



HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES

**Assessment of the environmental status of angling waters and the
impact of recreational fishery management in Hungary**

Theses of Doctoral (PhD) Dissertation

Anna Hegedűs

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Name of doctoral school: Doctoral School of Agricultural and Food Sciences

Discipline: Animal husbandry

Head of doctoral school: Prof. Dr. Melinda Kovács
full professor, full member of the Hungarian Academy of Sciences
Hungarian University of Agriculture and Life Sciences

Supervisors: Dr. Árpád Ferincz
associate professor
Hungarian University of Agriculture and Life Sciences
Institute of Aquaculture and Environmental Safety

Dr. Ádám Staszny
Business Intelligence Developer
Alphavet Veterinary Ltd.

.....
Supervisor

.....
Supervisor

1. RESEARCH BACKGROUND AND OBJECTIVES

During the past few decades, fisheries around the world have faced growing challenges, mainly due to human activities and environmental changes. Fishing has long been an important source of income and food, especially in communities where fish is a key part of daily protein intake. The rise of large-scale commercial fishing, however, has caused overfishing, damage to habitats, and a decrease in biodiversity, highlighting the need to rethink fisheries management and strengthen regulations.

As commercial fishing has declined, recreational angling has taken on an increasingly important role as an alternative form of resource use. In Hungary, a key milestone was the ban on commercial fishing in natural waters in 2016, aimed at protecting native fish populations and aquatic ecosystems. While the ecological impacts of recreational fishing were long considered minimal, recent evidence increasingly suggests that, without proper regulation and monitoring, this activity can also impose significant environmental pressures. Nevertheless, regular assessment of the effectiveness of fisheries management measures is often lacking.

Climate change and increasingly strong anthropogenic pressures create unpredictable, and sometimes extreme, situations that require rapid and well-informed decision-making. Reliable and continuous data collection, along with regular evaluation of these data, is therefore essential. Due to the diverse nature, size, and characteristics of fishing waters, as well as their fragmented geographic distribution, effective management is only possible based on site-specific studies. However, since comprehensive monitoring of all waterbodies requires substantial resources, social science and citizen science–based approaches are playing an increasingly important role, providing valuable supplementary data for fisheries management.

Natural waters in Hungary (e.g. Lake Balaton, the Danube, and River Tisza) are regularly monitored through national and international programs. In contrast, smaller artificial waterbodies, such as reservoirs, mining lakes, and canals, often remain at the periphery of research and monitoring efforts, despite their widespread use for recreational fishing in industrialized countries. Through their hydrological connections, these waterbodies can also indirectly affect the condition of surrounding natural waters. Until now, there has been no comprehensive, scientifically rigorous assessment of the environmental and ecological impacts of recreational fisheries in Hungary, leaving fundamental data on the sustainability of such management practices unavailable. Therefore, a primary objective of this dissertation is to collect and analyze this essential information.

1.1. Objectives

My research was aimed to carry out a nationwide, holistic assessment of recreational fishing waters, as outlined below:

1. To collect consistent and detailed data on the ecological, environmental, and fisheries management characteristics of managed waters, in order to identify the main ecological and environmental challenges, as well as the potential impacts of fisheries management on aquatic ecosystems.
2. To examine the operations of recreational fishing organizations, including fisheries management strategies, demographic factors, and the competencies of leadership, in order to uncover the factors underlying decision-making processes.
3. To identify the mechanisms that hinder the sustainable management of waters. By analyzing fish population composition data, to reveal the gaps that significantly affect the effectiveness of population monitoring and the success of fisheries management strategies.
4. To assess the diversity of fisheries management tools aimed at maintaining fish populations, in order to analyze the potential impacts of individual measures on aquatic ecosystems.
5. To examine the extent and distribution of damage caused by protected piscivorous species (great cormorant, *Phalacrocorax carbo sinensis*, Linnaeus, 1758; Eurasian otter, *Lutra lutra* Linnaeus, 1758) as experienced by fisheries managers, in order to reveal the patterns and magnitude of such impacts.
6. To investigate the potential effects of anthropogenic pressures and climate change on recreational fishing waters, in order to reveal how these factors contribute to changes in water quality.

2. MATERIAL AND METHODS

Limited information is available for a significant portion of Hungary's recreational fishing waters, which justified the implementation of a nationwide data collection. In line with the research objectives, a questionnaire survey was conducted, enabling the creation of a consistent and comprehensive database with the involvement of recreational fishing organizations (angling clubs and associations).

2.1. Questionnaire Design

Data were collected using an online, self-administered questionnaire created on the Google Forms platform, which respondents could access via a link. The online questionnaire enabled rapid and cost-effective data collection and allowed responses to be recorded digitally. The use of skip logic and mandatory questions facilitated efficient completion and reduced missing data. However, the method also had limitations, including the possibility of multiple submissions and potential concerns about data reliability.

The questionnaire consisted of 75 questions, covering the following topics:

1. general information on fishing organizations,
2. examination of fisheries management practices,
3. knowledge of fish populations in managed waters,
4. fish stocking practices,
5. assessment of natural reproduction,
6. impact of piscivorous species,
7. water quality monitoring,
8. anthropogenic pollution,
9. effects of climate change,
10. ecological knowledge of board members.

The questionnaire was prepared in Hungarian (national language). When formulating the questions, particular attention was paid to clarity and ease of understanding. To ensure the most comprehensive data collection possible, a variety of question types were used, which are detailed below.

During data collection, primarily closed-ended questions were used to facilitate quick and easily interpretable responses. Dichotomous (yes-no) questions were employed to assess the use of certain fisheries management tools and the presence of environmental factors. For multiple-choice questions, respondents selected the most representative option from more than two possible answers. Multiple responses were allowed when assessing fish species present in the waters, as

well as organisms living in and around the waterbodies. For each multiple-choice question, an open-ended “other” option was also provided, allowing respondents to briefly record their own observations. To evaluate issues related to invasive fish species and protected piscivorous species, a numerical rating scale from 1 to 8 was used, where 1 indicated a minimal problem and 8 represented the maximum level of concern for the waterbody. Prior to finalizing the questionnaire, a pilot test was conducted to ensure the clarity of the questions and the smoothness of the completion process.

The questionnaire was distributed to 1,242 fishing organizations with the assistance of MOHOSZ. Data collection took place between April 21 and May 31, 2022, supplemented with reminder notifications. Throughout the entire data collection period, participants had access to telephone support for any technical questions.

Respondents were asked to complete the questionnaire separately for each waterbody under their management. Following data verification, incomplete, erroneous, and duplicate questionnaires were excluded. The final database includes information on 316 waterbodies, managed by 278 fishing organizations. The geographical distribution of the surveyed waterbodies is illustrated in Figure 1.

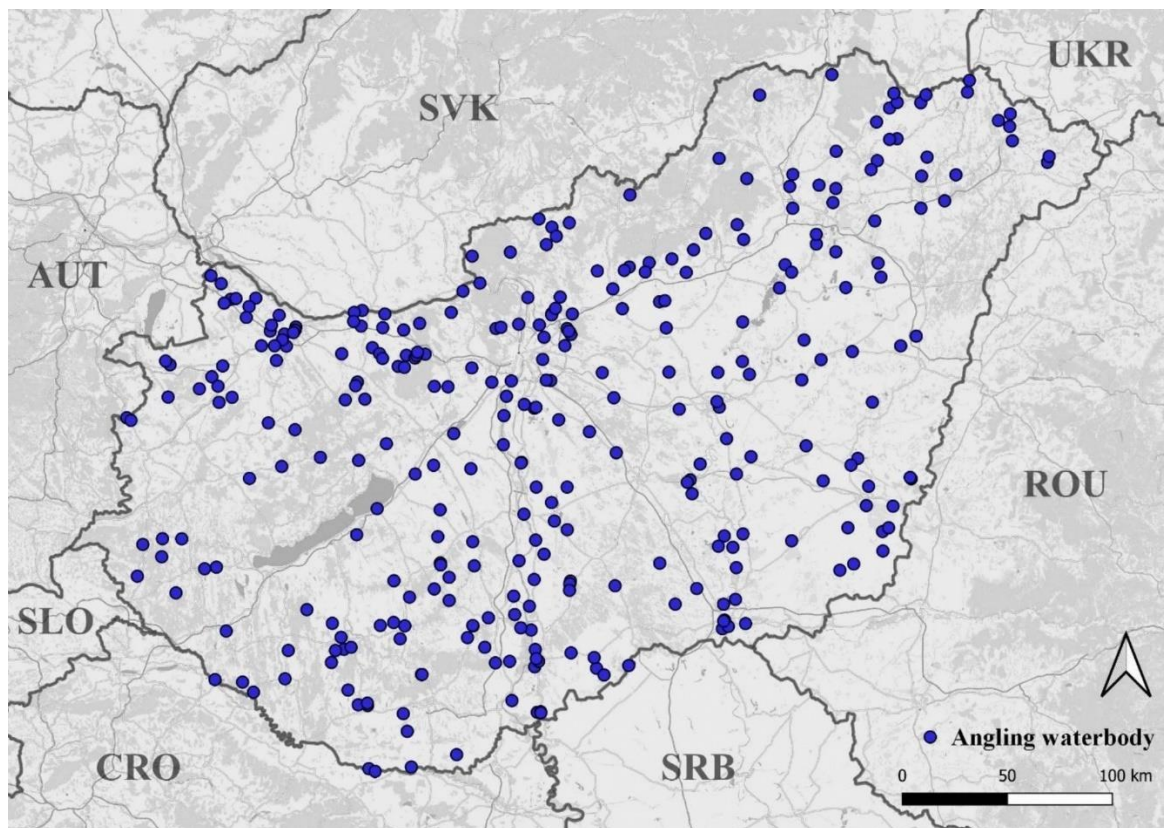


Figure 1: Location of angling waterbodies included in the analyses.

2.2. Data analysis

For the statistical analysis of the data, textual responses were first coded and quantified. Dichotomous (yes–no) answers were converted into binary (1–0) variables. For multiple-choice questions (e.g., duration of low water levels, frequency of water quality assessments), groups were quantified by taking the average of the two extreme values of each interval before including them in the analysis. By recording all fish species present in each waterbody, continuous numerical data were obtained.

