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CONTENTS

FOOD WEB STRUCTURE AND RESOURCE USE BY FISH IN THE UPPER PART OF THE VLTAVA RIVER, CZECH REPUBLIC

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ABSTRACT

Understanding trophic niche structure is essential for describing the organization and functioning of fish communities in river ecosystems. Stable isotope analysis of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) was used to characterize trophic niches and food web structure of eight species of fish inhabiting the upper reaches of the Vltava river (Czech Republic). Eight species were analysed together with six categories of food resources. The isotopic composition of muscle tissue and basal food resources was measured using a Delta V mass spectrometer, and trophic metrics were calculated using Stable Isotope Bayesian Ellipses in R (SIBER) and MixSIAR models. Results revealed distinct isotopic separation among species, indicating variation in resource use and trophic position. The highest $\delta^{15}N$ enrichment and thus the highest trophic position within the community were recorded for dace *Leuciscus leuciscus*, which is likely to be because it mainly feeds on terrestrial invertebrates. In contrast, nase, *Chondrostoma nasus* occupied the lowest trophic level and was the most enriched in $\delta^{13}C$, due to feeding on periphyton and sediment-associated organic matter. Chub (*Squalius cephalus*), roach (*Rutilus rutilus*) and bleak (*Alburnus alburnus*) occupy broad isotopic niches. Species with more specific habitat requirements, such as barbel (*Barbus barbus*) and bullhead (*Cottus gobio*), had narrower trophic niches, reflecting their feeding specialization on aquatic invertebrates. This study highlights the value of stable isotopes for understanding community trophic structure and supports their use in riverine ecosystem management and river community ecology.

Keywords: $\delta^{13}C$; $\delta^{15}N$; freshwater fish; food web; MixSIAR; SIBER; stable isotopes; trophic niche; Vltava river

Introduction

Understanding the trophic niches of fish is fundamental to describing river community ecology. The position of trophic niches within isotopic niche space and their overall arrangement within fish assemblages are essential for elucidating patterns of productivity and energy flow in river ecosystems. Stable isotope analysis provides an effective way of quantifying trophic niches, as it integrates long-term foraging behaviour and dietary sources of fish. Traditionally, Gut Content Analysis (GCA) was used to assess fish diets; however, this approach primarily reflects short-term feeding activity and is limited in its ability to characterize community-wide trophic structure or long-term interspecific trophic relationships. Here, carbon (C) and nitrogen (N) stable isotopes were used to construct the detailed food web in the upper part of the Vltava river. Eight species of fish were analysed, quantifying both the size and spatial position of their isotopic niche space. Trophic variability is influenced by environmental conditions, anthropogenic effects and availability of food resources (Van Valen 1965; Grant et al. 1976; Horka et al. 2023). By incorporating food resources into the analysis, a more precise characterization of individual species' positions within the riverine food web was achieved. The aim was to describe the structure of the food web of the fish community in the upper part of the Vltava river. Stable isotope analysis of $\delta^{15}N$ and $\delta^{13}C$ was used to assess the trophic positions of individual species, as well as the size and spatial arrangement of their trophic niches within isotopic space, reflecting the positions of their respective food sources. The isotopic ratio $\delta^{15}N$ provides valuable information about the trophic position of consumers (Fry 2006). The stepwise enrichment of $\delta^{15}N$ along the food chain serves as an important tool for estimating the trophic levels of organisms and for identifying their positions within a food web (Wada et al. 1991; Post 2002). In contrast, the carbon isotope ratio $\delta^{13}C$ is commonly used to identify the sources of organic matter for consumers. It reflects the contribution of different food resources and can indicate habitat use and the extent of resource assimilation (deNiro and Epstein 1978; Newsome et al. 2007; Baeta et al. 2017). The diversity and arrangement of trophic niches determine how energy flows through food webs and how fish affect the transfer of nutrients between trophic levels. Understanding trophic niches thus helps to reveal the functional role of species in maintaining riverine ecosystem stability and resilience.

Material and Methods

Samples of white dorsal muscle tissue, obtained from 93 specimens of 8 species of fish and of their prey (basal food resources), were analysed. Samples of fish were collected by electric fishing, with an output voltage of 300–600 V (50 Hz) powered by a Honda engine and a LENA generator (Bednář, Czech Republic). Fish were

