in the Baltic Sea area (Table 4.1.2). The median dispersal distance increased after mid-September (Fig. 4.1.6) which was earlier than observed among birds of Danish origin. The median dispersal distance in birds of Swedish origin peaked in late November at ca. 1800 km (Fig. 4.1.6).

During the winter months cormorants of Swedish origin were widely distributed in Europe (Fig. 4.1.7, Appendix 5.2). The majority of recoveries were from France (29%), the Baltic Sea area (21%), Switzerland and Germany (15%) and Italy (11%). A small proportion of birds were recovered as far south as North Africa (6%) and Spain and Portugal (4%). When compared to birds of Danish origin, Swedish birds travelled further to reach their wintering grounds (compare Fig. 4.1.3 and 4.1.6). Additionally a larger proportion of Swedish cormorants overwintered in the central-eastern parts of

Europe, in Czech Republic, Austria, Slovakia, Croatia and Hungary (Fig. 4.1.7 and Appendix 5.2). Similar to the pattern observed in cormorants of Danish origin, a decline was observed in the median dispersal distance from December to February.

Changes in the wintering distribution of cormorants of Swedish origin includes a decrease in the proportion wintering on the Balkan Peninsula and an increase in the proportion wintering in the western Baltic Sea (see Appendix 5.2).

4.1.6 Poland

The total number of recoveries of cormorants of Polish origin was fairly small compared with the number of recoveries from some of the other breeding areas around the Baltic Sea (Table 4.1.2).

Polish cormorants dispersed mainly in northwesterly and southerly directions during the post-breeding period (Table 4.1.1, Fig. 4.1.7). First-year birds tended to disperse more in a northwesterly direction, whereas older birds were more scattered in their dispersal pattern, with a larger proportion dispersing towards the south and east during post-breeding period but sample sizes were small (Table 4.1.1). During the post-breeding period 36% of the cormorants of Polish origin were recovered in the Baltic Sea area (Table 4.1.2), contrasting with over 90% of birds originating in Denmark and Sweden and 66% of the German population. Furthermore, contrasting to cormorants of Danish, Swedish and German origin, only a small proportion was recovered in the western parts of the Baltic Sea area, i.e. around the Kattegat area in Denmark (Fig. 4.1.7). Instead, the majority were recovered in the German and Polish areas of the eastern Baltic Sea (Fig. 4.1.7). Furthermore over half of the cormorants of Polish origin were recovered in the area including Switzerland, Germany and Central East during the post-breeding period (Table 4.1.2). However despite the difference in recovery location during the post-breeding period, the dispersal distance was comparable to other Baltic breeding populations, at least in first-year birds. Similar to birds from Denmark, Germany and Sweden 50% of the first-year birds stayed within a distance of up to 200 km to the ringing site during the post-breeding period (Fig. 4.1.8).

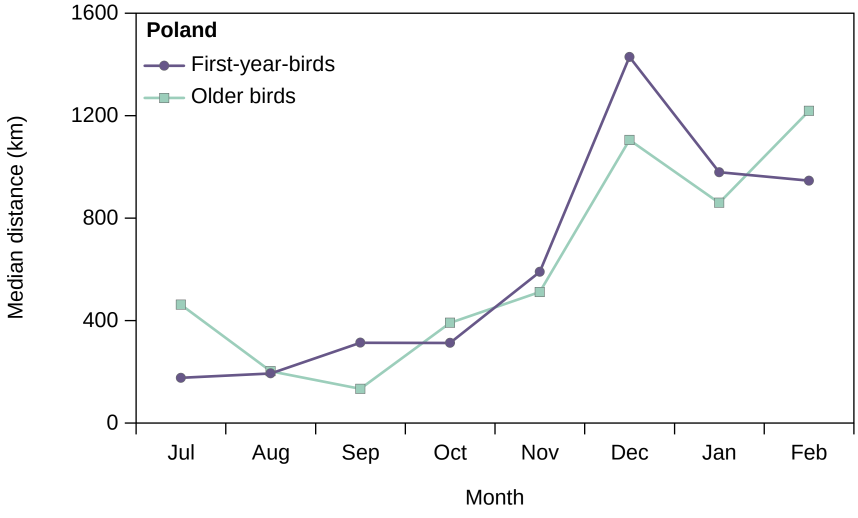


Figure 4.1.8. Median distance from ringing site to recovery site for first-year and older Great Cormorants ringed in Poland during 1979-2013 and recovered in 1983/84-2013/14 presented for each month during July-February.

During the autumn months a similar tendency was observed: Relatively few recoveries of cormorants of Polish origin were from the Baltic Sea area (20%) whereas a large proportion of recoveries were from the Central East area (48%, Table 4.1.2, Fig. 4.1.7). This is in contrast to the distribution of recoveries of cormorants from Denmark, Germany and Sweden. First-year cormorants and older cormorants of Polish origin showed a more gradual departure from the post-breeding areas than birds of Danish, German and Swedish origin (Fig. 4.1.8). There seemed to be a difference in dispersal direction during the autumn months between the first-year birds and older birds. First-year birds dispersed from the north over west to the south, while older birds dispersed primarily from west over south to east (Table 4.1.1).

During the winter months cormorants of Polish origin were recovered primarily in the southern parts of central and eastern Europe, in a relatively small geographical area when compared to other Baltic populations (Table 4.1.2, Fig. 4.1.7). The majority of recoveries were from the Balkan area (26%), Italy (19%) and the Central East area (17%). During the winter months, Poland had a fairly high percentage of recoveries in North Africa (11%). A small proportion of birds were recovered in the northern and western parts of Europe, with only 2 birds recovered in the Baltic Sea area (Table 4.1.2).

4.1.7 Finland

Among the adult cormorants of Finnish origin, some were recovered very far from the breeding areas already in July-August whereas the vast majority of first-year birds stayed fairly close to the breeding areas at this time of the year (Fig. 4.1.9). By July, half of the older birds were recovered more than 1000 km from the original ringing site (see section 4.1.9 for a discussion of the possible reasons behind these differences). Half of the first-year birds reached a similar distance in September. Similar to cormorants of Swedish and Danish origin the majority of the Finnish population (82%) were recovered in the Baltic Sea area during July and August (Table 4.1.2), however, the majority were recovered in the eastern Baltic Sea area (Fig. 4.1.10).

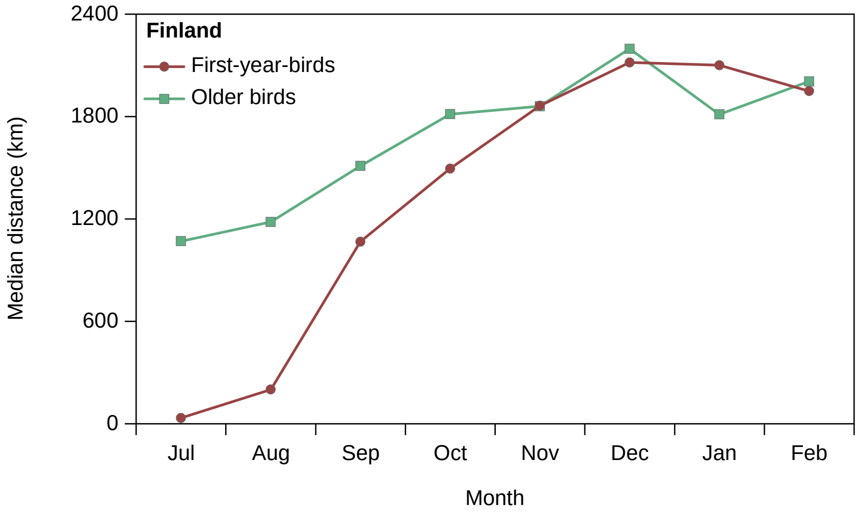
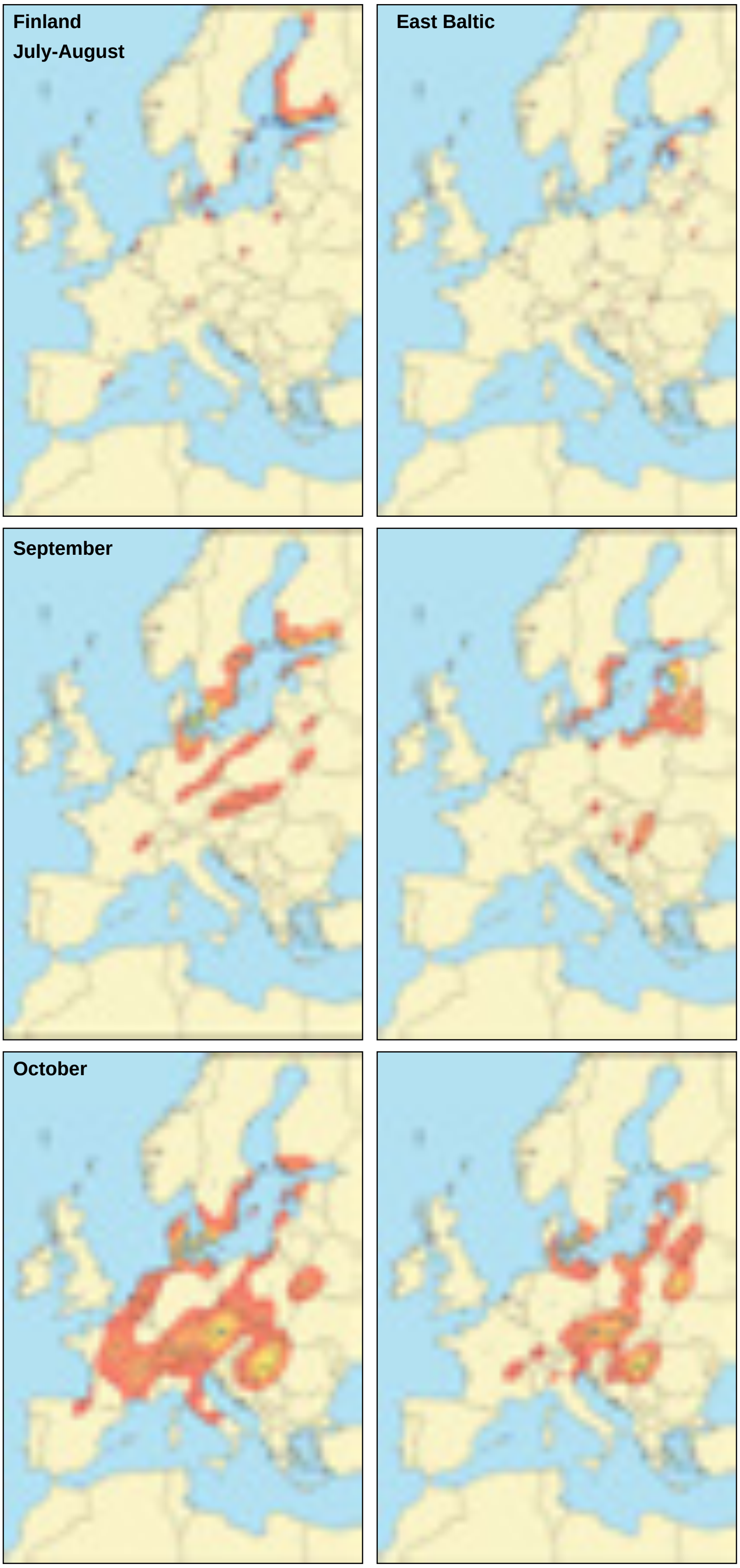


Figure 4.1.9. Median distance from ringing site to recovery site for first-year and older Great Cormorants ringed in Finland during 1997-2013 and recovered in 1997/98-2013/14 presented for each month during July-February.


Finland
July-August
East Baltic
September
October

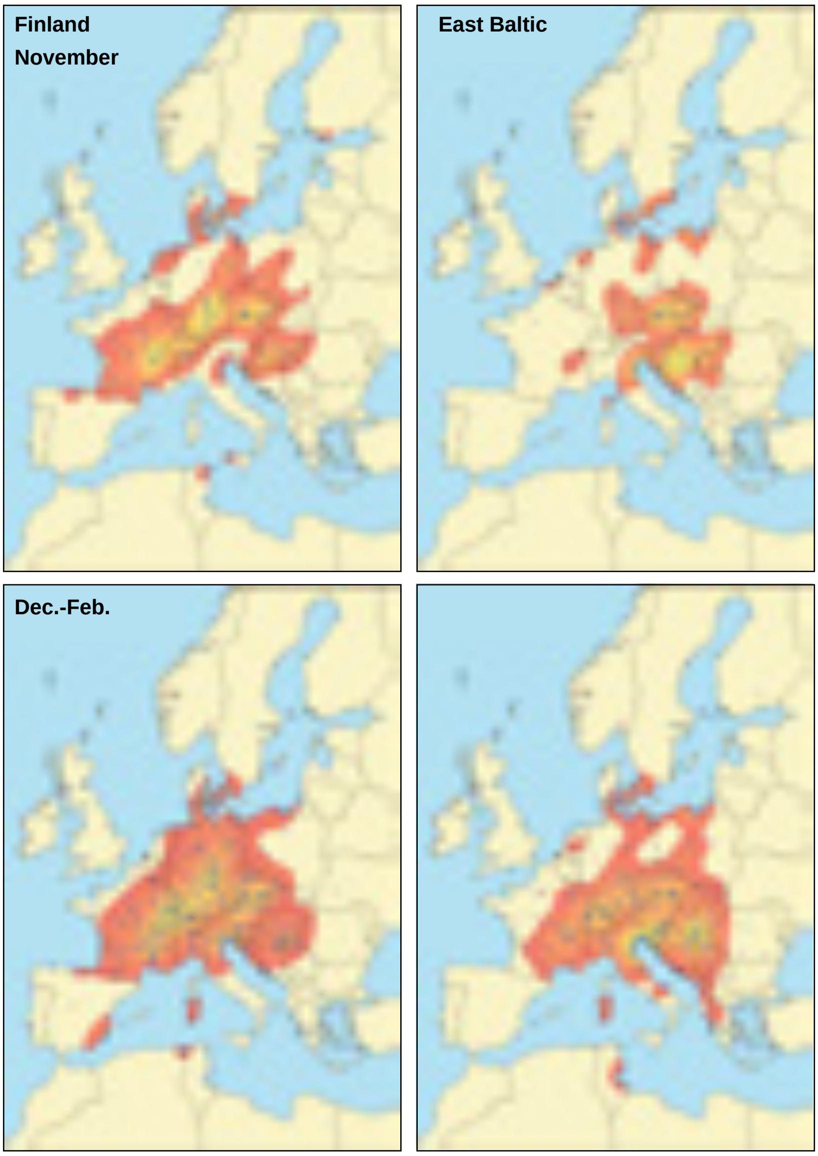


Figure 4.1.10. Recovery sites of Great Cormorants ringed in Finland (left) and the East Baltic (right) and recovered as dead in July-August (post-breeding period), September, October, November and December-February, 1983/84-2013/14. The East Baltic includes the countries/areas: Russian part of the Gulf of Finland, Estonia, Latvia, Lithuania and Kaliningrad. The coloured areas indicate higher recovery density, with yellow identifying areas with the highest densities.

During the post-breeding period cormorants of Finnish origin dispersed primarily in westerly and southwesterly directions across a large geographical area (Table 4.1.1, Fig. 4.1.10). Compared to birds of Swedish origin, first-year birds from Finland displayed a similar dispersal pattern (west-southwest), whereas older birds were more restricted in their dispersal direction (southwest). For both age groups the southwestern dispersal pattern became more pronounced during the autumn and winter months (Table 4.1.1, Fig. 4.1.10).

Cormorants from Finland departed for the overwintering grounds before populations from other Baltic countries. The recoveries suggested that by September almost half the Finnish population had arrived at the wintering areas located in area Central East

(20%), France (12%) and Switzerland and Germany (12%); only 40% were recovered in the area around the Baltic Sea (Table 4.1.2).

Cormorants of Finnish origin flew further to overwintering grounds than birds from other Baltic countries, with a peak in the median dispersal distance in December of ca. 2100 km for both age groups (Fig. 4.1.9). The Finnish cormorants appeared to occupy a similar range of wintering areas as Danish and Swedish cormorants (Fig. 4.1.10), but the cormorants of Finnish origin were overwintering further east than Swedish and Danish cormorants: 17% of the winter recoveries of Finnish cormorants came from the Central East area, compared to 4% of Swedish birds and only 1% of Danish birds. In contrast only half as many birds of Finnish origin overwintered around the Baltic Sea (10%) compared to birds of Swedish (21%) and Danish origin (22%). The proportion of Finnish birds wintering in Central East and Switzerland and Germany increased between 1998/99-2002/03 and 2008/09-2013/14 (see Appendix 5.2).

4.1.8 East Baltic

The majority of the Great Cormorants that were ringed in the East Baltic area and later recovered had been ringed in Estonia (560 recoveries) and the Russian part of the Gulf of Finland (229 recoveries) whereas only a small number had been ringed in Lithuania (16 recoveries) and Latvia (9 recoveries; see also Fig. 3.5.2).

After the breeding season dispersal was mainly in southwesterly directions (Table 4.1.1, Fig. 4.1.10) and this was most pronounced among first-year birds. Similar to birds of Finnish origin, many of the birds ringed in the East Baltic area were recovered at long distances from the ringing site during the post-breeding period (the median ranging from 200 to 700 km, Fig. 4.1.11). Similar to birds of Finnish origin, the majority of birds of East Baltic origin (72%) were recovered inside the Baltic Sea area during July and August (Table 4.1.2), but few were recovered in the western Baltic Sea area (Fig. 4.1.10). Some cormorants did migrate to quite distant locations already during the post-breeding period (Fig. 4.1.10).

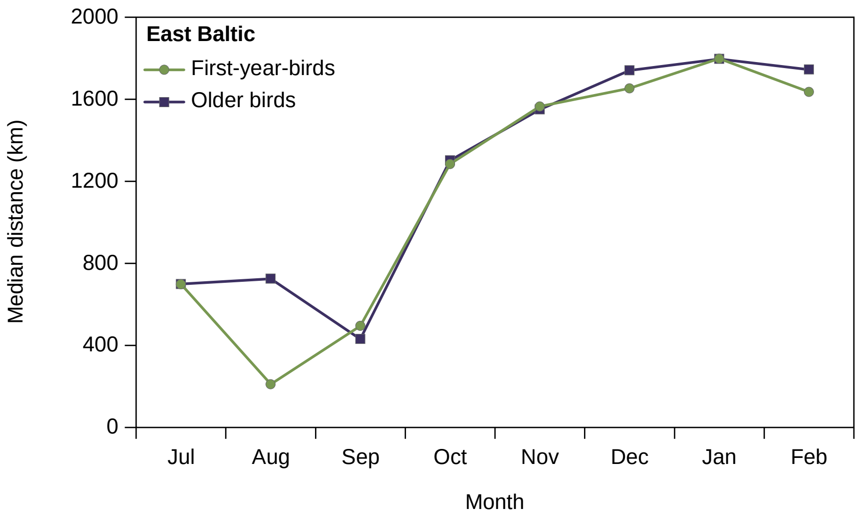


Figure 4.1.11. Median distance from ringing site to recovery site for first-year and older Great Cormorants ringed in the East Baltic during 1987-2013 and recovered in 1988/89-2013/14 presented for each month during July-February.

Among cormorants from the East Baltic area, a sharp increase in the median dispersal distance was observed between September and October (from 450 km to 1300 km). Half of all recoveries (52%) from September to November were from countries around the Baltic Sea. The remainder came from the Czech Republic, Austria, Slovakia, Croatia and Hungary.

The recoveries of East Baltic birds during the winter months were fairly concentrated to central and eastern Europe (Fig. 4.1.10), similar to the pattern observed for birds of Polish origin. Over one third of the winter recoveries came from the Balkan area (20%) and Italy (15%). The median dispersal distance suggested that half of the cormorants ringed in the East Baltic area travelled more than 1700 km to reach their overwintering grounds (Fig. 4.1.11) and they occupied areas as far south as Greece and Tunisia (Fig. 4.1.10).

4.1.9 Discussion

Great Cormorants ringed in countries surrounding the Baltic Sea displayed both similarities and differences in dispersal direction, timing, distance migrated and distribution among overwintering areas.

Post-breeding period: After the end of the breeding season, between July and August, cormorants initially stayed close to the breeding areas. This pattern was most evident among cormorants originating from the western and central parts of the Baltic Sea area whereas cormorants of a more northeastern origin travelled further during the first months after the breeding season. A difference was also observed between the more northerly and southerly breeders with fewer cormorants of German and Polish origin remaining in the Baltic Sea area (66% and 36% respectively), compared to birds of Danish (93%), Swedish (91%), Finnish (82%) and East Baltic origin (73%).

The huge difference observed in the median dispersal distance between first-year birds and older birds of Finnish origin (Fig. 4.1.9) may be the combined result of an earlier departure for the wintering grounds among adults and recoveries of individuals that had stayed south and southwest of Finland during the breeding season, either as over-summering non-breeders or as breeders that had settled to breed in colonies outside of Finland.

The initial dispersal, immediately after the breeding season, was broadly scattered in all directions among breeders from more southern latitudes (e.g. Denmark, Germany and Poland) whereas a more focused pattern in a specific direction was observed in more northern and northeastern breeders (e.g. Sweden and Finland). In general younger birds (first-year birds) dispersed across a wider spectrum of directions, while older birds travelled in a more specific direction during the post-breeding period.

Differences in dispersal behaviour between first-year birds and older birds are described for cormorants of Danish origin in Bregnballe & Rasmussen (2000).

Autumn: Between September and November almost half of the cormorants of Baltic origin seem to have remained in the Baltic Sea area (ca. 40-70% of the recoveries, excluding Poland). Cormorants of Polish origin displayed a different tendency, with almost half of all recoveries coming from the Central East area during the autumn months.

Cormorants from the Baltic countries displayed differences in the timing of departure from the post-breeding areas towards the wintering grounds. Older birds from Finland were the first to depart, with high dispersal distances observed already in July and August. First-year birds of Finnish origin followed the older birds, departing in August. In September cormorants from Germany (older birds), Sweden and the East Baltic countries left the post-breeding areas. Finally in October birds of Danish origin along with first-year birds from Germany and Poland began to migrate. There seemed to be an age-related difference in the timing of departure in cormorants from Finland, Poland and Germany, with older birds migrating before first-year birds. This tendency was not observed in Denmark, Sweden or the East Baltic countries. The median recovery distances suggested that a large proportion of the birds from the Baltic Sea area had reached their wintering areas by mid-November but it was also clear that many birds were moving further south during November-December (see Figs 4.1.3, 4.1.6, 4.1.8, 4.1.9, 4.1.11).

During the autumn months the dispersal direction became more focused in a south-southwesterly direction, especially among populations originating from Finland and the East Baltic area. Cormorants from Denmark and Germany continued to have a more broad dispersal pattern compared to the populations from other Baltic counties. In general the dispersal patterns were similar among first-year and older birds, except among birds of Polish origin, where first-year birds dispersed more often in a north-northwest direction compared to older birds.

Winter: Cormorants originating from the Baltic countries were widely dispersed across Europe during the winter with some remaining close to the breeding areas in the Baltic Sea whereas other migrated to wetlands located along the Atlantic Ocean, in central Europe or to the Mediterranean including the coastal areas and even inland wetlands in North Africa (Fig. 4.1.2).

Cormorants of Danish, Swedish and Finnish origin displayed a fairly broad distribution pattern during the winter months with cormorants widely distributed across northern, western and parts of central Europe. A large proportion of cormorants from these three countries were recovered in France (24-33%; see Appendix 5.2 for estimates corrected for spatiotemporal variation in recovery probabilities). A smaller proportion of the Finnish population overwintered in the northern parts of Europe around the Baltic Sea. Furthermore birds of Swedish and Finnish origin travelled to wintering areas further east when compared to the Danish population. Cormorants of German origin were distributed over a more restricted geographical area, centered around central Europe. Fewer cormorants of German origin overwintered in the northern parts of Europe (5% in the Baltic Sea area) and almost one third overwintered in the Switzerland and Germany area (31%) with a further 14% in Italy (but see Herrmann et al. (2015) for a more complete description of the winter distribution of German cormorants).

Cormorants of Polish and East Baltic origin displayed some similarities in overwintering dispersal patterns. A large proportion of birds from both regions were recovered from the Balkan area (20-26%), the Central East area (16-22%) and from Italy (15-19%). However cormorants of East Baltic origin were more widely dispersed during the winter, with a larger proportion overwintering in the Baltic Sea area, in western Europe and south along the Balkan Peninsula.

Approximately 20% of the winter recoveries of cormorants from Denmark and Sweden were from the Baltic Sea area, but this figure was much lower among populations originating from central and eastern Baltic countries (1-12%), which appear to have a higher tendency to migrate away from their region of breeding. This is not surprising since the northeast and eastern parts of the Baltic Sea region are covered in ice during shorter or longer periods in most winters. Cormorants from the northern parts of Europe (Denmark, Sweden, Finland and Germany) commonly overwintered in western Europe (20-33% in France), however this figure is much lower among cormorants of Polish and East Baltic origin (e.g. 3-10% in France). However a larger proportion of cormorants of Finnish, Polish and East Baltic origin overwintered in the Central East area (16-22%), when compared with cormorants from the western Baltic countries. Approximately one quarter of birds of East Baltic and Polish origin overwintered in the Balkan area (20-26%), while numbers were much lower among cormorants from other Baltic countries (less than 7%).

Cormorants of Finnish, Swedish and East Baltic origin travelled furthest to the wintering grounds with median distances from 1800 to 2100 km reported in the winter months. Populations from Denmark, Germany and Poland travelled less, with median distances ranging from 1100 km to 1400 km. An apparent age-related difference in migration distance was observed among cormorants from Poland where the median dispersal distance among first-year birds was ca. 300 km further than for older birds.

Among two populations, from Denmark and Sweden, a decline in dispersal distance was observed during the winter months. It is unclear whether this was a result of early departure from the wintering grounds or merely that mortality rates are higher in northern areas in late winter.

4.2 Cormorants from the Netherlands, Belgium and France

4.2.1 Breeding population

Overall breeding numbers in this part of Europe increased from around 9000 pairs in 1983 to 34,000 pairs in 2010 (Fig. 4.2.1). The Netherlands have had the largest numbers of breeders throughout the 31 years covered by this study. The Dutch breeding population increased during the 1980s to a preliminary peak of 21,000 pairs in 1992-1993. After a 'crash' in breeding numbers in 1994 to 15,000 pairs, numbers began to increase again and a fairly stable number of cormorants (22,000-24,500 pairs) were breeding during 2002-2013. The Belgian breeding population increased from 36 pairs in 1993 to 1650 pairs in 2006 where after breeding numbers stabilized. The breeding population in France increased from 950 pairs in 1983 to app. 9000 pairs in 2013. Some of the cormorants breeding in France belong to the Atlantic sub-species *Ph. c. carbo* of the Great Cormorant (Marion 2014).

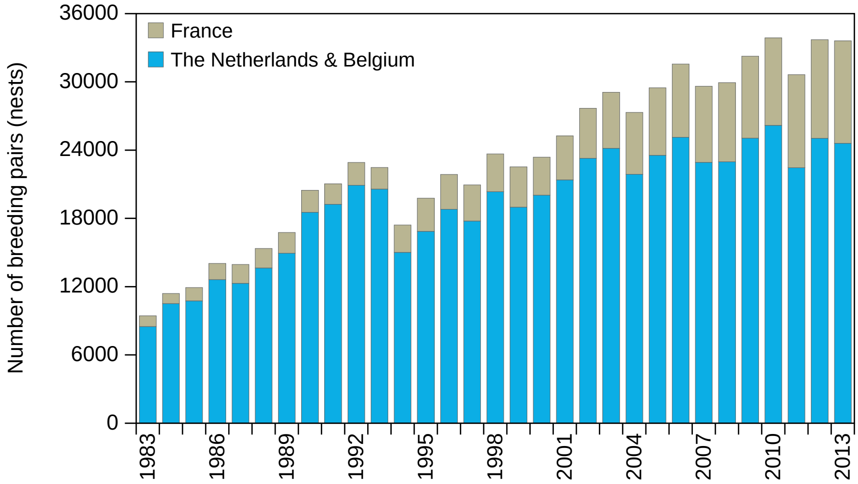


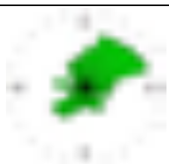
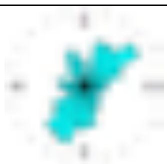
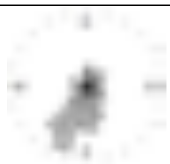
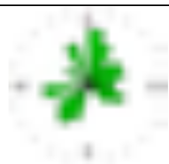
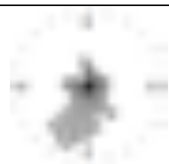
Figure 4.2.1. Development of the number of Great Cormorants breeding in the Netherlands and Belgium (breeding numbers combined for these two countries) and in France, 1983-2013. In 14 of the 31 years the breeding numbers given for France were based on interpolation due to the absence of country wide counts of breeding colonies.

4.2.2 The Netherlands and Belgium

The vast majority of the ringed cormorants from this breeding area were of Dutch origin. Thus 98.3% of the 1130 recovered cormorants originating from this breeding area had been ringed in the Netherlands whereas 1.7% (19) had been ringed in breeding colonies in Belgium (see also Fig. 3.5.3). To make it easier, we therefore refer to the cormorants from the Netherlands and Belgium as being of Dutch origin.

After the end of the breeding season, in July-August, dispersal in all directions was observed, but dispersal in northeastern directions dominated among the first-year birds (Table 4.2.1). The high occurrence of dispersal in northeastern directions during the post-breeding period was mainly the due to movement of Dutch cormorants to the Baltic region of Germany (Fig. 4.2.2).

Table 4.2.1. Dispersal directions from ringing site to recovery site in first-year birds and older birds given for three time-periods for Great Cormorants originating from the breeding area covering the Netherlands and Belgium. The length of each segment relates to relative frequency.

	1-year-birds			**Older birds**		
	Jul.-Aug.	**Sep.-Nov.**	**Dec.-Feb.**	**Jul.-Aug.**	**Sep.-Nov.**	**Dec.-Feb.**
The Netherlands and Belgium						
	189	105	87	33	43	108

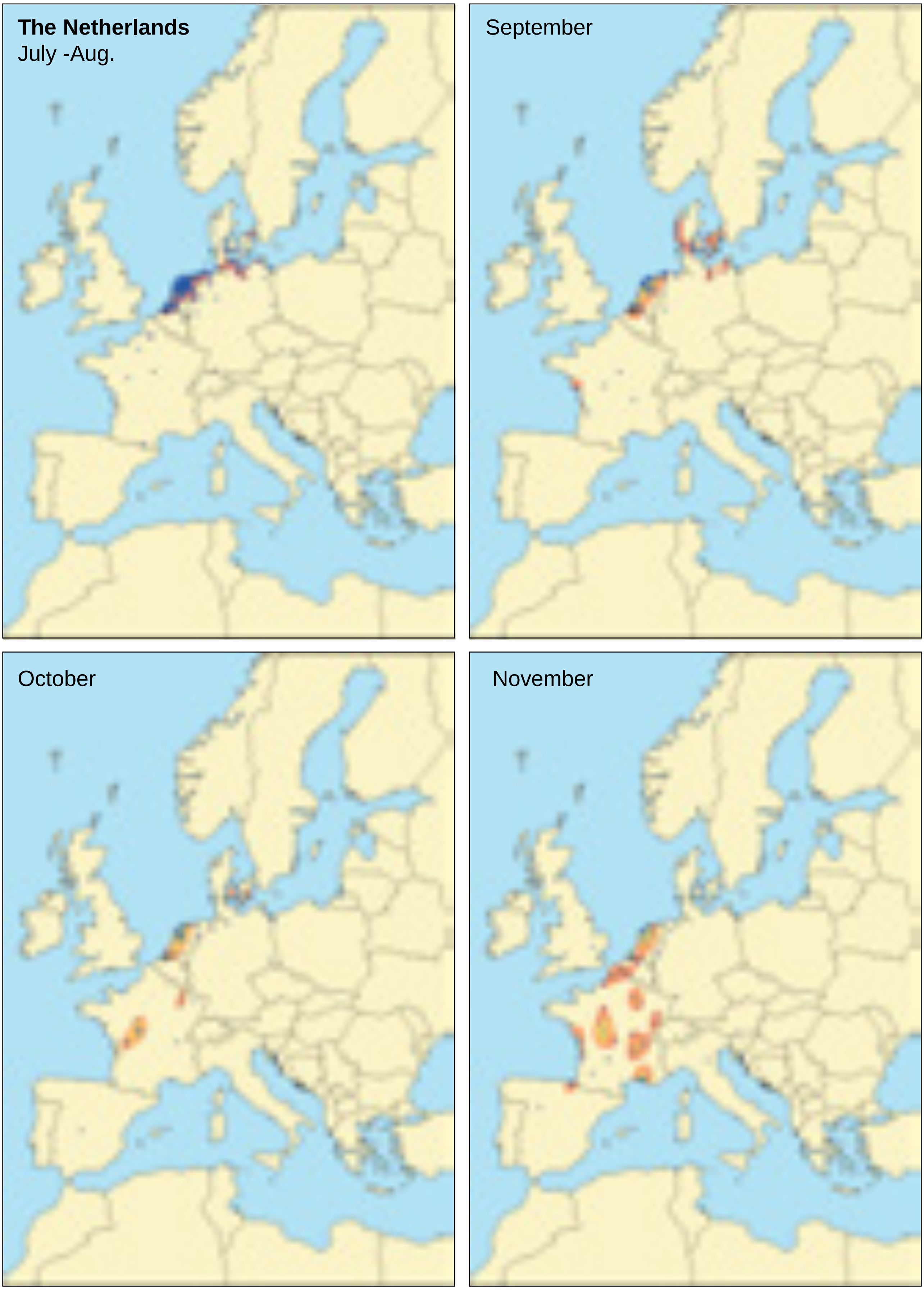

The Netherlands
July -Aug.
September
October
November

Figure 4.2.2. Recovery sites of Great Cormorants ringed in the Netherlands and Belgium and recovered as dead in July-August (post-breeding period), September, October, November and December-February, 1983/84-2013/14. The coloured areas indicate higher recovery density, with yellow identifying areas with the highest densities.