Simple descriptive statistical methods (percentages, mean, minimum, maximum, standard deviation) were applied to provide a general overview of the recreational fishing organizations. These analyses covered organizational data, the number of fishing permits sold, as well as the number and size of the managed waterbodies.

For the yes/no variables, one-sample, non-parametric Z-tests were used to test if the ratio of answers differs from 50%.

The relationship between the size of the waterbodies and the perceived impact of the great cormorant on fisheries was assessed using Fisher's exact test, evaluated through a contingency table. This test is robust to both sample size and distribution. In this case, the null hypothesis (H_0) assumes that the size of the waterbody and the perceived severity of the great cormorant's impact are independent of each other.

Correspondence Analysis (CA) was used to reveal the connection pattern between the highest qualification of an AC's leader (chairperson) and the categorized potential threats (i. e. habitat degradation, urbanization, negative impact of agricultural and water engineering activities on naturally reproducing fish populations, biodiversity loss, water scarcity) to waterbodies and fishery management.

To explore differences between waterbody types for continuous or ordinal variables, the Kruskal-Wallis test was applied, as there were more than three independent groups. To determine which waterbody types differed from each other, Dunn's post hoc test was used, allowing for pairwise comparisons across all groups. Analyses were carried out using IBM SPSS v27. 95% confidence levels were used in all cases.

3. RESULTS

After excluding invalid questionnaires (partially filled, duplicated, etc.), the final database contained data from 278 organizations (of the total 1242), responsible for 316 waterbodies, covering 33,662.4 hectares. This represents approximately 25% of the total area of waterbodies used by anglers in Hungary.

3.1. General characteristics of angling waters in Hungary

86% of angling waterbodies are small (less than 50 hectares). 69% of surveyed angling waterbodies are of artificial origin (e.g. gravel pits, reservoirs, canals), which highlights the role of small artificial waterbodies in society (Fig. 2a and b).

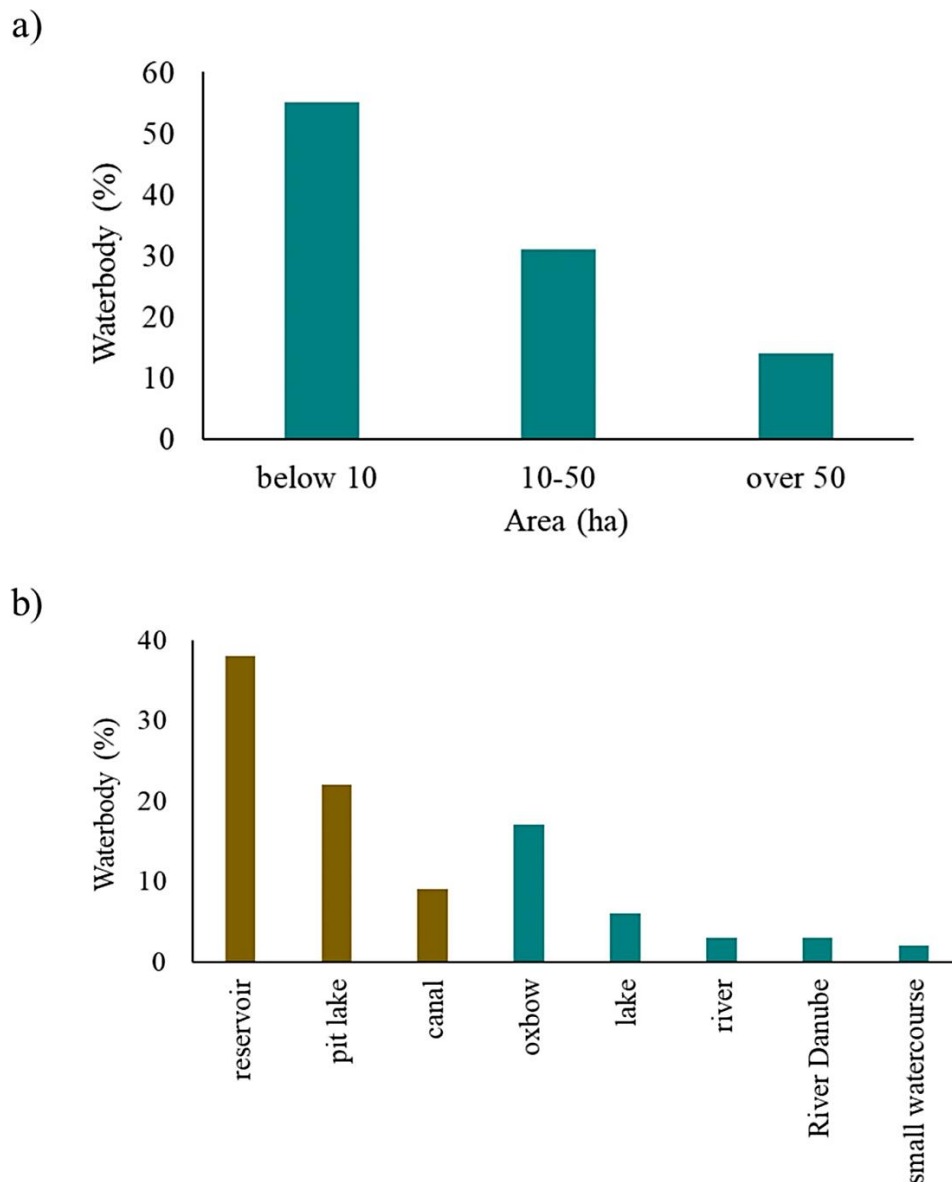


Figure 2: a) Size distribution of surveyed angling waterbodies; b) Waterbody category (Brown for artificial waterbodies and green for natural waters).

3.2. General characteristics of Hungarian Angling Clubs

Base data (i.e. demography, waterbody areas, license sales) of angling clubs was collected in order to characterize their organizations' structure (Table 1). The number of management board members was 5.5 (± 2.6). A typical Hungarian AC had 335 (± 632) adult members according to managers' data, of which almost two-thirds, 199 (± 343), were active (i.e. spent at least one day angling) in 2021. The numbers of youth (adolescent) and child members were 3% and 14% respectively of the total membership. ACs issued approximately two times more periodic (e.g. 24 h; 36 h etc.) licenses than annual. The average AC manages 1.1 waterbodies (± 0.7), and these clubs have been active since 1993 (± 18.8 years). In contrast, recreational fishing associations in Germany typically have 50–60 years of management experience.

Table 1: Descriptive characteristics of Hungarian angling clubs: basic data (demography, licenses).

Variable	N (respondents)	Min	Max	Mean	\pm SD
Management board members	278	0	19	5,5	2,6
Members (adults)	278	0	5389	337,1	664,2
Adolescent members (14-18years)	278	0	500	11,3	34,2
Child members (below 14years)	278	0	5412	75	347,6
Active members (2021)	278	0	9460	240,7	678,9
Number of managed waterbodies	278	1	8	1,1	0,7
Year of foundation	316	1929	2022	1993	18,8
Number of licenses (annual)	316	0	14074	383	1359,8
Number of licenses (24–168 h)	316	0	27387	843,2	2479
Number of extra tickets (i.e. overnight)	316	0	1000	17,8	77,1

3.3. Fish fauna monitoring and assemblage composition

The proportion of waterbodies where fish assemblage composition surveys and fish diet analyses are regularly (i. e. within three years) carried out by external experts was 10% and 13% respectively, which is significantly lower ($Z = -14.06$; $p < 0.01$; $Z = -13.05$; $p < 0.01$) than 50% in both cases. Fish parasitological surveys (15%) and sediment thickness surveys (23%) are also scarce ($Z = -12.49$; $p < 0.01$; $Z = -9.45$; $p < 0.01$) (Fig. 3a). Although water quality is crucial for management, the majority of ACs carries out water physical and chemical parameter measurements only annually (33%) or even more rarely (38%) (Fig. 3b).

