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Fisheries Management of the European Catfish *Silurus glanis* Is Strongly Correlated to the Management of Non-Native Fish Species (Common Carp *Cyprinus carpio*, Rainbow Trout *Oncorhynchus mykiss*, and Grass Carp *Ctenopharyngodon idella*)

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Abstract: Intensive multi-species fish stocking management is a popular yield enhancement tool that supposedly leads to elevated yields in recreational angling. This study aimed to analyze the relationships between fisheries management of an apex predator and its putative prey. The GAM (generalized additive model) was used to analyze the relationships between the yields and the stocking intensities of European catfish and non-native fish species. The fish yields and stocking intensities were obtained from mandatory angling logbooks collected from 38,000 individual recreational anglers by the Czech Fishing Union on 176 fishing sites during the years 2005–2017 in central Bohemia and Prague (the Czech Republic). Our results show that the stocking intensities of the targeted species positively correlated to their yields. However, intensive catfish stocking negatively correlated to the yields of the non-native fishes. Other factors that were strongly correlated to the yields include the angling effort, size of a fishery, and yield of catfish. In conclusion, a significant relationship is found between the fisheries management of a predator and its putative prey. The results suggest that catfish should not be intensively stocked in the same rivers as non-native fishes.

Keywords: angling diary; fisheries management; game fishing; mixed model; population dynamics

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1. Introduction

Introduction of non-native fish species into new geographical regions has been a popular way for managers of fisheries to increase the attractivity of fisheries for anglers. Introductions have been either accidental (e.g., fish escaping from aquaculture or private ponds, releasing of fish baits) or on purpose (legal or illegal stocking of species that were pollution tolerant, trophy sized, fast growing, suited for aquaculture, attractive looking, or otherwise advantaged for angling purposes) [1–4]. Common carp *Cyprinus carpio* and rainbow trout *Oncorhynchus mykiss* are among the most important non-native, intensively stocked species on larger rivers and smaller streams, respectively, in Europe. Both species are more tolerant of anthropogenic alterations of rivers and streams and easier to produce in larger numbers in comparison to their native counterparts—crucian carp *Carassius carrasius* and brown trout *Salmo trutta*. Grass carp *Ctenopharyngodon idella* were initially introduced to central Europe to fill the empty niche in commercial pond-based fish production because adults grass carp feeds on emerged macrophytes. The non-native fishes may fall prey to local wild predators.

The European catfish *Silurus glanis* is an apex fish predator in European freshwater ecosystems that feeds on a large variety of prey items, including fish, water birds, and invertebrates. Catfish mostly occupy lakes and large slow-flowing rivers with higher average water temperatures. However, catfish have expanded in the last 20 years into new and previously unoccupied ecosystems—mainly smaller rivers with faster flowing water [5,6]. Other studies connect this expansion to climate change, increased average water temperature, and anthropogenic alterations of freshwater ecosystems [7–9]. There is some evidence of a negative effect of catfish predation and stocking on prey fish populations [5–9]. Catfish are a popular target for recreational fishermen, which has resulted in both legal and illegal introductions of catfish into new regions out of their native range [7–9]. The popularity of catfish angling has been increasing recently due to the expansion of catfish populations as well as the access of anglers to high-quality fishing gear and angling know-how via the Internet (e.g., websites and Facebook groups that specialize in catfish angling). Similar to non-native fishes, catfish are also a subject of intensive fish stocking.

However, multi-species stocking management is a tricky business. Significant negative relationships between the stocking of predatory fish species and the yields of their prey were reported. Studies show that intensive stocking of predatory fishes can lead to lower yields of their prey [10,11]. Multi-species stocking is performed to satisfy both the anglers (who fish for food and fun) and the conservationists (who want stable wild fish populations). While both reasons for stocking are functioning reasonably, a problem may occur when fish stocking is performed simultaneously on the same rivers. Multi-species stocking can have negative effects on the yields of the targeted fishes if it is done with the wrong mix of species and at the wrong intensity. This is because the stocked fish compete for food, habitats, and shelter. Even though multi-species stocking management could lead to different yields in comparison to single species restocking, analyses of multi-species relationships between stocking and yields are still rare.

