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Changes in recreational catfish *Silurus glanis* harvest rates between years 1986–2017 in Central Europe

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Abstract

The European catfish *Silurus glanis* is an important fish species in both commercial and recreational fisheries. Catfish is a spreading species that was reported to potentially benefit from increasing temperatures. The goal of this study was to estimate long-term changes in harvest rates of catfish in Central Europe. This study used individual mandatory angling logbooks collected by the Czech Fishing Union in the Czech Republic (Central Europe) over the course of years 1986–2017 (32 years) to assess harvest rates of catfish. This study discovered that harvest of catfish has been increasing over time. Moreover, rivers that previously showed zero harvested catfish are beginning to display higher harvest rates of catfish. Increasing average air temperature and angling effort in the study area have positively affected harvest rates of catfish. The increased harvest of catfish could not be reliably explained by intensive fish stocking. In conclusion, while other studies show that many fish species are negatively affected by human activities and therefore show decreased harvest rates, catfish angling seems to benefit from anthropogenic changes.

KEYWORDS

angling diaries, European catfish, fisheries management, piscivorous species, population dynamics, *Silurus glanis*

1 | INTRODUCTION

The European catfish *Silurus glanis* is among the most popular freshwater fish species among both recreational and commercial anglers in Central and Southern Europe (Copp et al., 2009; Cucherousset et al., 2018). Catfish is native to Central and Eastern Europe. However, due to its popularity among anglers, catfish was introduced to different areas and even to different continents (Britton, Cucherousset, Davies, Godard, & Copp, 2010; Cucherousset et al., 2018; Syväranta et al., 2010). Due to its ability to adapt to new environment, catfish sometimes becomes an invasive and unwanted species in newly introduced areas (Britton et al., 2010; Cucherousset et al., 2018; Syväranta et al., 2010). Studies assume that climate change and river damming greatly helped the population increase of catfish (Britton et al., 2010; Copp et al., 2009; Cucherousset et al., 2018). Anglers and fisheries managers were reported to illegally stock catfish outside of its native range. The goal of this catfish stocking is to provide large-bodied and trophy-sized fish (up to 50–100 kg) for angling purposes (Copp et al., 2009; Cucherousset et al., 2018). Previous studies stated that catfish predation can negatively affect native fish populations (Vejřík, Vejříková, Kočvara, et al., 2017), especially when the predatory pressure of catfish is combined with human-induced effects like fishing pressure, river damming, straightening of river flows, and pollution (Britton et al., 2010; Copp et al., 2009; Cucherousset et al., 2018). Popularity of catfish angling has been increasing, the numbers of anglers-specialists have also been increasing, and catfish is becoming one of the main targets of recreational anglers on larger rivers in Europe (Britton et al., 2010; Copp et al., 2009; Cucherousset et al., 2018).

Poulet, Beaulaton, and Dembski (2011) reported increased population densities of European catfish in metropolitan France which were not related to spawning temperature. Cucherousset et

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al. (2018) claims that the expansion of catfish is mostly related to climate change. However, Rypel (2011) claims that growth of catfish individuals is not depending on environmental conditions such as temperature or type of waters (lentic and lotic). Due to climate change and increasing temperature, Britton et al. (2010) claims that the European catfish could potentially become an invasive threat to inland freshwater ecosystems in England and Wales. Slavík, Horký, Bartoš, Kolářová, and Randák (2007) and Daněk et al. (2016) discovered that movement of catfish is positively correlated to water temperature and sunshine intensity. Vejřík et al. (2019) claims that the expanding catfish populations can be effectively controlled by angling activities but such activities can also represent a threat to catfish populations. In other study Vejřík, Vejříková, Blabolil, et al. (2017) and Vejřík, Vejříková, Kočvara, et al. (2017) discovered that catfish can have a significantly negative effect on resident fish populations due to its prey adaptability.

Many authors argue that angling statistics that are derived from individual angling logbooks can be potentially used as an inexpensive and efficient way to roughly monitor changes in fish populations (Jayasinghe, Amarasinghe, & Silva, 2006; Mosindy & Duffy, 2007; Skov, Jansen, & Arlinghaus, 2017). While there other factors that potentially drive harvest rates of fish (e.g., preferences of anglers, angling regulations), above listed studies claim that harvest rates partially reflect population statuses of fish species.

There is not enough literature describing interactions between catfish and recreational anglers. There are several studies that describe recaptures of catfish (Britton, Pegg, Sedgwick, & Page, 2007) and anecdotal catches of catfish outside of its native range (Gago, Anastácio, Gkenas, Banha, & Ribeiro, 2016; Moreno-Valcárcel, Miguel, & Fernández-Delgado, 2013). Other studies describe effects of specialized fishing techniques on catfish harvest (Copp, Moffatt, & Wesley, 2007) and also popularity of catfish angling in general (Rees et al., 2017). However, there is no study that describes harvest of catfish on larger spatio-temporal scale.