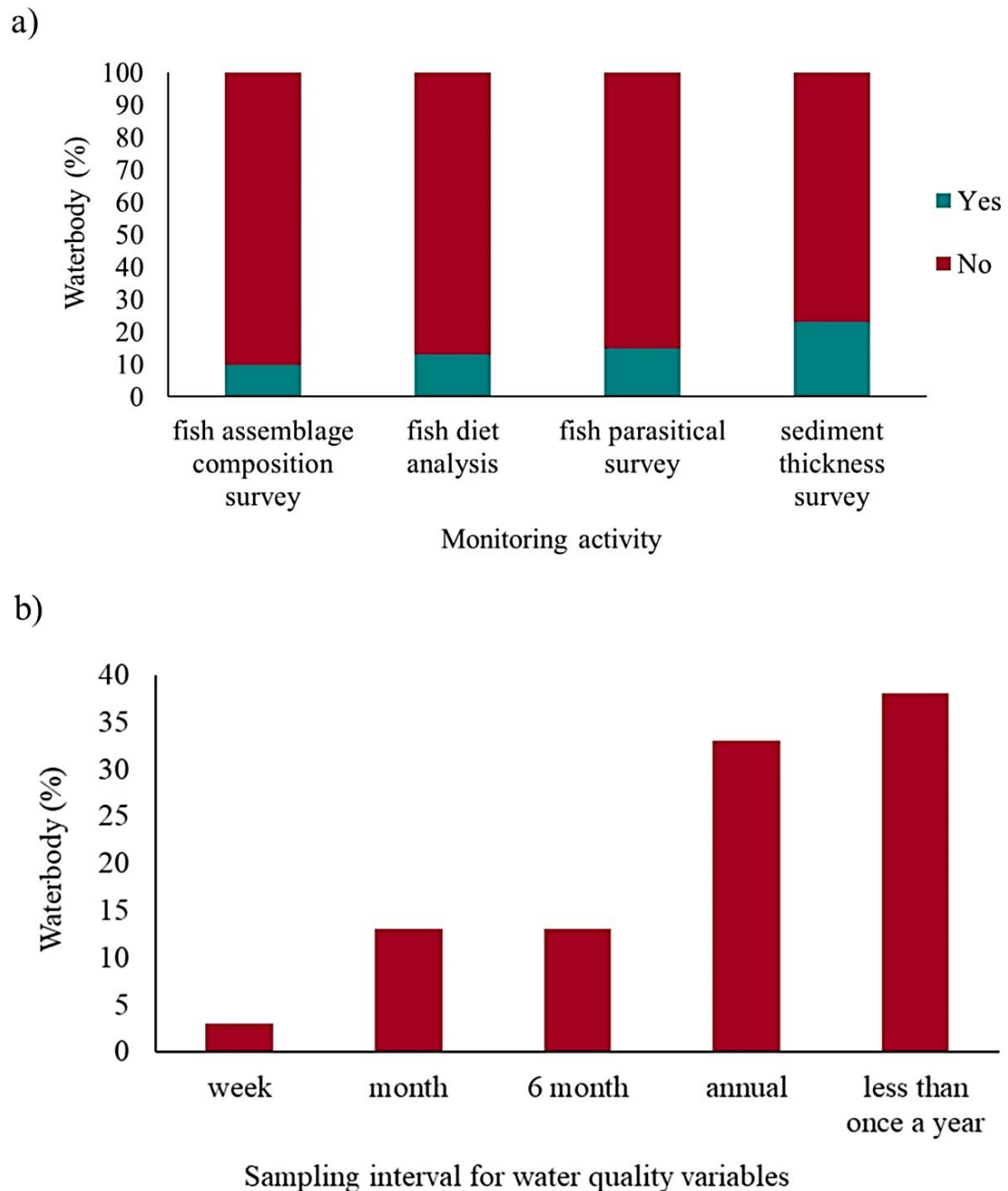
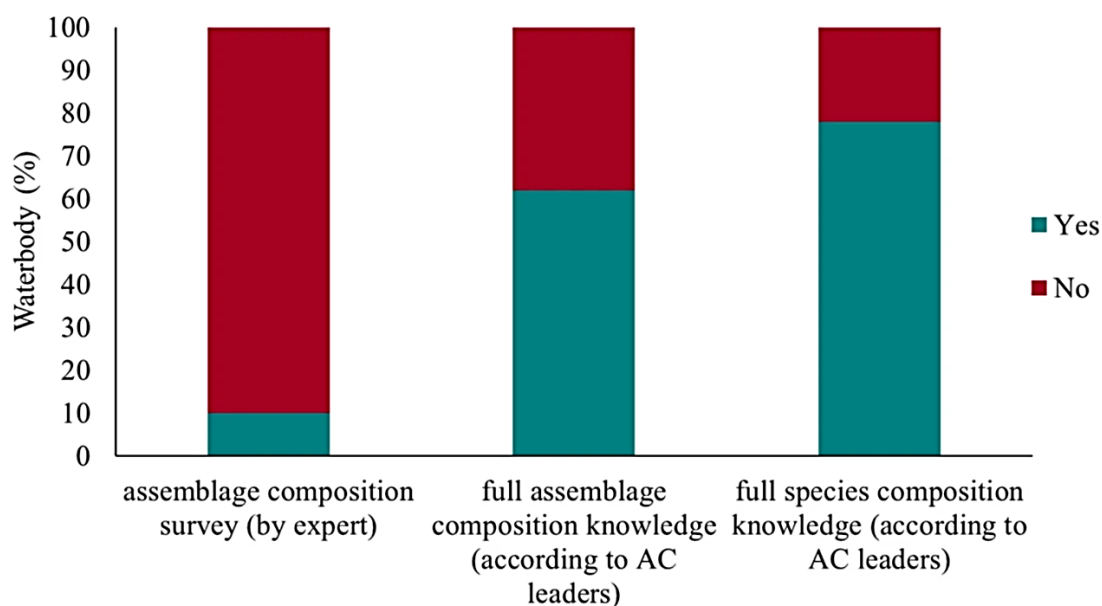


Figure 3: a) Regular (within three years) monitoring activities on the surveyed waterbodies; b) Regularity of sampling for water quality variables in the last 5 years; (N=316).

Contrary to the low abundance of fish assemblage composition surveys, most of the ACs answered that the fish species composition ($Z = 10.13$; $p < 0.01$) and the stock composition ($Z = 4.27$; $p < 0.01$) of their managed waterbody is known (Fig. 4). In most cases, managers in international practice also rely on data from catch logs. However, these data provide only a partial picture of the fish populations in the waters, as they do not account for species misidentification, inaccurate reporting of size and weight, fishing selectivity, or illegal fish removal.



Knowledge on fish species and stock composition

Figure 4: Knowledge on fish species and stock composition, according to ACs answers (N=316).

Among the fish species reported by the ACs in average 2.2 ± 3 had conservation value (i.e. listed as ‘protected’ or ‘not catchable’ in the 133/2013 decree of the Rural Development Ministry) at the surveyed 316 sites. crucian carp (*Carassius carassius* L., 1758), bitterling (*Rhodeus amarus* BLOCH, 1782) and weatherfish (*Misgurnus fossilis* L., 1758) proved to be the most frequent with (57%. 26%. 16% frequency of occurrence, respectively; Fig. 5). Misidentification of individual fish species is a common phenomenon, influencing the conservation of threatened species and the effectiveness of fisheries management measures. Populations of the crucian carp are declining across Europe, and the situation is no different in Hungary. Data provided by recreational fishing organizations show substantial discrepancies compared to national and international research findings. This divergence can be explained by the spread of the gibel carp (*Carassius gibelio* BLOCH, 1782) across the country, which closely resembles the crucian carp in appearance and also hybridizes with it, significantly increasing the risk of misidentification.

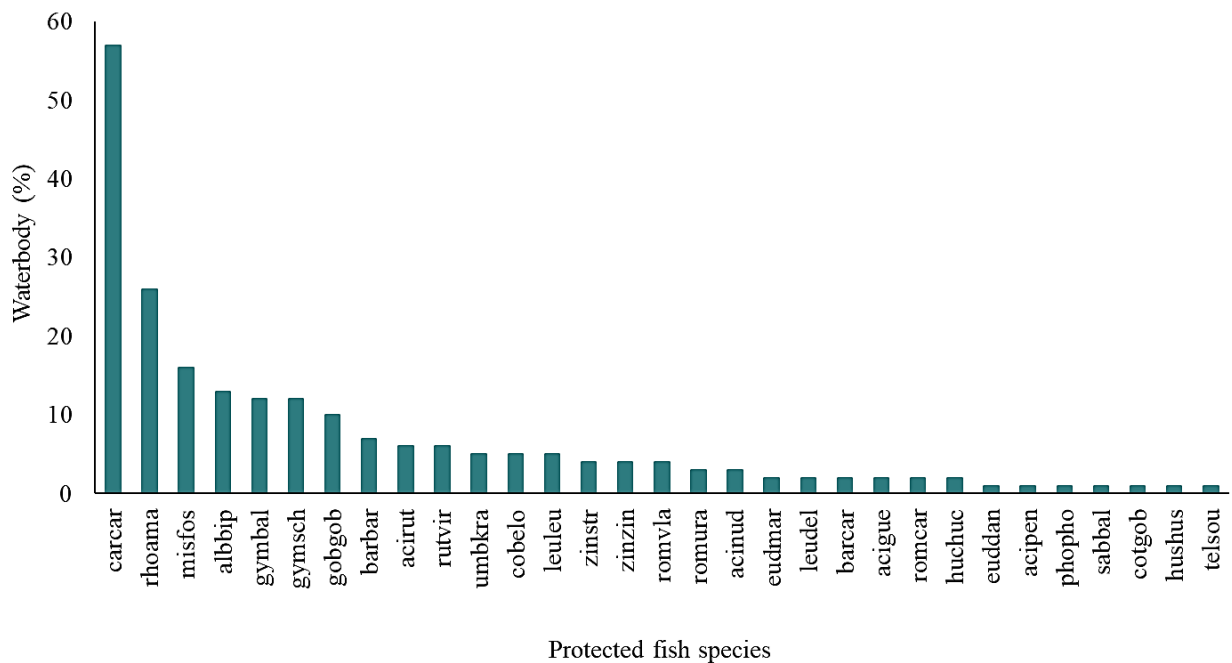


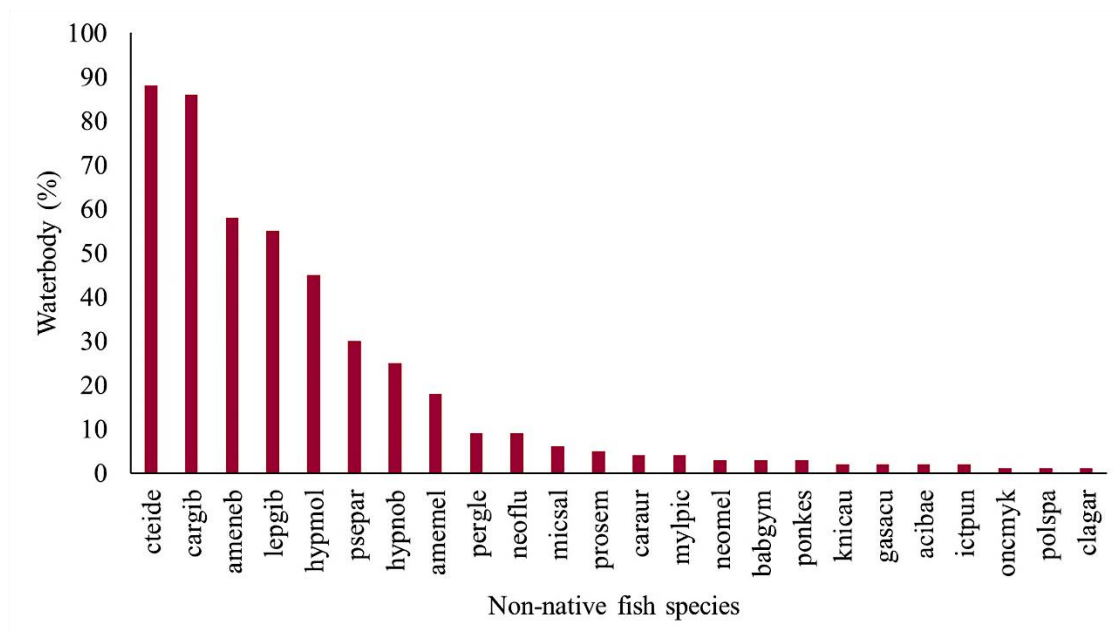
Figure 5: Protected fish species in surveyed angling waterbodies (N = 316). The abbreviations of fish names in the figure are derived from the first three letters of the species' scientific name. e.g. cypcar refers to *Cyprinus carpio*, amesp. refers to *Ameiurus sp.*

The reported number of non-indigenous species was 4.6 ± 3 , with grass carp, gibel carp and brown bullhead (*Ameiurus nebulosus* LESUEUR, 1819) showing the highest frequencies of occurrence (88, 86 and 58%, respectively; Fig. 6a). The perception/judgement of non-indigenous species were also surveyed. In this regard bullhead species (brown bullhead and black bullhead (*Ameiurus melas* RAFINESQUE, 1820) proved to be the most problematic species (74%). Based on available national fish population survey data, the black bullhead has almost completely displaced the brown bullhead (*Ameiurus nebulosus*) from Hungarian waters. The black bullhead is often confused with the brown bullhead in other European countries as well, and it is likely the same in Hungary, meaning that a significant portion of bullheads present in recreational fishing waters may belong to the black bullhead species. It should also be noted that, regardless of precise species identity, these fish represent a management concern for water managers.