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caught by electrofishing using a two-pass depletion method to ensure representative estimates of fish abundance at each site. Sampling site was located at the upper part of the Vltava river (near Borsov, 48°53′47.6″N 14°23′38.2″E) in June 2019. It was surrounded by naturally heterogenous habitats and characterized by a combination of shallow fast-flowing reaches with aquatic vegetation interspersed with deeper and slower flowing sections. Samples were kept frozen until laboratory processing at the Centre for Stable Isotope Research of Charles University, Prague, Czech Republic. Muscle samples were dried and homogenised using a ball mill (MM400, Retsch, Germany) and then ±0.50 mg of a sample was placed in a tin capsule. The resources were divided into six categories: terrestrial invertebrates, aquatic invertebrates, terrestrial plants, aquatic plants, periphyton and sediment. Total carbon and nitrogen content as well as their isotope ratios were measured using a Delta V mass spectrometer coupled to a Conflo IV and elemental analyser Flash 2000 (all instrumentation by Thermo Fisher Scientific, Bremen, Germany). The carbon and nitrogen isotope ratios are expressed in delta notations as follows: $\delta X = (R_{sample}/R_{standard} - 1) \times 1000$, where X stands for ^{13}C or ^{15}N, respectively, and R is the carbon or nitrogen isotope ratio ($R = {}^{13}C/{}^{12}C$ or $^{15}N/^{14}N$). Repeated measurements of a series of international standards (IAEA-CH3, IAEA-CH6, IAEA-600, IAEA-N1, IAEA-N2, IAEA-NO3) were used to normalise the measured isotope ratios to the Vienna Pee Dee Belemnite (VPDB) and the atmospheric N_2 scales (Coplen 1996). In addition, a glycine standard was measured after every 10th sample to provide calibration for elemental composition and a quality control for isotopic measurement. Analytical precision was within 0.2 ‰ for both $\delta^{13}C$ and $\delta^{15}N$.

All statistical analyses were conducted using R 4.0.5 (R Core Team 2021). Isotopic niche area of species, and trophic position of species in the community were evaluated using stable isotopes $\delta^{13}C$ and $\delta^{15}N$ (Laymann et al. 2007; Jackson et al. 2011). Bayesian ellipse analyses were used *via* the SIBER package (Stable Isotope Bayesian Ellipses in R; Jackson et al. 2011). Stable isotope metrics of the fish assemblage were evaluated and presented using three approaches: (i) Trophic niche areas (SEA – *Standard Ellipse Area*, SEAc – *corrected Standard Ellipse Area*, TA – *Total Area*), showing isotopic niche width and overlap among species, (ii) trophic positions derived from $\delta^{15}N$ values indicating relative trophic levels, and (iii) MixSIAR model outputs estimating percentage contributions of fish diets, showing isotopic positions of each species relative to food sources (Phillips et al. 2014). Values of Standard Ellipse Area (SEA, ‰^{2}), sample-size corrected ellipse area (SEAc, ‰^{2}), and Total Area of the convex hull (TA, ‰^{2}) were evaluated for each species of fish (Table 1). SEA represents the core isotopic niche area encompassing approximately 40% of the data and provides an estimate of trophic niche width. SEAc adjusts for small sample sizes, allowing for more robust comparisons among species with different *n*. TA is the total extent of the isotopic space occupied by a species and reflects the overall dietary variability within the population. Large SEAc and TA values indicate broad trophic niches and high dietary variability within the population. Mean (± SD) $\delta^{15}N$ values of individual species describe differences in trophic level within the fish assemblage. Posterior probability distributions from the Bayesian mixing model (MixSIAR, Stock et al. 2018) were used to show estimated percentage contributions of the diet of each species of fish. The model incorporated six resource categories: terrestrial invertebrates, aquatic invertebrates, terrestrial plants, aquatic plants, periphyton and sediment. Species-specific isotope values are plotted in isotopic $\delta^{13}C$-$\delta^{15}N$ bi-space alongside modelled mean source signatures.

