FACULTY OF FISHERIES AND PROTECTION OF WATERS
UNIVERSITY OF SOUTH BOHEMIA IN ČESKÉ BUDĚJOVICE

Secondary losses caused by feeding activities of great cormorant (*Phalacrocorax carbo sinensis*) on fishponds

Sekundární škody způsobené potravní aktivitou kormorána velkého (*Phalacrocorax carbo sinensis*) **na rybnících**

Jiří Kortan

Vodňany, Czech Republic, 2010

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Dedicated to all of people that collaborated on this thesis

Rector of University of South Bohemia České Budějovice (Prof. PhDr. Václav Bůžek, Ph.D.) and dean of Faculty of Fisheries and Protection of Waters (Prof. Dipl.-Ing. Otomar Linhart, DSc.) will award Ph.D. in fisheries (30th September 2010 at 10:00 in Town Hall Vodňany) to the author of the thesis. From that time the author of the thesis can use the title Ph.D.

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CONTENTS

CHAPTER 1

GENERAL INTRODUCTION

1.1. INTRODUCTION

Increasing occurrence of cormorants *Phalacrocorax carbo sinensis* L. associated with increased nesting in the Czech Republic has been recorded since the end of 80's. This is considered as consequence of permanent expansion of this species over the whole Europe since it has been covered by a general protection scheme under Council Directive 79/409/EEC of the 2 April 1979 on the conservation of wild birds (the Birds Directive). Predation of migrating northern cormorant populations on commercial fishponds mainly in Central Europe is considered to be a serious problem especially during the periods of spring and autumnal migrations. Growing population has led to a rise in reported damages to commercial fisheries, aquaculture and recreational fisheries. For that reasons, cormorant issues currently cause sharpen conflicts between fisheries and nature protection.

The population of great cormorant within the EU has increased significantly over the last 20–30 years and the species is now considered to be healthy (in favourable condition) in terms of overall population size and range. Two pan European censuses were conducted in 2003 (wintering) and again in 2006 (breeding) by Wetlands International (Cormorant Research Group). They estimated a minimum of 372.300 breeding pairs and total population is depending of the conversion factors used. This estimate is for whole of the Western Palearctic Region which includes 47 countries such as Russia, Ukraine, Turkey, Egypt, Libya etc. as well as the EU-27. Total number of wintering cormorants in Czech Republic was estimated as more than 10 000 individuals in 2006. According to the situation and prospective report of Czech Ministry of Agriculture (2009), economical losses caused by migrating cormorants during winter 2008 in the Czech Rep. reach in total more than 146 million of CZK, from which 138.005 million was caused by migrating and 8.237 million by nesting cormorants.

Presented Ph.D. thesis concentrate results of several studies aimed on secondary impact of great cormorant upon pond fish stock, which is manifested by wounding and stressing the fish. This cormorant issue is nowadays frequently debated under conditions of the Czech pond aquaculture, as well as in other Central European countries, regularly visited by cormorants. The results are supposed to support fish farmers' effort especially in the process of request applications for compensation of damages and losses caused by cormorants.

1.2. IMPACT OF CORMORANT UPON FISH

Great cormorants as a top fish eating predators cause serious damages to fisheries in several ways. Besides direct consumption, which is estimated to 340–520 g of daily meal (Marquiss and Carss 1994), cormorants affect the pond fish stock by wounding the fish and altering their behaviour (Adámek et al., 2007). Fishing cormorants hunt in flocks or as individuals. In case of collective hunting near the shore, fish are crowded to the shoreline where, due to high concentrations and panic behaviour, they may become easy prey for cormorants and some other predatory birds (grey heron, *Ardea cinerea* L., in particular). This tactic is frequently recorded mainly on eutrophic waterbodies like ponds, because it is more effective under the conditions of limited visibility (Veldkamp 1996). Systematic attacks upon pond fish stocks result in more or less continuous stress of fish linked up with production decrease (Berka 1989; Adámek 1991). Stressed fish may suffer, hiding in the littoral zone, for several weeks with serious consequencies for spring harvesting operations. Stricken fish, which have escaped from cormorant beak or which cannot be swallowed due to their size, suffer from various deep and/or surface injuries, which are a frequent precursor to subsequent infection and mortality.

Healed wounds than reduce the commercial value of afflicted fish (Davies et al., 1995). The types of wounds caused by piscivorous fish predatory birds were documented by Carss (1990) and Kortan & Adámek (2010). Fish eating birds represent an important group of hosts with wide range of parasite species using fish as an intermediate host (Sitko et al., 2006). Cormorants are an important carrier of helminths, which was observed in the study of Sitko and Polčák (1996).

1.3. STRESS IN FISH

Occurrence of cormorants associated with hunting lead to the stress load in affected fish especially in pond habitats. After the birds´ attack, school of fish could stay crowded in littoral parts of the pond for several days. This behavioural manifest could be seen especially during the spring (February – March) migrations of cormorants, when numerous flocks of birds feed on fish ponds stocked with one or two-year old carp. The effect of birds´ mighty feeding attempts is worsen by the fact, that fish are already weakened after wintering and it can result to vast mortality. Unfortunately, lack of scientific data about this type of effects of bird predation upon fish stock is very obvious so far (Kortan et al., 2010). Until today, the stress of fish was studied particularly in association with fish manipulation and harvesting (Svobodová et al., 1998). Fish responses to stress are manifested, among others, also in the plasma corticosteroid changes (chiefly cortisol in actinopterygian fishes) that occur following a stressful event (Barton 2002). Various biochemical and haematological indices are used to indicate and assess the effect of stressors in fish, e.g. concentration of glucose, cortisol, lactate, ammonia and chlorides in blood plasma, spleen somatic index etc. (Thomas 1990; Palíková and Svobodová 1995).

Figure 1 *and* ***2****. Flock of hunting comorants attack the pond. Immediately after attack, fish stock is along the shoreline.*

1.4. WOUNDING OF FISH

Primarily during collective hunting, cormorants cause to fish numerous injuries. They do not select the prey size and attack the fish, which due to their size and proportions, could not be swallowed and often escape from cormorants´ grasp. The wounding of fish by piscivorous birds may cause severe problems to fish farmers and fishermen. Wounded fish prove a decrease of their fish market value or fish are even unmarketable (Marquiss and Carss 1994; Adámek et al., 2007). Wounded parts are invaded by ectoparasites, viral and fungal infections. These wounds often don't heal, particularly in low water temperatures.

Infections than can spread outward and downward through the musculature, resulting in complete breakdown of the skin and even rupture of the body cavity. Its likely that many such fish die of their wounds (Carss 1990).

Injuries caused by cormorant are mostly well recognizable. Contrary to herons, which make only superficial scars on both body sides, the wounds caused by cormorants are triangle shaped (due to their sharp and hook-like upper part of the beak) on one side of body, on the other side, scars and contusions are presented (Carss 1990).


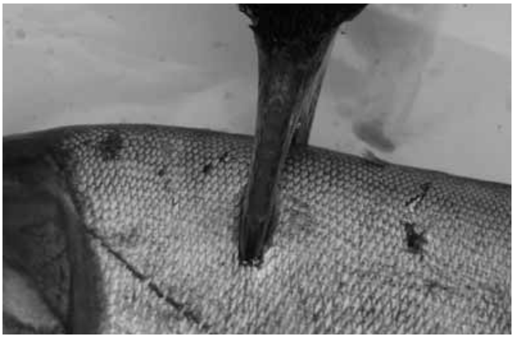

Figure 3 *and* ***4****. Great cormorant cause typical beak imprints. Hooklike sharp tip of cormorants' upper mandible causes deep subdermal wounds, while the lower mandible scratch the epithelium by sharp edges of the beak without penetrating the skin.*


Figure 5 *and* ***6****. Typical triangle shaped beakprint on the right body side and scars caused by upper mandible pressure on the opposite body side of two-year old mirror carp.*

1.5. LITERATURE REVIEW

Only a few studies (Kortan et al., 2008; Adámek et al., 2007; Carss 1990; Davies et al., 1995) were focused on this topic and data about these issues are still very scarce, or rather lacking. However wounding of fish may cause serious problems. For example Poor (2005), who studied cormorants predation presented, that indirect (elicited) looses may, depending on other conditions, reach up to 20–100% of losses caused by direct consumption by them. Under conditions of typical Czech fish-pond area, which is attractive for cormorants, the quantity of damaged fish range from 1 to 47% on individual ponds. Its range depends above all upon the frequency and intensity of bird visits and fish stock composition (Kortan 2010).

Fish wounding was observed not only under fish pond conditions, but also on the rivers and/or cage fisheries. For example in the study of Wissmath (1996), where fishermen and scientists co-operated on the study of fish populations on several rivers in Bavaria (Germany), was recorded besides a rapid decrease of population density, also big number of injured fish with symetric scratches on both sides of their body and extensive suffusions. Seiche and Wünsche (1996) concluded on the reports of fishermen in Saxony (Germany), where except natural losses, also increasing numbers of fish damaged by herons and cormorants were recorded. They classify the wounds into four levels according to their age, from old scarred contusions to new deep and bloody holes, which perforate the skin. The size of the majority of injured fish ranged between 26 and 35 cm. In the study of Suter (1995) was reported that the proportion of grayling (*Thymallus thymallus* L.), which bore marks of recent cormorant attack amounted to 10–16% of fish which survived the winter period of increased cormorant predation in a Swiss river. Fish wounding by cormorants was also recorded in the Boyces Beck, tributary of the River Ribble, Lancashire, UK as described by Davies et al. (1995). The proportion of chub, dace and roach individuals showing wounds amounted to 14.1–18.2, 2.3–7.0 and 6.7%, respectively in individual fish species. Conclusions of this study proved that the size is one of the limiting factors of susceptibility to cormorant predation, which was also recorded by Moerbeek et al. (1987) who found, that extent of injuries was largest in market size carp, because smaller fish are usually directly swallowed by cormorants. Engström (1998), who observed fish wounding on several Swedish lakes, proved size differences between injured fish, which were bigger than 0.5 kg, and fish consumed which average weight was 0.2 kg. Sutter (1997), who studied the food of cormorants in Switzerland asserted, that smallest fish found in the guts of cormorants measured 5.9 cm and weighed 0.8 g, while the biggest fish – eel, *Anguilla anguilla*, measured 68.7 cm. Average prey size ranged up to 45.5 cm. The average width of back of these fish was 10.4 cm, which corresponds to supposedly limiting width given by ability of a cormorant to open its beak. Fish of bigger proportions carried numerous injures and were found dead on the water surface (max. 50.8 cm, 1030 g). Impact of cormorant was also registered on recreational fisheries. Kirby et. al. (1995) refered fish wounding associated with decrease of attraction of anglig grounds in Chew Valley Lake in UK. During anglers´ competition, respective 21.3 and 5.8% of captured trout (n = 1.023) carried scars and deep wounds caused by feeding activities of cormorants.

Fish wounding by cormorants and herons is relatively common in cage fish farms. Injuries arise during effort of cormorants catch the fish through the cage meshes which was observed e.g. by Carss (1990). He found, that using of "antipredatory" nets significantly decreases the proportion of wounded fish, which corresponded to 38% while 80% of fish were injured without nets installation. Using underwater video systems, Gremillet et al. (2006) evaluated the proportion of successful pursuits of cormorants on live fish. They proved that although cormorants are regarded as highly efficient predators, they aborted about half of their pursuits.

Above mentioned literature data pointed out, that issues of secondary impacts of great cormorant upon fish stock are very serious and required more detailed studies.

IN THIS THESIS

The overall aim of present thesis was to evaluate secondary losses on fish stock caused by cormorant.

The specific objectives were to:

- *Evaluate the extent of injuries in fish wounded by cormorant.*
- *Evaluate the body condition of wounded fish and amount of injured fish on several fish ponds.*
- *Evaluate the stress in fish in reaction to presence of hunting cormorants.*
- *Document the behavioural response of fish in reaction to hunting cormorants.*
- *Evaluate the susceptibility of wounded fish to ectoparasite infection and its correlation with wound extent.*

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CHAPTER 2

COMPUTER-ASSISTED IMAGE ANALYSIS IN THE EVALUATION OF FISH WOUNDING BY CORMORANT [*PHALACROCORAX CARBO SINENSIS* (L.)] ATTACKS

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COMPUTER-ASSISTED IMAGE ANALYSIS IN EVALUATION OF FISH WOUNDING BY CORMORANT [*PHALACROCORAX CARBO SINENSIS* (L.)] ATTACKS

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ABSTRACT

Fish, which have escaped from a cormorant's (*Phalacrocorax carbo sinensis* (L.) grasp and/or which could not be swallowed due to their size, suffer from various injuries resulting in consecutive infections and subsequent increased mortality. A computer assisted image analysis was applied to describe the extent of such injuries. Two-year-old mirror carp, *Cyprinus carpio* L. (TL 200–300 mm, W 200–300 g) showed injuries ranging over approximately 10% of the total body surface. Immediately after wounding, the damaged epithelium (scars) cover 5–35%, and deeper sub-dermal wounds, caused by the beak tip pervading into muscle tissue, cover an area of 1–2% of the total body surface. On the side impacted by cormorant lower mandible, extensive areas of epidermal contusions (scars) occur. As the time progresses, these ratios change – deeper necroses represent up to 10 % of total body surface and healing epithelial scars comprise just 1–2%. In wounded silver carp, *Hypophthalmichthys molitrix* Val. (300–400 mm, W 500–700 g), the share of sub-dermal wounds usually does not exceed 0.5% due to their compact scaly cover. During pond draining due to fish harvesting, the size spectrum of wounded fish increases and may also often include bigger fish (e.g. European catfish, *Silurus glanis* L.) up to 2.2 kg.

Keywords: cormorant, image analysis, fish wounding, fish predators, carp pond farming

1. INTRODUCTION

An increasing occurrence of cormorants *Phalacrocorax carbo sinensis* L. associated with their increased nesting in the Czech Republic has been recorded since the end of 80´s. This is considered an attendant phenomenon of the current permanent expansion of this species in appropriate sites over the whole of Europe. The predation of migrating northern cormorant populations on commercial fish ponds is considered to be a serious problem during theperiod of the birds´ spring and autumnal migration flights (Kortan and Adámek 2002).

The problems of cormorant versus fisheries relationships have been the topic of many more or less detailed studies. Their conclusions have been summarised e.g. in Berka (1989) and Carss (1997). The damage to fisheries caused by cormorant predation pressure consist of losses due to direct predation and subsequent indirect losses elicited by cormorant feeding activities resulting in fish wounding and stress. Stricken fish, which have escaped from cormorant attack or which cannot be swallowed due to their size, suffer from various deep and/or surface injuries, which are a frequent precursor to subsequent infection and mortality. The types of wounds caused by piscivorous fish predators (herons, cormorants and shags) were documented by Carss (1990). Healed wounds reduce the commercial value of afflicted fish (Davies et al., 1995).

The aim of our study was to evaluate the surface extent of injuries caused by cormorants' unsuccessful attacks at commercial carp pond fish species.

2. MATERIAL AND METHODS

Examined fish specimens were selected randomly from wounded fish collected during the spring harvesting period of South Moravian (Czech Republic) carp ponds in March – April 2004. Altogether, six pond-fish species (common carp, *Cyprinus carpio* L.; silver carp, *Hypophthalmichthys molitrix* Val.; grass carp, *Ctenopharyngodon idella* Val.; perch, *Perca fluviatilis* L.; pike, *Esox lucius*, and European catfish, *Silurus glanis* L.) were subject to the evaluation of a superficial surface extent of injuries using a digital computer-assisted image analysis. For details of fish length and weight parameters see Tab. 1. Two types of injuries were distinguished in examined fish: (1) damaged skin (contusions) and (2) open sub-epithelial wounds, usually followed by subsequent necroses.

Digital images of wounded fish (high resolution, TIFF format) were processed by means of an image analyser (Olympus MicroImage v. 4.0 sw), using the mode of manual measurement. The body outline of the fish without fins as well as outlines of the injuries, were created as polygon features using a trace/wand tool (Fig. 1 and 2). Data on areas measured in pixel values were collected, saved and transferred to Microsoft Excel 2002 for analysis of fish body area versus injury area ratios and assessment.

Table 1. *Basic data on fish examined.*

Species (strain)	Age (years)	n	TL(mm)	W(g)
Cyprinus carpio (mirror)	1	8	187 ± 29.6	145.0 ± 49.37
Cyprinus carpio (mirror)	2	19	247 ± 28.4	206.9 ± 66.57
Cyprinus carpio (scaly)	2	12	234 ± 36.8	296.7 ± 88.27
Hypophthalmichthys molitrix	3	14	357 ± 22.0	630.0 ± 85.46
Ctenopharyngodon idella	2	2	243 ± 37.5	300.0 ± 60.00
Perca fluviatilis	4	2	265 ± 10.0	310.5 ± 35.00
Esox lucius	2	2	398 ± 2.5	416 ± 23.5
Silurus glanis	3	3	640 ± 32.6	1880.0 ± 262.8

Note: mean values ± standard deviation

Ponds, from which the examined fish originated, were managed as ongrowing carp ponds (Rybníkářství Pohořelice Co.). Their area amounted to 5.15 ha and 18.34 ha (Nohavice and Šumický horní ponds, respectively). According to the managing company documentation, the stock biomass consisted of 2.757 kg and 872 kg of one- and two-year-old carp per hectare, respectively, and the total biomass of other fish species biomass did not exceed 338 kg and 127 kg per hectare, respectively.