Asian carps (Silver and Bighead carp; *Hypophthalmichthys molitrix* VALENCIENNES, 1844) and *Hypophthalmichthys nobilis* RICHARDSON, 1845) were also highlighted as challenging from a management point of view. Species of the genus *Hypophthalmichthys* are generally considered undesirable by anglers due to their poor catchability and flesh quality, moreover they are difficult to sample with standard survey methods. Nevertheless, they are present in all medium and large Hungarian rivers, as well as in certain canals and lakes. Although the gibel carp is the most common species in nationwide surveys, fishing managers report it as problematic in only about 17% of waters, likely because it is a popular target species.

In 6% of the surveyed waterbodies, no non-native fish species were reported as problematic by water managers (Fig. 6b).

a)



b)

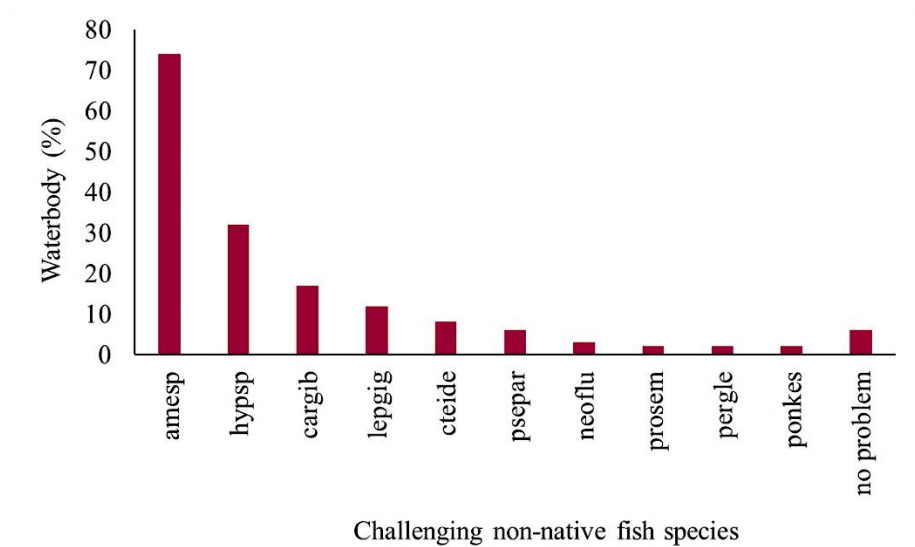


Figure 6: a) The non-native fish species in surveyed angling waterbodies (n = 316). b) The most challenging non-native fish species for managers to deal with (n = 296). The abbreviations of fish names in the figure are derived from the first three letters of the species' scientific name. e.g. cypcar refers to *Cyprinus carpio*, amesp. refers to *Ameiurus sp.*

Over the past five years, selective removal of non-native fish was conducted in 28% of surveyed waters ($Z = -7.9$; $p < 0.01$). In these waters ($n = 83$), the measures primarily targeted bullhead species, which were the focus in 89% of cases. The second most common target taxa were Asian carps, which were subject to selective removal in 18% of the waters where such measures were applied, as illustrated in Fig. 7. The focused management of bullheads and Asian

carps reflects their generally negative perception among anglers across Europe. Bullhead removal was carried out using trap nets in 72% of the treated waters. Examining the effectiveness of these removals, no significant differences were found between the waters ($Z = -0.22$; $p = 0.83$), with interventions reported to have resolved the problem in 49% of the waters. Traps can effectively remove bullheads and other non-native fish, but success depends on size selectivity, number of attempts, and sustained effort over time.

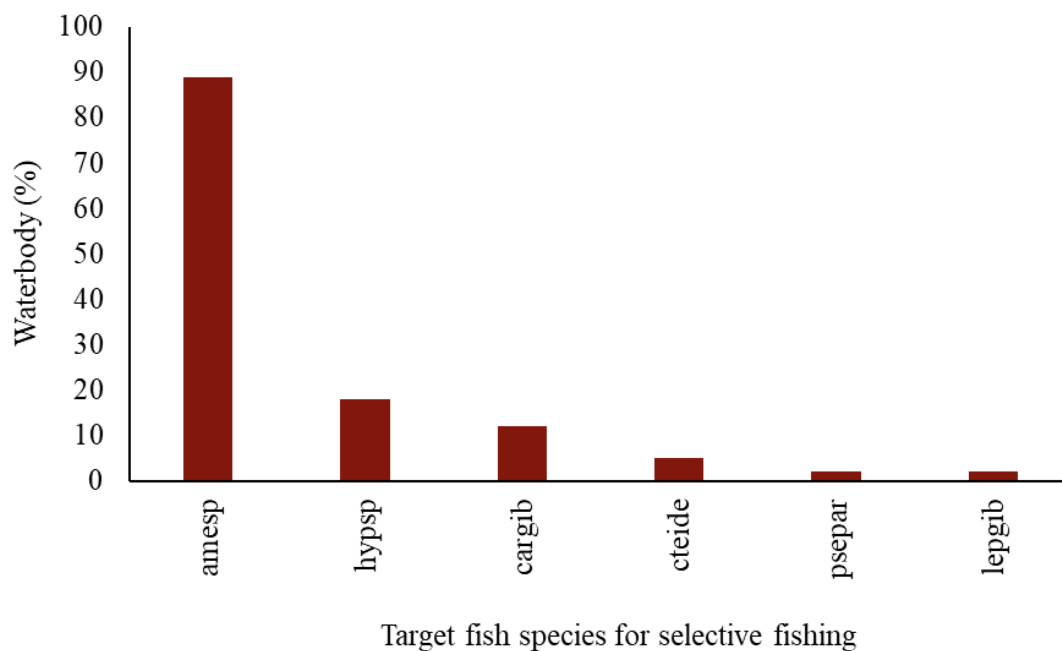


Figure 7: Distribution of target species for selective fishing in the surveyed waters (n = 83) The abbreviations of fish names in the figure are derived from the first three letters of the species' scientific name. e.g. cypcar refers to *Cyprinus carpio*, amesp. refers to *Ameiurus sp.*

Translocation and spread of non-indigenous species are potentially boosted by the practice of using living fish for baiting purposes in most of the waterbodies (94%; $Z = 15.64$; $p < 0.01$). Anglers' compliance is crucial for limiting the spread of non-native fish. In Hungary, live non-native fish can be used as bait, but only at the site where they were caught. Another major source of non-native fish spread is escape from fishponds. According to water managers, 60% of the surveyed fishing waters ($Z = -3.60$; $p < 0.01$) have no direct, fish-passable connection to natural waters.

3.4. Management practices for fish stock maintenance and prevention of overexploitation

Most common fisheries management measures to protect fish populations: stocking (95%), stricter minimum size and bag limits (82%), and reduced annual catch quotas (87%) (Table 2). Stocking is the most common method for maintaining fish populations in Hungary and many

European countries. Practices are driven mainly by economic and social factors, with ecological considerations playing a lesser role. Minimum size and bag limits are mandatory, but organizations may voluntarily apply stricter rules.

Table 2: Fish stock maintenance and prevention of overexploitation practices in Hungarian waters (N=316).
*Significant: $p < 0.05$.

Management activity	Proportion of „yes” answer	Z-value	P-value
Fish stocking 2020	95 %	15,86	<0,01*
Fish stocking 2021	95 %	15,98	<0,01*
Size limit/bag limit (fish to take)	82%	11,36	<0,01*
Annual quota (fish to take)	87%	13,28	<0,01*
Areas for sawning or nursing, restricted from anglers	53%	1,01	0,31
Limited number of anngling sites	20%	-10,58	<0,01*
C&R regulation	43%	-2.59	0,01
C&R fish mortality	8%	-14.85	<0,01*

Implementation of further, obligatory ‘catch and release’ (C&R) regulations (i.e. carp cradle, antibacterial spray and other fish friendly tackles and methods) were found to be infrequent management tools, however no increased mortality (8%) was associated with the lack of these practices. Application of restrictions regarding the number of licenses or available angling sites is not characteristic among the studied ACs.

In the surveyed waters, an average of only 2.3 (± 1.3) and 2.2 (± 1.4) fish species were stocked in 2020 and 2021, respectively. The most important stocked fish species was common carp, as ACs stocked this species in more than 90% of the waterbodies. Pikeperch (*Sander lucioperca* L., 1758), pike (*Esox lucius* L., 1758) and breams (*Abramis* spp., *Blicca bjoerkna* L., 1758) were also frequently stocked. Stock management is still heavily dominated by natural recruitment i.e. local spawning for numerous taxa (e.g. tench, European catfish, asp) (Fig. 8).

Fish stocking composition is strongly affected also by the availability of certain fish taxa. More than one third (37%) of ACs expressed their intent to diversify their stocking composition with breams. 13–25% of them planned to stock tench (*Tinca tinca* L., 1758), crucian carp, european perch (*Perca fluviatilis* L., 1758) or pike as well, however the stocking material was unavailable on the market. In Hungary, fish production facilities still primarily focus on common carp, while the quantities of predatory species (pikeperch, pike, catfish) and breams remain limited.

