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RESEARCH PAPER

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Only Survivors Grow – Effects of Predation on Stocked Juvenile Common Carp (*Cyprinus carpio* Linnaeus, 1758) in a Stagnant Waterbody

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Abstract

This study aims to investigate the suitability of an entirely stocking-based fisheries management strategy to establish a self-sustaining carp population in two water bodies within the Danube catchment east of Vienna. The assessment was generally based on two factors: the effect of predation on juvenile carp's mortality and potential differences in the growing performance of different age classes. The investigation on predation effects showed, that after one year ~541 of initially 1000 stocked K1 survived in the water body with decreased pressure of predation, while there was no evidence of surviving stocked juveniles in the water body with increased pressure. Regarding the growth-rate, the stocked K1 showed the overall steepest growth curve compared both to the stocked K2 cohort and selected wild populations. After five years the younger stocked cohorts ML was even higher than the older cohorts one at the same age, although the stocked K2 had by far a larger initial TL.

Our results showed that predation can massively impact the mortality rate of stocked K1 juveniles and thus the success of fisheries management strategies. Moreover, it demonstrated the benefits of stocking fish in early life stages regarding a best possible adaptation to the given environmental conditions.

Introduction

According to Balon (1995) the common carp (*Cyprinus carpio*) origins from the area of the Caspian Sea from where it spread into the basins of Black and Aral Sea. After the end of the last glacial period (~11.000 years before present) its natural range expanded towards west, eventually colonizing the Danube and towards east to eastern Asia. The geographical boarder regarding its natural range in Europe is still discussed. Balon (1995) claims the western most distribution is located in the Danube at the confluence with the Morava River. His assertion is based on a linguistic thesis. Therefore, in all countries where carp became introduced by Romans more than thousand years ago (west of Morava), the name of the species was formed by the term "carp" (Celtic origin). Indeed, this thesis seems valid regarding the different names along the Danube and in Western Europe beyond its catchment: *Karpfen* in Germany, *carpe* in France and *carp* in England, while *ponty* in Hungary, *sharan* in Serbia and *saran* in Bulgaria. Banarescu and Paepke (2002) on the other side include the upper Danube River sections of Austria and Germany to the European carp's natural range. In Austria, the carp is treated as a native fish species (Freyhof & Kottelat, 2008).

Outside its natural range, carp stocks are mostly not self-sustaining due to the lack of suitable spawning habitats, which are primarily considering backwaters and flooded meadows (Arlinghaus et. al, 2015; Freyhof

& Kottelat, 2008). Within its natural range, the number of wild populations declined dramatically in the past decades. Hybridization with introduced domesticated carps as well as river regulations, which mostly hinder spawning migrations to significant flooded areas, are regarded as the two main causes for this negative trend (Freyhof and Kottelat, 2008). As a consequence of restricted carp recruitment, fisheries managers of both artificial but also natural waters often stock the species, especially under consideration of carps` popular status for recreational angling in many European countries (e.g. Hickley & Chare 2004; Wedekind et. al, 2001). The most commonly practiced management tool is the stocking of hatchery-propagated fish with the primary intention to satisfy angler expectations (Cowx, 1994; Arlinghaus & Mehner, 2005). In general, this strategy is carried out regardless of life-cycle habitat suitability or survival and hence sustainability (Unfer & Pinter, 2018). Thus, ecological principles regarding this management tool, like preferably stocking fish at early life-stages or the primary aim of supporting or reestablishing self-sustainable populations, mostly are not considered (Arlinghaus et. al, 2015).

The Austrian Federal Forests yearly stocked thousands of one-summer-year-old (K1) carps into waterbodies inside and in vicinity of the National Park Donauauen. Although there was no proof on the suitability of this management strategy regarding sustainability (survival rate, self-reproduction, etc.) annual stocking was carried out between 1996 and 2016. However, low numbers of catches raised doubts concerning the followed strategy, which consequently led to the initiation of the given study in 2016.

The present study is primarily focusing on the impact of predatory fish species on mortality of one-year-old stocked carps in two stagnant floodplain water bodies. We hypothesized that stocked K1 and K2 carp would survive better in the water body with significantly reduced predation pressure compared to the second water body where predation pressure was additionally increased. In addition, an investigation on the growth-rate of juvenile carps was carried out as both factors are relevant for fisheries management (Pope et. al, 2010). Moreover, the investigation should provide evidence of natural reproduction. The outcomes of this study should serve as a basis for sustainable fisheries management decisions in floodplain water bodies comparable to those studied.

Study Area

The investigated water bodies are part of a former sidearm in the floodplain of the Danube River in Lower Austria. The remnants of this sidearm are disconnected from the Danube floodplain (National Park Donauauen) by a dyke system and therefore lost its natural flood dynamics several decades ago and remains only connected to the groundwater layer. It is separated into two water bodies (eastern and western part), enabling parallel *in situ* investigations (Figure 1). Both