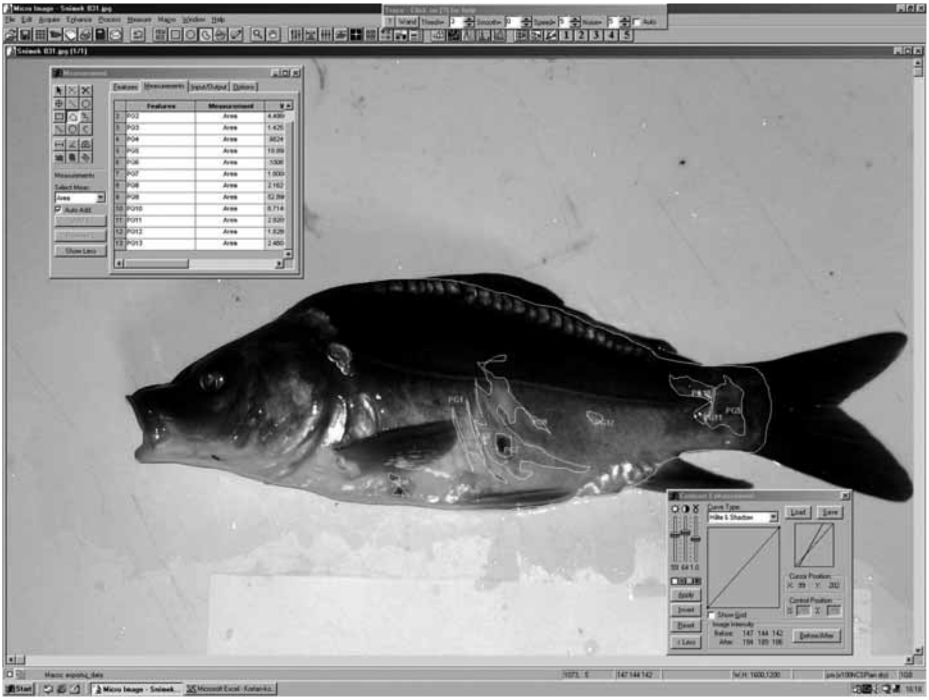

Figure 1. *Computer-assisted image analysis of carp wounding appearance shortly after the cormorant's attack.*

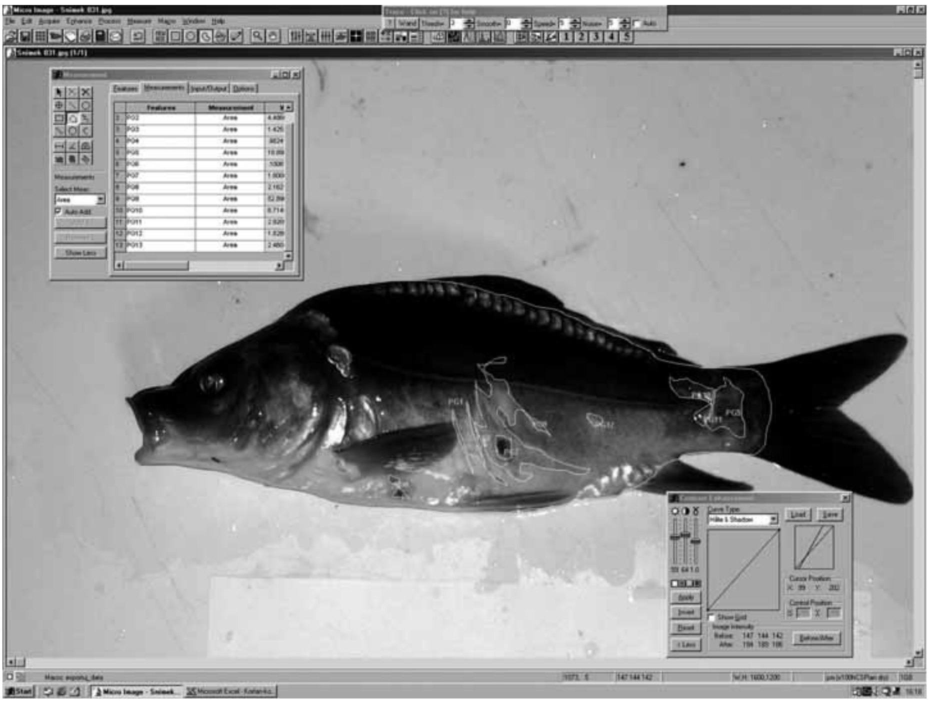

Figure 2. *Computer-assisted image analysis of carp wounding appearance after a several-month time interval following the cormorant's attack.*

The occurrence of cormorants was recorded by the pond managing company daily in morning and afternoon hours. The average daily number of cormorants recorded on the study ponds was 3.69 and 1.47 individuals per ha, respectively, during the late autumn and winter migration period (November 2003 and March – April 2004) preceding to harvesting and sampling collection.

Fish (common carp) condition coefficient (FCC) was assessed as a ratio of their individual weight (W in g) and total length (TL in cm) as

$$FCC = (W \,.\, TL^{-3}) \,.\, 100.$$

For statistical evaluation, the data on FCC were analysed using the Mann-Whitney non-parametric *t*-test.

3. RESULTS

The average total extent of woundings caused by cormorants to one- and two-year-old mirror carp corresponds to 27.5 ± 10.92% and 4.3 ± 2.40% of body surface respectively. No open necrotic wounds were recorded in one-year-old fish whilst in the two-year–old fish they covered the area of 1.7 ± 1.12% (Tab. 2). Open sub-dermal necrotic wounds were recorded in all two-year-old mirror carp examined but in 5 of 12 of the scaly carp examined, only superficial scars were recorded. The maximal extent of scars amounted up to 5.7 and 34.5% in individual two-year-old mirror and scaly carp specimens, respectively. In herbivorous cyprinids (silver carp and grass carp), the average total extent of sub-dermal open wounds was found to be 9.5 and 5.6% of fish body surface, with the proportion of sub-dermal necroses amounting to 0.1 and 0.6% respectively. The frequency of their occurrence corresponded to 30 and 50% respectively. Maximum registered values of the extent of scars were 19.2 and 7.1% of total body surface in silver carp and grass carp respectively.

Among predatory pond fishes, wounding caused by cormorants occurred in perch, pike and European catfish amounting to 9.2, 7.4 and 4.9% of fish body surface on average. No sub-dermal open injuries were registered in perch and only one case was recorded among two pike and three catfish individuals.

Table 2. *The extent of injuries caused by cormorant attacks as percentage (mean values ± standard deviation) of total body surface.*

Fish	n	Necroses	Scars	Total
Cyprinus carpio mirror, one-year-old	8	0.00	27.53 ± 10.92	27.53 ± 10.92
Cyprinus carpio mirror, two-year-old	19	1.73 ± 1.12	2.42 ± 1.85	4.31 ± 2.40
Cyprinus carpio scaly	12	1.66 ± 2.57	13.47 ± 10.95	15.13 ± 12.48
Hypophthalmichthys molitrix	14	0.14 ± 0.33	9.41 ± 4.41	9.54 ± 4.33
Ctenopharyngodon idella	2	0.64 ± 0.91	5.60 ± 2.18	6.23 ± 1.28
Perca fluviatilis	2	0.00	9.22 ± 3.91	9.22 ± 3.91
Esox lucius	2	0.16 ± 0.20	7.25 ± 3.27	7.40 ± 3.49
Silurus glanis	3	0.18 ± 0.31	4.70 ± 3.56	4.87 ± 3.87

Note: necroses – open subdermal woundings pervading into muscle tissue, scars – woundings not penetrating underneath fish skin.

The biggest individual fish wounded by cormorant attack were 336 (mirror carp), 400 (scaly carp), 360 (grass carp), 346 (perch) and 439 g (pike), respectively. In silver carp and European catfish, the size of biggest wounded fish exceeded 0.5 kg, being 760 and 2220 g respectively.

The average Fulton´s coefficient of condition in healthy two-year-old mirror carp individuals (n = 19) was 1.48 ± 0.11 whilst in wounded fish (n = 19) it declined significantly to 1.33 ± 0.14 (P = 0.0011). No significant differences (P > 0.05) were found between fish condition and either the extent of subdermal necrotic injuries or the total extent of wounds.

4. DISCUSSION

Recently published data on fish wounding by attacking cormorants has not included information from fish in carp ponds, despite these habitats suffer from cormorant invasions very seriously (Adámek and Kortan 2002). Fish ponds in Germany, Belgium, Czech Republic and Israel have been particularly mentioned as regular cormorant feeding sites (Adámek et al., 1997). Only Moerbeck et al. (1987) studied the impact of cormorants on carp in ponds in the Netherlands and found that fish up to 550 g were eaten by cormorants but that fish up to 700 g were subject to severe wounding and only carp over 1000 g appeared to be completely safe from cormorant attacks. However, anglers in north-west England have complained that cormorants have inflicted wounds on a variety of cyprinid species including 33–53 cm carp, which means the upper value represents fish over 2 kg (Davies et al., 1995).

A rise in an extent of necrotic changes on fish skin at the expense of superficial epidermal contusions can be recorded as the time progresses – compare the exterior of carp shortly (Fig. 1) and later (Fig. 2) after cormorant wounding attack. Fish suffering from wounds inflicted by cormorants also loose condition and become considerably more susceptive to lethal factors.

Suter (1995) reported that the proportion of grayling (*Thymallus thymallus* L.), which bore marks of recent cormorant attack amounted to 10–16% of fish which survived the winter period of increased cormorant predation in a Swiss river. His statement, that despite this, no evidence exists for negative implications of such injury rates on grayling population dynamics, is in a distinct contrary to our findings of severely dropping condition coefficient in wounded carp. Moreover, common carp is by far more resistant to injuries in comparison to grayling known to be extra sensitive to handling and mechanical impacts causing epithelial damages, which are consequently subjected to fatal fungal and bacterial infestations (Lusk et al., 1987).

Wounding of fish in Boyces Beck, a tributary of the River Ribble, Lancashire, UK, caused by cormorant was described by Davies et al. (1995). The proportion of chub, dace and roach individuals showing wounds consistent with cormorant attacks amounted to 14.1–18.2, 2.3–7.0 and 6.7%, respectively in individual fish species.

Cormorants do not cause economic losses only by their direct fish consumption but they also harm fish during hunting (Berka 1989; Adámek 1991). Poór (2005) concluded that the degrees of fish wounded by cormorants preying on ponds are high and may reach up to 0.3–0.4 kg of fish per cormorant daily. Using underwater video systems, Gremillet et al. (2006) evaluated the proportion of successful pursuits of cormorants on live fish. They proved, that although cormorants are regarded as highly efficient predators, they aborted about half of their pursuits.

The extent and character of wounds differ considerably with respect to fish species and size categories, including differences between mirror and scaly carp strains. The highest total superficial extent of wounds (27.5 ± 10.92%) was registered in the form of scars in mirror carp fingerlings (one-year-old fish).

However, the zero occurrence of open subdermal wounds was recorded in this fish category, which suggests that cormorants do not hit this size fish utilizing their sharp beak tip but they rather capture fish of this size (100–150 g) whole. The area impacted by unsuccessful cormorant attack in two-year old mirror carp was much smaller and amounted to 4.3 ± 2.40%, of which only 2.4 ± 1.85% were the scars.

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CHAPTER 3

INDIRECT MANIFESTATION OF CORMORANT (*PHALACROCORAX CARBO SINENSIS* (L.)) PREDATION ON POND FISH STOCK

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INDIRECT MANIFESTATION OF CORMORANT (*PHALACROCORAX CARBO SINENSIS* (L.)) PREDATION ON POND FISH STOCK

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ABSTRACT

The damage to fisheries caused by cormorant predation pressure consists of losses due to direct predation and subsequent indirect losses elicited by cormorant feeding activities resulting in fish wounding and stress. Healed wounds reduce the commercial value of afflicted fish and stress may impact fish body and health condition. Fulton´s condition coefficient (FCC) was calculated for wounded and healthy two–year old carp originating from five South Moravian (Czech Republic) fishponds. Significant (P = 0.0011) differences in FCC (mean ± s.d.), were found between non-wounded (1.48 ± 0.11, n = 19) and wounded mirror common carp, *Cyprinus carpio* (1.33 ± 0.14, n = 19). However no differences (P > 0.05) were recorded in scaly common carp between non-wounded (FCC 1.41 ± 0.25, n = 33) and wounded (FCC 1.46 ± 0.47, n = 33) fish of the same age and size category. A computer assisted image analysis was applied to describe the extent of such injuries. In the case of two-year old mirror, scaly and bighead carp (*Aristichthys nobilis*), signs of serious injuries (necroses) were recorded on 1.93, 0.89 and 1.61% of body surface, respectively. Fish with deep wounds and scars, often accompanied with progressive necroses, were subject to parasitological examination. The percentage of wounded fish from total fish harvested was evaluated as ranging between < 1 and 47.4% in five ponds under study.

Keywords: piscivorous predators, fish wounding, fish condition, image analysis, carp pond culture

RESUMÉ

Les dommages causés au pêcheries par les cormorants sont dus non seulement à la prédation directe des oiseaux, mais également aux pertes indirectes résultant de leur activité de pèche, qui se traduit par des poissons blessés et stressés. Les blessures guéries réduisent la valeur commerciale des poissons touchés et le stress peut avoir un effet sur leur intégrité corporelle et leur santé. Le coefficient de condition de Fulton (FCC) a été calculé pour des carpes de deux ans blessées et en bonne santé provenant de cinq étangs de Moravie du sud (république Tchèque). Des différences significatives (P = 0.0011) du FCC ont été mises en évidence entre les poissons non atteints (1.48 ± 0.11, n = 19) et des carpes miroir communes, *Cyprinus carpio* blessées (1.33 ± 0.14, n = 19). Cependant, aucune différence (P > 0.05) n'a été trouvée entre des carpes communes à écailles blessées (FCC 1.46 ± 0.47, n = 33) et non blessées (FCC 1.41 ± 0.25, n = 33) du même âge et de la même catégorie de taille. L'analyse d'image assistée par ordinateur a été utilisée pour décrire les marques des blessures. Des signes de graves blessures (nécroses) correspondant à 1.93, 0.89 et 1.61% de la surface corporelle ont été enregistrés sur des carpes miroir, à écailles et à grosse tête (*Aristichthys nobilis*) respectivement.

Des poissons présentant des blessures et des cicatrices profondes, souvent accompagnées de nécroses, ont été soumis à un examen de parasitologie. La proportion des poissons blessés a été évaluée en pourcentage du total des poissons pêchés. Ce pourcentage varie entre < 1 et 47.4% dans les étangs individuels (n = 5) étudiés.

Mots clés: prédateurs piscivores, poissons blessés, état des poissons, analyse d'image, élevage de carpes en étang

1. INTRODUCTION

Great cormorants (*Phalacrocorax carbo*) are piscivorous birds which are suspected to deplete valuable fish stocks and compete with fisheries (Gremillet et al., 2006). Pond systems of the Central Europe provide profuse food habitats for them. Shallow water bodies of carp fishponds with dense stocks consisting of fish, which in majority fully correspond to cormorant requirements regarding the prey size, attract particularly migrating cormorants to stop for certain period of time for feeding. Cormorants are perceived to damage the fish stock in two ways – directly by consuming large amounts of fish (Davies et al., 1995) and indirectly by altering fish behaviour and wounding them. Contrary to herons, which make only superficial seams from both body sides, the wounds caused by cormorants are triangle shaped (due to their sharp and hook-like upper part of the beak) on one side of body, on the other side, scars and contusions are presented. (see fig. 1 and 2) (Carss 1990). It leads to increased disease susceptibility and/or reduced market value (Marquiss and Carss 1994; Adámek et al., 2007).

The study was focused on the evaluation of indirect impact of cormorant attacks upon the pond fish stocks. This provides the basic information about the type of injuries caused by cormorants and the impact of wounding upon fish condition, which might help to clarify the core of the conflicts between fish farmers and nature conservation. Any credible data about these issues are still very scarce, or rather lacking, since the majority of the information is based on observations missing any quantitative figures. However wounding of fish may cause serious problems. Poór (2005) presented that indirect (elicited) losses can, depending on other conditions, reach up to 20–100% of losses caused by direct fish consumption by cormorants. Former studies (Adámek et al., 2007) support these estimations since fish injuries caused by cormorant attacks may cover up to 28% of fish body surface.

Figure 1. *„Scars" – superficial wounds from lower mandible of cormorant on right hand body side.*

Figure 2. *Necroses" – deep wounds caused by hook-like beak (typical triangle shape) on left body side.*

Table 1. *Numbers of cormorants (mean per day) recorded on the fish ponds under study during the winter period previous to fish wounding evaluation.*

Pond	Month				
	XI	**XII**	**I**	**II**	**III**
Nohavice	7.7	9.3	0	0	18.6
Týnský	0	0	0	0	8.0
U Dubu dolní	0	0	0	0	5.6
Moravské Prusy	50.1	0	0	0	0
Pohořelický			no data		

2. MATERIAL AND METHODS

2.1. LOCALITY

Wounded fish used for examination were collected from five South Moravian (Czech Republic) ponds, managed by the Rybníkářství ("Pond Fisheries") Pohořelice Co., where the occurrence of cormorants was regularly recorded (Tab. I) particularly during their autumnal and spring migration. The wounded carp individuals were randomly collected in the course of spring pond harvesting from the Nohavice pond (overwintering pond, 5.15 ha) in March 2004, and from the ponds U Dubu dolní (8.68 ha) Týnský (25.46 ha), Moravské Prusy (11.25 ha) and Pohořelický (5.6 ha) in March and April 2007. The ponds were stocked mostly with two-year-old fish (Table II). The proportion of wounded fish from the total number of fish harvested was assessed by direct counting related to official harvest figures provided by the managing company.

2.2. FISH CONDITION

Fulton´s condition coefficient (FCC) was calculated for "healthy" fish (individuals without any marks of injuries caused by cormorant beak) and for wounded fish as the ratio between their individual weight (W in g) and total length (TL in cm):

$$FCC = (W * TL^{-3}) * 100.$$

The length and weight data of fish evaluated are presented in Table III. For comparing the FCC of wounded and not wounded fish Mann – Whitney U-test was used.

2.3. DESCRIPTION OF THE WOUNDS

Wounded fish, which were examined for ectoparasite occurrence and histopathological description of wounds, originated from the U Dubu dolní and Pohořelický ponds – for details see Table IV. The samples were prepared by regrating from the body surface above the lateral line on both body sides and from the first left branchial arch. The prevalence and intensity of parasite invasions were evaluated microscopically.

The extent of injuries was calculated as a percentage of wounded area from the total body surface. The injuries were distinguished into two types: scars – superficial wounds caused mostly by lower part of cormorant beak (Fig. 1) and necroses – deep wounds from upper mandible hook of the beak usually progressing as necrotic lesions (Fig. 2). Digital images of wounded fish were provided by Panasonic Lumix FZ 50 fixed on tripod. Fish were positioned on the white background. Images (high-resolution TIFF format) were processed by means of the image analyzer (Olympus MicroImage v. 4.0 sw) using the manual measurement mode. The body outlines of the fish without fins as well as outlines of the injuries were created as polygon features using a trace/wand tool. Data on areas measured in pixel values were collected, saved and transferred to Microsoft Excel 2002 for analysis of fish body area versus injury area ratios and assessment. The mean length and weight of fish analyzed is presented in Tab IV.

