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Summary of the thesis

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The role of fish-eating predators and socio-economic trends in recreational fishing

Role rybožravých predátorů a socio-ekonomických trendů ve sportovním rybaření

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List of Publications

1. Lyach R. and Čech M., 2017. Do otters target the same fish species and sizes as anglers? A case study from a lowland trout stream (Czech Republic). Aquatic Living Resources 30, 11.

2. Lyach R. and Čech M., 2017. The effect of cormorant predation on newly established Atlantic salmon population. Folia Zoologica 66: 167-174.

3. Lyach R. and Čech M., 2018. A new trend in Central European recreational fishing: More fishing visits but lower yield and catch. Fisheries Research 201: 131-137.

4. Lyach R. and Čech M., 2018. Great cormorants (Phalacrocorax carbo) feed on larger fish in late winter. Bird Study (accepted)

5. Lyach R. and Čech M. Differences in catch, yield, fishing visits, and angling guard controls on differently sized fishing grounds. Fisheries Management and Ecology (under review)

6. Lyach R. and Čech M. The differences in catch, yield, fishing visits, and angling guard controls on natural and urban fishing grounds. Urban Ecosystems (under review)

7. Lyach R. and Čech M. Do cormorants and recreational anglers take fish of the same species and sizes as anglers? Ardea (under review)

8. Lyach R. and Čech M. Solidarity of anglers is more important than any fishing regulation: a case study of grayling *Thymallus thymallus* in the Czech Republic. Fisheries Research (under review)

9. Lyach R. and Čech M. A tale of two trout: the intensively stocked, non-native rainbow trout *Oncorhynchus mykiss* is not replacing the native brown trout *Salmo trutta* in catches of recreational anglers. Fisheries Management and Ecology (under review)

10. Lyach R. Public attitudes towards and trends in recreational fisheries across the world: Central Europe: the Czech Republic. In: Arlinghaus R. (ed.). Global participation in and public attitudes towards recreational fishing: international perspectives and developments (in preparation)

Abstract

Recreational fishing is a very important leisure activity and one of the most important ways how humans influence freshwater habitats and wild fish populations. Both fish-eating predators and socio-economic trends play a major role in recreational fishing.

This thesis found that the Eurasian otter feeds mainly of small (5-10 g) and very abundant fish species of low angling value. In this case, gudgeon *Gobio gobio* dominated in the otter diet. The overlap between catches of otters and anglers was very low, and commercially important salmonids made up only 10 % of the otter diet by biomass. Cormorants also prey mostly on smaller (10-100 g) a very abundant fish species. In this case, roach *Rutilus rutilus* dominated in the cormorant diet. The overlap between catches of cormorants and anglers was also quite low. Commercially important fish species made up less than 10 % of the cormorant diet. Even though cormorants consume mostly smaller fish, they are potentially removing fish that serve as prey for piscivores, and they are also removing smaller fish that would grow into angling size.

The Atlantic salmon *Salmo salar* reintroduction programme has not yet been successful. However, cormorant predation is not the main reason for its low success. The main problem is somewhere on the lower River Elbe in Germany. If this programme is to be a success, the main reasons of high salmon mortality need to be found.

Recreational fishing seems to be on the rise. The numbers of anglers and angling visits are increasing, anglers visit more fishing grounds, and they are less loyal to their favourite fishing grounds. The amount of angling guard controls in the field is increasing as well. On the other hand, catch and yield of fish is steadily decreasing, and it is mostly because the catch-and-release fishing strategy is gaining popularity. Fishing grounds in urban and natural (rural) areas showed different patterns in recreational fishing. While the visit rates were similar on both types of fishing grounds, urban fishing grounds showed higher catch and yield. Inversely, natural fishing grounds showed higher amount of angling guard controls. Smaller and larger fishing grounds also showed different patterns in recreational fishing. Most importantly, large fishing grounds did not show the highest catch and the most visit rates. Instead, mid-sized fishing grounds showed the highest catch and the most visit rates. The fisheries management should reflect on the fact that fishing is gaining popularity and that different types of fishing grounds should be managed differently.

The large-scale regulation of angling size of grayling *Thymallus thymallus* did not affect the overall catch and yield of grayling in the study area. However, it affected the distribution of catches between fishing grounds, and also the average body weight of caught fish. Anglers displayed high solidarity with grayling, and they are strongly supporting grayling conservation, mostly because they are aware of its poor population status. While fishing regulations may be sometimes effective, it is mainly the actual opinion and behaviour of anglers in the field that matters the most.