Previous studies analyzed the relationships between the fish yields and stocking intensity of non-native species and the European catfish on either a smaller sample of fisheries or over a short period. However, how the interactions between basic fisheries parameters work on larger scale is unknown. This study tries to fill this knowledge gap.

The aim of this study is to analyze, on larger spatio-temporal scale, correlations between the stocking intensity and yields of the European catfish and three non-native fish species (common carp, grass carp, and rainbow trout) as well as correlations between the stocking intensity and yields with the angling efforts of the fishery.

We expected to find strong positive correlations between the stocking intensities and yields of the predatory catfish and the non-native fishes. We also expected to assess strong correlations between the yields with angling effort and the size of the fishery.

2. Materials and Methods

2.1. Study Area

This study was carried out on lowland mesotrophic rivers that are 30–250 m wide, cover an area of 150 km^2, and have a fish biomass of 150–300 kg per ha [11]. They are situated in the city of Prague and the agricultural region of central Bohemia (49.5–50.5° N, 13.5–15.5° E), the Czech Republic, central Europe (Figure 1). The regions cover an area of 11,500 km^2, are in the temperate zone, and belong to the North Sea drainage area and the Elbe River Basin.

The studied rivers are separated into individual fishing sites—river stretches that are divided by obstacles or structures (a dam, a weir, a bridge, or a hydro-power plant). The 176 fishing sites studied here are 4–160 ha large (median 9 ha) and located in 38 rivers.

2.2. Fish Species

The European catfish *S. glanis* is a native large-growing non-migratory piscivorous fish species. A previous study from this area confirmed a strong relationship between the catfish stocking intensity and its yield [12]. Common carp *Cyprinus carpio* and grass carp *Ctenopharyngodon idella* are non-native omnivorous cyprinids, while the rainbow trout *Oncorhynchus mykiss* is a non-native predatory salmonid. While the local catfish populations were expanding during the years 2000–2018 [12], the non-native fish populations relied on intensive stocking. All four studied species—the common carp, the grass carp, the rainbow trout, and the European catfish—have a cumulative daily bag limit of either 7 kg of fish or two individual fish (whichever comes first).