3. RESULTS

3.1. FISH CONDITION

The average value of condition coefficient (FCC) in two-year-old mirror carp from the Nohavice pond without the cormorant beak marks (n = 19) was 1.48 ± 0.11 (mean ± s.d.), while its values in the wounded fish of the same size and age category (n = 19) were significantly lower (1.33 ± 0.14, $P < 0.01$). The lower FCCs were also recorded in the wounded mirror carp from the Týnský pond. Average value of FCC corresponded to 1.48 ± 0.21 (n = 33), while in healthy fish (n = 33), it amounted to 1.66 ± 0.26 ($P < 0.01$). Insignificant differences were recorded in healthy and wounded scaly common carp from the same pond with FCC 1.41 ± 0.25 (n = 33) and 1.38 ± 0.12 (n = 33), respectively ($P > 0.05$).The fish from the U Dubu dolní and Moravské Prusy ponds showed significant differences ($P < 0.01$) between healthy (1.64 ± 0.25, n = 33 and 1.62 ± 0.13, n = 33) and wounded fish (1.46 ± 0.33, n = 33 and 1.51 ± 0.25, n = 33), respectively. Also bighead carp individuals from the Pohořelický pond proved significant differences between healthy (1.07 ± 0.06) and wounded individuals (0.95 ± 0.16) ($P < 0.05$). For details see Table 6 and Figure 3.

Table II

Fish stocking rates (total density) of the fish ponds under study. (Note: *C – carp* (Cyprinus carpio, *L.*), *GC – grass carp* (Ctenopharyngodon idella, *L.*), *BC – bighead carp* (Aristichthys nobilis, *Rich.*), *PP – pikeperch* (Sander lucioperca, *L.*), *CF – catfish* (Silurus glanis, *L.*), *I – ide* (Leuciscus idus, *L.*), *P – pike* (Esox lucius, *L.*).

Tableau II

Densité totale en poissons dans les étangs étudiés. (Note : C-carpe (*Cyprinus carpio*, L.), GC – carpe amour (*Ctenopharyngodon idella*, L.), BC – carpe à grosse tête (*Aristichthys nobilis*, Rich.), PP – sandre (*Sander lucioperca*, L.), CF – silure glane (*Silurus glanis*, L.), I – ide dorée (*Leuciscus idus*, L.), P – brochet (*Esox lucius*, L.).

Pond		Fish species							Total density (kg·ha^{-1})
Nohavice		C	GC	BC	PP	CF	I	P	
	Age	2	2	-	-	-	-	-	
	Density (kg·ha^{-1})	3790.3	394.2	-	-	-	-	-	4184.5
U Dubu dolní									
	Age	2	2	2	1 + 2	-	2	-	
	Density (kg·ha^{-1})	1129.3	40.3	23.1	1.9	-	11.5	-	1206.2
Týnský									
	Age	2	2	2	2	2	-	-	
	Density (kg·ha^{-1})	765.9	19.6	27.3	0.78	0.78	-	-	814.4
Mor. Prusy									
	Age	2	2	-	-	-	2	2	
	Density (kg·ha^{-1})	933.3	97.8	-	-	-	13.3	13.3	1057.7
Pohořelický									
	Age	2	1	1	-	-	-	1	
	Density (kg·ha^{-1})	158.9	8.9	10.7	-	-	-	3.6	182.1

Table III
Characteristics of fish examined (total length and weight, mean ± standard deviation). (Note: *MC = mirror carp, SC = scaly carp, BC = bighead carp.)*

Tableau III
Caractéristiques des poissons étudiés (longueur totale et poids, moyenne ± écart type). (Note : MC = carpe miroir, SC = carpe commune, BC = carpe à grosse tête.)

Pond	Species/form	*n*	TL (mm)		W (g)	
			Healthy	Wounded	Healthy	Wounded
Nohavice	MC	19	251.74 ± 25.90	247.37 ± 28.42	243.63 ± 79.06	206.89 ± 66.57
Týnský	MC	33	184.09 ± 24.79	219.58 ± 43.41	107.58 ± 51.16	173.03 ± 94.88
Týnský	SC	33	230.0 ± 44.89	288.30 ± 42.93	191.82 ± 136.61	353.94 ± 144.14
U Dubu dolní	MC	33	243.0 ± 20.20	264.39 ± 43.37	237.88 ± 55.69	302.85 ± 227.60
Moravské Prusy	MC	33	200.39 ± 19.90	206.0 ± 33.10	133.33 ± 36.94	136.06 ± 59.23
Pohořelický	BC	33	310.73 ± 14.04	316.45 ± 23.67	323.94 ± 47.11	296.0 ± 49.06

3.2. HISTO-PATHOLOGICAL AND PARASITOLOGICAL EXAMINATION

The histo-pathological and parasitological examination of wounded fish from the U Dubu dolní pond revealed superficial wounds with lesions 1–5 mm deep, which perforate the skin and muscle tissue, accompanied with hemorrhages. Older wounds were surrounded by inflammated 2–4 mm margins and necrobiotic processes begun in the direction from margins to the centre of wounds. In one fish, the abdominal cavity was even perforated. Parasitic infusorians Trichodina sp. and Chilodonella were commonly recorded on fish gills and skin. In bighead carp from the Pohořelický pond, the superficial wounds do not intervene into the pigmentation layer and just scale losses were recorded, but higher amount of deeper perforated wounds appeared there. Parasitological examination revealed the occurrence of Dactylogyrus sp. in one fish and the ordinary density of Trichodina sp.

Table 4. *Basic data on fish examined for parasitological and histo-pathological analyses and image analyses (mean ± standard deviation.) (Note: PaH – parasitological and histo-pathological analyses; IA – Image analysis; MC = mirror carp, SC = scaly carp, BC = bighead carp).*

Anal.	Pond	N	Age (years)	Species /form	TL (mm)	W(g)
PaH	U Dubu dolní	15	2	MC	433.3 ± 25.08	211.00 ± 68.31
PaH	Pohořelický	15	2	BC	299.67 ± 43.11	339.33 ± 175.17
IA	U Dubu dolní	22	2	MC	198.46 ± 35.85	131.82 ± 58.06
IA	U Dubu dolní	2	2	SC	307.0 ± 13.0	282.5 ± 22.5
IA	Pohořelický	22	3	BC	312.97 ± 11.89	270.0 ± 9.68

Table 5. *The extend of injures caused by cormorant attacks as a percentage (mean ± standard deviation) of total body surface. (Note: necroses – open subdermal wounds pervading into muscle tissue; scars – wounds not-penetrating underneath fish skin: MC = mirror carp, SC = scaly carp, BC = bighead carp).*

Fish (Species/form)	Age (years)	n	Necroses	Scars	Total
MC	2	22	1.93 ± 1.55	0.83 ± 1.04	2.76 ± 2.03
SC	2	2	0.89 ± 0.89	12.49 ± 0.78	13.38 ± 1.67
BC	3	22	1.61 ± 1.24	3.68 ± 2.90	4.12 ± 2.76

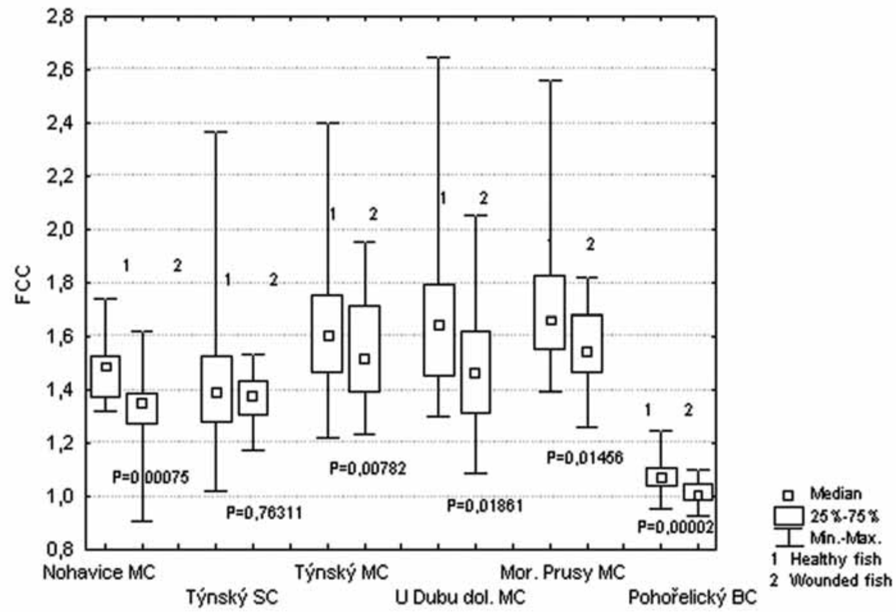
Table VI
*Percentage of wounded fish from total fish harvested and FCC of examined healthy and wounded fish (mean ± standard deviation). (Note: MC = mirror carp, SC = scaly carp, BC = bighead carp, wounded fish – % of fish wounded from total fish harvested, NS – $P > 0.05$; * – $P < 0.05$; ** – $P < 0.01$.)*

Tableau VI
Poissons blessés en pourcentage du total des poissons pêchés et FCC des poissons en bonne santé et blessés examinés (moyenne ± écart type). (Note : MC = carpe miroir, SC = carpe commune, BC = carpe à grosse tête, wounded fish (%) – la proportion des poissons blessés a été évaluée en pourcentage du total des poissons pêchés, NS – $P > 0,05$; * – $P < 0,05$; ** – $P < 0,01$.)

Pond	Species/form	Wounded fish (%)	*N*	FCC		Z	*P*
				Healthy	Wounded		
Nohavice	MC	2.7	19	1.48 ± 0.11	1.33 ± 0.14	3.372	**
Týnský	MC	< 1	33	1.66 ± 0.26	1.48 ± 0.21	0.301	**
Týnský	SC	< 1	33	1.41 ± 0.25	1.38 ± 0.12	2.661	NS
U Dubu dolní	MC	21	33	1.64 ± 0.25	1.46 ± 0.33	2.353	*
Moravské Prusy	MC	47.4	33	1.62 ± 0.13	1.51 ± 0.25	2.443	*
Pohořelický	BC	< 1	33	1.07 ± 0.06	0.95 ± 0.16	4.270	**

3.3. WOUND EXTENT

Maximum registered total values of injury extends (Tab. V.) were recorded in two-year-old scaly carp amounting to 13.38 ± 1.67% of total body surface with major parts composed of scars. The percentage of necroses was highest in mirror carp (1.93 ± 1.55). Bighead carp wound extent was 2.68 ± 1.24%. The highest percentage of wounded fish from total fish harvest (47.4%) was recorded in the Moravské Prusy pond. Corresponding values on the U Dubu dolní pond were 21.0%, Nohavice 2.7% whilst on the Pohořelický and Týnský ponds, less than 1% of fish harvested showed the signs of cormorant attacks (Table VI).



4. DISCUSSION

Secondary impacts of fish-eating predators, like heron (*Ardea cinerea*), otter (*Lutra luttra*) and great cormorant (*Phalacrocorax carbo*) on fish stock are often registered, but not presented on appropriate level supported by exact scientific data. Above all, the cormorant impacts are currently a regularly discussed issue. Cormorants do not cause economic losses only by direct fish consumption but also harm fish due to failed feeding attempts (Berka 1989; Adámek 1991). Poór (2005) concluded that the amounts of fish wounded by cormorants preying on ponds are high and may reach up to 0.3–0.4 kg of fish per cormorant daily. Using underwater video systems, Grémillet et al. (2006) evaluated the proportion of successful pursuits of cormorants on live fish. They proved that, although cormorants are regarded as highly efficient predators, they aborted about half of their pursuits.

Fish suffer from wounds which are deep and bloody (often triangle or irregular shape), caused by sharp cormorant tip of the upper mandible beak on one side of the body and in lesser extent, from superficial contusions on the other side. It was observed, that particularly two- and/or three-year-old fish (200–300 g carp) are threatened by cormorant attacks. Contrary to one-year-old fish, which are easily captured and swallowed by cormorant, many of bigger two-year-old fish escape from the beak grasp.

Fish wounding was observed on some rivers in Bavaria (Germany), where fishermen and scientists co-operated on the study of fish populations. They found, besides rapid decrease of population density, also high numbers of injured fish with symetric scratches on both sides of body and extensive suffusions (Wissmath and Wünner 1996). Seiche and Wünsche (1996) concluded, using the reports of fishermen in Saxony (Germany), that except natural losses, there were recorded also increasing numbers of fish damaged by herons and cormorants. They classify the wounds into four levels according to their age, from old scarred contusions to new deep and bloody holes, which perforate the skin. The size of the most injured fish ranged from 26 to 35 cm. This conclusion fully matched the results of this study.

Fish condition indices were calculated for healthy and wounded individuals. Significant differences were recorded in mirror carp and bighead carp but insignificant differences were registered in scaly carp. This statement can be explained by the fact, that scaly cover of the fish protects the body against the penetration of cormorant hook tip of the beak. This phenomenon was also recorded in the study of Adámek et al. (2007), where the scaly covered fish like silver carp (*Hypophthalmichthys molitrix*, Val.) and pike (*Esox lucius*, L.) had significantly ($P < 0.05$) lower extent of open subdermal wounds compared to mirror carp with inconsiderable scaly cover. In perch (*Perca fluviatilis*, L.), even zero values of this type of wounds were recorded. On the other hand, the loss of scales can also disturb the fish health condition but need not result in significant decrease of body condition factor (FCC), which was almost identical in healthy and wounded scaly carp (1.41 ± 0.25 and 1.38 ± 0.12, $P > 0.05$, respectively).

The description of wounded fish can provide more detailed information about the character of the injury. Fish, weakened due to the injury are more susceptible to parasite infestation. The invasions of *Trichodina* sp., *Chilodonella* sp. and *Dactylogyrus* sp. on the gills and skin were recorded in common quantity in examined wounded fish. The intensity of parasite invasion depends upon many factors, particularly on the time duration and extent of the injury. However, more detailed studies are required on this topic since some signs of extraordinary numbers of some ectoparasites, which are able to leave the fish when disturbed (e.g. *Argulus* sp.), were registered (Adámek, unpubl.).

The extent of injuries was studied by methods of computer assisted image analysis. The percentage of wounded areas in two-year-old mirror carp (2.76 ± 2.03) were not found as high as in the study of Adámek et al. (2007) (4.31 ± 2.40). The highest total superficial extent of wounds was registered in scaly carp (13.38 ± 1.67) but the major proportion related to scars and contusions (12.49 ± 0.78). Total values of wounded fish on the ponds were alarming mainly in the case of Moravské Prusy pond (47.4%). This percentage is nearly the same as the estimation of fish stock losses caused by direct consumption, which was calculated as 54.5% missing individuals. On the U Dubu dolní pond, the wounded fish represented 21% and fish stock losses were estimated as 72.5%. Taking into account the natural mortality of two-year-old common carp during an overwintering period, which is assumed as 5% under conditions of the Pohořelice pond region (according to Pohořelice Pond Fisheries company documentation), the total proportion of fish afflicted by cormorant consumption and wounding during overwintering corresponded to 50–60% in these particular case studies. Moreover, certain proportion of missing individuals belonged to complementary fish species (zander, *Sander lucioperca* L. and ide, *Leuciscus idus* L.) of first age class, which were totally eliminated by hunting cormorants.

5. CONCLUSION

Beyond direct consumption of fish, cormorants are accused of injuring vast number of prey fish without eating them (Gremillet et al., 2006). In the conditions of typical Czech fish-pond area, which is attractive for cormorants, the quantity of damaged fish range from 1 to 47% on individual ponds. Its range depends above all upon the frequency and intensity of cormorant visits and fish stock composition (Kortan, unpubl.). Predominantly, the two–year-old mirror carp are endangered by cormorant attacks. The fish with scaly cover are more resistant against injuries caused by cormorant attacks. The values of condition coefficient are significantly lower in wounded fish than in non-wounded ones except for scaly carp, which decrease in condition coefficient was not proved to be significant. Parasitological analyses did not reveal any outstanding invasions of ectoparasite in comparison with standard level of carp infestation in spring (Balakhin 1993). Documentation of the secondary impacts could be very useful for the evaluation of total economic losses caused by cormorant predation of fish ponds.

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CHAPTER 4

STRESS RESPONSES OF CARP POND FISH STOCK UPON HUNTING ACTIVITIES OF GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*, L.)

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STRESS RESPONSES OF CARP POND FISH STOCK UPON HUNTING ACTIVITIES OF GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*, L.)

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ABSTRACT

In addition to direct predation, cormorants can affect carp pond fish stock through disturbance and wounding of the fish. Fish stress response was evaluated by CPUE using lift-net sampling. A significantly higher ($P < 0.001$) CPUE was recorded in the littoral region of ponds affected by cormorant visits (43.6 ± 39.6) in comparison to a control pond without their occurrence (0.9 ± 1.1). Stress indices, spleen somatic index (SSI) and Fulton's condition coefficient (FCC), were evaluated for fish subject to two stress factors, hunting cormorants (HC) and pond harvesting (PH), and compared with levels in fish from the control pond (CP). Both SSI and FCC decreased significantly ($P < 0.05$) in PH and HC fish in comparison to the control group, while non-significant differences were recorded in both SSI and FCC indices among the HC and PH groups. Plasma biochemical indices (cortisol, glucose and lactate concentrations) were significantly higher ($P < 0.01$) in the PH group as compared with the HC and CP groups. Concentrations in the HC and CP groups did not differ significantly. Total plasma protein levels were significantly higher ($P < 0.01$) in HC fish compared to CP fish, but did not differ significantly from PH fish.

Keywords: Cormorant, Phalacrocorax carbo, stress, cortisol, carp pond harvesting

1. INTRODUCTION

The great cormorant (*Phalacrocorax carbo* L.) and Eurasian otter (*Lutra lutra* L.) are the two predators most commonly blamed for serious damages to fish stock in ponds in Central Europe (Kranz 2000). In addition to direct consumption of fish, cormorants may also cause indirect losses during their feeding activities through wounding of fish and stress (Kortan et al., 2008).

Fishing cormorants hunt in flocks or as individuals. In the case of collective hunting near the shore, fish are crowded along the shoreline where, due to high concentrations and panic behaviour, they become easy prey for cormorants and some other predatory birds (grey heron (*Ardea cinerea* L.) in particular). This tactic is frequently recorded on eutrophic water bodies such as ponds as it is more effective under conditions of limited visibility (Veldkamp 1996). Systematic attacks upon pond fish stocks result in more or less continual stress to fish, which in turn decreases production (Berka 1989; Adámek 1991). Stressed fish, which hide in the littoral zone, may suffer for several weeks, with serious consequences for spring harvesting operations.

Fish display a wide variation in their physiological responses to stress. Among these responses is a change in plasma corticosteroid levels (chiefly cortisol in actinopterygian fishes) following a stressful event (Barton 2002). Various biochemical and haematological indices are used to indicate and assess the effect of stressors on fish, e.g. concentrations of glucose, cortisol, lactate, ammonia and chlorides in blood plasma, the Spleen Somatic Index (SSI), etc. (Thomas 1990; Palíková and Svobodová 1995). Concentrations of cortisol and glucose are considered among the most important stress indicators in fish. Short-term intensive stress (handling, netting, stocking) leads to considerably elevated cortisol levels, followed by a gradual decline to normal values that can take from hours to weeks (Barton et al., 1980; Pickering et al., 1981). Plasma glucose levels become elevated in stressed fish because of an increase in blood catecholamine levels. As plasma glucose concentration is a function of many factors, however, such as diet, age or season, its value is more equivocal than cortisol (Dobšíková et al., 2006).