Abstrakt

Sportovní rybaření je jednou z nejvýznamnějších rekreačních aktivit a zároveň jedním s nejvýraznějších způsobů jak člověk ovlivňuje vodní ekosystémy a rybí populace. Socio-ekonomické trendy i rybožraví predátoři přitom hrají ve sportovním rybaření důležitou roli.

Jedním z poznatků práce byl fakt, že se vydra říční živí převážně malými rybami (5-10 g), a to u druhů, které jsou velice početné, a mají malý význam pro rybáře. V tomto případě dominoval v potravě vydry hrouzek obecný. Překryv mezi úlovky vyder a rybářů byl velice malý. Rybářsky významné druhy lososovitých ryb tvořily pouze malý podíl potravy vydry (10 % podle biomasy). Kormoráni se také živí především malými rybami (10-100 g), a to u druhů, které jsou taktéž velice početné. V tomto případě dominovala v potravě kormoránů plotice obecná. Rybářsky významné druhy ryb představovaly pouze 10 % v potravě kormoránů. Kormoráni sice odstraňují především početné druhy a malé ryby, nicméně tyto ryby slouží jako potrava pro dravce. Malé ryby by zároveň mohly v budoucnu dorůst do lovitelné velikosti.

Záchranný program lososa obecného nebyl prozatím příliš úspěšný. Predace kormoránů na lososech není ovšem důvodem jeho neúspěchu. Největší problém je na dolním Labi na území Německa, kde dochází k vysoké mortalitě migrujících lososů. Pokud má být tento program úspěšný, bude potřeba zjistit, jaký je hlavní důvod mortality lososů právě na dolním Labi.

Sportovní rybaření je na vzestupu. Počty rybářů i rybářských návštěv na revírech se zvyšují, rybáři navštěvují více různých revírů a jsou méně fixováni na své oblíbené revíry. Počet kontrol rybářské stráže se také zvyšuje. Na druhou stranu, úlovek ryb se snižuje, a to především proto, že roste popularity strategie chyť-a-pusť. Revíry v městských a přírodních lokalitách se většinou odlišují ve svém využívání. Počty návštěv jsou podobné, ale rybáři si odnášení více ryb z městských revírů. Na druhou stranu, přírodní revíry vykazují více kontrol rybářské stráže. Rybaření vypadá také výrazně jinak na malých a velkých rybářských revírech. Největší revíry nevykazují nejvíce návštěv ani nejvíce úlovků – toto prvenství patří středně velkým revírům. Rybářský management by měl při rozhodování vzít v potaz fakt, že se rozdílné typy revírů chovají rybářsky jinak.

Velkoplošná regulace úlovků lipana podhorního pomocí zvýšení minimální lovné míry z 30 na 40 cm neměla žádný vliv na celkový počet úlovků lipana ve studované lokalitě. Tato regulace ale výrazně ovlivnila rozložení úlovků mezi jednotlivými rybářskými revíry, a také ovlivnila průměrnou hmotnost ulovených lipanů. Rybáři vykázali vysoko míru solidarity s lipanem, a ukázalo se, že výrazně podporují ochranu lipana obecně, a to především proto, že jsou si vědomi špatného stavu populací lipana. Regulace lovu mohou být někdy prospěšné a užitečné, nicméně ve výsledku záleží především na názoru rybářů a jejich chování na samotných revírech.

Introduction

Recreational fishing is defined as fishing of aquatic animals (mainly fish) that do not constitute the individual's primary resource to meet basic nutritional needs and are not generally sold or otherwise traded on export, domestic, or black markets (FAO 2012). Cooke and Cowx (2004, 2006) roughly estimated that all anglers around the world might catch up to 47 billion fish annually. Further, they claimed that the overall catch in recreational fishing is about 12 % of catch in commercial fishing. While commercial fishing still remains the main source of fish removal by man, it is clear that recreational fishing has been catching up lately. By studying fishing in European inland freshwater ecosystems, previous researchers claimed that recreational fishing has become more important and impactful than commercial fishing (Arlinghaus et al. 2002). Commercial fishing has lost its importance in inland waters mainly due to the increasing importance of hatcheries and aquaculture. Basically, fishing at sea is dominated by commercial fishing, while fishing in inland waters is dominated by recreational fishing. In addition to that, recreational fishing has been recognized as one of the main factors that influence populations of commercially valuable fish species in inland freshwater ecosystems (Cooke and Cowx 2004). Fish species with lower commercial value are influenced by recreational fishing as well, mostly because large-scale targeted removal of piscivorous fish species has a significant effect on all fish populations. Arlinghaus et al. (2015) claimed that approximately 10.5 % of population in developed countries practice angling. Recreational fishing has been on the rise in many countries and can be counted among the most popular outside leisure activities (Marta et al. 2001). Recreational fishing is probably the most important way in which people influence freshwater ecosystems. The Czech Fishing Union is collecting fisheries data with high precision (Boukal et al. 2012). We believe that this dataset has not yet been utilized enough.