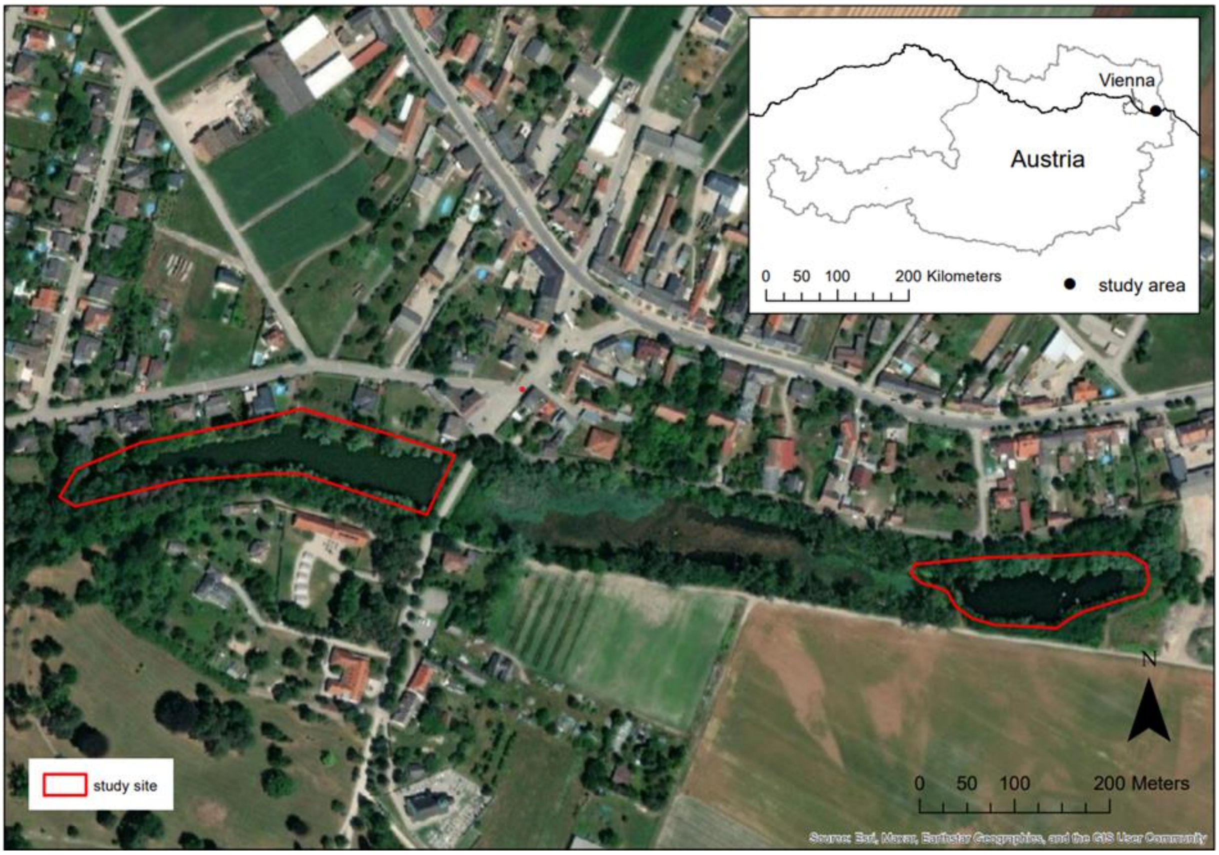

Figure 1. Location of the two studied waterbodies in the village Eckartsau in Lower Austria on the edge of the National Park Donauauen (Esri, Maxar, Earthstar Geographics, and the GIS Community).

waterbodies are characterized by water temperatures of up to ~25 °C during summer. The average water depth in the eastern waterbody (~0.5 ha) are ~2 m (max. ~3 m). Moreover, the eastern waterbody encompasses a reed bed which is generally dry and only fills after weeks of heavy rain up to around 10 cm water level. This has never been the case during this investigation. The water depths in the western waterbody (~0.75 ha) are more homogeneous and vary around 1.5 m.

Material and Methods

Assessment of fish populations

A mark-recapture survey by boat-electrofishing was carried out on two consecutive days in autumn from 2016 to 2020 in both waterbodies (Table 1). The fishing was conducted using a boat with an anode fence and a stationary generator fixed in the boat with a power of 13 kW, which was generating an electric field of approximately 6 meters wide and 2.5 meters deep around the boat. Two handlers with dipnets in the front of the boat caught the fish while another two persons were in charge of emptying the dipnets into a tank, attend to the fish and drive the boat respectively. Sampling time was fixed per time of four hours per event per waterbody. The high number of recaptures per year underlined the suitability of the chosen approach for this mark-recapture study.

All caught fish were measured (total length, TL [mm]), weighted [g] and marked with Visible Implant Elastomer (VIE) tags and/or Passive Integrated Transponder (PIT) tags. After sampling, all carps were released back to the section they were caught. On the second day the methodology was repeated with the same effort. The data collected during both sampling days served as basis for a total stock estimation (capture-mark-recapture).

In 2016 all predatory fishes such as pike (*Esox lucius*), perch (*Perca fluviatilis*) and pikeperch (*Sander lucioperca*) caught in the western section were marked with VIE and afterwards transferred to the eastern section, with the intention to decrease respectively increase predation pressure in the respective waterbodies. Our intention was to reduce the population of predatory fish in the western water body as much as possible, but we were aware that we would not be able to catch all predatory fish (Table 1). This limitation had to be accepted for a field experiment in experimental water bodies of about 0.75 and 0.5 hectares. Additionally, all caught individuals (TL>50 mm) of bream (*Abramis brama*), roach (*Rutilus rutilus*), bleak (*Alburnus alburnus*) and rudd (*Scardinius erythrophthalmus*) were transferred from the western to the eastern waterbody to reduce potential predation upon naturally reproduced carp larvae in the western waterbody. The small remnant stocks of these species were not quantitatively assessed thereafter. Non- native individuals of grass carp (*Ctenopharyngodon idella*) and silver carp (*Hypophthalmichthys molitrix*) were removed and disposed of.

