

DOES HARVEST OF THE EUROPEAN GRAYLING, *THYMALLUS THYMALLUS* (ACTINOPTERYGII: SALMONIFORMES: SALMONIDAE), CHANGE OVER TIME WITH DIFFERENT INTENSITY OF FISH STOCKING AND FISHING EFFORT?

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Background. The European grayling, *Thymallus thymallus* (Linnaeus, 1758), is a fish species of high value in recreational fishing. The monitoring of changes in grayling populations is a high priority in fisheries. Data on the harvest of recreational anglers can potentially serve as an easy and inexpensive way to monitor changes in fish populations. This study aimed to assess spatio-temporal trends in catches of grayling in a larger geographical area.

Materials and methods. This study analysed harvest rates of grayling by recreational anglers on 241 fishing grounds, in the Czech Republic, within 1986–2015 (30 years). Data from individual angling logbooks were used. The data were collected by individual anglers and processed by the Czech Fishing Union (Český rybářský svaz).

Results. Over the period of 30 years, Czech anglers harvested a total of 9 928 grayling specimens weighing altogether 3 357 kg. Within the period surveyed, both parameters (the grayling biomass harvested and the representation of grayling in overall fish harvest) decreased to 10% of the initial values. The percentage of fishing grounds with a harvest of grayling decreased to 30% of the initial values. Harvest per effort decreased to 20% of the initial values over 11 years. There was only a weak correlation between fish stocking and fish harvest. There was a negative relation between the number of angler fishing visits with both catch (fish number) and yield (biomass) of grayling. The harvest was positively correlated with fishing effort. The mean size of harvested grayling remained constant (~0.35 kg) over 30 years.

Conclusion. Harvest of grayling significantly declined over the last three decades, implying that increased effort in conservation of grayling is necessary. Future studies should focus on monitoring of the remaining self-reproducing grayling populations.

Keywords: angling diaries, catch per unit effort, fisheries management, population dynamics, salmonids

INTRODUCTION

In central Europe, the European grayling, *Thymallus thymallus* (Linnaeus, 1758), is a fish species of high value in recreational fishing, commercial fishing, and species conservation. Grayling is a native fish species that used to be common in streams and smaller rivers located under mountain ranges (Persat 1996). However, anglers, fisheries managers, and environmentalists claim that populations of grayling have been steadily decreasing in central Europe over the last 20–30 years (Gum et al. 2009, Weiss et al. 2013, Mueller et al. 2018). Recently, grayling has become one of the most threatened inland freshwater fish species in central Europe. By studying the effect of both natural and human-induced effects on grayling populations, other authors discovered that the main reasons for the decrease in grayling populations are droughts, climate change, predation from fish-eating birds and mammals, fishing pressure, river damming and

straightening, loss of spawning substrates, land-use, and pollution (Northcote 1995, Persat 1996, Uiblein et al. 2001, Gum et al. 2003, Duftner et al. 2005, Sternecker et al. 2014, Geist and Hawkins 2016, Bierschenk et al. 2019). By studying human–fish interactions, previous studies have also found that the interaction between recreational fisheries and grayling is one of the most important drivers of grayling populations (Duftner et al. 2005, Näslund et al. 2005, 2010).

Data from angling logbooks can be used as proxy data for changes in abundances of fish populations (Sztramko et al. 1991, Gudbergsson 2004, Jayasyngha et al. 2006, Mosindy and Duffy 2007, Skov et al. 2017, Kerr unpublished*). The results of the studies listed above suggest that a change in harvest rate potentially suggests a change in abundance in the ecosystem. In addition, data from angling logbooks were previously used by other authors to monitor fish abundances and populations,

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water quality, fish sizes, effects of water damming on fish populations, and changes in water temperatures (Cowx and Broughton 1986, Binet 1997, Lorenzen et al. 1998, Draščík et al. 2004, Jayasynghé et al. 2006, Younk and Perreira 2007, Zeeberg et al. 2008, Gerdeaux and Janjua 2009). The interaction between anglers and grayling is crucial in the conservation of grayling. However, there are only a few studies that describe the angler–grayling interaction (Näslund et al. 2005, 2010). In addition, those studies describe catches of grayling on small spatio-temporal scale. No study describes the angler–grayling interaction on a larger spatio-temporal scale in a larger geographical area.

This study aimed to describe changes in the catch (fish number) and yield (biomass) of grayling on a large spatio-temporal scale (241 studied fishing grounds, 30 years of data) in the Czech Republic. We expected that the harvest of grayling was decreasing, mostly because anglers, fisheries managers, and environmentalists claim that grayling populations have been declining. It was hypothesized that both catch and yield would follow and mirror this trend. Another aim of this study was to describe changes in the number of fishing grounds with actual catches of grayling. We expected that smaller grayling populations would perish over time, and that human-induced effects would lead to a decreased number of streams where self-sustainable grayling populations exist. Another aim was to assess changes in the size of caught grayling over time. We expected that anglers would be catching smaller fish every year, mostly because the angling and predation pressure on grayling populations seems to be increasing. The last aim was to assess the effect of fish stocking on the fish harvest. We expected that fishing grounds with higher stocking rates would also display higher harvest rates.