Changes in SSI have been used by a number of authors to assess intensity of stress in a variety of fish species (Svobodová et al., 1999; Mukopadhyay 2003). A decrease is recorded in SSI levels while fish are exposed to stressors such as pond harvesting due to the washing out of blood elements into the bloodstream (Svobodová et al., 2006).

The aim of this study is to record the reactions of fish stock associated with attacks by cormorants and to evaluate the stress load in affected fish. Any manifestation of stress in blood plasma and SSI of fish affected by cormorant presence will be compared with samples of fish subject to the pond harvesting process. Pond harvesting (as practiced in Central Europe) consists of slow pond draining, causing fish to move slowly with the descending water into the deepest part of the pond known as the harvesting pit (as described by e.g. Horváth et al. (1984), from which fish are removed by netting (usually seining). This harvesting procedure is stressful to fish (Svobodová et al., 2006). For this reason, only fish collected from the pond with the minimum possible disturbance were considered as a control. To date, no cogent data have been published for stress caused by bird predation upon fish stocks. Such knowledge of the interactions between protected bird predators and fish is needed in order to understand and mitigate the cormorant/fisheries conflict, which is becoming increasingly serious throughout Europe

2. MATERIAL AND METHODS

2.1. SITES

Two-year-old common carp (*Cyprinus carpio* L.), raised in fishponds, were used to document cormorant impact on behavioural and selected physiological traits. Monitoring of cormorant and fish behaviour was carried out in March 2008 on two ponds, Naděje (69 ha, mean depth 1.9 m) and Láska (17 ha, mean depth 2.1m). Both ponds are situated in the Třeboň fishpond area (South Bohemia, Czech Republic) and are supplied from the same water inflow.

On the Naděje pond, cormorant numbers were recorded on a daily basis during both the morning and afternoon. Hunting cormorants were first recorded on 28 February and the mean daily number visiting the pond during March was 50 birds, or 0.72 individuals per hectare. In the autumn and spring of 2007/2008, the Naděje pond was stocked with two-year–old common carp with an average weight of 155 g (3704 ind.ha^{-1}, 574 kg.ha^{-1}) and supplementary fish species, including grass carp (*Ctenopharyngodon idella* Val.) and tench (*Tinca tinca* L.), at 788 ind.ha^{-1}, ~ 85 kg.ha^{-1}.

Fish samples were taken commencing on the third day (3 March) of cormorant presence (HC – hunting cormorant group) and on the first day of harvesting at the same pond (PH – pond harvesting group), which started eight days later on 11 March. Cormorants left the roost site four days after their arrival (on 4 March) as fisheries staff scared them off.

The Láska pond, which served as the control pond site (CP), was also stocked with two-year-old carp with an average weight of 150 g (6478 ind.ha^{-1}, ~ 972 kg.ha^{-1}) and supplementary fish species such as grass carp, tench and zander (*Sander lucioperca* L.) at 25029 ind.ha^{-1}, or around 40 kg.ha^{-1}. No cormorant occurrence was recorded on this pond during March 2008.

The HC and CP fish samples were collected randomly by lift net from the shore zone at the pond feeding-site, though no food was supplied. During the harvesting process, PH fish samples were also taken randomly using a dip net, directly from the harvesting seine fishnet.

Basic water environmental parameters, such as temperature and dissolved oxygen, were regularly measured before sampling. No fluctuations and/or unfavourable values were recorded. During sampling events, the mean values of temperature and dissolved oxygen corresponded to 6.0, 6.0 and 5.8 °C, and 12.56, 12.48 and 8.22 mg L^{-1} on the CP, HC and PH sampling sites, respectively.

2.2 CPUE (CATCH PER UNIT EFFORT)

The CPUE approach was used to assess the fish density resulting from fish displacement close to the shore in response to cormorant feeding behaviour. Fish were caught randomly in the littoral zone by lift net (1 x 1 m, mesh size 10 x 10 mm), with 30 replicates on both ponds.

2.3 FCC (FULTON´S CONDITION COEFFICIENT)

Fulton´s condition coefficient (FCC) was calculated for all three groups (HC, PH and CP) as the ratio between fish individual weight (W in g) and total length (TL in cm):

$$FCC = (W * TL^{-3}) * 100.$$

2.4 BLOOD SAMPLING AND SSI (SPLEEN SOMATIC INDEX) ASSESSMENT

Twenty-two individuals were taken from all three sample sites (HC, CP and PH). Blood samples were immediately taken from all fish caught by lift net and during pond harvesting. An average of 0.7 ml of blood was taken from the caudal vein of each individual using a heparinised syringe fitted with a 40 x 0.5 mm single use needle (Svobodová et al., 1986). Fish blood was centrifuged (10 min., 100G) immediately after sampling and blood plasma was transferred by pipette (0.5 ml) into Eppendorf test tubes and stored at -80 °C for future analysis.

Following blood sampling, fish (length and weight determinants in Table 1) were sacrificed by overdosing with anaesthetic clove oil (0.2 ml L^{-1}). The spleen was removed and weighed to 0.001 g precision. SSI was calculated using the formula (spleen mass (g)/fish mass (g)) x 10^4 (Lai et al., 2006).

Table 1. *Length and weight data in examined fish samples.*

Pond	Sampled group	n	TL(mm)	W(g)
Naděje	HC	22	188.45 ± 18.88	109.09 ± 35.50
Naděje	PH	22	207.82 ± 25.18	151.55 ± 53.57
Láska	CP	22	198.45 ± 19.75	149.20 ± 54.51

Note: Values are mean ± s.d., HC – fish stressed by hunting cormorants, PH – fish stressed by pond harvesting, CP – control group.

2.5 PLASMA BIOCHEMICAL INDICES

Glucose and cortisol levels, assessed according to Svobodová et al. (1999), and total protein (TP) and lactate levels were used to evaluate the stress load by both cormorants and harvesting. Glucose, lactate and TP were measured using the Cobas EMira biochemical analyser (Roche Diagnostics, Switzerland) and commercial test kits. Concentration of plasma cortisol was measured using the ELISA method (Tizard 1996).

2.6 STATISTICS

All values were examined for normal distribution (Kolmogorov-Smirnov test) and homoscedasticity (Levene test). FCC, glucose and TP values were analysed using one-way ANOVA with Tukey's post hoc test, while SSI, cortisol and lactate values were analysed using the non-parametric Kruskal-Wallis test. The Student t-test was used to compare CPUE data. All data were analysed using Statistica v.8.0 software for Windows (StatSoft Inc. 1999).

3. RESULTS

3.1. CORMORANT OCCURRENCE

After three days of bird presence and activity (hunting and resting on trees along the pond shore), fish had been driven to the pond margin opposite the cormorant roosting sites. At the same time, fish displayed normal behaviour on the Láska control pond.

3.2. CATCH PER UNIT EFFORT (CPUE)

A significant difference ($P < 0.001$) was recorded between the number of fish captured in one lift net session in the littoral zone of Láska pond (CP, mean ± standard deviation = 0.9 ± 1.1) and that at the Naděje pond (HC, 43.6 ± 39.6).

3.3 SPLEEN SOMATIC INDEX (SSI) AND FCC (FULTON´S CONDITION COEFFICIENT)

Relative spleen weight was significantly lower in PH and HC fish ($P < 0.01$) than in CP fish ($P < 0.05$), while non-significant differences (ANOVA: $H(2, n = 66) = 22.393$, $P = 0.0001$) were detected between the HC and PH groups (Fig. 1a). FCC was significantly higher ($P < 0.01$) in the control group in comparison with PH and HC, though no significant differences (ANOVA: $F(2, 63) = 15.947$, $P = 0.0001$) were recorded between groups HC and PH (Fig. 1b).

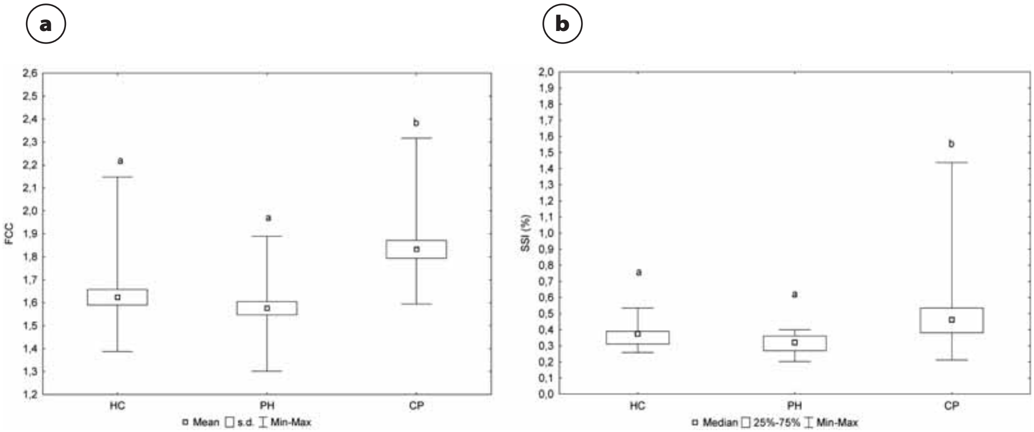

Figure 1. ***a)*** *Changes in FCC (Fulton's condition coefficient) and* ***b)*** *SSI (spleen somatic index, %) in three examined fish groups.*

Note: Data which have not normal distribution are shown as median and quartiles. HC – fish stressed by hunting cormorants, PH – fish stressed by pond harvesting, CP – control group. Values (mean ± s.d.) are: FCC in HC 1.62 ± 0.16, PH 1.58 ± 0.14, and CP 1.83 ± 0.18. SSI in HC 0.37 ± 0.07%, PH 0.32 ± 0.05%, and CP 0.54 ± 0.28%. Values that do not differ significantly (P > 0.05) share common superscripts.

3.4. PLASMA BIOCHEMICAL INDICES

The mean plasma cortisol level in PH fish was significantly higher ($P < 0.01$) than in the HC and CP groups ($P < 0.01$), while the difference between groups HC and CP was not statistically significant (ANOVA: $H(2, N = 66) = 40.752$, $P = 0.0001$) (Fig. 2a). A similar situation was recorded with glucose concentration, where the values from harvested PH fish differed significantly ($P < 0.01$) from the HC and CP ($P < 0.01$) groups. No significant difference was found between groups HC and CP (ANOVA: $F(2, 63) = 67.928$, $P = 0.0001$; Fig. 2b).

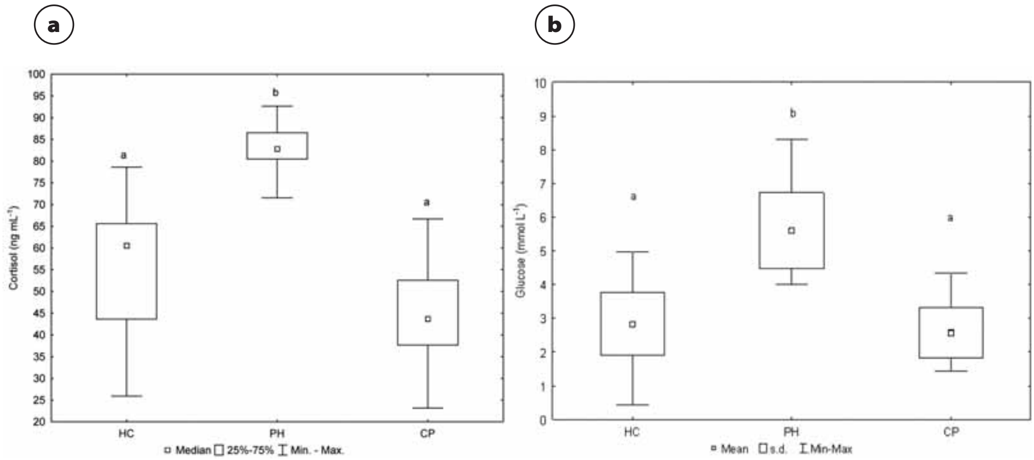

Figure 2. ***a)*** *Cortisol (ng.mL^{-1}) and* ***b)*** *glucose (mmol.L^{-1}) levels.*

Note: For abbreviations see Fig. 1. Values (mean ± s.d.) are: Cortisol in HC 56.24 ± 13.85, PH 83.0 ± 4.96 and CP 46.44 ± 16.13. Glucose in HC 2.83 ± 0.93, PH 5.67 ± 1.16 and CP 2.58 ± 0.76. Values that do not differ significantly (P > 0.05) share common superscripts.

TP assessment showed significantly higher values in the stressed HC group than in the CP group ($P < 0.01$), while comparisons of values for the PH and CP groups, and between the PH and HC groups, did not differ significantly (ANOVA: $F(2, 63) = 5.839$, $P = 0.0047$). Lactate concentration differed among treatments in a pattern similar to those of blood glucose and cortisol. The value recorded for PH fish differed significantly from the HC and CP groups (ANOVA: $F(2, 63) = 87.483$, $P = 0.0001$; Figs. 3a and b).

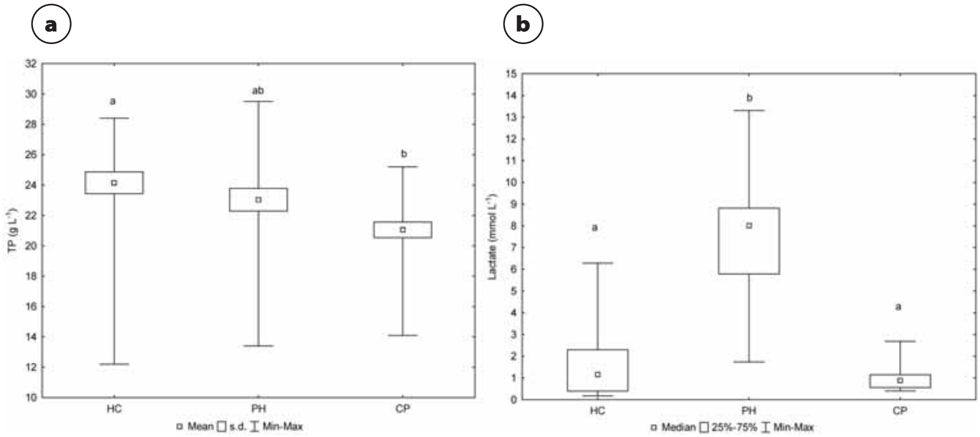

Figure 3. ***a)*** *Total plasma protein (TP, g.L⁻¹) and* ***b)*** *lactate (mmol.L⁻¹) levels.*

Note: For abbreviations see Fig. 1. Values (mean ± s.d.) are: Total plasma protein in HC 25.21 ± 6.19, PH 23.03 ± 3.41 and CP 21.04 ± 2.51. Lactate in HC 1.54 ± 1.44, PH 7.50 ± 2.74 and CP 0.97 ± 0.51.Values that do not differ significantly (P > 0.05) share common superscripts.

4. DISCUSSION

Fish movements towards the pond shoreline due to cormorant feeding activities are well known on Czech fishponds, especially during the spring (February – April) cormorant migration flights (fish farmers' reports 2000–2008). There is a lack of scientific data, however, describing this behavioural phenomenon. In the present study, the CPUE results show highly significant differences between fish numbers in the littoral zone of the pond visited by cormorants and the control pond without cormorants, indicating an immediate fish evasion response into shallow littoral areas.

Studies of fish wounded by cormorants while hunting have proved that the condition of wounded fish is significantly lower than that of fish without cormorant beak marks (Adámek et al., 2007; Kortan et al., 2008). FCC showed significantly higher values for fish from the CP group than for the HC and PH groups, probably due to energy release without food intake, though the difference between harvested fish and fish stressed by cormorants was not statistically proved. The environmental conditions in both ponds correspond to typical conditions in Czech fishponds and, therefore, these are unlikely to have affected the coefficient.

Relative weight of spleen (SSI) is frequently used as a stress indicator (Palíková & Svobodová 1995; Svobodová et al., 1998; Lai et al., 2006; Dobšíková et al., 2006). According to Svobodová et al. (1998), the SSI calculated for fish undergoing long distance transport did not show a significant decrease, though a significant decrease in SSI was demonstrated during pond harvesting (Svobodová et al., 2006).

Our study indicates a significantly higher SSI in the control CP group in comparison with the HC and PH groups, i.e. cormorant-disturbed and harvested fish. Pond harvesting appears to be a greater stressor than cormorant attack, therefore, though the differences in SSI were not significant.

Biochemical indices of fish blood plasma are also considered as indicators of stress (Svoboda 2001). Blood plasma glucose concentration is a characteristic trait utilised for the evaluation of acute stress in fish (Pottinger 1998; Bau et al., 2001; Ruane et al., 2001). Svobodová et al. (2006) proved experimentally (that glucose levels increased during pond harvesting, and that they returned to normal levels one month after the fish were transferred to storage ponds. In our study, the increase in glucose level was significantly higher in HP fish collected during harvesting, with no significant difference recorded between the control CP sample and HC fish impacted by cormorant hunting. Blood plasma samples were taken from stressed fish after the third day of cormorant presence. This delay in sampling may explain why no statistically significant difference was found between the HC and CP groups, as glucose levels can both fall over a three-day period and as the stress is unlikely to have been less acute than that experienced during pond harvesting.