A few days after the stock assessment surveys, 1000 one-summer-year-old juvenile carps (K1) with a TL of 80 – 160 mm and a total biomass of 30 kg were stocked into each of the two water bodies in October 2016 (Table 1). Since no carps <300 mm TL had been caught during the survey, tagging of these K1 carps was not necessary. Still present individuals of this cohort were PIT-tagged in 2018. Further, 30 two-summer-year-old PIT-tagged individuals (K2) with TL of 325 – 415 mm were stocked into the western section in October 2016.

The yearly mark-recapture surveys were repeated in the consecutive years till 2020 (Table 1) using the same methodology and effort. The total stocks of common carp, pike, prussian carp (*Carassius gibelio*) and European catfish (*Silurus glanis*) were calculated based on the mark-recapture method (Otis et. al, 1978; Lindberg, 2012).

Calculation of Potential Biomass Loss

To determine possible correlations between the potential loss of K1 biomass (LB) and the estimated feeding consumption of pike (FC) within a year we defined the following calculation for the western section, based upon a feed conversion rate of 1:10 for pike (Geldhauser & Gerstner, 2003; Hochleithner, 2015):

$$B_{pot} = B_{i-1} + A_i \times (\bar{W}_i - \bar{W}_{i-1})$$

Table 1. Development of carp and pike stocks in the two water bodies between 2016 and 2020

Section	Species/ Age-class	2016			2017			2018			2019			2020		
		24. & 25. Oct.			19. & 20. Oct.			29. & 30. Oct.			5. & 6. Nov.			19. & 20. Nov.		
		Abundance (Ind.)	Weight (kg)	Median TL (mm)	Abundance (Ind.)	Weight (kg)	Median TL (mm)	Abundance (Ind.)	Weight (kg)	Median TL (mm)	Abundance (Ind.)	Weight (kg)	Median TL (mm)	Abundance (Ind.)	Weight (kg)	Median TL (mm)
West	K1*-K5	1000	30	120	541	61	191	313	85.7	238	76	61.4	413	57	140.5	523
	K2*-K6	30	22	365	28	29.9	405	18	20.2	415	18	25.8	463	16	42.2	543
	Adult carp	29	154.9	650	11	82.2	820	9	76.2	830	10	101.1	840	10	100.8	840
	Pike	38**	24**	405**	5	5.9	550	6	10.4	677	6	14	713	5	10.5	645
East	K1*	1000	30	120												
	Adult carp	36	162.6	630	26	111.9	630									
	Pike	125***	94***	450***	32	15	375									

*stocked on 8. Nov. 2016
**all caught pikes were transferred to eastern waterbody on both sampling days in 2016
***including 38 stocked individuals from the western waterbody

The potential biomass of a given year (B_{pot}) is calculated by the sum of the total biomass of the preceding year (B_{i-1}) and the abundance of the current year (A_i) times the mean weight increment of the past year ($\overline{W}_i - \overline{W}_{i-1}$). The LB of a given year is consequently calculated by subtracting the total biomass (B_i) from the potential biomass (B_{pot}).

For 2017 and 2020, the calculation of FC was not possible since no information regarding the remaining individuals was available due to the predator transfer in 2016 and in 2020 the biomass of pike decreased due to the loss of two individuals during the year.

Results

Abundance – Carp

During the first sampling session in the western part in 2016 a total number of 38 pikes (24 kg), 32 perches (0.5 kg) and six pikeperches (4.2 kg) (Table. 1) was transferred from the western to the eastern waterbody. Beside these predatory species, 285 breams (25.5 kg), 341 roaches (4.6 kg), 102 rudds (2.7 kg) and 1 bleak were transferred to the eastern part. Two weeks later 1000 K1 were stocked into both waterbodies (Table 1).

Figure 2 shows the development of the K1 abundance in the two water bodies over the study period (2016-2020). In 2017 the abundance of K2 (stocked as K1) in the western waterbody was calculated with 541 remaining individuals and a total biomass (TB) of ~61 kg (Table 1). In addition, the sampling campaign in 2017 showed that five pikes (5.9 kg) were still present in the western waterbody. Further, a total biomass of non-predatory fish of approximately 75 kg was calculated.

After 2017, the stocked cohort declined from 313 (2018) to 76 (2019) and 57 individuals (2020), consequently resulting in carp biomasses of 86 kg (2018), 61 kg (2019) and 141 kg (2020) (Figure 2). The population of pike within the same period was constant with five to six individuals. The pike's TB ranging between 10 kg and 14 kg (Table 1). No natural reproduction respectively recruitment of the remnant stock of adult carps, nor the stocked cohort could be observed.

Growth-rate – Carp

Since there was no evidence of remaining stocked K1 in the eastern waterbody already in 2017 (Figure 2), the investigation on growth-rate had to focus entirely on the K1 and K2 cohort in the western waterbody. Figure 3 shows the development of the length-frequency distribution of the cohort stocked as K1 between October 2017 and November 2020.

The boxplots in Figure 4 represent the development of TL both for the stocked K1 and K2 cohorts between October 2016 and November 2020.