MATERIALS AND METHODS

Study area. This study was carried out in the regions of Prague (50°N, 014.5°E) and the Central Bohemian Region (Středočeský kraj) (49.5°–50.5°N, 013.5°–015.5°E), Czech Republic, central Europe (for map of the study area see Lyach and Čech 2018a). Both regions together cover an area of 11 500 km². The region of Prague has mostly urban character while the region of Central Bohemia has a mostly rural character. The study area is dominated by the rivers Elbe and Vltava. Both rivers belong to the upper Elbe River basin. All rivers in the study area belong to the North Sea drainage area. Studied fishing grounds are situated in lowlands of an altitude of 200–600 m above sea level. Waters in the study areas are mostly mesotrophic and eutrophic with biomass of 150–300 kg of fish per ha (Lyach and Čech 2017b, 2018a, 2018b). The study area includes salmonid streams (smaller streams, mostly < 10 m wide, usually dominated by salmonids) and non-salmonid rivers (wider streams and rivers, usually 10–300 m wide, dominated by cyprinids or percids). Studied rivers and streams are mostly at their carrying capacity

due to natural fish reproduction and intensive fish stocking (Závorka et al. 2013). Grayling is a native fish species in the study area.

Recreational fishing in the Czech Republic. Recreational fishing in the Czech Republic is organized by the Czech Fishing Union (Český rybářský svaz). The Union is the principal authority in recreational fishing in the Czech Republic and is centralized for the whole country. Each angler has to carry an angling logbook with him/her at all times during fishing. When an angler catches and keeps a fish, he/she is obliged to write down the catch (identified fish species, size of the fish in TL in cm, date of the catch, and ID/name of the fishing site). Filled logbooks are then collected in January of the following year by the Czech Fishing Union. Only anglers who submit their old filled angling logbook will receive a new angling logbook for the next year. Errors in filling of angling logbooks may result into confiscation of fishing equipment, harvested fish, or fishing permit. Proper usage of angling logbooks is checked in the field by angling guards. Only killed (harvested) fish are recorded in individual angling logbooks. Fish that are undersized, caught during the closed season, or otherwise released are not recorded in logbooks. For a detailed description of recreational fishing in the Czech Republic see Lyach and Čech (2018a, 2018b).

Angling rules for grayling. Grayling, *Thymallus thymallus*, is an important fish species in recreational fishing in the Czech Republic. The bag limit for salmonids is either two fish or 7 kg of fish per angler per day, whichever comes first. Within 1986–2015 the minimum legal angling size for grayling was 30 cm (TL, total length). Any grayling that does not reach this size has to be returned back to the water without any unnecessary delay. All harvested graylings must be noted in individual angling logbooks, including the date of catch, the weight of fish, and the ID of the fishing ground.

Grayling stocking. Annual stocking of grayling is common and traditional in the study area. Most stocking is performed on smaller salmonid streams and rivers (<10–20 m wide) outside the main rivers. Grayling is mostly stocked as 1–2 year fish (5–10 cm TL). Fish are usually stocked in hundreds or thousands per stream. The main goal of the fish stocking is to support wild populations. Before fish stocking occurs, all stocked fish are weighed together (in one bag) to the nearest 100 g. The number of stocked fish is then estimated from the overall weight by applying length–weight equations of the specific fish species. The length–weight equations are based on data from catches of a larger amount (at least 100) of fish that were caught in the study area by fisheries managers. Fish stocking is performed by local fisheries managers.

Data sources. Data from annual summaries of all collected angling logbooks were used for this study. This data originated from angling logbooks that were collected from individual anglers. Fishing grounds are defined as stream and river stretches where recreational fishing can be legally conducted. The selected fishing grounds covered an

* Kerr S.J. 1996. A summary of Muskies Canada Inc. angler log information, 1979–1994. Technical Report TR-011. Ontario Ministry of Natural Resources, Kemptville ON, Canada.

area of 125 km². This data was originally collected by the Czech Fishing Union and later processed by the authors of this study. Data from 241 fishing grounds collected within 2005–2015 (11 years) were used to analyse catch and yield per fishing effort (data on fishing effort were available only from the year 2005 onwards). For that reason, the harvest of grayling over the years 1986–2004 was not related to fishing effort in the analyses. Data from years 2016 and 2017 were not used because the legislative rules in recreational fishing significantly changed since 2016 (minimum legal angling size of grayling was increased from 30 cm to 40 cm TL, total length). In the rest of the analyses, data from 241 fishing grounds within 1986–2015 (30 years) were used. A similar dataset was previously used for scientific purposes (Humpl et al. 2009, Jankovský et al. 2011, Boukal et al. 2012, Lyach and Čech 2017a, 2018a, 2018b).