Similar differences were also found in plasma cortisol. The literature indicates that cortisol levels increase in the initial stages of stress situations, but return to baseline levels within a few hours due to fish adaptation (Pickering and Pottinger 1989; Svoboda 2001). This has also been proved by Svobodová et al. (2006), where high values of cortisol during the harvesting period returned to normal after one-month storage. In the present study, high values of cortisol were found in PH fish. Fish from the control pond (CP) showed lower levels of cortisol than HC fish, though the difference was not significant. These results are consistent with the findings for blood glucose levels, i.e. the presence of cormorants is not as acute a stressor as pond harvesting, with cortisol levels decreasing slowly to normal values three days after exposure to the stressor. The increase in plasma lactate level is a result of anaerobic metabolism and reflects the imposition of severe exercise (Pottinger 1998). Lactate, as a stress indicator, was used in the study of Pankhurst and Dedualj (1994), who evaluated the effect of capture and recovery in rainbow trout (*Oncorhynchus mykiss* (Walbaum)). In their study, significant elevation of lactate level was recorded within 15 min. of capture, which decreased to normal levels within 24 h. This finding corresponds with our experiment, where the highest increase in lactate level was found in PH fish, while HC fish showed no statistically significant increase in lactate level compared to CP fish. This indicates a fall in blood lactate levels due to acclimatisation to the stressor after three days of exposure to cormorants. Total plasma protein in fish ranges from 20 to 80 g L^{-1} and appears to be fairly constant within and among species (McDonald and Milligan 1992). Stress can lead to an increase in total plasma protein. For example, in rainbow trout, an increase in TP in blood plasma was concluded to be a response to strenuous exercise (Milligan and Wood 1986) and exposure to low environmental pH (Milligan and Wood 1982). TP concentration in blood plasma decreases in the first shock phase of the stress reaction. During the anti-shock reaction phase, TP concentrations increase due to the effect of cortisol, which is responsible for protein catabolism (Novák 2002). In our investigation, the increase in TP level was significantly higher in HC fish than in CP fish, while the TP value in PH fish did not differ from HC fish and/or the CP fish. The results of TP assessment are consistent with those reported in the literature, though it remains a matter of conjecture as to why they differed from other stress indicators (cortisol, glucose and lactate), which were higher in PH fish (harvested) than in HC fish (cormorant impacted). It is highly likely that this is a matter of timing and of numbers of blood sampling repetitions.

The influence of time span between cormorants leaving and the beginning of pond harvesting is also a matter for debate. It is known that stress levels decrease with time due to adaptation and/or stressor disappearance (Pickering and Pottinger 1989). In the case of PH, which was initiated eight days after the cormorants left, stressor values (glucose, cortisol, lactate) were higher than in HC. This indicates that a co-effect of cormorant presence and harvesting was not apparent.

5. CONCLUSION

Blood plasma stress indicators (glucose, cortisol and lactate concentrations) do not indicate a significant impact of cormorant hunting activities upon fish (common carp) as their values did not differ significantly from those found in control non-impacted fish. According to our results, the stress caused by pond harvesting is a more important cause of physiological response in fish than that resulting from a three-day period of cormorant disturbance. Avoidance behaviour of fish, with resulting high densities in the pond littoral zone, was demonstrated by CPUE estimates. These phenomena indicate a distinct negative influence of the presence of cormorant flocks upon fishpond stock behaviour, with possible adverse effects on pond harvesting, starvation and subsequent fish condition, along with suppressed immunity when persisting for long periods.

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CHAPTER 5

BEHAVIOURAL RESPONSE OF CARP (*CYPRINUS CARPIO*, L.) POND STOCK UPON OCCURRENCE OF HUNTING GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*) FLOCKS

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BEHAVIOURAL RESPONSE OF CARP (*CYPRINUS CARPIO*, L.) POND STOCK UPON OCCURRENCE OF HUNTING GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*) FLOCKS

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ABSTRACT

Besides various physiological and biological indices, stress in fish can be expressed directly by changing their behaviour. Electrofishing point sampling approach based on CPUE (Catch per Unit Effort) was used to evaluate fish density (escapement) into the littoral zones of four Czech ponds as a reaction upon the occurrence and hunting activities of great cormorant (*Phalacrocorax carbo sinensis*) flocks. Fish behaviour of two-year-old common carp (Cyprinus carpio) before and after cormorant arrival was compared. Significant differences ($p < 0.001$) in CPUE were recorded in fish density before and after cormorant arrival on all of four ponds under study – Žofinský: 0.04 ± 0.18 and 22.38 ± 26.87 (mean ± SD), Starý Hospodář: 0.05 ± 0.29 and 25.49 ± 25.45, Žebrákov: 0.16 ± 0.57 and 28.58 ± 24.75 and Travičný: 0.03 ± 0.19 and 17.18 ± 18.20, respectively. The evaluation of fish wounding in the CPUE fish samples proved the proportion of fish injured by cormorant attacks ranging from 3.33 to 18.19% in the ponds under study.

Keywords: CPUE (catch per unit effort), Phalacrocorax carbo sinensis, pond aquaculture, stress

1. INTRODUCTION

In Central Europe, there is a long tradition of common carp (*Cyprinus carpio*) pond culture for human consumption. Shallow pond waterbodies which are densely stocked by carp and several other complementary fish species provide profuse food habitats for piscivorous birds. The most problematic species inducing continuously increased production losses in pond aquaculture of the Czech Republic is the great cormorant (*Phalacrocorax carbo sinensis*). Flocks of hundreds of cormorants feed on fish ponds in the periods of early spring (late February – early April) and autumnal (October – November) migrations, preferably those stocked with one- and/or two–year-old carp. Besides direct consumption, cormorants affect the pond fish stock by wounding the fish and altering their behaviour (Adámek et al., 2007a). Impact on fish can be high especially when cormorants use collective hunting in flocks in order to chase the whole shoal of fish to the centre of the hunting circle of birds or to the shallow shore so they can be easily caught. In Europe, this hunting tactic is a relatively new phenomenon, and is used as an adaptation to reduced water transparency due to eutrophication (Van Erden & Voslamber 1995). Hunting flocks of cormorants induce stress load in fish, which is expressed in their displacements into the pond shoreline as the fish strive to escape and hide in the littoral vegetation. Crowded fish stay in the pond littoral even for several days (up to one week) after birds fly away (Škrabánek, pers. comm.). This more or less continuous stress can lead to severe decrease in production, as fish do not ingest the food and/or suffer from various secondary disease events caused by starvation and subsequent losses of body and health condition (Berka 1989; Adámek 1991).

This phenomenon is well-known from Czech pond systems among fish farmers but no scientific data on crowding the fish stock to the shoreline caused by cormorant predation has been published so far. First authentic data have been recently obtained by Kortan et al., 2010. The results of this study should therefore bring the cogent data on atypical manifestation of pond fish stock behaviour in reaction to cormorants´ hunting activities, which is manifested by moving and hiding of fish in shallow littoral parts of the pond.

2. MATERIAL AND METHODS

2.1. STUDY SITES

The study was performed in March 2009 in South Bohemia pond region (Czech Republic). For the documentation of fish stock behavioural response to the cormorant hunting, four ponds were chosen on the basis of experience and recommendations of local farmers: Žofinský (ZF – 11.09 ha, 48°58´43.02´´ N; 14°52´30.73´´ E), Starý Hospodář (SH – 67.06 ha, 48°58´59.90´´ N; 14°52´16.28´´ E), Žebrákov (ZB – 12.49 ha, 48°59´42.29´´ N; 14°53´05.86´´ E) and Travičný (TR – 10.38 ha, 49°00´04.97´´ N; 14°53´52.41´´ E). All ponds belong to the fish farm Chlum u Třeboně, which represents a typical Czech carp pond farm (Fig. 1) and is managed by the Rybářství (Fishery) Třeboň Co. The ponds are used for the production of two-year-old carp.

2.2. CPUE (CATCH PER UNIT EFFORT)

To record the fish movement to the shoreline as a response to the cormorant feeding manner, the CPUE (catch per unit effort) was used. Fish were collected using backpack electrofishing equipment (Smith & Root Inc.) with a dip net of 30 cm in diameter and 30 cm height at the end of anode handle. The "point method" (Jurajda et al., 2006; Kubečka & Prchalová 2006) using 3-second exposition, 500 V, 50–130 Hz was applied in littoral zones of the ponds. On each pond, 100 m section was chosen at the part of the shore where fish were usually seen crowded in previous years. Before cormorant arrival, 55 points were sampled immediately after the ice cover melting on 13 March 2009 as a control record and 55 points after the cormorant arrival. The points were approximately equally distributed. The depth of sampling points ranged between 20 to 50 cm and distance from the shore was 1–2 m depending on the pond morphology. Sampling stretches were often canebrake (approximately 50% covered by reed, Phragmites communis, and 50% open water). From each pond, 33 randomly chosen carp individuals were weighed and measured (Table 3). Weight, length and numbers of complementary fish species were not recorded as these species are not commercially important. The fish were also examined for the presence of wounds caused by cormorants according to Kortan and Adámek 2009.

2.3. MONITORING OF CORMORANT PRESENCE

The monitoring of cormorant occurrence and movement was conducted daily at 7 am and 4 pm by the fishery staff. Stocking rates and cormorant numbers are shown in Table 1.

Table 1. Stocking rates (biomass per $kg.ha^{-1}$) and cormorant occurrence (maximum numbers per day) on the ponds under study.

Fish species		common carp			grass carp			Cormorant occurrence
Pond		year	age	density	year	age	density	
ZF	S	2007	0	~ 100 (in 2008)			0	autumn 2008 – 100 ind.
	H	2009	2	900			0	spring 2009 – 50 ind.
SH	S	2008	2	694	2008	2	67	autumn 2008 – 500 ind.
	H	supposed in 2010						spring 2009 – 500 ind.
ZB	S	2007	1	1994			0	autumn 2008 – 100 ind.
	H	2009	2	931			0	spring 2009 – 100 ind.
TR	S	2007	0	~ 100 (in 2008)	2007	0	77	autumn 2008 - 0
						2	73	spring 2009 – 100 ind.
	H	2009	2	481	2009	2	17	
						4	0	

Note: ZF – Žofínský, SH – Starý Hospodář, ZB – Žebrákov, TR – Travičný, common carp – *Cyprinus carpio*, grass carp – *Ctenopharyngodon idella*, S – stocked, H – harvested.

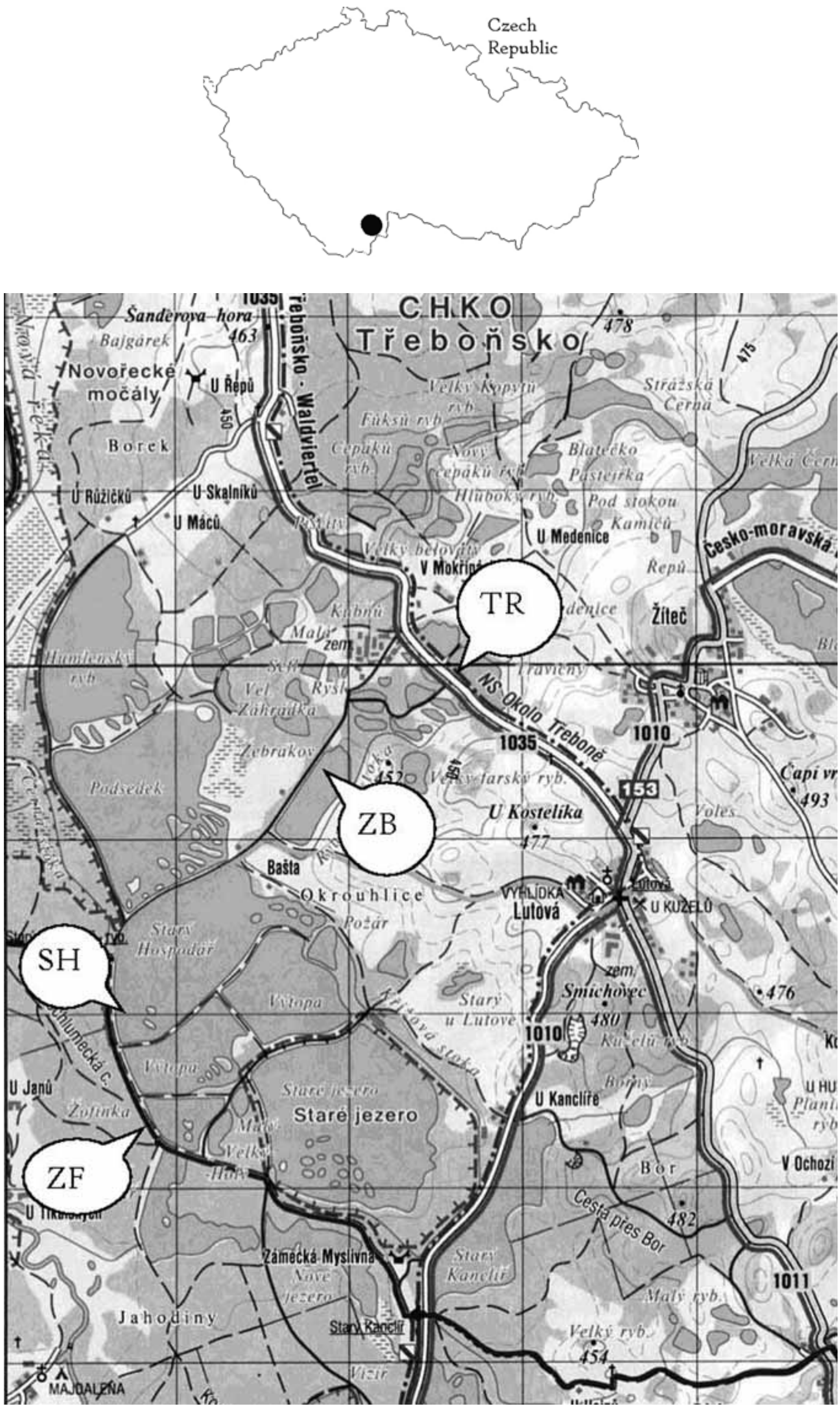

Figure 1. *Location of studied ponds in the Třeboň pond area.*

2.4. WATER ENVIRONMENTAL PARAMETERS

Water environmental parameters, namely temperature, concentration of dissolved oxygen, pH, conductivity (WTW Multi 340i) and turbidity (WTW Turb 430 IR) were measured before cormorant occurrence and during sampling events following the attack when fish were crowded along the shoreline at 60 cm depth nearby the pond dam (Table 2).

Table 2. *Water parameters of the ponds before (B – 13/03/09) and during fish crowding due to cormorant presence (D) on 15/03/09 (ZF), 16/03/09 (SH) and 19/03/09 (ZB and TR).*

Pond	T °C		O_2 mg.l^{-1}		pH		turbidity NTU		conductivity mS.m^{-1}	
	B	D	B	D	B	D	B	D	B	D
ZF	3.5	5.8	12.75	9.82	7.50	7.30	2.95	3.51	12.0	10.9
SH	3.7	5.9	14.30	12.21	8.50	8.27	3.98	5.09	17.0	18.3
ZB	3.0	4.9	15.32	13.25	8.00	8.32	6.23	7.06	18.9	19.6
TR	3.6	5.4	15.80	12.50	7.60	6.90	7.80	6.30	17.1	18.3

2.5. STATISTICS

For the statistical evaluation of CPUE data, the non – parametric Wilcoxon pair test was applied. The data were analysed using Statistica v.8. (StatSoft Inc. 1999) software.

3. RESULTS

The CPUE values in littoral zones were significantly higher in the period of cormorant occurrence on all four afflicted ponds (Fig. 2). On the ZF pond, the first flock of 50 cormorants was observed feeding on 14 March and fish stock response in crowding along the shoreline was recorded on 15 March. Fish were crowded in a 150 m long zone of the littoral vegetation (Fig. 3). The CPUE value before their arrival corresponded to 0.04 ± 0.18 (mean ± SD), while in the period of cormorant occurrence significantly higher numbers (22.38 ± 26.87, $p < 0.001$) were recorded.

On the biggest of all monitored pond sites (SH), fish behavioural response was recorded on 16 March, when 500 cormorants occupied the water surface and trees on the pond dam and hunted collectively during the day. The majority of crowded fish were hidden in the branches of fallen oak tree and under the small feed storage shed in the water. The total length of the shoreline with crowded fish was 120 m. The CPUE values without and with cormorant occurrence were significantly different ($p < 0.001$) corresponding to 0.05 ± 0.29 and 25.49 ± 25.45 individuals, respectively.

On ZB pond, the flock of 100 hunting cormorants was recorded on 19 March. Many fish were found hidden in a big fallen tree within 5 hours after cormorant arrival. A significant difference ($p < 0.001$) was recorded between CPUE on this pond without cormorant occurrence (0.16 ± 0.57) and after their arrival (28.58 ± 24.75).

On the TR pond, 100 cormorants were recorded the first in the morning of 19 March. The differences in CPUE before and after cormorant arrival were highly significant (0.03 ± 0.19 and 17.18 ± 18.20, respectively, $p < 0.001$). The median values for all ponds are shown in Fig. 2.

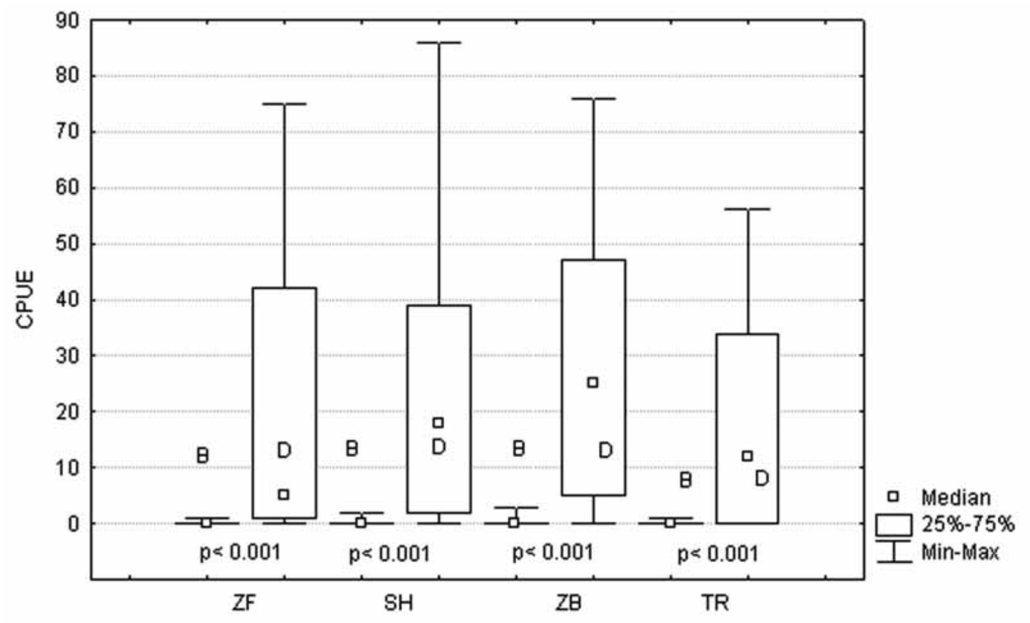

Figure 2. *CPUE (Catch Per Unit Effort) values (median and quartiles) in the pond littoral before (B) and during (D) fish crowding due cormorant presence.*

Monitoring of beak marks (wounds) on fish revealed that from 33 individuals taken from each pond (ZF, SH, ZB and TR), 1, 2, 6 and 2 fish individuals respectively bear new injuries caused by cormorant attacks (Table 3)

Table 3. *Length-weight determinants of fish sample from afflicted ponds and the number of fish wounded by cormorants.*

Pond	Carp form	n	TL (mm)	W (g)	Wounded fish (n)
ZF	MC	16	165 ± 20.56	64.0 ± 23.45	1
	SC	17	142 ± 15.72	43.0 ± 14.85	0
SH	MC	30	143 ± 22.95	50.6 ± 25.20	2
	SC	3	122 ± 14.72	24.1 ± 7.05	0
ZB	MC	30	218 ± 25.12	167.6 ± 59.62	6
	SC	3	251 ± 55.15	272.1 ± 181.09	0
TR	MC	27	234 ± 19.38	205.2 ± 53.54	2
	SC	6	174 ± 82.38	148.6 ± 177.9	0

Note: mean values ± standard deviation, M – mirror carp and SC – scaly carp.