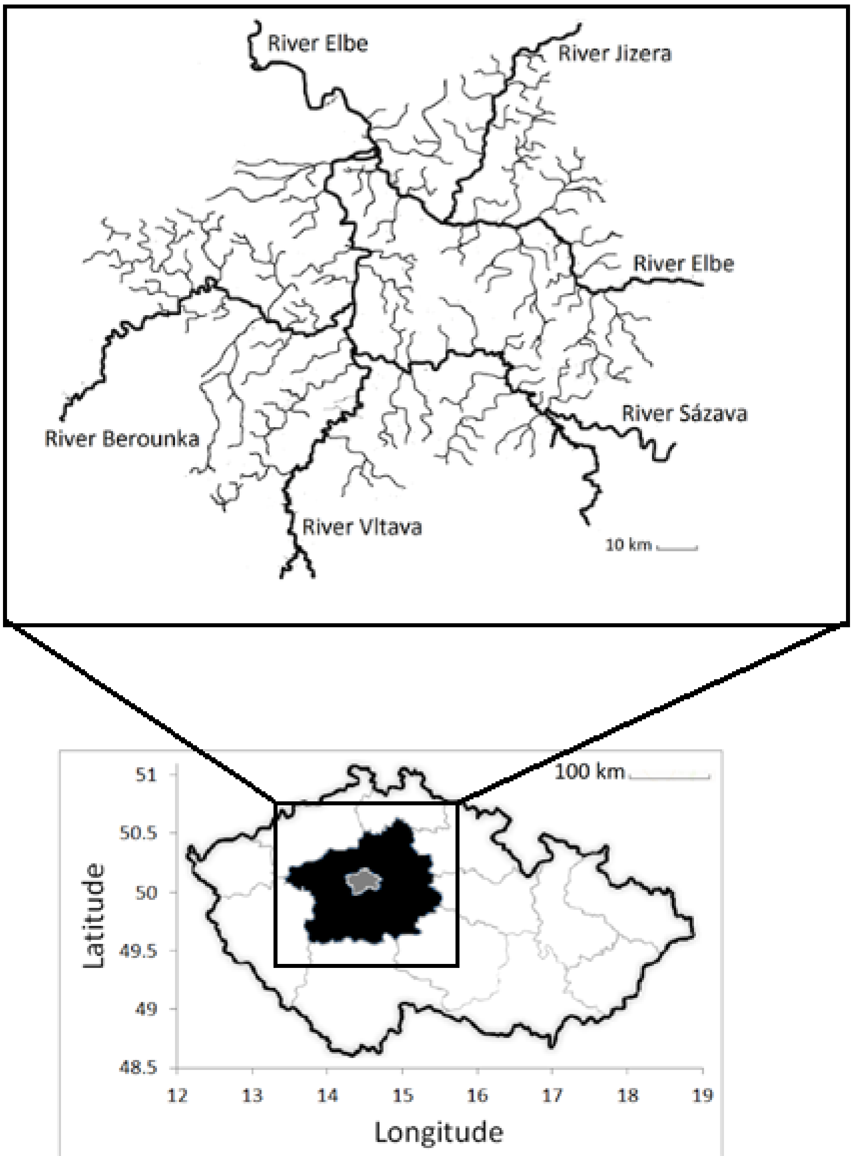

Figure 1. Map of the study area where the fishing logbooks were collected: highlighted rivers (upper picture) and highlighted regions of Prague (grey shaded) and central Bohemia (black shaded) in the Czech Republic (lower picture).

2.3. Fish Stocking

Non-native fish species are frequently stocked in the study area every year. The fishery management releases mostly larger individuals of legal or almost legal angling size (common carp and grass carp: 25–50 cm TL; rainbow trout: 20–30 cm TL). However, a lower number of smaller fish, such as 0, 0 +, and YOY (young-of-the-year) fish (5–10 cm TL), is released as well. The fisheries managers reported the numbers, biomasses, and sizes of the stocked fish into their mandatory stocking logbooks (Table S1). The information on the sizes and biomasses of the stocked fish was obtained from aquaculture managers who hatch and grow the fish in local and regional hatcheries. The Czech Fishing Union is the sole authority that stocks fish at the studied fishing sites.

To estimate the effect of the non-native fish stocking intensity on their yields during each individual year, data 0–2 years old were used for fish stocking prior to the year when the fish were harvested. For catfish, data 0–10 years old were used prior to the year when the catfish were harvested. For example, to estimate the effect of the non-native fish stocking on their harvest rates in the year 2010, data on the fish stocking from the years

2008–2010 were used. The time lag between the stocking year and the harvest year was calculated based on the estimated growth and survival rate of the non-native fish species and the catfish from fish growth and survival studies [13–16].

2.4. Data Collection

The Czech Fishing Union collected and processed the data from personal angling logbooks and restocking reports, and the data were processed by the author of this study. The union provided an annual summary of the yields, angling visits, stocking activities, and activities of angling guards from each fishing site individually (Table S2). In this way, data from 38,219 individual anglers during 2005–2017 were analyzed. Since each angler who fishes in the study area must obtain a fishing permit together with a fishing license (and must also report all killed fish into a mandatory angling logbook), the data were collected from almost all anglers (over 99%) who fished at the studied fishing sites. Each angler was a member of one local angling organization and passed a knowledge test on angling rules and fish biology before obtaining an angling license. Each angler delivered a filled angling logbook and a summary of fishing visits and killed fish for the whole year (Tables S3–S5). Anglers did not provide angling hours; only the number of fishing trips was provided. Each angler received a new angling logbook only after submitting the old filled one; this ensured that over 99% of the anglers who fished in the study area submitted a full summary of killed fish (Czech Fishing Union, unpubl. data). Anglers did not report released fish (only killed fish were reported). As a rule, the anglers can release all caught fish; they do not have to kill every single fish they catch. However, they have to release all fish that (1) are caught during the closed season, (2) do not meet the minimum or maximum legal angling size, or (3) exceed a daily bag limit. Anglers measured each killed fish to the nearest cm (TL, total length) and assigned a weight using species-specific length–weight tables. These tables were pre-provided by the fishing union and were based on length–weight equations from FishBase. Each angler used no more than two fishing rods. No boats, nets, or other fishing techniques were allowed.