Biometric data. This study assessed the overall catch (number of fish individuals killed) and yield (total weight/biomass of all fish killed), catch and yield per one hectare of fishing grounds, catch and yield per effort (one fishing visit), the representation of grayling in the overall fish harvest, fish body sizes (medium body weight), the percentage of fishing grounds with and without harvested grayling, catch per stocked fish per hectare, and yield per stocked biomass per hectare. To estimate the effect of fish stocking on fish catch, data were used on fish stocking from 3–5 years before the fish were caught. The mean value of three consecutive years was used in the analysis. Data on fish stocking from 0–2 years before the catch were not included because stocked fish were small (10 cm TL) and unlikely to grow to legal angling size (30 cm) over two years. Data on fish stocking that were six years or older were also not included, mainly for two reasons: (1) the usual lifespan of grayling is 5–6 years maximum, and (2) stocked fish usually display high mortality due to stocking stress, predation, angling, and inability to adapt to natural conditions. Stocked graylings were very unlikely to survive for six years in the study area. Therefore, the effect of stocking on catch and yield was calculated based on data collected within 1991–2015.

Statistical analyses. The statistical programme R (R i386 3.4.1.; R Development Core Team 2017) was used for statistical testing. The package for generalized linear mixed models (GLMM) was used to fit the models (Hadfield 2010). The function *lmer* in the package *lme4* (version 0.99937542; Bates et al. 2015) was used to calculate *R*-squared values (Nakagawa et al. 2013). In the models, catch (fish number), yield (biomass), and body weight of fish were used as explained variables. The year, the intensity of fish stocking, and fishing visits were used as explanatory fixed variables. The fishing ground variable was used as a random factor. One fishing ground was used as one sample in the analysis. Gamma error distribution with log link function was used in the models that described changes over time. The basic equation for models was

$$\text{Catch} \sim \text{fishery} + \text{year}$$

In other models, the catch was replaced with yield or size, and (1|fishery) was removed from the analysis in the case when the model described the number of fishing grounds with and without catches of grayling. All fishing grounds were used in the analysis of fish harvest. Only fishing grounds with non-zero catches of fish (any species) were used in the analysis of the representation of grayling in overall catch and yield. Only fishing grounds with non-zero catches of grayling were used in the analysis of size (body weight) of caught grayling. Only fishing grounds with non-zero stocked grayling were used in the analysis of the effect of fish stocking on catch and yield. The minimum probability level of $P = 0.05$ was accepted for all the statistical tests, and all statistical tests were two-tailed. Bonferroni correction was applied when multiple groups were compared in statistical analysis. The results presented in the Table 1 are derived from models in R while the figures were drawn in MS Excel. The method described above was previously used to analyse similar data sets on fish harvest (Humpl et al. 2009, Jankovský et al. 2011, Boukal et al. 2012, Lyach and Čech 2017a, 2018a, 2018b, Lyach and Remr 2019a, 2019b).

RESULTS

Overall summary. Within 1986–2015 (30 years), anglers caught altogether 9 928 graylings of the total weight of 3 357 kg. In comparison, over 30 years, anglers caught altogether 7 715 156 fish (of different species) of the total weight of 11 512.87 t. Within 2005–2015 (11 years), anglers visited selected fishing grounds 5 739 535 times and caught 1 320 graylings of the total weight of 436 kg. In comparison, over 11 years, anglers caught altogether 2 234 110 fish (all species) of the total weight of 4 385 t. Anglers visited one hectare of studied fishing grounds 238 times, on average, and harvested 0.0096 graylings of the biomass of 0.0032 kg per hectare of fishing grounds annually. Fisheries managers stocked 1.44 graylings of the biomass of 0.03 kg per hectare of fishing grounds annually. The results of all used statistical models are listed in Table 1.

Catch and yield of grayling. Both catch and yield of grayling decreased to 10% of the initial values over the course of 30 years (Figs. 1A, 1B). Anglers were catching 0.6 fish and 0.2 kg of fish per hectare of fishing grounds in 1986. However, catch and yield decreased to only 0.07 fish and 0.02 kg of fish per hectare of fishing grounds in the year 2015. The model explained 16% and 5% of the variability in catch and yield, respectively.

Catch and yield per fishing visit. Anglers were catching fewer grayling per fishing effort (fishing visit) every year. Both catch and yield per fishing visit decreased to 20%–25% of the initial values over 11 years (Figs. 2A, 2B). Anglers caught 0.0003 fish and 0.0001 kg of fish per visit in 2015. After 11 years, both catch and yield per visit dropped to 0.00007 fish and 0.00003 kg of fish per fishing visit, respectively, in 2015. The model explained 11% and 12% of the variability in catch and yield, respectively. Both catch and yield were positively correlated to the fishing effort (intensity of fishing visits). Fishing grounds

Table 1

Changes of basic metrics in recreational fishing over time with different fisheries management (data are for catches of grayling *Thymallus thymallus* by recreational anglers in the Czech Republic within 1986–2015)