Despite this dispersal of some of the birds, 50% of the Dutch cormorants recovered during July-August were found within 110 km of the colony were they were ringed (Fig. 4.2.3). This suggests that compared to other countries Dutch cormorants largely remained near to the breeding areas during the post-breeding period. During this period 78% of the birds (first-year birds and adults combined) were found inside the region covering the Netherlands, Belgium and NW Germany (area E in Fig. 3.3.2).

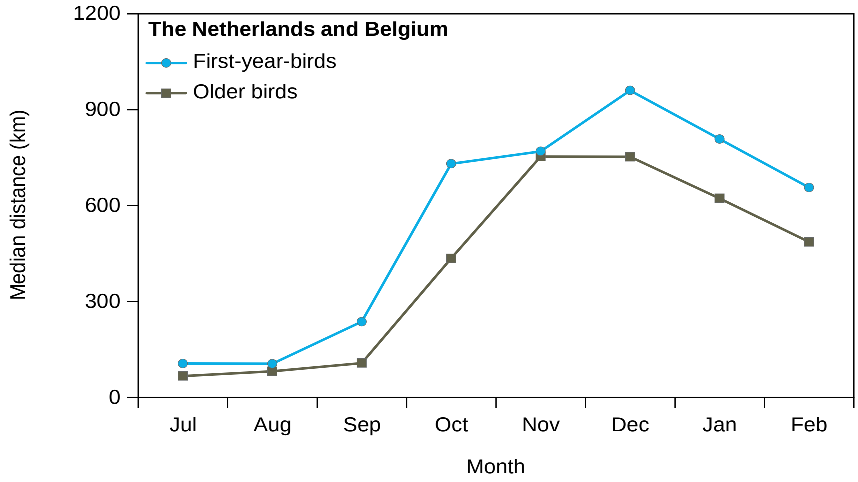


Figure 4.2.3. Median distance from ringing site to recovery site for first-year and older Great Cormorants ringed in the Netherlands and Belgium during 1983-2013 and recovered in 1983/84-2013/14 presented for each month during July-February.

The movements of Dutch birds to France increased from the post-breeding period to the autumn, i.e. 4% of the recoveries made during July-August were from France whereas the proportion was 30% during September-November (Table 4.2.2). Despite the movements in south and southwesterly directions by some birds during the autumn (Table 4.2.1), a large number of Dutch cormorants (43% of the recoveries) were still found in the Netherlands, Belgium and NW Germany in the autumn months (Table 4.2.2). Dutch cormorants were also recovered in Danish and northeast German waters in September-October (Fig. 4.2.2) and overall for the autumn months, 20% of the recoveries were from the southwestern part of the Baltic area (Table 4.2.2). By November a large proportion of the Dutch cormorants were recovered in France (61%, see also Fig. 4.2.2).

Table 4.2.2. The distribution of recoveries of Great Cormorants originating from the Netherlands and Belgium (area 7) and France (area 8), given for the post-breeding period (July-August), the autumn (September-November) and the winter (December-February), 1983/84-2013/14. Sample sizes are given in the last column. The delineation of the staging and wintering areas is shown in Fig. 3.3.2. Breeding area number 7 includes Belgium.

	Breeding area number	Breeding area	A Baltic Sea and S Norway	B Central East	C Switzerland and Germany	D United Kingdom	E The NL, Belgium, Germany	F France	G Spain and Portugal	H Italy	I Balkan	J Black Sea	K North Africa	Outside study area	N
Post-breeding	7	The Netherlands	14.9	0.5	1.8	0.5	78.4	4.1	0	0	0	0	0	0	222
	8	France	0	0	0	17.9	17.9	64.3	0	0	0	0	0	0	28
Autumn	7	The Netherlands	19.6	0	2.0	1.4	42.6	30.4	1.4	0.7	0	0	2.0	0	148
	8	France	3.4	0	3.4	0	10.3	72.4	10.3	0	0	0	0	0	29
Winter	7	The Netherlands	2.1	0.5	3.1	2.1	24.1	47.2	7.7	6.7	0	0	6.7	0	195
	8	France	0	0	0	12.8	8.5	44.7	34.0	0	0	0	0	0	47

The winter distribution of recoveries of Dutch cormorants is shown in Fig. 4.2.2 and Table 4.2.2. These suggest that cormorants of Dutch origin were present in an area ranging from England in the northwest, southern Denmark in the northeast, Italy and Tunisia in the east and south, and southern Spain in the southwest. Within this part of Europe the Dutch cormorants were present in largest numbers in the Netherlands, Belgium and France according to the distribution of recoveries. The corrected estimates (see Appendix 5.2) suggested that the proportion of adult Dutch cormorants that were wintering in the Netherlands, Belgium and NW Germany increased from 1990 to 2010. The median distance between ringing sites and recovery sites declined after December, possibly because some of the Dutch birds moved closer to the breeding areas in late winter (cf. van Eerden & Munsterman 1986), although there may also have been higher mortality among the cormorants staying in the northern areas in mid-winter and late in winter than among those wintering further south. There appeared to be a difference in the median distance between first-year birds and adults in December-February (Fig. 4.2.4) suggesting that among Dutch cormorants first-year-birds were wintering further south than older birds (cf. van Eerden & Munsterman 1986).

4.2.3 France

The cormorants that were ringed in France and later recovered had all been ringed as chicks in breeding colonies located in western France (see Fig. 3.5.3). Some of the chicks ringed and later recovered were from colonies where the Atlantic sub-species *Ph. c. carbo* of the Great Cormorant is breeding. The results presented here are therefore a mix of recoveries of the *sinensis* and *carbo* sub-species .

The distribution of the recoveries during July-September, October-November and December-February is shown in Fig. 4.2.4. It is evident from these maps and Table 4.2.3 that some of the French cormorants dispersed in northern directions (e.g. to England) and in northeastern directions (e.g. to Belgium and The Netherlands and even Denmark) during the post-breeding season and the autumn. These countries located to the north and northeast of the breeding areas were also used as wintering areas by cormorants originating from France. Cormorants of French origin were recorded in Spain and Portugal during October-November and during the winter months (Fig. 4.2.4).

Table 4.2.3. Dispersal directions from ringing site to recovery site in first-year birds and older birds given for three time-periods for Great Cormorants originating from France. The length of each segment relates to relative frequency.

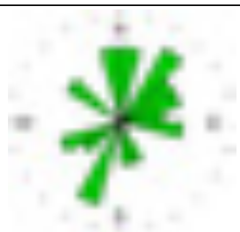
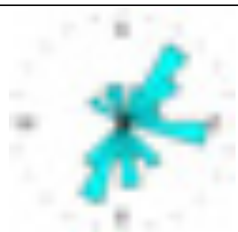
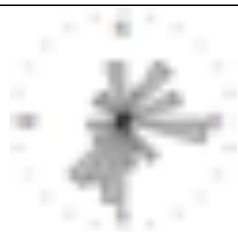
	Jul.-Aug.	Sep.-Nov.	Dec.-Feb.
France			
	28	29	40

Figure 4.2.4. Recovery sites of Great Cormorants ringed in France and recovered as dead in July-September, October-November and December-February, 1983/84-2013/14.

4.3 Cormorants from Central Europe and the Adriatic

4.3.1 Breeding population

The exact development of the breeding population in this region is not known because of lack of annual counts of nests in some of the breeding colonies in the region. The lack of coverage was most pronounced in Croatia and Hungary, and we used interpolation to correct for the missing information. Breeding numbers have been fairly stable in Croatia with between 2600 and 5000 breeding pairs, and Croatia has had the largest numbers of breeders up until 2012 (Fig. 4.3.1). The breeding population in northern Italy increased slowly from approximately 35 pairs in 1983 to 1560 in 2005, and thereafter numbers increased to 4500 pairs in 2012. The breeding population in the Czech Republic has been small throughout the study period, with 50-116 pairs during 1983-1985 and 163-682 pairs during 1986-2013. The Great Cormorant began to breed in Switzerland in 2001 and numbers had increased to 1500 pairs in 2014.

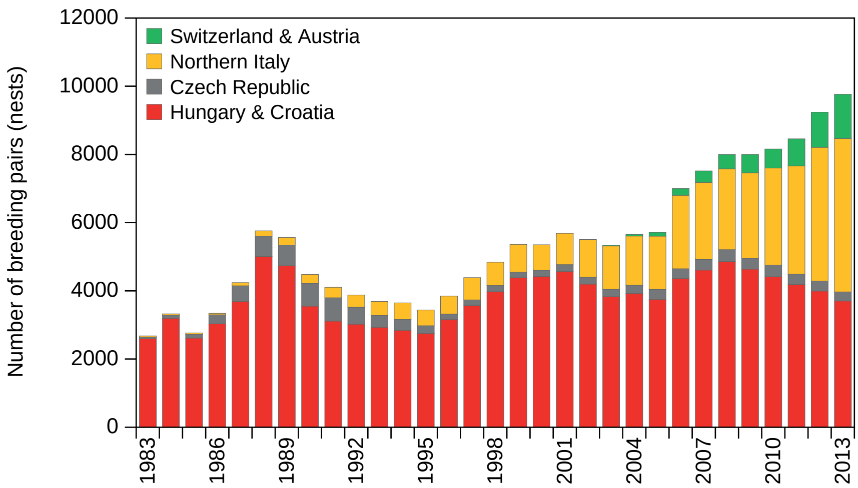


Figure 4.3.1. Development of the number of Great Cormorants breeding in Hungary and Croatia, the Czech Republic, Italy and in Switzerland, 1983-2013. Counts were conducted annually in the Czech Republic and Switzerland but not in Croatia, Hungary and Italy, and for these three countries breeding numbers were for some of the years based on interpolation.

4.3.2 Switzerland

There were only a few recoveries of Swiss cormorants from the post-breeding period, but the 29 recoveries from September-November suggested that most birds moved in a southwestern direction in autumn, i.e. to France and Spain (Table 4.3.1 and 4.3.2; Fig. 4.3.2). There were only two recoveries from northern Italy. In winter the Great Cormorants of Swiss origin were primarily found in France, Spain, Morocco and Algeria (Table 4.3.2, Fig. 4.3.2). See also Antoniazza et al. (2012) for a description of the migration patterns of Swiss cormorants.

Table 4.3.1. Dispersal directions from ringing site to recovery site in first-year birds and older birds given for three time-periods for Great Cormorants originating from breeding areas in central and eastern Europe. The length of each segment relates to relative frequency.

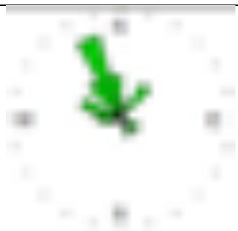
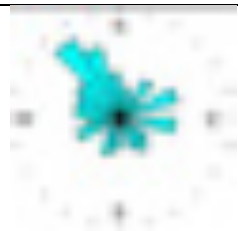
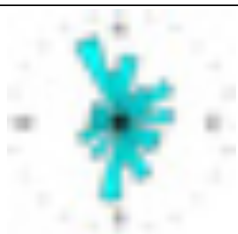
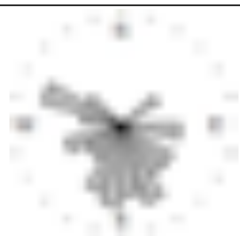
	Jul.-Aug.	**Sep.-Nov.**	**Dec.-Feb.**
Switzerland and Austria		 29	 68
Czech Republic	 52	 84	 21
Croatia. Hungary. Slovakia and Serbia	 61	 51	 44

Table 4.3.2. The distribution of recoveries of Great Cormorants originating from the Switzerland and Austria (area 9), Italy (area 10), the Czech Republic (area 11) and Croatia and Hungary (area 12), given for the post-breeding period (July-August), the autumn (September-November) and the winter (December-February), 1983/84-2013/14. Sample sizes are given in the last column. The delineation of the staging and wintering areas is shown in Fig. 3.3.2.

	Breeding area number	Breeding area	A Baltic Sea and S Norway	B Central East	C Switzerland and Germany	D United Kingdom	E The Netherlands, Belgium, Germany	F France	G Spain and Portugal	H Italy	I Balkan	J Black Sea	K North Africa	Outside study area	N
Post-breeding	9	Switzerland and Austria	0	0	60	0	0	0	40	0	0	0	0	0	5
	10	Italy	33.3	66.7	0	0	0	0	0	0	0	0	0	0	3
	11	Czech Republic	11.5	51.9	36.5	0	0	0	0	0	0	0	0	0	52
	12	Croatia, Hungary and Slovakia	6.6	75.4	4.9	0	0	0	0	0	13.1	0	0	0	61
Autumn	9	Switzerland and Austria	0	0	13.8	0	0	48.3	20.7	3.4	0	0	13.8	0	29
	10	Italy	0	0	16.7	0	0	0	0	83.3	0	0	0	0	6
	11	Czech Republic	4.8	83.3	7.1	0	0	0	0	2.4	1.2	0	1.2	0	84
	12	Croatia, Hungary and Slovakia	5.9	56.9	5.9	0	0	0	0	2.0	29.4	0	0	0	51
Winter	9	Switzerland and Austria	0	0	5.9	0	0	35.3	44.1	2.9	0	0	11.8	0	68
	10	Italy	0	0	8.3	0	0	0	0	83.3	0	0	8.3	0	12
	11	Czech Republic	0	23.8	28.6	0	0	0	0	14.3	28.6	4.8	0	0	21
	12	Croatia, Hungary and Slovakia	0	22.7	0	0	0	0	0	13.6	47.7	6.8	9.1	0	44

Figure 4.3.2. Recovery sites of Great Cormorants ringed in Switzerland and recovered as dead in July-September, October-November and December-February, 2004/05-2013/14.

4.3.3 Czech Republic

The post-breeding dispersal of the Great Cormorants of Czech origin was mainly in a north-northwestern direction (Table 4.3.1) to Germany and Denmark (Fig. 4.3.3). Most of the 84 recoveries from October-November were from the Czech Republic, Hungary and Croatia (Fig. 4.3.3). The recoveries from late summer and autumn were mainly of birds that had been shot (Table 3.5.7). There were 21 winter recoveries and these suggested that cormorants from the Czech Republic were wintering both to the southwest and southeast of the breeding areas (Table 4.3.1) with recoveries coming from southern Germany, Switzerland, Italy and especially from the Balkan Peninsula (Table 4.3.2). Overall the recoveries indicated that a fair proportion of the cormorants of Czech origin had travelled north in the post-breeding period and then later in the autumn had travelled south to spend the winter in central Europe or on the Balkan Peninsula. It is uncertain whether these patterns would have differed if the proportion of birds recovered as shot had been much smaller.

See also Musil et al. (1997) for a description of the movements of cormorants from the Czech Republic.

Great Cormorants occur in largest numbers in areas with extensive shallow waters and sandbanks are frequently used as safe roosting sites during daytime and night. Photo: F. Möllers.

Figure 4.3.3. Recovery sites of Great Cormorants ringed in the Czech Republic and recovered as dead in July-September, October-November and December-February, 1985/86-2013/14.

4.3.4 Croatia and Hungary

The cormorants originating from this breeding area for which we have recoveries were a mix of birds from Croatia (72 recoveries), Hungary (67 recoveries) and Serbia (10 recoveries). The location of the colonies were these birds were ringed is given in Fig. 3.5.4.

As observed among the cormorants from the Czech Republic the majority of the cormorants recovered in the post-breeding period had moved to the north of the breeding areas (Table 4.3.1), e.g. to northeast Germany, Poland and the Czech Republic, although many were also recovered in Hungary and Croatia (Fig. 4.3.4, Table 4.3.2). The recoveries from October-November suggested that some of the birds had remained in the areas to the north of breeding areas and that migration to the south was not necessarily taking place before late autumn or early winter (Fig. 4.3.4, Table 4.3.1). The 44 winter recoveries were mainly from the Balkan Peninsula (including Greece), but there were also recoveries from Italy and coastal areas in Tunisia and Egypt (Fig. 4.3.4, Table 4.3.2).

Great Cormorants spend many hours roosting at safe locations and they prefer to roost very close to water. This roosting site is dominated by first-year birds. Photo: S. Ortmann.

Figure 4.3.4. Recovery sites of Great Cormorants ringed in Croatia and Hungary and recovered as dead in July-September, October-November and December-February, 1983/84-2013/14. The maps include 10 recoveries of cormorants ringed in Serbia.

4.3.5 Italy

The number of Great Cormorants that were ringed in Italy and later recovered between July and February amounted to only 21. Three of the recoveries from July were from Germany and the Czech Republic suggesting that also cormorants from north Italy may disperse in northern directions during post-breeding. The recoveries from October-November were from Germany (2 recoveries) and Italy (7 recoveries). The remaining nine recoveries were from December-February and these cormorants had been recovered in northern Italy except for one bird that was found in Tunisia (Fig. 4.3.5).

Figure 4.3.5. Recovery sites of Great Cormorants ringed in Italy and recovered as dead between July and February, 1996/97-2010/11.

4.4 Factors affecting migration routes and winter distribution

4.4.1 Introduction

The migratory behaviour of cormorants and their choices of where to stopover and overwinter can be expected to vary depending on a range of internal and external factors such as the genetic pre-determination of migration direction, the age and sex of the individual, the presence of physical barriers, the spatial distribution of wetlands, year-to-year variation in the climate, food availability and availability of safe roosting sites and night roosts.

We used some of the collated data to explore degrees of variability in how cormorants are distributed outside the breeding season, and we tried to identify some of the factors that have influenced the patterns we observe in the distribution of cormorants in Europe during post-breeding, autumn and winter.

4.4.2 Factors affecting migration routes and choice of wintering area

During the analyses of the recoveries of cormorants found dead we found evidence for effects of the following factors on the distribution of cormorants in Europe during post-breeding, autumn and/or in winter:

- *Sex-related differences in migration distance and choice of wintering area* was found among adult cormorants of Danish origin. Due to the large number of Danish cormorants that had been sexed we were able to compare the distance between the ringing site and the recovery site or resighting site for 413 females and 512 males in winter. We found a difference in the median distance between the ringing site and the wintering site of 217 km, i.e. females migrated 30% further south than males (916 km for females vs 699 km for males). There was no difference between the sexes in the median dispersal and migration distance during the post-breeding period or during the autumn. We also found that the percentage of males was highest among those wintering in the northern areas and in central Europe and lowest in Italy, Spain-Portugal and France (Table 4.4.1).

Table 4.4.1. The proportion (%) of males among Danish-ringed cormorants recovered or resighted in eight different wintering areas. Individuals are only included once.

Area	% males	N
Denmark, Sweden	70.1	87
Germany	64.0	186
Switzerland, Austria	53.3	135
The Netherlands	55.8	165
Belgium, Luxembourg	61.3	62
France	49.5	202
Spain, Portugal	51.3	39
Italy	33.8	71

- *The geographical location of the breeding colony* both on an east-west axis and in relation to the outline of the nearby coastal areas. The effect of this was that cormorants originating from colonies that were located within a distance of for example 100 km could show quite different patterns of distribution outside the breeding season. Some of the results are presented in Bregnballe et al. (2015). These findings were in concordance with Bregnballe & Rasmussen (2000), Reymond & Zuchuat (1995), L. Marion (unpubl.).

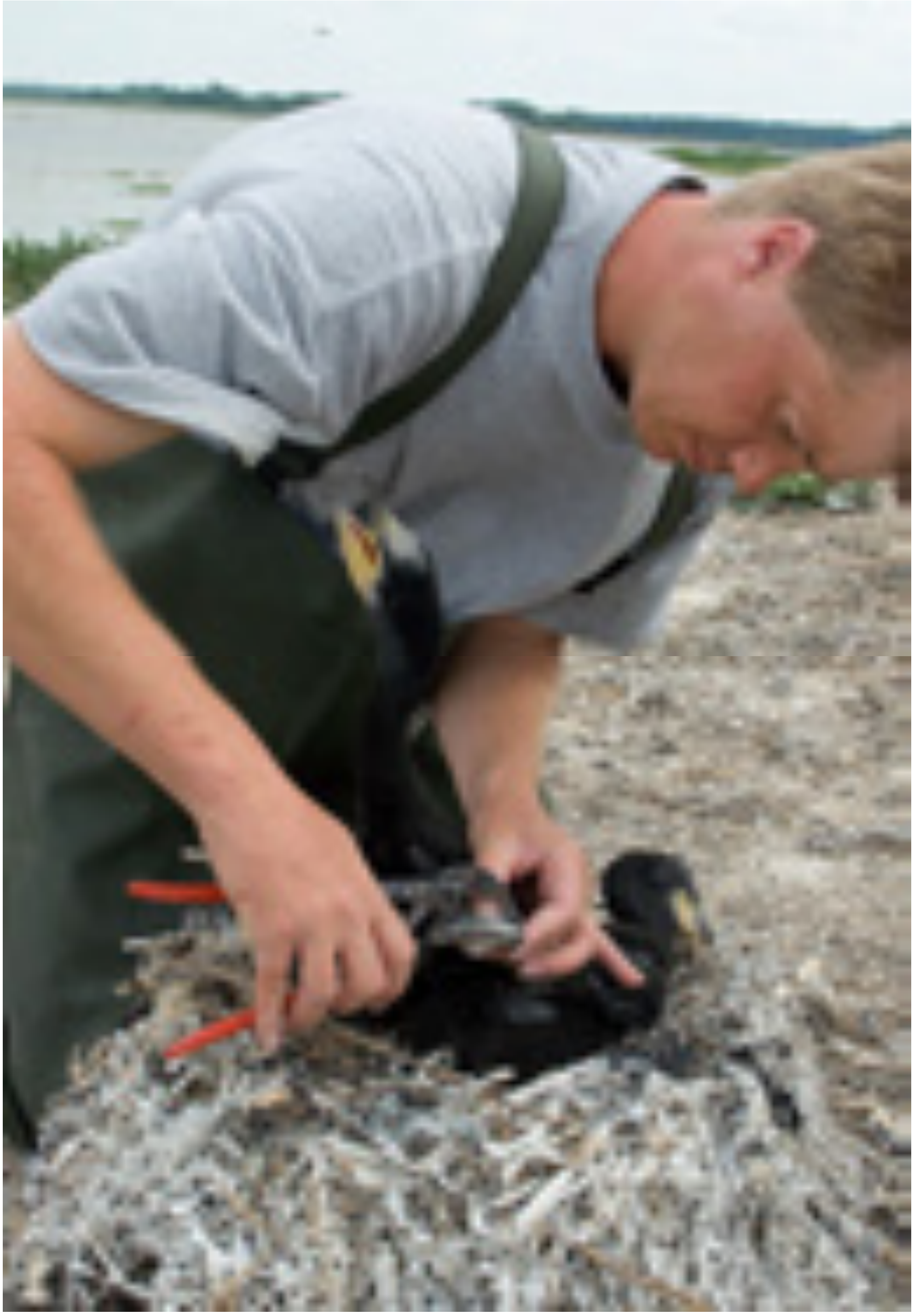
- *The presence of barriers* in the form of extensive areas of open sea, land or mountains. These findings were in concordance with Coulson & Brazendale (1968), Bregnballe et al. (1997), Bregnballe & Rasmussen (2000) and Voisin & Posse (2005).

- *The geographical location of attractive feeding areas*. It was evident from the distribution of recoveries that large shallow waterbodies were attractive to Great Cormorants during the post-breeding period, in autumn and during winter. Many of these areas are known as highly productive waters with fairly high densities of fish. See van Eerden et al. (2012) for a detailed description of the distribution of cormorants in relation to different types of waterbodies.

- *Year-to-year variation in winter severity* during the first winter of an individuals' life seemed to influence where the individual decided to spend subsequent winters. The apparent effect of this is that individuals belonging to cohorts that experience a cold winter in their first year of life, tend to migrate further south than cohorts exposed to mild winters in their first year of life. We also found that analyses of recoveries were not a reliable tool to study short-term effects of weather conditions on winter distribution of cormorants simply because of the higher risk of mortality and thus higher probability of recovery in northern areas when these were exposed to severe cold. However, we know from counts of cormorants at night roosts and from detailed studies of colour-ringed individuals that cormorants in general leave their wintering site after a few weeks of temperatures below zero and/or after abrupt declines to temperatures far below zero (e.g. Buchheim 1997).

Against expectations, we did not find evidence to validate the prediction that first-year birds generally migrate further than older birds before they settle in a wintering area. Thus, there were no such differences among cormorants of Danish, Swedish, Finnish, East Baltic or German origin. However, there were indications of differences in the mean migration distance between first-year cormorants and adult cormorants of Dutch origin.

Studies using resightings of colour-ringed cormorants have shown that individual variation can have a marked influence on migration routes and timing of migration of cormorants in Europe. It has been found that some individuals have highly fixed migration schedules and use the same wintering areas and stopover sites year after year, whereas others show a highly flexible migratory behaviour both in terms of low site tenacity and high variability in timing of migration (e.g. Reymond & Zuchuat 1995, Yésou 1995, Paquet et al. 2003, Bregnballe et al. 2006). Frederiksen et al. (2002) and Lekuona & Campos (2000) used resightings of colour-ringed cormorants to quantify the extent of site fidelity of cormorants wintering in central Europe and Spain.



Ringing of very young Great Cormorant chicks in a Danish ground nesting colony.
Photo: S. Ortmann.

4.4.3 Changes in distribution

It can be very difficult to quantify the changes over the years in where cormorants decide to stop-over and stay for the winter. There are methodological challenges in analysing distributional changes using recoveries of ringed cormorants found dead. This is partly because there is spatiotemporal variation in the probability that a ringed cormorant will die, and in the probability that it will be recovered and reported. Furthermore, changes over time in the relative importance of the various causes of mortality can inflate patterns and lead to unreliable trends in, for example, the distance between ringing and recovery position. For example, the probability that a ringed cormorant wintering in France will be shot and reported dead may have changed since 1980, and this will influence the apparent patterns of distribution. Hence, what appears to be a change in distribution may be caused by a change in the probability of recovery of ringed individuals.

Estimated proportion migrating to different wintering areas

Using the model described in chapter 5, we explored whether changes had occurred in the wintering areas that were used mostly by the cormorants originating from the various breeding areas. The use of the model allowed us to correct for some of the spatiotemporal variation in recovery probability. There were a sufficient number of recoveries from eight of the breeding areas (Sweden, Finland, East Baltic, Poland, Denmark, Germany, the Netherlands and Switzerland) to look for changes over five-year periods (see Appendix 5.2).

We found that cormorants from all eight of these breeding populations had changed their prime choices of where to winter (examples of pie charts are given in Appendix 5.2)..

Median location of recoveries

We looked for changes over the study years in the median location of recoveries made during the post-breeding period, the autumn and the winter, but only for populations for which sufficient recoveries were available. With focus on changes in winter, we here give the major results of our exploration of changes over the following 10(11)-year periods:

- Period I: 1983/84-1993/94
- Period II: 1994/95-2003/04
- Period III: 2004/05-2013/14

<u>Sweden</u>. The median location of the winter recoveries of cormorants originating from Sweden had moved approximately 500 km towards the northwest from Period I to Period III. The median coordinates of the autumn recoveries had moved to the west from Period I to III. The change in winter distribution towards the north was even more evident when excluding recoveries of cormorants reported as being shot.

<u>East Baltic</u>. The median coordinates of winter recoveries of Cormorants from the East Baltic had moved 350 km towards the north from Period I to II and III, but the sample sizes from Period I were small.

<u>Poland</u>. The median coordinates of winter recoveries of Cormorants from Poland did not indicate that changes had taken place over the three periods.

Denmark. The median coordinates of the recoveries of cormorants originating from Denmark moved towards the west in autumn and in winter from Period I to Period III. The median coordinates of the winter recoveries had also moved to the north between Period I and Period II. These changes were also evident when excluding recoveries of cormorants reported as being shot.

Germany. The median coordinates of winter recoveries of Cormorants from Germany shifted over the study years and indicated that an increasing proportion of German cormorants only migrated 'short' distances before settling for the winter. This was also the case when excluding all recoveries of cormorants that had been reported as shot. But see Herrmann et al. (2015) for a more detailed description of the changes in winter distribution of cormorants of German origin.

The Netherlands. The median coordinates of winter recoveries of Cormorants from the Netherlands had moved more than 500 km towards the north from Period I to III. These changes were also evident when excluding recoveries of cormorants reported as being shot.

Median distance to wintering area

We compared the median distance between the ringing sites and the recovery sites for the post-breeding period, the autumn and the winter for countries where a sufficient number of cormorants had been ringed over most of the study period. The major results concerning the distance to the wintering areas were:

Sweden. The recovery data were grouped into 2-year periods and the median distance was calculated for each pair of winters between 1989/90 and 2013/14. There were no changes in the median distance to the recovery sites over this series of pairs of winters.

Denmark. The median distance to the recovery sites was calculated for each winter between 1983/84 to 2013/14. The median distance to the winter recovery sites decreased from the mid-1980s to the winter 2009/10 but increased again in the following winters.

Germany. The 31 study years were grouped into four periods. The median distance to the recovery sites in winter decreased with 300 km from the first two periods lasting from 1983/84 to 1998/99 to the last two periods lasting from 1999/00 to 2013/14. See also Herrmann et al. (2015) for a description of the changes in winter distribution of cormorants of German origin.

The Netherlands. The study years were grouped into four periods as for the analyses of recoveries from Germany. The median distance to the recovery sites in winter decreased by 700 km from the first period 1983/84-1990/91 to the last period 2007/08-2013/14.

5 Migratory connectivity and composition of wintering populations

5.1 Introduction

One of the major aims of the CormoDist project is to use ring recoveries of cormorants found dead to estimate the degree of connectivity between breeding and wintering areas, and specifically estimate the composition of wintering populations in terms of their breeding origin (see Fig. 5.1.1).

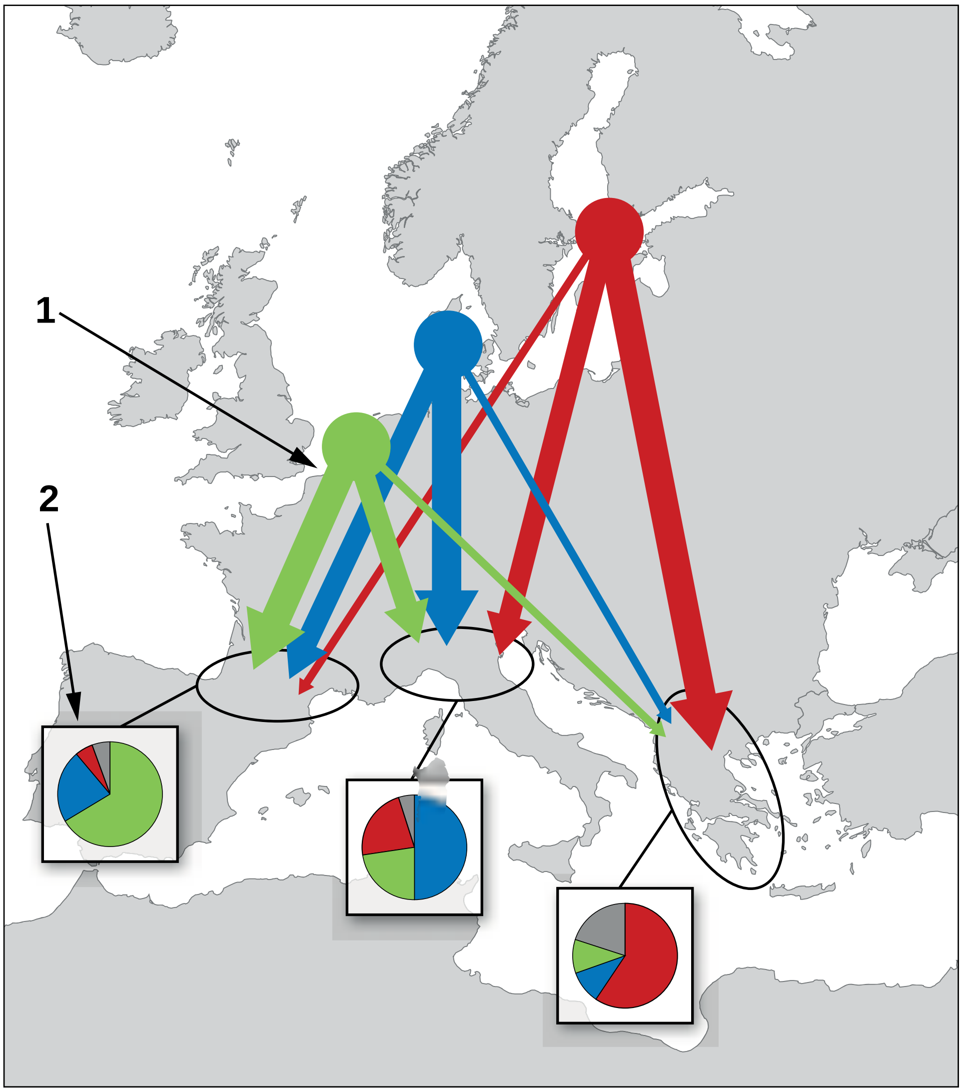


Figure 5.1.1. Figure illustrating a theoretical example of migratory connectivity between breeding and wintering areas. The number '1' refers to the estimation of the proportion of birds migrating from specific breeding areas to various wintering areas, and the number '2' refers to the estimation of the composition of the winter population in different parts of Europe with respect to the geographical origin of the birds present in winter.