There is anecdotic evidence on increase in catfish harvest in Central Europe which can be tested by analysis of individual angling

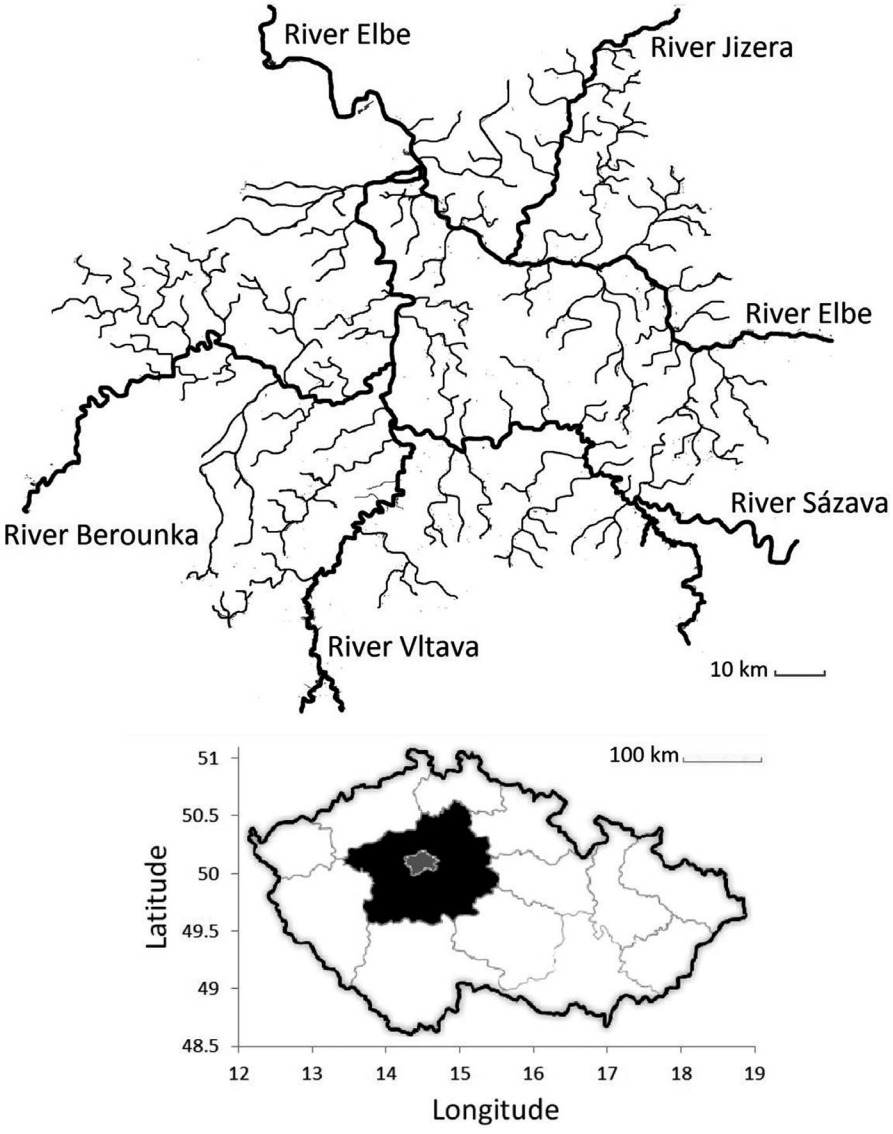

FIGURE 1 Map of the study area with highlighted regions of the Central Bohemia (in black; 49.5°–50.5°N, 13.5°–15.5°E) and Prague (in grey; 50°N, 14.5°E). Data were collected on 241 fishing grounds in the regions of Prague and Central Bohemia, Czech Republic, Central Europe, over the course of years 1986–2017 (catch, stocking) and 2005–2017 (visit rates)

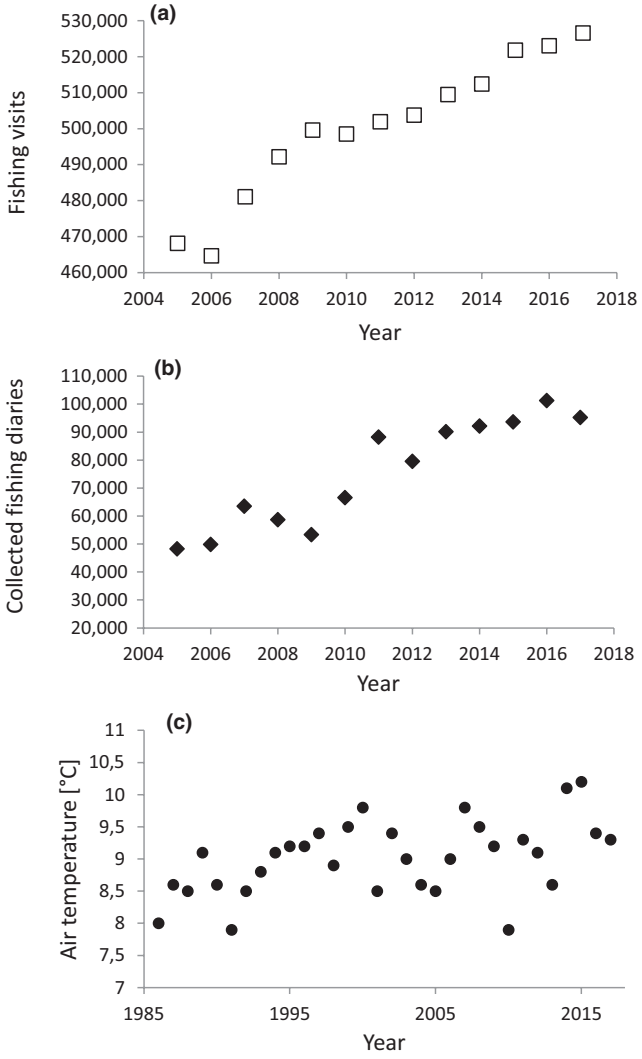

FIGURE 2 Changes over time: (a) in the number of fishing visits on studied fishing grounds; (b) in the number of collected fishing diaries of individual anglers; (c) in average air temperature in the study area

diaries. The goal of this study was to assess changes in harvest of catfish on larger spatio-temporal scale. The presented study asked the following questions (Q) and had the following hypotheses (H):

Q1: Is harvest of catfish positively correlated with air temperature?