Dependent variable	Explanatory variable	Intercept \pm SD	Slope \pm SD	<i>P</i> -value	Var (RE)	<i>R</i> ²	DF
Catch \times ha ⁻¹	year	0.35 \pm 0.14	-0.048 \pm 0.0030	<0.001	2.8200	0.1600	2 681
Yield \times ha ⁻¹	year	0.19 \pm 0.11	-0.016 \pm 0.0020	<0.001	1.5940	0.0500	2 681
Catch \times fishing visit ⁻¹	year	4.22 \pm 1.14	-0.002 \pm 0.0009	<0.001	0.0004	0.1100	2 681
Yield \times fishing visit ⁻¹	year	2.02 \pm 0.75	-0.001 \pm 0.0003	0.007	0.0002	0.1200	2 681
Catch \times ha ⁻¹	fishing visit	0.023 \pm 0.071	0.00004 \pm 0.000010	0.002	0.0048	0.04	2 681
Yield \times ha ⁻¹	fishing visit	0.012 \pm 0.021	0.00020 \pm 0.000004	0.002	0.0039	0.04	2 681
% in overall catch	year	27.24 \pm 4.37	-0.013 \pm 0.0020	<0.001	0.0050	0.0500	2 681
% in overall yield	year	24.87 \pm 4.49	-0.012 \pm 0.0022	<0.001	0.0180	0.0500	2 681
Catch \times visit ⁻¹	stocked fish <i>n</i> \times ha ⁻¹	0.00016 \pm 0.00007	0.00008 \pm 0.00003	0.26	0.00003	0.008	566
Yield \times visit ⁻¹	stocked b. \times ha ⁻¹	0.00009 \pm 0.00003	0.00003 \pm 0.00001	0.21	0.00001	0.003	566
<i>N</i> of sites with catches	year	6.78 \pm 2.78	-0.003 \pm 0.0010	0.016	NA	0.1800	2 681
Mean body weight	year	-23.82 \pm 2.98	0.012 \pm 0.0014	0.410	0.0030	0.1800	164

SD = standard deviation, var (RE) = variance for random effect, DF = degrees of freedom, NA = not applicable; *N* = number; stocked b. = stocked biomass, stocked fish *n* = stocked fish number.

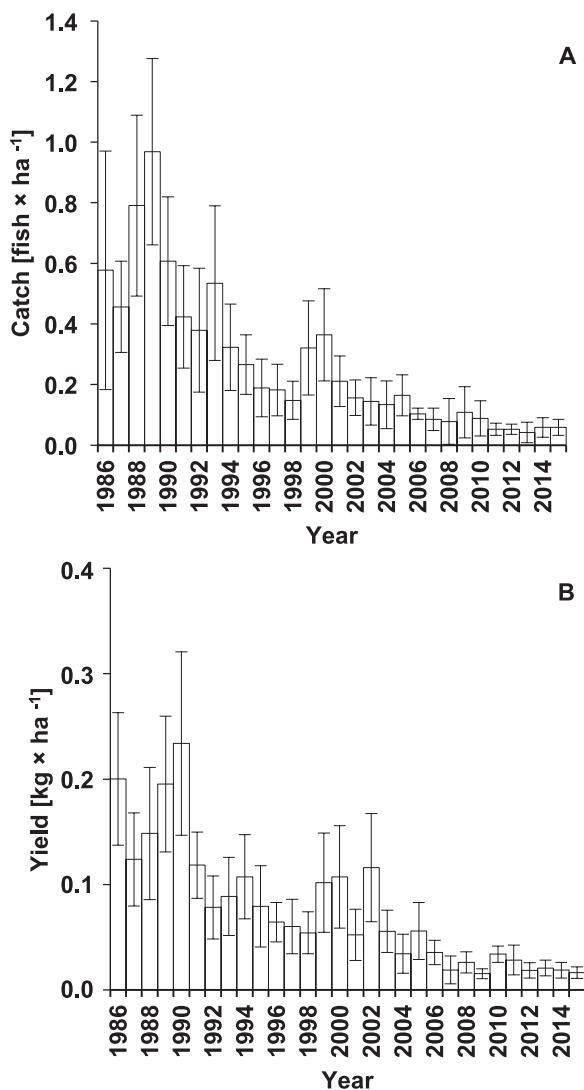


Fig. 1. (A) Catch (fish number) and (B) yield (biomass) of grayling, *Thymallus thymallus*, per hectare of fishing grounds in the Czech Republic within 1986–2015; the whiskers represent the standard error of mean

with higher visit rates also displayed higher catch and yield of grayling. However, fishing grounds with the highest visit rate (35 000–100 000 visits per year) displayed zero catches of grayling (Figs. 2C, 2D). The positive effect of fishing effort on catch and yield was mostly observed on fishing grounds with lower visit rates (10–10 000 visits per year). For larger fishing grounds, there was a negative relation between the number of angler fishing visits with both catch and yield of grayling.

Representation in overall catch and yield. The representation of grayling in the overall catch and yield of all fish decreased to 20% and 10% of the initial value (in catch and yield, respectively) over the course of 30 years. The representation of grayling decreased from 0.24% to 0.05% and from 0.08% to 0.008% in catch and yield, respectively (Figs. 3A, 3B). The model explained 5% of the variability in the representation in both catch and yield.