Estimating migratory connectivity from ring recovery data is not straightforward, chiefly because the probability that a bird dies and the ring number is reported is likely to differ among wintering areas and change over time. Improved statistical methods for estimating the proportion of birds from a breeding area moving to specific wintering areas, while correcting for variation in reporting probability, have recently become available (Thorup & Conn 2009, Korner-Nievergelt et al. 2010, Korner-Nievergelt et al. 2014). However, estimating the proportional composition of wintering populations in terms of their breeding origin necessitated inclusion of information on population size and breeding success in each breeding area. Furthermore, it necessitated the development of an entirely new model. Such a model has been developed during the CormoDist project by Fränzi Korner-Nievergelt (Swiss Ornithological Institute) and Morten Frederiksen (Aarhus University).

Since the 1970s, very large numbers of cormorant chicks have been ringed throughout Europe, and this effort has provided large amounts of information that can be used to quantify migratory connectivity. The ringing effort has included all parts of the breeding range in the Baltic region, central and western Europe since the early 1980s. This high level of coverage allows a formal quantitative approach to the estimation of migratory connectivity.

Here, we use the thousands of recoveries of dead ringed cormorants throughout the winter range (Europe and North Africa) to quantify migratory connectivity. This analysis is therefore restricted to dead recoveries during the winter period of cormorant chicks ringed 1983-2013.

5.2 Material and methods

5.2.1 Material: Ringing and recovery data

Information about the number of cormorant chicks ringed was obtained from the national ringing centres and in a few cases from key cormorant ringers. Recovery data were obtained from the EURING database (www.euring.org) and from the national ringing centres.

The recoveries included in the present part of the study were the result of ringing of 222,467 cormorant chicks during 1983-2013. A series of criteria were applied in order to extract relevant and reliable recoveries. For example, records where only the ring was found and those with a highly uncertain finding date were excluded (see also chapter 3). Among all the dead recoveries we extracted 4511 recoveries made during the winters of 1983/84-2013/14. The winter period was defined as 15 November - 28 February, i.e. we assumed that the vast majority of cormorants had reached their wintering areas by then and remained fairly stationary (Bregnballe, Frederiksen & Gregersen 1997; Frederiksen *et al.* 2002). A large proportion of the recoveries included were recoveries of individuals that had been shot (2003 of the recoveries) whereas the other 2508 recoveries were birds that had been reported dead from other or unknown causes. All the recoveries were allocated to the defined wintering areas (Fig. 5.2.2) by use of ArcGIS 10.2.

5.2.2 Spatial coverage and structure

Our aim was to provide estimates of migratory connectivity for the population of the sub-species *Ph. c. sinensis* breeding in northern and central Europe. We therefore excluded breeding areas populated exclusively or mainly by the sub-species *Ph. c. carbo* (the British Isles incl. the Channel Islands, Iceland, Norway except the south-eastern region, Arctic Russia), as well as those populated by the Black Sea population of *Ph. c. sinensis*. The Atlantic sub-species *Ph. c. carbo* also breeds in western France mixed with *Ph. c. sinensis*, and this population is included here.

We included all known wintering areas of our target population. However, some of the wintering areas used by our target population are also used by cormorants that do not belong to our target population. This is the case in parts of the wintering areas in Norway, Sweden, Denmark, the British Isles, western France and the Iberian peninsula where our target population mixes with cormorants belonging to the *Ph. c. carbo* sub-species (Wernham, Ekins & Sellers 2002; Bakken, Runde & Tjørve 2003). Our target population also mixes with cormorants from the breeding population along the Black Sea. Mixing with this breeding population occurs in Romania, Bulgaria, Greece and eastern North Africa. Our estimates of compositions of wintering populations only includes cormorants originating from our target population and to not take birds from any other breeding populations into account.

We defined 12 breeding areas (Fig. 5.2.1) and 11 wintering areas (Fig. 5.2.2); see also chapter 3 (Tables 3.3.1 and 3.3.2) for a list of countries and provinces included in each of the defined areas. The breeding areas were largely defined based on national administrative borders, because data on numbers ringed were usually only available at the national level. Wintering areas were defined using a combination of administrative and biogeographic criteria, but for the exact definitions we used local administrative borders.

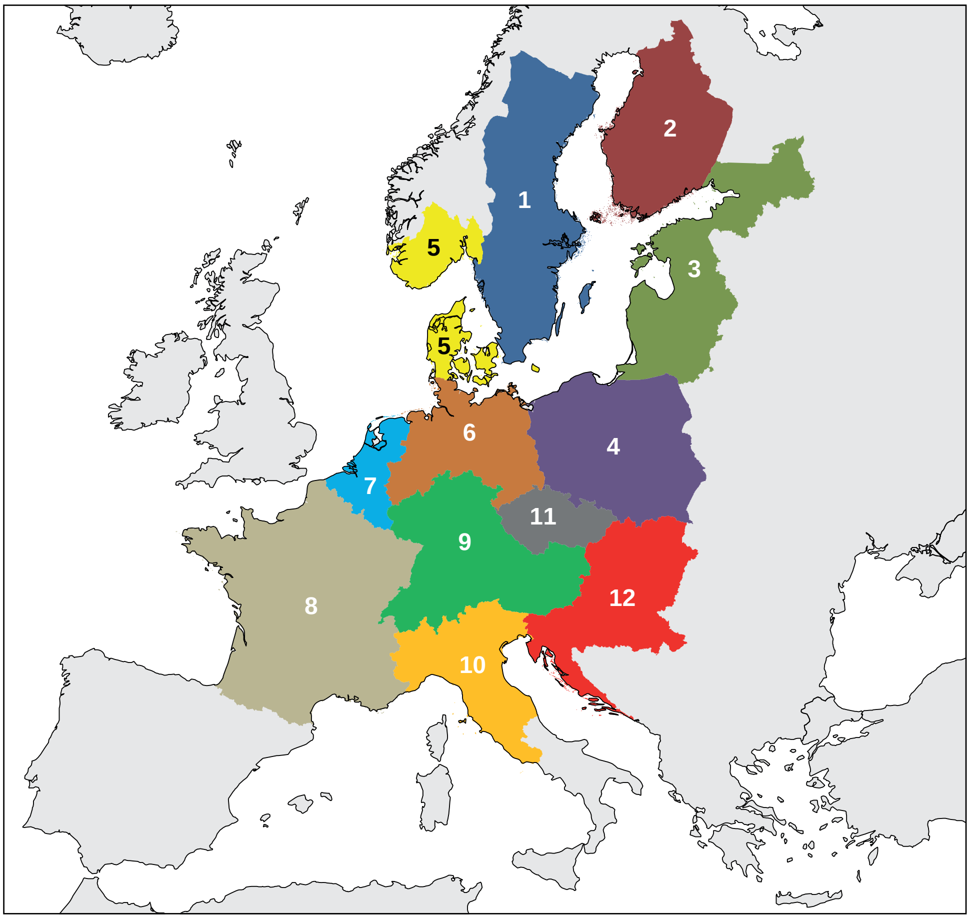


Figure 5.2.1. Delineation of the 12 defined breeding areas in Europe. The countries and provinces included in each of the defined breeding areas are listed in Table 3.3.1.

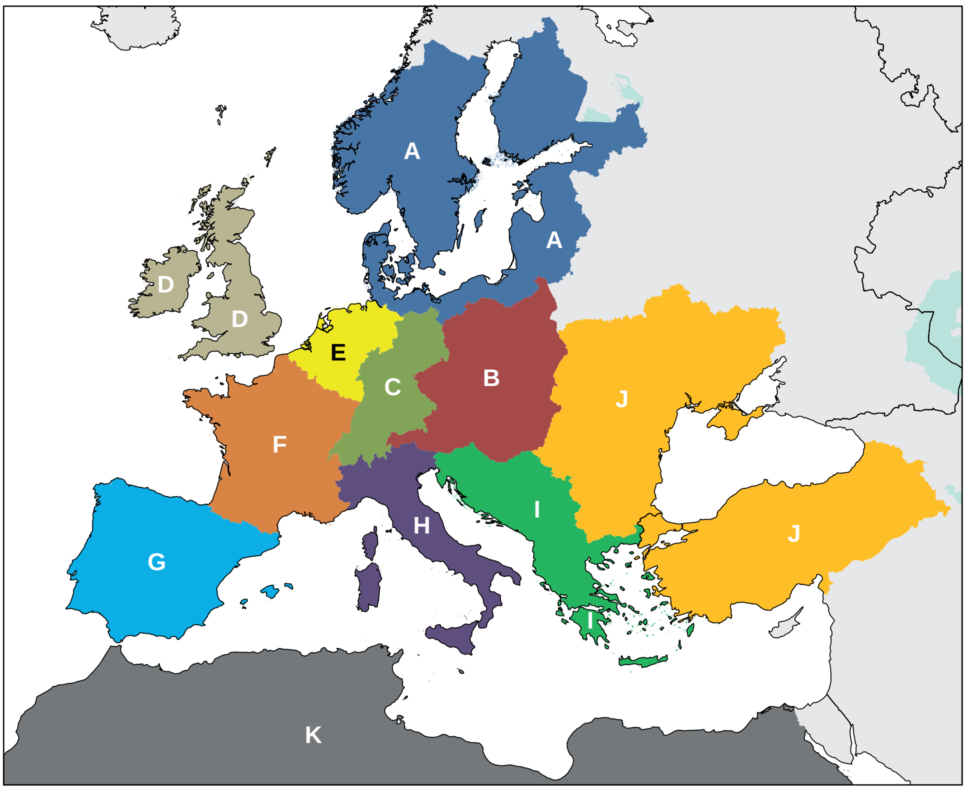


Figure 5.2.2. Delineation of the 11 defined wintering areas in Europe. The countries and provinces included in each of the defined wintering areas are listed in Table 3.3.2.

5.2.3 Variables used for modelling

For the modelling we used information about the following variables for each breeding area:

- The number of cormorant chicks ringed per year.
- The annual number of breeders. We have interpolated missing values (see Appendix 5.1).
- The annual number of non-breeders. This number was estimated by use of information on the numbers of breeders, estimates of survival and the assumption that all birds began to breed at the age of 3 years.
- The number of young produced per year and breeding area. There were many gaps in this data set, and we had to make 'guesstimates' for most years and breeding areas based on general knowledge of the species (including density-dependent declines in breeding success as local populations grow).

The material and methods applied for estimating these variables is further described in Appendix 5.1.

5.2.4 The model

The model contains two steps:

1) A multi-state ring-recovery model (Lebreton et al. 2009) based on dead recoveries of cormorants ringed in the breeding areas is used for estimating the distribution probabilities, i.e. the proportion of birds from each of the 12 breeding areas that migrate to each of the 11 wintering areas. This is done separately for the first-year birds, and for older birds. The proportions are estimated for 5-year periods.

2) The results from step 1 are then combined with counts of breeding pairs and estimates of breeding success in each breeding area to estimate the number of cormorants migrating from each breeding area to each wintering area. Because all important breeding populations are included, this allows estimation of the size and composition of each wintering population. All model parameters are allowed to vary over time, leading to time series of estimates of winter population composition.

The model also estimates temporal and geographical variation in recovery probabilities and in the survival of first-year birds and older birds, but these results are not presented in this report.

The model is written in R (R Core Team 2013), with estimation of the parameters of the multi-state model carried out in a Bayesian framework in JAGS (Plummer 2003). The estimation model is fully developed and has been extensively tested on simulated data. In addition, procedures for importing real ringing, recovery, population size and breeding success data have been developed.

Further details about the overall structure of the model and the methods applied for estimating and validating parameters can be found in Appendix 5.1.

5.2.5 Assumptions, uncertainties and weaknesses

In relation to the data we have assumed that:

- The breeding and wintering areas we have decided on are reasonably homogeneous, in terms of migration behaviour, population development and probability of a dead bird being reported.
- Linear interpolation provides a reasonable approximation to population development in each breeding area, in cases where there were data gaps. This is probably a fairly robust assumption.
- Our guesstimates of breeding success are reasonable. This assumption is difficult to verify, and we certainly underestimate year-to-year variability (although these are means over rather large areas). Because first-winter birds make up a relatively small part of the population, errors in breeding success estimates will not have a large impact on the results.

In relation to statistics and modelling we have assumed that:

- Ringed birds are representative of the population (within each breeding area). This is a standard assumption of all mark-recapture methods.
- Within each wintering area and year, all dead birds have the same probability of being reported, regardless of *origin*, *sex*, *age* and *cause of death*. Reporting probabilities are thus allowed to vary over time and space. This assumption is potentially problematic. In particular, birds dying from different causes clearly do

not have the same chance of being reported. This is only critical to the extent that age classes or sexes are differentially exposed to various mortality sources, within a wintering area. The assumption about age is necessary because too few adults have been ringed to provide independent estimates of their reporting probability.

- All birds start breeding when 3 years old. This is a simplifying assumption, which ignores density-dependent changes in age of recruitment.
- Males and females do not differ in migration behaviour. This is a necessary assumption, because ringed and recovered birds generally have not been sexed. The estimated migratory connectivity is thus an average across sexes, provided that the sex ratio among ringed birds is representative.
- Migration behaviour does not change with age after the first year.

The output from the modelling has some weaknesses of which some are:

- Very few adults have been ringed. This means that we have to assume that reporting probability does not change with age – which may be a problem if age groups are exposed to different mortality sources, and birds dying from different causes have different probability of being reported. Both scenarios are likely.
- Data on breeding success are sparse. We have therefore had to 'make up' a large part of the data set. However, we believe the principles used for imputing these data are robust, and in any case the consequence of errors should be moderate.
- For some breeding areas and years, numbers of birds ringed are low. This means that some estimates will be quite imprecise.
- The cormorants that belong to the sub-species *Ph. c. carbo* and/or originate from breeding populations located outside of our defined breeding areas but spend the winter within wintering areas defined here are not included. In other words cormorants breeding in e.g. the UK, Norway (outside the southeast) and Ukraine are not included in the model. This means that the size of some wintering populations is underestimated, and their estimated composition to some extent misleading.

5.3 Proportions migrating to different wintering areas

By use of the multi-state ring-recovery model the proportion of birds from each of the 12 breeding areas that migrated to each of the 11 wintering areas was estimated. An example of the outputs from this modelling is given in Fig. 5.3.1. The pie diagrams show the proportion of adult cormorants from the Swedish breeding population estimated to have been present in each of the wintering areas defined in Fig. 5.2.2. Each of the three pie diagrams refers to an estimate based on recoveries made over five winters. It is evident from this example that the proportion of Swedish birds migrating to countries in the Balkan (light green colour) decreased between 2000 and 2010 whereas the proportion remaining in the Baltic Sea (dark blue) increased. It is also clear that the proportion wintering in France (dark orange) was highest during the winters around 2000. Similar pie diagrams showing the estimated distribution of adult cormorants among the 11 wintering areas is given for most of the 12 breeding areas in Appendix 5.2.

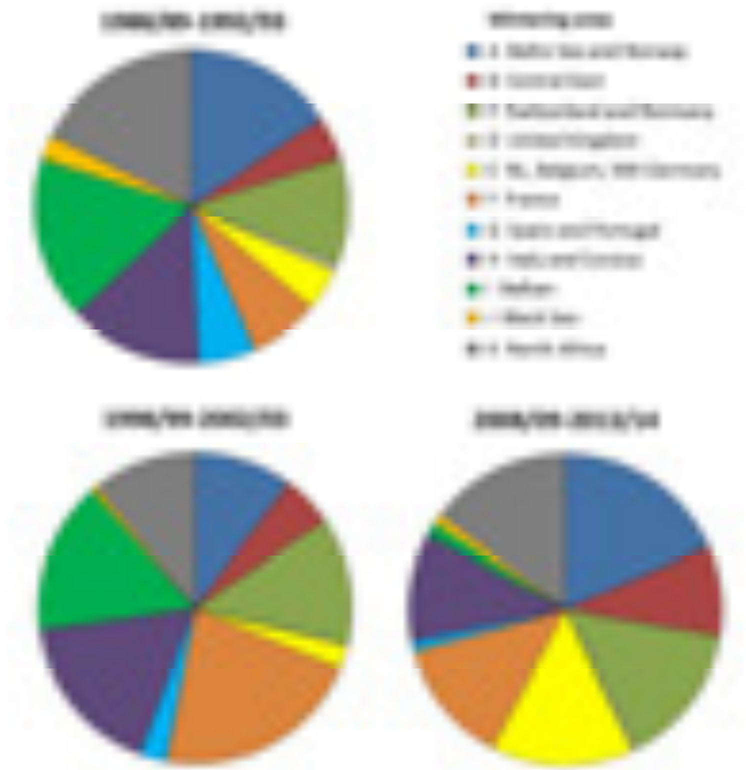


Figure 5.3.1. The proportion of adult Great Cormorants belonging to the Swedish breeding population estimated to have been wintering in each of 11 areas in Europe and North Africa in a series of winters around 1990, 2000 and 2010. The estimates behind the three pie charts were based on 112, 280 and 209 winter recoveries of adult cormorants of Swedish origin. Similar pie charts for other breeding populations are given in Appendix 5.2.

An example of another way of illustrating the changes from one 5-year period to the next in the estimated proportion of first-year birds and older birds migrating to specific wintering areas is given in Fig. 5.3.2 and 5.3.3. These graphs also include a measure of uncertainty (confidence limits) of the estimates. It is evident from this example that the proportion of birds of Danish origin that migrated to specific wintering areas deviated to some extent between first-year birds and older birds and that, over time, there were changes in where the majority of birds were wintering. For example, the proportion of first-year birds and older birds that attempted to winter in the Baltic Sea and in France increased during the mid- or late 1990's.

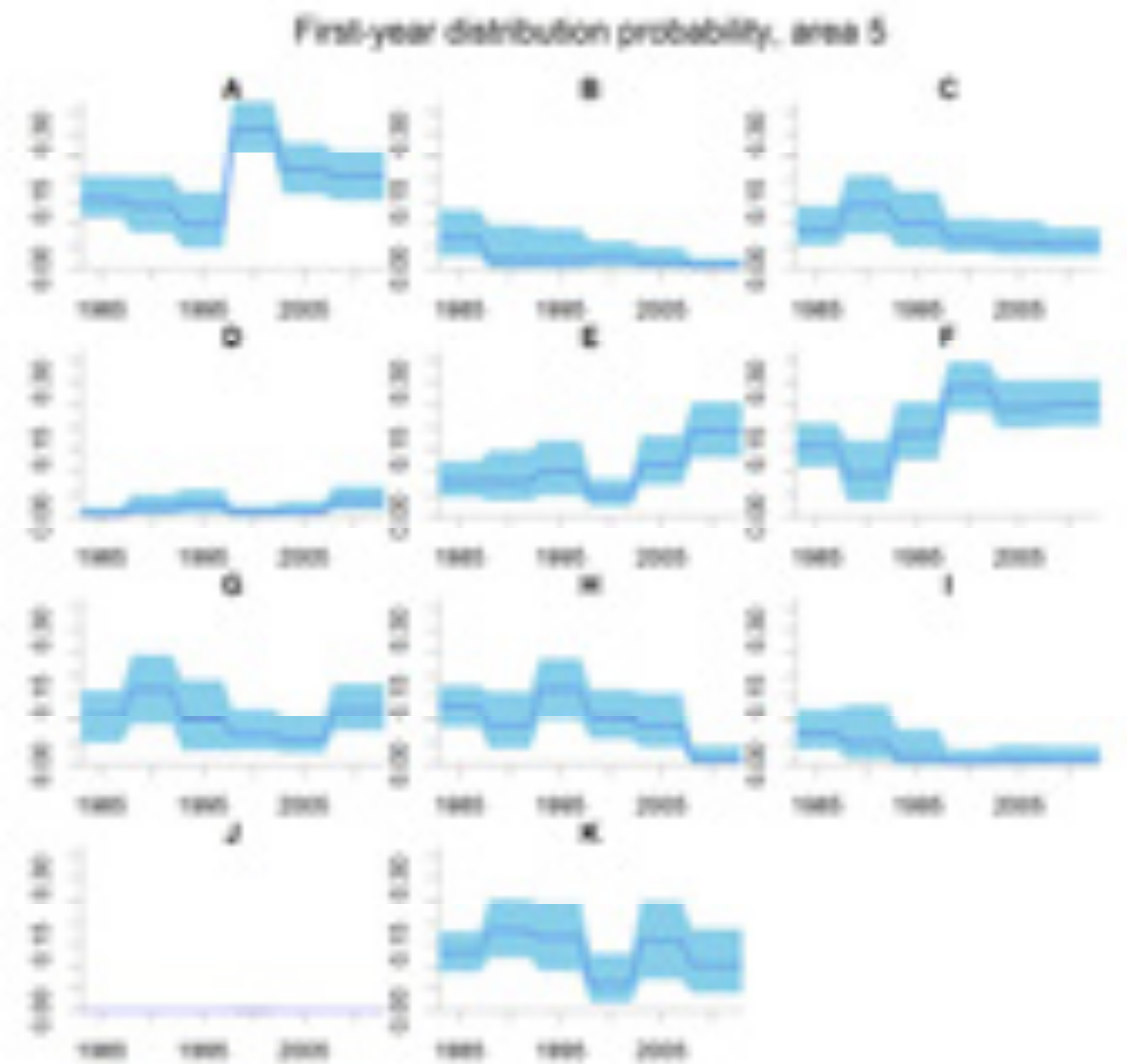


Figure 5.3.2. The estimated first-year distribution probabilities shown for breeding area no. 5 covering Denmark and south Norway. Figures show median posterior estimates with 95% credible intervals. These are the Bayesian analogues of traditional confidence intervals.

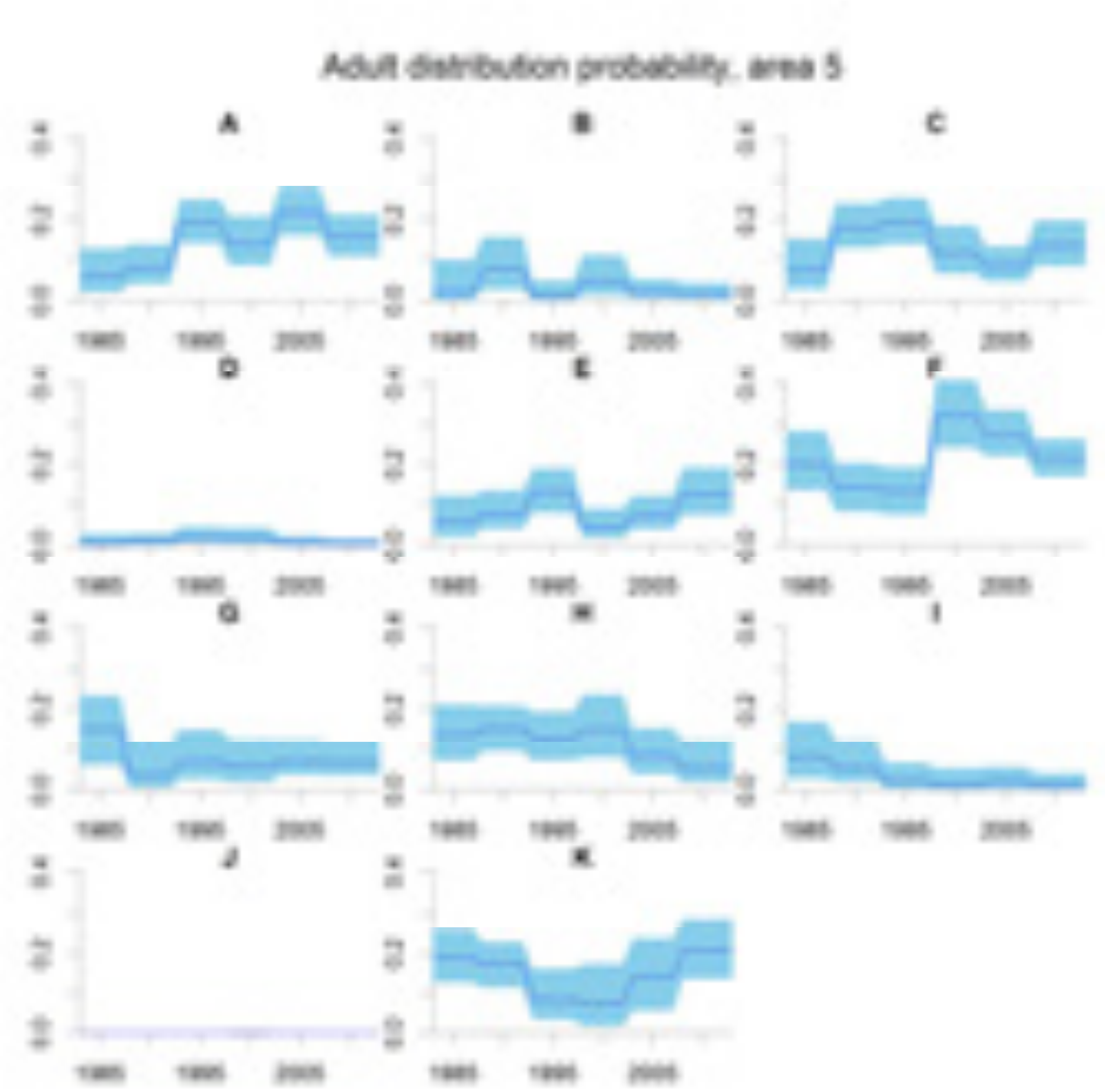


Figure 5.3.3. The estimated distribution probabilities for adults shown for breeding area no. 5 covering Denmark and south Norway. Figures show median posterior estimates with 95% credible intervals. These are the Bayesian analogues of traditional confidence intervals.

5.4 Geographical origin of wintering cormorants

The composition of the wintering populations found in each of the 11 wintering areas with respect to the geographical origin of the cormorants present was estimated for each of the 31 winters between 1983/84 and 2013/14. The estimates were made separately for first-year birds and adult birds.

An example of the results obtained from the modelling is given in Fig. 5.4.1. The pie diagrams show the estimated composition of the wintering population in France in three winters, i.e. three 'snapshots' as examples. The pattern in the temporal change in the composition of the wintering population in France is shown in Fig. 5.4.2. The estimates are based on the recoveries of ringed cormorants found dead but by use of the model, corrections are made for spatial and temporal variation in a number of factors such as the size of breeding populations, ringing activity, recovery probability and survival. Appendix 5.3 gives a complete set of figures showing the estimated proportional contributions from each breeding area to each of the 11 wintering areas with 1-3 winters as 'snapshots'.

It is evident from Fig. 5.4.1 and Fig. 5.4.2 that the composition of the wintering population in France changed over the years. For example, the proportion of cormorants coming from The Netherlands declined over the years whereas the proportion coming from Sweden, Finland and the East Baltic increased.

Another example of how dynamic the composition of the wintering populations can be is given in Fig. 5.4.3. This figure shows the origin of the cormorants wintering in the area including Poland, the Czech Republic, Slovakia, Austria and Hungary. Note the decline in the proportion of cormorants of Danish origin and the increase in the proportion of cormorants of East Baltic and Finnish origin.

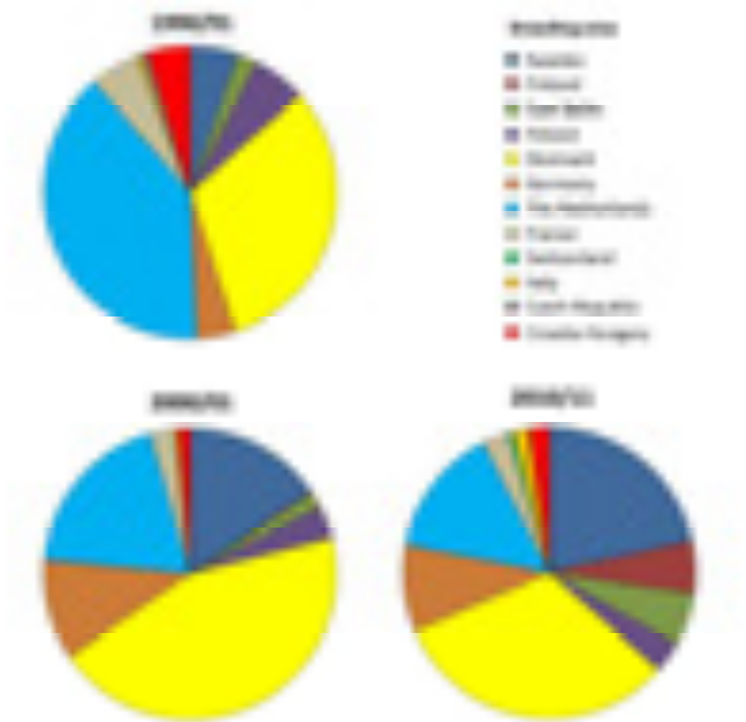


Figure 5.4.1. The estimated composition – with respect to geographical origin – of the population of Great Cormorants wintering in France in the winters 1990/91, 2000/01 and 2010/11. Cormorants originating from the United Kingdom are not included.

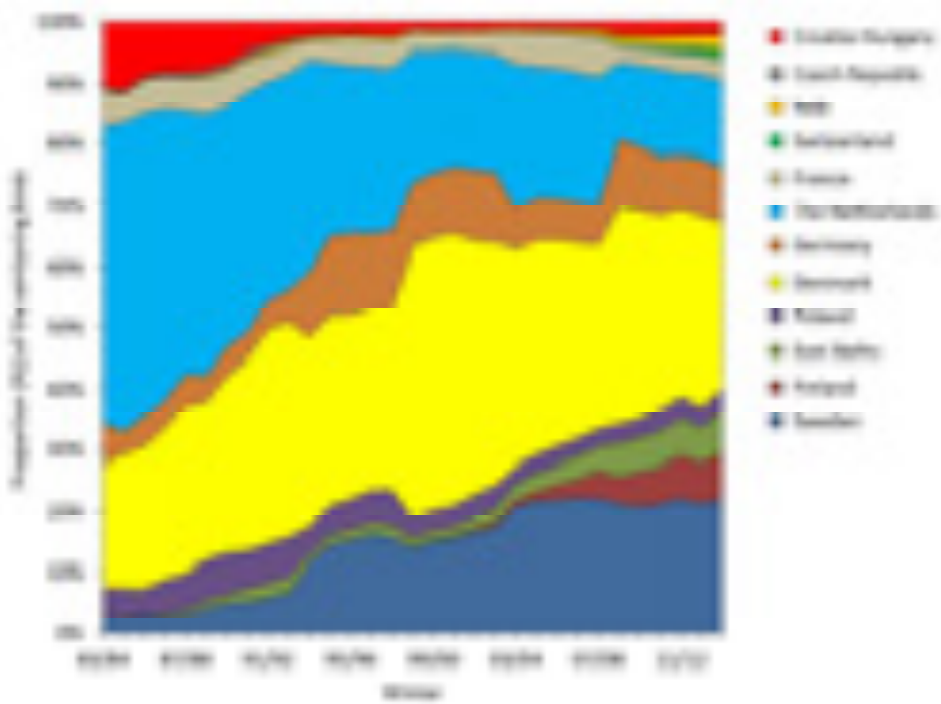


Figure 5.4.2. The estimated composition – with respect to geographical origin – of the population of Great Cormorants wintering in France over the winters from 1983/84 to 2013/14. Cormorants originating from the United Kingdom are not included.

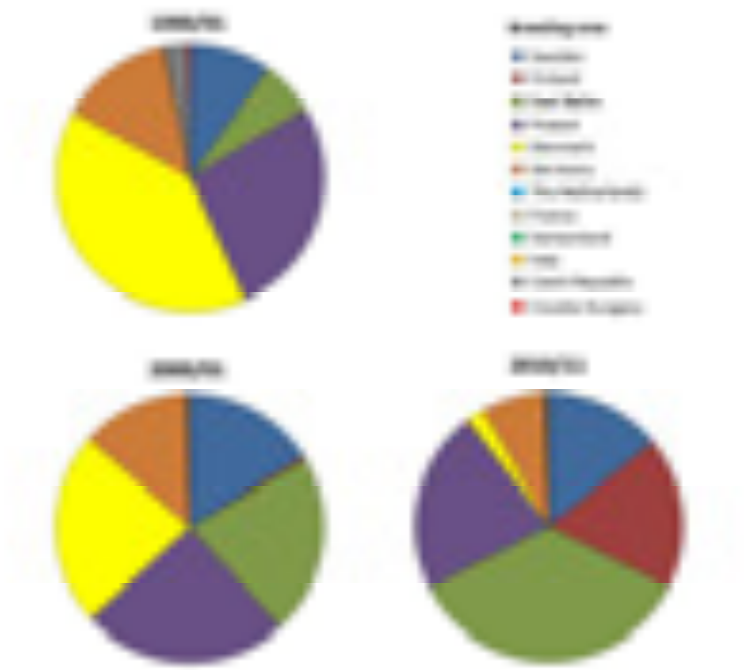


Figure 5.4.3. The estimated composition – with respect to geographical origin – of the population of Great Cormorants wintering in the area including Poland, the Czech Republic, Slovakia, Austria and Hungary in the winters 1990/91, 2000/01 and 2010/11.

