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ORIGINAL ARTICLE

Great cormorant predation on Cisalpine pike: a conservation conflict

Giovanni B. Delmastro[1] · **Giovanni Boano**[1] · **Paolo Lo Conte**[2] · **Stefano Fenoglio**[3]

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Abstract In the last decades, the distribution and abundance of great cormorants have extraordinarily increased throughout Europe. Many studies reported that great cormorants may impact fish populations not only by consuming large number of individuals but also by wounding them. Most studies regarded fish farms and cultured species, but there is less information about wild fish populations. In this study, we examined the incidence of wounds caused by great cormorants on an endemic and threatened species, the Cisalpine pike (*Esox cisalpinus* Bianco and Delmastro 2011). The object of our research was to quantify this impact and indirectly to estimate if cormorant predation may be one of the causes of the rapid decline of this Esocidae. In the years 2009–2013, 139 pikes were collected in some gravel pits in Northwestern Italy. More than a half of the specimens (57 %) reported wounds attributable to great cormorant attacks. Most wounds were localized in the dorsal and lateral surfaces of pikes. We detected a significant difference in the occurrence of wounds between fish sizes, with 73.5 % of adults showing some kind of injury. In a context of general freshwater habitat alteration, quarry lakes represent important sites for Cisalpine pike conservation. Unfortunately, pike breeding season overlaps with the presence of large colonies of overwintering cormorants, increasing the probability of interactions in a period of extreme importance for this Esocidae. Our data evidenced that the increase of cormorants represents an important menace for Cisalpine pike conservation. Finally, we suggest some management options to minimize the problem.

Keywords *Esox cisalpinus* · *Phalacrocorax carbo sinensis* · Predation · Italy · Wildlife conflict

✉ Stefano Fenoglio
fenoglio@unipmn.it

[1] Natural History Museum of Carmagnola, via S. Francesco di Sales 188, Carmagnola I-10022, Italy

[2] Città Metropolitana di Torino, Servizio Tutela della Fauna e della Flora, Corso Inghilterra 7/9, Torino I-10138, Italy

[3] DISIT, Università del Piemonte Orientale, Via Teresa Michel, Alessandria I-15121, Italy

Introduction

The great cormorant is present in Europe with two subspecies: *Phalacrocorax carbo carbo* (Linnaeus 1758) and *Phalacrocorax carbo sinensis* (Blumenbach 1798). The first is mainly sedentary on European Atlantic coasts, while the second inhabits wetlands and breeds in colonies, often with herons, on the trees or at ground. *P. c. sinensis* is widely distributed across the Palearctic from China to Western Europe (del Hoyo et al. 1992): mainly migratory, overwinters South of 65°, around the Mediterranean basin. The species is markedly gregarious also in the cold season, where some ten to thousands of birds aggregate to roost overnight.

During the last 30–40 years, there has been a large increase in the populations of *P. c. sinensis* across Europe (Van Eerden and Gregersen 1995; Bregnballe et al. 2003; Steffens 2010). In the past, direct persecution because of its fish eating habits and the massive use of agricultural biocides (in particular chlorinated carbons like PCBs and DDT; Van Eerden and Gregersen 1995) had drastically reduced the populations of this species, leading to its total extinction in most European countries in the 1960s. Since its legal protection in 1965 in the Netherlands (Van Bommel 2003) and after the inclusion by the European Commission in the Annex 1 of the Birds Directive as species of particular conservation interest (79/409/EEC) populations of cormorants rapidly increased, and

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nowadays, they are much larger and widespread than in previous centuries, with about 1.5–2.0 millions of great cormorants at present living in Europe (Van Eerden et al. 2011). Furthermore, in the past, great cormorants were typical inhabitants of coastal zones and estuaries, while nowadays, their exponential growth has led them to colonize all kinds of inland waters, from great lakes to ponds and different order lotic systems.