Complementary fish species, roach (*Rutilus rutilus*) and rudd (*Scardinius erythrophthalmus*), were also recorded in small numbers in the catch after cormorant arrival on all study sites. Several individuals of topmouth gudgeon (*Pseudorasbora parva*) were recorded on the ZB pond during control sampling. However, during the sampling after cormorant arrival this species did not occur in any sample.

Figure 3. *Two-year-old carp crowding and hiding in littoral plant beds during hunting activities of about 500 cormorant flock (Žofínský on 16/03/09).*

4. DISCUSSION

The water environment determinants corresponded to the range required for successful carp pond culture after the overwintering period (Čítek et al., 1998) both before and during fish crowding along the shorelines due to cormorant occurrence. Thus, their values did not affect fish behaviour.

CPUE values on all (ZF, SH, ZB and TR) ponds correspond to the figures recorded by Kortan et al. 2010 who compared the CPUE in shorelines of two ponds with and without cormorant presence. Significant differences ($p < 0.001$) were recorded between CPUE of fish numbers captured by 1 x 1 meter lift net drive on the pond with hunting cormorants (43.6 ± 39.6) and without cormorant presence (0.9 ± 1.1). The sampling distance between points was very short in this study (55 points on 100 m stretch) which might affect the results under usual conditions. However, the numbers of fish caught in neighbouring points were very similar and very high, even when walking and sampling in chased school of fish. Fish behaviour proved signs of strong disorientation and stress due to cormorants´ occurrence. Nevertheless, majority of fish were hidden in littoral refuges (branches, vegetation), which may advert to conscious behaviour. No other data dealing with the phenomenon of fish displacement due to cormorants feeding habits have been recorded or published so far.

Fish stress response to disturbances caused by piscivorous predators was also studied by Poledník et al. (2008) who observed the impact of Eurasian otter (*Lutra lutra*) feeding on the stock of carp ponds. The study was based on plasma biochemical indices assessments aimed at cortisol, glucose and lactate concentrations. Physiological and biochemical indices regarding fish stress response upon some technological operations in carp pond farming have been recently described (Svobodová et al., 1999, 2006; Dobšíková et al., 2006), but there is a significant lack of any conclusive data with respect to fish behavioural physiology and movements (displacements) in pond during their culture. Bauer & Schlott (2004) studied fish stock behaviour during overwintering and fish reaction to the oxygen deficiency using radio telemetry, which provides accurate data on fish location. However, this approach is feasible only on small (≤ 2 ha) pond areas. Carp ponds visited by cormorants during their spring and autumnal migration flights are usually much bigger with significant preference for ponds > 10 ha (Adámek et al., 2007b), which makes the fish radio telemetry monitoring hardly practicable.

Fish wounding by cormorants as a secondary impact on fish stock has been widely reported in the literature (Berka 1989; Adámek 1991; Poór 2005; Grémillet et al., 2006; Adámek et al., 2007a; Kortan et al., 2008). The common conclusions of these authors that mainly two-year-old mirror carp suffer from wounding by cormorants is in accordance with our findings, where two-years-old mirror carp were injured by cormorant attacks on all four studied ponds. The proportion of the fish stock injured by cormorants, reported during harvesting at neighbouring localities in previous season (2008), ranged between < 1 to 47.4% (Kortan et al., 2008). These figures correspond to our results, where these amounts varied between 3.00% and 18.19% on the ZF and TR ponds, respectively. As proved already in previous studies (Adámek et al., 2007a; Kortan and Adámek 2009), the scaly form of common carp is less responsive to wounding by unsuccessful cormorant attacks than mirror carp with body surface unprotected by scales. All fish with marked cormorant beak marks belonged to the mirror form, whilst no scaly form carp were found to be wounded by cormorants (Table 3). However these data may be influenced by higher quantity of mirror carp in the sample.

Several individuals of topmouth gudgeon recorded during the control sampling before cormorant arrival may indicate relatively strong population of this species on the ZB pond. Due to its small size, this species may effectively occupy different refuges inaccessible for cormorants in the littoral after cormorant attack which explains why no individual was recorded among crowded fish. Despite its small size, topmouth gudgeon was reported as a regular cormorant food item from the South Moravian (Czech Republic) ponds (Adámek et al., 2007b) probably due to its numerous occurrence in pond ecosystems all over the country.

According to the experience of fish farmers, subsequent problems may appear during spring pond harvesting when fish stressed by cormorants do not follow the water level decline and stay in the littoral. Their presence in shallow parts of pond makes the regular course of fish netting in a harvesting pit complicated and also makes them easily affordable to other predators, grey herons (*Ardea cinerea*) and white herons (*Egretta alba*) in particular (Škrabánek, pers. comm.). The fact that fish crowded in the pond shoreline could be caught to only with a landing net without electrofishing equipment even in repeated trials proves high level of stress and the absence of normal behaviour among crowded fish.

5. CONCLUSION

Collective hunting of cormorants can significantly alter behaviour of fish stock in carp ponds. Shoals of fish chased by hunting birds take refuge in the littoral zone of the pond, where they stay crowded along the shoreline in order to hide in reed beds and wooden debris. Fish with low energy deposits after overwintering period which suffer from starvation and stress during the period of spring cormorant occurrence may be more susceptible to loss of body condition and subsequently to diseases and parasite invasions. The more accurate data on the time period spend by stressed fish stock in the littoral without feeding, loss of fish weight and mortality during this period, susceptibility to parasite invasions as well as to predation by other piscivorous predators are needed to evaluate the impact of cormorants on pond aquaculture production more exactly.

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CHAPTER 6

PARASITE INFECTION AND BODY CONDITION OF COMMON CARP WOUNDED DURING GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*) ATTACKS

Ondračková, M., Valová, Z., Kortan, J., Vojtek L., Adámek Z., 2010. Parasite infection and body condition of common carp wounded during great cormorant (*Phalacrocorax carbo sinensis*) attacks. Veterinary Parasitology. (submitted)

PARASITE INFECTION AND BODY CONDITION OF COMMON CARP WOUNDED DURING GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*) ATTACKS

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ABSTRACT

Fish wounded by cormorants during their hunting activities may suffer from increased susceptibility to the infections and consequently decreased body condition. Two-year old stocked common carp *Cyprinus carpio* harvested in late March were examined for ecto- and endoparasites, injuries extent and lysozyme concentration in skin mucus. Additionally, four body condition indices were measured. Endoparasite infection occurred only scarcely. Higher vulnerability to ectoparasite infection in wounded fish was confirmed for three parasite taxa; increased abundance in monogenean *Gyrodactylus* spp. and *Dactylogyrus* spp. and intensity of infection of *Ichthyophthirius multifiliis* were observed, whilst the intensity of *Eudiplozoon nipponicum*, *Argulus* spp. and *Trichodina* spp. infection did not differ between wounded and control fish. Lysozyme concentration in fish mucus was significantly higher in wounded fish, and was positively associated with the extent of damaged epithelium and *Gyrodactylus* spp. abundance. Concerning fish body condition, there were no differences in Fulton's condition factor, lipid content in muscle and liver tissues between wounded and control fish in both scaly and mirror carp. Higher values of spleen-somatic index in wounded fish corresponded to increased intensity of parasite infection, probably related to increased requirements on fish immune system. Although our results did not show any significant effect of cormorant attacks on fish condition, wounded fish suffered with higher intensities of ectoparasite infection what may have additional consequences in the subsequent growing season.

Keywords: Parasite infection, fish condition, Phalacrocorax carbo sinensis, common carp

1. INTRODUCTION

The impacts of great cormorants (*Phalacrocorax carbo sinensis* L.) on fish stock are currently a regularly discussed issue. The predation of migrating northern cormorant populations on commercial fish ponds in Central Europe is considered to be a serious problem particularly during the period of birds' spring and autumnal migration flights (Adámek and Kortan 2002). The damage to fisheries caused by cormorant predation pressure originally consists of losses due to direct consumption of fish. Besides that, cormorants may cause also subsequent indirect losses elicited by cormorant feeding activities resulting in fish wounding and stress (Kortan et al., 2008). Although cormorants are regarded as highly efficient predators, they abort about half of their pursuits (Grémillet et al., 2006). Affected fish, which escaped from cormorant's beak grip or which cannot be swallowed due to their size (Moerbeek et al., 1987), suffer from various deep or surface injuries.

The wounds caused by cormorants, consisting of perforated skin as triangle shaped injury on one body side and scars and contusions on the other side (Carss 1990), are then a frequent precursor to subsequent infection or mortality. Consequently, weakened fish are more susceptible to predation, succumb various diseases and loose their market value (Poór 2005).

Increased susceptibility of infected host to predation is often associated with an impact of parasites with indirect life cycles, which transmissibility depends on the ingestion of infected prey. Fish eating birds represent an important group of hosts with wide range of parasite species using fish as an intermediate host (Sitko et al., 2006). Therefore, the first objective of this study focused on parasites as a potential cause of increased fish susceptibility to the bird predation. Trophically transmitted parasites may increase their transmission efficiency by altering the behaviour of infected host to increase their susceptibility to predation by final host (Barber et al., 2000). Therefore, we predicted that fish infected by endoparasites (mainly their larval stages) are more susceptible to bird attacks.

In the second hypothesis, we predicted that wounded fish with various levels of injuries will be more susceptible to ectoparasite infections, as indicated in publications describing the losses in fish ponds after the cormorant attacks (Poór 2005), although recent studies did not support this general assumption (Kortan et al., 2010a). In the last objective, we hypothesised that fish affected by cormorant wounding together with possible secondary infections will tend to have lower condition status. This effect was already tested comparing fish from ponds with and without cormorant presence (Kortan et al., 2008). In this study, both wounded and control fish originated from the same pond and were therefore exposed to identical external conditions.

2. MATERIAL AND METHODS

2.1. FISH SAMPLING

Two-year-old common carp (*Cyprinus carpio* L.), standard length 130–253 mm (mean 178 ± 31 mm) were collected in the Týnský pond (25.46 ha), which belongs to the Rybníkářství ("Pond Fisheries") Pohořelice Co. (South Moravia, Czech Republic). Fish stock (244 $kg.ha^{-1}$, 1+ fish) was composed of typical pond polyculture species, i.e. common carp (84.5% total biomass), grass carp, *Ctenopharyngodon idella*, (8.0%), silver carp, *Hypophthalmichthys molitrix*, (1.6%), bighead carp, *Aristichthys nobilis*, (1.6%), zander, *Sander lucioperca*, (0.2%), pike, *Esox lucius*, (3.2%) and European catfish, *Silurus glanis*, (0.9%). Mean monthly numbers of hunting cormorants on the pond amounted to 179 and 211 individuals in October and December, respectively. Since January, no occurrence of cormorants was recorded.

Fish were captured by seine netting during early spring (26 March, 2009) pond harvesting. Twenty four fish with distinct wounds and 25 non-wounded control fish were individually placed into the plastic bags filled with original pond water and transported under oxygen atmosphere to the laboratory for further examination. In the laboratory, the fish were sacrificed by cutting the cervical spine prior to consecutive procedures. Standard length (SL, to the nearest mm), total and eviscerated body weight (W and WE, both to the nearest g), and weight of liver and spleen (WL and WS, both to the nearest mg), were measured.

2.2. DESCRIPTION OF THE WOUNDS

Immediately after killing the fish, digital images of individual wounded fish were provided by camera (Panasonic Lumix FZ 50). The images were processed by means of the image analyser (Olympus MicroImage 4.0) using the manual measurement mode. The extent of injuries was calculated as a percentage of wounded area from the total body surface. The injuries were distinguished as scars (surface wounds) and necroses (deep wounds perforated the fish skin). For details see Kortan et al. (2008).

2.3. PARASITOLOGICAL EXAMINATION

Individual fish were examined under binocular microscope for the presence of metazoan parasites according to standard methods. Ectoparasites infecting skin, fins and gills were identified to the genera (*Trichodina*, *Gyrodactylus*, *Dactylogyrus*, *Argulus*) or species (*Ichthyophtirius multifiliis*, *Eudiplozoon nipponicum*) levels. Collected endoparasites located in the intestinal organs, eyes and muscle tissue, were preserved in 4% formaldehyde. Prior to species identification, digenean and cestodes were stained in ferric acetocarmine (IAC), dehydrated in gradual alcohol series, and mounted into "Canada" balsam. Endoparasite species were identified using a light microscope.

2.4. LYSOZYME CONCENTRATION

The amount of lysozyme was assessed *in vitro* by radial diffusion in agarose gel mixed with *Micrococcus luteus* (CCM 169). Samples of 5 μl of mucus from individual fish were applied into the well cut in the agarose placed in glass plates, and incubated at room temperature (20 °C). After 24 h, mean diffusion zone was measured and the amount of lysozyme in the sample was converted to mg per ml of mucus according to calibration curve (for details see Poisot et al., 2009).

2.5. FISH CONDITION

Three indices of fish condition were calculated for each individual fish: (1) Fulton's condition factor: $K = WE * 10^5/SL^3$; (2) Hepatosomatic index: $HSI = WL * 10^2/WE$; (3) Splenosomatic index: $SSI=WS * 10^3/WE$; using WE and weight of organs in g and SL in mm. For the lipid content evaluation, a subsample of hypaxial muscle tissue (5.3 ± 2.4 g) and liver tissue (3.1 ± 0.7) were weighed to the nearest 0.0001 g, rinsed six times over six hours (or longer) in petroleum ether to extract soluble nonstructural fats, dried overnight at 40 °C, and reweighed. The lipid content was quantified as the residual from least-squares linear regression of mass of somatic fat (calculated as pre-extraction mass minus post-extraction mass) on pre-extraction mass (Marsh-Matthews et al., 2005).

2.6 DATA ANALYSES

Epidemiological parameters of parasite infection (prevalence, abundance and intensity of infection) were used according to Bush et al. (1997). In *Trichodina* spp., three levels of intensity of infection were used for each location (individual fins, gills and body surface): occasional (1), common (2) and extensive (3).

The mean of these values for each fish was used as a mean abundance for comparative analyses. For data analyses, all parasite abundance data were log(x + 1) transformed, and arcsin transformation was used for percentage data (wound extent). No differences between scaly carp and mirror carp were found for parasite infection and lysozyme concentration (MW-*U* test); hence both, scaly and mirror carp, were evaluated altogether. Non-parametric Mann-Whitney *U* tests (MW-*U*) were used for comparisons of parasite abundance between wounded and control fish. The association between parasite abundance, lysozyme concentration and wound extent was analyzed using Spearman rank correlation test.

Parametric t-tests were used for comparison of K, HSI, SSI, lipid content in the muscle and liver tissue and lysozyme concentration between wounded and control fish.

Four of the five condition indices measured showed significant difference in mean values between mirror and scaly carp, therefore fish condition was analysed for both carp forms (scaly and mirror) separately. All analyses were performed using Statistica 9 for Windows (StatSoft Inc.). For all data, the significance of fixed effects was set at $p < 0.05$ and the trends were discussed when $0.05 < p < 0.1$.

3. RESULTS

3.1. WOUND EXTENT

The total value of epithelium damage extent ranged from 0.2 to 30% and 1.3 to 12.7% of the fish body surface in wounded scaly carp and mirror carp, respectively. Presence of scars was more frequent in mirror carp (71.4% of fish) compared to scaly carp (5.9%). Necroses occurred only in mirror carp (42.9%) and the scale losses were registered in 76.5% of scaly carp. Secondary fungal infection was recorded in both scaly carp (64.7%) and mirror carp (57.1%). Mean extent of injuries caused by cormorants expressed as a percentage of the total body surface is shown in Table 1.

Table 1. *Evaluation of the wound extent caused by cormorants in scaly and mirror carp, expressed in percentage (mean ± standard deviation) of the total body surface.*

	N	Scars	Necroses	Fungi	Scale losses	Total
Scaly carp	17	0.03 ± 0.1	0	6.3 ± 7.9	7.4 ± 6.6	13.7 ± 8.7
Mirror carp	7	1.6 ± 1.2	1.2 ± 1.9	2.5 ± 3.6	0	5.3 ± 3.3

3.2. PARASITE INFECTION AND LYSOZYME CONCENTRATION

Endoparasite infection was extremely low in general. Five taxa, namely metacercariae of *Apharyngostrigea cornu* (Digenea, located in peritoneal cavity), metacercariae of *Tylodelphys clavata* (Digenea, located in vitreous humour), and larva of *Proteocephalus* sp. and adult *Khawia sinensis* (Cestoda, both of them located in the intestine), were recorded in only one fish. Metacercariae of *Diplostomum* spp., Digenea, located in eye lens, were found in 66% of all fish with mean abundance 1.3 and maximum intensity of infection 4 metacercariae per fish. No difference in *Diplostomum* spp. abundance was found between wounded and control fish (MW-*U* test: $U = 292.5$; $Z = 0.378$; $p = 0.705$).