The composition of the wintering populations can also be estimated for larger geographical areas. An example is given in Fig. 5.4.4. It is evident from the two pie charts in this figure that cormorants from one and the same breeding area appears in both 'sectors' of Europe but birds originating from the more westerly located breeding areas dominate in the Atlantic sector whereas birds from the more eastern part of the breeding range dominate in the central-east sector.

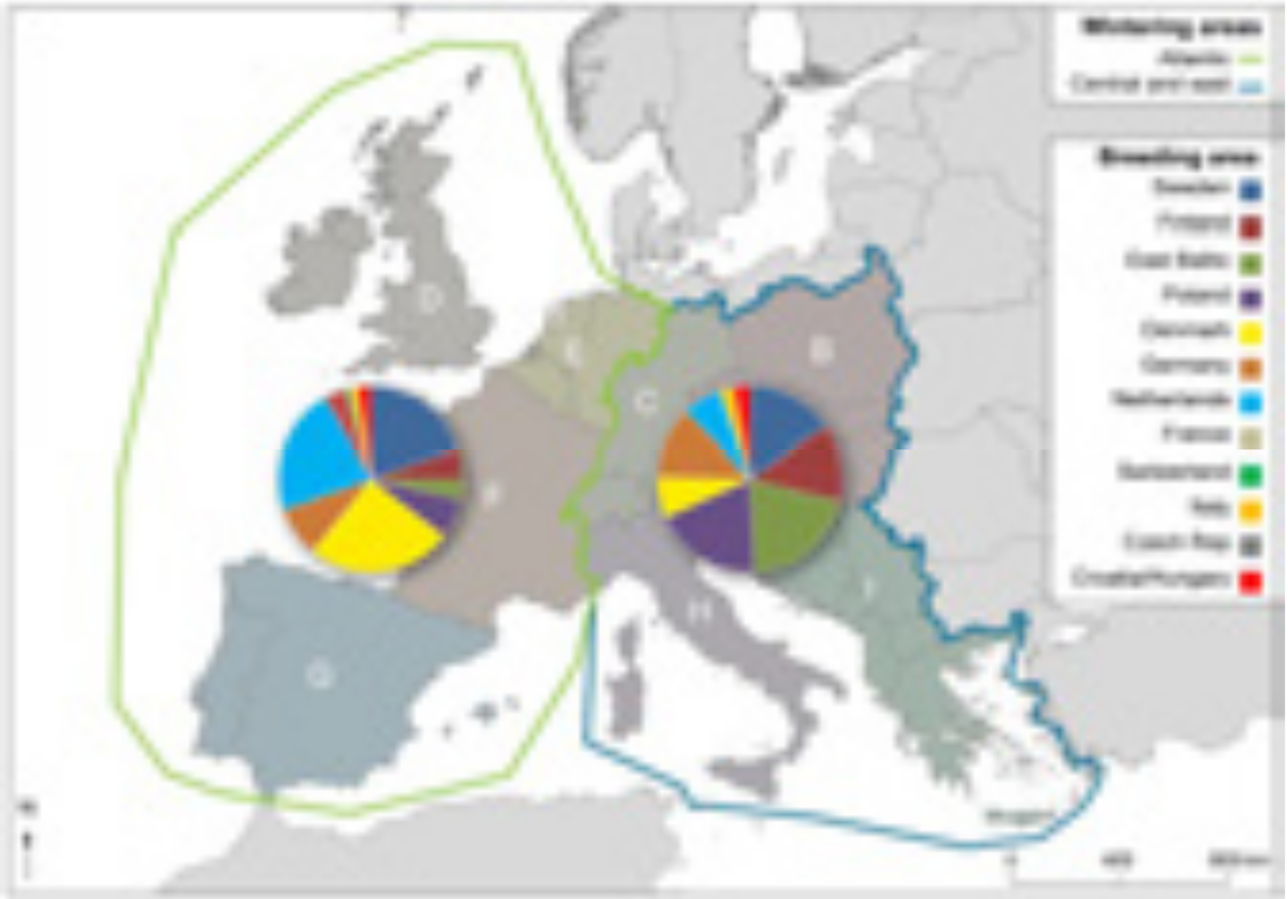


Fig. 5.4.4. The estimated composition – with respect to geographical origin – in 2010 of the wintering population of Great Cormorants in the Atlantic sector (wintering areas D, E, F, G) and in a more central-east sector (wintering areas C, B, H, I).

The temporal changes in the estimated composition of the wintering birds present in these two major sectors of Europe are illustrated in Fig. 5.4.5 and 5.4.6. The major changes that have taken place in the winter composition of cormorants in these two parts of Europe are:

- Cormorants from The Netherlands have made up a declining proportion of the wintering population.
- The proportion originating from Sweden among those wintering in the countries along the Atlantic Sea increased up until the winter 2003/04.
- Cormorants from Finland and other the East Baltic countries have become more common among the cormorants wintering in Europe. This is most evident in the central and eastern parts of Europe where cormorants of Finnish-East Baltic origin were estimated to make up 38 % of the birds present in the winter 2013/14. Their proportion among those wintering in countries close to the Atlantic Ocean was lower, e.g. 11 % of the winter population in 2013/14.
- The proportion of Danish cormorants among the wintering birds in the central and eastern parts of Europe declined markedly between the early 1990s and 2013/14.

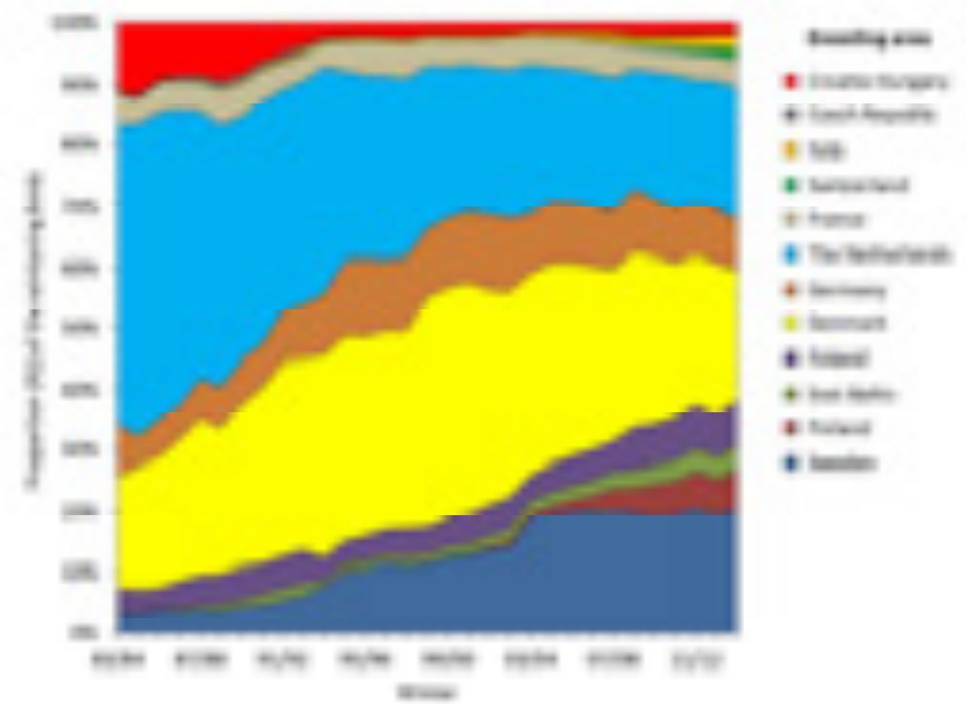


Figure 5.4.5. The estimated composition – with respect to geographical origin – of the population of Great Cormorants wintering in the Atlantic sector (countries along the Atlantic Ocean, wintering areas D, E, F and G) over the winters from 1983/84 to 2013/14 (the delineation of this sector of Europe is given in Fig. 5.4.4).

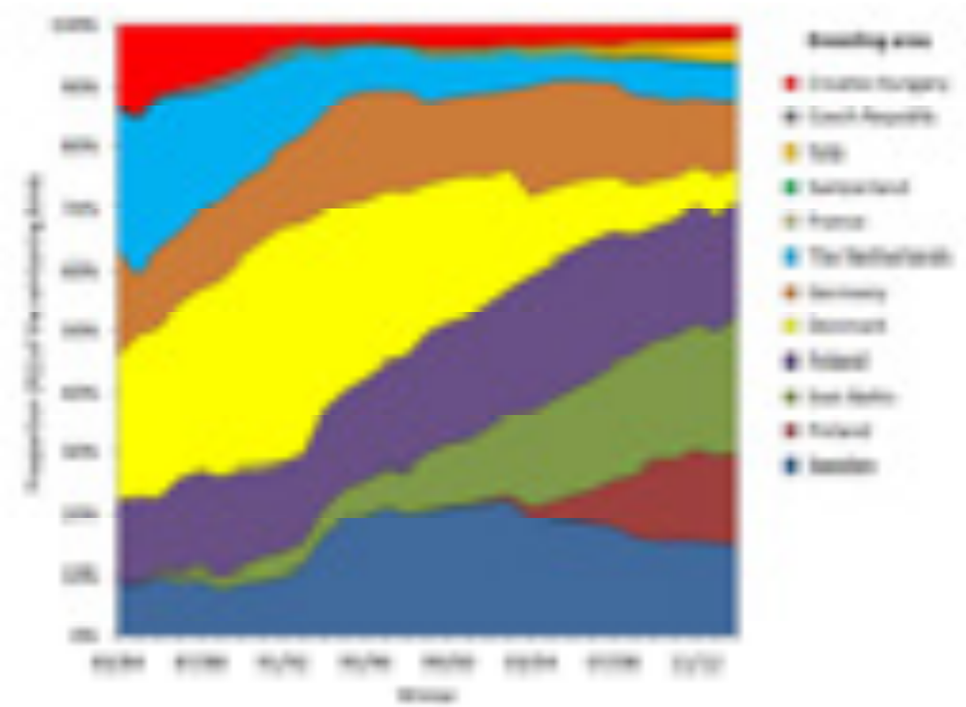


Figure 5.4.6. The estimated composition – with respect to geographical origin – of the population of Great Cormorants wintering in countries in the central and eastern parts of Europe (wintering areas B, C, H and I) over the winters from 1983/84 to 2013/14 (the delineation of this sector of Europe is given in Fig. 5.4.4).

5.5 Uncertainties in the estimates

In order to quantify the wintering distribution of birds breeding in a specific area, it is necessary to estimate the variation in space and time of the probability that a dead ringed bird is reported back to the ringing centre. This probability depends on many factors, including the cause of death (e.g., shot birds are more likely to be found and reported than those dying from natural causes) and human behaviour. The number of birds recovered in a given area and time period does therefore not reflect directly the number of birds present. In the model, we have tried to capture this variation by allowing recovery probabilities to vary among wintering areas, and to change gradually over time. This should ideally allow unbiased estimation of the distribution probabilities, and thus of the size and composition of wintering populations. Overall, we therefore regard our estimates as reliable.

However, some uncertainties remain. One of the main issues is that changes in recovery probability over time in a given area in reality are likely to be more complex than the linear trend allowed in the model. For instance, when a culling campaign is initiated in a wintering area, this is likely to lead to a sudden increase in both mortality, the proportion of all dead birds which are shot, and the chance that a dead ringed bird is reported once found. These effects may then gradually fade out over the following years. Such a pattern would result in a spike of recoveries in the country affected, which given the structure of the model would translate into a higher estimated probability that birds from all breeding areas migrated to this wintering area during the period in question (unless similar campaigns were carried out in other wintering areas simultaneously).

There is therefore a risk that movements to certain wintering areas (both probabilities and numbers of birds) are overestimated during some periods. This may be the case for birds wintering in France around 2000, when a large-scale culling programme was introduced. However, this should affect birds from all breeding areas equally, and the weighting by population size included in the population model should allow unbiased estimation of the proportion of birds in a given wintering area originating from each breeding area. We therefore regard the estimates of composition of wintering populations as more robust to this type of uncertainty than the distribution probabilities.

We have assumed that dead birds of all ages have the same chance of being reported (within a wintering area and year), notwithstanding the likely difference in mortality sources between first-year and older cormorants. Our judgement is that violation of this assumption has only minor consequences for the resulting estimates. Another source of uncertainty is that sample size (numbers of birds ringed, and thus numbers recovered) is low for some breeding areas generally, and for other areas in certain periods. This inevitably means that distribution probabilities are difficult to estimate, and that the resulting estimates are quite imprecise. However, this problem has limited implications for the estimation of the composition of wintering populations, because the breeding populations with low sample size generally also are quite small. Thus, while distribution probabilities from some breeding areas are so uncertain that they are not shown in Appendix 5.2, this has a very limited influence on the estimated compositions (e.g. Appendix 5.3).

6 Use of artificial versus natural feeding areas

The rationale behind this element of the CormoDist project was to estimate the proportions of autumn staging and wintering cormorants that rely for foraging on natural wetlands and in artificial commercial fisheries (i.e. aquaculture).

For such a consideration, in consultation with the Commission, it was assumed that "artificial commercial fisheries (i.e. aquaculture)" simply related to the extensive carp *Cyprinus carpio* aquaculture ponds to be found across Europe in Member States such as France, Germany, the Czech Republic, Poland and Hungary (see Seiche *et al.* 2012 for comprehensive synthesis).

Whilst this fishery industry is economically and environmentally important and is geographically widespread across continental Europe (and appears to be one of the fishery sectors particularly troubled by cormorant problems), it covers a relatively small area. It is reported to cover some 340,000 ha[1] (Seiche *et al.* 2012) and these authors comment that "[T]his area is thus equivalent to 0.5% the area of Germany, 1% of the area of France and 1.4% of the area of the United Kingdom. It is very similar in size to the Romanian sector of the Danube Delta and about half the size of the delta incorporated into UNESCO's Biosphere Reserve."

In practice, it was known that the ringing data used in the CormoDist project would not offer an insight into the proportions of cormorants relying on natural versus artificial commercial fisheries. Similarly, it would be very difficult to quantify (or even predict) the number (and, hence, proportions) of cormorants that permanently or temporarily forage in artificially developed commercial fisheries (i.e. aquaculture ponds) outside the breeding season. There are several reasons for this:

(a) Most cormorant counts take place at night roosts, and usually it will be impossible to link a specific roost site with either natural or artificial feeding habitats.

(b) The probability of observations of live ringed birds and recoveries of dead birds are likely to differ between natural and artificial habitats, in unpredictable ways. Converting numbers of observed ringed birds to numbers present will thus be problematic.

(c) Individual cormorants are highly unlikely to specialize on either natural or artificial habitats. Their use of the two types of habitats is likely to change dynamically over both short and long time scales, according to e.g. age, experience, weather conditions and food availability in the two types of habitat.

Two further options[2] were contemplated originally – but, on further consideration, neither was found to be useful or to offer meaningful biological insight.

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[1] Information relates to 27 Member States and is from International Carp Conference, 15-16 September 2011, Kazimierz Dolny, Poland – available at http://www.aller.aqua.com/cms/front_content.php?idcat=561.

[2] These two rejected options were: (1) that knowledge about the number of cormorants counted in coastal wetlands and in inland wetlands without fish farms might give a rough idea about the minimum number of cormorants that cover their daily food requirements without foraging at fish farms. (2) that by estimating the number of fish farms for certain countries or parts of Europe, and combining these numbers with assumptions and knowledge about the number of cormorants that on a daily basis forage at different types of fish farms, and by scaling-up these estimates, a rough (if highly uncertain) overall estimate could be derived.

Great Cormorants usually migrate in smaller flocks, in this case two adults flying together with 7 first-year birds/immatures. Photo: C. M. Olsen.

After careful consideration (including discussions with the IUCN/Wetlands International Cormorant Research Group), it was thus decided that the most biologically meaningful way of explore the proportions of autumn staging and wintering cormorants that rely for foraging on natural wetlands and in artificial commercial fisheries (i.e. aquaculture) was to refer to published material on the relationships between cormorants and their use of feeding habitats at specific water bodies (see chapter 9 of van Eerden *et al.* 2012).

These authors established a so-called Water Systems Database, based on discrete water bodies, in order to broadly assess the relationship(s) between cormorants and fish, and the factors that determine them. They (van Eerden *et al.* 2012, p. 57) "[p]ooled knowledge from 65 experts in 26 countries (in total, 179 different cases) of georeferenced water bodies were included in the analysis. These waters accounted for approximately 30,000 km^2 of sampled water surface and related to a maximum number of about 350,000 Cormorants." Information on fish species was also included in the original analyses but is not discussed further here.

Ultimately, the cases included in the Water Systems database represented a large area of the European continent but, as van Eerden *et al.* (2012) highlighted the cases tended to be concentrated a little more in eastern countries (including Baltic Sea, Sweden, the Alpine zone, Italy, Greece and that western Europe (i.e. Netherlands, Belgium, UK) was also well represented but that there were gaps in southern Europe, for instance in the interior parts of France and Spain. Outside Europe, water systems information was also obtained from Israel and Georgia.

The variety of European water systems types was strongly reflected by the geographical range of waters within the continent and included open seas, inland seas and estuaries, large lakes, large rivers, smaller rivers and streams from high altitudes to lowland situations, reservoirs and fishponds. The latter were "distributed in a wide area of inland Europe but are concentrated in a belt of eastern European countries from the Baltic States and Poland to the Czech Republic and France, but also extending further southeast into the Balkan countries" (van Eerden *et al.* 2012, p. 58).

van Eerden *et al.* (2012, p. 59) concluded that "over the whole data set, there is a clear relationship between the annual number of 'bird days' spent by cormorants at a particular site and the surface area of the water body concerned [see Fig. 6.1]. In absolute terms, large water bodies have far more cormorants (i.e. more bird days, and so a heavier overall 'use' by cormorants) than do smaller ones. However, corrected for surface area, this equates roughly to some 5,000–10,000 cormorant days per square kilometre of water per year for smaller waters and lower at 1,000–5,000 cormorant days per square kilometre of water per year for large surface areas. As can be seen from Fig. 6.1, the variation in the data set is large with some individual cases diverging by a factor of around 10 (plus or minus) from this general pattern." Importantly here, almost all individual carp pond farms are likely to have fallen into the 'small waters' category in this analysis.

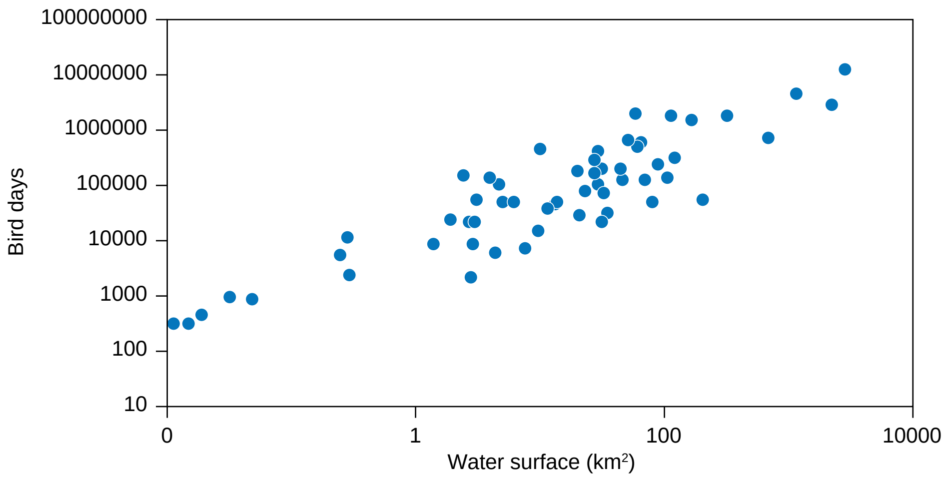

Figure 6.1. The relationship between water surface area (km^2) and cormorant use measured as 'bird days' for 132 reported cases providing both cormorant and environmental data. Reproduced from van Eerden *et al.* (2012). 'Bird days' is a measure of cormorant use of a waterbody based on an assessment of the number of birds present and the length of time they spend there.

In relation to the original ambition to estimate the proportions of autumn staging and wintering cormorants that rely for foraging on natural wetlands and in artificial commercial fisheries (i.e. aquaculture). The relationship above clearly shows that – at the *population level* - large numbers of cormorants and/or the length of their residence time at specific sites across Europe are associated with large water bodies. In relation to *individual birds*, the data also indicate that smaller water bodies – importantly, including artificial commercial fisheries (i.e. extensive aquaculture) – are more intensively used than larger water bodies as the slope of the regression line is less steep than the 1:1 relationship with water surface area.

Further elucidation of cormorant foraging site-choice may come from further analysis of the size and specific location of fish pond farms in relation to other potential feeding sites and the relationship between these and particular migratory corridors. Attempts to quantify the relative use that cormorants make of artificial versus natural feeding areas really require knowledge about factors affecting the 'choices' that cormorants make during their autumn/spring migrations and after their arrival at their wintering grounds: ultimately, their choices of where and when to move and where and when to forage. The fairly new approach of individual-based modelling also offers potential for addressing these issues. For example, in attempting to predict future changes in distribution of cormorants in Europe outside the breeding season, these types of models can incorporate knowledge and assumptions about how cormorants respond (in their choice of staging and wintering sites) to factors such as changes in the climate, intensity of competition for food and changes in levels of disturbance.

Data thus suggests that extensive fish farms are likely to play only a small role on the population level for European cormorants although they may be used extensively by individual birds, and there may well be a high (but, as yet, unquantified) turnover of foraging birds between natural wetlands and artificial commercial fisheries. Furthermore, this situation suggests very strongly that the 'expansion' of the European cormorant population (throughout Europe overall and/or in the Baltic region specifically) has little to do with extensive fish ponds in Europe. However such an expansion does mean that, during migration and overwintering, individual birds will exploit the opportunities of foraging at fish ponds, particularly those located on migration routes or in regions where birds spend the winter.

Whilst far from complete, the analysis discussed here suggests strongly that extensive fish ponds are not relied upon by cormorants at the population level across Europe. Individual birds may however feed intensively at such sites and there is likely to be turnover between these and more natural feeding sites. Fish ponds on migratory routes or in the overwintering areas of cormorants are likely to be visited by these birds which raises the issue of potential alternative foraging sites for them and their proximity to, and location within, migratory corridors.

7 Viable options to deal with cormorant-fisheries interactions[3]

In this chapter, the results produced during the CormoDist project together with existing published information about cormorant ecology and behaviour are used to discuss the pros and cons of applying various strategies in attempts to deal with the interactions between cormorants and fisheries at the local, regional and European levels. These interactions and associated conflicts (well described elsewhere, e.g. van Eerden *et al.* (2012)) tend to be most pronounced in western, central and southern regions of Europe during the winter and in autumn and spring when cormorants move to/from their wintering quarters.

The work discussed in this chapter suggests strongly that it will not be possible to protect specific wintering areas from cormorant predation through the reduction of breeding numbers elsewhere in Europe. The data and analysis here thus suggest that population level management is unlikely to be a viable option to deal with cormorant-fishery interactions. However, there are numerous potentially viable options on a smaller geographical scale, and these are also discussed in this chapter.

7.1 Introduction

Large increases in cormorant populations have occurred across Europe over the past 30-40 years, particularly birds of the *sinensis* sub-species in Western Europe. Cormorants have also greatly extended their breeding and wintering ranges into areas where they had previously been scarce or even absent for some time, with many more birds accessing inland fisheries. This has resulted in widespread conflicts with fishery interests. Conflicts occur at different sites and different times of the year, partly reflecting large variations in cormorant numbers as birds move between breeding and wintering areas. A diverse range of fishery interests are affected by cormorants in marine, brackish and – particularly – freshwater habitats, and including commercial fisheries, fish farms (intensive and extensive) and recreational angling. Cormorant predation can have serious economic implications by damaging fish stocks, reducing catches, limiting aquaculture production and through other social and economic effects. In many cases, serious damage can result and justify management action (see EU 2013).

Many stakeholders, particularly angling and fishery ones, believe that the current cormorant population size of the *sinensis* sub-species in Europe represents an unacceptable and unsustainable threat to fishery interests. They believe that a form of long-term, internationally co-ordinated cormorant control, preferably at the pan-European level, is needed, focusing in particular on actions taken at breeding sites. The aim would be to reduce the *sinensis* population to a size at which damage to fisheries was reduced to a more acceptable level.

3 In this chapter, much of the introductory text, and that dealing with issues at the 'European' or 'population' levels is taken from 'A review of the issues relating to control of cormorant populations at the pan-European level' available on the EC Cormorant Platform. Published at the EU Cormorant Platform http://ec.europa.eu/environment/nature/cormorants/home_en.htm
by CorMan for the European Commission under service contract N° 07-0307/ 2010/575579/SER/B3

At its simplest, one of the key questions with respect to strategies for managing cormorant-fisheries conflicts through a reduction in damage to fisheries to acceptable levels is: should this be attempted through site-specific (i.e. regional) management actions or through an overall reduction in cormorant numbers at a European or population level?

The CormoDist project has demonstrated, from an extensive analysis of ringing recoveries, that European cormorants are extremely widespread and well-mixed in the non-breeding period. Thus it is highly unlikely that wintering numbers in specific areas could be affected directly by managed reductions in breeding numbers, perhaps several thousand kilometres away. This demonstration, substantiating the implications of many other studies of cormorant ecology and overwintering behaviour, allows us to be more confident in terms of discussing the viability of continental (i.e. European) versus other, smaller spatial-scale management approaches.

Putting aside here the important issue of quantifying damage (i.e. economic, see EU 2013) to fisheries in such a way as to allow verifiable demonstration of damage and any subsequent reduction in this, the legal positions and those of the European Commission are important in the context of this chapter.

7.2 The legal position

Like all wild birds species in Europe, the Great Cormorant is protected under European Directive 2009/147/EC (the Birds Directive). Its deliberate capture and killing, disturbance, destruction of its nests or taking of its eggs can only be allowed by Member States if this is done in accordance with the derogation system set out in Article 9 of the Directive. Article 9 provides that Member States may derogate for a number of purposes, including preventing serious damage to crops, livestock, forests, fisheries and water, or the protection of flora and fauna, provided that there is no other satisfactory solution. The European Commission has developed a non-binding guidance document regarding application of the derogations in Article 9.

Population management is considered to be a legitimate option under the derogations within the Birds Directive, provided it is designed to prevent serious damage and is consistent with the objectives and requirements of the Birds Directive, including maintaining the population of a species at a satisfactory level.

The derogation system is already being widely used by Member States to reduce or prevent serious damage by cormorants. However, there are significant differences in the way this is done, both in terms of the choice of sites where control actions are undertaken and on the methods used. Some Member States use the derogation possibilities extensively, including actions at breeding colonies, whilst others do not allow scaring measures or control of cormorant numbers at all. In line with the subsidiarity principle, the implementation of the derogation system lies within the competence of Member States.

7.3 The current position of the European Commission

Given that cormorants are spread widely throughout Europe and may undergo large-scale migrations between breeding areas and wintering areas, any implementation of a pan-European management strategy would require collaborative action and planning by a large number of European countries for such a plan to be applied across the broad scale necessary. This would depend on independent decisions at a national level. As noted previously, the implementation of the derogation system lies within the competence of Member States. Thus, countries which might be opposed to using the derogation scheme or to participate in any pan-European plan to control cormorant populations cannot be compelled to do so, irrespective of whether or not they are members of the EU. Of course, it would still be possible for the Commission to develop a plan, should it be so minded, and use this as a basis for discussion and consensus building with Member States.

In response to concerns from fishery stakeholders, the Commission has stated (see doc ref. SP(2009)401) that
"While [they are] not persuaded of the need for such a management plan, it is apparent that in several Member States the size of the cormorant population is giving rise to increasing conflicts. However, there is no consensus between Member States on the type of action to take. Whilst some Member States or some regions are supportive of an EU-wide management plan, others are not persuaded that there is a problem or that there is no need to address it at EU level. If one Member State decides that there is no need for measures, the Commission cannot change that position. Also the Commission is not in favour of an EU wide strategy as the problems are localised. Therefore, it is not proportionate to argue for action at EU level to solve a problem of regional scale. An alternative way to address this issue could be found in the existing mechanisms that are available under the provisions of the Birds Directive."

Thus, where necessary, the European Commission is encouraging Member States to consider the potential for co-ordinating management actions against cormorants across broader scales through bilateral (or perhaps larger) agreements, and it has indicated that it would be prepared to help facilitate such arrangements.

7.4 What form might pan-European cormorant management take?

After widespread consultation, the European Commission considered that an EU-wide management plan would not be an appropriate measure to address the problem of cormorant conflicts. Rather, the Commission considered that the existing derogation provisions of Article 9 of the Birds Directive provided Member States with adequate powers, and that cormorant problems were best addressed at a regional scale.

Although this remains the current position of the European Commission, many fishery stakeholders continue to believe that some form of pan-European or internationally coordinated management plan is still required to reduce cormorant numbers at the population level across Europe.

Advocates of a pan-European approach to managing cormorants suggest that this might be achieved by agreeing on an appropriate population 'reference' level, or population range, around which bird numbers would be managed. From a legal perspective, such management decisions would fall within the competency of Member States. It is thus likely that reference levels would need to be set separately by each country, although this could be based on compatible principles and in consultation with neighbouring countries. Under such an approach, relevant national authorities would need to reach consensus on general criteria, establish appropriate reference levels and agree a number of associated issues. These would include decisions about the geographic scale for the 'target' population (or populations), monitoring arrangements to assess population status and the co-ordination and evaluation of management activities. It is stressed, however, that cormorant population management would not be the main objective in itself; rather, the aim would be to reduce the incidence of serious damage at fishery sites. So, fisheries would also need to be monitored to ensure there was a benchmark against which the efficacy of the measures could be assessed as a basis for ongoing management decisions.

The calls for cormorant management put forward by fishery stakeholders typically advocate population management measures targeted at breeding colonies, rather than in wintering areas when birds are more widely dispersed, since this is considered more effective and would enable better control. These calls further advocate the use of measures such as egg oiling rather than shooting as the primary means of control (e.g. EIFAC 2008). Such measures are seen as particularly appropriate for use in cormorant ground-nesting colonies, although alternative methods (e.g. disturbing birds to make eggs cool off) could also be applied effectively in tree-nesting colonies, although at greater expense. The extent of ground-nesting, as opposed to nesting on trees, varies considerably between countries.

Monitoring, including assessments of damage, would be a key requirement alongside any population control measures, as this would be necessary to inform ongoing management decisions and enable the efficacy of any such strategy to be assessed and modified as necessary. This would also ensure that the plan was in line with the requirements of the Birds Directive, that a secure status of the species is maintained, and that there was a reduction in the incidence of serious damage at fishery sites. This monitoring and feedback process, known as *adaptive resource management* is increasingly used in managing wildlife resources - for example, in respect of hunted duck and goose populations in North America. It has been suggested that such a strategy would also be broadly similar to the biological reference points and associated assessment and management procedures that are used in the sustainable management of many fish stocks.

7.5 Biological considerations relevant to possible pan-European cormorant management

i. Predator/prey interactions

Predator/prey interactions are a natural part of the complex relationships that take place within ecosystems. Thus, predation on fish by cormorants and other fish-eating birds, and predation by fish on other animals, is a normal part of the natural interactions that occur between species in aquatic habitats (see chapter 7 and chapter 10 of Carss *et al.* 2012). In a natural, 'unmanaged' situation predator numbers would typically be closely linked to, and governed by, the availability of suitable prey species. Where prey is readily available and abundant, predator numbers typically increase, either through an increase of the population (e.g. due to better survival or increased breeding output) and/or as a result of predators moving into an area. Conversely, in the absence of good access to ample prey, predator numbers fall. Similarly, this can be as a consequence of a reduction in population size (e.g. higher mortality rates, reduced breeding output) or due to bird movements out of a particular area.

In simple situations (e.g. one predator and one prey population within a closed area), these processes often result, in the long term, in predator/prey numbers oscillating around a particular level – the predator/prey equilibrium. In practice, predator/prey interactions are rarely so simple and any such natural equilibrium level, even if attained, may be unacceptable where the resource (the prey) is also of interest to man. In such circumstances the predators are viewed as competitors for the same resource as they conflict directly with man's use of the resource, with potentially wider social and economic implications.

Country-wide counts of Great Cormorant nests are conducted annually in a few countries in Europe. Photo: T. Bregnballe.

ii. Cormorant population dynamics

The European cormorant population has increased rapidly and the breeding population has gradually expanded into parts of Europe where the species was absent or scarce for many decades. The pattern of expansion illustrates the capacity of the *sinensis* sub-species to newly colonise or recolonise suitable breeding areas and respond positively: (a) to protection against persecution and pollution; (b) to access to safe breeding and roosting sites; and (c) to easy access to waters rich in fish. Adult Great Cormorants that are not exposed to shooting will normally have a high probability (80 - 90%) of surviving from one year to the next (although they may suffer higher mortality in cold winters). In addition, when food conditions are favourable they are able to breed when two years old and raise 2 to 4 young to fledging, whereas the age of first breeding is delayed and the fledgling numbers are less when the birds' diets are more impoverished. Consequently, cormorant populations can increase by more than 25% year-on-year. Furthermore, birds can respond quickly to deteriorating food conditions by changing their choice of foraging sites. They can also move to alternative breeding sites, but such responses will typically be from year to year.