The Eurasian otter *Lutra lutra* is one of the most important fish-eating mammals in European freshwater ecosystems (Mason and Macdonald 1986). Otters are highly adaptable piscivorous predators that can easily utilize new sources of prey. That goes especially for naïve hatchery-reared stocked fish. Otter populations in Europe declined dramatically during the 20th century, mainly due to water pollution, poaching, increased road traffic, and habitat loss (Kranz 2000), yet have begun to recover in the last 20-30 years (Kranz 2000). After being driven close to extinction, numbers of otters in the wild have begun to stabilize. Recently, otters have been returning to the wild, and numbers of wild otters have been increasing throughout the whole European range. With rising numbers of otters in the wild, their effect on fish stocks is being heatedly debated between anglers and fishermen on one side and environmentalists and the society itself on the other (Kruuk et al. 1991). The main problem is that otters are usually hunting on smaller streams with very limited fish stocks and small fish populations. In some cases, the high density of otters can lead to significant loss on fish stocks, and this is especially problematic in areas where financially expensive fish stocking and reintroductions take place. Together with poor water sources management in general,

the addition of predation pressure form otters can lead to declines of fish populations. Salmonids were reported to be especially vulnerable to otter predation.

The Great Cormorant *Phalacrocorax carbo* is one of the most important fish-eating avian predators and a widespread water bird. It is an opportunistic predator that feeds almost entirely on fish (Cramp and Simmons 1977). Cormorants are able to move great distances and utilise new sources of prey, especially stocked fish. Cormorants were driven close to extinction during the second half of the 20th century, mainly due to poaching, hunting, and contamination of freshwater ecosystems with DDT (Suter 1995). However, cormorant populations have been increasing since 1970 in the European range mainly due to legal protection, availability of prey, intensive fish farming, and eutrophication of freshwater habitats (Russell et al. 1996). In particular, numbers of the continental subspecies *Phalacrocorax carbo sinensis* have increased greatly, and Cormorants have moved to previously unoccupied areas (Carss and Marzano 2005). In the last decades, cormorants went from endangered species to one of the most important issues of the fisheries industry. Conflicts between environmentalists and ornithologists on one side and fisheries and anglers on the other have been reported in many countries (Russel et al. 1996). In Central Europe, migrating and overwintering Cormorants cause conflicts with fisheries, mostly because the Czech Republic is one of the most important migration corridors for European cormorant population. The numbers of Cormorants in freshwater ecosystems in Central Europe significantly increase during winter due to migration, and Cormorants consume more fish during winter than during the rest of the year (Čech and Vejřík 2011). While the nesting cormorant population in the Czech Republic is relatively small (200-600 pairs), the numbers of wintering migrants reach 7-14 000 birds per year. Since wintering cormorants have become one of the most important (and the most debated) piscivores in European freshwater ecosystems (Čech and Vejřík 2011), it is becoming more important to assess their diet preferences at different overwintering areas. Only analyses of cormorant diet can provide data on their actual diet and therefore point out the magnitude of the conflict between cormorants and man.

The Atlantic salmon, *Salmo salar* L. 1758, is a native European anadromous fish species. It used to be one of the most important fish species in recreational and commercial fisheries in Europe (Frič 1893). In the past, hundreds of salmon used to migrate through the Elbe River every year. Anglers used to catch and kill salmon using specialised salmon traps. Salmon used to be abundant across Northern, Western, and Central Europe, migrating into majority of European rivers in significant numbers. During the 20 th century, salmon populations have declined in the whole Europe. The population in the Elbe River basin perished completely. The last salmon in the Elbe River was caught in the 1950s. The main reason why salmon vanished from the Elbe River was river fragmentation (Chanseau et al. 1999). Migrating adult salmon were not able to overcome the newly constructed river dams, and therefore were not able to reach their spawning sites, not being able to reproduce. However, other factors such as presence of diseases and parasites, predation, climatic change, water pollution,

overfishing, and losses of spawning habitats were also important factors in the extirpation of salmon populations (Frič 1893).

Aims, questions, and hypotheses

Aims of the study

To assess the differences in fish catches between an important piscivorous mammal, the Eurasian otter *Lutra lutra*, and recreational anglers.

To assess the effect of predation of an important piscivorous bird, great cormorant *Phalacrocorax carbo*, on newly established populations of migratory fish species, the Atlantic salmon *Salmo salar*.