Regarding the stocked K1 cohort, the highest median growth was documented for the period 2018/19 (see Figure 4). Their variation in TL increased continuously from ± 80 mm (2016) to ± 300 mm (2020). The stocked K2 cohort showed a slower growth (~+ 14%) between 2016 – 2018 compared to the period 2018 – 2020 (~+ 31%). The variation in TL increased from ±90 mm (2016) to ± 175 mm (2020).

Development of Carp Biomass

The development of the calculated potential loss in K1 biomass (LB) between 2017 and 2020 is shown in

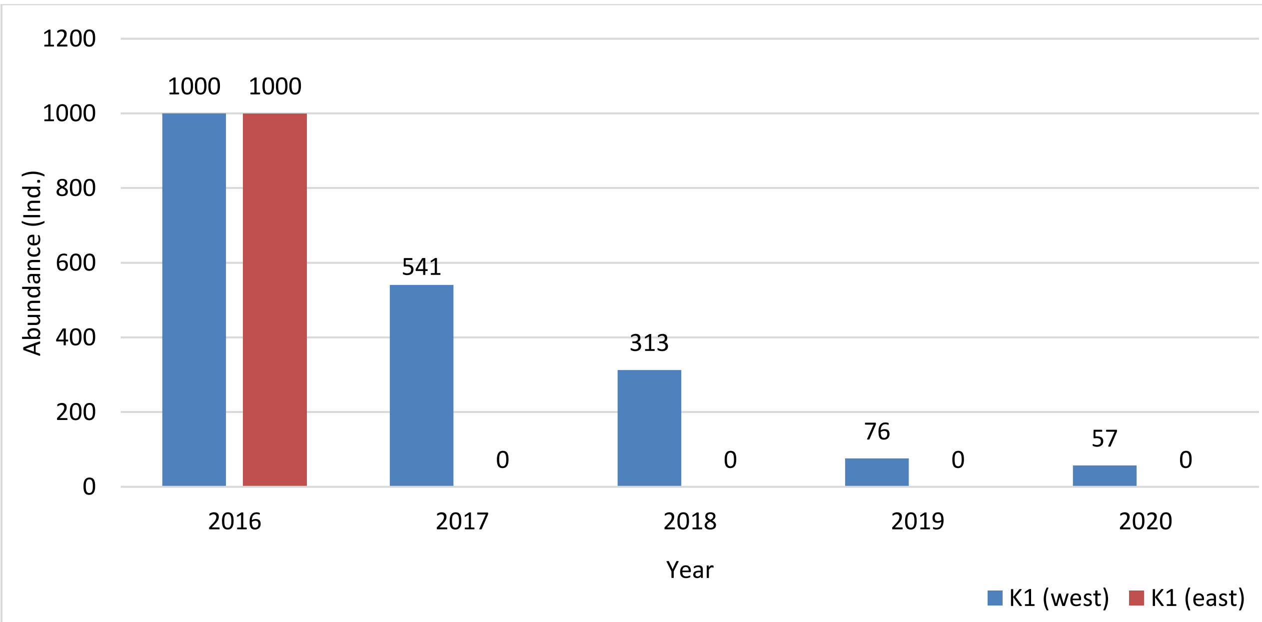

Figure 2. Abundance of the stocked K1 cohort between 2016 and 2020.

Table 2. The development of LB partly showed substantial differences between the three years (2017 – 2019). In the period 2017/18 LB gets relatively close to the estimated feeding consumption by pike (FC) while in 2018/19 LB is clearly higher than FC.

As the calculated LB represents the potential maximum value, it needs to be assumed that the predation pressure between the samplings in 2017 and 2018 had a large impact on the mortality of K2 (stocked as K1).

Eastern Waterbody – Abundance

Including the transferred individuals, the abundance of pike was enlarged from 97 to 125 individuals and the biomass of pikes was increased from ~71 kg to ~94 kg in 2016 (Table 1). Catfish was also present in the eastern waterbody with three individuals and a calculated biomass of ~19 kg. Six pikeperches (~4.2 kg) were stocked. Eventually, the TB of predators in the eastern part was at ~120 kg in 2016. Additionally,