Nonetheless, several studies have shown that cormorants can become seriously constrained by limitations in the access to safe breeding sites and rich feeding areas. For example, cormorant breeding performance can decline markedly if a colony continues to increase and/or foraging conditions nearby deteriorate as a consequence of predator/prey cycles or other developments. This is one of several ways in which natural density dependence can operate and cause a transition from growth to decline and subsequent stabilisation within a colony or population.

Almost all cormorant breeding populations in Europe will - after some years of growth - become limited in size and further growth by the amount of food available around the existing colonies and the access to hitherto uncolonised, attractive and safe breeding sites. In theory, and given enough consistent effort, humans could influence these factors in a number of ways and thereby affect the size at which cormorant populations begin to stabilise.

In light of the above, a key factor that can be expected to influence the efficacy of any possible pan-European management strategy is the extent of density-dependent population regulation and the strength of the compensatory (feedback) mechanisms that might apply.

For example, our knowledge of cormorant population dynamics indicates that a reduction in numbers of breeding birds in an area (not caused by food shortage) often leads to an increase in the numbers of young birds per nest that are fledged successfully by those birds that do breed there, and where productivity is below maximum potential. This is a consequence of reduced competition among cormorants for food and the greater availability of fish with which adults can feed their offspring. Under such a scenario, the greater the (downwards) 'pressure' that is applied to reduce bird numbers, the stronger will be the (upwards) compensatory mechanisms (within limits) that will operate to re-build population sizes. Such factors make it more difficult to predict the impact of population reduction measures and would make reducing numbers over large areas or at the population level a challenge.

Some population management strategies for cormorants seek to avoid the problem of constantly working against compensatory mechanisms by working with density dependence. Thus, a management approach is adopted where the objective is to restrict birds to a particular area and limit their expansion to other surrounding areas through control measures. In such a scenario, population size in the 'permitted' area would, in effect, become regulated by the available resources (e.g. food and breeding sites) and numbers would be expected to fluctuate about some equilibrium or carrying capacity level within the more limited area available to the cormorants. Active measures would be required outside this area – for example, preventing new colonies and/or new roosts establishing and/or the use of active deterrents at feeding sites – in order to restrict expansion. Of course, preventing such expansion of the population would not normally be easy, particularly at a larger scale. Nonetheless, such an approach has been applied successfully in certain countries and situations. Thus, preventing the formation of new breeding colonies in Denmark has been used to restrict the fish resources available to cormorants during the breeding season and thereby limit the population from further expansion and reduce impacts on fisheries in particular areas.

7.6 The practicalities of pan-European cormorant control

The possibility of pan-European control has been the subject of previous theoretical assessments using population models. A simple model based on the 1998-99 continental cormorant population was developed to predict the effect of different levels of culling. However, one drawback of this early model was that it did not take into account any geographical variation in culling intensity. A later model included some geographical sub-division of the winter range (France vs. the rest of Europe), because, in recent years, culling intensity has been greater in France than elsewhere in Europe. This model indicated that the effects of culling are highly dependent on the extent of immigration into an area. The modelling investigations suggested that some form of pan-European population control might be feasible, in principle, but presented a number of challenges.

In practice, there are many reasons why attempts to reduce the continental cormorant population, and to manage it around some 'acceptable' level, would be difficult on such a broad scale. For example, the large territory, widespread breeding populations and further mixing and dispersing of the birds in winter (see Chapter 4 and 5 of this report) means that there will be no simple relationship between management actions in a restricted part of the breeding areas (e.g. in one country) and the consequences of these actions in wintering areas, or *vice versa*. Furthermore, since numbers and distribution patterns of the birds are partly determined by density-dependent factors operating both within and outside the breeding season, there is considerable potential to compensate for reductions in numbers through changes in both the distribution of the birds, and their fertility and mortality rates. Public acceptability and ethical concerns would also need to be considered.

Any use of lethal techniques for population control at a broad scale would need to take account of a range of factors, including the level of mortality achieved relative to immigration and breeding rates, migratory patterns and the relative levels of controls in different areas. This would make it difficult to achieve a successful, pre-determined outcome. Population control has typically proved most cost-effective and long-lasting where the bird species causing problems has been contained in relatively small, localised populations. The widespread nature of cormorant breeding populations, with birds mixing and dispersing across Europe in winter as demonstrated in this CormoDist project, makes it a challenging task to develop models that can predict realistic outcomes from different management strategies. Nevertheless, this work suggests strongly that it will not be possible to protect specific wintering areas from cormorant predation through the reduction of breeding numbers elsewhere in Europe. Similarly, it is clear that the Commission does not have the authority to request individual Member States to reduce cormorant numbers. Even if this were the case, the best ecological understanding that, on some level at least, birds are attracted to the 'better/optimal' foraging sites (with many birds feeding in 'suboptimal' areas), and that these 'optimal' foraging sites can often be those of high fisheries value too, implies that a large proportion of the overall European cormorant population would need to be removed annually to produce a verifiable reduction in damage at such sites. Even if legally possible, such a strategy would appear to be unviable.

7.7 Adaptive Resource Management

A general conclusion of population modelling is that constant population management with fixed rules, quotas or rates is typically either too ineffective in terms

of population reduction or poses risks for population viability. Fishery stakeholders consider that any broad-scale population reduction plan for cormorants would need to be adaptable, tightly monitored and consistent with Birds Directive objectives. This is also consistent with the adaptive resource management approach that is commonly now advocated for managing many wildlife species. With increased levels of monitoring in place, management measures are reviewed and updated in light of population changes. Such an approach is judged to be both effective and safe, since it provides feedback mechanisms and the opportunity to stop control measures, should this be necessary, before a population becomes critically reduced. For cormorants, this would allow management rules to be adopted taking into account the current state of the cormorant population, as well as whether the management actions are reducing the incidence of serious damage at fishery sites as planned.
A recent example of adaptive resource management is provided by the International Species Management Plan that has recently been agreed in relation to the Pink-footed Goose *Anser brachyrhynchus*. Further details are provided below.

Another example of the application of modelling and an adaptive resource management approach is provided by the cormorant licensing strategy used in England in recent years to determine a 'reasonable' upper limit of cormorant numbers allowed to be shot each year. The approach relies on a simple population model, informed by annual wintering counts, to assess the effect of different levels of shooting. This allows the number of birds permitted to be shot in the following year to be reviewed and, as necessary, adjusted. The process benefits from the fact that the wintering population in England is relatively small and has limited immigration relative to mainland Europe, and that it operates within a single national jurisdiction. It is unlikely that the same approach could be readily applied to the much larger, more migratory populations across Europe.

7.8 How might a reduction in cormorant numbers affect levels of damage to fisheries?

It is unclear how any overall reduction in cormorant numbers might affect degrees of damage at fisheries. It is generally accepted that cormorants are attracted to, and will attempt to exploit, feeding sites where they can forage in the most energetically efficient manner and in relative safety. However, other factors may also influence site selection. Thus, for migrating birds, there is evidence, for some areas at least, that the bird's first choice may be large water bodies, with birds expanding from these to smaller water bodies subsequently. It is perhaps less clear whether these first choice sites represent optimum foraging sites or reflect, in part at least, the use of rivers and large waterways as migration corridors. It is also uncertain to what extent the subsequent spread to smaller foraging sites is driven by increasing numbers of birds, and thus competition for resources, or the fact that foraging opportunities are better at these other smaller sites and that new 'habits' develop over the years.

Biologically, it can be assumed that cormorants (as with most animals) select their foraging locations on an energetic basis – put simply, they are likely to try to maximise their energy intake through encounters with prey and food consumption, and minimise their energy expenditure on things like travel to foraging sites, diving times and prey capture. Even at this simple level it is clear that some foraging sites will therefore be 'better' than others (through the abundance of prey and its availability) and so biologists often refer to foraging (and other) locations as being either optimal or sub-optimal. Just as some foraging sites are 'better' than others, some individual birds are 'better' foragers than others – at its simplest and most general, young (i.e. first-year) birds tend to be less efficient foragers than older individuals, for instance. A consequence of all this is therefore likely to be 'competition' between individual birds in any particular area for specific foraging sites, with the most efficient/experienced birds dominating at optimal sites and less efficient/experienced ones being forced to feed at sub-optimal sites. Furthermore, at some point along this spectrum of declining site quality, it will become unprofitable for an individual bird to forage at a specific site and they will have to move to another one.

Cormorants consistently and predictably turn up to forage at particular sites, and numerous conflicts arise with fisheries interests where these are the sites most valued by recreational anglers, commercial fishermen or fish farmers. This is because the sizes of fish consumed or damaged by the birds often coincide with those that are of interest to users. Given this situation, it might well be assumed that these sites are also optimal foraging sites for cormorants and/or are sub-optimal sites used frequently by the birds. In other words there is some sort of 'pressure' on the birds to be foraging where they do at what might be termed 'prime' sites. Because of the mobility of cormorants, killing or scaring birds at such prime sites commonly creates opportunities for new birds to replace those that have been killed or scared. Even where large, organised cormorant culls take place each year, bird numbers can recover quickly as replacement individuals move in, particularly at sites that are on established cormorant migration routes. This suggests that large-scale killing of birds may not necessarily provide the ready solution to local cormorant conflicts that is often imagined.

A reduction of the cormorant population to a lower, more acceptable level would reduce the overall impact of the birds on fish stocks and fisheries – fewer cormorants across Europe would eat fewer fish. This is unequivocal. However, scientific opinion suggests that the decline in the pressure on fisheries would be less than the decline in bird numbers might suggest, as birds are likely to continue to favour high quality habitats that offer the best foraging potential. Ecological theories and our limited understanding of cormorant movements and foraging-site choice suggest that, where cormorant populations are constrained by available resources, a reduction in bird numbers results in the abandonment of marginal, sub-optimal, foraging areas first. Thus, although fewer birds should mean fewer fisheries with problems, conflicts may well persist at many of the 'prime' sites. Since such sites are often those that are most valuable or desirable to fisheries stakeholders, the reduction in conflicts may be disproportionately small.

On the other hand, in this situation where scientific evidence is incomplete, some fishery stakeholders believe that a reduction of cormorant numbers would result in a significant reduction of damage at most fisheries, not least those which currently suffer the heaviest damage because local on-site management measures are not effective. This expectation is based on their general assumption that population management would reduce cormorant numbers at breeding colonies and wintering roosts to a level which prevents the over-exploitation of adjacent waters. In breeding areas the effects of population reduction are seen by some fishery stakeholders as being relatively easy to predict: If management succeeds in holding colony size at a level which prevents over-exploitation this would ensure that cormorant predation stays below the threshold of 'serious damage' and consequently would result in higher prey availability in adjacent waters. This, they claim, would reduce the need for birds to commute relatively long distances to forage and so fisheries more distant from a colony would see a disproportionally large reduction in levels of damage. Effects in wintering areas are more difficult to predict, but fishery stakeholders believe it is not unreasonable to expect that a reduction of the overall population would, to a certain extent, reverse the geographical expansion of cormorants, or at least reduce the predation pressure in newly colonised areas.

There is also a belief among some fishery stakeholders that a reduction of cormorant numbers in a particular area could result in an over-proportional reduction in damage at fishery sites. This is based, in part, on the view that the pressure to abandon larger water bodies would be reduced or removed if bird numbers were lower, resulting in reduced pressure on fishery resources in other smaller sites more distant from roosts. Such arguments are also based on the fact that the damage at many of these smaller sites can be of greater significance, on the grounds that the fish populations are of higher commercial value, recreational interest and/or conservation concern than those in many large water bodies. It is clear that economic and conservation considerations will be important in the context of assessing damage (and in targeting management action), and such arguments may be valid, for example, in the case of alpine river fish populations in central Europe. However, not all stakeholders subscribe to this opinion, and it is not the case universally across Europe that smaller water bodies are of the highest commercial or recreational interest (and, in some cases, the opposite is true).

7.9 Practical considerations related to the timing and scale of cormorant control measures

i. Control of cormorant numbers at breeding sites

There is general consensus that any attempt at pan-European control would need to be targeted at concentrations of breeding birds because only when the birds are congregated together could measures be applied on a sufficiently large scale. Measures against breeding birds are already employed in some countries (e.g. Denmark), typically through egg destruction in ground-nesting colonies, where nests can be accessed with relative ease. However, measures at breeding colonies aren't necessarily restricted to ground-nesting birds as, for example, actions could perhaps be used to scare birds from their nests in trees such that eggs become cold and embryos fail to hatch, although this would be more difficult and costly.

Nest or egg destruction, or actions against birds at breeding colonies, over a sufficiently broad scale will reduce the breeding output of the birds. It follows that with fewer fledged birds at the end of the breeding season, a reduced number of older birds will visit fisheries in winter, and, in subsequent years, fewer adult birds will recruit to the breeding part of the population. However, such measures would need to be applied each year to achieve a lasting effect; the effect on recruitment in any year may be less than expected if there is a surplus of younger birds in the population. Eggs can be destroyed by several methods: egg removal, egg pricking or egg oiling, although oiling is the method most commonly used and generally regarded as cheaper, more effective and more humane. Investigations have demonstrated that egg destruction can be effective at reducing local populations of cormorants, although the results can be variable and studies in North America have shown that there may be an increase in dispersion of cormorants away from nesting colonies where oiling takes place.

A number of factors can influence the efficacy of different egg destruction methods. The oiling of eggs usually has the advantage over egg-removal or destruction in that the adults will commonly not lay a new clutch and will continue to sit on the oiled eggs until it is too late in the season to lay a replacement egg clutch that year. The management methods used to reduce breeding numbers will thus vary and depend on factors such as whether cormorants are nesting in trees (where nest/egg destruction is likely to be very difficult and expensive) or on the ground, and whether or not the particular methods are acceptable and permitted. For example, the killing of adult breeding birds has been used to reduce cormorant populations in a few colonies in Japan. However, in parts of Europe such actions may be considered unacceptable or inappropriate and attract opposition on animal welfare, ethical or other grounds. In any event, the experience from parts of Europe, North America and Japan is that success generally requires actions that are repeated over several years and which affect a large proportion of the breeding birds; this can be counteracted by sudden changes in food availability.

Great Cormorants need to dry their feathers in between foraging trips. Photo: S. Ortmann.

ii. Control of wintering cormorants

The large-scale control of cormorants over the winter period when birds are widely dispersed across Europe would present a huge challenge. Experiences at sites in Europe where relatively large-scale shooting has previously been carried out on cormorants migrating between breeding and winter feeding areas (e.g. Bavaria and France) have indicated that shooting was not generally effective in reducing cormorant numbers in the area over the remainder of the season, with shot birds being rapidly replaced by individuals from elsewhere, especially at attractive feeding sites. The fact that these areas are on migration fly-ways is seen as a key reason for the apparent rapid replacement of shot birds. The chances of achieving a decline in the numbers of birds appearing in later seasons are not high, and it has so far been impossible to clearly demonstrate any impact of such regional shooting on the wider population as a whole.

Any pan-European measures at winter feeding grounds would be expected to require repeated and intensive intervention at day and/or night roosts on a wide scale, and would likely be most effective if undertaken at a majority of sites. Such efforts would be very demanding, especially where cormorants respond by dispersing within an area, thus establishing a greater number of roosts each containing fewer birds. Pan-European control measures could, of course, be applied on both breeding and wintering birds.

7.10 Practical (and other) considerations

Aside from the biological issues, broad scale population reduction through culling, nest destruction or egg oiling raises practical, economic, political and ethical issues.

The application of all lethal (and non-lethal) techniques requires repetitive use of manpower, so costs depend to a large extent on whether or not responsibility for payment is made by or to those involved in any control programmes. Costs can be substantially reduced where manpower is available on a voluntary basis, or where it may be possible to implement controls in conjunction with other activities (e.g. hunting or as part of normal fish husbandry activities). Where dedicated expenditure is incurred, costs will be relatively high, and the costs of guns and ammunition can also be substantial. Beyond this, the costs will mainly be dependent on the scale of the programme. In the absence of any current plan, there is little, if any, information on which to assess the likely cost of a co-ordinated cormorant management plan operating across Europe. Although there are no readily-available cost estimates for such management options in the public domain, some fishery stakeholders argue that actions targeted at limited numbers of breeding colonies should be considerably lower than the cost of shooting and deterrent measures employed at thousands of individual foraging sites. However, even if cheaper, it is unclear whether such management in the summer would reduce the damage cormorants are considered to have on fisheries at other times of year, especially in the winter.

If lethal measures were to be employed on a larger scale, an additional practical consideration would be the need to co-ordinate actions effectively. This may require the establishment of collaborative stakeholder groups and real-time communication networks to ensure that efforts are targeted to best effect at appropriate times and places. Alternatively, agreements might be established between national governments or regional authorities. In addition, it would be necessary to decide who might fund any culling and who actually carries it out. This is relevant because conflicts tend to occur at bird foraging sites where shooting is the only practical lethal control measure, whereas the control of cormorant populations at nesting sites would often be required in countries and, sometimes, at sites other than where the conflicts actually occur.

The acceptability of lethal control measures depends to some extent on the viewpoint of the stakeholders involved. For a fishery owner or fish farmer faced with a cormorant problem, shooting to kill may be seen as a more acceptable option. For some other stakeholders (e.g. conservationists) lethal measures will be less acceptable or even unacceptable.

Wildlife management is carried out throughout Europe with actions ranging from attempts to eradicate invasive non-native species and control pest species to species conservation and restoration activities. Such activities occur over various geographic scales, sometimes requiring collaboration between countries, for example the Large Carnivore Initiative for Europe (see LCIE, 2008). The majority of citizens recognise the validity of such actions and accept that lethal control measures can be a legitimate activity where this is done in support of a reasonable objective, is undertaken in a proportionate and legal manner, and implemented as humanely as possible.

In the context of cormorants, the use of lethal control measures to address localised or short-term conflict issues is typically seen as a necessary and acceptable management option and has general support across stakeholder groups. Large-scale population control at a national or pan-European scale is more contentious, raising concerns not only about its necessity / likely effectiveness, but also in relation to the potential degree of impact on cormorant populations. This would be expected to attract differing views among stakeholders and politicians, and the killing of any wildlife can also attract comment, criticism and opposition from the general public on ethical grounds. Many fishery stakeholders believe that a co-ordinated and appropriately regulated pan-European population control plan, particularly one principally concerned with reducing breeding output, would be the best way to allay such concerns, and they advocate this as the preferred management option.

7.11 An example of pan-European population management of a bird species

While wildlife management is practiced widely across Europe, there appear to be few examples of co-ordinated action on a European scale to regulate a bird population. However, management of the population of one goose species which is in conflict with agriculture and causes damage to high-Arctic tundra vegetation might prove informative in further assessing the likely success of any pan-European cormorant management plan. A new adaptive international management plan concerning the population of Pink-footed Goose breeding on Svalbard (Norway) and staging and wintering mainly in four countries (Norway, Denmark, the Netherlands and Belgium) has been initiated under the Asian-Eurasian Waterbird Agreement (AEWA). This involves shooting of geese (mostly in Norway and Denmark) to stabilise the population size within an agreed range. It also encompasses habitat management and co-ordination of various other management efforts.

The plan has four objectives:
1. Maintain a sustainable and stable Pink-footed Goose population and its range;
2. Keep agricultural conflicts to an acceptable level;
3. Avoid increase in tundra vegetation degradation in the breeding range; and
4. Allow for recreational use that does not jeopardise the population.

The target for Pink-footed Geese is to maintain the population over the long term at around 60,000 individuals such that the favourable conservation status is maintained but the risk of population explosion avoided.

There are a number of key differences between this plan for the Pink-footed Goose and any potential plan in respect of cormorants. In particular, the Pink-footed Goose is considered a threat to itself – a rapid population increase would reduce the quality of its limited breeding habitat and could lead to a subsequent population crash. From a practical perspective, the goose population is fairly easy to monitor compared with Great Cormorant populations, and the number of countries that have to agree on goals, objectives and management actions is relatively limited. Further, the cormorant population could already be said to have ‘exploded’, meaning that the initial focus here would need to be on population reduction rather than largely maintaining a *status quo*. There are also resource use issues in respect of the goose, due to its recreational interest (i.e. for hunting). There are, however, also similarities between the two species – both are successful migratory birds which cause localised economic and ecological damage. Thus, the goose plan will provide Europe with more experience about how to flexibly manage migrating populations of birds that are in conflict with human interests. This, in turn, may prove informative in further considerations related to the potential management of cormorant populations at a pan-European scale.

7.12 Cormorant management approaches at smaller spatial scales

As Marzano *et al.* (2013, p. 10) point out “The multi-dimensional nature of cormorant-fisheries conflicts and the current philosophy of devolving management decision making to Member States currently precludes a single, co-ordinated solution to managing European cormorants in terms of continental-scale reduction in their breeding numbers or reproductive output”. Moreover, the results of the CormoDist project give further ecological evidence suggesting that such action will not reduce the numbers of cormorants wintering in specific areas

However, as Marzano *et al.* (2013, p. 10) go on to say: “this situation is not necessarily restrictive and it arguably offers considerable opportunity for tackling cormorant problems across Europe in practice. Key to this is the apparent under use of actions under derogation and, ultimately, the possibility of integrating actions to tackle problems over relatively large areas. Importantly, there is potential scope for defining, interpreting and quantifying ‘serious damage’ to make derogations more practical (see EU 2013). Similarly, the achievement of favourable conservation status for the cormorant is not required as it is currently listed in the Birds Directive. Thus, the current issue of cormorant population management is not one of conserving an endangered species but of managing one that some believe to be ‘overabundant’. This is not primarily an ecological term but one associated with human perceptions and the human management of wildlife (cf. Caughley 1981). There may be scope for transboundary coordinated management actions, carefully based on the derogation conditions in Article 9 ... Nevertheless, there are likely to be technology-transfer issues involved, as particular fisheries (even within the same regional fishery type) often consider themselves to be unique (Carss & Marzano 2005). Cormorant management would require flexibility and effort, and would come at a cost to fisheries owners and occupiers, but it might be achieved through acknowledging that these stakeholders face substantial problems (including cormorants) and therefore need the provision of advice, encouragement and financial support, compensation or incentives (cf. LCIE 2008, pp. 80-81). To help this process further, there would also be a need for an international network exchanging ecological data, information and contextual understanding, as well as practical advice and experience-sharing on the use of local management techniques between interested parties across Europe”.

Great Cormorants do to some extent follow rivers during migration over land. Photo: F. Möllers.

7.13 Management of cormorant numbers at a regional scale

In the absence of any plan to manage the size of the Great Cormorant population on a pan-European scale many fishery stakeholders focus on options for managing numbers at local or regional scales. The Birds Directive offers possibilities for taking steps aimed at lowering numbers locally or regionally. Furthermore, as already mentioned, the European Commission is encouraging Member States to consider the potential for co-ordinating management actions against cormorants across broader scales through bilateral (and larger) agreements.

Previous experience suggests that national or regional authorities can be successful in reducing breeding numbers within an area or region, whereas the chances of successfully controlling the numbers of cormorants that appear in areas and regions used for staging and/or wintering are likely to be more limited. The main methods used to reduce regional bird numbers outside the breeding season typically involve killing or scaring of birds on their feeding grounds and/or roosts. This is likely to be most successful if intensive disturbance is targeted at the majority of such sites.

Intensive scaring at feeding sites and/or at night roosts has, in some cases, been shown to result in marked reductions in the number of cormorants appearing in a particular area or region during the remainder of the season, although as noted in the previous section this may not always occur (e.g. Bregnballe *et al.* 2015). In other instances, such efforts have resulted in fragmentation, with birds establishing many smaller roosts in surrounding waterbodies. The likelihood of success with such actions will likely be affected by the area under consideration, but seems to depend partly on whether the cormorants use the area or region as a staging place to 'stop over' during their migration, or whether they are wintering permanently in the region. In the latter case, actions at numerous sites may, in theory, be more likely to affect national populations. The location of the area or region in relation to broader European migration patterns is thus important in considering the possible outcome of intensive scaring. In any event, scaring and harassment would normally, as a minimum, have to be repeated both during the season and in subsequent years to have a lasting effect. Such efforts may need to be pretty much continuous on sites located on migration pathways, at least for the duration of the migration period.

As noted previously, an alternative strategy that can be appropriate at a regional scale is to restrict birds to a particular area and limit their expansion to other surrounding areas through control measures. Local scale actions in Switzerland provide an example of such an approach, where birds are allowed to forage freely on certain lakes but are actively scared from small rivers. In this way, the local bird population within the 'permitted' area is regulated by available resources (i.e. the carrying capacity of the area) and expansion beyond this area is prevented by targeted actions. This approach has the benefit that it works with density-dependent regulatory mechanisms rather than against them.

7.14 Further practical smaller-scale measures, capacity building, technology transfer and demonstration projects

Given that one single, overall solution to cormorant problems (i.e. continental population reduction) seems highly unlikely, the most effective approach is to frame things in terms of problems that are best be addressed through targeted management. This could be management targeted at particular locations and at particular times of year. We are now in a position to apply all our knowledge in practice. Such a strategy could also support the implementation of EU directives and move toward 'sustainable' adaptive management for cormorant issues.

As described on the EC Cormorant Platform, and in greater detail in Russell *et al.* (2012), there are numerous management actions that can limit the interaction between cormorants and fish. Such actions fall into one of four broad categories: (1)

scaring birds away from a fishery, (2) protecting the fish by preventing cormorants from reaching them, (3) altering fish availability to cormorants by making a fishery less attractive as a foraging site, and (4) reducing overall cormorant numbers for example by killing birds locally to reinforce scaring, killing them more intensively, or reducing their reproductive efficiency. These management actions do not always work, but all have been shown to be successful in certain circumstances, times of year and places.

The key is perhaps to devise 'demonstration projects' that would (1) focus on demonstration and practical experimentation, (2) building capacity through knowledge-sharing and conflict resolution work, (3) explore economics (particularly the 'cost-effectiveness' of management actions) and, (4) involve regional and trans-boundary co-operation where appropriate.

As cormorant fisheries conflicts are very often not human:wildlife conflicts at all but are human:human conflicts (see chapter 1 of Marzano & Carss 2012), there is considerable scope for reducing the perceptions of such conflicts and the role (if any) of cormorants in fisheries declines. This might best be achieved through carefully targeted, and facilitated, conflict resolution activities. Similarly, the issue of technology-transfer as a barrier to effective cormorant-fishery conflict management has been noted elsewhere (see above; Marzano *et al.* 2013) and so an inclusive, proactive approach to this is necessary. The aim of such targeted management, perhaps through demonstration projects, should be to 'up-scale' the so-called site-specific management measures described above and the concept of 'local' or even 'regional' to cover particular fishery sectors. Currently some of the most volatile conflicts and the most tractable situations for such work include recreational angling on sub-Alpine rivers, extensive Carp pond farming, and possibly commercial fisheries and environmental issues on Baltic Sea archipelago coasts.

Here, the key to success might be in capacity building and conflict resolution to address many of the human:human issues and the practical experimentation and demonstration of so-called site-specific management actions - under the flexible interpretation and use of derogations – over increasingly larger geographical areas through proactive technology transfer. Such progress is likely to require some dedicated management and financial funding and would also benefit from some further targeted research to improve our understanding of cormorant movements and foraging site-choice, including (i) which factors influence the foraging- and roosting-site choices of cormorants, (ii) what influences movements – why and how birds decide to leave (or remain on) a particular foraging site or wider staging or wintering area, and (iii) modelling the migratory behaviour of cormorants to feed into effective, targeted management. Furthermore, the fairly new approach of individual-based modelling offers potential for addressing these difficulties. For example, in attempting to predict future changes in distribution of cormorants in Europe outside the breeding season, these types of models can incorporate knowledge and assumptions about how cormorants respond (in their choice of staging and wintering sites) to factors such as changes in the climate, intensity of competition for food and changes in levels of disturbance.

8 Discussion and concluding remarks

The CormoDist project was initiated to achieve two major objectives. First, to provide an overview of where cormorants from different breeding populations occur in Europe during autumn and winter. Second, to determine the geographical origin of the cormorants occurring in the various Member States by quantifying the proportion originating from different parts of the northern breeding range. The results of the CormoDist project are based upon recoveries of cormorants ringed since the early 1980's and so include some 30-35 years of data collection. By organising and analysing these data as well as by developing and using a new model, the project achieved both of its main aims, as presented in this report.

The present study has led to a number of major findings that add to our current understanding of the migration patterns of Great Cormorants of the *sinensis* sub-species in Europe.

8.1 Migration patterns

8.1.1 Overall patterns of migration and distribution

The majority of Great Cormorants of the *sinensis* sub-species in Europe breed in colonies located in countries around the Baltic Sea. These countries supported a total breeding population of 168,000 pairs in 2012 (Bregnballe et al. 2014). The cormorants originating from this part of the breeding range generally dispersed in various directions during the post-breeding period, but tended to remain within a few hundred kilometers of their breeding colonies. The cormorants originating from the western and central parts of the Baltic Sea area stayed closer to the breeding areas in the first months after the end of the breeding season than cormorants of a more northeastern origin. There were differences in the timing of departure from the post-breeding areas towards the wintering grounds. Finnish birds were the first to depart with birds migrating in southwesterly directions already in July-August. Many of the cormorants from Germany, Sweden and the East Baltic countries left the post-breeding areas during September. Finally in October birds of Danish origin along with first-year birds from Germany and Poland began to migrate. The recovery data suggested that a large proportion of the birds from the Baltic Sea area had reached their wintering areas by mid-November. The Baltic cormorants were widely distributed in winter with some birds hardly migrating and others migrating to wintering areas located more than 3000 km away. The Baltic cormorants were also widely distributed in east-west directions from Romania-Bulgaria in the east to Portugal and the United Kingdom in the west (see Fig. 4.1.4).

The breeding population of Great Cormorants in the Netherlands, Belgium and France had close to 34,000 breeding pairs in 2012 (Bregnballe et al. 2014). After the end of the breeding season, in July-August, most Dutch birds stayed within 100 kilometers from the breeding colonies. The recoveries from July-November showed that first-year and older cormorants from this part of Europe had dispersed in all directions after breeding, although dispersal in northeastern and southwestern directions dominated. Some of the cormorants had moved as far to the northeast as to reach the Baltic Sea. Wintering of cormorants from these three Atlantic countries ranged from Denmark in the north to Spain and North Africa in the south and to northeast Italy in the east.

Cormorants have been breeding in fairly low numbers in central Europe and in the countries close to the Adriatic. In 2012, a total of around 9000 pairs of cormorants were breeding in southern Germany, Switzerland, Austria, the Czech Republic, Slovakia, Hungary, Croatia and Italy (Bregnballe et al. 2014). The cormorants breeding in Switzerland were in autumn mainly recovered to the southwest of the breeding areas, i.e. in France and Spain, and in winter also along the western coasts of North Africa. In contrast, during post-breeding and autumn, cormorants from the Czech Republic, Hungary, Croatia and Italy were recovered both to the north of their breeding areas (even along the southern coasts of the Baltic Sea) and to the south. Most birds from these countries were wintering in central Europe, in the central part of the Mediterranean and on the Balkan Peninsula.

8.1.2 Migratory connectivity

Overall, we found that cormorants from all breeding areas dispersed widely to wintering areas throughout Europe and North Africa. There were, however, clear differences between breeding areas. In particular, birds breeding further east also tended to winter further east, although there was a large overlap in winter distribution between eastern and western birds (see next section). These results confirm the earlier findings from the direct analysis of ringing recoveries (chapter 4), but the statistical model employed took into account the geographic variation in the probability of a dead bird being reported.

8.1.3 Factors affecting migration behaviour

Age-related variation in migration behaviour and winter distribution was not pronounced. There were almost no differences in migration behaviour and winter distribution between first-year and adult cormorants. The largest differences were observed during the post-breeding period when first-year birds tended to disperse in a greater variety of directions than did older birds. For a few of the breeding populations we also found indications of a more southerly wintering distribution of first-year birds than of adults. See also van Eerden & Munsterman (1995) and Bregnballe et al. (1997).

Although the winter distribution of males and females overlapped, more males remained in central and northern parts of Europe compared to females. This is in accordance with the findings of Eerden & Munsterman (1995) and Bregnballe et al. (1997).

The location of breeding colonies along an east-west axis, a north-south axis and in relation to the geomorphological outline of the surrounding coasts and landmasses had effects on the directions taken by birds and the distances moved during post-breeding and autumn migration. It was also evident from the recoveries that the consequence of this under some circumstances was that cormorants from almost neighbouring colonies showed differences in where the majority of individuals were wintering.

Count data have showed that year-to-year variation in winter harshness can influence the overall distribution of cormorants in Europe, but this could not be fully studied in this project. Recovery data was used to provide support for the hypothesis that an individual experiencing a very cold winter in its first year of life tended to choose more southerly wintering areas later in life compared to an individual that was not exposed to a very cold winter in its first year.