To assess trends in basic variables in recreational fishing (catch, yield, fishing visits, angling guard controls) over the course of time.

To assess the changes in body size of fish in the diet of overwintering cormorants on the River Elbe.

To assess the differences in recreational fishing on smaller and larger fishing grounds.

To assess the differences in recreational fishing on urban and natural fishing grounds.

To assess the differences in fish catches between the great cormorant and recreational anglers.

To assess the effect of a large-scale angling regulation on catches of endangered and commercially important fish species, grayling *Thymallus thymallus*.

To assess the long-term trends in catch and yield of rainbow trout and brown trout.

Research questions and hypotheses

Manuscript 1

Q: Do otters catch fish of the same species and sizes as recreational anglers?

H: We hypothesized that otters catch different fish species and different fish sizes than anglers. Otters usually feed on the most common and available species in the ecosystem and those are usually small species of low angling interest. Inversely, anglers usually target rare large-growing stocked fish species.

Q: Do small fish dominate in otter diet?

H: We hypothesised that small fish would dominate in otter diet in this study area. Previous authors discovered that otters preferably target small fish. In addition, small fish are the most common and available prey item for otters, especially in smaller streams like the one in this study.

Q: Do otters feed on non-fish prey as well?

H: We hypothesised that we wound also find remains of non-fish prey in the otter diet. Otters are known to feed on non-fish prey, especially amphibians, crayfish, birds, small mammals, and even cadavers of larger animals.

Q: Do otters mostly consume fish of high commercial value?

H: We hypothesised that otter would mostly consume fish of lower commercial value. The most common fish species in the study are was the gudgeon *Gobio Gobio*, a fish species with no commercial value. Salmonids made up only about 10 % of the fish biomass in the stream, and so we expected that otter diet would reflect this distribution.

Manuscript 2

Q: Do cormorants feed on the newly stocked salmon parr and migrating salmon smolts?

H: We hypothesized that a few remains of salmon would be found in the diet of cormorants. Cormorants usually feed on the most common and available prey, which is not salmon, but rather cyprinids.

Q: Do newly stocked salmon grown and survive in nursery streams?

H: We hypothesized that salmon would survive and grow in nursery streams because the streams were carefully chosen for the reintroduction of salmon in the Czech Republic, and the streams should be able to support salmon populations.

Q: Do salmon adults return to spawning habitats?

H: We hypothesised that adult salmon would be returning to nursery streams because the downstream barriers that prevented salmon reintroduction have been equipped with fish passes. Also, since salmon fry is stocked to the nursery streams in tens of thousands of individuals, a few salmon adults should return.

Manuscript 3

Q: Is the number of angling visits recently increasing?

H: We hypothesised that more anglers should be visiting fishing grounds because recreational fishing seems to be on the rise.

Q: Is the overall catch and yield of fish recently increasing?

H: We hypothesised that catch and yield should be decreasing because the catch-and-release fishing strategy is gaining popularity.

Q: is the amount of angling guard controls in the field increasing?

H: We hypothesised that the amount of angling guard controls should be increasing because recreational fishing is gaining popularity.

Manuscript 4

Q: Is the average body size of fish in cormorant diet changing over the course of winter?

H: We hypothesised that the size of fish in cormorant diet would be fluctuating during winter but we did not expect to find any significant trend.

Q: Are shoaling fish species dominating in cormorant diet?

H: We hypothesised that shoaling fish species, especially cyprinids, would dominate in cormorant diet in this study area. As other authors found, cormorants are known to prefer shoaling fish species. Cyprinids dominate in the study area, and we expected that cormorants found feed predominantly on cyprinids.

Manuscript 5

Q: In general, do smaller fishing grounds have lower catch, yield, number of fishing visits, and amount of angling guard controls than larger fishing grounds?

H: We hypothesised that smaller fishing grounds would show lower catch, yield, number of fishing visits, and amount of angling guard controls in general. We did not know how those variables would change when standardized to one hectare of fishing grounds.

Q: How do the variables such as catch, yield, number of fishing visits, and number of angling guard controls per hectare change when standardised to one hectare of fishing grounds?

H: We did not know how those variables would change when standardized to one hectare of fishing grounds.

Manuscript 6

Q: Is there a difference in angling visit rates between urban and natural fishing grounds?

H: We hypothesised that natural fishing grounds would show higher rates of angling visits because they are located in natural areas. Anglers are known to prefer natural areas.

Q: Is there a difference in angling catch and yield between urban and natural fishing grounds?

H: We hypothesised that natural fishing grounds would show higher catch and yield because they are located in natural areas with better environment for fish growth and reproduction.

Q: Is there a difference in angling guard controls between urban and natural fishing grounds?