Professional angling guards (15 people) and amateur angling guards (1000 people) performed random checks on the anglers in the field (20,000–40,000 annually). The guards checked whether the anglers wrote down each killed fish (including the date, the ID of a fishery, the species, and the size) and submitted the date of the check into their angling logbook. This ensured a relative quality of the reported data.

2.5. Data Analysis

The statistical program R [17] was used for statistical testing. The distributions of the fish harvest and stocking rates were tested by Shapiro–Wilk normality tests.

The yields of the fishes were not normally distributed ($p < 0.01$ for each tested species); the package for generalized additive models (GAM) was used to fit the models of the yields. The GAM assumptions were checked and assessed regarding the quality of the models according to statistical studies [18–21]. The GAM was used because it is an extension of the generalized linear model (GLM) with a smoothing function, and it is composed of a sum of smooth functions of covariates instead of (or in addition to) the standard linear covariate effects. The GAM was preferred to the GLM because it allowed the models with non-linear functions to fit with more precision. It allowed for modeling of non-linear data while maintaining explainability.

Three models were constructed—one for each species (common carp, grass carp, rainbow trout). The response variable in each model was the yield of the non-native fish species per effort per hectare. The fixed factors in all three models were: (1) the angling effort, (2) the surface area of a fishing site, (3) the size (the median body weight) of the stocked non-native fish species, (4) the stocking intensity of the non-native fish species, (5) the yield of the catfish, and (6) the stocking intensity of the catfish. The angling effort was calculated as the number of fishing trips (visits) per year. Fishing site was added as a random factor to exclude the effect of individual fishing sites on the yield and, because individual fishing sites (river stretches) were connected, to allow the stocked fish to migrate between the fishing sites. Collective annual data from one fishing site were used as one observation in the analyses. A gamma error distribution with a log link function was used in the models because the data had continually distributed positive values. A minimum probability level of $p = 0.05$ was accepted for all two-tailed statistical tests. The Bonferroni correction was applied in all three models because multiple groups were tested for differences. This method of fisheries data analysis was previously used to analyze fish harvest rates in different research papers [22–24].

3. Results

The anglers analyzed in this study made 6.73 million fishing trips during the years 2005–2017. The yield of the catfish and the non-native fishes was 219 and 2500 tons, respectively. The yields of the European catfish and the grass carp were approximately 12 and 15 times higher, respectively, than their stocking intensity. Conversely, the yields of the common carp and rainbow trout were only 30% and 50%, respectively, of their stocking intensity (Table 1).

Table 1. The numbers, biomasses, and mean body sizes (weights) of harvested and stocked fish in the study area during years 2005–2017 (cumulative absolute values over 13 years).

Species	Harvested Fish (n)	Harvested Fish (kg)	Size of Harv. Fish (kg)	Stocked Fish (n)	Stocked Fish (kg)	Size of Stock. Fish (kg)
C. carpio	929,840	2,138,632	2.30	8,352,487	6,646,407	0.80
O. mykiss	128,965	52,145	0.40	315,412	108,325	0.34
C. idella	128,632	303,456	2.36	45,821	20,157	0.44
S. glanis	19,214	218,563	11.38	133,524	18,562	0.14
all fish species	12,462,547	13,254,781	1.06	201,352,847	10,012,955	0.05

The yield of all three non-native fish species was strongly correlated to the yield and the stocking intensity of the catfish. In addition, it was also strongly correlated to the angling effort and the size of the river where the fish were caught. In particular, the stocking of each of the non-native fishes always led to higher yields of the stocked species. Similarly, intensive stocking of the European catfish always led to a plummet in the yield of the non-native fish species. However, the remaining correlations between the non-native fish yields and the explanatory factors had mostly different slopes (positive or negative) in each of the three species (Tables 2–4).

Table 2. Results of the model describing the relationship between the yield of common carp *C. carpio* and selected fisheries and environmental factors.