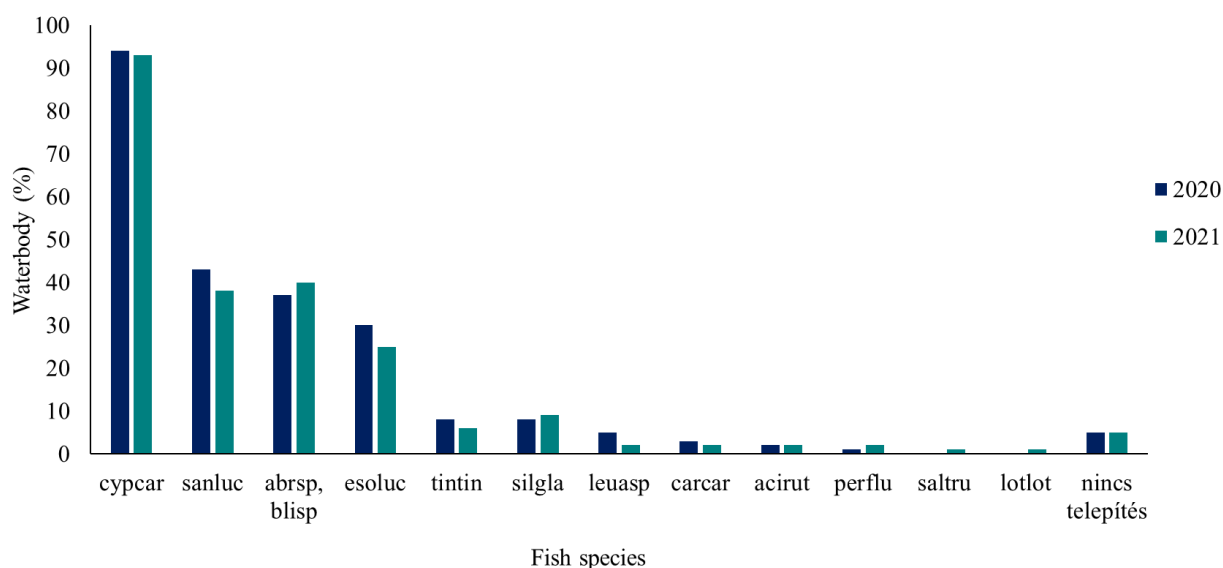


Figure 8: Frequency of stocking of different fish species in 2020 and 2021. The abbreviations of fish names in the figure are derived from the first three letters of the species' scientific name, e.g. cypcar refers to *Cyprinus carpio*. abrsp. refers to *Abramis sp.*

According to ACs, the importance of stocking is crucial for the maintenance of fish fauna of angling waterbodies. Stocked common carp characteristically belong to the 2+ and 3+ age categories and are of directly catchable size (30+ cm; Table 3).

Table 3: Age composition of stocked common carps.

	common carp	
	n=297	n=294
	2020	2021
fry	2%	1%
pre-reared (1-2 cm)	5%	4%
1+ (6-15cm)	7%	7%
2+ (18-30cm)	41%	43%
3+ (30+ cm)	92%	93%

Predatory (piscivore) species, like asp (*Leuciscus aspius* L., 1758), pikeperch, european catfish (*Silurus glanis* L., 1758) and pike are also popular target species for anglers, therefore their stocking occurs in numerous cases (Table 4). The age composition of stocked piscivores showed different patterns from common carp and a higher prevalence of younger specimens.

Table 4: Age composition of stocked fish species.

	asp		pikeperch		catfish		pike	
	n=15	n=7	n=135	n=121	n=24	n=29	n=96	n=80
	2020	2021	2020	2021	2020	2021	2020	2021
fry	33%	14%	13%	14%	0%	7%	10%	9%
pre-reared (1-2 cm)	53%	57%	41%	31%	17%	17%	39%	40%
1+ (6-15cm)	13%	0%	13%	19%	25%	14%	10%	10%
2+ (18-30cm)	0%	14%	30%	34%	42%	31%	35%	34%
3+ (30+ cm)	7%	14%	20%	19%	38%	55%	20%	31%

Most fish stockings are intended for recreational purposes, targeting popular species and large individuals, while supporting natural populations is secondary. Non-native species are sometimes introduced despite legal prohibitions. Poorly executed stocking can quickly degrade water quality. Overstocking of carp or other large benthic omnivorous fish can cause significant bioturbation, further worsening water quality.

In the surveyed waters, stricter catch limits than the national regulations were applied to an average of 2.7 (± 2.2) fish species. Significant differences were observed among waterbody types in the number of species subject to extended restrictions (Kruskal-Wallis $H = 19.91$; $p < 0.01$). Fish species in canals are less protected than those in gravel pits ($p = 0.01$) and reservoirs ($p < 0.01$). On average, stricter catch limits were applied to 3.1 (± 2.3) species in reservoirs and 2.7 (± 2.1) species in gravel pits, compared to only 1.3 (± 1.9) species in canals (Fig. 9). Canals can host diverse and conservation-important fish species, which are protected mainly by environmental regulations rather than fisheries rules. They also provide habitat for angler-targeted species (e.g., pike, barbel, asp, bream, perch, tench, crucian carp). Since fishing is common in these waters, additional protective measures during the spawning season—such as sanctuary areas or extended closed seasons—should be considered.

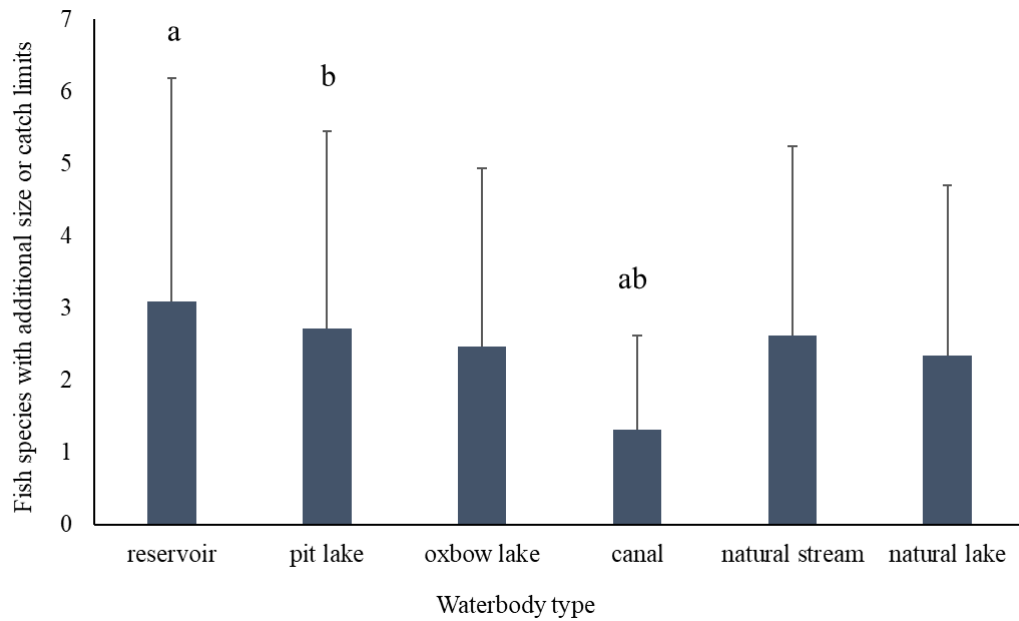


Figure 9: Average number of fish species per waterbody type with stricter size and/or bag limits than prescribed by legislation (N = 255). Waterbody types labeled “ab” differ significantly from those labeled “a” and “b” ($p < 0.05$).

Our results show that extended restrictions are primarily applied to the most popular angling species, while national regulations are considered sufficient for other species. For common carp, the most important species for Hungarian anglers, stricter local regulations are applied in 87% of waters. Bag limits were tightened for pikeperch (56%), pike (50%), and grass carp (45%) in half of the waters (Fig. 10). Grass carp (*Ctenopharyngodon idella*), a non-native species, is legally catchable without size or closed-season restrictions, yet many fishing organizations impose local size limits. Its popularity among sport and culinary anglers, and its consumption of higher aquatic vegetation, drives these regulations. However, grass carp activity poses ecological risks, as it can reduce dense vegetation that serves as secondary habitat for native and protected species (e.g., weatherfish (*Misgurnus fossilis*), european mudminnow (*Umbra krameri*), sunbleak (*Leucaspius delineatus*)) altering habitat structure.

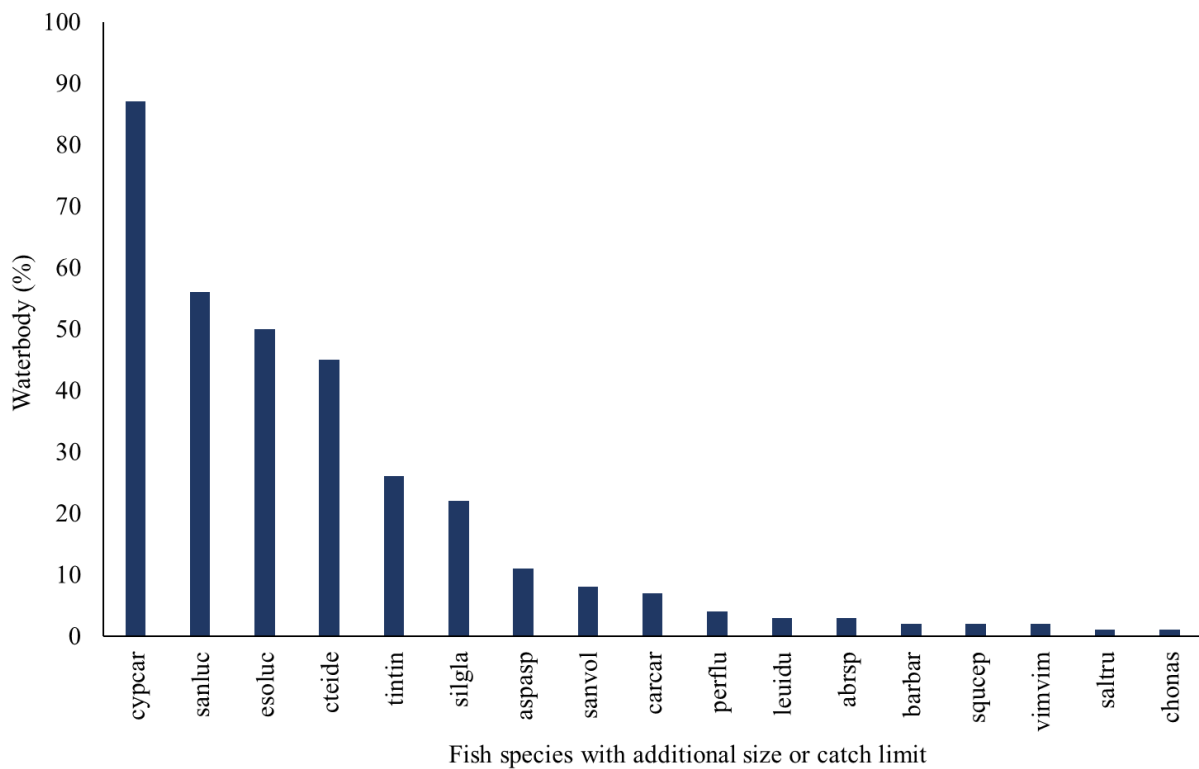


Figure 10: Fish species subject to stricter regulations than national rules (N=255). The abbreviations of fish names in the figure are derived from the first three letters of the species' scientific name, e.g. cypcar refers to *Cyprinus carpio*. abrsp. refers to *Abramis sp.*