In Piemonte (NW Italy), the great cormorant was considered a regular and uncommon migratory and wintering bird (Salvadori 1872) until 1980 (Boano and Mingozzi 1981); then, the number grew exponentially from 90 individuals in the winter 1984–1985 to 5200 in the winter 1994–1995 in 14 roosts (Alessandria et al. 1999). Afterwards, the number leveled at around 4000 (3913 counted in 1999–2000 in 22 roosts) with 3056 birds counted in 2013. Worth noting that after the mid 1990, the cormorants were frequently observed also away from the main rivers and lakes, along little streams, channels, and in little ponds (Fig. 1). At the same time, the number of little roosts augmented, making more difficult to perform accurate censuses. The first breeding attempt in Piemonte was observed in 1989 (Carpegna et al. 1990), and the breeding population reaches now about 600 pairs in nine colonies (Volponi and CorMoNet.it 2013). Many factors have contributed to this impressive growth, such as broad habitat choice, long lifespan, high survival rate, environmental alterations of aquatic habitats, but the protection of the species has surely played a leading role (Marion and Le Gentil 2006). Like most cormorant species, the great cormorant is an opportunistic piscivore, able to exploit most waters, and therefore, its increase in numbers has led to conflicts with fisheries (Dieperink 1995; Leopold et al. 1998; Carss 2003; Vetemaa et al. 2010). Each cormorant ingest on average 4–500 g of fish every day, or even more, and many studies on feeding habits have reported wide trophic range, high adaptability to varying environmental conditions, and an impressive plasticity in the daily amount and size of prey (Gagliardi et al. 2007). Furthermore, apart from direct consumption, cormorants may affect freshwater fish communities in other indirect ways. First, a percentage of attacked fish is only wounded but not ingested because of the size. They usually report deep and/or surface injuries which often result in diseases and mortality (Adámek et al. 2007; Ondračková et al. 2012). Poór (2005) reported that in lentic habitats, the percentage of wounded fish can be high (approximately 0.3–0.4 kg of fish per cormorant daily), but realistic data on fish wounding by cormorants in the wild are relatively scarce, because most studies have been realized in semi-artificial conditions such as aquaculture areas, fish farms, or even experimental mesocosms (Davies et al. 1995; Grémillet et al. 2006; Adámek et al. 2007; Kloskowski 2011).

For these reasons, the growth in both density and distribution of this specialized piscivore predator could represent an important additional threat to local fish faunas, which are already entrenched by the alteration of most aquatic environments. Obviously, these concerns are particularly important in the case of endemic or threatened fish species.

While the pike *Esox lucius* (Linnaeus 1758) is widespread and relatively common over Eurasia and North America (Kottelat and Freyhof 2007), the Italian population has been recently described as a new species, the Cisalpine or Italian pike *Esox cisalpinus* Bianco and Delmastro 2011 on the basis of morphological and genetic peculiarities (Lucentini et al. 2006). In this study, we focused on this newly described species, which seems to be extremely localized and threatened. Cisalpine pike is a primary, moderately cold stenotherm, preferentially limnophilous species, native of the Padano-Veneto district, Tuscany and Latium (Bianco and Delmastro 2011; Bianco 2014).