Response Variable	Fixed Variables	Estimate	95 CI: Low	95 CI: Up	SD (Slope)	*p*-Value
Yield per effort of *C. carpio*	Intercept	4.97×10^{-1}	4.45×10^{-1}	5.63×10^{-1}	7.64×10^{-2}	<0.01
	angling effort	-9.43×10^{-4}	-1.14×10^{-3}	-7.33×10^{-4}	8.47×10^{-4}	<0.01
	area	-8.78×10^{-4}	-9.85×10^{-4}	-6.33×10^{-4}	3.80×10^{-4}	0.02
	C. carpio stocking	2.26×10^{-1}	1.97×10^{-1}	2.63×10^{-1}	1.11×10^{-1}	0.04
	C. carpio—size of stocked fish	-6.60×10^{-4}	-8.65×10^{-4}	-3.25×10^{-4}	8.42×10^{-3}	0.94
	S. glanis yield	9.17×10^{-1}	7.63×10^{-1}	$1.10 \times 10^{+0}$	5.21×10^{-1}	<0.01
	S. glanis—size of harv. fish	-2.83×10^{-4}	-3.52×10^{-4}	-2.31×10^{-4}	2.07×10^{-4}	0.17
	S. glanis stocking	-6.86×10^{-2}	-8.85×10^{-2}	-4.25×10^{-2}	6.90×10^{-2}	<0.01
	S. glanis—size of stocked fish	-5.17×10^{-3}	-6.63×10^{-3}	-3.52×10^{-3}	3.82×10^{-3}	0.18

Additional information on the model: DF = 2385, AIC = 37,148, R^2 = 0.25. Significant factors are in bold. Note: 95 CI = 95% confidence interval, DF = degrees of freedom, AIC = Akaike information criterion.

Table 3. Results of the model describing the relationship between the yield of rainbow trout *O. mykiss* and selected fisheries and environmental factors.

Response Variable	Fixed Variables	Estimate	95 CI: Low	95 CI: Up	SD (Slope)	*p*-Value
Yield per effort of *O. mykiss*	Intercept	-1.61×10^{-3}	-1.95×10^{-3}	-1.42×10^{-3}	$1.35 \times 10^{+0}$	<0.01
	angling effort	-3.39×10^{-7}	-3.52×10^{-7}	2.84×10^{-7}	$1.00 \times 10^{+1}$	<0.01
	area	8.03×10^{-5}	6.33×10^{-5}	9.23×10^{-5}	$1.39 \times 10^{+1}$	<0.01
	O. mykiss stocking	1.23×10^{-3}	9.53×10^{-4}	1.49×10^{-3}	$9.63 \times 10^{+0}$	<0.01
	O. mykiss—size of st. fish	6.68×10^{-3}	4.12×10^{-3}	8.23×10^{-3}	$2.39 \times 10^{+0}$	0.06
	S. glanis yield	-2.33×10^{-2}	-2.63×10^{-1}	-1.93×10^{-1}	9.80×10^{-2}	<0.01
	S. glanis—size of harv. fish	1.95×10^{-6}	1.25×10^{-6}	2.85×10^{-6}	4.70×10^{-1}	0.66
	S. glanis stocking	-8.96×10^{-4}	-1.01×10^{-3}	-6.13×10^{-4}	8.47×10^{-1}	<0.01
	S. glanis—size of stocked fish	7.98×10^{-6}	6.63×10^{-6}	9.54×10^{-6}	1.71×10^{-1}	0.87

Additional information on the model: DF = 2385, AIC = 4880, R^2 = 0.16. Significant factors are in bold. Note: 95 CI = 95% confidence interval, DF = degrees of freedom, AIC = Akaike information criterion.

Table 4. Results of the model describing the relationship between the yield of grass carp *C. idella* and selected fisheries and environmental factors.

Response Variable	Fixed Variables	Estimate	95 CI: Low	95 CI: Up	SD (Slope)	*p*-Value
Yield per effort of *C. idella*	Intercept	2.03×10^{-4}	1.56×10^{-4}	2.56×10^{-4}	7.14×10^{-3}	<0.01
	angling effort	3.59×10^{-7}	2.86×10^{-7}	4.86×10^{-7}	4.71×10^{-7}	<0.01
	area	-3.79×10^{-5}	-5.52×10^{-5}	-2.24×10^{-5}	8.92×10^{-5}	<0.01
	C. idella stocking	1.59×10^{-2}	1.24×10^{-2}	1.86×10^{-1}	9.96×10^{-4}	<0.01
	C. idella—size of stocked fish	5.62×10^{-3}	4.33×10^{-3}	6.63×10^{-3}	6.14×10^{-3}	0.36
	S. glanis yield	6.91×10^{-1}	4.33×10^{-1}	8.86×10^{-1}	9.12×10^{-2}	<0.01
	S. glanis—size of harvested fish	8.43×10^{-7}	6.63×10^{-7}	9.96×10^{-7}	9.86×10^{-6}	0.93
	S. glanis stocking	-7.56×10^{-3}	-8.33×10^{-3}	-6.85×10^{-3}	5.82×10^{-3}	0.02
	S. glanis—size of stocked fish	-6.47×10^{-4}	-7.53×10^{-4}	-5.24×10^{-4}	2.58×10^{-4}	0.07