8.1.4 Changes in migration behaviour

We found clear changes over time in the winter distribution of birds from some of the breeding areas, presumably reflecting changes in migration behaviour. In particular, it appeared that cormorants from Sweden, Denmark, Germany and the Netherlands had shifted their winter distribution north- and westward over the study period. This shift could be a consequence of increased competition in central European wintering areas from the growing easterly breeding populations.

8.2 Composition of wintering populations

The results from our model clearly document that wintering cormorant populations throughout Europe consist of a mixture of birds from different breeding areas, i.e. cormorants from many different breeding populations winter in the same area. There is thus not a one-to-one correspondence between breeding and wintering areas. At the same time, the connectivity between breeding and wintering areas is, however, sufficiently strong to maintain distinctly different compositions within eastern and western wintering populations. This follows directly from the observation that cormorants from all breeding areas in northern Europe tend to migrate towards the south and west in autumn (see earlier sections). The roughly parallel migration routes imply that more westerly breeding birds also tend to winter further west (see also chapter 4 and 5).

The composition of the wintering population has changed markedly over time in most wintering areas (see chapter 5). This is a consequence of changes in migration behaviour of some breeding populations (see above), combined with non-synchronous changes in abundance in the various breeding areas. For example, the recent and rapid growth of the breeding populations in Finland and the East Baltic, combined with a westward shift in wintering distribution of the Danish population for example, has led to a profound change in the composition of the population wintering in east-central Europe (e.g. Fig. 5.4.6).

The size and composition of wintering cormorant populations will probably also continue to be dynamic in the coming years. Even in the absence of changes in migration behaviour, wintering populations will change as a consequence of differential growth between the various breeding populations. Although density dependence in wintering populations is not well documented, we judge it as being highly likely that cormorants will change their distribution in response to changes in local numbers, so that an influx of 'new' wintering birds will contribute to a redistribution of birds that usually wintering in that area. On the other hand, a local decline, due to the reduced influx from birds from a given breeding area, is likely to make the wintering area more attractive to other cormorants. These mechanisms will tend to buffer wintering numbers in a specific area over time, but may also lead to rapid changes in composition. Other factors, such as changes in winter climate or fish productivity, may also contribute to changes in the attractiveness of a given wintering area.

8.3 Implications of migration patterns for management

Our results clearly show that the distribution and composition of wintering cormorants in Europe are complex and highly dynamic over time. Any attempt at managing cormorant numbers in wintering areas would therefore have to take this into account. Because there is no direct and clear correspondence between numbers on wintering and breeding areas, changes in numbers of one breeding or wintering sub-population are likely to lead to redistribution of other cormorants, thus buffering the effect of any management actions.

8.4 Use of artificial versus natural feeding areas

Although the CormoDist project was tasked with estimating the proportions of autumn staging and wintering cormorants that rely for foraging on natural wetlands and in artificial commercial fisheries (i.e. aquaculture), this objective was acknowledged to present a challenge from the outset. In consultation with the Commission, it was agreed that "artificial commercial fisheries (i.e. aquaculture)" would be interpreted as the extensive carp *Cyprinus carpio* aquaculture ponds to be found across Europe in many Member States.

It was known that the ringing data used in the CormoDist project would not offer any insight into the proportions of cormorants relying on natural versus artificial commercial fisheries. Similarly, it would be very difficult to quantify or predict the number (and, hence, proportions) of cormorants that permanently or temporarily forage in artificial commercial fisheries (i.e. aquaculture ponds) outside the breeding season.

Two further options were: (1) that knowledge about the relative numbers of cormorants counted in coastal wetlands and in inland wetlands without fish farms might give a rough idea about the minimum number of cormorants that achieve their daily food requirements without foraging at fish farms. (2) that by estimating the number of fish farms for certain countries or parts of Europe, and combining these numbers with assumptions and knowledge about the number of cormorants that on a daily basis forage at different types of fish farms, and by scaling-up these estimates, a rough (if highly uncertain) overall estimate could be derived. However, on further consideration, neither was found to be useful or to offer meaningful biological insight.

After careful consideration (including discussions with the IUCN/Wetlands International Cormorant Research Group), it was thus decided that the most biologically meaningful way of exploring the proportions of autumn staging and wintering cormorants that rely for foraging on natural wetlands and in artificial commercial fisheries (i.e. aquaculture) was to refer to published material on the relationships between cormorants and their use of feeding habitats at specific water bodies throughout Europe.

This material comprised a data set based on 132 reported 'case studies' of European waterbodies where data on cormorant numbers and presence, water surface area, and other environmental factors (including fish composition) were known. Whilst not comprehensive of course, it seemed likely that the data set comprised a representative sample of European waterbodies, at least of those occupied by cormorants at some time of year. It was possible to analyse this data set in a manner that would suggest something about the relative use of natural wetlands and artificial commercial fisheries, as it was known that many of the small water surface area sites were commercial fish ponds and it was assumed that the remainder were likely to be so-called 'natural' wetlands.

These data suggested that extensive fish farms are likely to play only a small role on the population level for European cormorants, although they may be used extensively by individual birds. The data also suggested that there may well be a high (but, as yet, unquantified) turnover of foraging birds between natural wetlands and artificial commercial fisheries. Furthermore, this situation suggests very strongly that the 'expansion' of the European cormorant population (throughout Europe overall and/or in the Baltic region specifically) has little to do with extensive fish ponds in Europe. However such an expansion does mean that, during migration and overwintering, individual birds will exploit the opportunities of foraging at fish ponds, particularly those located on migration routes or in regions where birds spend the winter.

Whilst far from complete, the analysis discussed here suggests strongly that extensive fish ponds are not relied upon by cormorants at the population level across Europe. Individual birds may however feed intensively at such sites and there is likely to be turnover between these and more natural feeding sites. Fish ponds on migratory routes or in the overwintering areas of cormorants are likely to be visited by these birds which raises the issue of potential alternative foraging sites for them and their proximity to, and location within, migratory corridors.

In very general terms, this analysis shows that it is very unlikely that European cormorants are being supported (or maintained) at the population level by artificial commercial fisheries in the form of extensive carp ponds. Thus it is highly unlikely that aquaculture has 'caused' the increase in European cormorant numbers. This is probably a very important message from the available data.

However, the analysis also suggests that there is a relatively higher use of smaller (rather than larger) waterbodies (many of which are presumed to be fish farm ponds) by cormorants. Thus, at the individual level, fish ponds are clearly important foraging areas for birds in winter. This suggests two things. First, that cormorants are likely to present conflicts at fish ponds as they are presumably attractive foraging sites for all birds. Secondly, that the location – and predictability – of these ponds in relation to the migratory corridors of the birds (and to any alternative feeding sites) is likely to be an important issue. Overall, this suggests that improved knowledge of cormorant foraging site choice and use of space in overwintering areas, and their ability to 'switch' between foraging sites would be very helpful in informing potential management options for pond fish farms in particular (but probably other sensitive fishery types as well).

8.5 Viable options to deal with cormorant-fisheries interactions

The work of the CormoDist project suggested strongly that it will not be possible to protect specific wintering areas from cormorant predation through the reduction of breeding numbers elsewhere in Europe. The data and analysis thus suggest that population level management is unlikely to be a viable option to deal with cormorant-fishery interactions.

In practice, there are many reasons why attempts to reduce the continental cormorant population, and to manage it around some 'acceptable' level, would be difficult on such a broad scale. For example, the large geographical range, widespread breeding populations and further mixing and dispersing of the birds in winter means that there will be no simple relationship between management actions in a restricted part of the breeding areas (e.g. in one country) and the consequences of these actions in wintering areas, or vice versa. Furthermore, since numbers and distribution patterns of the birds are partly determined by density-dependent factors operating both within and outside the breeding season, there is considerable potential to compensate for reductions in numbers through changes in both the distribution of the birds, and their fertility and mortality rates. Public acceptability and ethical concerns would also need to be considered.

Of course, given coordinated action across Member States that could include annual reduction in the numbers of breeding cormorants and/or their reproduction output, it would be possible – in theory – to lower the European cormorant population drastically. Although presently unquantified, the effort and cost of such actions are likely to be prohibitive. It is also likely that such a population cull would be unacceptable (both to the general public and for ethical reasons). Our current ecological understanding suggests that the most viable options for dealing with cormorant-fishery interactions (conflicts) are not at the population level but at more local or regional levels.

Given that one single, overall solution to cormorant problems (i.e. continental population reduction) seems highly unlikely, the most effective approach is to frame things in terms of conflicts that are best addressed through targeted management. This could be management targeted at particular locations and at particular times of year. We are now in a position to apply all our knowledge in practice. Such a strategy could also support the implementation of EU directives and move toward 'sustainable' adaptive management for cormorant issues.

There are numerous potentially viable options on a smaller geographical scale, which are discussed in detail elsewhere. The key issues here seem to be that although these so-called site-specific management 'tools' are not always successful, they have been demonstrated to work at certain locations and at certain times in terms of limiting the interaction between cormorants and fish. Such actions fall into one of four broad categories: (1) scaring birds away from a fishery, (2) protecting the fish by preventing cormorants from reaching them, (3) altering fish availability to cormorants by making a fishery less attractive as a foraging site compared to elsewhere, and (4) reducing overall cormorant numbers for example by killing birds locally to reinforce scaring, killing them more intensively, or reducing their reproductive efficiency.
The key is perhaps to devise 'demonstration projects' that would (a) focus on demonstration and practical experimentation, (b) building capacity through knowledge-sharing and conflict resolution work, (c) explore economics (particularly the 'cost-effectiveness' of management actions) and, (d) involve regional and trans-boundary co-operation where appropriate.

As cormorant fisheries conflicts are very often not human:wildlife conflicts at all but are human:human conflicts, there is considerable scope for reducing the perceptions of such conflicts and the role (if any) of cormorants in relation to fisheries. This might best be achieved through carefully targeted, and facilitated, conflict resolution activities. Similarly, the issue of technology-transfer as a barrier to effective cormorant-fishery conflict management has been noted and so an inclusive, proactive approach to this is necessary. The aim of such targeted management, perhaps through demonstration projects, should be to 'up-scale' the so-called site-specific management measures described above to embrace the concept of 'local' or even 'regional' concerted actions to cover particular fishery sectors. Currently some of the most volatile conflicts and the most tractable situations for such work include recreational angling on sub-Alpine rivers, extensive Carp pond farming, and possibly conflicts between commercial fisheries and environmental issues along Baltic Sea archipelago coasts.

Here, the key to success might be in capacity building and conflict resolution to address many of the human:human issues and the practical experimentation and demonstration of so-called site-specific management actions – under the flexible interpretation and use of derogations – over increasingly larger geographical areas through proactive technology transfer. Such progress is likely to require some dedicated management and financial funding and would also benefit from some further targeted research to improve our understanding of cormorant movements and foraging site-choice, including (i) which factors influence the foraging- and roosting-site choices of cormorants, (ii) what influences movements – why and how birds decide to leave (or remain on) a particular foraging site or wider staging or wintering area, and (iii) modelling the migratory behaviour of cormorants to feed into effective, targeted management. Furthermore, the relatively new approach of applying individual-based modelling offers the potential to address some of these difficulties. For example, in attempting to predict future changes in distribution of cormorants in Europe outside the breeding season, these types of models can incorporate knowledge and assumptions about how cormorants respond (in their choice of staging and wintering sites) to factors such as changes in the climate, intensity of competition for food and changes in levels of disturbance.

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Appendix 5.1

Migratory connectivity: Details of material and methods

Introduction

The degree of connectivity between breeding and non-breeding areas, and specifically the composition of wintering populations in terms of their breeding origin, is an important research question in both fundamental and applied ecology. Migratory connectivity has thus become a central theme in ecology and conservation biology (Webster et al. 2002). Many different techniques have been used to investigate and quantify migratory connectivity, including stable isotopes (Hobson & Wassenaar 2008, Guillemain et al. 2014), population genetics (Sonsthagen et al. 2015), and tracking using electronic devices (Frederiksen et al. 2012). However, traditional ringing remains the most useful technique for the study of migratory connectivity in many bird species (Thorup et al. 2014), particularly in cases where large-scale ringing has taken place throughout the breeding range over long periods, and where many live or dead re-encounters have accumulated. For the quantification of migratory connectivity, information from many populations covering a large geographic area is needed. Ringing and recovery data are often available from such large area, whereas e.g. tracking data in most cases is restricted to one or a few populations or individuals.

Since the 1970s, very large numbers of cormorant chicks have been ringed throughout Europe, and this effort has provided large amounts of information that can be used to quantify migratory connectivity. The ringing effort has included all parts of the breeding range in the Baltic region, central and western Europe since the early 1980s. This high level of coverage allows a formal quantitative approach to the estimation of migratory connectivity.

Here, we use the thousands of recoveries of dead ringed cormorants throughout the winter range (Europe and North Africa) to quantify migratory connectivity. In addition, a large (but spatially and temporally variable) proportion of the ringed chicks have been equipped with engraved plastic colour rings that can be read from a distance. Observations of these colour-ringed birds also provide large amounts of information on migratory connectivity, but we have not had access to these data for all ringing programmes. This analysis is therefore restricted to dead recoveries during the winter period of cormorant chicks ringed 1983-2013.

Methods

Parameters, variables, sub- and superscripts

B->W: period from breeding season until winter
BS: breeding success, mean number of chicks fledged per pair
i: superscript indicating breeding area
j: superscript indicating non-breeding area
k: subscript indicating year of ringing
ma: distribution probability of adults
mj: distribution probability of first-year birds
NB: breeding population size (number of pairs)
NWa: winter adult population size (1 Y+, number of individuals)
NWj: winter first-year population size (number of individuals)
r: recovery probability
Sa: annual survival probability of adults (1 Y+)
Sj: annual survival probability of first-year birds
t: subscript indicating year of recovery [also used in population model]

Spatial coverage and structure

Our aim was to provide estimates of migratory connectivity for the population of *Ph. c. sinensis* breeding in northern and central Europe. We therefore excluded breeding areas populated exclusively or mainly by *Ph. c. carbo* (the British Isles incl. the Channel Islands, Iceland, Norway except the south-eastern region, Arctic Russia), as well as eastern and south-eastern areas of Europe having breeding populations of *Ph. c. sinensis* (see borders of areas included in Fig. 5.2.1). *Ph. c. carbo* also breeds in western France mixed with *Ph. c. sinensis*, and this population is included here.

We included all known wintering areas of our target population. However, some of these areas are shared with *Ph. c. carbo* (Norway, Sweden, Denmark, the British Isles, western France, the Iberian peninsula) (Wernham et al. 2002, Bakken et al. 2003) or Black Sea *Ph. c. sinensis* (the Black Sea region, Greece, eastern North Africa), and our estimates of wintering population size and composition thus do not reflect all cormorants present in these areas.

We defined 12 breeding areas and 11 non-breeding areas (Fig. 5.2.1 and 5.2.2). The breeding areas were largely defined based on national administrative borders, because data on numbers ringed were usually only available at the national level. Non-breeding areas were defined using a combination of administrative and biogeographic criteria, but the exact definitions used local administrative borders for convenience.

Ringing and recovery data

Cormorants have practically only been ringed as unfledged chicks in Europe, and in this study we did not include the very few birds ringed as adults, either during the breeding season or in winter. Ringing and recovery data were obtained from the EURING database (www.euring.org) and from the national ringing centres. We used data from 1983 until 2013, including recoveries from the 2013/14 winter. A total of 222,467 cormorants chicks were ringed in the study area during this period (Table 1).

[illegible]

A substantial proportion (but highly variable in space and time) of these chicks also received a plastic colour ring with an alphanumeric code on the other leg; the presence of a colour ring may have enhanced the probability that these birds were reported if found dead. However, we did not have access to information about the colour ring status of each bird (or in some cases, even the proportion of all birds which were colour-ringed), so we were unable to include this potential effect in our model.

We included dead recoveries from the winter period (15 Nov – 28 Feb), when cormorants were assumed to have reached their wintering areas and remain fairly stationary (Bregnballe et al. 1997, Frederiksen et al. 2002). Records where only the ring was found and those with a highly uncertain finding date were excluded. We retained 4,511 recoveries (Table 2), of which 2,003 referred to shot birds, and 2,508 to birds reported dead from other or unknown causes. Recoveries were allocated to non-breeding areas in ArcGIS 10.2.

[illegible]

Population size

The breeding population of cormorants has been counted annually in most European countries since the 1970s (Bregnballe et al. 2014). Cormorant colonies are easy to detect and nests are fairly easy to count accurately, and we assumed that the count error was negligible. In cases where counts were unavailable for one or more years, we used linear interpolation to estimate population size, or guesstimates when the year in question was at the end of the time series. Of 487 non-zero counts at the country level, 134 were obtained by linear interpolation and 11 as guesstimates (Table 3).

[illegible]

Breeding success

For our conversion of numbers of recoveries to relative numbers of cormorants, we needed to estimate the number of fledged young produced per colony per year in all the breeding areas in Europe. The reproductive output from cormorant colonies has been studied in breeding colonies throughout most of the breeding range of the *Ph. c. sinensis* subspecies in Europe. However, these studies have usually lasted for only a single or a few years and only covered years when the specific breeding colony was either growing, stable or in decline. Nonetheless, we assessed that the number of published studies was sufficient to allow reasonable estimates of the number of fledglings produced per year in the European cormorant colonies during their respective phases of population development. Our estimates or guesstimates of the annual mean breeding productivity for each of the 12 breeding areas is given in Table 4.

Bayesian multi-state CMR model

Overall structure

We developed a novel Bayesian multi-state capture-mark-recovery model to estimate the proportions of cormorants from each breeding area that wintered in each non-breeding area. The model was an extension to a long-lived species of that employed by Korner-Nievergelt et al. (2010, 2014), which again was based on the division coefficient method of Kania and Busse (1987). Under this model, these proportions (here termed distribution probabilities) are only estimable if the number of marking (here, breeding) areas is equal to or larger than the number of recovery (here, non-breeding) areas, and if birds from different breeding areas have different non-breeding distributions. It is assumed that all individuals spend the non-breeding season in one of the recovery areas considered, i.e., no individual should leave the study area. Furthermore, it is assumed that all marked birds dying in a given non-breeding area have the same probability of being found and reported to the ringing centre, regardless of their breeding origin.

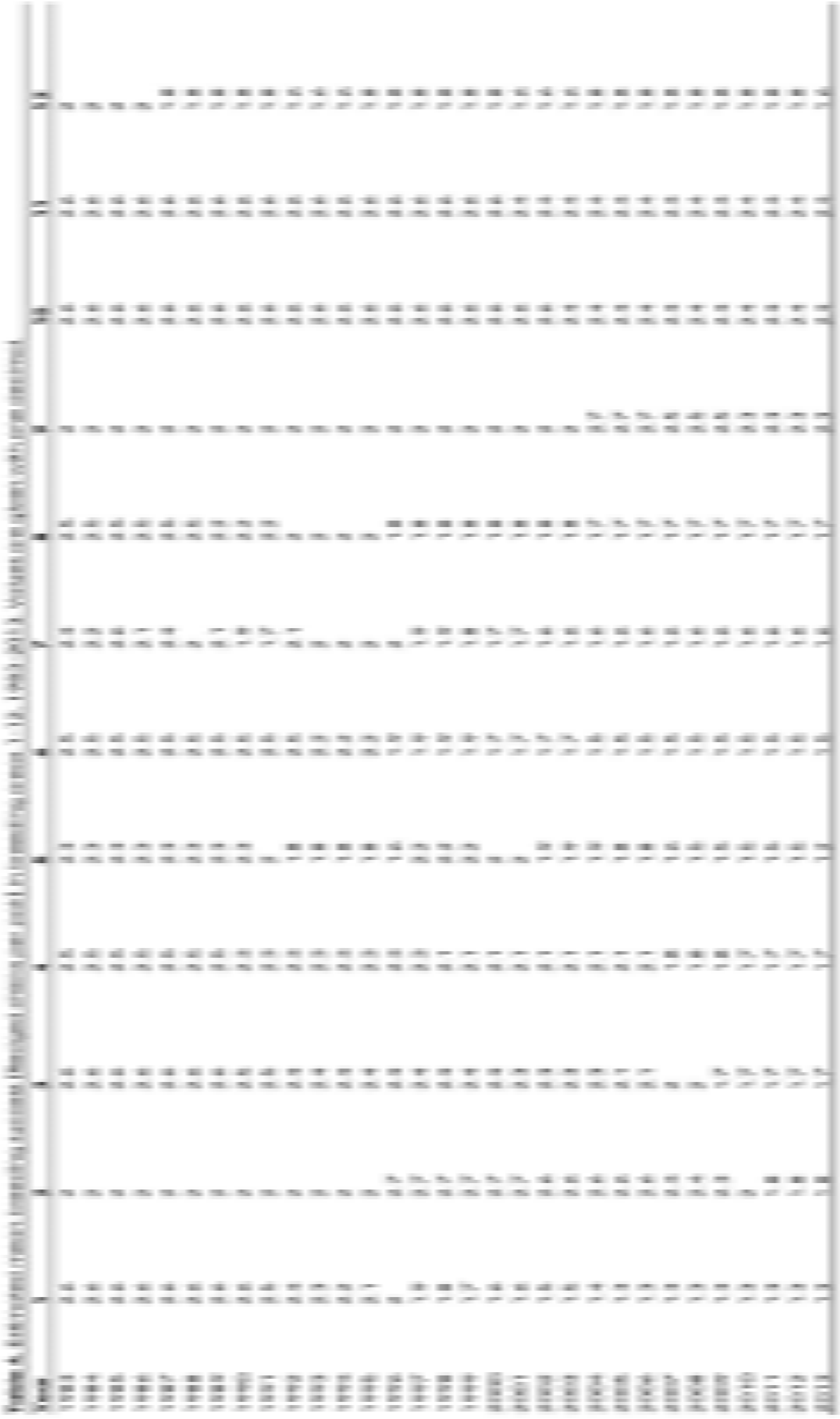
For simplicity, we used only two age classes (first-year and adult) for survival and distribution probabilities, and assumed that the recovery probability (probability that a dead bird is found and its ring reported) was independent of age.

Likelihood and estimated parameters

Recovery data were summarised as a four-dimensional m-array (by ringing and recovery year, breeding and non-breeding area), $\mathbf{R}_{ikjt}$. We assumed that the recoveries of birds ringed during the same year and in the same breeding area ($\mathbf{N}_{ik}$) were multinomially distributed, $R_{ik} \sim Multinom(p_{ik}, N_{ik})$. Cell probabilities $\mathbf{p}_{ik}$ were then modelled as functions of survival, distribution and recovery probabilities.

Sj_t and Sa_t represent standard annual (year-dependent) survival probabilities for respectively the first year of life and subsequent years. For both, we included a normal random between-year variance on the logit-scale.

The recovery probability r_t^j represents the probability that a dead bird, which has died during the non-breeding season of year t in non-breeding area j, is found, and that the ring number is reported to the ringing centre. Recovery probabilities in each non-breeding area were modelled with independent logit-linear trends over time (z-transformed).



The first-year and adult distribution probabilities mj_t^{ij} and ma_t^{ij} represent the (in principle year-dependent) probability that a bird 'belonging' to breeding area *i* (i.e. fledged there) spends the winter in non-breeding area *j*. The distribution probabilities for one cohort of birds during one time period sum to one (e.g. $\sum_{j=1}^{11} mj_t^{ij} = 1$), i.e. the 11 non-breeding areas include the whole winter distribution of the studied population. The distribution parameters are not transition probabilities in the usual sense, because these parameters are not dependent on where the bird has been during the last year, but where it has been ringed (there is no Markovian relationship). The parameters mj_t^{ij} and ma_t^{ij} are not individual characteristics but describe characteristics of the population. Due to data limitations, the distribution probabilities were modelled as period-dependent rather than year-dependent, initially using six 5-year periods (with a final period of 6 years).

Priors

For the means of the logit of first-year and adult survival, we used flat normal distributions (mean=0, sd=10) as priors. For the standard deviation of the random year effects we used folded-t distribution (mean = 0, sd = 1, df=2) priors (Gelman 2006).

The priors for the intercept in the logistic regression for recovery probabilities (i.e. area-specific recovery probabilities for 1998, the central year of the study) were constructed so that their order was partly fixed. Based on a general understanding of patterns of ring recovery activity, we assumed that recovery probabilities were highest in the UK and lowest in North Africa, with other wintering areas ranked in between: $r^D > r^A, r^E > r^C, r^F > r^B, r^G, r^H > r^I, r^J > r^K$. The prior for r^D was normal (mean= 0, sd = 5) on the logit scale, and for each subsequent level of the series, a uniform prior between -12 and the previous level was used. Normal priors (mean= 0, sd = 5) were used for the slopes.

For the distribution probabilities, we used beta(1,1) priors which were then scaled to sum to 1 for each cohort of birds during one time period. Some movements were regarded as highly unlikely, e.g. birds moving north in winter, or very extensive east-west movements. For these *a priori* rare movements, we used a beta(1,1000) prior before scaling as above.

Model validation etc.

Convergence

To fit the model, we used Markov chain Monte Carlo simulations as implemented in JAGS (Plummer 2003) that was used from R (R Core Team 2015) using the R package R2jags (Su & Yajima 2015). Two chains of length 60,000 were simulated and from the last 50,000 iterations, every 10th was used to describe the posterior distributions of the model parameters. Convergence was assessed graphically, by the r-hat value (Brooks & Gelman 1998) and the number of effective samples.

Posterior predictive checking

To assess model fit, we used posterior predictive checking (Gelman et al. 1996). Thereby, we simulated from the posterior distribution of the model parameters 1000 replicated data sets taking the uncertainty of the model parameters into account (predictive distribution). We compared the total number of recoveries in each of the 11 non-breeding areas in the original data with the 1000 replicated data sets. This comparison identified non-breeding areas for which the model predictions fail.

Prior-posterior overlap

In highly parameterized models like the one here, the estimability of parameters can be of concern. When using Bayesian methods, parameters for which the data contain no or only weak information the posterior distribution is essentially equal to the prior distribution. Therefore, the comparison between the prior and the posterior distribution can inform about how much information the data contains about a specific parameter. We, therefore, calculated the overlap between the prior and the posterior distribution for each parameter. The closer this overlap is to one, the less information from the data is contained in the parameter estimates.

Winter population model

Winter population size and composition in the 11 non-breeding areas was estimated by combining parameter estimates (survival and distribution probabilities) from the Bayesian CMR model with data on population size and breeding success in the 12 breeding areas (assumed known without error). Assuming equal survival probability before and after the winter census, we calculated survival of adults (1 Y+) from breeding season until winter as the square root of the annual estimate of survival: $\widehat{Sa}_t^{B\to W} = \sqrt{\widehat{Sa}_t}$. For first-year birds, we assumed that survival was similar to adults from the first winter on, and calculated survival from fledging until winter as:
$\widehat{Sj}_t^{B\to W} = \widehat{Sj}_t / \sqrt{\widehat{Sa}_t}$.

The counts only included breeding birds (pairs), whereas cormorants start breeding at an age of 2-4 years (Frederiksen & Bregnballe 2001). In the model, we assumed that all cormorants started to breed at age 3 years. The estimated numbers of adult and first-year cormorants from breeding area *i* wintering in non-breeding area *j* in year *t* were then calculated as respectively:

$$\widehat{NWa}_t^{ij} = \widehat{ma}_t^{ij} * \left(2 * NB_t^i * \sqrt{\widehat{Sa}_t} + NB_{t-1}^i * BS_{t-1}^i * \widehat{Sj}_{t-1} / \sqrt{\widehat{Sa}_{t-1}} * \sqrt{\widehat{Sa}_t} + NB_{t-2}^i * BS_{t-2}^i * \widehat{Sj}_{t-2} / \sqrt{\widehat{Sa}_{t-2}} * \sqrt{\widehat{Sa}_{t-1}} * \sqrt{\widehat{Sa}_t} \right)$$, and

$$\widehat{NWj}_t^{ij} = \widehat{mj}_t^{ij} * NB_t^i * BS_t^i * \widehat{Sj}_t / \sqrt{\widehat{Sa}_t}.$$

For adults, this calculation was not possible for the first two study years due to missing estimates of breeding success and survival before 1983, and we therefore assumed that 3 adults (1 Y+) were present in winter for each breeding pair (i.e. $\widehat{NWa}_t^{ij} = \widehat{ma}_t^{ij} * 3 * NB_t^i$) , a value close to the average for the early part of the study.

Estimates of the annual total numbers present in each wintering area were then obtained by summing across breeding areas and age classes. All these calculations were carried out for each iteration of the Bayesian model, and we thus obtained full posterior distributions of the winter population estimates.

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Appendix 5.2

Proportions migrating to different wintering areas

The following pie charts show the proportion of adult Great Cormorants estimated to have been wintering in each of 11 areas in Europe and North Africa. For most of the 12 breeding areas the estimated distribution among the wintering areas is shown for selected 5(6)-winter periods as examples. The delineation of the 11 wintering areas is shown in Fig. 5.2.2. The number of winter recoveries of birds originating from each of the breeding areas and included in the models estimate of the proportion migrating to different wintering areas is given in Table 1.

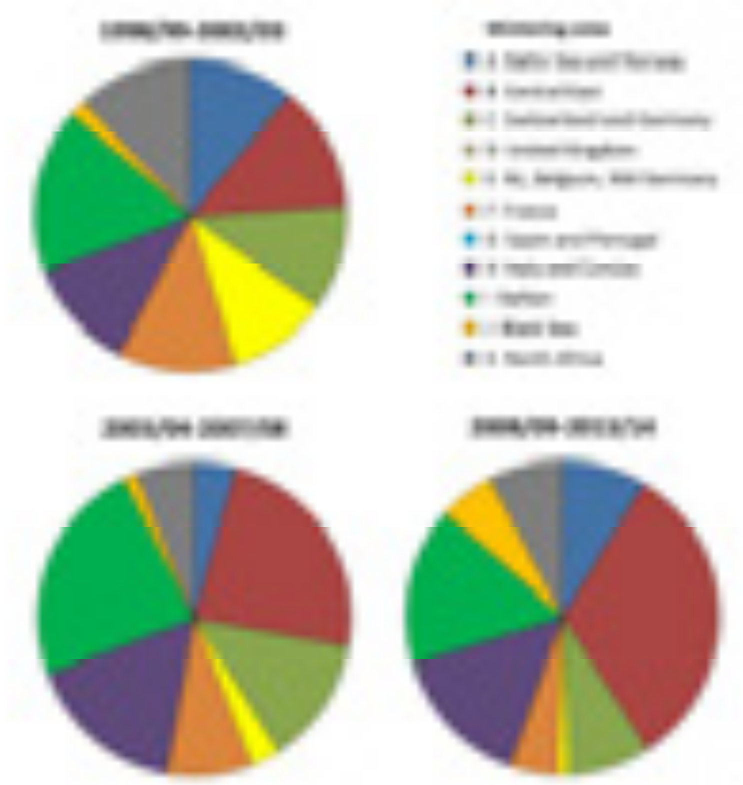
Table. 1. Number of winter recoveries during 5(6)-winter periods of adult Great Cormorants originating from each of the 12 breeding areas. Numbers in bold refer to winters for which pie charts are shown.

