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Indirect manifestation of cormorant (*Phalacrocorax carbo sinensis* (L.)) predation on pond fish stock

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ABSTRACT

Key-words: *piscivorous predators, fish wounding, fish condition, image analysis, carp pond culture*

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.

RÉSUMÉ

Pertes indirectes résultant de la prédation des poissons d'étang par les cormorans (*Phalacrocorax carbo sinensis* (L.))

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

Les dommages causés aux pêcheries par les cormorans sont dus non seulement à la prédation directe des oiseaux, mais également aux pertes indirectes résultant de leur activité de pêche, 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 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

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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.

INTRODUCTION

Great cormorants (*Phalacrocorax carbo*) are piscivorous birds which are suspected to deplete valuable fish stocks and compete with fisheries (Grémillet *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 perforate skin as triangle shaped injury (due to the sharp and hook-like upper part of the beak) on one body side, whilst on the other side, scars and contusions are presented (Carss, 1990, see also Figures 1 and 2). 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 1
"Cicatrices" – blessures superficielles faites par la partie inférieure du bec des cormorans sur la partie droite du corps.

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

Figure 2
"Nécroses" – blessures profondes causées par la partie supérieure du bec (forme triangulaire typique) sur la partie gauche du corps.

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

Tableau I
Nombre de cormorans (moyenne journalière) pendant l'hiver précédant l'évaluation des poissons blessés dans les étangs étudiés.

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				

MATERIAL AND METHODS

> *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 (Table 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.

> *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, the Mann-Whitney *U*-test was used.

> *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 (Figure 1) – and necroses – deep wounds from upper mandible hook of the beak usually progressing as necrotic lesions (Figure 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 Table IV.

RESULTS

> *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 VI and Figure 3.

> *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

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

Table IV

*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.)*

Tableau IV

Données brutes des poissons examinés pour les études de parasitologie, d'histologie et d'analyse d'images (moyenne ± écart type). (Note : PaH – analyse parasitaire et histologique, IA – analyse d'image, MC = carpe miroir, SC = carpe commune, BC = carpe à grosse tête.)

Analysis	Pond	*n*	Age (year)	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 V

*The extent 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.)*

Tableau V

Évaluation des blessures causées par les attaques de cormorans en pourcentage (moyenne ± écart type) de la surface corporelle. (Note : necroses – nécroses ou blessures ouvertes profondes touchant le muscle ; scars – cicatrices ou blessures ne pénétrant pas sous la peau, MC = carpe miroir, SC = carpe commune, BC = carpe à grosse tête.)

Fish (species/form)	Age (year)	*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

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* sp. 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.

> *WOUND EXTENT*

Maximum registered total values of injury extents (Table 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).

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	**

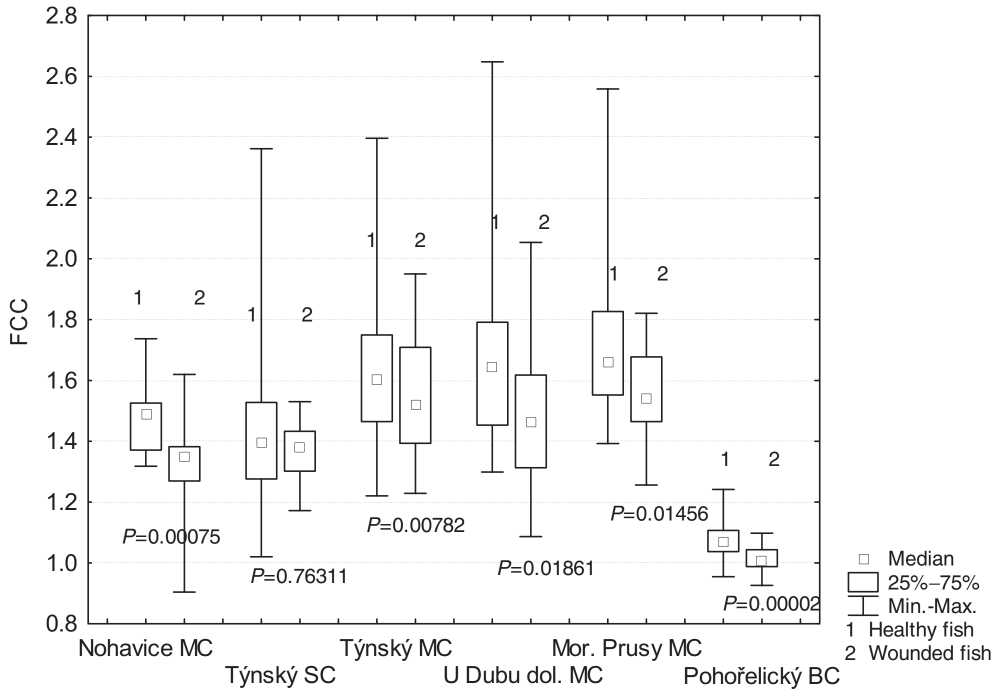

Figure 3
FCC (Fulton's coefficient) of examined healthy (1) and wounded (2) fish (median and quartiles). (Note: MC = mirror carp, SC = scaly carp, BC = bighead carp.)

Figure 3
FCC des poissons en bonne santé (1) et blessés (2) examinés (médians et quartiles). (Note : MC = carpe miroir, SC = carpe commune, BC = carpe à grosse tête.)

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 Wunner, 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 (*Exox 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 can be estimated as 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.

CONCLUSIONS

Beyond direct consumption of fish, cormorants are accused of injuring vast number of prey fish without eating them (Grémillet *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 (Balakhnin, 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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