On the surveyed waters, an average of 23% (± 24.2) of caught fish were released by anglers, including all captured individuals, even those not subject to size or bag limits. The C&R is widely practiced worldwide to prevent overexploitation of fish stocks. Available data from Poland indicate that anglers value releasing legally caught fish, emphasizing the recreational aspect of fishing. Significant differences exist among waterbody types in the proportion of anglers practicing C&R (Kruskal-Wallis $H = 21.33$; $p < 0.01$). Significantly fewer anglers practice C&R in canals than in reservoirs ($p < 0.01$) and gravel pits ($p < 0.01$). The average proportion of C&R anglers is 9.7% (± 10.2) in canals, 24.7% (± 19.7) in reservoirs, and 29.5% (± 29.6) in gravel pits (Fig. 11). The lower proportion of C&R anglers in canals is likely due to different fishing motivations, as fishing in these waters is driven more by food provision than by sport or recreational purposes.

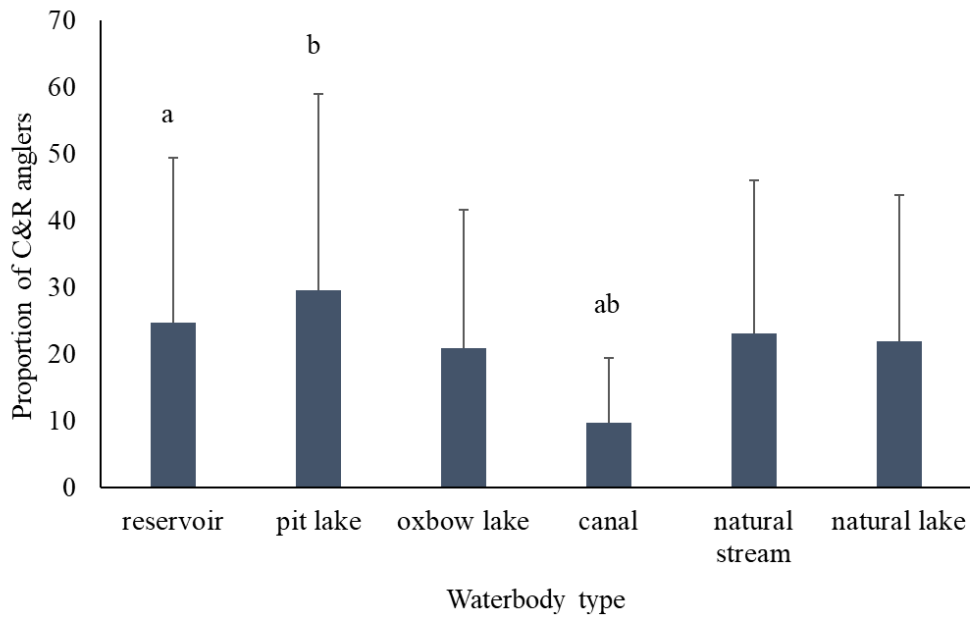


Figure 11: Average proportion of anglers practicing C&R by waterbody type (N = 313). Waterbody types labeled “ab” differ significantly from those labeled “a” and “b” ($p < 0.05$).

Fisheries organization leaders believe that there are sufficient spawning sites (68%; $p < 0.01$) and adequate natural recruitment (72%; $p < 0.01$) for target species in their waters. Nevertheless, water managers would implement artificial spawning habitats in 82% of the waters ($p < 0.01$) to support natural reproduction and enhance stock sustainability.

Statistically significant differences exist among waterbody types regarding the designation of sanctuary areas. While such areas are commonly established at least during spawning in sections of the Danube (88%; $p < 0.05$) and reservoirs (66%; $p < 0.01$), oxbow lakes with natural characteristics rarely have angler-excluded areas even during spawning (38%; $p < 0.05$). This is particularly concerning, as oxbow lakes are crucial for maintaining fish biodiversity, providing spawning and refuge habitats as well as food resources for numerous species.

On most waters, natural reproduction provided fry for breams: common bream (69%), white bream (40%), and roach (59%). Although bleak and rudd are abundant in managed waters, their natural recruitment was considered adequate in only 2% and 3% of waters, respectively. Misidentification of fry—a common issue among anglers worldwide—may partly explain these low values. According to water managers, most surveyed waters provide suitable habitat for spawning and juvenile survival of predatory fish —catfish (63%), pikeperch (60%), pike (59%) —as well as common carp (58%). Suitable spawning and habitat are limited for crucian carp (14%), burbot (3%), and sterlet (2%). Crucian carp now persists in only a few isolated Hungarian waters, sterlet populations are declining across their range, and rising summer temperatures increasingly limit burbot habitats (Fig 12).

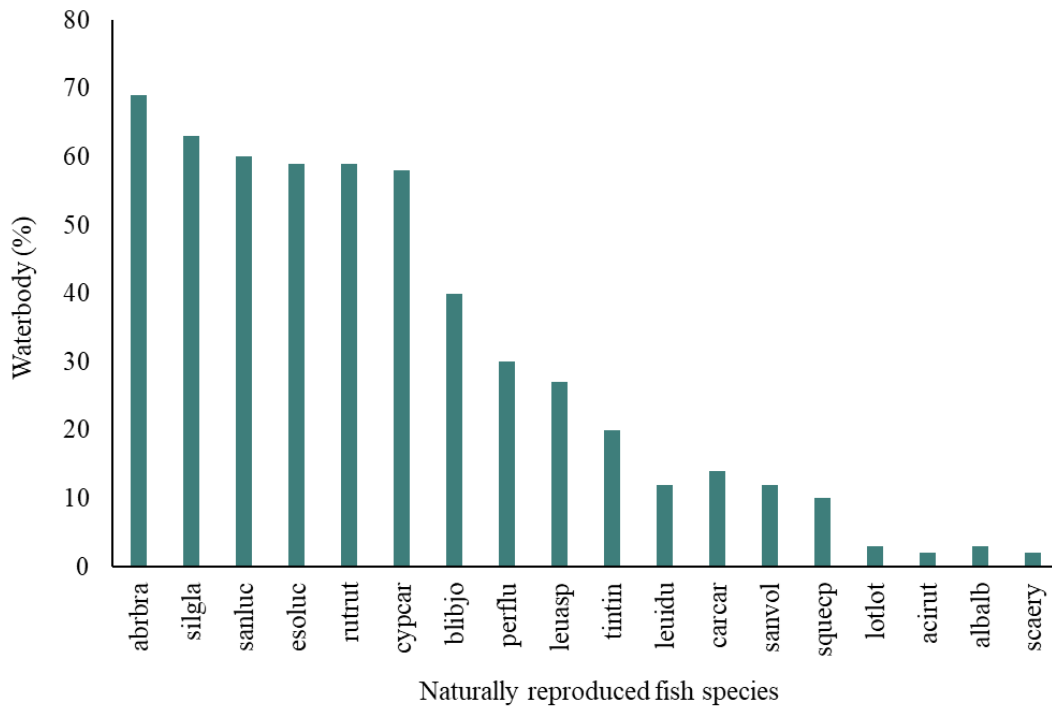


Figure 12: Proportion of fish species producing natural reproduction and viable fry in the surveyed waters. (n=223). The abbreviations of fish names in the figure are derived from the first three letters of the species' scientific name, e.g. cypcar refers to *Cyprinus carpio*. abrsp. refers to *Abramis sp.*

Differences exist among water types in the number of self-sustaining (non-stocked) fish species (Kruskal-Wallis $H = 21.6$; $p < 0.01$). According to fisheries managers, most self-sustaining fish species occur in natural rivers (6.6 ± 5.7) and oxbow lakes (5.2 ± 3.9). However, these values are lower than reported in the literature, suggesting that the number of species in these water types is higher than managers assume or are aware of.

The number of self-sustaining fish species in gravel pits (2.7 ± 2.9) is significantly lower than in oxbow lakes (5.2 ± 3.9 ; $p = 0.01$) and natural rivers (6.6 ± 5.7 ; $p = 0.03$). In reservoirs (3.2 ± 3), the number also differs significantly from oxbow lakes (5.2 ± 3.9 ; $p = 0.04$) (Fig. 13). Literature data support that the natural rivers and oxbow lakes have higher self-sustaining fish diversity than artificial waters like gravel pits and reservoirs.

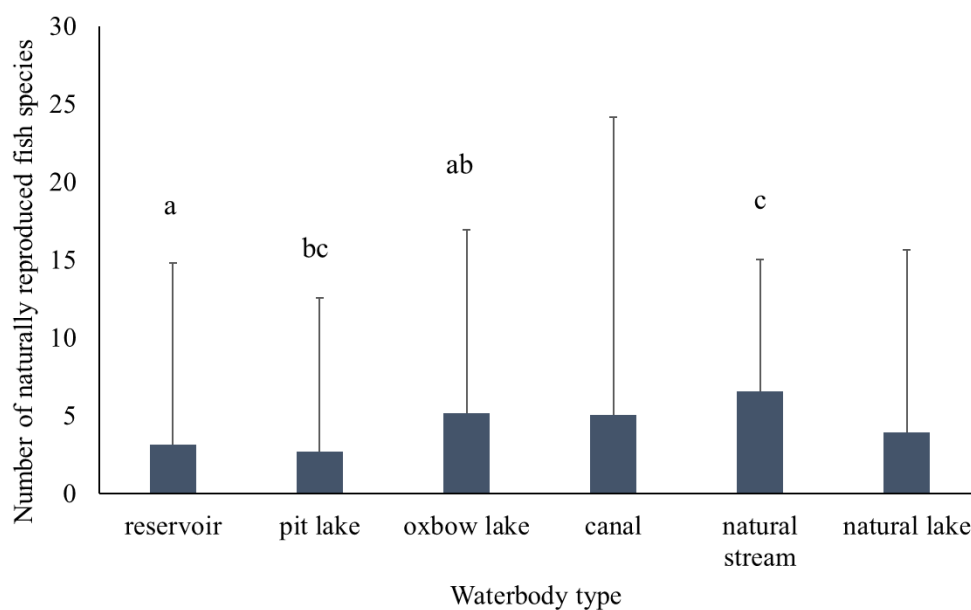


Figure 13: Average number of self-sustaining fish species by waterbody type (n = 223). Waterbody types labeled “a” differ significantly from “ab,” and types labeled “bc” differ significantly from “ab” and “c” (p < 0.05).