H1: It is hypothesized that increased temperature has positive effect on catfish harvest, mostly because catfish prefer warmer waters.

Q2: Is harvest of catfish positively correlated with intensity of fishing effort?

H2: It is hypothesized that fishing sites with higher fishing effort display higher harvest rates as long as catfish populations are not overfished.

Q3: Is harvest of catfish positively correlated to intensity of fish stocking?

H3: It is hypothesized that intensive fish stocking leads to higher harvest rates, mostly because the goal of catfish stocking is to provide catches for anglers.

2 | MATERIALS AND METHODS

2.1 | Study area

This study was carried out in the regions of Prague (50°N, 14.5°E) and Central Bohemia (49.5°–50.5°N, 13.5°–15.5°E), Czech Republic, Central Europe (Figure 1). Both regions together cover an area of 11,500 km^2. The region of Prague has mostly urban character while the region of Central Bohemia has mostly agricultural 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 (stretches of a river or stream) are situated in lowlands with an altitude of 200–600 m above sea level. Flowing waters in the study areas are mostly mesotrophic and eutrophic with biomass of 150–300 kg of fish per hectare (Lyach & Čech, 2017b, 2018a, 2018b). The study area includes salmonid streams (smaller streams, <10 m wide, usually dominated by salmonids) and non-salmonid rivers (larger streams and rivers, 10–300 m wide, usually dominated by cyprinids or percids). Studied rivers and streams are mostly at their carrying capacity due to natural fish reproduction and intensive fish stocking (Czech Fishing Union, unpubl. data). Majority of rivers in the study area have naturally reproducing populations of catfish (Vejřík, Vejříková, Blabolil, et al., 2017; Vejřík, Vejříková, Kočvara, et al., 2017). Eurasian catfish is a native fish species in the study area.

2.2 | Recreational fishing in the Czech Republic

Recreational fishing in the Czech Republic is organized by the Czech Fishing Union and the Moravian Fishing Union (the main authorities in recreational fishing in the Czech Republic) and is centralized for the whole country. All fishing grounds in the study are managed by the Czech Fishing Union. Both fishing unions shelter all recreational anglers in the Czech Republic (approximately 320,000 anglers in the year 2019). Anglers are required to report all fishing visits and harvested (killed) fish into individual angling logbooks. Fish that are undersized, caught during closed season, or otherwise released are not recorded in logbooks. Filled logbooks are collected at the end of each year (or in January or the following year). Anglers are obliged to retrieve filled logbooks in order to receive a new empty logbook for the next year. Therefore, return rates of filled logbooks are above 99%. Fishing sites are divided into two categories: salmonid and non-salmonid sites. Salmonid sites are defined as smaller streams and rivers while non-salmonid sites are defined as larger rivers. Salmonid fishing sites should provide good environmental conditions for natural salmonid growth and reproduction. Non-salmonid fishing sites are defined as fishing sites that do not support natural salmonid reproduction. Fishing sites are defined as stretches of rivers or streams that are divided by obstacles or buildings (weir, dam, water power plant, bridge). Size of studied fishing sites was 0.4–150 ha of water surface.

The number of fishing visits has been increasing over the course of the last 10 years (Figure 2; Lyach & Čech, 2018a). Fishing unions pay for using rivers and streams where they perform fisheries management (fish stocking, garbage collecting, and angling guard activities) and sell fishing permits. Each angler who wants to fish in the study area has to be a member of a fishing union (non-organized fishing is not allowed). The basic current angling rules have been effective since year 1963 with legislative changes in year 2004 that were not related to angling (but rather to regime changes due to the fall of the Communist regime in year 1989). The system of angling data collection has not changed since 1963. The only exceptions in organized fishing in the study area are several ponds with private owners where private recreational fishing is conducted. Commercial fishing is non-existent in the study area. For detailed description of recreational fishing in the Czech Republic see Lyach and Čech (2018a, 2018b).

2.3 | Angling rules for catfish

Salmonid and non-salmonid fishing grounds have different rules for catfish fishing. On salmonid fishing grounds (smaller streams), anglers are not allowed to release caught catfish back to water (all caught catfish must be removed from the stream). There is no closed season or minimum legal angling size set for catfish on salmonid streams; catfish is considered an unwanted predatory fish species on salmonid streams. Inversely, on non-salmonid fishing grounds (larger rivers), a closed season is set for catfish from 1 January to 15 June, and catfish has a minimum legal angling size set to 70 cm for the rest of the year. Any catfish that is caught during closed season or is smaller than 70 cm has to be returned back to water. The bag limit (maximum weight or number of all caught fish) for catfish is set to 7 kg or two fish per day (whichever comes first). When an angler reaches or exceeds this bag limit, the angler is obliged to stop fishing for that day. The limit of 7 kg can be exceeded (e.g., killing three fish each weighing 3 kg is legal). All caught fish must be noted in individual angling logbooks, including the date of catch, size of fish (cm and kg), and the ID of the fishing ground. Listed fishing regulations did not change over the course of years 2005–2017 and were effective for all fishing sites in the study area (Act on Fisheries 99/2004; Lyach & Čech, 2018a, 2018b).