Harvest in relation to fish stocking. There was only a weak correlation between fish stocking and fish harvest. Higher intensity of fish stocking did not lead to significantly higher rates in the fish harvest. Fisheries managers stocked 5–1000 fish with a total weight of 0.1–27 kg per one hectare of fishing grounds, however, several fishing grounds with high intensity of fish stocking displayed zero harvested grayling. Inversely, several fishing grounds with low intensity of fish stocking displayed relatively high harvest rates (considering that overall harvest of grayling was very low in general).

Fishing grounds with catches. Anglers were catching grayling on a lower number of fishing grounds every year. The percentage of fishing grounds with one or more harvested grayling was decreasing over time. The number of fishing grounds with catches of grayling decreased to 30% of the initial value (from 12.5% to 3.7%) over 30 years (Fig. 4A). The model explained 18% of the variability in the percentage of fishing grounds with fish catches.

Size of caught fish. Anglers were catching grayling of comparable size (body weight) every year. The size of

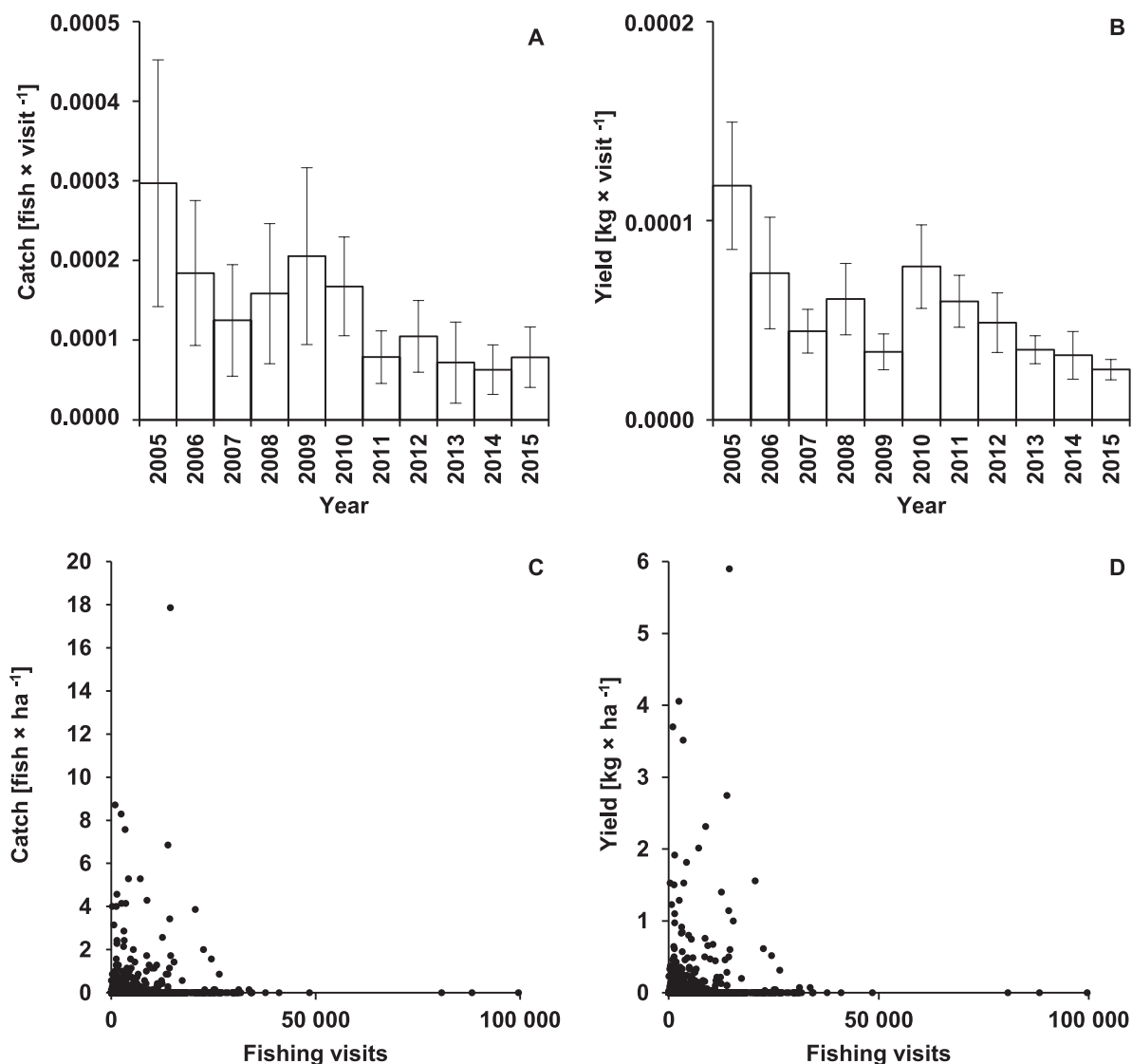


Fig. 2. (A, B) Catch (fish number) and yield (biomass) of grayling, *Thymallus thymallus*, per fishing visit; (C, D) the relation between fishing visit rates and harvest (catch and yield) in the Czech Republic within 1986–2015; the whiskers (A and B) represent the standard error of mean

caught grayling did not significantly change over 30 years (Fig. 4B). The mean size of caught grayling per fishing ground was 0.35 kg and ranged from 0.25 kg to 1.8 kg. The model explained 18% of the variability in fish size.