Breeding area	1983/84-1987/88	1988/89-1992/93	1993/94-1997/98	1998/99-2002/03	2003/04-2007/08	2008/09-2013/14
Sweden	5	**112**	226	**280**	273	**209**
Finland	0	0	0	**35**	**229**	**270**
East Baltic	0	4	67	**75**	**113**	**100**
Poland	5	**19**	**26**	8	**15**	11
Denmark and south Norway	**244**	170	174	**297**	368	**589**
Germany	6	**47**	41	**28**	20	**61**
The Netherlands and Belgium	24	27	45	**38**	35	**26**
France	0	2	10	11	12	11
Switzerland	0	0	0	0	**16**	**52**
Italy	0	0	1	2	4	5
Czech Republic	2	9	2	3	4	1
Croatia-Hungary	13	9	4	5	9	2

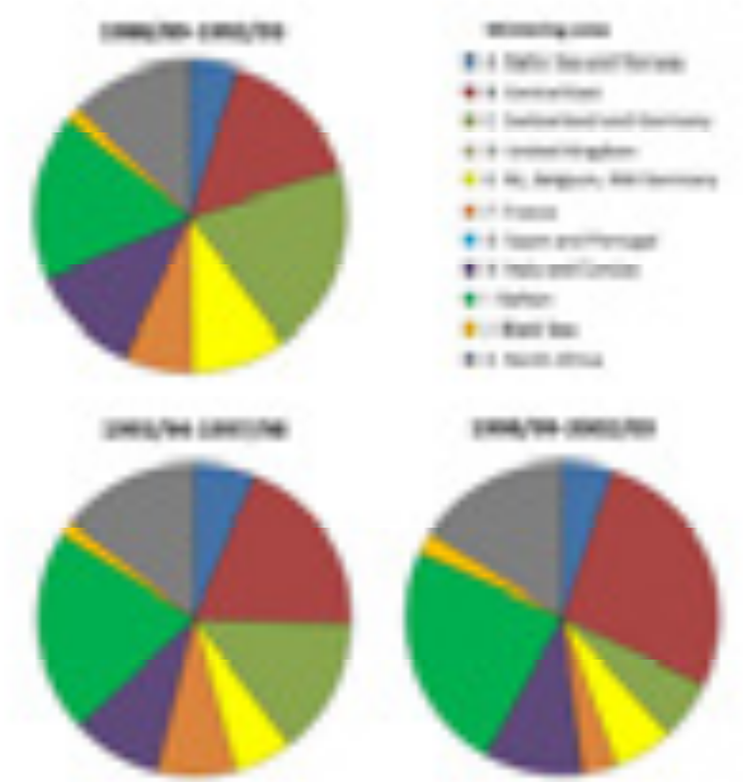
Cormorants from Sweden:

Cormorants from Finland:

Cormorants from the East Baltic, i.e. the Russian Gulf of Finland, Estonia, Latvia and Lithuania:



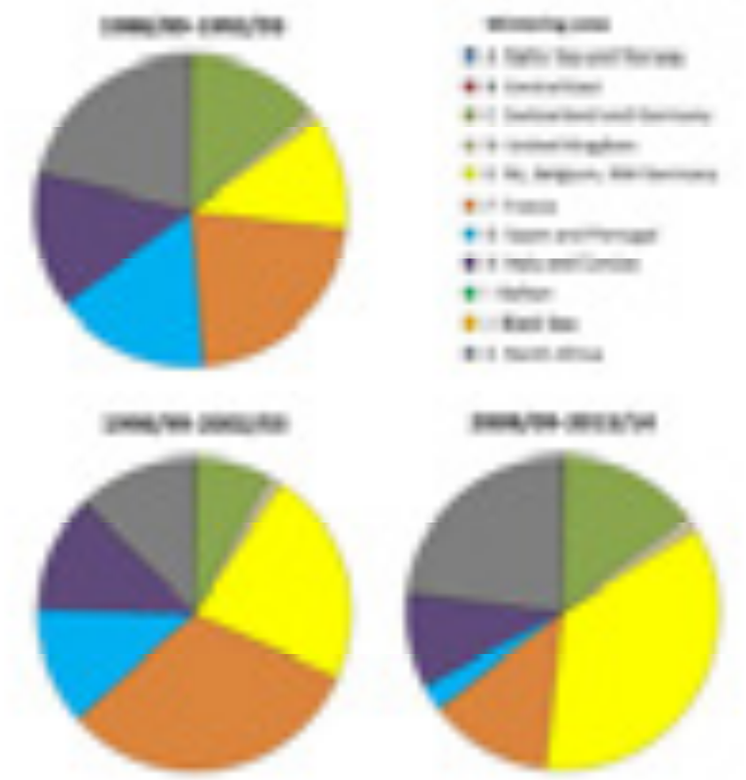
Cormorants from Poland:



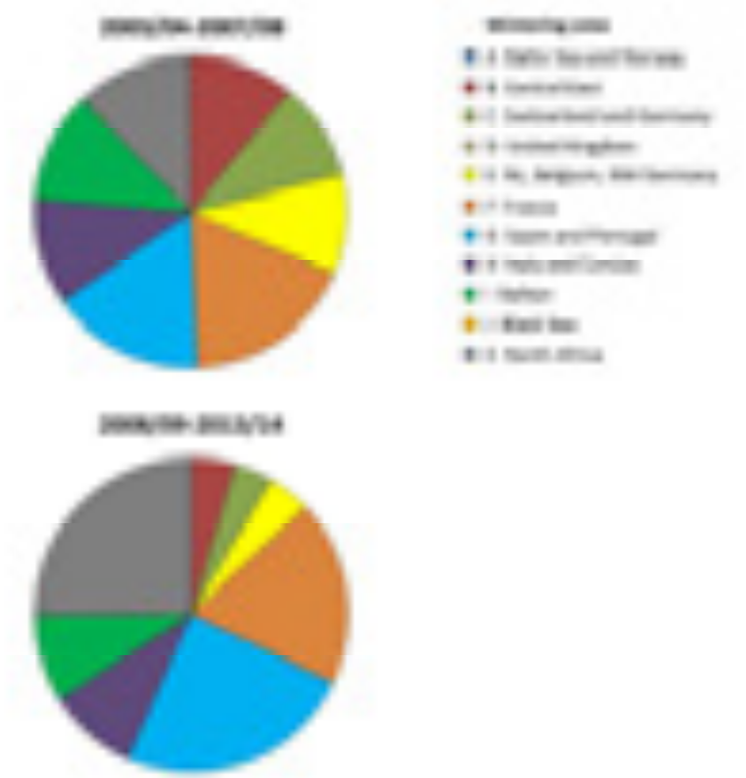
Cormorants from Denmark and southern Norway:

Cormorants from northern Germany:

Cormorants from the The Netherlands and Belgium:



Cormorants from Switzerland:

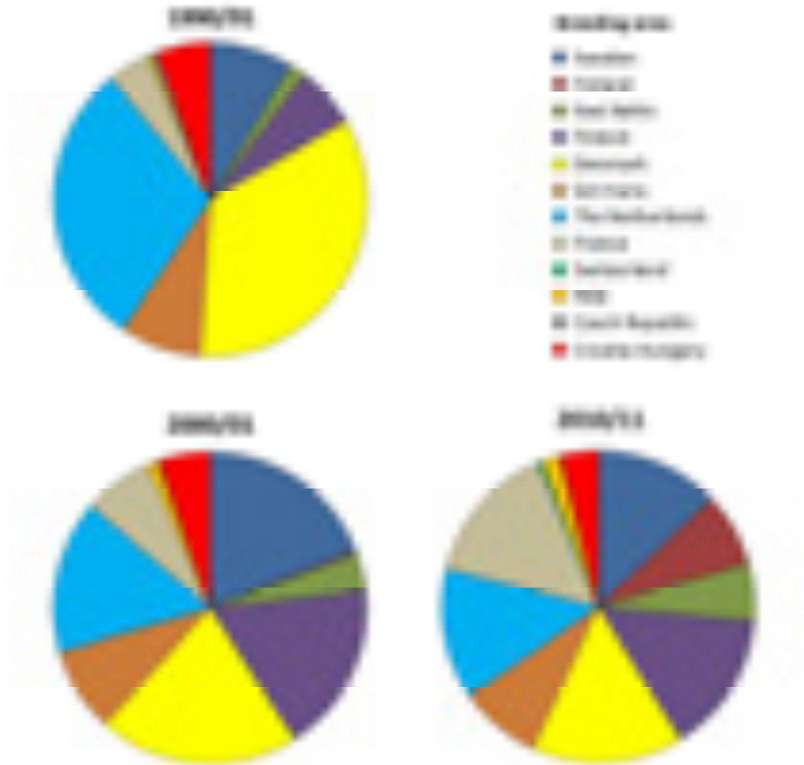


Appendix 5.3

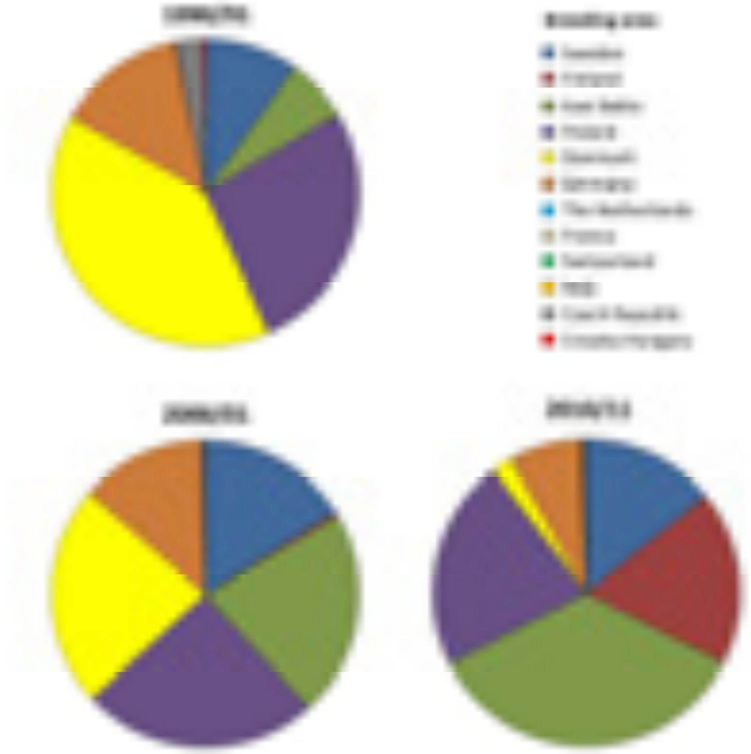
Geographical origin of wintering cormorants

The following pie charts show the estimated composition of the wintering populations in 11 areas with respect to the geographical origin of the cormorants present. Pie charts are only shown as 'snap shots' for the winters 1990/91, 2000/01 and 2010. Only the composition of adult birds is shown.

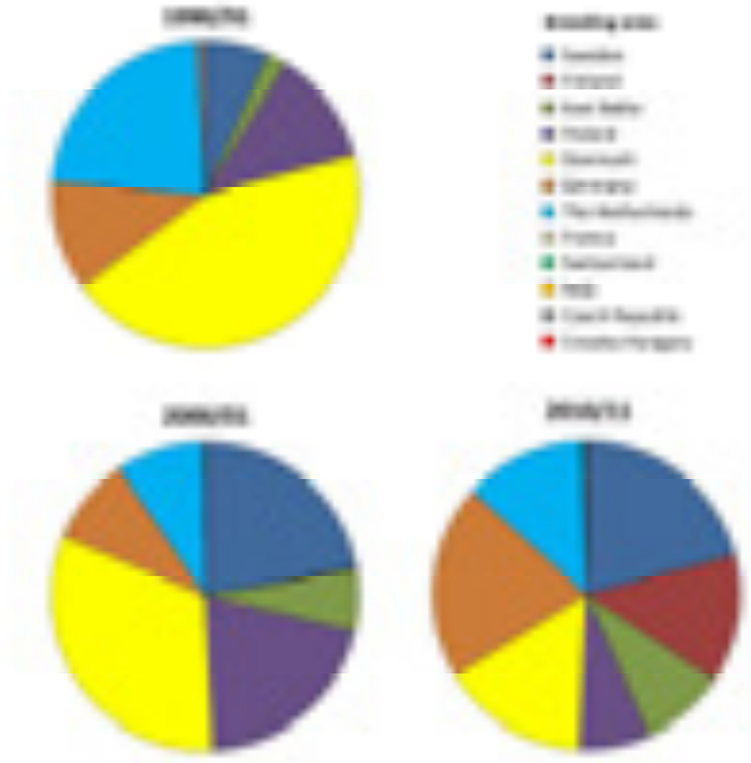
Cormorants wintering in area A – The Baltic Sea and southern Norway:



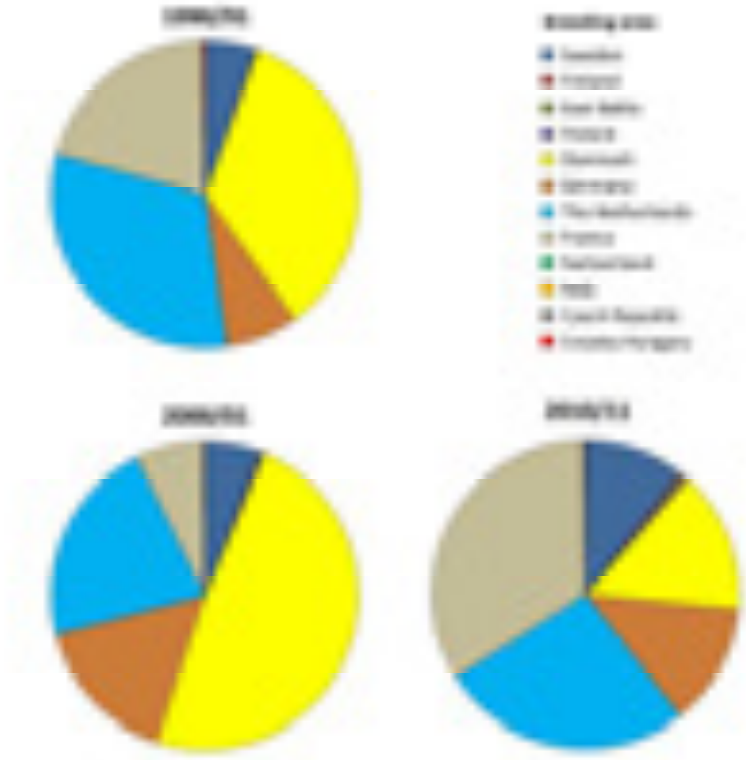
Cormorants wintering in area B – Poland (central and south), Czech Republic, Slovakia, Hungary and Austria (central and east):



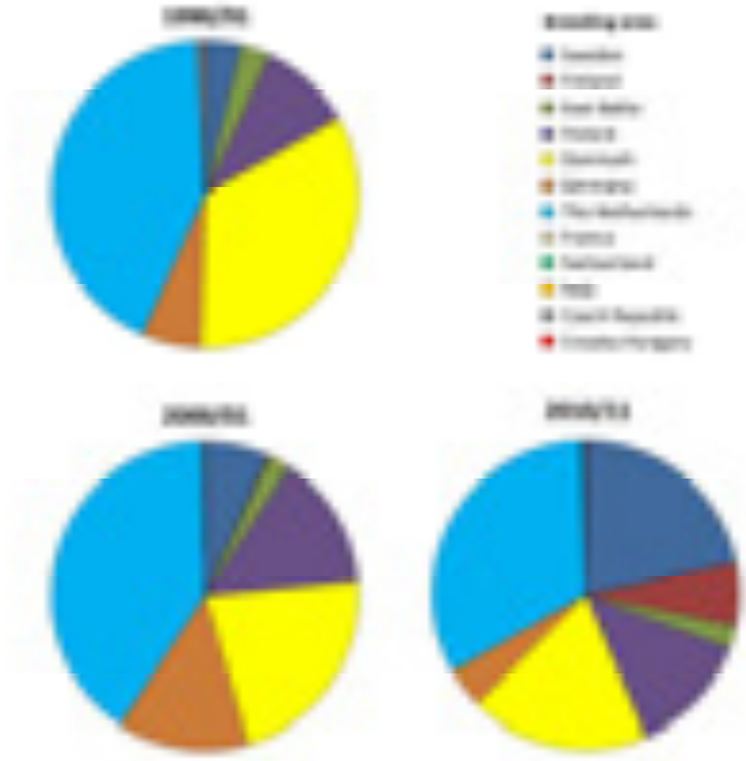
Cormorants wintering in area C – Switzerland, Germany (except N and NW Germany), Austria west and Liechtenstein:



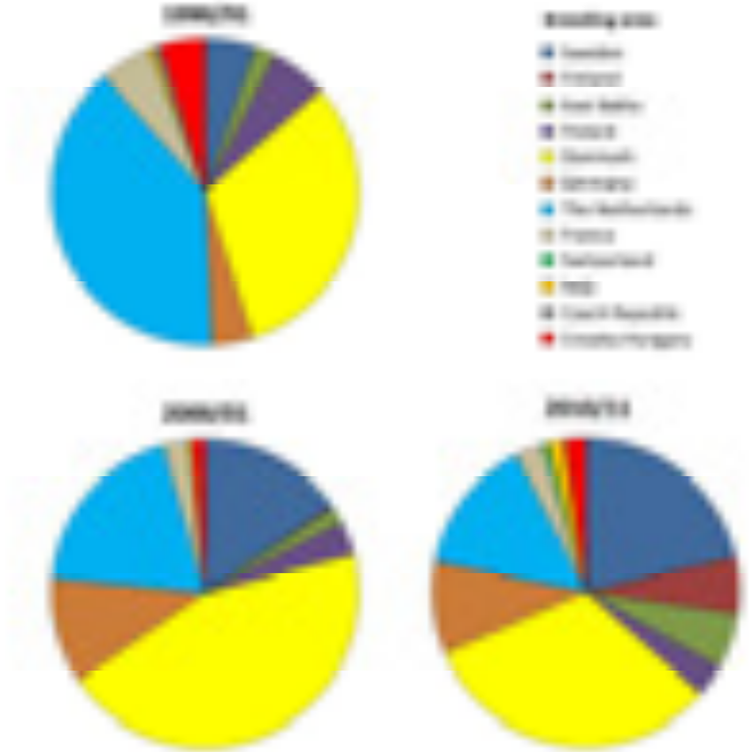
Cormorants wintering in area D – United Kingdom and Ireland:



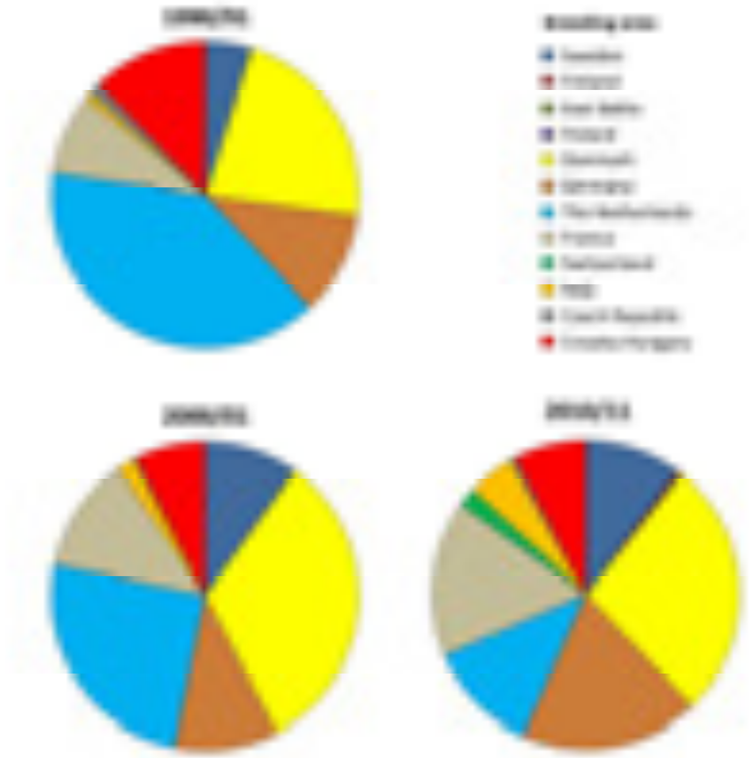
Cormorants wintering in area E – The Netherlands, Belgium, NW Germany (Niedersachsen, Nordrhein-Westfalen, Rheinland-Pfalz and Saarland) and Luxembourg:



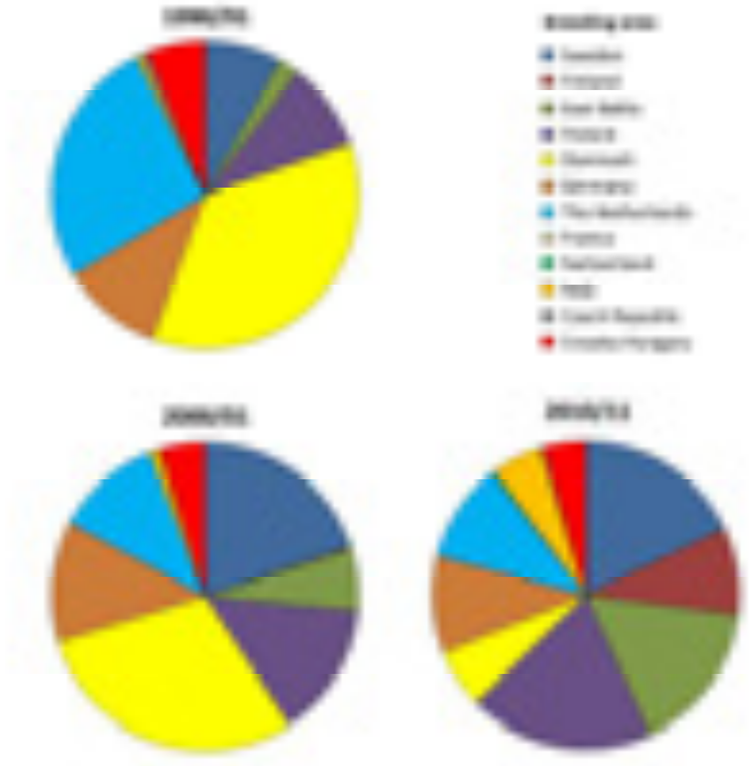
Cormorants wintering in area F – France:



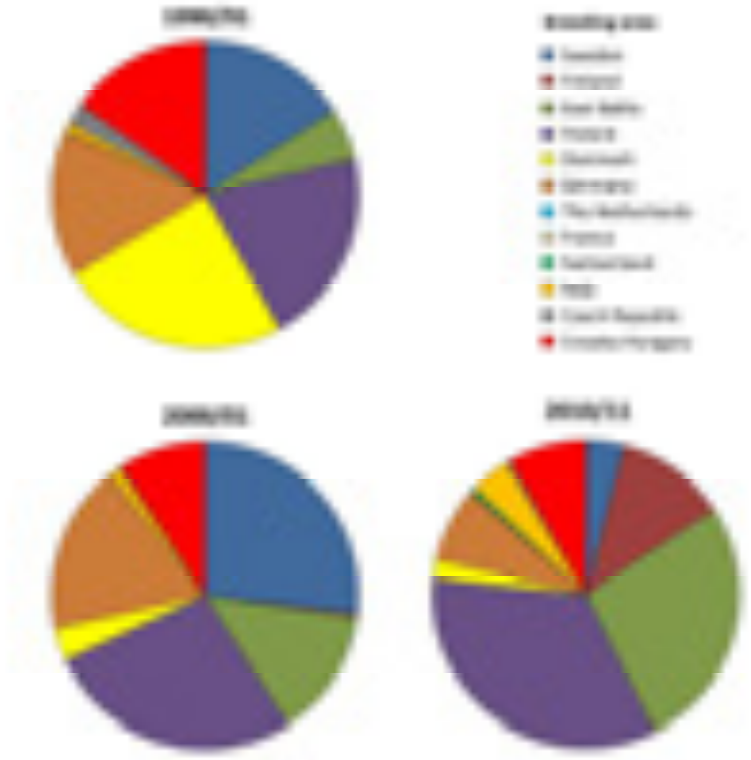
Cormorants wintering in area G – Spain and Portugal:



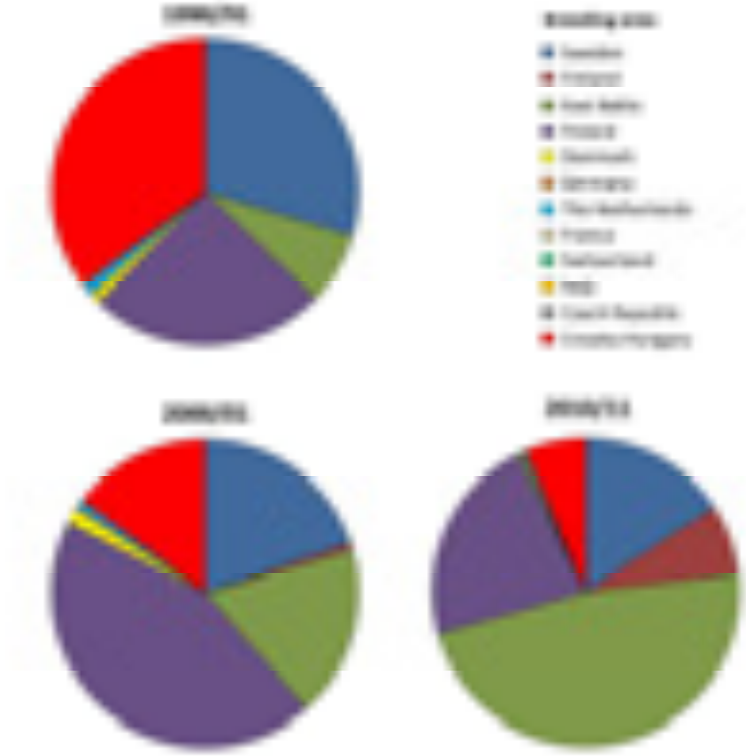
Cormorants wintering in area H – Italy:



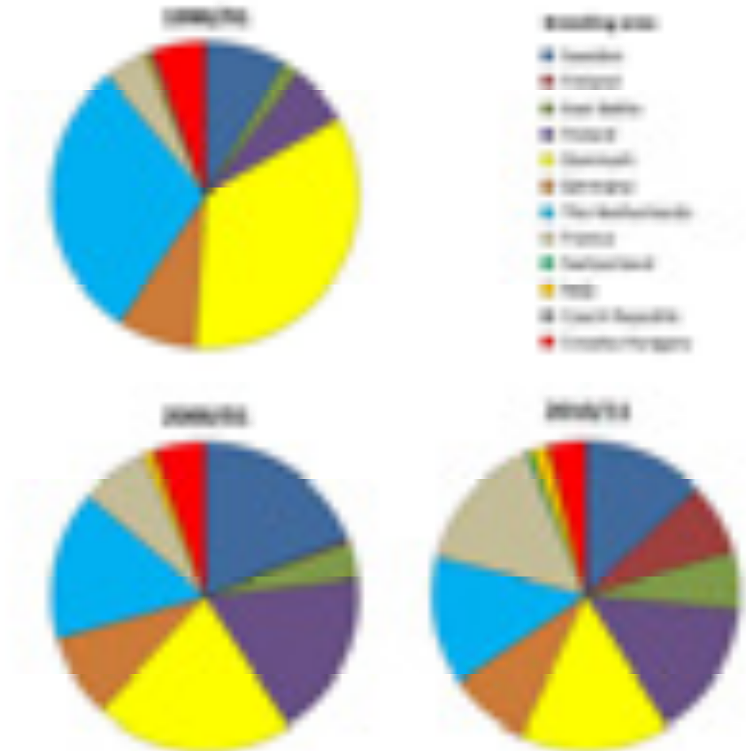
Cormorants wintering in area I – Balkan, i.e. Slovenia, Croatia, Bosnia, Serbia, Montenegro, Macedonia, Albania and Greece:



Cormorants wintering in area J – Ukraine, Romania, Bulgaria and Turkey:



Cormorants wintering in area K – North Africa:



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7 Viable options to deal with cormorant-fisheries interactions[3]

In this chapter, the results produced during the CormoDist project together with existing published information about cormorant ecology and behaviour are used to discuss the pros and cons of applying various strategies in attempts to deal with the interactions between cormorants and fisheries at the local, regional and European levels. These interactions and associated conflicts (well described elsewhere, e.g. van Eerden *et al.* (2012)) tend to be most pronounced in western, central and southern regions of Europe during the winter and in autumn and spring when cormorants move to/from their wintering quarters.

The work discussed in this chapter suggests strongly that it will not be possible to protect specific wintering areas from cormorant predation through the reduction of breeding numbers elsewhere in Europe. The data and analysis here thus suggest that population level management is unlikely to be a viable option to deal with cormorant-fishery interactions. However, there are numerous potentially viable options on a smaller geographical scale, and these are also discussed in this chapter.

7.1 Introduction

Large increases in cormorant populations have occurred across Europe over the past 30-40 years, particularly birds of the *sinensis* sub-species in Western Europe. Cormorants have also greatly extended their breeding and wintering ranges into areas where they had previously been scarce or even absent for some time, with many more birds accessing inland fisheries. This has resulted in widespread conflicts with fishery interests. Conflicts occur at different sites and different times of the year, partly reflecting large variations in cormorant numbers as birds move between breeding and wintering areas. A diverse range of fishery interests are affected by cormorants in marine, brackish and – particularly – freshwater habitats, and including commercial fisheries, fish farms (intensive and extensive) and recreational angling. Cormorant predation can have serious economic implications by damaging fish stocks, reducing catches, limiting aquaculture production and through other social and economic effects. In many cases, serious damage can result and justify management action (see EU 2013).

Many stakeholders, particularly angling and fishery ones, believe that the current cormorant population size of the *sinensis* sub-species in Europe represents an unacceptable and unsustainable threat to fishery interests. They believe that a form of long-term, internationally co-ordinated cormorant control, preferably at the pan-European level, is needed, focusing in particular on actions taken at breeding sites. The aim would be to reduce the *sinensis* population to a size at which damage to fisheries was reduced to a more acceptable level.

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3 In this chapter, much of the introductory text, and that dealing with issues at the 'European' or 'population' levels is taken from 'A review of the issues relating to control of cormorant populations at the pan-European level' available on the EC Cormorant Platform. Published at the EU Cormorant Platform http://ec.europa.eu/environment/nature/cormorants/home_en.htm
by CorMan for the European Commission under service contract N° 07-0307/ 2010/575579/SER/B3

At its simplest, one of the key questions with respect to strategies for managing cormorant-fisheries conflicts through a reduction in damage to fisheries to acceptable levels is: should this be attempted through site-specific (i.e. regional) management actions or through an overall reduction in cormorant numbers at a European or population level?

The CormoDist project has demonstrated, from an extensive analysis of ringing recoveries, that European cormorants are extremely widespread and well-mixed in the non-breeding period. Thus it is highly unlikely that wintering numbers in specific areas could be affected directly by managed reductions in breeding numbers, perhaps several thousand kilometres away. This demonstration, substantiating the implications of many other studies of cormorant ecology and overwintering behaviour, allows us to be more confident in terms of discussing the viability of continental (i.e. European) versus other, smaller spatial-scale management approaches.

Putting aside here the important issue of quantifying damage (i.e. economic, see EU 2013) to fisheries in such a way as to allow verifiable demonstration of damage and any subsequent reduction in this, the legal positions and those of the European Commission are important in the context of this chapter.

7.2 The legal position

Like all wild birds species in Europe, the Great Cormorant is protected under European Directive 2009/147/EC (the Birds Directive). Its deliberate capture and killing, disturbance, destruction of its nests or taking of its eggs can only be allowed by Member States if this is done in accordance with the derogation system set out in Article 9 of the Directive. Article 9 provides that Member States may derogate for a number of purposes, including preventing serious damage to crops, livestock, forests, fisheries and water, or the protection of flora and fauna, provided that there is no other satisfactory solution. The European Commission has developed a non-binding guidance document regarding application of the derogations in Article 9.

Population management is considered to be a legitimate option under the derogations within the Birds Directive, provided it is designed to prevent serious damage and is consistent with the objectives and requirements of the Birds Directive, including maintaining the population of a species at a satisfactory level.

The derogation system is already being widely used by Member States to reduce or prevent serious damage by cormorants. However, there are significant differences in the way this is done, both in terms of the choice of sites where control actions are undertaken and on the methods used. Some Member States use the derogation possibilities extensively, including actions at breeding colonies, whilst others do not allow scaring measures or control of cormorant numbers at all. In line with the subsidiarity principle, the implementation of the derogation system lies within the competence of Member States.

7.3 The current position of the European Commission

Given that cormorants are spread widely throughout Europe and may undergo large-scale migrations between breeding areas and wintering areas, any implementation of a pan-European management strategy would require collaborative action and planning by a large number of European countries for such a plan to be applied across the broad scale necessary. This would depend on independent decisions at a national level. As noted previously, the implementation of the derogation system lies within the competence of Member States. Thus, countries which might be opposed to using the derogation scheme or to participate in any pan-European plan to control cormorant populations cannot be compelled to do so, irrespective of whether or not they are members of the EU. Of course, it would still be possible for the Commission to develop a plan, should it be so minded, and use this as a basis for discussion and consensus building with Member States.

In response to concerns from fishery stakeholders, the Commission has stated (see doc ref. SP(2009)401) that
"While [they are] not persuaded of the need for such a management plan, it is apparent that in several Member States the size of the cormorant population is giving rise to increasing conflicts. However, there is no consensus between Member States on the type of action to take. Whilst some Member States or some regions are supportive of an EU-wide management plan, others are not persuaded that there is a problem or that there is no need to address it at EU level. If one Member State decides that there is no need for measures, the Commission cannot change that position. Also the Commission is not in favour of an EU wide strategy as the problems are localised. Therefore, it is not proportionate to argue for action at EU level to solve a problem of regional scale. An alternative way to address this issue could be found in the existing mechanisms that are available under the provisions of the Birds Directive."

Thus, where necessary, the European Commission is encouraging Member States to consider the potential for co-ordinating management actions against cormorants across broader scales through bilateral (or perhaps larger) agreements, and it has indicated that it would be prepared to help facilitate such arrangements.

7.4 What form might pan-European cormorant management take?

After widespread consultation, the European Commission considered that an EU-wide management plan would not be an appropriate measure to address the problem of cormorant conflicts. Rather, the Commission considered that the existing derogation provisions of Article 9 of the Birds Directive provided Member States with adequate powers, and that cormorant problems were best addressed at a regional scale.

Although this remains the current position of the European Commission, many fishery stakeholders continue to believe that some form of pan-European or internationally coordinated management plan is still required to reduce cormorant numbers at the population level across Europe.

Advocates of a pan-European approach to managing cormorants suggest that this might be achieved by agreeing on an appropriate population 'reference' level, or population range, around which bird numbers would be managed. From a legal perspective, such management decisions would fall within the competency of Member States. It is thus likely that reference levels would need to be set separately by each country, although this could be based on compatible principles and in consultation with neighbouring countries. Under such an approach, relevant national authorities would need to reach consensus on general criteria, establish appropriate reference levels and agree a number of associated issues. These would include decisions about the geographic scale for the 'target' population (or populations), monitoring arrangements to assess population status and the co-ordination and evaluation of management activities. It is stressed, however, that cormorant population management would not be the main objective in itself; rather, the aim would be to reduce the incidence of serious damage at fishery sites. So, fisheries would also need to be monitored to ensure there was a benchmark against which the efficacy of the measures could be assessed as a basis for ongoing management decisions.