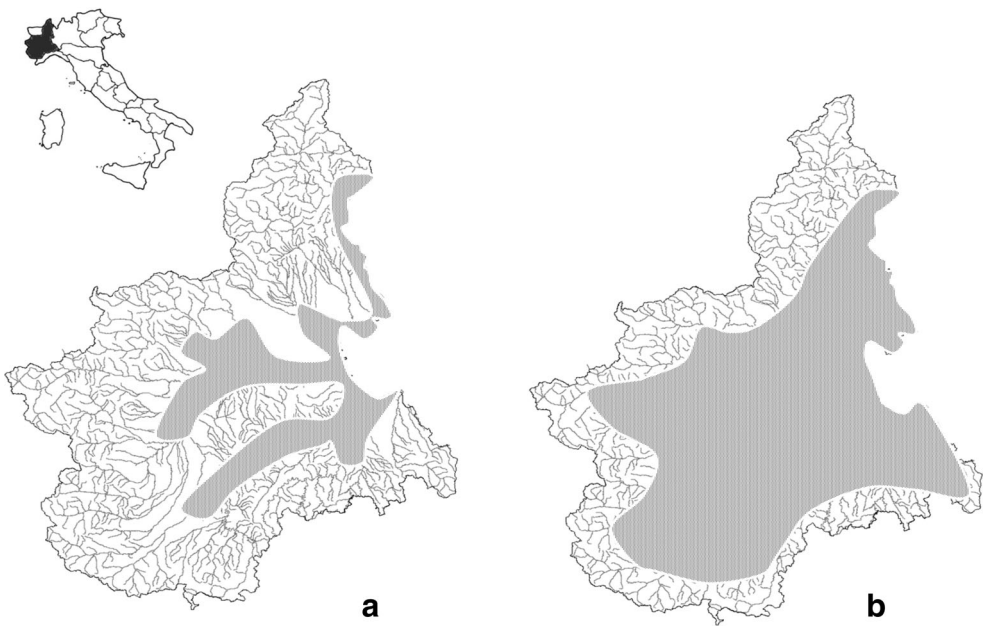

Fig. 1 Approximate winter (November–January) distribution of *Phalacrocorax carbo sinensis* in Piemonte (NW Italy): **a** years 1986–1992 (from Cucco et al. 1996) and **b** years 2006–2012

In Piemonte, area in which is localized the *locus typicus* of *E. cisalpinus*, this species inhabits a wide range of still and slow course lowland freshwaters, abounding in aquatic plants and fine sediment substrates (Gandolfi et al. 1991). In all this area, Cisalpine pike reduced drastically its distribution and, in approximately 15 years, disappeared from 54 % of the sampled stations (Regione Piemonte 1992, 2006). Main threats are over-fishing, habitat loss and degradation, damage of breeding areas (aquatic vegetation), and introduction of exotic species (Delmastro et al. 2007). With the increasing alteration of natural environments, gravel pit lakes host nowadays a relevant part of the remaining population. The object of our research was to quantify the incidence of cormorant-related wounds on natural populations of Cisalpine pike and indirectly to verify if cormorant predation can be considered among the causes of the rapid decline of this Esocidae.

Material and methods

The study area is localized in Piemonte (NW Italy), in a lowland area characterized by many gravel pit lakes located along the Po River. In this area, the massive extraction of gravel and sand started in the early 1970 and resulted in the realization of a series of man-made lentic environments. Demographical and distributional data about great cormorant in this area were obtained from published literature (Alessandria et al. 1999, 2001), census of wintering waterfowl made by Gruppo Piemontese Studi Ornitologi (GPSO) from 1979 to 2008 (Della Toffola et al. unpublished data), and data reported by bird watchers from 2009 to 2011 on the website "aves.piemonte" (www.regione.piemonte.it/aves). Moreover, specific field researches were conducted in the study area with evening count at roosts, spot counts on gravel pit lakes (maximum number of birds feeding or resting in a single lake), and regular field trips (to collect data about local phenology of the birds). Counts were performed in three roosts localized in our study area: roost "a" (44° 53′ 16″ N 7° 42′ 21″ E, altitude 232 m a.s.l.), "b" (44° 46′ 49″ N 7° 40′ 25″ E, altitude 255 m a.s.l.), and "c" (44° 52′ 43″ N 7° 52′ 02″ E, altitude 256 m a.s.l.). Pikes were collected in five gravel pit lakes located near the Po river, upstream of the city of Torino (Table 1, see more details in Delmastro and Balma 2010). Fish were captured by electrofishing in February–March in the years 2009–2013 (with the exception of a single specimen collected in May and another one in June). Electrofishing is a widely used technique in quantitative studies of freshwater fish (Penczak and Głowacki 2008). All studied specimens belong to the endemic Cisalpine (or Italian) pike *E. cisalpinus*. Fish total length (TL) was measured with an ichthyometer to the nearest lower millimeter (mm). Each fish was accurately examined for cormorant-related wounds, as described by Carss (2003) and Adámek et al. (2007). The presence and localization (dorsal, lateral, ventral, on the head, on the caudal peduncle and fins) of wounds were recorded. For statistical analysis, specimens were grouped in two categories according to their size: juveniles (TL<30 cm) and adults (TL>30 cm; Gandolfi et al. 1991). To evaluate if significant differences in wound occurrence existed between pikes of different size and sex, we performed Mann-Whitney *U* tests using the software Systat 8.0 (Wilkinson 1992).