3.5. Assessment of Piscivorous Organisms and Illegal Fishing Activities

Fish community composition is influenced not only by angling, stock management, and natural recruitment, but also by the activities of piscivorous animals, which can cause ecological impacts relevant to fisheries management.

Assessing the impact of piscivorous animals on fisheries, Z-tests showed no significant difference between affected and unaffected waters. According to respondents, the European otter poses a challenge in 52% of surveyed waters ($Z = 0.56$; $p = 0.57$), and the great cormorant in 49% ($Z = -0.45$; $p = 0.65$). Both species’ impacts were rated as moderate, with mean scores of 4.8 ± 2.1 for otters and 5.8 ± 2.0 for cormorants on an eight-point Likert scale.

Regarding the European otter, Z-tests indicate that fisheries managers report significantly more problematic sections along the Danube (88%), whereas in gravel pits (33%) otters typically do not pose issues. Research shows otters are permanently present across various water types, including fishponds, oxbow lakes, reservoirs, fens, rivers, and recreational fishing waters. Their occurrence is less affected by human activities (such as fishing or wildlife management) and more strongly influenced by habitat naturalness. Otters are more frequent in areas with dense vegetation than in built-up or intensively used environments. Fish predation by the great cormorant is considered a major problem on sections of the Danube (100%) and in oxbow lakes (77%), but it does not pose an issue for water managers in the surveyed reservoirs. The perceived impact of the great cormorant correlates with waterbody size (Fisher = 75.07; $p < 0.01$). As shown in Fig. 14, predation is negligible in waters smaller than 10 ha, whereas in waters over 80 ha, managers

predominantly report high impact. Studies indicate that cormorant numbers and associated damages are greatest in larger waterbodies.

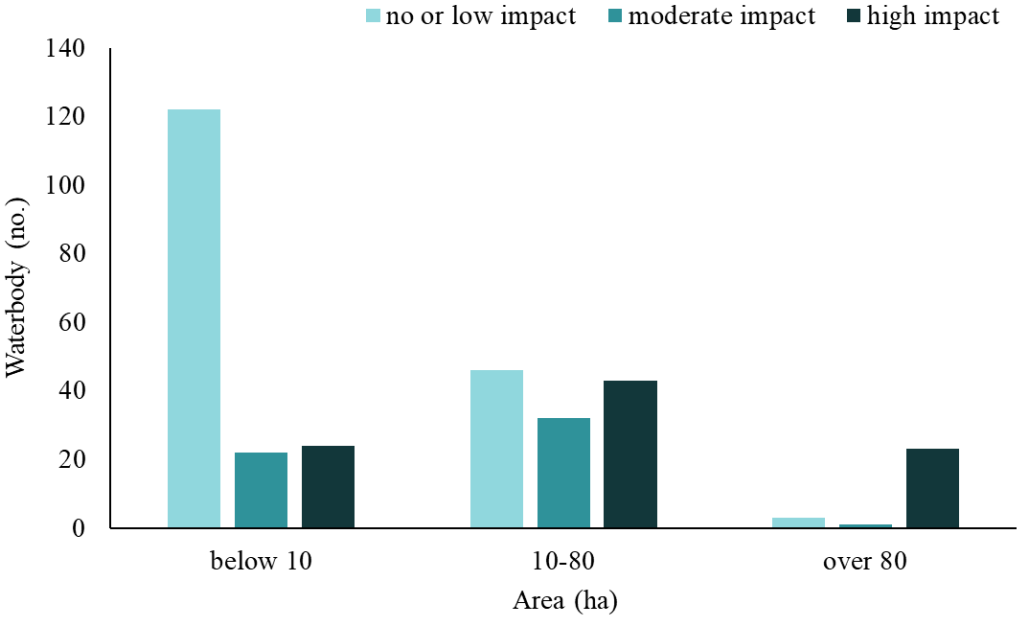


Figure 14: Perceived impact of the great cormorant by waterbody size (n = 316). Perceived impact was assessed using an 8-point Likert scale. The low impact category includes responses indicating no impact (coded as 0) as well as Likert scores 1–2. Moderate impact includes scores of 3–5, and high impact includes scores of 6–8

In recent years, fisheries managers have increasingly focused on fish protection to reduce illegal fishing and fish removal. According to the survey, most waters (69%) experience only occasional issues with illegal fishing. Managers rated the problem at 2.8 ± 1.8 on an 8-point Likert scale, and it is significant in less than 5% of waters. Illegal fishing can impact not only fish stocks but also aquatic habitats, reducing biodiversity and compromising the effectiveness of protected areas.

3.6. Environmental challenges: climate change and water quality

Potential effects of climate change were surveyed via the water level anomalies and water supply opportunities registered by the ACs. A significant (i.e. higher than in a 'usual' year) drop in water level occurred in the last 5 years was registered in (60%) of the cases ($Z = 3.71$; $p < 0.01$), and the duration of the water shortage exceeded 6 months in more than 25% of the cases (Fig.15). The reason for the water shortage was the lack of sufficient summer inflow in 47% of the cases ($Z = -0.90$; $p = 0.37$). Z-tests indicate that fisheries managers reported significant water level decreases in oxbow lakes (66%), canals (76%), Danube sections (88%), and natural lakes (75%). Adequate water replenishment was perceived only in the Danube (88%).

Changing climatic conditions may further exacerbate problems, including reduced water flow and velocity, increased salinity and temperature, higher likelihood of algal blooms, and disrupted oxygen balance.

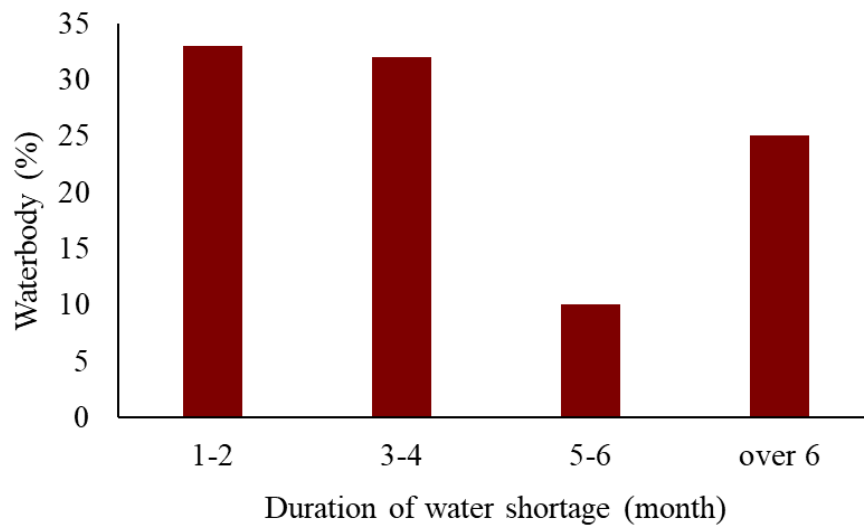


Figure 15: Duration of extreme water level decreases in the surveyed waters (n = 189)

Runoff from arable lands or livestock farms may represent a significant source of nutrient input, as most surveyed waterbodies (78%) are located near intensively cultivated areas ($Z = 10.01$; $p < 0.01$). Treated wastewater discharge was less common (27%) ($Z = -8.21$; $p < 0.01$), with the exception of the Danube, where it occurred in all cases (100%, $Z = 2.83$; $p < 0.01$). The negative effects of fertilizer use on water quality are widely documented in the literature. Municipal wastewater and the discharge of treated effluents also contribute to excess nutrient inputs.

Another negative effect of wastewater discharge is the presence of micropollutants. In the survey, seven water managers (2%; $Z = -16.99$; $p < 0.01$) reported detecting micropollutants in water or sediment, although such monitoring is not yet widespread among fishing organizations. Increasingly, studies report the occurrence and potential ecological risks of pharmaceutical compounds, but only a few case studies examine their actual impact on aquatic life. The presence of these pollutants in fish tissues raises concerns not only for physiological effects but also for potential human health risks through consumption.

Large-scale groundbaiting may also affect water quality; however, it is prohibited in most waters (66%) ($Z = -5.74$; $p < 0.01$). Based on my results, water managers consider limiting the amount of groundbait particularly important in still waters, with affirmative responses by water type as follows: natural lakes 20%, reservoirs 30%, gravel pits 30%, and oxbow lakes 36%. The role of groundbait in nutrient dynamics is debated. Some case studies have identified a noticeable impact, while others reported little or no increase in nitrogen (N) and phosphorus (P) loads.

Algal blooms, common consequences of nutrient loads, have occurred in 47% of the waterbodies, between 2019 and 2021. This value was found to be similar to the proportion of waterbodies that were not affected by algal blooms ($Z = -1.01$; $p = 0.31$). Oxygen deficiency (31%) and fish mass mortality (10%) also affected these waterbodies.

3.7. Management planning and human resources

A significant proportion (96%) of the waterbodies are managed exclusively by a given AC with no collaboration of other stakeholders ($Z = 16.20$; $p < 0.01$). They mainly develop fisheries management plans themselves (61%), without the involvement of external experts. The majority of ACs rely heavily on the practical experience of managers (64%) or use the cumulative catch data (28%) solely. These sources can be misleading, as they lack data on non-target species and do not account for predation, mortality, illegal fishing, or natural reproduction. Only a minority of waterbodies (7%) have data from standardized surveys carried out by experts. A significantly low proportion (36%) of ACs have at least one board member with a professional degree in agriculture or natural sciences ($Z = -3.49$; $p < 0.01$) (Fig 16).