H: We hypothesised that urban fishing grounds would display higher amount of angling guard controls because they are located in highly populated areas with close proximity to public transportation.

Manuscript 7

Q: Do cormorants catch fish of the same species and sizes as recreational anglers?

H: We hypothesised that cormorants catch different fish species of different sizes than anglers. Cormorants prefer common and available fish prey. Inversely, anglers usually target rare large-sized stocked fish species of high commercial value.

Manuscript 8

Q: Does the large-scale increase in minimum angling size of grayling have any effect on the overall catch and yield of grayling?

H: We hypothesised that the increase in angling size would lead to decrease in the overall catch and yield of grayling. The increase from 30 to 40 cm is significant, and fish over 40 cm in size are quite rare in the conditions of Central Europe.

Q: How do anglers view conservation of grayling?

H: We hypothesised that anglers would be supporting conservation of grayling, mainly because grayling is and endangered and vanishing species with high angling value. Anglers are aware of the poor state of grayling populations.

Manuscript 9

Q: What is the long-term trend of catches of rainbow trout and brown trout by recreational anglers?

H: We hypothesised that catch of rainbow trout is increasing. We also hypothesised that catch of brown trout is decreasing.

Materials and Methods

Study areas

The Eurasian otter study was conducted on the Chotýšanka stream in Central Bohemia. The cormorant studies were conducted on the upper Elbe River in Northern Bohemia. The Atlantic salmon study was conducted on the upper Elbe River, on the Kamenice stream, the Liboc stream, and the Ještědský stream, located in Northern and Western Bohemia. The studies regarding trends in recreational fishing were conducted in Prague, Central Bohemia, and Eastern Bohemia.

Dietary analyses

The diet of otters and cormorants was analysed via analyses of spraints and pellets, respectively. Samples were collected and diagnostic bones and other identifiable remains were extracted. Those bones and remains were then analysed under stereo microscope. Identified bones and remains were identified to species, measured, and used for analyses of estimated original fish weights and lengths. Non-fish prey was listed only as an occurrence.

Fisheries data analyses

Data regarding fishing visits, fish catches, and angling guard controls were obtained from the annual summaries provided by the Czech Fishing Union. Data regarding electrofishing surveys and salmon observations were provided by the Czech Fishing Union and the Office of the National Park Bohemian Switzerland.

Major findings

1. Lyach R. and Čech M., 2017. Do otters target the same fish species and sizes as anglers? A case study from a lowland trout stream (Czech Republic). Aquatic Living Resources 30, 11.

The aim of this study was to assess the differences in fish catches between Eurasian otter and recreational anglers. We discovered that otters catch and feed on very different fish species of different sizes than anglers. The diet of otter was dominated by small fish but non-fish prey (mainly crayfish and amphibians) was also found in the diet. Otters mainly preyed upon gudgeon Gobio gobio, a small and very common fish species in the study area. Inversely, anglers mostly caught rainbow trout *Oncorhynchus mykiss* and European chub *Squalius cephalus*. Otters mostly caught very small fish (5-10 g) but anglers mostly caught large fish (100-200 g). Stocked salmonids made up only a small amount of otter diet (13 %). That is quite a low number of salmonids in otter diet. Usually, otters prefer salmonids as prey, and especially brown trout *Salmo trutta* and rainbow trout make up significantly more in otter diet than in this case. Otters mostly consumed fish of lower or no commercial value. The overlap between catches of otters and anglers was very low but that does not exclude competition – on estimate, otters still caught tens of stocked rainbow trout over the course of winter. While it is clear that preferences of otters and anglers are different, the competition between animals and fisheries exists even when the overlap in catches is low. On the other hand, the anglers´ claim that otters feed mainly on commercially valuable salmonids was not proved. Note that this competition for fish between otters and anglers could be higher in different areas. For example, in the Třeboň biosphere area, otters that visit carp ponds and feed on resident common carps *Cyprinus carpio* could be causing more potential loss on commercially valuable fish species than otter living in natural areas with high abundances of commercially unimportant fish species.

2. Lyach R. and Čech M., 2017. The effect of cormorant predation on newly established Atlantic salmon population. Folia Zoologica 66: 167-174.