The calls for cormorant management put forward by fishery stakeholders typically advocate population management measures targeted at breeding colonies, rather than in wintering areas when birds are more widely dispersed, since this is considered more effective and would enable better control. These calls further advocate the use of measures such as egg oiling rather than shooting as the primary means of control (e.g. EIFAC 2008). Such measures are seen as particularly appropriate for use in cormorant ground-nesting colonies, although alternative methods (e.g. disturbing birds to make eggs cool off) could also be applied effectively in tree-nesting colonies, although at greater expense. The extent of ground-nesting, as opposed to nesting on trees, varies considerably between countries.

Monitoring, including assessments of damage, would be a key requirement alongside any population control measures, as this would be necessary to inform ongoing management decisions and enable the efficacy of any such strategy to be assessed and modified as necessary. This would also ensure that the plan was in line with the requirements of the Birds Directive, that a secure status of the species is maintained, and that there was a reduction in the incidence of serious damage at fishery sites. This monitoring and feedback process, known as *adaptive resource management* is increasingly used in managing wildlife resources - for example, in respect of hunted duck and goose populations in North America. It has been suggested that such a strategy would also be broadly similar to the biological reference points and associated assessment and management procedures that are used in the sustainable management of many fish stocks.

7.5 Biological considerations relevant to possible pan-European cormorant management

i. Predator/prey interactions

Predator/prey interactions are a natural part of the complex relationships that take place within ecosystems. Thus, predation on fish by cormorants and other fish-eating birds, and predation by fish on other animals, is a normal part of the natural interactions that occur between species in aquatic habitats (see chapter 7 and chapter 10 of Carss *et al.* 2012). In a natural, 'unmanaged' situation predator numbers would typically be closely linked to, and governed by, the availability of suitable prey species. Where prey is readily available and abundant, predator numbers typically increase, either through an increase of the population (e.g. due to better survival or increased breeding output) and/or as a result of predators moving into an area. Conversely, in the absence of good access to ample prey, predator numbers fall. Similarly, this can be as a consequence of a reduction in population size (e.g. higher mortality rates, reduced breeding output) or due to bird movements out of a particular area.

In simple situations (e.g. one predator and one prey population within a closed area), these processes often result, in the long term, in predator/prey numbers oscillating around a particular level – the predator/prey equilibrium. In practice, predator/prey interactions are rarely so simple and any such natural equilibrium level, even if attained, may be unacceptable where the resource (the prey) is also of interest to man. In such circumstances the predators are viewed as competitors for the same resource as they conflict directly with man's use of the resource, with potentially wider social and economic implications.

Country-wide counts of Great Cormorant nests are conducted annually in a few countries in Europe. Photo: T. Bregnballe.

ii. Cormorant population dynamics

The European cormorant population has increased rapidly and the breeding population has gradually expanded into parts of Europe where the species was absent or scarce for many decades. The pattern of expansion illustrates the capacity of the *sinensis* sub-species to newly colonise or recolonise suitable breeding areas and respond positively: (a) to protection against persecution and pollution; (b) to access to safe breeding and roosting sites; and (c) to easy access to waters rich in fish. Adult Great Cormorants that are not exposed to shooting will normally have a high probability (80 - 90%) of surviving from one year to the next (although they may suffer higher mortality in cold winters). In addition, when food conditions are favourable they are able to breed when two years old and raise 2 to 4 young to fledging, whereas the age of first breeding is delayed and the fledgling numbers are less when the birds' diets are more impoverished. Consequently, cormorant populations can increase by more than 25% year-on-year. Furthermore, birds can respond quickly to deteriorating food conditions by changing their choice of foraging sites. They can also move to alternative breeding sites, but such responses will typically be from year to year.

Nonetheless, several studies have shown that cormorants can become seriously constrained by limitations in the access to safe breeding sites and rich feeding areas. For example, cormorant breeding performance can decline markedly if a colony continues to increase and/or foraging conditions nearby deteriorate as a consequence of predator/prey cycles or other developments. This is one of several ways in which natural density dependence can operate and cause a transition from growth to decline and subsequent stabilisation within a colony or population.

Almost all cormorant breeding populations in Europe will - after some years of growth - become limited in size and further growth by the amount of food available around the existing colonies and the access to hitherto uncolonised, attractive and safe breeding sites. In theory, and given enough consistent effort, humans could influence these factors in a number of ways and thereby affect the size at which cormorant populations begin to stabilise.

In light of the above, a key factor that can be expected to influence the efficacy of any possible pan-European management strategy is the extent of density-dependent population regulation and the strength of the compensatory (feedback) mechanisms that might apply.

For example, our knowledge of cormorant population dynamics indicates that a reduction in numbers of breeding birds in an area (not caused by food shortage) often leads to an increase in the numbers of young birds per nest that are fledged successfully by those birds that do breed there, and where productivity is below maximum potential. This is a consequence of reduced competition among cormorants for food and the greater availability of fish with which adults can feed their offspring. Under such a scenario, the greater the (downwards) 'pressure' that is applied to reduce bird numbers, the stronger will be the (upwards) compensatory mechanisms (within limits) that will operate to re-build population sizes. Such factors make it more difficult to predict the impact of population reduction measures and would make reducing numbers over large areas or at the population level a challenge.

Some population management strategies for cormorants seek to avoid the problem of constantly working against compensatory mechanisms by working with density dependence. Thus, a management approach is adopted where the objective is to restrict birds to a particular area and limit their expansion to other surrounding areas through control measures. In such a scenario, population size in the 'permitted' area would, in effect, become regulated by the available resources (e.g. food and breeding sites) and numbers would be expected to fluctuate about some equilibrium or carrying capacity level within the more limited area available to the cormorants. Active measures would be required outside this area – for example, preventing new colonies and/or new roosts establishing and/or the use of active deterrents at feeding sites – in order to restrict expansion. Of course, preventing such expansion of the population would not normally be easy, particularly at a larger scale. Nonetheless, such an approach has been applied successfully in certain countries and situations. Thus, preventing the formation of new breeding colonies in Denmark has been used to restrict the fish resources available to cormorants during the breeding season and thereby limit the population from further expansion and reduce impacts on fisheries in particular areas.

7.6 The practicalities of pan-European cormorant control

The possibility of pan-European control has been the subject of previous theoretical assessments using population models. A simple model based on the 1998-99 continental cormorant population was developed to predict the effect of different levels of culling. However, one drawback of this early model was that it did not take into account any geographical variation in culling intensity. A later model included some geographical sub-division of the winter range (France vs. the rest of Europe), because, in recent years, culling intensity has been greater in France than elsewhere in Europe. This model indicated that the effects of culling are highly dependent on the extent of immigration into an area. The modelling investigations suggested that some form of pan-European population control might be feasible, in principle, but presented a number of challenges.

In practice, there are many reasons why attempts to reduce the continental cormorant population, and to manage it around some 'acceptable' level, would be difficult on such a broad scale. For example, the large territory, widespread breeding populations and further mixing and dispersing of the birds in winter (see Chapter 4 and 5 of this report) means that there will be no simple relationship between management actions in a restricted part of the breeding areas (e.g. in one country) and the consequences of these actions in wintering areas, or *vice versa*. Furthermore, since numbers and distribution patterns of the birds are partly determined by density-dependent factors operating both within and outside the breeding season, there is considerable potential to compensate for reductions in numbers through changes in both the distribution of the birds, and their fertility and mortality rates. Public acceptability and ethical concerns would also need to be considered.

Any use of lethal techniques for population control at a broad scale would need to take account of a range of factors, including the level of mortality achieved relative to immigration and breeding rates, migratory patterns and the relative levels of controls in different areas. This would make it difficult to achieve a successful, pre-determined outcome. Population control has typically proved most cost-effective and long-lasting where the bird species causing problems has been contained in relatively small, localised populations. The widespread nature of cormorant breeding populations, with birds mixing and dispersing across Europe in winter as demonstrated in this CormoDist project, makes it a challenging task to develop models that can predict realistic outcomes from different management strategies. Nevertheless, this work suggests strongly that it will not be possible to protect specific wintering areas from cormorant predation through the reduction of breeding numbers elsewhere in Europe. Similarly, it is clear that the Commission does not have the authority to request individual Member States to reduce cormorant numbers. Even if this were the case, the best ecological understanding that, on some level at least, birds are attracted to the 'better/optimal' foraging sites (with many birds feeding in 'suboptimal' areas), and that these 'optimal' foraging sites can often be those of high fisheries value too, implies that a large proportion of the overall European cormorant population would need to be removed annually to produce a verifiable reduction in damage at such sites. Even if legally possible, such a strategy would appear to be unviable.

7.7 Adaptive Resource Management

A general conclusion of population modelling is that constant population management with fixed rules, quotas or rates is typically either too ineffective in terms of population reduction or poses risks for population viability. Fishery stakeholders consider that any broad-scale population reduction plan for cormorants would need to be adaptable, tightly monitored and consistent with Birds Directive objectives. This is also consistent with the adaptive resource management approach that is commonly now advocated for managing many wildlife species. With increased levels of monitoring in place, management measures are reviewed and updated in light of population changes. Such an approach is judged to be both effective and safe, since it provides feedback mechanisms and the opportunity to stop control measures, should this be necessary, before a population becomes critically reduced. For cormorants, this would allow management rules to be adopted taking into account the current state of the cormorant population, as well as whether the management actions are reducing the incidence of serious damage at fishery sites as planned. A recent example of adaptive resource management is provided by the International Species Management Plan that has recently been agreed in relation to the Pink-footed Goose *Anser brachyrhynchus*. Further details are provided below.

Another example of the application of modelling and an adaptive resource management approach is provided by the cormorant licensing strategy used in England in recent years to determine a 'reasonable' upper limit of cormorant numbers allowed to be shot each year. The approach relies on a simple population model, informed by annual wintering counts, to assess the effect of different levels of shooting. This allows the number of birds permitted to be shot in the following year to be reviewed and, as necessary, adjusted. The process benefits from the fact that the wintering population in England is relatively small and has limited immigration relative to mainland Europe, and that it operates within a single national jurisdiction. It is unlikely that the same approach could be readily applied to the much larger, more migratory populations across Europe.

7.8 How might a reduction in cormorant numbers affect levels of damage to fisheries?

It is unclear how any overall reduction in cormorant numbers might affect degrees of damage at fisheries. It is generally accepted that cormorants are attracted to, and will attempt to exploit, feeding sites where they can forage in the most energetically efficient manner and in relative safety. However, other factors may also influence site selection. Thus, for migrating birds, there is evidence, for some areas at least, that the bird's first choice may be large water bodies, with birds expanding from these to smaller water bodies subsequently. It is perhaps less clear whether these first choice sites represent optimum foraging sites or reflect, in part at least, the use of rivers and large waterways as migration corridors. It is also uncertain to what extent the subsequent spread to smaller foraging sites is driven by increasing numbers of birds, and thus competition for resources, or the fact that foraging opportunities are better at these other smaller sites and that new 'habits' develop over the years.

Biologically, it can be assumed that cormorants (as with most animals) select their foraging locations on an energetic basis – put simply, they are likely to try to maximise their energy intake through encounters with prey and food consumption, and minimise their energy expenditure on things like travel to foraging sites, diving times and prey capture. Even at this simple level it is clear that some foraging sites will therefore be 'better' than others (through the abundance of prey and its availability) and so biologists often refer to foraging (and other) locations as being either optimal or sub-optimal. Just as some foraging sites are 'better' than others, some individual birds are ‘better’ foragers than others – at its simplest and most general, young (i.e. first-year) birds tend to be less efficient foragers than older individuals, for instance. A consequence of all this is therefore likely to be ‘competition’ between individual birds in any particular area for specific foraging sites, with the most efficient/experienced birds dominating at optimal sites and less efficient/experienced ones being forced to feed at sub-optimal sites. Furthermore, at some point along this spectrum of declining site quality, it will become unprofitable for an individual bird to forage at a specific site and they will have to move to another one.

Cormorants consistently and predictably turn up to forage at particular sites, and numerous conflicts arise with fisheries interests where these are the sites most valued by recreational anglers, commercial fishermen or fish farmers. This is because the sizes of fish consumed or damaged by the birds often coincide with those that are of interest to users. Given this situation, it might well be assumed that these sites are also optimal foraging sites for cormorants and/or are sub-optimal sites used frequently by the birds. In other words there is some sort of ‘pressure’ on the birds to be foraging where they do at what might be termed ‘prime’ sites. Because of the mobility of cormorants, killing or scaring birds at such prime sites commonly creates opportunities for new birds to replace those that have been killed or scared. Even where large, organised cormorant culls take place each year, bird numbers can recover quickly as replacement individuals move in, particularly at sites that are on established cormorant migration routes. This suggests that large-scale killing of birds may not necessarily provide the ready solution to local cormorant conflicts that is often imagined.

A reduction of the cormorant population to a lower, more acceptable level would reduce the overall impact of the birds on fish stocks and fisheries – fewer cormorants across Europe would eat fewer fish. This is unequivocal. However, scientific opinion suggests that the decline in the pressure on fisheries would be less than the decline in bird numbers might suggest, as birds are likely to continue to favour high quality habitats that offer the best foraging potential. Ecological theories and our limited understanding of cormorant movements and foraging-site choice suggest that, where cormorant populations are constrained by available resources, a reduction in bird numbers results in the abandonment of marginal, sub-optimal, foraging areas first. Thus, although fewer birds should mean fewer fisheries with problems, conflicts may well persist at many of the ‘prime’ sites. Since such sites are often those that are most valuable or desirable to fisheries stakeholders, the reduction in conflicts may be disproportionately small.

On the other hand, in this situation where scientific evidence is incomplete, some fishery stakeholders believe that a reduction of cormorant numbers would result in a significant reduction of damage at most fisheries, not least those which currently suffer the heaviest damage because local on-site management measures are not effective. This expectation is based on their general assumption that population management would reduce cormorant numbers at breeding colonies and wintering roosts to a level which prevents the over-exploitation of adjacent waters. In breeding areas the effects of population reduction are seen by some fishery stakeholders as being relatively easy to predict: If management succeeds in holding colony size at a level which prevents over-exploitation this would ensure that cormorant predation stays below the threshold of 'serious damage' and consequently would result in higher prey availability in adjacent waters. This, they claim, would reduce the need for birds to commute relatively long distances to forage and so fisheries more distant from a colony would see a disproportionally large reduction in levels of damage. Effects in wintering areas are more difficult to predict, but fishery stakeholders believe it is not unreasonable to expect that a reduction of the overall population would, to a certain extent, reverse the geographical expansion of cormorants, or at least reduce the predation pressure in newly colonised areas.

There is also a belief among some fishery stakeholders that a reduction of cormorant numbers in a particular area could result in an over-proportional reduction in damage at fishery sites. This is based, in part, on the view that the pressure to abandon larger water bodies would be reduced or removed if bird numbers were lower, resulting in reduced pressure on fishery resources in other smaller sites more distant from roosts. Such arguments are also based on the fact that the damage at many of these smaller sites can be of greater significance, on the grounds that the fish populations are of higher commercial value, recreational interest and/or conservation concern than those in many large water bodies. It is clear that economic and conservation considerations will be important in the context of assessing damage (and in targeting management action), and such arguments may be valid, for example, in the case of alpine river fish populations in central Europe. However, not all stakeholders subscribe to this opinion, and it is not the case universally across Europe that smaller water bodies are of the highest commercial or recreational interest (and, in some cases, the opposite is true).

7.9 Practical considerations related to the timing and scale of cormorant control measures

i. Control of cormorant numbers at breeding sites

There is general consensus that any attempt at pan-European control would need to be targeted at concentrations of breeding birds because only when the birds are congregated together could measures be applied on a sufficiently large scale. Measures against breeding birds are already employed in some countries (e.g. Denmark), typically through egg destruction in ground-nesting colonies, where nests can be accessed with relative ease. However, measures at breeding colonies aren't necessarily restricted to ground-nesting birds as, for example, actions could perhaps be used to scare birds from their nests in trees such that eggs become cold and embryos fail to hatch, although this would be more difficult and costly.

Nest or egg destruction, or actions against birds at breeding colonies, over a sufficiently broad scale will reduce the breeding output of the birds. It follows that with fewer fledged birds at the end of the breeding season, a reduced number of older birds will visit fisheries in winter, and, in subsequent years, fewer adult birds will recruit to the breeding part of the population. However, such measures would need to be applied each year to achieve a lasting effect; the effect on recruitment in any year may be less than expected if there is a surplus of younger birds in the population. Eggs can be destroyed by several methods: egg removal, egg pricking or egg oiling, although oiling is the method most commonly used and generally regarded as cheaper, more effective and more humane. Investigations have demonstrated that egg destruction can be effective at reducing local populations of cormorants, although the results can be variable and studies in North America have shown that there may be an increase in dispersion of cormorants away from nesting colonies where oiling takes place.

A number of factors can influence the efficacy of different egg destruction methods. The oiling of eggs usually has the advantage over egg-removal or destruction in that the adults will commonly not lay a new clutch and will continue to sit on the oiled eggs until it is too late in the season to lay a replacement egg clutch that year. The management methods used to reduce breeding numbers will thus vary and depend on factors such as whether cormorants are nesting in trees (where nest/egg destruction is likely to be very difficult and expensive) or on the ground, and whether or not the particular methods are acceptable and permitted. For example, the killing of adult breeding birds has been used to reduce cormorant populations in a few colonies in Japan. However, in parts of Europe such actions may be considered unacceptable or inappropriate and attract opposition on animal welfare, ethical or other grounds. In any event, the experience from parts of Europe, North America and Japan is that success generally requires actions that are repeated over several years and which affect a large proportion of the breeding birds; this can be counteracted by sudden changes in food availability.

Great Cormorants need to dry their feathers in between foraging trips. Photo: S. Ortmann.

ii. Control of wintering cormorants

The large-scale control of cormorants over the winter period when birds are widely dispersed across Europe would present a huge challenge. Experiences at sites in Europe where relatively large-scale shooting has previously been carried out on cormorants migrating between breeding and winter feeding areas (e.g. Bavaria and France) have indicated that shooting was not generally effective in reducing cormorant numbers in the area over the remainder of the season, with shot birds being rapidly replaced by individuals from elsewhere, especially at attractive feeding sites. The fact that these areas are on migration fly-ways is seen as a key reason for the apparent rapid replacement of shot birds. The chances of achieving a decline in the numbers of birds appearing in later seasons are not high, and it has so far been impossible to clearly demonstrate any impact of such regional shooting on the wider population as a whole.

Any pan-European measures at winter feeding grounds would be expected to require repeated and intensive intervention at day and/or night roosts on a wide scale, and would likely be most effective if undertaken at a majority of sites. Such efforts would be very demanding, especially where cormorants respond by dispersing within an area, thus establishing a greater number of roosts each containing fewer birds. Pan-European control measures could, of course, be applied on both breeding and wintering birds.

7.10 Practical (and other) considerations

Aside from the biological issues, broad scale population reduction through culling, nest destruction or egg oiling raises practical, economic, political and ethical issues.

The application of all lethal (and non-lethal) techniques requires repetitive use of manpower, so costs depend to a large extent on whether or not responsibility for payment is made by or to those involved in any control programmes. Costs can be substantially reduced where manpower is available on a voluntary basis, or where it may be possible to implement controls in conjunction with other activities (e.g. hunting or as part of normal fish husbandry activities). Where dedicated expenditure is incurred, costs will be relatively high, and the costs of guns and ammunition can also be substantial. Beyond this, the costs will mainly be dependent on the scale of the programme. In the absence of any current plan, there is little, if any, information on which to assess the likely cost of a co-ordinated cormorant management plan operating across Europe. Although there are no readily-available cost estimates for such management options in the public domain, some fishery stakeholders argue that actions targeted at limited numbers of breeding colonies should be considerably lower than the cost of shooting and deterrent measures employed at thousands of individual foraging sites. However, even if cheaper, it is unclear whether such management in the summer would reduce the damage cormorants are considered to have on fisheries at other times of year, especially in the winter.

If lethal measures were to be employed on a larger scale, an additional practical consideration would be the need to co-ordinate actions effectively. This may require the establishment of collaborative stakeholder groups and real-time communication networks to ensure that efforts are targeted to best effect at appropriate times and places. Alternatively, agreements might be established between national governments or regional authorities. In addition, it would be necessary to decide who might fund any culling and who actually carries it out. This is relevant because conflicts tend to occur at bird foraging sites where shooting is the only practical lethal control measure, whereas the control of cormorant populations at nesting sites would often be required in countries and, sometimes, at sites other than where the conflicts actually occur.

The acceptability of lethal control measures depends to some extent on the viewpoint of the stakeholders involved. For a fishery owner or fish farmer faced with a cormorant problem, shooting to kill may be seen as a more acceptable option. For some other stakeholders (e.g. conservationists) lethal measures will be less acceptable or even unacceptable.

Wildlife management is carried out throughout Europe with actions ranging from attempts to eradicate invasive non-native species and control pest species to species conservation and restoration activities. Such activities occur over various geographic scales, sometimes requiring collaboration between countries, for example the Large Carnivore Initiative for Europe (see LCIE, 2008). The majority of citizens recognise the validity of such actions and accept that lethal control measures can be a legitimate activity where this is done in support of a reasonable objective, is undertaken in a proportionate and legal manner, and implemented as humanely as possible.

In the context of cormorants, the use of lethal control measures to address localised or short-term conflict issues is typically seen as a necessary and acceptable management option and has general support across stakeholder groups. Large-scale population control at a national or pan-European scale is more contentious, raising concerns not only about its necessity / likely effectiveness, but also in relation to the potential degree of impact on cormorant populations. This would be expected to attract differing views among stakeholders and politicians, and the killing of any wildlife can also attract comment, criticism and opposition from the general public on ethical grounds. Many fishery stakeholders believe that a co-ordinated and appropriately regulated pan-European population control plan, particularly one principally concerned with reducing breeding output, would be the best way to allay such concerns, and they advocate this as the preferred management option.

7.11 An example of pan-European population management of a bird species

While wildlife management is practiced widely across Europe, there appear to be few examples of co-ordinated action on a European scale to regulate a bird population. However, management of the population of one goose species which is in conflict with agriculture and causes damage to high-Arctic tundra vegetation might prove informative in further assessing the likely success of any pan-European cormorant management plan. A new adaptive international management plan concerning the population of Pink-footed Goose breeding on Svalbard (Norway) and staging and wintering mainly in four countries (Norway, Denmark, the Netherlands and Belgium) has been initiated under the Asian-Eurasian Waterbird Agreement (AEWA). This involves shooting of geese (mostly in Norway and Denmark) to stabilise the population size within an agreed range. It also encompasses habitat management and co-ordination of various other management efforts.

The plan has four objectives:

1. Maintain a sustainable and stable Pink-footed Goose population and its range;
2. Keep agricultural conflicts to an acceptable level;
3. Avoid increase in tundra vegetation degradation in the breeding range; and
4. Allow for recreational use that does not jeopardise the population.

The target for Pink-footed Geese is to maintain the population over the long term at around 60,000 individuals such that the favourable conservation status is maintained but the risk of population explosion avoided.

There are a number of key differences between this plan for the Pink-footed Goose and any potential plan in respect of cormorants. In particular, the Pink-footed Goose is considered a threat to itself – a rapid population increase would reduce the quality of its limited breeding habitat and could lead to a subsequent population crash. From a practical perspective, the goose population is fairly easy to monitor compared with Great Cormorant populations, and the number of countries that have to agree on goals, objectives and management actions is relatively limited. Further, the cormorant population could already be said to have 'exploded', meaning that the initial focus here would need to be on population reduction rather than largely maintaining a *status quo*. There are also resource use issues in respect of the goose, due to its recreational interest (i.e. for hunting). There are, however, also similarities between the two species – both are successful migratory birds which cause localised economic and ecological damage. Thus, the goose plan will provide Europe with more experience about how to flexibly manage migrating populations of birds that are in conflict with human interests. This, in turn, may prove informative in further considerations related to the potential management of cormorant populations at a pan-European scale.

7.12 Cormorant management approaches at smaller spatial scales

As Marzano *et al.* (2013, p. 10) point out "The multi-dimensional nature of cormorant-fisheries conflicts and the current philosophy of devolving management decision making to Member States currently precludes a single, co-ordinated solution to managing European cormorants in terms of continental-scale reduction in their breeding numbers or reproductive output". Moreover, the results of the CormoDist project give further ecological evidence suggesting that such action will not reduce the numbers of cormorants wintering in specific areas

However, as Marzano *et al.* (2013, p. 10) go on to say: "this situation is not necessarily restrictive and it arguably offers considerable opportunity for tackling cormorant problems across Europe in practice. Key to this is the apparent under use of actions under derogation and, ultimately, the possibility of integrating actions to tackle problems over relatively large areas. Importantly, there is potential scope for defining, interpreting and quantifying 'serious damage' to make derogations more practical (see EU 2013). Similarly, the achievement of favourable conservation status for the cormorant is not required as it is currently listed in the Birds Directive. Thus, the current issue of cormorant population management is not one of conserving an endangered species but of managing one that some believe to be 'overabundant'. This is not primarily an ecological term but one associated with human perceptions and the human management of wildlife (cf. Caughley 1981). There may be scope for transboundary coordinated management actions, carefully based on the derogation conditions in Article 9 … Nevertheless, there are likely to be technology-transfer issues involved, as particular fisheries (even within the same regional fishery type) often consider themselves to be unique (Carss & Marzano 2005). Cormorant management would require flexibility and effort, and would come at a cost to fisheries owners and occupiers, but it might be achieved through acknowledging that these stakeholders face substantial problems (including cormorants) and therefore need the provision of advice, encouragement and financial support, compensation or incentives (cf. LCIE 2008, pp. 80-81). To help this process further, there would also be a need for an international network exchanging ecological data, information and contextual understanding, as well as practical advice and experience-sharing on the use of local management techniques between interested parties across Europe".

potential for co-ordinating management actions against cormorants across broader scales through bilateral (and larger) agreements.

Previous experience suggests that national or regional authorities can be successful in reducing breeding numbers within an area or region, whereas the chances of successfully controlling the numbers of cormorants that appear in areas and regions used for staging and/or wintering are likely to be more limited. The main methods used to reduce regional bird numbers outside the breeding season typically involve killing or scaring of birds on their feeding grounds and/or roosts. This is likely to be most successful if intensive disturbance is targeted at the majority of such sites.

Intensive scaring at feeding sites and/or at night roosts has, in some cases, been shown to result in marked reductions in the number of cormorants appearing in a particular area or region during the remainder of the season, although as noted in the previous section this may not always occur (e.g. Bregnballe *et al.* 2015). In other instances, such efforts have resulted in fragmentation, with birds establishing many smaller roosts in surrounding waterbodies. The likelihood of success with such actions will likely be affected by the area under consideration, but seems to depend partly on whether the cormorants use the area or region as a staging place to 'stop over' during their migration, or whether they are wintering permanently in the region. In the latter case, actions at numerous sites may, in theory, be more likely to affect national populations. The location of the area or region in relation to broader European migration patterns is thus important in considering the possible outcome of intensive scaring. In any event, scaring and harassment would normally, as a minimum, have to be repeated both during the season and in subsequent years to have a lasting effect. Such efforts may need to be pretty much continuous on sites located on migration pathways, at least for the duration of the migration period.

As noted previously, an alternative strategy that can be appropriate at a regional scale is to restrict birds to a particular area and limit their expansion to other surrounding areas through control measures. Local scale actions in Switzerland provide an example of such an approach, where birds are allowed to forage freely on certain lakes but are actively scared from small rivers. In this way, the local bird population within the 'permitted' area is regulated by available resources (i.e. the carrying capacity of the area) and expansion beyond this area is prevented by targeted actions. This approach has the benefit that it works with density-dependent regulatory mechanisms rather than against them.

7.14 Further practical smaller-scale measures, capacity building, technology transfer and demonstration projects

Given that one single, overall solution to cormorant problems (i.e. continental population reduction) seems highly unlikely, the most effective approach is to frame things in terms of problems that are best be addressed through targeted management. This could be management targeted at particular locations and at particular times of year. We are now in a position to apply all our knowledge in practice. Such a strategy could also support the implementation of EU directives and move toward 'sustainable' adaptive management for cormorant issues.

As described on the EC Cormorant Platform, and in greater detail in Russell *et al.* (2012), there are numerous management actions that can limit the interaction between cormorants and fish. Such actions fall into one of four broad categories: (1)

scaring birds away from a fishery, (2) protecting the fish by preventing cormorants from reaching them, (3) altering fish availability to cormorants by making a fishery less attractive as a foraging site, and (4) reducing overall cormorant numbers for example by killing birds locally to reinforce scaring, killing them more intensively, or reducing their reproductive efficiency. These management actions do not always work, but all have been shown to be successful in certain circumstances, times of year and places.

The key is perhaps to devise 'demonstration projects' that would (1) focus on demonstration and practical experimentation, (2) building capacity through knowledge-sharing and conflict resolution work, (3) explore economics (particularly the 'cost-effectiveness' of management actions) and, (4) involve regional and trans-boundary co-operation where appropriate.

As cormorant fisheries conflicts are very often not human:wildlife conflicts at all but are human:human conflicts (see chapter 1 of Marzano & Carss 2012), there is considerable scope for reducing the perceptions of such conflicts and the role (if any) of cormorants in fisheries declines. This might best be achieved through carefully targeted, and facilitated, conflict resolution activities. Similarly, the issue of technology-transfer as a barrier to effective cormorant-fishery conflict management has been noted elsewhere (see above; Marzano *et al.* 2013) and so an inclusive, proactive approach to this is necessary. The aim of such targeted management, perhaps through demonstration projects, should be to 'up-scale' the so-called site-specific management measures described above and the concept of 'local' or even 'regional' to cover particular fishery sectors. Currently some of the most volatile conflicts and the most tractable situations for such work include recreational angling on sub-Alpine rivers, extensive Carp pond farming, and possibly commercial fisheries and environmental issues on Baltic Sea archipelago coasts.

Here, the key to success might be in capacity building and conflict resolution to address many of the human:human issues and the practical experimentation and demonstration of so-called site-specific management actions - under the flexible interpretation and use of derogations – over increasingly larger geographical areas through proactive technology transfer. Such progress is likely to require some dedicated management and financial funding and would also benefit from some further targeted research to improve our understanding of cormorant movements and foraging site-choice, including (i) which factors influence the foraging- and roosting-site choices of cormorants, (ii) what influences movements – why and how birds decide to leave (or remain on) a particular foraging site or wider staging or wintering area, and (iii) modelling the migratory behaviour of cormorants to feed into effective, targeted management. Furthermore, the fairly new approach of individual-based modelling offers potential for addressing these difficulties. For example, in attempting to predict future changes in distribution of cormorants in Europe outside the breeding season, these types of models can incorporate knowledge and assumptions about how cormorants respond (in their choice of staging and wintering sites) to factors such as changes in the climate, intensity of competition for food and changes in levels of disturbance.

commercial fisheries, as it was known that many of the small water surface area sites were commercial fish ponds and it was assumed that the remainder were likely to be so-called 'natural' wetlands.

These data suggested that extensive fish farms are likely to play only a small role on the population level for European cormorants, although they may be used extensively by individual birds. The data also suggested that there may well be a high (but, as yet, unquantified) turnover of foraging birds between natural wetlands and artificial commercial fisheries. Furthermore, this situation suggests very strongly that the 'expansion' of the European cormorant population (throughout Europe overall and/or in the Baltic region specifically) has little to do with extensive fish ponds in Europe. However such an expansion does mean that, during migration and overwintering, individual birds will exploit the opportunities of foraging at fish ponds, particularly those located on migration routes or in regions where birds spend the winter.

Whilst far from complete, the analysis discussed here suggests strongly that extensive fish ponds are not relied upon by cormorants at the population level across Europe. Individual birds may however feed intensively at such sites and there is likely to be turnover between these and more natural feeding sites. Fish ponds on migratory routes or in the overwintering areas of cormorants are likely to be visited by these birds which raises the issue of potential alternative foraging sites for them and their proximity to, and location within, migratory corridors.

In very general terms, this analysis shows that it is very unlikely that European cormorants are being supported (or maintained) at the population level by artificial commercial fisheries in the form of extensive carp ponds. Thus it is highly unlikely that aquaculture has 'caused' the increase in European cormorant numbers. This is probably a very important message from the available data.

However, the analysis also suggests that there is a relatively higher use of smaller (rather than larger) waterbodies (many of which are presumed to be fish farm ponds) by cormorants. Thus, at the individual level, fish ponds are clearly important foraging areas for birds in winter. This suggests two things. First, that cormorants are likely to present conflicts at fish ponds as they are presumably attractive foraging sites for all birds. Secondly, that the location – and predictability – of these ponds in relation to the migratory corridors of the birds (and to any alternative feeding sites) is likely to be an important issue. Overall, this suggests that improved knowledge of cormorant foraging site choice and use of space in overwintering areas, and their ability to 'switch' between foraging sites would be very helpful in informing potential management options for pond fish farms in particular (but probably other sensitive fishery types as well).

8.5 Viable options to deal with cormorant-fisheries interactions

The work of the CormoDist project suggested strongly that it will not be possible to protect specific wintering areas from cormorant predation through the reduction of breeding numbers elsewhere in Europe. The data and analysis thus suggest that population level management is unlikely to be a viable option to deal with cormorant-fishery interactions.

In practice, there are many reasons why attempts to reduce the continental cormorant population, and to manage it around some 'acceptable' level, would be difficult on