Additional information on the model: DF = 2385, AIC = 15,937, R^2 = 0.16. Significant factors are in bold. Note: 95 CI = 95% confidence interval, DF = degrees of freedom, AIC = Akaike information criterion.

The common carp and the grass carp had a lot in common, while the rainbow trout was the "odd one out". The yields of the common carp and grass carp were negatively correlated with the size of the fished river. This means that each angler harvested fewer fish from larger rivers than smaller ones. Conversely, each angler harvested more rainbow trout from larger rivers than smaller ones. The yields of both species were then positively correlated to the catfish yield, meaning that the yield of the non-native fishes went up on the rivers with a high catfish yield. However, rainbow trout showed the opposite trend. Each angler harvested more trout from larger rivers, and the yield of the rainbow trout plummeted on the rivers with a high catfish yield.

The common carp and rainbow trout also had something in common: The yields of both the common carp and the rainbow trout were negatively correlated to the angling effort. This means that each angler harvested fewer fish from a river where more anglers also fished. However, the grass carp showed the opposite trend: each angler harvested more grass carps from a river where more anglers also fished.

4. Discussion

This study revealed a correlation between the stocking intensity of non-native fish (*C. carpio*, *O. mykiss*, and *C. idella*) and the apex fish predator (*S. glanis*).

The decreasing yield of common carp at fishing sites with high angling pressure could be explained by the increasing popularity of the catch-and-release fishing strategy. Previous studies found that anglers released a large percentage of the fish caught on larger rivers [24]. If anglers killed all the fish that they catch, then the yield would be probably higher because more anglers should catch more fish. This catch-and-kill angling rule applies, for example, in Germany [25]. It is also possible that anglers who fish at fishing sites with higher angling pressures do not specialize in common carp angling. This theory is supported by other studies that show higher angling pressures at smaller fishing sites where the anglers usually target salmonids and not carp [26,27].

The connection between the decreased yield of common carp and the high stocking intensity of those carp is interesting for fisheries management. This shows that it may not pay off to stock carp at high intensities because the financial loss may be reaching unsustainable levels. However, the absolute number of harvested carp increased with a higher stocking intensity. That is likely the reason why intensive carp stocking still pays off financially; fisheries managers must lure anglers to fishing sites and persuade them to buy fishing permits, which is often done by intensive carp stocking (even over the carrying capacity of the ecosystem). Previous studies reported that angler satisfaction is sometimes positively correlated with fish catches (especially trophy-sized fish) and with the intensity of fish stocking [28]. Conversely, other studies found that fish catch is not the main motivation to go fishing and that anglers enjoy the nature, peace, and quiet more than the actual fishing [29,30].

The negative effect of intensive rainbow trout stocking on its yield could be explained by the fact that trout is stocked mostly in smaller rivers where the carrying capacity can be filled or exceeded. The carrying capacity of stocked streams is also influenced by populations of other fish species, mainly native and stocked brown trout. Both species share a similar ecological niche, though the hatchery-reared rainbow trout is usually more pollution tolerant and attacks more diverse prey (including fish) due to its higher aggressivity [31].

The negative relationship between the yield of rainbow trout on one side and the yield of catfish on the other side could be caused by differences in the ecological niche between rainbow trout and catfish. Rainbow trout occupy smaller rivers with faster flowing water, but catfish occupy larger rivers with slow water flow and higher water temperatures. There are no natural still waters (e.g., lakes) in the study area, and the largest rivers are relatively smaller (maximum 150–300 m wide) in comparison to the largest rivers in Europe. Despite the niche differences, there were many fishing sites where fisheries managers stocked, and anglers harvested, both rainbow trout and catfish. It is possible that the ecological niches of the rainbow trout and catfish will overlap in the future because some smaller rivers periodically dried up during the years 2015–2020 [32], and catfish expanded to smaller rivers [5,6].