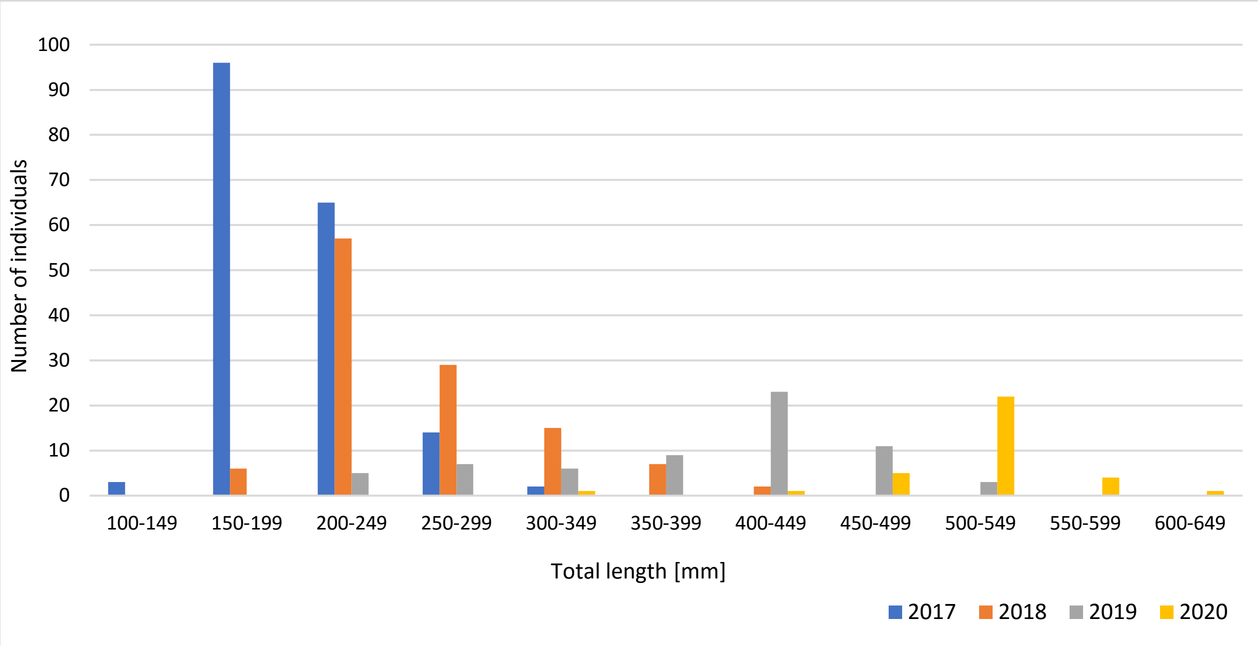

Figure 3. Length-frequency of the stocked K1 cohort between 2017 and 2020.

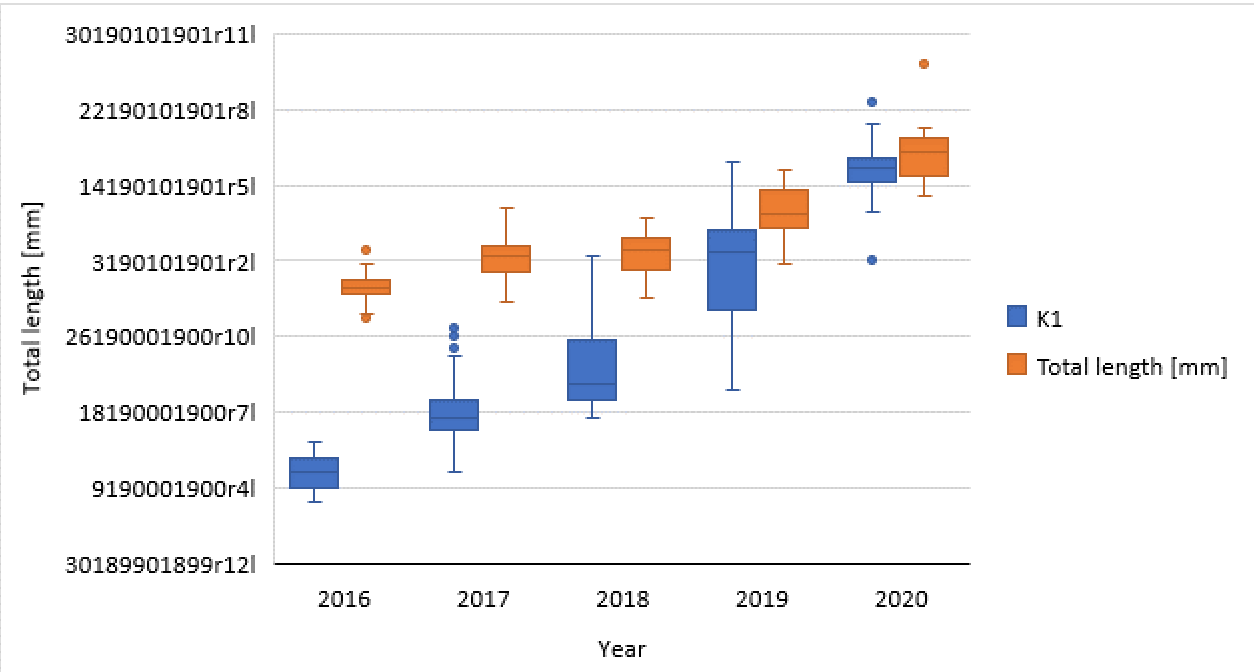

Figure 4. Development of K1 and K2 TL in the western waterbody between 2016 and 2020.

a TB of ~1084 kg of primarily non-predatory fishes, including prussian carp, bream, carp (remnant stock), roach, pumpkinseed (*Lepomis gibbosus*), perch and rudd was calculated for this section. After the sampling also there 1000 K1 were stocked.

Unlike the development of stocked carps in the western waterbody, not a single individual of the 1000 stocked K1 could be found in the eastern waterbody neither during the two sampling days in 2017 nor in the subsequent years (Figure 2).

In addition to the total loss of the stocked K1, also a decrease in the predator abundance and biomass from 125 (including 38 stocked pikes) to 25 individuals and a biomass decrease from 119 kg to 57 kg respectively was observed between 2016 and 2017 (Figure 5). Although larger individuals (>550 mm) were almost totally missing, the loss in abundance was quantitatively highest at smaller size classes of pike (<550 mm).

Discussion

The stock assessment in 2017 has shown, that within one year all stocked K1 individuals disappeared in the eastern waterbody under the given predation pressure, while in the western waterbody about half of the stocked K1 had survived. Additionally, we documented a sharp reduction in pike abundances in the eastern waterbody within the first study year (2016-2017). Regarding the growth performance of the two stocked carp-cohorts in the western water body, it was interesting to see that the K1 individuals showed an overall steeper growth rate compared to the older carp-cohort stocked as K2 during the five years of investigation. During the entire study period, there was no evidence of natural reproduction neither in carp nor in pike.