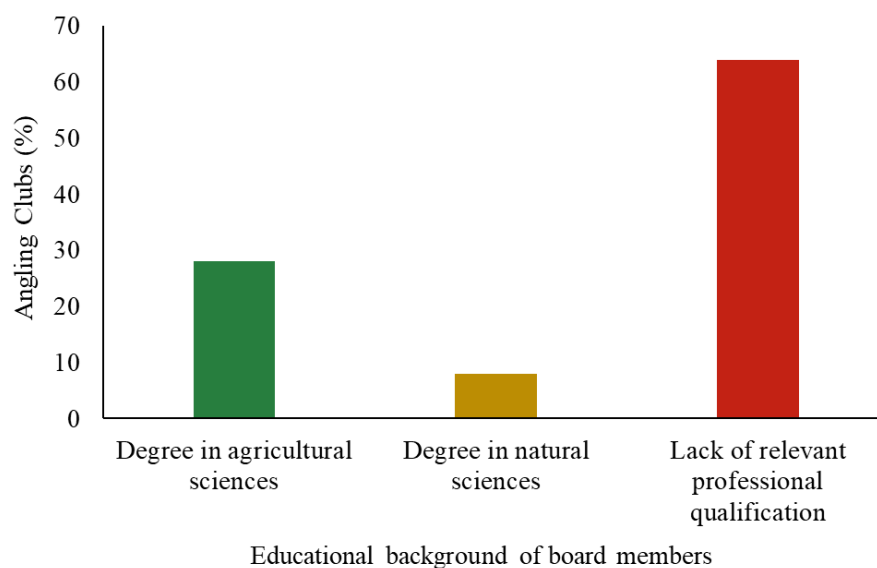


Figure 16: Educational background of the board members of angling organizations (N = 316)

Correspondence Analysis suggests a connection between the kind of threat to fish stocks and specialization of an AC chairman's degree. Water shortage and biodiversity loss were associated with the presence of natural science degrees (e.g. MSc. in biology, geography etc.). While AC leaders without at least graduation (e.g. skilled workers) do not realize any risk regarding the fish stocks of the managed waterbodies. Highly qualified non-experts (lawyers, economist etc.) highlighted only the decline of fish stocks as a potential risk (Fig. 17). The Hungarian system is analogous to the German; however, the latter mandates a concise vocational training program in

the field of fisheries. A more knowledge-based system is functioning in the Czech Republic, where the selection process for fisheries managers is primarily overseen by the leadership of the Fisheries Union, with emphasis placed on the candidate’s educational background, skills and practical experience with fisheries.

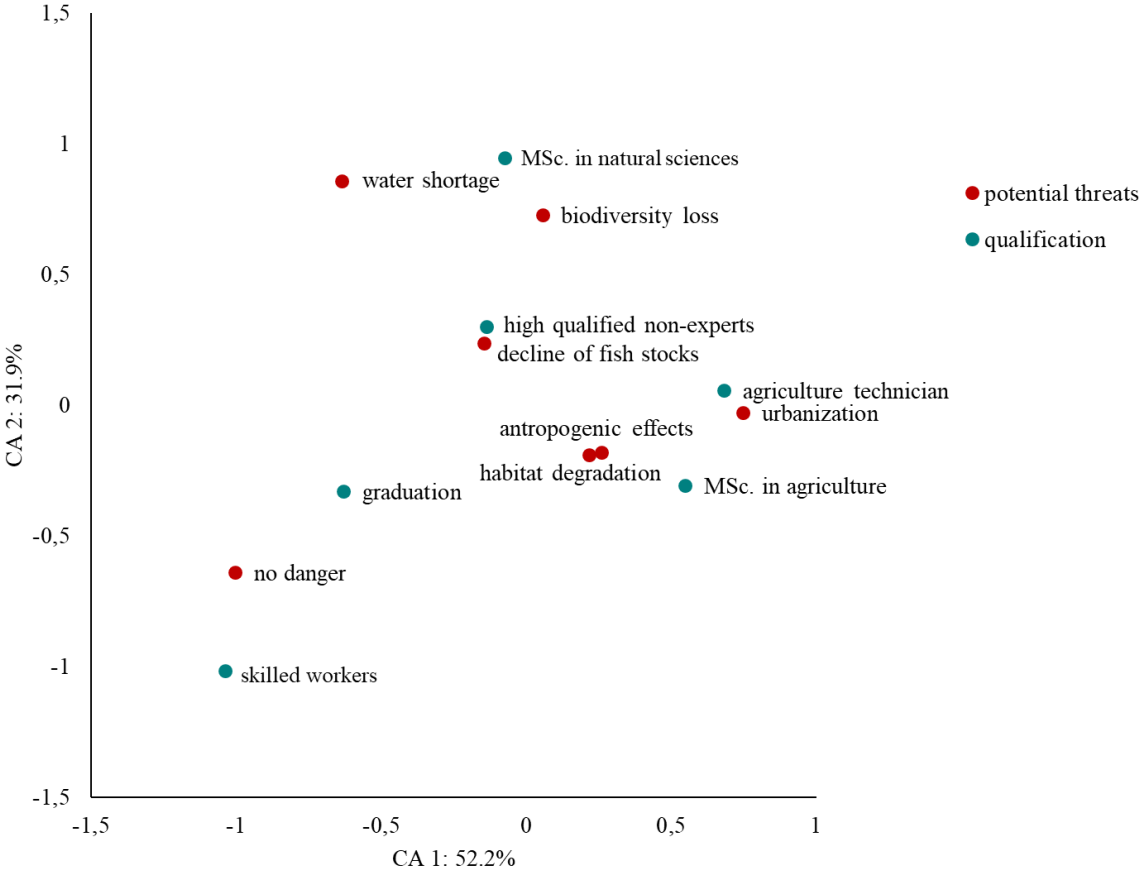


Figure 17: Correspondence analysis of board members’ education and knowledge of potential threats to fish stocks (n=316)

4. CONCLUSIONS AND RECOMMENDATIONS

Over the past decade, Hungary's recreational fishing regulations and culture have primarily evolved at the organizational level. However, recreational fisheries management continues to face significant challenges that require expert-guided interventions. Decisions are often driven by anglers' preferences, which hinders the implementation of sustainable, ecologically based practices—a phenomenon observed not only in Hungary but also elsewhere in Europe.

In small, artificial waterbodies, water managers play a key role in maintaining ecological status, and decisions should be based on scientific evidence. However, the lack of comprehensive and up-to-date data limits effective fisheries management across Europe, including Hungary. Another challenge is the shortage of managers with relevant professional qualifications in many angling associations, who would understand the diversity of fisheries management tools and use resources optimally.

Fisheries management often prioritizes measures that promise quick and visible results, such as daily catch quotas or size and bag limits. While these can be effective in the short term, their long-term sustainability is limited by anglers' behavior and compliance. Stocking remains one of the most commonly used tools; however, costly stockings usually target popular species and often overlook ecological improvement objectives. Stocking effectiveness can be enhanced through clear goals, knowledge of reference natural fish communities, long-term monitoring, and diversification of stocked species. This requires the development of breeding techniques for certain species like sichel, ide, chub, vimba bream, common nase.

Water quality is influenced by catchment characteristics, fisheries management practices, and angling methods, as well as the increasing impacts of climate change—prolonged droughts, heat waves, and flash floods—which are particularly concerning. These events may increase the occurrence of emergency situations, such as oxygen depletion and fish kills, highlighting the need for data-driven monitoring and regular water quality assessments to support sustainable fisheries management.

Protected piscivorous species—such as great cormorants and otters—can exert significant local predation pressure, causing both economic and ecological problems. The occurrence of cormorants is closely linked to climate change, as mild winters increase the vulnerability of fish shoals to predation. These findings highlight the importance of conflict management and adaptive strategies in fisheries management.

Currently, an unified ecological assessment system for recreational fisheries is lacking. Such a system would allow comprehensive evaluation of water quality, habitat condition, and biodiversity, providing a basis for sustainable fisheries management decisions. Overall, promoting

sustainable fisheries requires strengthening the ecological approach, expanding monitoring programs, ensuring compliance with angling regulations, and diversifying management tools, including online water quality monitoring, artificial spawning habitats, and studies on fish feeding.

The research highlights that addressing complex ecological and environmental issues goes beyond anglers' responsibilities. Therefore, it is crucial to utilize national and EU funding opportunities, provide continuous professional training for managers, and enhance their ecological and hydrobiological knowledge. This study contributes to evidence-based development and the sustainable use of waterbodies in Hungary.

5. NEW SCIENTIFIC RESULTS

1. It was found that in case of the majority of surveyed waterbodies, angling organizations independently manage fisheries, typically preparing management plans without external experts. These plans primarily rely on past experience and catch log data, as standard survey-based information is largely lacking.
2. It was proven that in most of the surveyed angling waters, boards lack members with relevant professional qualifications. The study revealed that leaders with formal training possess broad ecological knowledge, whereas non-specialist leaders have limited expertise in this area. This clearly supports the necessity of ecological and hydrobiological expertise in fisheries management decisions.
3. It was demonstrated that fisheries management measures in the surveyed waterbodies primarily aim to protect and maintain carp populations, while ecological considerations and the preservation of natural species composition are largely neglected. This also reflects the strong carp-centric approach of recreational fisheries management in Hungary.
4. It was found that the high level of knowledge reported by water managers regarding fish species composition and fish assemblage composition was not supported by standard fish survey data in most of the surveyed waterbodies.
5. It was demonstrated that otters and great cormorants cause some level of problems for fisheries managers in approximately half of the surveyed waterbodies. While no national-level threat was confirmed, they can pose significant local challenges, often generating conflicts between fisheries management objectives and conservation goals. Furthermore, it was shown that for great cormorants, the perceived level of damage reported by managers increases with waterbody size.
6. It was proven that the main anthropogenic threats to recreational fisheries in the surveyed waterbodies were water scarcity and increased nutrient loads, which locally sometimes led to algal blooms, oxygen deficiency, and fish mass mortality.

6. SCIENTIFIC PAPERS PUBLISHED ON THE SUBJECT OF THE DISSERTATION

6.1 Scientific Publications in International and National Journals

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7.2. Scientific Publications in International and National Conference Proceedings

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