DISCUSSION

Data limitations. The dataset that is derived from individual angling logbooks provided long-term data on fish catches on a large number of fishing grounds, however, the data should be used and interpreted with caution. Fish catches are reported by regular anglers and not by scientists. Since the data are based on citizen science, the error in the data is probably a bit higher when compared to real scientific data. On the other hand, recreational fishing connects regular people to nature, and, to a certain point, to scientific work. That is a big advantage in a similar type of research. However, this dataset has several limitations. Anglers may overestimate or underestimate the numbers and sizes of caught fish,

disobey fishing rules, and incorrectly identify harvested species. Listed errors are made either unknowingly or on purpose (Essig and Holliday 1991, Pollock et al. 1994, Cooke et al. 2000, Bray and Schramm 2001, Mosindy and Duffy 2007, Lyach and Čech 2017a, 2018a, 2018b). Fisheries data also do not cover poaching or the catch-and-release fishing strategy. Especially salmonids display high post-release mortality (Clark 1991, Casselman 2005). However, the dataset provided data on 30 years of catches on 240 fishing grounds, and the data were collected by approximately 60 000–80 000 different people during at least tens of millions of working hours (Lyach and Čech 2018a, 2018b). If the data were collected by a few scientists, the bias in the selective collection of the data would be higher, mostly because every person performs fishing a bit differently. It would also be impossible to collect data on this strength. This dataset was collected by approximately 60 000–80 000 people in the field, and therefore the bias in data collection should be low.