The impact of recreational fishing during the investigation period can be considered as very low. Before the start of our investigation anglers were informed to document removed fish (photo, TL). Within the five years, information about the removal of three individuals from the adult carp stock and two of the stocked K2 in the western part in 2016/17 as well as five more of the stocked K2 in 2017/18 was received. Illegal fishing can be excluded as impact since the waterbodies are situated directly next to a facility of the fishing right owners.

Table 2. Development of parameters considered in the calculation of potential loss in former stocked K1 biomass in the western waterbody between 2016 and 2020.

Parameter	Symbol	2016	2017	2018	2019	2020
Individual carp mean weight (g)	$\bar{W}_i$		113	277	820	2114
TB carp (kg)	B_i	30	61	85.7	61.4	140.5
Abundance carp current year (ind.)	A_i	1000	541	313	76	57.1
Mean weight gain carp past year (g)	$\bar{W}_i - \bar{W}_{i-1}$		89	164	543	1294
Potential biomass carp (kg)	B_{pot}			149.9	255.7	159.7
Potential loss in carp biomass (kg)	LB_{carp}			64.2	194.3	19.2
Estimated feeding consumption pike (kg)	FC			45	36	
TB pike (kg)	B_{pike}		5.9	10.4	14	10.5

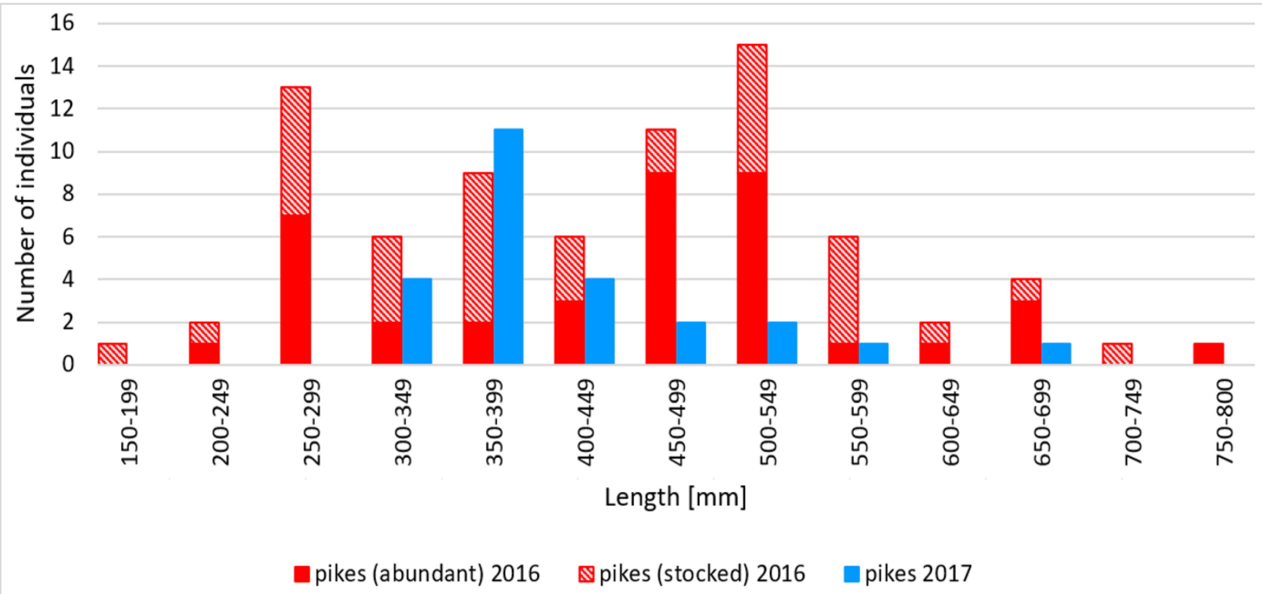

Figure 5. Development of the length-frequency of pike in the eastern waterbody between 2016 and 2017.

Problems with survival directly after the stocking can be ruled out since both water bodies were visually monitored in the weeks after the stocking and no dead fish were observed. This is additionally underlined by the recaptures of stocked K1 & K2 in the western waterbody.

Mortality Rate 2016/17

K1 mortality rates in the two waterbodies differ greatly. While in the western part ~54% of the stocked individuals survived, there was no trace of the stocked carps in the eastern waterbody after one year. It can be assumed that the presence of predators in the eastern waterbody resulted in the total loss of the K1. This observation leads to the assumption, that the survival of stocked juvenile carps is highly dependent on predation pressure and that small carps seem to be a favourable prey.