Ectoparasites were represented by six taxa (Table 2): *Ichthyophthirius multifiliis* and *Trichodina* spp. (Ciliophora), *Dactylogyrus* spp., *Gyrodactylus* spp. and *Eudiplozoon nipponicum* (Monogenea), and *Argulus* spp. (Crustacea). No differences in parasite abundance between wounded and control fish were found for *Ichthyophthirius*, *Trichodina*, *Eudiplozoon* and *Argulus*, but the mean intensity of *I. multifiliis* infection was significantly higher in wounded fish (MW-*U* test: U = 31.5; Z = -2.53; p = 0.011). Higher abundance of *Dactylogyrus* spp. (MW-*U* test: U = 151.0; Z = -2.97; p = 0.003) and *Gyrodactylus* spp. (MW-*U* test: U = 180.0; Z = 2.39; p = 0.017) was recorded in wounded fish, in comparison to control fish individuals. Increased abundance of *Gyrodactylus* spp. was registered on fins and body surface as well as on gills (Fig. 1a, b, c). Parasite abundance was not associated with the extent of damaged epithelium (p > 0.05 for all parasite taxa)

Table 2. *Prevalence (P, in %), abundance (A) and range of intensity of ectoparasite infection (min-max) in wounded and control carp.*

	Wounded fish			Control fish		
***Parasite* taxa**	**P (%)**	**A**	**Range**	**P (%)**	**A**	**Range**
Trichodina spp.	95.8	0.9		96	0.6	
Ichthyophthirius multifiliis	50	3.1	1–21	52	1.0	1–4
Gyrodactylus spp.	100	113.8	18–3756	100	475.7	6–774
Dactylogyrus spp.	91.7	27.7	3–81	92	11.9	1–43
Eudiplozoon nipponicum	45.8	0.58	1–2	44	0.52	1–2
Argulus spp.	29.2	0.46	1–3	36	0.44	1–2

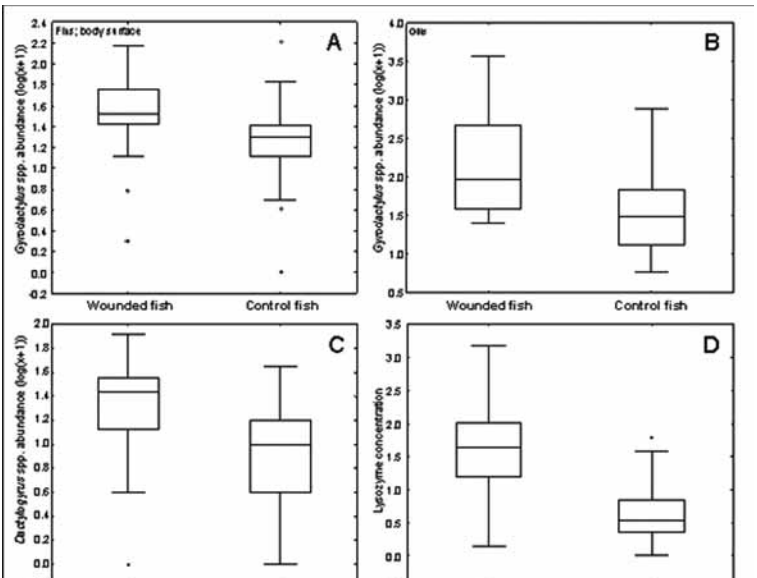

Figure 1. *Abundance of Gyrodactylus spp. located in fins and body surface (a) and gills (b), abundance of Dactylogyrus spp. (c) and lysozyme concentration (d) in wounded and control carp. Boxes are the second and third quartiles, whiskers limits are minimum and maximum; — median; O outliers.*

Lysozyme concentration was significantly higher in wounded fish ($t = 5.49$; $p < 0.0001$; Fig. 1d). Lysozyme concentration significantly correlated with the wound extent in wounded fish ($N = 24$, $r_s = 0.65$, $p < 0.001$) and this trend was consistent when analysing wounded and control fish altogether ($N = 49$, $r_s = 0.72$, $p < 0.001$; Fig. 2). There was no association between lysozyme concentration in fish skin mucus and abundance of ectoparasite infection except for Gyrodactylus spp. ($N = 49$, $r_s = 0.38$, $p = 0.008$).

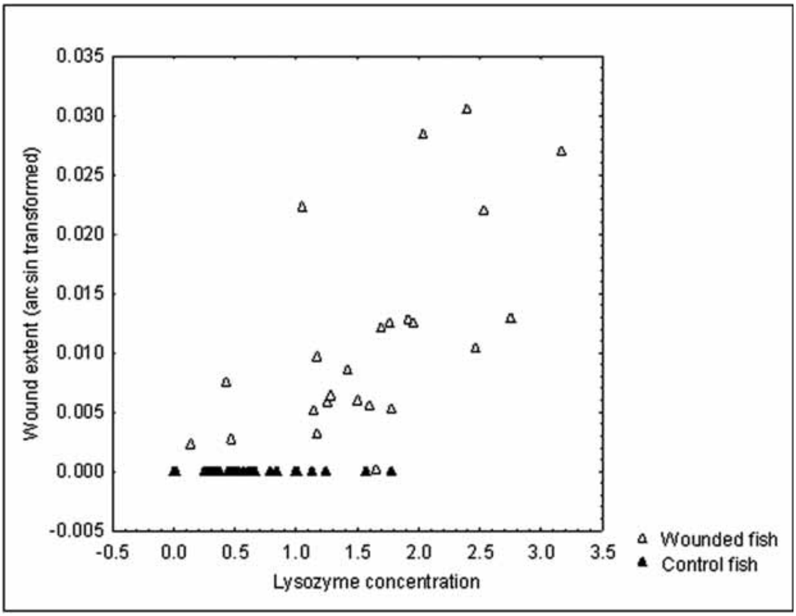

Figure 2. *The relationship between lysozyme concentration and wound extent after great comorant attacks. White triangles – wounded fish, black triangels – control fish.*

3.3 FISH CONDITION

Fulton's condition factor did not differ between wounded and control fish in both scaly and mirror carp (t-tests; $p > 0.05$). Identical results were found in the lipid content in muscle tissue. HSI was significantly higher in wounded scaly carp ($t = 3.33$; $p < 0.01$), but the lipid content in the liver tissue did not differ between wounded and control fish. No differences in HSI and lipid content in the liver tissue were found in mirror carp. Significantly higher values of SSI in wounded fish were found in mirror carp ($t = 3.67$; $p < 0.01$), whilst only marginally significant difference with the same trend was found in scaly carp ($t = 2.02$; $p = 0.05$).

4. DISCUSSION

Cormorants are perceived to cause damage to fisheries in several ways: by direct fish consumption, by fish scaring and altering their behaviour, and by wounding fish, consequently increasing their susceptibility to disease and/or reducing their commercial value (Davies and Feltham 1995). This study targeted the last point, focusing on potential higher susceptibility to infections and body condition decrease in common carp pond stock.

Cormorants are frequent hosts for many endoparasite species using fish as intermediate hosts in their life cycles (Sitko et al., 2006). However, the infection of larval endoparasites in stocked carp was extremely rare in general; only eye fluke *Diplostomum* spp. occurred more frequently in eye lens of both wounded and control fish. The infection of eye fluke in aquacultures is relatively common (Buchmann and Bresciani 1997; Overstreet and Curran 2004). The importance of these parasites consists of direct reduction of fish vision ability by lodging in the eyes and inducing cataract formation, which gives them the opportunity to affect fish antipredator behaviour (Seppälä et al., 2005), or reduction of fish feeding efficiency and growth (Crowden and Broom 1980). In our study, the maximum intensity of this parasite infection was four metacercariae per fish. Moreover, there was no difference between wounded and control fish in the intensity of infection. Thus, there was no evidence that more infected specimens were attacked more frequently by cormorants in this study.

Skin epithelium and mucous secretion represent passive physical barriers as a component of innate protective mechanisms in fish (Davis et al., 2002). Damaged epithelium thus does not perform its function and increases infection risk, primarily caused by microparasites. Despite no difference in protozoan (*Trichodina* spp. and *Ichthyophthirius multifiliis*) abundance between the fish groups, wounded fish infected with *Ichthyophthirius* showed significantly higher intensity of infections compared to the control fish. However, the prevalence of infection was comparable and the intensity did not increase with wound extent. The ciliate *Ichthyophthirius multifiliis* is one of the most widespread parasites of freshwater teleost with wide geographical range. Ichthyophthiriosis accounts for significant economic losses to the aquaculture industry (Matthews 2005). Increased susceptibility to *Ichthyophthirius multifiliis* induced by stress was found in handled channel catfish (Davis et al., 2002), probably due to suppression of an innate protection mechanism, or in fish exposed to pollutants (Ewing et al., 1982). Although the maximum intensity of *Ichthyophthirius multifiliis* infection in wounded fish was five-times higher than in control fish, it was still relatively too low to display any pathological effect on its host.

Perforated fish skin represents convenient environment for successive progress in bacterial and viral infections but these were not investigated in this study. Alternatively, concentration of lysozyme in fish mucus was measured, reflecting increased activity against microbial infection. Lysozyme is an important defence molecule of the innate immune system, possessing a lytic activity against bacteria (Saurabh and Sahoo 2008). Wounded fish showed significantly higher concentration levels of lysozyme in the mucus compared to the control fish and, moreover, the lysozyme concentration was positively associated with the extent of injury. Therefore, the increased lysozyme level could indicate increased activity against microbial diseases in injured fish and/or a response of fish organism to crowding stress (Caipang et al., 2009), or combination of both indications.

Serum lysozyme in fish can alter also in response to parasite infections. Increase in lysozyme activity was found in trout infected by organism *Ichthyophthirius multifiliis* (Alvarez-Pellitero 2008), but these results were not confirmed in this study. Although the direct association with metazoan ectoparasites such as monogenea was not confirmed (Buchmann and Lindenstrøm 2002), lysozyme concentration was positively correlated with *Gyrodactylus* infection, including both microhabitats – fish body surface, fins and gill surface.

Monogeneans, due to the direct life cycle, are important parasites especially in aquacultures (Andersen and Buchmann 1998). Among them, gyrodactylids are considered to be the most invasive fish parasites, due to their reproduction strategy (Blažek et al., 2008).

Gyrodactylids are viviparous; the new-born worms are fully grown and able to parasitize the fish host immediately. This process allows a rapid increase of the population size in a relatively short period of time, which can have a negative effect on condition and survival of the fish host (Bakke et al., 1992). Extremely high increase in intensity of *Gyrodactylus* infection was observed only in wounded fish, when several fish were parasitized with more than 1000 worms. Transmission and dissemination of gyrodactylids is also affected by stress-induced immunosuppression (Harris et al., 2000). In particular, stressful conditions have an immunosuppressive effect and may affect disease resistance (Oppliger et al., 1998). Increased fish density in the pond littoral zone after cormorant attacks resulting in crowding stress (Kortan et al., 2010a) may be an important factor for increased possibility of gyrodactylid transmission.

Decreased condition in fish affected by cormorant predation pressure in comparison to fish from ponds without predatory birds' occurrence was documented by Kortan et al. (2008, 2010b). In contrary, no differences in somatic condition (condition factor, lipid content in muscle and liver tissue) were observed between wounded and control fish inhabiting the same pond,. Two explanations may be used for the clarification of this discrepancy. Firstly, both wounded and control fish were stressed by presence of cormorants, therefore condition factor was decreased in both groups. Secondly, fish were collected and examined several months after the main cormorant attack. Therefore, heavily affected fish in low condition might have died during the winter and only fish with sufficient energy reserves survived. Nevertheless, quite probably, both approaches might be valid.

Relative weight of spleen (splenosomatic index) can be successfully used as a stress indicator (Palíková and Svobodová 1995). Our results showed significantly (or a tendency to) increased splenosomatic index in fish stressed by cormorant wounding compared to the control fish. In contrary, Kortan et al., 2010a found opposite results – fish stressed by cormorant disturbance and harvesting had lower SSI in comparison to control group. Thus, increased spleen weight in wounded fish, as well as increased liver weight in scaly carp, found in this study might have consequences with increased infection level (Seppänen et al., 2009).

Contrary to parasite infection, fish condition indices showed differences between scaly and mirror carp. Fish with scaly cover are more resistant against injuries caused by cormorant attacks (Adámek et al., 2007). Whilst mirror carp suffered by heavier damages (scars, necroses), secondary fungal infections were present more often in scaly carp, predominantly located on the epithelium damaged by loss of scales. Anyway, the relation of fish condition to wound extent was more or less comparable for both fish forms.

Although increased parasite abundance and the extent of injury in wounded fish was not reflected in host's condition, possible effects during the subsequent growing season must be considered. Parasites are known to affect the life-histories and fitness of their hosts. Thought wounded fish survive the winter and maintain its good somatic condition, they suffer with increased ectoparasite infection. Therefore the negative impact may be manifested indirectly in the subsequent year.

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CHAPTER 7

GENERAL DISCUSSION ◆ ENGLISH SUMMARY ◆ CZECH SUMMARY ◆ ACKNOWLEDGEMENTS ◆ TRAINING AND SUPERVISION PLAN DURING STUDY ◆ CURRICULUM VITAE

GENERAL DISCUSSION

Secondary impacts of fish-eating predators, mainly otter (*Lutra lutra*) and great cormorant (*Phalacrocorax carbo*) on fish stock are often registered, but not presented on appropriate level supported by exact scientific data. Above all, the cormorant impacts are currently a regularly discussed issue and cause serious conflicts between fisheries and nature protection. Current thesis presented results of several observations which could particularly help in the solving of cormorant – fisheries contradiction. For practical use could be very helpful during the process of requesting for compansation of damages.

COMPUTER-ASSISTED IMAGE ANALYSIS IN THE EVALUATION OF FISH WOUNDING BY CORMORANT [*PHALACROCORAX CARBO SINENSIS* (L.)] ATTACKS

Cormorants do not cause economic losses only by their direct fish consumption but they also harm fish during hunting (Berka 1989; Adámek 1991). The extent and character of wounds differ considerably with respect to fish species and size categories, including differences between mirror and scaly carp strains. In our study, highest total extent of superficial wounds (27.5 ± 10.92%) was registered in the form of scars in one-year-old mirror carp (145.0 g), while in two- year- old (207 g) mirror carp was impacted area much smaller (4.3 ± 2.40%). The size of wounded fish was smaller than reported by Moerbeck et al. (1987) who studied the impact of cormorants on carp in ponds in the Netherlands and found that fish up to 550 g were eaten by cormorants but that fish up to 700 g were subject to severe wounding and only carp over 1000 g appeared to be completely safe from cormorant attacks. Also Davies et al., 1995 concluded in his study from north-west England, that cormorants have inflicted wounds on a variety of cyprinid species including 33–53 cm carp, which means the upper value represents fish over 2 kg. The extent of injures was also studied by Seiche and Wünsche (1996), who clasify the wounds to four levels according to its size and age from old scared contusions to deep bloody holes perforate the skin. The size of the most injured fish ranged from 26 to 35 cm which approach to the results of our study. However, the size of fish wounded by cormorant depends above all on locality on which the birds feed.

INDIRECT MANIFESTATION OF CORMORANT (*PHALACROCORAX CARBO SINENSIS* (L.)) PREDATION ON POND FISH STOCK

Beyond direct consumption of fish, cormorants are accused of injuring vast number of prey fish without eating them (Gremillet et al., 2006). In our study on the several Czech fish-ponds, which are typical feeding sources for cormorants, the quantity of damaged fish ranged from 1 to 47% on individual ponds, which corresponds to data of Poór (2005) who concluded that the amounts of fish wounded by cormorants preying on ponds are high and may reach up to 0.3–0.4 kg of fish per cormorant daily. The body condition (Fultons´ coefficient) in wounded mirror carp and bighead carp was significantly lesser than in non-wounded individuals but non- significant differences were registered in scaly carp. This statement can be given by the fact, that scaly cover of the fish protects the fish against the penetration of epithelium by cormorant hook tip of the beak. The same phenomenon was also recorded in the study of Adámek et al. (2007). The description of wounded fish can provide more detailed information about the character of the injury. The extent of injuries was studied by computer assisted image analysis program.

The results show, that percentage of wounded areas in two-year-old mirror carp (2.76 ± 2.03%) were not found as high as in the study of Adámek et al. (2007) (4.31 ± 2.40%). The highest total superficial extent of wounds was registered in scaly carp (13.38 ± 1.67%) but the major proportion related to scars and contusions (12.49 ± 0.78%). According to knowledge, that cormorants are an important hosts of adult stadiums of various ectoparasites (Sitko and Polčák 1996; Sitko et al. 2006), 30 wounded fish individuals were analysed. The invasions of *Trichodina* sp., *Chilodonella* sp. and Dactylogyrus sp. on the gills and skin were recorded in common quantity in examined fish. However, more detailed studies are required on this topic since some signs of extraordinary numbers of some ectoparasites, which are able to leave the fish when disturbed (e.g. *Argulus* sp.), were registered (Adámek, own data).

STRESS RESPONSES OF CARP POND FISH STOCK UPON HUNTING ACTIVITIES OF GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*, L.)

Various biochemical and haematological indices are used to indicate and assess the effect of stressors in fish, e.g. concentration of glucose, cortisol, lactate, ammonia and chlorides in blood plasma, spleen somatic index etc. (Thomas 1990; Palíková and Svobodová 1995). In our study the blood plasma stress indicators (glucose, cortisol and lactate concentrations) do not indicate significantly the impacts caused by cormorant hunting activities upon fish (common carp). Their values did not differ significantly between HC and CP groups, however, significantly higher levels of stress indicators were recorded in PH compared to both HC and CP groups. Our findings particularly correspond with data of Svobodová et al., 2006, who studied the changes in stress levels during harvesting. No data about stress in fish in context with cormorant impact have been published. Changes in spleen somatic index (SSI) have been already used by a number of authors for stress intensity assessment in various fish species (Lai et al., 2006; Mukopadhyay 2003; Svobodová et al., 1999; Svobodová et al., 2006,). The SSI calculated during long distance transport of fish did not show a significant decrease (Svobodová et al., 1998), but significant decrease in SSI was demonstrated during pond harvesting period (Svobodová et al., 2006). This corresponds to our results, where PH shows significantly lower values than CP and HC groups. Fish condition in association with impact of cormorants was previously studied by Adámek et al., 2007; Kortan et al., 2008. They found that FCC (Fulton's condition coefficient) of wounded fish was significantly lower than that of fish without cormorant beak marks. Also our results showed significantly higher values of FCC for fish from the control group than in the HC and PH stages, probably due to energy release without food intake, while no differences were recorded between HC and PH.

BEHAVIOURAL RESPONSE OF CARP (*CYPRINUS CARPIO*, L.) POND STOCK UPON OCCURRENCE OF HUNTING GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*, L.) FLOCKS

Besides various physiological and biological indices, stress in fish can be expressed directly by changing their behaviour. Using CPUE (Catch per unit effort) method was found statistically higher fish density in the littoral parts of the ponds during occurrence of hunting cormorants in comparison with values before the cormorants' arrival. The water environment determinants corresponded to the range required for successful carp pond culture after overwintering period (Čítek et al., 1998) both before and during fish crowding along the shorelines due to cormorant occurrence.

Thus, their values did not affect fish behaviour. Our data rather corresponds to study of Kortan et al., 2010 (own data), who compared the CPUE in shorelines of two ponds with and without cormorant presence. Significant differences ($p < 0.001$) were recorded between CPUE of fish numbers captured by 1 x 1 meter lift net drive on the pond with hunting cormorants (43.6 ± 39.6) and without cormorant presence (0.9 ± 1.1). This behavioural phenomenon is frequently recorded by fish farmers, but any other scientific data have been published. Fish wounding by cormorants is more often mentioned in literature (Berka 1989; Adámek 1991; Poór 2005; Grémillet et al., 2006; Adámek et al., 2007) was also observed in our study where amounts of injured fish in fish samples varied between 3.00% and 18.19% on the ZF and TR ponds, respectively, which is in accordance to Kortan et al. (2008), where the proportion of fish injured by cormorants on the total stock reported during pond harvesting on neighbouring localities in previous season (2007) ranged between < 1 to 47.4%. However, values found in our study could be influenced by sample size (33 fish from each pond). More detailed studies on fish reaction to hunting cormorants are required.