This study aimed to estimate predation pressure of cormorants on the newly established population of Atlantic salmon in the Czech Republic. We discovered that stocked salmon fry and parr in nursery streams are able to survive, grow, and smoltify in order to undergo migration. While the conditions in nursery streams are suitable for salmon, very few adult salmon return to nursery streams for reproduction. It is clear that there is some kind of problem downstream of the nursery streams, probably in the lower Elbe River area. Cormorants were not important predators of salmon fry, parr, smolts or adults – no signs of salmon remains were found in the diet of cormorants. The reason why cormorants did not consume any salmon was the low amount of salmon in the study area. When compared to the amount of cyprinids in the study area (about 100-200 kg per hectare), the amount of stocked and migrating salmon is insignificant. Cormorants are known to prefer feeding on

shoaling fish species like roach *Rutilus rutilus* or bream *Abramis brama*. Also, salmon smolts usually migrate during night, while cormorants are strictly diurnal predators. In addition, the main salmon smolt run occurs during April and May, and by then, majority of the wintering cormorants is already gone. The Salmon 2000 programme is producing good amount of smolts but the migration path in the Elbe River is still too problematic to support salmon migration. If the salmon reintroduction programme is to be successful, movement of salmon should be monitored, and the main cause of salmon mortality needs to be addressed. In the future, if the programme is a success, and salmon start returning and spawning in greater numbers, we expect that cormorant predation could become more significant.

3. Lyach R. and Čech M., 2018. A new trend in Central European recreational fishing: More fishing visits but lower yield and catch. Fisheries Research 201: 131-137.

This study aimed to evaluate long-term changes in the most important variables in recreational fishing – mainly catch, yield, fishing visits, and angling guard controls. We discovered that more anglers are visiting fishing grounds each year. In addition, the number of all fishing visits is increasing as well. Inversely, we found that the overall catch (individual fish) and yield (kg of fish) is decreasing in time. The amount of angling guard controls is increasing in time, making it harder for anglers to break fishing rules. Anglers are getting more mobile and they keep switching fishing grounds more often than they used to. Anglers also return to their favourite fishing grounds less frequently than they used to. It is linked to the increased mobility of anglers. The higher visitation rate is linked to increasing popularity of recreational fishing and also to improved economic situation and increasing well-being of people in general. The decreasing catch and yield is linked to the increasing popularity of the catch-and-release fishing strategy. It seems that recreational fishing is not just about catching and killing a fish anymore, but rather about the fishing experience itself. This trend is also linked to improved economic situation. In conclusion, recreational fishing in the Czech Republic is gaining popularity but the catch is decreasing due to the catch-and-release strategy.

4. Lyach R. and Čech M., 2018. Great cormorants (Phalacrocorax carbo) feed on larger fish in late winter. Bird Study

This study aimed to assess diet of overwintering cormorants over the course of one winter. We discovered that the size of fish in cormorant diet is increasing throughout the course of winter. Cormorants feed on mostly small fish in early winter but the size keeps on increasing in time. Cormorants feed on the largest fish in late winter. This was true for majority of the most important fish species in the diet. There are two possible explanations for this phenomenon – firstly, cormorants actively select larger fish during late winter. Ectothermic fish are significantly weakened over the course of long winter. That makes fish more

susceptible to bird predation. Larger fish have more developed anti-predation behaviour, and significantly faster and therefore harder to catch. Cormorants are also limited by the gap size of their beak, making it harder to swallow a lager fish. Secondly, cormorants simply prey upon the most common fish in the ecosystem, and smaller fish are less abundant in the study are in late winter. Small fish are more vulnerable to starvation and mortality during winter, and that explains why there is lower abundance of small fish in late winter. Cormorants could also be switching feeding sites, mostly because different areas could be available for birds during different parts pf winter. Roach dominated the diet of cormorants (50 % by biomass). We suggest that the fisheries management should reflect on the fact that cormorants compete with anglers for large fish mostly in late winter. The conflict between cormorants and fisheries is the highest in late winter and early spring. For that reason, we suggest that stocking of potentially vulnerable fish should be put off to mid spring when all overwintering birds are gone.

5. Lyach R. and Čech M. Differences in catch, yield, fishing visits, and angling guard controls on differently sized fishing grounds. Fisheries Management and Ecology

This paper aimed to compare the most important variables in recreational fishing – catch, yield, fishing visits, and amount of angling guard controls – on smaller and larger fishing grounds. We discovered that the relationship between the size of a fishing ground and the variable is not always linear. It was not true that the largest fishing grounds would show the highest visit rates and the highest catch, yield, and amount of angling guard controls. Most important and surprising discovery was that mid-sized fishing grounds showed the highest rates of fishing visits, catch, yield, and amount of angling guard controls. Larger fishing grounds showed significantly lower numbers, and smaller fishing grounds showed the smallest numbers. When standardized to one hectare, smaller fishing grounds showed the highest rates of fishing visits, catch, yield, and amount of angling guard controls. Largest fishing grounds showed the lowest numbers. In conclusion, the most important variables in recreational fishing respond to the size of a fishing ground, but not always in a linear way. The fisheries management should reflect on the fact that fishing grounds of different sizes are very different in basic variables in recreational fishing. The smallest fishing grounds are under the highest pressure per one hectare, and fisheries management should adjust the management of smaller fishing grounds to partially remove the fishing pressure.