Results

Cormorant

In the study area, two roosts are known (a, b) and another one is localized about 15 km east. The roost (a) was used by 375–500 birds in 1995–1996, but the population dropped to 120 in 2012 and 55 in 2013. The roost (b) was much more stable with 100–120 birds, and in the same site, a few pairs breed since 2008 (Beraudo and Giammarino 2011). The third roost count 100–150 birds in the last years (139 in 2014). Other roosts in the region are more than 25–30 km apart of the study area and are not considered here. Spot counts of resting and feeding birds in the gravel pits of the study area during winter (December–March) counted up to 35 (and even 70) cormorants in a single lake and averaged 130 (1993–2008) and 65 (2009–2013) over all the gravel pits of the study area. Regarding monthly abundances, regular counts in the area showed an evident increase of cormorant presences from summer months to winter period, with a peak during March, in relation to migratory movements (Fig. 2).

Pike

We collected and examined 139 specimens of *E. cisalpinus* (48 males, 42 females, and 49 undetermined, see Table 1 for sample distribution). Mean fish total length was 441 mm (±174 SD), with a maximum of 940 mm and a minimum of 187 mm. More than a half of the specimens (n=79; 57 %) reported injuries attributable to great cormorant attacks. Among these, 64 specimens showed superficial wounds and/or healed scars, five subjects showed deep hypodermic wounds while 15 specimens were characterized by both wound types. Considering all data together, injuries were mainly localized in the dorsal (32.3 % of total wounds detected) and lateral surfaces (28.2 %) of the pikes, interesting caudal peduncle and fins more infrequently (respectively 10.5 and 17.7 %). In very few occasions, injuries were detected in the ventral surface (9.0 %) or in the head (5.0 %). No differences were detected between sex (Mann-Whitney U test=831.0 p= n.s.), but a significant difference in the occurrence of wounds between the two size categories was detected (Mann-Whitney U test=864.5 p<0.001). Only 17 % of juveniles were

Table 1 Main characteristics of gravel pit lakes in the study area

ID	Name	Coordinates	Altitude a.s.l.s	Area (ha)	Depth (m)	Pike Specimens
1	Escosa	44° 56′ 20″ N 7° 40′ 48″ E	229 m	40.0	50	27
2	Ceretto	44° 51′ 41″ N 7° 39′ 42″ E	236 m	30.3	55	13
3	Germaire	44° 51′ 39″ N 7° 40′ 18″ E	234 m	30.0	55	46
4	Monviso	44° 49′ 11″ N 7° 36′ 47″ E	241 m	13.5	40	02
5	Fontane	44° 48′ 57″ N 7° 34′ 43″ E	243 m	22.6	40	51

interested by wounds, while 73.5 % of adults showed some kind of injury (Fig. 3).

Discussion

More than half of the examined specimens have some type of wounds; nevertheless, this percentage may be an underestimation of the cormorant impacts on this species. In fact, direct underwater observation indicated that cormorant rarely injuries small size fish without eating them, while the rate of prey loss (and potential injury) might increase with fish size (Grémillet et al. 2006). The significant difference in the wound occurrence between the two size/age classes in our study undoubtedly suggests that attacks toward small subjects (LT<30 cm) conclude with an higher success rate, i.e., with effective predation. This agree with previous observations reporting that the most commonly foraged fish usually is around 15–25 cm (Jepsen and Olesen 2006; Spairani et al. 2010). In particular, for ingested pike, a mean length of 24 and 37 cm was respectively observed by Santoul (2005) and Keller (1995).

Our findings are particularly worrying since perifluvial, lentic areas represent one of the last refuges for pikes, because of the widespread alteration of most lotic environments (Fochetti 2012). The pike reproductive season falls between the third week of February and mid-April, with a peak in March. In this period, pikes approach shallower waters, reaching higher densities near breeding areas. Unfortunately, in the same period, these environments are also home to the highest concentrations of cormorants (see Fig. 2). These birds regularly overwinter and forage in quarry lakes, because they never freeze due to their morpho-hydrological characteristics. The possibility of predation on pike is also enhanced by the fact that during winter months, most of Ciprinidae, which abound in shore areas during warm months, are largely absent; in fact, in this season, minnows prefer to reach deeper areas of the lake characterized by relatively warmer temperatures.