PARASITE INFECTION AND BODY CONDITION OF COMMON CARP WOUNDED DURING GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*, L.) ATTACKS

Cormorants are frequent hosts for many endoparasite species using fish as intermediate hosts in their life cycles (Sitko et al., 2006). However, the infection of larval endoparasites in stocked carp was extremely rare in general; only eye fluke *Diplostomum* spp. occurred more frequently in eye lens of both wounded and control fish. The infection of eye fluke in aquacultures is relatively common (Buchmann and Bresciani 1997; Overstreet and Curran 2004). In our study, no difference in parasite intensity between wounded fish and control was recorded. Despite no difference in protozoan (*Trichodina* spp. and *Ichthyophthirius multifiliis*) abundance between the fish groups, wounded fish infected with *Ichthyophthirius* showed significantly higher intensity of infections compared to the control fish. Ichthyophthiriosis accounts for significant economic losses to the aquaculture industry (Matthews 2005). Increased susceptibility to *Ichthyophthirius multifiliis* induced by stress was found in handled e.g. in channel catfish (Davis et al., 2002), probably due to suppression of an innate protection mechanism, or in fish exposed to pollutants (Ewing et al., 1982). Although the maximum intensity of *Ichthyophthirius multifiliis* infection in wounded fish was five-times higher than in control fish, it was still relatively too low to display any pathological effect on its host. Significantly higher concentration levels of lysozyme in the mucus in wounded fish compared to the control fish was found, moreover, the lysozyme concentration was positively associated with the extent of injury. Therefore, the increased lysozyme level could indicate increased activity against microbial diseases in injured fish and/or a response of fish organism to crowding stress (Caipang et al., 2009). Extremely high increase in intensity of *Gyrodactylus* infection was observed only in wounded fish, when several fish were parasitized with more than 1000 worms. Transmission and dissemination of gyrodactylids is also affected by stress-induced immunosuppression (Harris et al., 2000). In particular, stressful conditions have an immunosuppressive effect and may affect disease resistance (Oppliger et al., 1998). No differences in somatic condition (condition factor, lipid content in muscle and liver tissue) between wounded and control fish were recorded. Although, in previous study on the same pond (Kortan et al., 2008) was observed significant decrease in condition factor in wounded fish in comparison with control. It could be clarified by the explanation that fish were collected and examined several months after the main cormorant attack.

Therefore, heavily affected fish in low condition might have died during the winter and only fish with sufficient energy reserves survived. Fish condition indices showed differences between scaly and mirror carp. Fish with scaly cover are more resistant against injuries caused by cormorant attacks (Adámek et al., 2007). Whilst mirror carp suffered by heavier damages (scars, necroses), secondary fungal infections were present more often in scaly carp. SSI (spleen somatic index) significantly increased in fish stressed by cormorant wounding compared to the control fish. In contrary, Kortan et al., 2010 found opposite results – decrease of SSI in fish stressed by harvesting and disturbance by cormorants. Increased spleen weight in wounded fish, as well as increased liver weight in scaly carp, found in this study might have consequences with increased infection level (Seppänen et al., 2009). The fish, wounded due to unsuccessful cormorant attacks suffered with higher intensities of ectoparasite infection which may have additional negative consequences in the subsequent growing season.

MAJOR CONCLUSIONS

- *Largest extent of wounds caused by cormorant was recorded in one- year old mirror carp, however, no deep necrotic wounds were recorded. In two-year old mirror carp both deep wounds and scars were observed. In the scaly covered fish (carp and predatory fish) majority of injuries are caused by scales loss.*

- *In the conditions of typical Czech fish-pond area the quantity of damaged fish range from 1 to 47% on individual ponds, depends upon the frequency and intensity of cormorant visits and fish stock composition. Predominantly, the two-year-old mirror carp are endangered by cormorant attacks. The fish with scaly cover are more resistant against injuries caused by cormorant attacks, which was proved by calculation of condition coefficient.*

- *According to stress indices in blood plasma (cortisol, glucose, lactate), stress in fish caused by pond harvesting, proved to be a major stressor in comparison with responses upon three-day cormorant performance on a pond. Although, significant decline in cormorant affected fish, comparable with the impact of pond harvesting, was recorded in values of the spleen-somatic index and condition coefficient.*

- *Collective hunting of cormorants can significantly alter behaviour of fish stock in carp ponds. Shoals of fish chased by hunting birds take refuge in the littoral zone of the pond, where they stay crowded along the shoreline in order to hide in littoral plants. Subsequent problems may appear during spring pond harvesting when fish do not follow the water level decline and stay in littoral.*

- *Parasitological examination proved that endoparasite infection in wounded fish occurred only scarcely. Higher vulnerability to ectoparasite infection in wounded fish in comparison to control was confirmed for three parasite taxa; increased abundance in monogenean* Gyrodactylus *spp. and* Dactylogyrus *spp. and intensity of infection of* Ichthyophthirius multifiliis *were observed. Wounded fish showed higher concentration levels of lysozyme in the mucus compared to the control fish and the lysozyme concentration was positively associated with the extent of injury.*

ACCORDING TO THE CONCLUSIONS, IT IS RECOMMENDED:

- *to record fish injuries (mainly during the process of harvesting) caused by cormorants and their extent with the aim to provide the data about the damages due to unsuccessful cormorant attacks;*

- *to audit fish stress responses upon hunting cormorants (date, site and numbers of fish escaped to pond littoral zones) supported by appropriate photo-documentation.*

These data are of high importance for recompensation procedures and requirements for the damages caused by cormorants.

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ENGLISH SUMMARY

Indirect impacts of hunting activities of great cormorant (*Phalacrocorax carbo sinensis*) upon pond fish stock

Jiří Kortan

CHAPTER 2 – COMPUTER-ASSISTED IMAGE ANALYSIS IN EVALUATION OF FISH WOUNDING BY CORMORANT [*PHALACROCORAX CARBO SINENSIS* (L.)] ATTACKS

This study was focused on evaluation of fish injuries caused by cormorants attacks during their feeding behaviour on fish pond culture. A computer assisted image analysis was applied to describe the extent of such injuries which were calculated as a percentage of wounded area from total body surface. Beside mirror and scaly carp *Cyprinus carpio* L., several fish species like silver carp *Hypophthalmichthys molitrix* Val., grass carp *Ctenopharyngodon idella* Val., pike *Esox lucius*, perch *Perca fluviatilis* L. and catfish *Silurus glanis* L.were examined. The results proved, that most threatened by surface epithelium damage caused by cormorant wounding is one-year-old carp mirror (27.53 ± 10.92%, mean ± SD), whilst two-year-old mirror and scaly carp shown the highest proportion of deeper subdermal wounds (1.73 ± 1.12% and 1.66 ± 2.57% respectively). In the other species the deep injuries occurred less than 1% of body surface and average total extent of wounds did not exceed 10%.

CHAPTER 3 – INDIRECT MANIFESTATION OF CORMORANT (*PHALACROCORAX CARBO SINENSIS* (L.)) PREDATION ON POND FISH STOCK

Changes in fish condition, wound extent evaluation, parasitological examination and percentage of wounded fish from total yield were evaluated in this study. Fulton´s condition coefficient (FCC) was calculated for wounded and healthy two–year old carp originating from five South Moravian (Czech Republic) fishponds. Significantly higher values were calculated for non-wounded mirror carp, while in scaly carp, no differences were found between healthy and wounded ones. Extent of injures was measured in scaly and mirror carp *Cyprinus carpio*, L., and bighead carp (*Aristichtys nobilis*, Rich.). Maximum registered average total values of injury extents were recorded in two-year-old scaly carp amounting to 13.38 ± 1.67% of total body surface with major parts composed of scars, necroses were recorded in less than 2% in all species (forms). Parasitological examination revealed the occurrence of *Dactylogyrus* sp. in one fish and the ordinary density of infusorians *Trichodina* sp. and *Chilodonella*. The percentage of wounded fish from total fish harvested was evaluated as ranging between < 1 and 47.4% in five ponds under study.

CHAPTER 4 – STRESS RESPONSES OF CARP POND FISH STOCK UPON HUNTING ACTIVITIES OF GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*, L.)

The objective of this study was to evaluate the level of stress indicators, spleen somatic index (SSI) and Fulton´s condition coefficient (FCC) for fish subject to two stress factors – hunting cormorants (HC) and pond harvesting (PH) compared to fish from the control pond (CP). Fish stress response was evaluated by CPUE using lift-net sampling in pond littoral zones.

Significantly higher density of fish was recorded in littoral parts of the pond with hunting cormorants than in control pond. Both SSI and FCC significantly decreased in PH and HC fish in comparison to the control group while non-significant (P > 0.05) differences were recorded between HC and PH groups. Cortisol, glucose and lactate concentrations were significantly higher (P < 0.01) in PH group than in HC and CP groups. However, their concentrations in groups HC and CP did not differ significantly (P > 0.05). Total plasma protein levels were significantly higher (P < 0.01) in HC fish compared to CP fish, while this value did not differ (P > 0.05) from PH fish. Concluded these results, the pond harvesting is the same or even greater stress factor than hunting cormorants, however more detailed studies are highly required.

CHAPTER 5 – BEHAVIOURAL RESPONSE OF CARP (*CYPRINUS CARPIO*, L.) POND STOCK UPON OCCURRENCE OF HUNTING GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*, L.) FLOCKS

This study evaluated the effect of hunting cormorants´ on pond fish stock behaviour, which is manifested by fish escapement to the pond shore and hiding in littoral vegetation opposite to birds roosting places. Fish stock density in littoral parts of four South Bohemian ponds before and after cormorants arrival was compared using CPUE (Catch per Unit Effort) through the use of electrofisher. Significantly higher mean CPUE values were found on all ponds affected by cormorant hunting activities than in those before the birds visit. The evaluation of fish wounding in the CPUE fish samples proved the proportion of fish injured by cormorant attacks ranging from 3.33 to 18.19% in the ponds under study.

CHAPTER 6 – PARASITE INFECTION AND BODY CONDITION OF COMMON CARP WOUNDED DURING GREAT CORMORANT (*PHALACROCORAX CARBO SINENSIS*, L.) ATTACKS

The main objective of this investigation was to evaluate the vulnerability of common carp *Cyprinus carpio* wounded by cormorant to parasite infection compared to healthy fish. Two-year old stocked carp harvested in late March were examined for ecto- and endoparasites, injuries extent and lysozyme concentration in skin mucus. Additionally, four body condition indices were measured. Higher abundance in monogenean *Gyrodactylus* spp. and *Dactylogyrus* spp. was recorded in wounded fish, in comparison to control fish individuals. Increased abundance and intensity of infection of *Ichthyophthirius multifiliis* in wounded fish than in control were observed as well. However, intensity of remaining found species – *Eudiplozoon nipponicum*, *Argulus* spp. and *Trichodina* spp. infection did not differ between wounded and control fish. Lysozyme concentration in fish mucus was significantly higher in wounded fish, and was positively associated with the extent of damaged epithelium and *Gyrodactylus* spp. abundance. Fulton's condition factor, lipid content in muscle and liver tissues between wounded and control fish did not differ.

CZECH SUMMARY – SOUHRN

Sekundární důsledky potravního chování kormorána velkého (*Phalacrocorax carbo sinensis*) na obsádky rybníku

Jiří Kortan

KAPITOLA 2 – VYUŽITÍ POČÍTAČOVÉ ANALÝZY OBRAZU K HODNOCENÍ ROZSAHU PORANĚNÍ RYB ZPŮSOBENÝCH KORMORÁNEM VELKÝM [*PHALACROCORAX CARBO SINENSIS* (L.)]

Studie byla zaměřena na vyhodnocení rozsahu poranění ryb způsobených kormoránem velkým při jeho lovných aktivitách pomocí počítačové analýzy obrazu (Olympus MicroImage v. 4.0 sw). Pomocí modu manuálního měření byl vypočítán rozsah poranění, jako procento z celkového povrchu těla (bez ploutví), přičemž poranění byla diferencována dle charakteru na povrchová – šrámy a zasahující pod kůži – nekrózy. Hodnocení proběhlo celkem u 6 druhů, a to u kapra lysce a šupináče *Cyprinus carpio* L., tolstolobika *Hypophthalmichthys molitrix* Val., amura *Ctenopharyngodon idella* Val., štiky *Esox lucius*, okouna *Perca fluviatilis* L. a sumce *Silurus glanis* L. Největší procento povrchových zranění bylo zaznamenáno u jednoleté šupinaté formy kapra (27.53 ± 10.92 %, prům. ± s.o.), nekrózy byly však v největší míře pozorovány u dvouletého kapra lysce (1.73 ± 1.12 %) a šupináče (1.66 ± 2.57 %). U ostatních druhů se hluboká zranění vyskytovala v rozsahu menším než 1 % a celkový rozsah poranění byl průměrně 7 % povrchu těla.

KAPITOLA 3 – SEKUNDÁRNÍ DŮSLEDKY PREDACE KORMORÁNA (*PHALACROCORAX CARBO SINENSIS* (L.)) NA RYBÍ OBSÁDKY

Cílem práce bylo vyhodnocení vlivu predace kormorána na kondici ryb, parazitologické vyšetření zraněných ryb, zjištění rozsahu poranění u napadených ryb a procento poraněných z celkového výlovku na 5 jihomoravských rybnících. Vyšší hodnoty koeficientu kondice byly zjištěny u nezraněných jedinců kapra lysce, zatímco u šupinaté formy kapra byly rozdíly mezi zdravými a zraněnými statisticky nevýznamné. Rozsah poranění (procento poškozené tkáně z celkového povrchu těla) byl hodnocen u šupinatého a lysého kapra *Cyprinus carpio*, L., a tolstolobika (*Aristichtys nobilis*, Rich.). Maximální hodnoty poranění byly zaznamenány u dvouletého šupinatého kapra (13.38 ± 1.67 %) z největší části tvořené povrchovými zraněními, nekrozy byly registrovány v rozsahu menším než 2 % povrchu těla u obou forem kapra a u tolstolobika. Při parazitologickém vyšetření zraněných ryb byli na žábrách a kůži v obvyklé míře zjištěni nálevníci *Trichodina* sp. a *Chilodonella*, pouze u jednoho jedince nalezen *Dactylogyrus* sp. Množství poraněných ryb z celkového výlovku se na sledovaných lokalitách pohybovalo od < 1 do 47.4 %.

KAPITOLA 4 – STRESOVÉ REAKCE RYBNIČNÍ OBSÁDKY KAPRA V ZÁVISLOSTI NA POTRAVNÍM CHOVÁNÍ KORMORÁNA VELKÉHO (*PHALACROCORAX CARBO SINENSIS*, L.)

Hladina stresových ukazatelů v krevní plazmě, slezino-somatický index (SSI) a koeficient kondice (FCC) byly porovnávány u tří skupin ryb – HC – ryby natlačené v litorálu v reakci na přítomnost lovících kormoránů, PH – ryby při výlovu, CP – kontrola (bez přítomnosti kormoránů). Stresová reakce (únik) ryb do příbřežních partií rybníka byla hodnocena metodou CPUE (Catch per Unit Effort) prováděnou opakovanými odlovy do sítě (1 x 1 m) v litorálu. Byly prokázány signifikantně vyšší ($P < 0.001$) hodnoty CPUE v litorálu rybníka s výskytem lovících kormoránů v porovnání s kontrolou. Slezino-somatický index a koeficient kondice byly nižší u PH a HC skupin v porovnání s kontrolou, vzájemně se však skupiny PH a HC statisticky nelišily ($P > 0.05$). Koncentrace kortisolu, glukosy a laktátu byly signifikantně vyšší u PH v porovnání s HC a CP. Mezi skupinami HC a CP nebyl statistický rozdíl ($P > 0.05$). Hladina celkového proteinu v krevní plazmě byla vyšší u HC v porovnání s CP ($P < 0.01$), ale statisticky se nelišila ($P > 0.05$) od PH skupiny. Z výsledků je patrné, že přítomnost lovících kormoránů vyvolává stresové reakce u ryb, hladina stresu je však stejná nebo vyšší při výlovu rybníka.

KAPITOLA 5 – CHOVÁNÍ OBSÁDKY KAPRA V REAKCI NA PŘÍTOMNOST LOVÍCÍCH KORMORÁNŮ (*PHALACROCORAX CARBO SINENSIS*, L.)

Na 4 lokalitách jižních Čech bylo sledováno chování ryb před příletem kormoránů a poté v přítomnosti lovících kormoránů, které se projevuje panickými reakcemi a ukrýváním ryb v litorálu rybníka. Hustota ryb v příbřežních partiích rybníků byla hodnocena metodou CPUE (Catch per Unit Effort) s použitím el. agregátu. Signifikantně vyšší průměrné hodnoty CPUE byly zaznamenány na všech rybnících po příletu kormoránů a během jejich lovných aktivit. Množství poraněných ryb na jednotlivých lokalitách se pohybovalo od 3.33 do 18.19 %.

KAPITOLA 6 – PARAZITACE A KONDICE KAPRA OBECNÉHO V DŮSLEDKU PORANĚNÍ KORMORÁNEM VELKÝM (*PHALACROCORAX CARBO SINENSIS*, L.)

Ve studii byla porovnána parazitace ryb zraněných při neúspěšném útoku kormorána velkého a ryb bez známek poranění. U dvouletých kaprů (*Cyprinus carpio*) získaných při výlovu rybníka proběhlo vyšetření ekto a endo-parazitofauny, sledování rozsahu poranění a koncentrace lysozymu v kožním slizu. Byly rovněž sledovány 4 kondiční ukazatele. U zraněných jedinců byla zaznamenána vyšší abundance monogeneí *Gyrodactylus* spp. a *Dactylogyrus* spp. a vyšší abundance a intenzita kožovce Ichthyophthirius multifiliis v porovnání se zdravými rybami. Avšak intenzita infekce u ostatních pozorovaných druhů – *Eudiplozoon nipponicum*, *Argulus* spp. a Trichodina spp. se signifikantně nelišila mezi oběma skupinami ryb. Koncentrace lysozymu byla vyšší u zraněných ryb a pozitivně korelovala s velikostí poranění a abundancí *Gyrodactylus* spp. Fultonův koeficient kondice, obsah lipidů ve svalovině a v játrech se stitisticky nelišily mezi skupinami.

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