2.4 | Catfish stocking

Catfish is irregularly stocked on selected fishing grounds in the study area. The goal of catfish stocking is to provide large and trophy-sized fish for angling purposes. Fish are mostly stocked to dammed parts of rivers and larger flowing rivers. Fish are stocked at various body sizes including small yearlings (5–20 cm) and larger adult fish (70–150 cm). Before fish stocking occurs, stocked fish are weighted together (in one bag) to the nearest 100 g. Smaller fish are weighed all together in one bag, larger fish are weighted in groups of 10–20. The number of stocked fish is then estimated from the overall weight by applying species-specific length-weight equations. The length-weight equations are based on data from catches of a larger amount (at least 1,000) of fish that were caught in the study area by fisheries managers. In the study area, fish stocking can be only performed by the Czech Fishing Union, specifically by managers of local angling organisations (similar to fishing clubs). Fish stocking is organized and monitored by the Czech Fishing Union; precise data on the number and biomass (kg) of stocked fish are available for each fishing ground and each year. Other forms of fish stocking are illegal. All local angling organisations in the study area are registered under the Czech Fishing Union. The Czech Fishing Union has a contract with producers of live fish (the aquaculture sector) where the Union pays the aquaculture sector in exchange for delivery of fish for stocking purposes. Since the Union is the only authority that sells fishing permits and financially benefits from fish stocking in the study area, it is unlikely that other subjects would benefit from illegal fish stocking. There is no evidence of illegal fish stocking of any kind in the study area (Czech Fishing Union, personal communication). However, there is a possibility of stocked catfish escaping from private ponds which are quite rare in the study area.

2.5 | Data sources

Data from annual angling reports were used for the purpose of this study (see table 3 in Lyach & Čech, 2018a). This data originated from angling logbooks, collected from individual anglers by administrative workers of the Czech Fishing Union. Each angler is obliged to write down each fishing visit, date of visit, ID and name of visited fishing ground, each harvested (killed) fish (together with determination to species, size in TL in cm, and weight in kg). The return rate of filled angling logbooks is over 99%; an angler who does not provide old fishing logbook does not receive a new logbook for the upcoming year (fishing without a logbook is illegal). The selected fishing grounds covered a surface water area of 125 km^2. Surface area (size in hectares) of each fishing ground was obtained from legal documents provided by fisheries managers of the Czech Fishing Union. The original size was estimated using GIS software based on average width and length of the river or stream. Studied fishing grounds have surface area of 0.4–150 ha. The mean surface area of a fishing ground was 7.4 ha. All fishing grounds in the study area were included in this study (no fishing sites were left out). The data were originally collected by the Czech Fishing Union and later processed by the authors of this study. Fishing grounds are defined as stream and river stretches where recreational fishing can be legally conducted. Individual fishing grounds are separated by obstacles or buildings (weir, dam, water power plant, bridge). Data from 241 fishing grounds over years 2005–2017 (13 years) were used to analyze catch and yield per fishing visit (data on fishing visits were available only from the year 2005 onwards). To analyze harvest per hectare, data from 241 fishing grounds over the course of years 1986–2017 (32 years) were used.

This database was used for various research questions before (Boukal, Jankovský, Kubečka, & Heino, 2012; Humpl, Pivnička, & Jankovský, 2009; Jankovský, Boukal, Pivnička, & Kubečka, 2011; Lyach & Čech, 2017a, 2018a, 2018b). Data on average air temperature were provided by the Czech Hydrometeorological Institute. Air temperature was measured by automatic measuring stations (six located in Prague and 18 in Central Bohemia). Each station measured air temperature three times a day (time of measurement varies seasonally). Data on average water temperature were not available in the area.

2.6 | Measured metrics

This study assessed the overall catch (individual fish) and yield (kg) per 1 ha of fishing grounds, catch and yield per fishing visit, the representation of catfish in the overall catch and yield of all fish, the percentage of fishing grounds with a catch of catfish, catch per stocked fish, and yield per stocked fish biomass. To estimate the effect of fish stocking on fish catch, data were used on fish stocking from 0–10 years before each fish was caught. The mean value of 11 consecutive years was used in the analysis. Data on fish stocking older than 10 years were not used because stocked fish display high mortality due to handling stress, harvest by anglers, predation, starvation, and inability to adapt to natural conditions (e.g., Brown & Day, 2002; Portz, Woodley, & Cech, 2006). For example, Storck and Newman (1988) reported 55%–73% natural mortality in stocked catfish after two seasons. For that reason, the effect of fish stocking that happened 10 or more years ago was considered insignificant in comparison to recent fish stocking. Therefore, the effect of stocking on catch and yield was calculated from data over years 1996–2017.

2.7 | Statistical analysis

The package for generalized linear mixed models (GLMM) was used to fit the models (Hadfield, 2010). The function *lmer* in the package LME4 (version 0.999375-42; Bates, Maechler, Bolker, & Walker, 2015) was used to calculate *R*-squared values (Nakagawa, Johnson, & Schielzeth, 2017). In the models, the following parameters were used as dependent (explained) variables: catch and yield (per hectare and per fishing effort), number of fishing grounds, representation of catfish in overall catch and yield, number of collected fishing diaries, air temperature, and the number of fishing visits. Independent (explanatory) variables were the following: fish stocking (number and biomass), air temperature, and year. The mixed effect models used the following equation: catch = stocked fish + fishing ground. Gamma and Poisson regressions with log link-functions were used in the models to describe data with discrete non-negative values and time trends, respectively. Minimum probability level of $p = .05$ was accepted for all the statistical tests, and all statistical tests were two-tailed. One fishing site was used as one sample in all analyses. Only fishing sites with catfish stocking were used in the analysis of the effect of fish stocking on harvest. Bonferroni correction was applied when multiple groups were compared in statistical analysis. Fishing ground was used as a random factor (effect) to avoid measuring variability between individual fishing grounds. The results presented in the tables were derived from models in R while the figures were drawn in MS Excel. The described method was previously used to analyze similar data sets on fish harvest (Boukal et al., 2012; Humpl et al., 2009; Jankovský et al., 2011; Lyach & Čech, 2017a, 2018a, 2018b, Lyach & Remr, 2019).