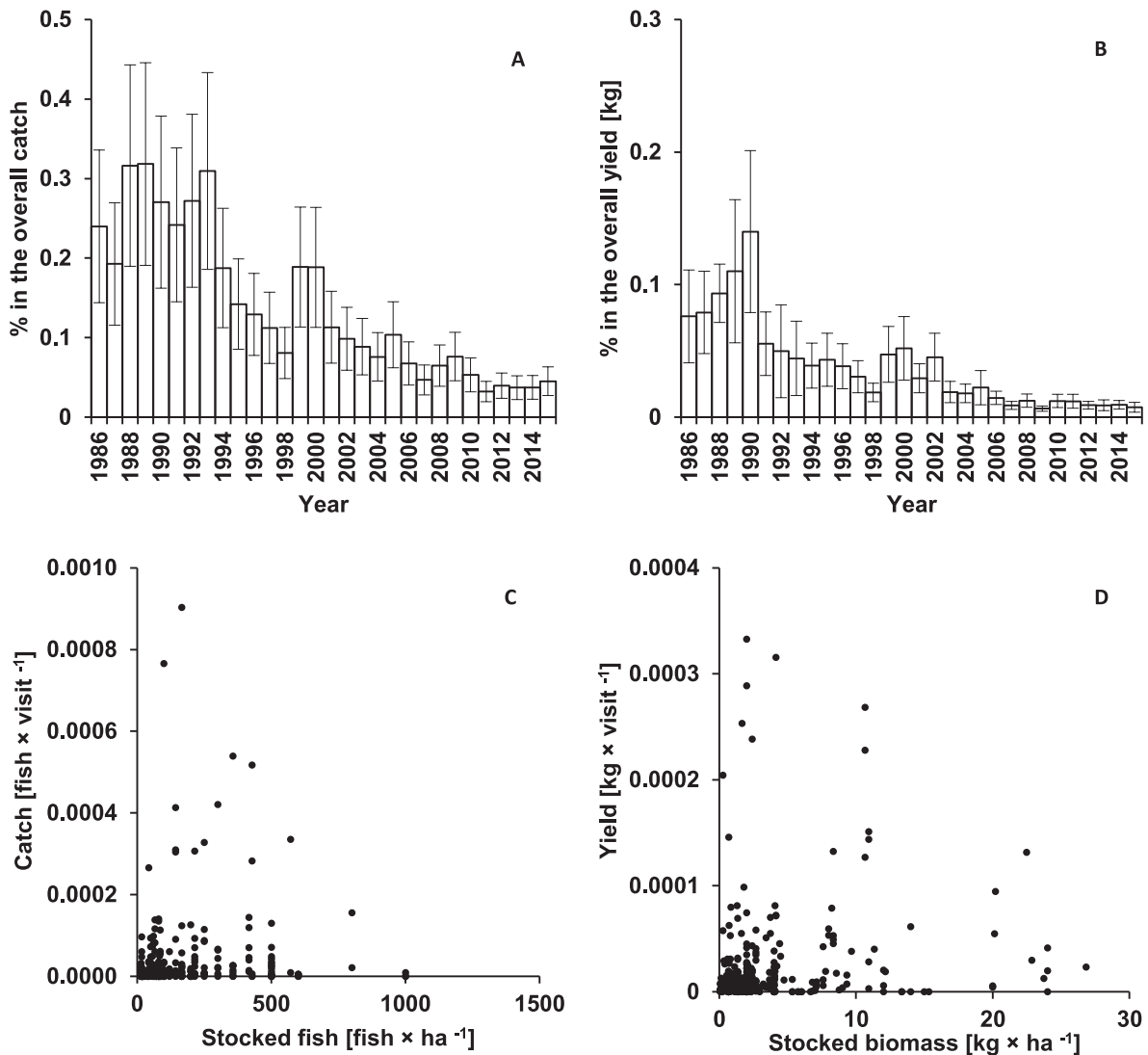


Fig. 3. (A, B) The percentage representation of grayling, *Thymallus thymallus*, in the overall catch (fish number) and yield (biomass) of all fish caught by anglers in the Czech Republic within 1986–2015; (C) the relation between the amount of stocked fish per hectare of fishing grounds and catch per fishing visit; (D) the relation between stocked biomass per hectare of fishing grounds and yield per fishing visit; the whiskers (A and B) represent the standard error of mean

Political changes. Both catch and yield displayed a significant and visible change over the years 1989 and 1990. In 1989, the velvet revolution (fall of the communist regime) took place in Czechoslovakia. The majority of metrics in recreational fishing were increasing until 1989, and after that, those metrics started to decrease. Fishing used to be a very popular leisure activity during the communist era, mostly because regular people were not allowed to travel to the western capitalist world (Europe, North America), and the possibilities of travelling to eastern Europe were very limited as well. Other means of entertainment were also significantly limited. People fished to obtain food, mostly because food supplies were also limited and often not available. After 1989, the borders opened and people could travel, participate in a wide variety of leisure activities, and buy the food that they wanted. For that reason, the popularity of fishing decreased, and the number of fishing visits also decreased. That could have caused a decrease in catch and yield. The

agricultural management also changed after 1989; the input of fertilizers into the environment decreased. That caused a decrease in primary production in most water ecosystems (Kunzová and Hejman 2009). Unfortunately, data on fish harvest before 1986 were not available. It seems that both catch and yield increased from 1986 through 1989, and it would be interesting to see when exactly the increasing trend started. In conclusion, it seems that the fall of the regime was one of the most important factors in recreational fishing.

Catch and yield. Both catch (fish number) and yield (biomass) are usually linked to the following three parameters: population changes of fish species in the environment, popularity of the catch-and-release fishing strategy, and interest in conservation of fish species (Jayasynghé et al. 2006, Mosindy and Duffy 2007, Skov et al. 2017). Those three parameters are also interconnected; anglers are more likely to release rare and endangered fish species (Arlinghaus et al. 2007,

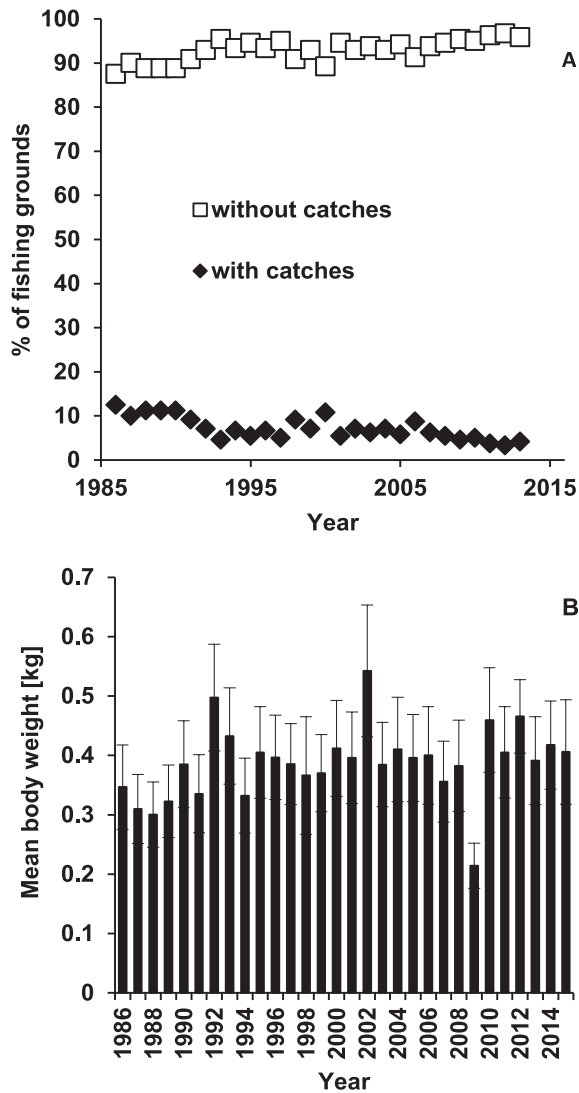


Fig. 4. (A) The percentage of fishing grounds with and without a catch of grayling, *Thymallus thymallus*; (B) the mean body weight of grayling caught by anglers in the Czech Republic within 1986–2015; the whiskers (B) represent the standard error of mean

Bartholomew and Bohnsack 2005). Since anglers are well aware of the poor population status of grayling, it is possible that decreased harvest was partially caused by the increasing popularity of catch-and-release fishing. By studying fisheries discussion forums on fisheries Web pages, we found that anglers are strongly supporting the conservation of grayling. Anglers claim that they are releasing all caught grayling (Authors' observation). When the results of this study are combined with opinions of local anglers and fisheries managers, it can be concluded that this dataset provided good proxy data on changes in grayling populations in the study area.