It is well known that most pike populations are in strong decline, because excessive fishing pressure, water pollution, anthropic alterations of aquatic environments, especially breeding sites such as lowland springs (Gandolfi et al. 1991). The last IUCN category of *E. cisalpinus* is still "data deficient" (Rondinini et al. 2013), but it should be classified at least as "vulnerable," as its native populations are threatened

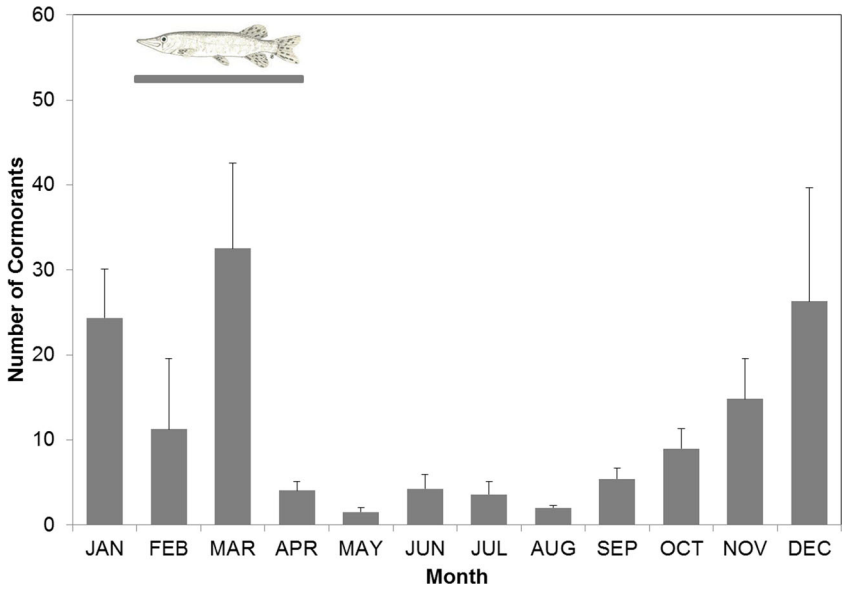

Fig. 2 Monthly distribution of cormorant density in the study area. *Horizontal bar* displays the Cisalpine pike reproductive period

Fig. 3 Superficial (**a**), deep (**b**, **c**), and a combination of both wound types (**d**) caused by cormorant attacks on Cisalpine pikes

and also affected by hybridization and competition with the allochthonous *E. lucius* (Bianco 2014). Currently, there is an elevate risk of disappearance in the whole distribution area and particularly in the western Po basin (Regione Piemonte 2006; Delmastro et al. 2007), so that recently this species has been considered highly endangered (Forneris et al. 2011).

Our data does not support the hypothesis that great cormorants mainly feed on pike, according with numerous studies reporting that pike normally accounts for a small percentage of cormorant food (Beccaria 1998, in Piemonte; Opačak et al. 2004; Santoul 2005). However, this relatively small intake can have dramatic consequences on a reduced Pike population. In fact, our data provide evidence that the predation of cormorants can represent an important, additional menace for the conservation of Cisalpine pike.

The management of cormorant population is a matter of great debates, and the solutions can be reached only with management efforts realized at continental level.

From 1997, the species was removed from the European Bird Directive (European Commission—IP/97/718 of July 30, 1997), and notwithstanding to be a protected species in most European countries, active control measures with nest destruction, egg oiling, and shooting adults have been undertaken now in many places (Van Eerden et al. 2012). We can hypothesize that the recent reduction of wintering cormorants in NW Italy may be related to these control strategies, particularly of the Danish populations from where about 81 % of the ringed cormorants observed in NW Italy came (Della Toffola et al. 1997). Nevertheless, in a situation of diffuse decline of Cisalpine pike populations (as reported above), also small number of cormorants can represent an important threat. For this reason, a local management action should be very effective, in particular in artificial habitats as the gravel pits. In this context, a reduction of predations and wounding could be probably obtained by diversifying the habitat morphology and in particular by introducing artificial refuges in the littoral areas (Russell et al. 2008; Puzzi et al. 2012).

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