3 | RESULTS

3.1 | Background data

Over the course of years 1986–2017 (32 years), anglers caught and recorded altogether 23,853 individual catfish with total weight of 313 tons. In comparison, anglers caught and recorded altogether 7,697,801 fish (all species) with total weight of 11,686 tons. Over years 2005–2017 (13 years), anglers visited studied fishing grounds 6,844,186 times and caught 2,737,204 fish (all species) with total weight of 5,392 tons. Fishing effort was increasing over time in the study area; the number of fishing visits increased from 470,000 to 530,000 visits per year over 13 years (Figure 2a). The number of collected fishing diaries from individual anglers increased over time as well; the number of filled and returned fishing diaries almost doubled over the course of 13 years (Figure 2b). The average air temperature in the study area increased by more than 1°C (from 8 to 9.3°C) over the course of 32 years (Figure 2c).

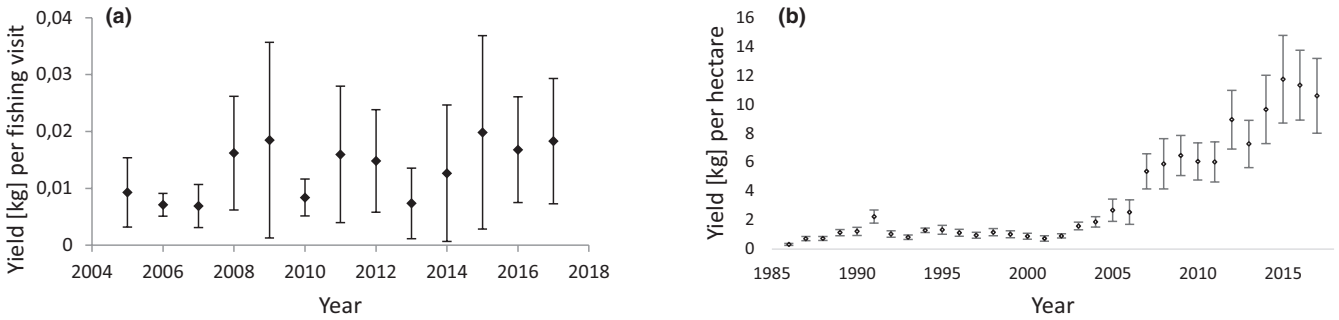

FIGURE 3 Changes over time: (a) in yield per effort and (b) in yield per hectare of fishing grounds. The bars represent standard errors of means

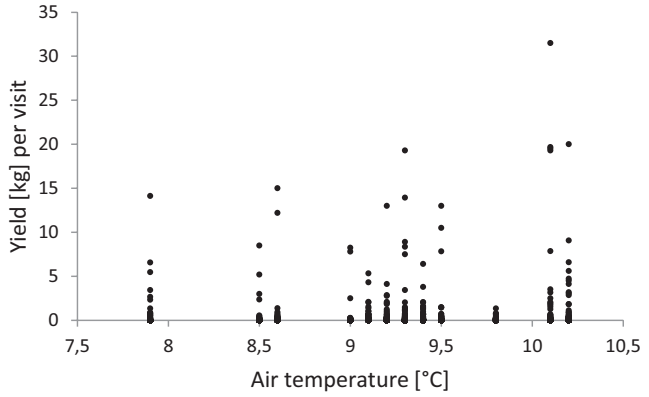

FIGURE 4 The relationship between average air temperature in the study area and yield per effort. One dot represents data from one fishing ground over 1 year

3.2 | Harvest and air temperature

Harvest per effort was increasing over time (Figure 3a). Anglers were catching more catfish per one fishing visit every year. This was also true for harvest of catfish per 1 ha of fishing grounds in the study area (Figure 3b). Harvest per effort was positively correlated with air temperature (Figure 4); anglers caught more catfish during warmer years when average air temperature was higher. The percentage of fishing grounds where anglers successfully harvested catfish increased three times over 32 years (Figure 5a); anglers were harvesting catfish on a higher number of fishing grounds every year. Percentage of fishing grounds where anglers successfully harvested catfish was also positively correlated with average air temperature in the study area (Figure 5b); anglers harvested catfish on more fishing grounds during years when the average air temperature in the study area was higher. The representation of catfish in the overall harvest of all fish species increased over time (Figure 6a); the importance (by %) of catfish in the overall angling harvest was higher every year. The percentage of catfish in the overall harvest was positively correlated with average air temperature in the study area (Figure 7b); catfish was more represented in the overall harvest during years when the average air temperature was higher.

3.3 | Harvest and fishing effort

Harvest of catfish was positively correlated with fishing effort (Figure 7a); fishing grounds that displayed higher fishing effort also displayed higher harvest rates of catfish.

3.4 | Harvest and fish stocking

There was only a weak and insignificant correlation between fish stocking and fish harvest; higher intensity of fish stocking did not lead to higher harvest rates.