One potential explanation for the complete disappearance of K1 under predation pressure is the hatchery origin of the stocked carp and the resulting domestication effects. For example, captive-reared animals are more prone to inappropriate predator avoidance behaviour because they have evolved in a predator-free environment that does not continually provide significant key experiences (Price, 1999). Furthermore, it was very interesting to see that the loss of all stocked carps was accompanied by a sharp decline of predators (- 77%, Table 1) although multiple other fishes in suitable prey sizes were abundant. These observations are comparable to results of investigations on the stocking of pike (TL ~170 – 580 mm) in natural waters with self-sustainable pike populations in Wisconsin (USA) which also showed high mortality rates within the first year after stocking (Krohn, 1969). There, one year after ~1000 pikes were stocked in the Nebish Lake (no emigration possible), the remaining population was estimated at ~150 individuals (including the initial stock). In the Murphy flowage ~8500 pikes were stocked of which ~1700 were still estimated to be present after one year (Snow, 1974). In contrast to the massive drop in abundance in the Nebish Lake, which according to the author was almost entirely driven by natural causes, the high losses in abundance of stocked pike in the Murphy flowage was most probably caused by emigration processes due to very high densities. Based on these observations, we assume that the natural carrying capacity of the eastern waterbody most likely was already reached prior to the stocking with pike from the western waterbody and was far exceeded after the transfer resulting in a sharp decline in pike density in 2017 (Figure 5). Such mechanisms are very likely to be driven by intraspecific self-regulation (Guillerault et. al, 2018). Given the observed thinning of the pike density, we assume that the effect of cannibalism on pike mortality rates was most likely less than the effect of competition for food and habitat, since the larger individuals (>550 mm) in particular were almost entirely missing in 2017 (Figure 5).

Carp Mortality Rate 2017/18

In the period 2017/18 the K1 abundance in the western waterbody declined down to 313 individuals, which means a relative loss in abundance of ~42% compared to the stock in October 2017 (541 ind.). With this the mortality rate remained relatively constant between the first two years, which means also that it is higher compared to mortality rates reported from European carp farms (20 – 30%; Seiche et al., 2012). The estimated FC of pike is relatively close to the calculated LB of K3 (former stocked K1), which leads us to the assumption that pike very likely had a relevant impact on the mortality of this cohort (see Table 2). In total we assume a multifactorial mix of causes for the loss in K1 abundance for this period, which is primarily considering both aquatic and terrestrial predation as well as density regulation.

Carp Mortality Rate 2018/19

While the loss of K1 in the western waterbody was lower (48%) respectively slightly higher (42%) compared to values used to calculate natural mortality at European carp farms in the first two years (K1: 70 – 80%; K2: 20 – 30%), the massive drop in abundance within the period 18/19 (- 75%) is clearly higher than the assumed value for aquacultures (~10%; Seiche et. al, 2012). A relevant influence of water temperature and oxygen concentration during the summer months can be excluded, since both parameters were measured continuously and were within the spectrum required for carp (Flajšhans & Hulata, 2007). In addition, the highest mean growth rate was documented in 2018/19 (Figure 6), indicating well-suited environmental conditions. Furthermore, due to the consistently low numbers of pike (5-6 individuals), increased predation pressure can be ruled out as a cause for the massively increased mortality rate. The loss of 194 kg of carp biomass during this period is five times higher than the estimated feeding consumption (FC) of pike. In contrast, in the previous year (2017/18), the feeding consumption (FC) and potential biomass loss (LB) parameters were close. (Table 2). Also, the extremely low angling pressure during the whole investigation period can be neglected. Thus, it can be assumed that other factors, primarily terrestrial predators are suspected, have caused the massive decline in the carp population during 2018/19. We assume that the decrease most likely was caused by the presence of cormorants (*Phalacrocorax carbo*) during winter.

Studies on the impact of cormorant on carp fish farms support this thesis. For example, an investigation at a carp farm in the Netherlands showed the major impact cormorants can have on the mortality rate of juvenile carps in shallow stagnant waters. There, the total annual losses of K1 and K2 in the fish farm were calculated with 20 – 97% within three years, which were primarily caused by massive cormorant invasions (Moerbeek et. al, 1987). Studies at Czech carp farms

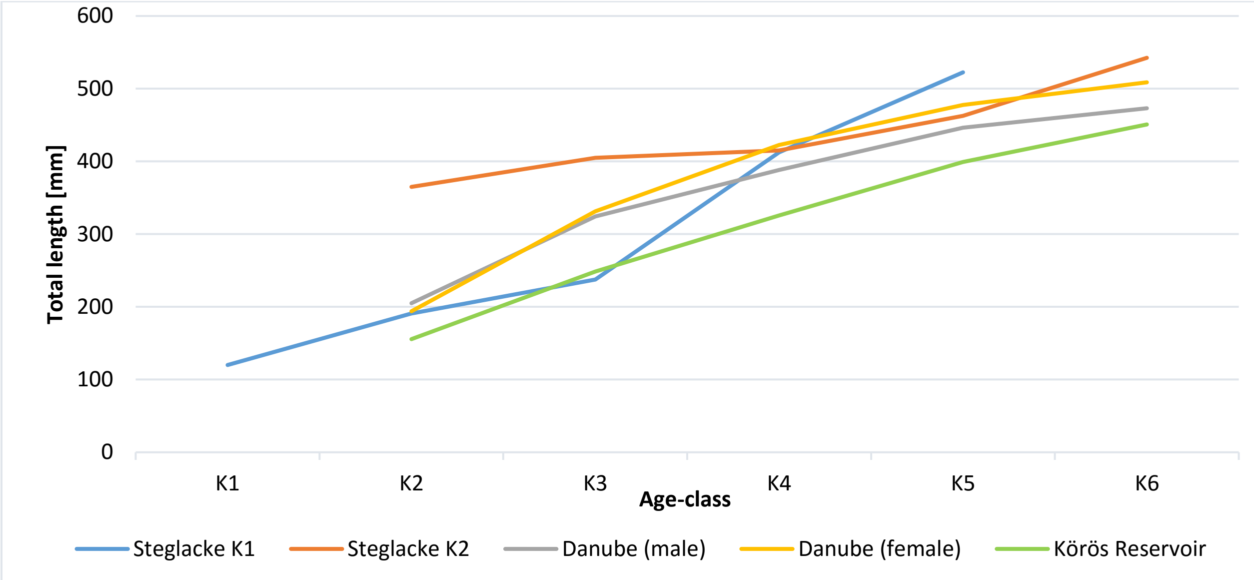

Figure 5. Development of the length-frequency of pike in the eastern waterbody between 2016 and 2017.