Fishing grounds with catches. The number of fishing grounds with reported catches of grayling were relatively low already 30 years ago, and the number was decreasing over time. Grayling is a typical inhabitant of streams, and the majority of streams in the area are not listed as fishing grounds (Czech Fishing Union, unpublished data). Instead,

they are listed as waters that are used for spawning and breeding purposes (fishing is not allowed there). Streams in the study area are significantly affected by pollution, predation from piscivorous predators (otter *Lutra lutra*, cormorant *Phalacrocorax carbo*, heron *Ardea cinerea*, mink *Mustela vison*), fishing pressure, and migration barriers (Adámek and Jurajda 2001, Humpl and Pivnička 2006, Slavík et al. 2012, Závorka et al. 2013, Lyach and Čech 2017a, Lyach et al. 2018). Another problem is a shortage of grayling for stocking purposes. There is usually not enough grayling to spawn, and therefore the amount of YOY fish and yearlings available for stocking is very limited (Czech Fishing Union, unpublished data). Artificial rearing of grayling in aquaculture is significantly less profitable than the rearing of common carp, *Cyprinus carpio* Linnaeus, 1758, or rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1792) (see Carlstein 1995). Import of grayling from abroad is not recommended due to genetic differences in fish populations (Gum et al. 2009).

Fish stocking. The effect of fish stocking on catch and yield could be different in areas with pristine unpolluted streams that support native grayling populations. Especially streams that are situated in the mountains will likely show higher catches of grayling. Return rates of grayling in areas with pristine streams could exceed 100%, mostly because anglers can catch both native and stocked grayling there. For example, the biomass of harvested graylings could be higher when compared to the biomass of stocked graylings. This effect was observed for self-reproducing fish populations of very abundant fish species that are harvested by anglers. For example, European chub, *Squalius cephalus* (Linnaeus, 1758), displayed harvested biomass of 50–100 kg in the Berounka River (Central Bohemia) even though no stocking of chubs occurred (Czech Fishing Union, unpublished data). Similarly, European catfish, *Silurus glanis* Linnaeus, 1758 displayed harvest rates of 8–10 kg per hectare on the same river even though no stocking of catfish occurred either (Lyach and Remr 2019c). There are streams with self-reproducing grayling populations located under mountains approximately 100 km from the study area (Horká et al. 2015). However, streams with natural grayling spawning are rare, and this study describes the situation on typical lowland streams.

Catch and visit rates. Catch per visit was decreasing even more rapidly than catch per effort. It is mostly because anglers were visiting fishing grounds more frequently each year, contributing to increased fishing pressure in the area. As determined by Lyach and Čech (2018a), the fishing pressure has been increasing recently. On the other hand, both catch and yield have been decreasing (Lyach and Čech 2018a). Another study found that fishing pressure was the highest on smaller streams where most grayling are caught (Lyach and Čech 2018b). Therefore, the effect of recreational fishing on grayling populations could be potentially even more important in the future. The presently reported study also found that the representation of grayling in the overall catch was decreasing. Since Lyach and Čech (2018a) found that the overall fish harvest

in the study area was, in general, decreasing, the presently reported study suggests that harvest of grayling has been decreasing more rapidly when compared to the majority of other fish species.

Size of caught fish. The size of caught grayling was constant over time, most likely because anglers are usually catching fish that are slightly larger than legal angling size (30 cm TL, total length). According to the length–weight equations that anglers use to estimate weights of caught fish, the mean weight of caught grayling (0.35 kg) represents a 35 cm (TL) specimen. A 30 cm (TL) large grayling should weigh 0.25 kg.

CONCLUSIONS AND FUTURE PERSPECTIVES

In conclusion, the dataset clearly shows that catch and yield of grayling have been decreasing over the last 30 years. The decrease in catch and yield can be most likely explained by population decrease and the increasing popularity of catch-and-release strategy. Intensive fish stocking had no significant effect on harvest rates of grayling, suggesting that intensive stocking of graylings was ineffective. Larger fishing grounds displayed low harvest rates of grayling, suggesting that anglers who want to harvest graylings should focus on smaller-sized rivers and streams. The data also suggest that the fall of the communist regime had a significant effect on recreational fishing, mostly because the harvest of grayling started decreasing immediately after the changes in the regime in 1989. This was likely due to new possibilities to travel abroad and also a higher supply of other recreational activities. This study provided yet another proof that conservation of grayling as a species is necessary, mostly because grayling is slowly vanishing from streams and rivers in central Europe. We believe that anglers, fisheries managers, and environmentalists should join forces with the scientific community to find a way to conserve grayling populations. We also conclude that angling logbooks provided a very useful set of data that can be used in fisheries research. We suggest that future studies should focus on monitoring of streams that still support self-reproducing grayling populations. Similar studies would hopefully help to conserve grayling populations for future generations.

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