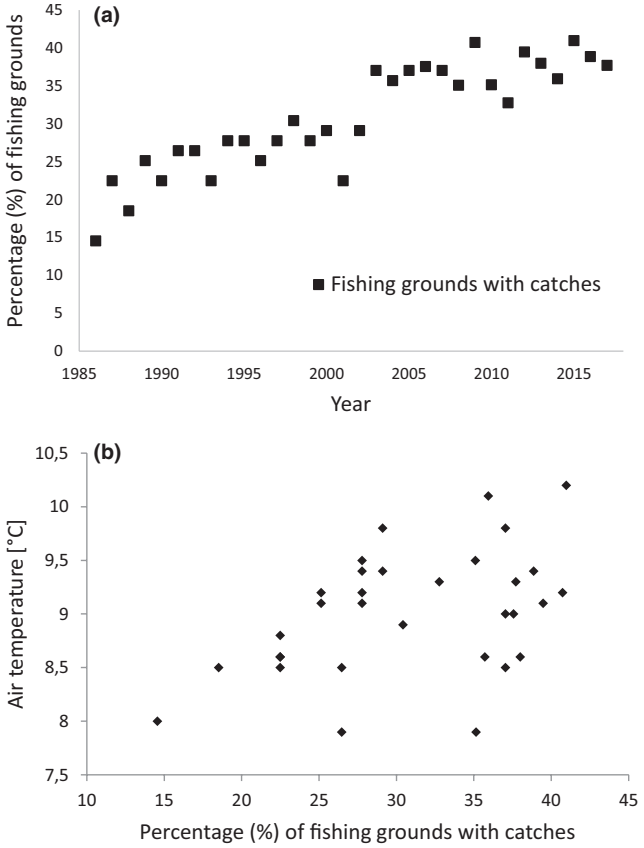

FIGURE 5 (a) changes over time in percentages of fishing grounds with successful harvest of catfish; (b) the relationship between the percentage of fishing grounds with catch of catfish and average air temperature in the study area

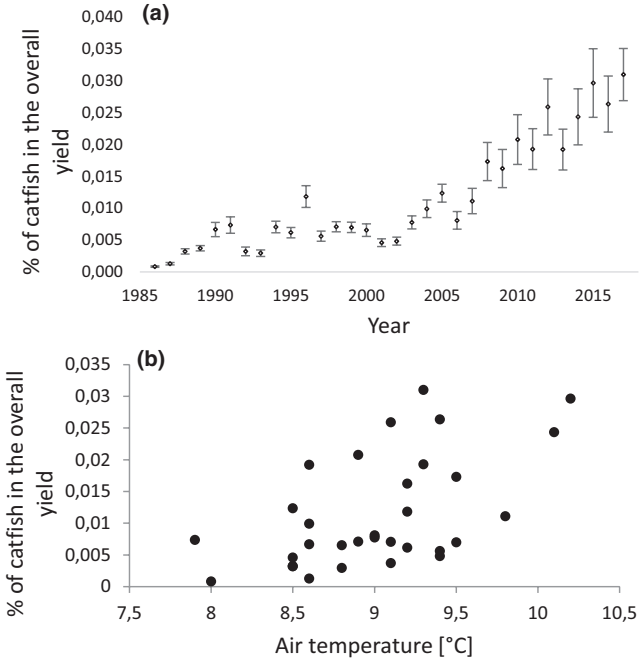

FIGURE 6 (a) changes over time in the representation of catfish in the overall fish yield; (b) the relationship between the representation of catfish in the overall fish yield and average air temperature in the study area. The bars represent standard errors of means

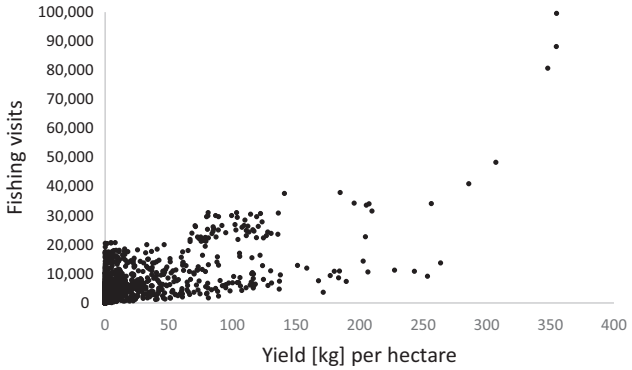

FIGURE 7 The relationship between yield per hectare of fishing grounds and the number of fishing visits. One dot represents data from one fishing ground over 1 year

3.5 | Differences between salmonid and non-salmonid fishing grounds

Salmonid and non-salmonid fishing grounds displayed similar results in terms of relationships between basic parameters in recreational fisheries (Tables 1 and 2).

4 | DISCUSSION

4.1 | Harvest

The increase in harvest of catfish was quite rapid, especially in the last two decades. This rapid increase is interesting especially when compared to the fact that the overall catch of all fish has been decreasing in the last decade in the study area (Lyach & Čech, 2018a). As far as catch and yield are concerned, catfish is displaying the opposite trend than other fish species (Lyach & Čech, 2018a). Inversely, catch and yield per fishing visit showed much slower increase, mainly because visit rates of fishing grounds have been increasing in the last decade in the study area as well (Lyach & Čech, 2018a). Previous studies showed that increased fish catch can be positively correlated with increased fish abundance in the ecosystem (Mosindy & Duffy, 2007; Skov et al., 2017). Since catfish predation can potentially have a significantly negative effect on freshwater fish populations (Vejřík, Vejříková, Blabolil, et al., 2017; Vejřík, Vejříková, Kočvara, et al., 2017), it is possible that catfish will become a new source of conflict between fisheries and environmental protection in Central Europe (similarly to Eurasian otter *Lutra lutra* and great cormorant *Phalacrocorax carbo*) (e.g., Kortan & Adámek, 2011; Lyach, Blabolil, & Čech, 2018; Lyach & Čech, 2017a, 2017b). Higher population densities of catfish could potentially lead to population decrease in prey fish species (mostly cyprinids) and therefore to decreased harvest of cyprinids. Intensive stocking of smaller fish in order to bolster resident fish populations could become less effective.

The increasing number of fishing grounds with catches of catfish could also be potentially linked to catfish migration, population expansion, higher population densities, and popularity of catfish angling and stocking. Slavík et al. (2007) suggested that catfish is a highly active and expansive species that easily migrates within rivers. Most migration barriers in the area are relatively old (more than 30 years) but most of them have been equipped with fish passes in the last decade. However, many fish passes and migration barriers did not recently have enough water due to droughts in Central Europe.