The results for grass carp were similar to results of common carp. A possible explanation is that both carps share a similar ecological niche, except for the feeding behavior of their adults—grass carp usually feeds on emerged macroplants, while common carp is a typically omnivorous fish and a bottom-feeder [33].

Conversely, grass carp showed an interesting positive relationship between yield per one angler and the number of anglers. Basically, the more anglers that fished at the fishing site, the more grass carp each angler harvested. To the knowledge of the author, this is the first time that a similar result has occurred in scientific literature; other studies usually reported the opposite effect, meaning that higher angling competition led to a lower yield per one angler. This was true, for example, of the common carp and rainbow trout in this study, and also for the perch, brown trout, European grayling, European catfish, nase, vimba bream, and barbel in the study area [12,23]. This was also reported by other studies [34–36]. There is one possible reason why this anomaly was observed. Anglers harvested approximately 15 times more grass carp than what was stocked (by biomass). This is an unusual rate for a non-native species in central Europe. Non-native fish species mostly have negative harvest rates, meaning that anglers manage to harvest 10–80% of the stocked fish by biomass [11,26].

The yields of the grass carp and rainbow trout were relatively low in comparison to that of the common carp. There are two possible explanations for this result. Firstly, rainbow trout and grass carp were stocked at significantly lower intensity than the common carp. In addition, there is a functional and reproducing wild catfish population in the study area [5,6]. Low yield could be also caused by lower number of stocked grass carp and rainbow trout in the study area, especially considering that fisheries managers stocked "only" 110 tons of rainbow trout and 20 tons of grass carp over 13 years into waters that cover an area of 150 km^2 and have a natural fish biomass of 150–300 kg per hectare. Secondly, the stocked fish are of hatchery-reared origin and, therefore, less adapted to natural conditions. These include lower survival skills, weaker anti-predation mechanisms, no prior knowledge of local habitats, and difficulties in catching prey [37–39]. Since both rainbow trout and grass carp are popular angling targets, it is less likely that anglers would prefer other fish species (although common carp and piscivorous fish could be preferred to grass carp).

The lower yield of non-native fish species on fishing sites with a high stocking intensity of European catfish could be caused by catfish predation of both stocked and wild fish. This could be true especially for naïve stocked fish that encounter catfish individuals that have grown to 120–150 cm (TL) or larger. Catfish have a wide mouth gape and can swallow relatively larger fish (in comparison to the predator's size) than, for example, a pike [5,6]. However, the interaction between the yields can be also driven by angler behavior. Anglers could have switched their preferences from non-native fish to catfish right after fisheries managers advertised catfish stocking. Other studies reported changes in angler preferences during the angling season and in response to changes in fish stocking and fisheries management [40,41]. In addition, sociological studies of angler preferences in Europe pointed out that anglers prefer larger fish and predators over smaller fish and omnivores [7,27,30]. This fits nicely into our hypothesis that anglers started fishing for the larger predatory catfish instead of the smaller omnivorous or insectivorous non-native fishes. However, since the data were collected over a long period, it is difficult to understand the long-term preferences of the anglers. This could have resulted in more released carp and trout because there is a limit to the fish that anglers can take in one day. The anglers could have also re-specialized from carp and trout to catfish, including the switching of angling gear, lures, and angling strategy. Another possible explanation is that stocked fish changed their behavior to appear timider as a response to the predation pressure of expanding catfish populations and other piscivorous predators, such as Eurasian otter *Lutra lutra*, great cormorant *Phalacrocorax carbo*, gray heron *Ardea cinerea*, and anglers themselves. Other studies reported timider behavior of the fish in areas with high predation and angling pressure [42,43].

A higher yield of catfish resulted in a higher yield of two out of the three non-native fish species. This further supports the theory that the dynamics between the yields of fish species is partially driven by the behavior of anglers [26]. Anglers who harvest more catfish could also harvest more non-native species. All four studied species are of high angling interest, and there is an existing archetype of anglers who are so-called "mass anglers" that kill every fish they catch. Studies reported that some killed fish are caught even outside of legal restrictions [44].