6. Lyach R. and Čech M. The differences in catch, yield, fishing visits, and angling guard controls on natural and urban fishing grounds. Urban Ecosystems

This study aimed to assess the differences in the most important variables in recreational fishing – catch, yield, fishing visits, and amount of angling guard controls – between urban and natural fishing grounds. Urban and natural fishing grounds showed similar visit rates.

Urban fishing grounds showed higher catch and yield and also higher amount of anglers who took home at least one fish. Inversely, natural fishing grounds showed higher amount of angling guard controls. Common carp dominated in catches of anglers on both types of fishing grounds. Urban fishing grounds showed higher catch of intensively stocked fish species while natural fishing grounds showed higher catch of bream *Abramis brama* and large-growing piscivorous fish species. Anglers caught on average larger fish on natural fishing grounds, mostly because natural areas offer better environmental conditions for fish populations. We suggest that fisheries management should take those differences into consideration, for example by advising angling guards to visit urban fishing grounds more frequently. For example, urban fishing grounds could be subjected to revitalisations in order to make the habitat more attractive for piscivorous fish species.

7. Lyach R. and Čech M. Do cormorants and recreational anglers take fish of the same species and sizes as anglers? Ardea

This study aimed to assess the differences in fish catches of cormorants and recreational anglers in a study area where the conflict between environmentalists and fisheries has been escalating for years. We discovered that cormorants mostly preyed upon smaller fish (50-100 g) of lower or medium angling value. Inversely, recreational anglers caught large fish (1000-2000 g) of medium and high angling value. Cormorants mostly preyed upon cyprinids such as roach, bream, ide, and European chub, and in addition to that also perch. Inversely, anglers mostly caught cyprinids like common carp, bream, and in addition to that also piscivorous species like pike *Esox lucius*, zander *Zander lucioperca*, and European catfish *Silurus glanis*. Cormorants mostly consumed fish that were undersized for angling purposes. The overlap of catches between cormorants and anglers was overall quite low. On the other hand, this low overlap of catches does not exclude competition between cormorants and fisheries. Firstly, cormorants were still consuming small fish that would grow into legal catchable size for anglers, and therefore cormorants were causing indirect financial loss on those fish. Secondly, cormorants were consuming cyprinids that serve as prey for highly valued piscivores. This way, cormorants are competing for catches with piscivorous fish species, potentially preventing them from growing to angling sizes.

8. Lyach R. and Čech M. Solidarity of anglers is more important than any fishing regulation: a case study of grayling *Thymallus thymallus* in the Czech Republic

The aim of this study was to evaluate the effect of a large-scale fishing regulation (increase in angling size of grayling from 30 to 40 cm) on the overall catch and yield of grayling. We discovered that the restriction in minimum angling size of grayling had no effect on the overall catch and yield of grayling. However, the change had an effect on the distribution of catches of grayling among fishing grounds. The percentage of fishing grounds with any

catches of grayling decreased after the restriction took place. In addition, the restriction had an effect on the average body weight of grayling in catches of anglers – the body weight increased due to the restriction. We also searched discussion forum regarding fisheries to find out the opinion of anglers on conservation of grayling. Those discussion forums revealed that anglers place high priority on conservation of grayling. Anglers support protection of grayling, they release all caught grayling back to the water, and they are actively trying to improve environmental conditions in grayling streams at their own expenses. We conclude that the large-scale restriction had no effect on the overall catch and yield of grayling, mostly because anglers were already releasing all caught grayling back to water before the restriction took place. The reason for this behaviour was that anglers are aware of the poor population status of grayling in the Central Europe. While fisheries regulations are usually an effective measurement that helps to prevent overfishing, in this case, it was not needed. Solidarity of anglers with an endangered species was more important than the actual fishing regulation.