Scientists argue that temperature has positive effect of catfish migration, spreading, and population increase (Britton et al., 2010; Copp et al., 2007, 2009; Cucherousset et al., 2018). However, harvest of catfish is likely affected by other factors other than climate change. It is possible that recent anglers manage to catch larger catfish individuals (50+ kg) due to better access to high quality fishing gear. Popularity of catfish fishing could have also increased over time. The positive effect of air temperature on harvest could be caused by increased mobility of catfish during warmer days (Slavík et al., 2007) or by increased interest in angling in warmer months. Popularity of catch-and-release fishing strategy could be also affecting fish harvest (Arlinghaus et al., 2007). Since presented study collected data on catfish harvest over 13 (32) years, other unknown factors likely had an effect on harvest as well.

4.2 | Fish stocking

The weak correlation between fish stocking and harvest rates was surprising. In general, fish stocking should lead to increased fish catch (e.g., Morita et al., 2006). By studying the effect of stocking on catch in various species of catfish, previous studies argued that controlled catfish stocking should lead to higher yield (Michaletz, Wallendorf, & Nicks, 2008; Storck & Newman, 1988). In case of this study, catch of catfish has been increasing while stocking rates have been decreasing. It is possible that catch is positively correlated to stocking only in rare and less abundant species.

To estimate correlation between fish stocking and harvest, fish stocking that happened 10+ years ago was not taken into account. On one hand, catfish is a long-living species (up to 25 years; e.g., Slavík et al., 2007). Britton et al. (2007) reported that specific catfish individuals were caught by anglers up to 26 times. On the other hand, other factors (ecosystem changes, recent fish stocking, and harvest rates) should overweigh the effect of fish stocking that happened 10–15 years ago. For example, by studying recreational fishing of common carp *Cyprinus carpio* in a large artificially dammed river (1,000 ha), Jankovský et al. (2011) argues that anglers catch most stocked carp within 2 years after stocking. Catfish harvest was increasing even without the help of intensive fish stocking, suggesting that catfish stocking might be ineffective and redundant in the area.

4.3 | Fishing effort

There was an increase in the number of fishing visits, individual anglers, and most importantly in mobility of anglers in the study area. The number of anglers who fished in the area increased more rapidly

TABLE 1 Results of the models used in this study (effective for salmonid fishing grounds)

Dependent variable	Independent variable	Intercept (*SD*)	Slope (*SD*)	*p*-Value	$var_{rand.eff}$	*R*-squared	*df*
Catch	Fishing visit	−2.17 (0.25)	0.0022 (0.0001)	<.001	0.000900	0.14	2,413
Yield	Fishing visit	−21.18 (0.02)	4.0321 (0.0001)	<.001	0.032000	0.13	2,413
Number of fishing grounds with catches	Air temperature	4.81 (3.16)	0.0263 (0.0072)	<.001	0.0022	0.08	2,413
Yield per fishing visit	Air temperature	1.13 (0.18)	0.0023 (0.0026)	<.001	0.0007	0.04	2,413
Representation of catfish in overall catch	Air temperature	0.001 (0.001)	0.0004 (0.0001)	<.001	NA	0.08	2,292
Representation of catfish in overall yield	Air temperature	0.003 (0.001)	0.0004 (0.0001)	<.001	NA	0.04	2,292
Catch per fishing visit	Air temperature	0.13 (0.08)	0.0052 (0.0042)	<.001	0.0003	0.05	2,413
Yield	Stocked biomass	261.46 (32.28)	4.7138 (3.5841)	.420	0.004900	0.001	125
Catch	Stocked fish	43.48 (5.22)	0.0012 (0.0011)	.430	0.000680	0.001	125
Collected fishing diaries	Year	−932.51 (188.51)	11.2492 (0.5438)	<.001	0.021356	NA	2,413
Air temperature	Year	5.61 (4.13)	0.0031 (0.0017)	<.001	NA	NA	2,413
Catch per fishing visit	Year	−341.22 (29.88)	0.1500 (0.0210)	<.001	0.005000	NA	2,413
Yield per fishing visit	Year	−299.72 (11.72)	0.1400 (0.0050)	<.001	0.005000	NA	2,413
Representation of catfish in overall catch	Year	−0.82 (0.11)	0.0004 (0.0001)	<.001	0.000001	NA	2,292
Number of fishing grounds with catches	Year	14.52 (0.63)	0.5500 (0.0500)	<.001	NA	NA	2,413
Representation of catfish in overall yield	Year	−3.38 (0.49)	0.0016 (0.0001)	<.001	0.000002	NA	2,292
Catch	Year	−1,214.71 (252.45)	0.6300 (0.1200)	<.001	0.020000	NA	2,413
Yield	Year	−11,631.41 (2,301.28)	5.5800 (1.1400)	<.001	0.190000	NA	2,413
Fishing visits	Year	−41,211.08 (2,951.04)	10.0086 (2.0083)	<.001	0.530000	NA	2,413

Abbreviations: *df*, degrees of freedom; NA, not applicable; *SD*, standard deviation; $var_{rand.eff}$, variance for random effect (fishing ground).

than the number of fishing visits mostly because anglers were more mobile. More anglers were coming from other regions and fished in the study area. There were many anglers who performed just one fishing trip to the region of Central Bohemia or Prague. Since those two regions are the richest and most developed in the whole Czech Republic, it was not surprising that anglers-outsiders travelled here to fish. Recreational fisheries in the Czech Republic is still under transformation after the fall of the Communist regime is 1989 and people are still learning to adjust their hobbies to the new freedom of travel. This phenomenon could affect research results because there are more anglers-outsiders fishing in this area when compared to other regions where more local people fish.