Interestingly, the effect of the size of a fishing site was different within the three species. This is partially because angling effort is negatively correlated to the size of a fishing site, meaning that smaller fishing sites are under higher pressure from anglers in comparison to larger ones [24]. One possible explanation is that the larger fishing sites had a lower angling effort per hectare. Other studies also reported that size of a fishery is an important factor in fisheries management [45]. Fish are more accessible and easier to spot at smaller fishing sites, which could explain the higher recapture rates of stocked fish. Inversely, stocked fish are harder to catch at larger fishing sites (e.g., dammed rivers), which could explain the lower harvest per one angler. There are also more disturbing elements, such as tourists and vacationists, on larger rivers. Other studies reported that larger fisheries are profound and well-known and, therefore, sought after by anglers from further travelling distances [46]. As previous studies found, anglers who travel from distant places prefer a catch-and-release strategy, which further decreases the harvest and recapture rates of stocked fish [47].

There are additional species of non-native fish that are stocked by fisheries managers in rivers in the study area. Those are mainly the silver carp *Hypophthalmichthys molitrix*, common huchen *Hucho hucho*, and brook trouts *Salvelinus fontinalis*, *Coregonus* sp., and *Acipenser* sp. [48]. However, data on the yields of these species were too weak to be processed by the statistical models. In some cases, no fishing sites were found where listed fish species were stocked together with catfish. There could be a strong relationship between angling and management of catfish and these species, but the data were not yet strong enough to support or reject this hypothesis. Other studies that analyzed the effect of sample size on the strength and reliability of scientific results reported that the bias of incorrectly accepting false positive results increased in underpowered studies [49].

The results of this study could have been influenced by fisheries managers who stocked the fish that were later studied. Specifically, when it comes to fish stocking, the author of this study had no influence on the sizes and numbers of stocked fish. This is shown in Table S1, where the average size of stocked catfish ranged widely from 0.02 kg to 5.73 kg in the years 1996 and 2017, respectively. Even though we tested for the effect of the size of the stocked catfish on fish yield, and no effect was observed, there could be indirect effects that influenced the fish yields.

The data were taken from mandatory angling logbooks and the fish-stocking notes of fisheries managers. Similar data can provide scientists with a large amount of information. However, there is an existing bias in this data set, and the results should be interpreted with caution. The most important limits are overestimation and underestimation of the body sizes and total biomass of harvested fish (e.g., purposely overestimating size of harvested fish to meet the minimum legal angling size); incorrect species identification by anglers (e.g., misinterpreting common carp for grass carp); inability of anglers to comply with fishing rules (e.g., using illegal backwards hooks and triple hooks); angling preferences for specific species of high angling value (mainly common carp); and popularity of the catch-and-release fishing strategy [50–54].

5. Conclusions

The study showed possible significant relationships between the yield and stocking intensity of an apex predator and three non-native fish species. The relationships were studied in connection to the expansion of European catfish across new ecosystems in the inland freshwaters of central Europe. Relationships between the angling and management of the European catfish and the intensively stocked non-native species could be driven by either predation pressure of the catfish or by changes in the preferences of anglers. However, the driver that is behind these relationships remains unknown. To find out more about this driver, future studies should use field tests and tag individual stocked catfish and non-native fish to assess the predation pressure of catfish on stocked fish. Complementary studies should assess changes in the preferences of anglers towards catfish angling over time using sociological techniques (questionnaires, half-structured interviews, in-depth interviews, focus groups) or an anthropologic approach (e.g., non-participant observation).

In addition, the system of collection of angling logbooks could be greatly improved. Most importantly, if anglers wrote down all released fish, in addition to killed ones, it would be possible to estimate the composition of fish stocks more precisely. This would allow us to determine whether the increased catfish yield is due to increased catfish populations or due to the preferences of anglers towards catfish. The government departments are the ones who should enforce this new rule.

It is also recommended not to stock a lot of catfish together with non-native fishes, as yields of the non-natives are likely to plummet in this case.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14106001/s1. Table S1: The summary of the stocking of the catfish and the rheophilic fish species. Table S2: An example of two annual angling reports from a large popular fishing site on the Elbe River. Table S3: An example of a fishing permit. Table S4: A report of killed fish. Table S5: A summary of killed fish for the whole year.

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