showed high shares of carp in cormorant diets (75 – 100% (Adámek et. al, 1999)). According to Moerbeek et. al (1987) individuals up to 550 g were vulnerable to predation. Other studies with focus on salmonid species showed selective preferences of cormorant on relatively large fish (>200 mm) (Jepsen et. al, 2018; Källo et. al, 2023). Thus, these findings support our hypothesis on the impact of cormorants, since the range in TL of the carp stock of this study (180 – 400 mm; Figure 3 & 4) in October broadly overlaps with the preferred range in prey size observed in the cited studies.

Beside cormorants also otters (*Lutra lutra*) may have had an impact on carp abundance in 2018/19. According to Adámek et. al (1999) the share of carps in otters' diet at Czech pond regions was up to 50%. During winter the risk of mortality caused by predation increases, due to reduced metabolism of carp (Adámek et. al, 2003). Regarding both terrestrial predator species, it is important to consider that losses in abundance are not only caused by direct but also by indirect mortality (e.g.: wounding, stress, diseases; Ondračková et. al, 2011; Kortan et. al, 2008; Adámek et. al, 2003).

Carp Mortality Rate 2019/20

In the last period of the investigation (2019/20) the abundance of the former stocked K1 (now K5) reduced from 76 to 57 individuals, which means a decrease of mortality from 75% in the preceding year to 25%. This value is even lower than the estimated natural mortality rate (37%) of wild carp populations with a comparable range in TL (230 – 860 mm) at the Danube in Romania (Gheorghe et. al, 2011). Therefore, we assume that the mortality in 2019/20 was no longer driven by terrestrial predators. Since the TL of most carps already exceeded the "predation window" (preferred prey size) of pike (<300 mm; Sammons 1994), also the impact of predation by pike can be neglected within this period and for the later years. This also applies for the vulnerability to cormorant predation. According to Moerbeek et. al (1987) there is no risk of cormorant predation for carps >1000 g (see Table 2).

Growth-rate K1 & K2

Variations in somatic growth among spatially separated fish populations are the result of a combination of numerous environmental factors (e.g. fish age & density, food supply, climate). Therefore, understanding growth patterns, considering these factors is central for fisheries management (Spurgeon et. al, 2020). To show differences in the growth performances of spatially separated carp populations under similar climatic conditions we compared the growth rates of this study to available data of two other populations within the Danube basin even though hydromorphological differences in the habitat likely also impact growth performances (Danube & Körös Reservoir; Balon, 1995; Talaat & Olah, 1986). Figure 6 shows the development of growth in TL per age class for each population.

It shows that the initial mean length of the stocked K2 is significantly higher compared to all other stocks in the same age class. Since the length of the stocked K1 after one year is about half the length of the stocked K2, originating from the same hatchery, it can be assumed that the stocked K2 benefitted from hatchery conditions and additional feeding during their additional year of foraging in the fish farm environment.

In the period 2017/18 both stocked cohorts showed their overall lowest growth rates. In the two following years we could observe clear increases in the growth rates for both but especially for the former stocked K1 cohort, which had the steepest growth curve, also compared to the Danube and Körös populations. Since in the period 2018/19 a massive decline (- 75%) in abundance of the former K1 had been observed, followed by this significant increase in growth rate, we assume that the remaining individuals benefitted from increased food availability.

The stocked K2 showed the overall flattest growth in their respective K3 to K5 period. Therefore, the stocked K1 caught up to the stocked K2 until 2019 and partly even exceeded them in size in 2020. This observation consequently leads to the assumption that the younger stocked individuals essentially adapted better and faster to the environmental conditions of the water body and the stocked K2 show stronger domestication traits and thus need longer to adapt to the natural conditions of the western Steglacke.

Summary

In summary, the investigation has shown that predation can massively impact the mortality rate of stocked K1 juveniles and thus the success of fisheries management strategies. Despite the high densities of other potential prey fish species in the eastern water body, the complete disappearance of stocked juvenile carp within a single year suggests that juvenile carp are preferred as prey primarily by pike. The stocked K1 cohort showed an overall steeper growth gradient compared to the K2 one. This leads us to the assumption that the earlier juveniles are stocked to a waterbody, the better/faster they adapt to the new environmental conditions and consequently the better the resulting growth. The trade-off between predation risk and adaption performance therefore needs to be evaluated on a case by case basis. The lack of evidence of natural reproduction throughout the study period raises doubts about achieving the stocking objective of establishing a self-sustaining carp population in the Steglacke under the given environmental conditions.

Ethical Statement

The procedures and methods used in the study followed the ethical guidelines of The University of Natural Resources and Life Sciences, Vienna and did not require an ethical statement.

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Author Contribution

Valentin Sturmberger: Data analysis, field work, manuscript preparation Günther Unfer: Project acquisition, field work, data quality control, supervision Thomas Friedrich: Project acquisition, project management, field work, data quality control, supervision

Conflict of Interest

The author(s) declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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