9. Lyach R. and Čech M. A tale of two trout: the intensively stocked, non-native rainbow trout *Oncorhynchus mykiss* is not replacing the native brown trout *Salmo trutta* in catches of recreational anglers. Fisheries Management and Ecology

The aim of this study was to evaluate long-term trends in catch, yield, average body weight of caught rainbow trout and brown trout. We discovered that catch and yield of both trout species has been increasing over time. While anglers are catching rainbow trout of similar size every year, the size of caught brown trout is increasing. The number of fishing grounds with trout catches has been stable. The idea that the number fishing grounds where trout can be seen and caught has been decreasing was not supported by results of this study. There was also a positive correlation between body size of caught rainbow trout and brown trout on individual fishing grounds. Similarly, there was a positive correlation in yield between both trout species on individual fishing grounds. The competition between the native and non-native trout species is not apparent from angling statistics. Rainbow trout is perceived as a weak competitor, stocked trout have high post-stocking mortality, and anglers usually remove stocked trout very quickly. Therefore, the time that stocked trout spend in the ecosystem is very limited. That is the main reason why native brown trout is usually not threatened by intensively stocked rainbow trout. However, more research should be done to actually analyse the competition more thoroughly.

10. Lyach R. Public attitudes towards and trends in recreational fisheries across the world: Central Europe: the Czech Republic. In: Arlinghaus R. (ed.). Global participation in and public attitudes towards recreational fishing: international perspectives and developments (in preparation)

The aim of this chapter was to bring more information on the perception of anglers and angling activities by the public, mainly by people who do not fish. While the data on similar studies that assess public opinion on recreational fishing are basically non-existent in the Czech Republic, the results of three studies that were presented by the Czech Fishing Union showed interesting ideas. Recreational fishing is a very important hobby in the Czech Republic – about 3 % of the Czech population practice recreational fishing. Anglers have mostly medium or low economic status. Most anglers are older (in age group 40-49 years) and seniors (60 plus) form 30 % of all anglers. About 50 % of all anglers practice the catch-and-release fishing strategy. Anglers are mostly perceived positively, although some aspects of angling and fisheries management and seen negatively by the public. Mainly, intensive stocking of non-native fish species (common carp, rainbow trout) is perceived negatively. Fishing competitions are also often perceived as cruel and unnecessary.

Conclusions

In conclusion, this thesis was addressing the main issues of fisheries. Especially, it was aiming at explaining the main drivers of recreational fishing, feeding ecology of the most important piscivorous birds and mammals, and also the issue of reintroductions of fish species of high commercial and angling value.

While the losses of fish that are caused by the Eurasian otter and the great cormorant are significant, the conflict between environmentalists and fisheries is perhaps not as intense. Piscivorous predators mainly feed on the most common and available fish species. Otters usually prey upon small and very abundant fish species of low angling value. Similarly, cormorants usually prey upon very abundant shoaling fish species of low and moderate angling value. The results did not support the statement that otters or cormorants select large-growing fish species of high commercial value. On the other hand, it is true that some percentage of prey consists of highly valuable salmonids and piscivorous fish species. Especially overwintering cormorants consume lots of fish over the course of winter, and even if the commercially valuable species made up fewer than 10 % of the diet, it is still a significant financial loss.

Recreational fishing has changed significantly over the course of the last decade. We observe the increase in visit rates but also the decrease in the catch and yield. Angling guards are getting more active every year, meaning that anglers should not get away with breaking the law that easily. Fishing grounds of different types also show different results, and sometimes not in a way that the fisheries management would expect. Fishing grounds in natural areas and in cities display different results, and so do smaller and larger fishing grounds. Most importantly, larger fishing grounds do not show the highest visitation rates and the highest catch and yield – the mid-sized fishing grounds are visited at much higher rates. The catch and yield is also the highest at mid-sized fishing grounds. In addition, urban fishing grounds

showed higher catch and yield but lower rates of angling guard controls. It is clear that the fisheries management should take those differences into consideration, mostly because they are not visible at first, and they are sometimes quite counter-intuitive.

The salmon reintroduction programme is certainly a good idea, and the Czech Republic is cooperating with other countries (mainly Sweden and Germany) in exchange of knowledge regarding salmon stocking. However, more research needs to be done on this topic. If we want to make the salmon reintroduction successful, this international cooperation is crucial, especially when both sides are trying to find the reason why, even after 20 years, the results are not what they should be.

Fishing restrictions are usually a god idea and certainly the easiest way to prevent streams and rivers from being overfished. However, the main result of similar restriction is mostly dependant on the actual opinion and education of anglers. It is clear that anglers need to be in agreement with such restriction, mostly because there is no real way to enforce it in the field. Angling guards are certainly playing a crucial role in those cases, yet even angling guards are very limited in what they can actually do. Recreational fishing is about people as much as it is about fish, and attitude of anglers is the most important factor in fisheries.

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Bachelor thesis

Chances of survival of stocked fish in the wild

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Conferences

Active participation with a speech – Zoological days (2015, 2017, 2018), Post Graduate Student Conference (2014, 2015, 2016, 2017), Agency for Landscape Protection Conference (2016), Conference on Ornithology (2016), Fresh Blood for Freshwater (2017)

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