4.4 | Data set limits

The dataset was derived from individual angling logbooks and provided us with a significant amount of data. However, the dataset has its limits in use. Since the data are collected by regular people (and not by scientists), the precision is probably slightly lower and the error is probably slightly higher when compared to studies that are based on data collected by scientists. For example, some anglers may provide incorrect fish sizes, incorrectly identify fish into species, take fish without writing down the catch, and disobey fishing rules (unknowingly or on purpose) (Bray & Schramm, 2001; Cooke, Dunlop, McLennan, & Power, 2000; Essig & Holliday, 1991; Gwinn et al., 2015; Lyach & Čech, 2017a, 2017b, 2018a, 2018b; Mosindy & Duffy, 2007; Pollock, Jones, & Brown, 1994). Since European catfish is the only catfish species that is native to the study area, it is unlikely that anglers mismatched catfish with other fish species. Writing down incorrect fish size could be an issue since the minimum legal angling size for catfish is quite high at 70 cm TL (total length). However, since presented study does not operate with fish sizes, this limitation should not apply here. Not recording a caught catfish could be a real issue since there is a bag limit (7 kg or two fish per

TABLE 2 Results of the models used in this study (effective for non-salmonid fishing grounds)

Dependent variable	Independent variable	Intercept (*SD*)	Slope (*SD*)	*p*-Value	$var_{rand.eff}$	*R*-squared	*df*
Catch	Fishing visit	−1.32 (0.12)	0.0018 (0.0001)	<.001	0.001100	0.16	5,630
Yield	Fishing visit	−13.56 (0.03)	4.0583 (0.0001)	<.001	0.030000	0.17	5,630
Number of fishing grounds with catches	Air temperature	5.21 (3.38)	0.0254 (0.0062)	<.001	0.0021	0.05	5,630
Yield per fishing visit	Air temperature	0.93 (0.22)	0.0024 (0.0021)	<.001	0.0007	0.06	5,630
Representation of catfish in overall catch	Air temperature	0.001 (0.001)	0.0003 (0.0001)	<.001	NA	0.06	5,348
Representation of catfish in overall yield	Air temperature	0.002 (0.001)	0.0004 (0.0001)	<.001	NA	0.05	5,348
Catch per fishing visit	Air temperature	0.12 (0.07)	0.0052 (0.0038)	<.001	0.0003	0.07	5,630
Yield	Stocked biomass	312.99 (31.52)	5.7214 (4.4215)	.310	0.004800	0.003	291
Catch	Stocked fish	61.38 (5.71)	0.0013 (0.0011)	.480	0.000610	0.001	291
Collected fishing diaries	Year	−912.88 (200.88)	12.2743 (0.5321)	<.001	0.028653	NA	5,630
Air temperature	Year	4.98 (3.27)	0.0024 (0.0016)	<.001	NA	NA	5,630
Catch per fishing visit	Year	−307.43 (28.91)	0.1400 (0.0116)	<.001	0.004000	NA	5,630
Yield per fishing visit	Year	−279.81 (11.52)	0.1700 (0.0050)	<.001	0.006000	NA	5,630
Representation of catfish in overall catch	Year	−0.97 (0.14)	0.0004 (0.0001)	<.001	0.000001	NA	5,348
Number of fishing grounds with catches	Year	13.21 (0.72)	0.5500 (0.0400)	<.001	NA	NA	5,630
Representation of catfish in overall yield	Year	−4.58 (0.88)	0.0016 (0.0001)	<.001	0.000003	NA	5,348
Catch	Year	−1,093.82 (251.25)	0.6200 (0.1100)	<.001	0.020000	NA	5,630
Yield	Year	−14,361.22 (2,201.20)	5.5800 (1.1400)	<.001	0.110000	NA	5,630
Fishing visits	Year	−38,208.00 (3,101.01)	12.0128 (2.0089)	<.001	0.710000	NA	5,630

Abbreviations: DF, degrees of freedom; NA, not applicable; *SD*, standard deviation; $var_{rand.eff}$, variance for random effect (fishing ground).

day) that anglers could exceed on regular basis. The real harvest rate of catfish could be therefore even higher in the study area.

The dataset also does not take poaching into account. Moreover, fish that are released back to the water as a part of the catch-and-release strategy are not recorded either. There is also a problem with recorded fish weights. Anglers in the field are obliged to measure caught fish but they are not obliged to weight them with measuring scales; weights of caught fish are afterwards calculated using length-weight estimations. The estimations are based on length-weight measurements of over 1,000 caught catfish. However, they do not reflect environmental conditions, trophic levels, or differences between individual fish.

The data on fish stocking should also be interpreted with caution. Smaller stocked fish (<10–15 cm TL, total length) are not individually counted but the number is rather estimated based on their summed weight. In statistical analyses, it is possible to compare different intensity of fish stocking; however, exact numerical results should be treated with caution, especially when the number of stocked fish is correlated to harvest rates.

To sum this up, similar fisheries datasets have usually an error in reported fish harvest (Alexiades, Marcy-Quay, Sullivan, & Kraft, 2015). Still, since the study uses data from 241 river and stream stretches over the course of 13 (32) years, the dataset should be strong enough to support the claims of this study. Similar dataset was successfully used for scientific purposes before (Boukal et al., 2012; Humpl et al., 2009; Jankovský et al., 2011; Lyach & Čech, 2017a, 2018a, 2018b).

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CONFLICT OF INTEREST

The authors declare that they have no conflict in interest.

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