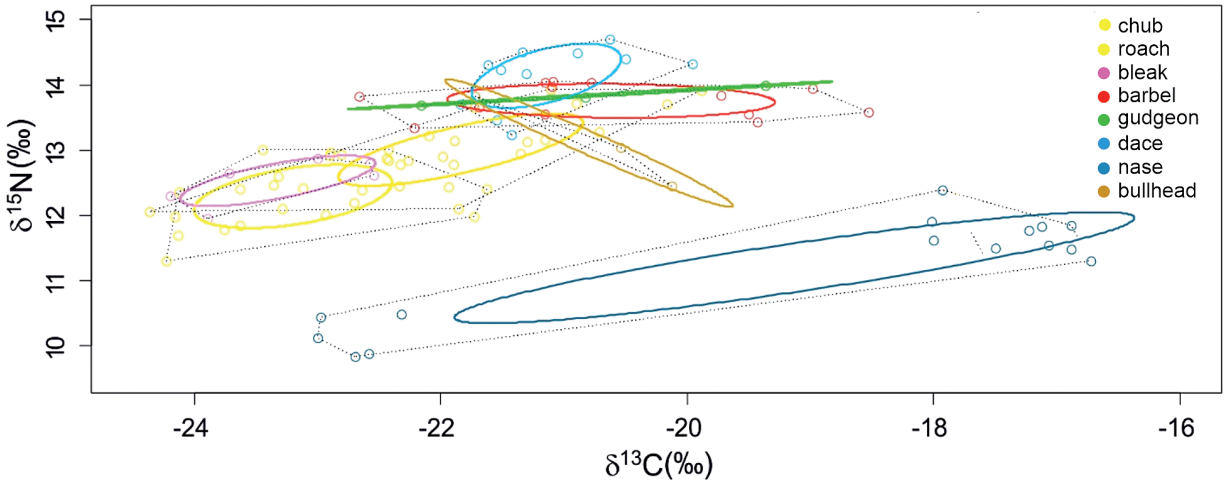

Fig. 1 Isotopic niche ellipses (SEAc) of fish in the upper Vltava river. Biplot of $\delta^{13}C$ and $\delta^{15}N$ stable isotope values (‰) showing corrected standard ellipses (SEAc) for eight species of fish inhabiting the upper Vltava river. Ellipses represent the core isotopic niche area and indicate trophic niche width and overlap between species.

Table 1 Isotopic niche metrics (SEAc and TA) of fish in the upper Vltava river. Values of Standard Ellipse Area (SEA), corrected Standard Ellipse Area (SEAc, ‰^{2}) and Total Area (TA, ‰^{2}) are shown for each species, which are the core isotopic niche and total isotopic niche breadth, respectively.

Fish species (*latin name*)	**SEA (‰^{2})**	**SEAc (‰^{2})**	**TA (‰^{2})**
European chub (*Squalius cephalus*)	1.041	1.103	2.924
Roach (*Rutilus rutilus*)	1.093	1.146	3.528
Bleak (*Alburnus alburnus*)	0.545	0.682	0.724
Barbel (*Barbus barbus*)	0.994	1.084	2.149
Gudgeon (*Gobio gobio*)	0.058	0.116	0.032
Dace (*Leuciscus leuciscus*)	0.718	0.797	1.429
Nase (*Chondrostoma nasus*)	3.020	3.253	6.257
European bullhead (*Cottus gobio*)	0.352	0.704	0.194

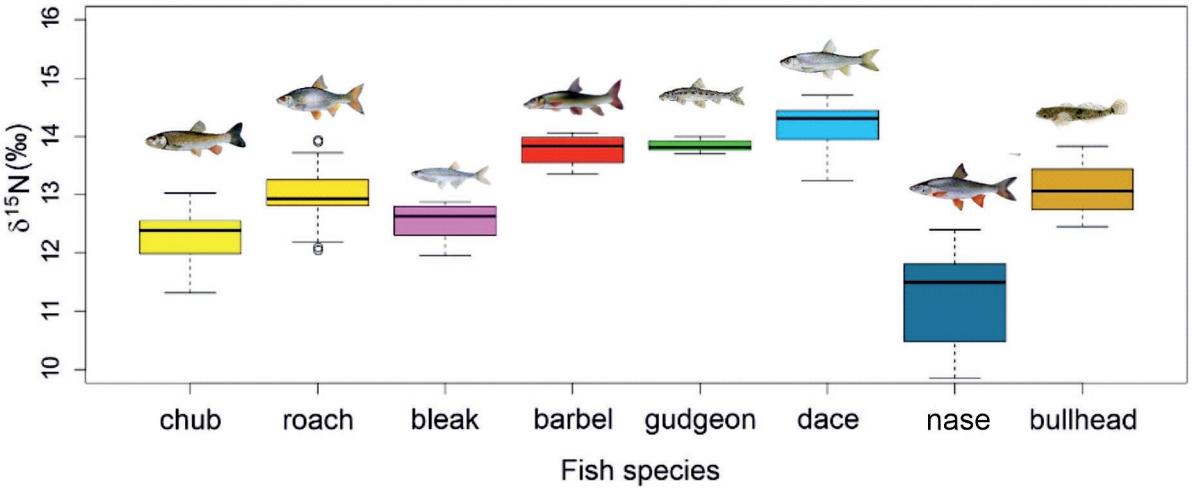

Fig. 2 Trophic positions of fish in the Vltava river based on $\delta^{15}N$ values. Mean (± SD) $\delta^{15}N$ values of individual species illustrate differences in trophic level within the fish assemblage.

Results

A total of 93 individuals of eight species of fish were analysed in order to evaluate trophic structure and resource use of the fish community in the upper part of the Vltava river. Chub, roach and nase had the largest SEA, SEAc and TA values, the narrowest trophic niches were recorded for gudgeon and bullhead (Fig. 1, Table 1). Nase was at the lowest trophic level and compared to other species was also the most enriched one in carbon isotope $\delta^{13}C$ (Fig. 1). Species such as chub, roach and bleak occupied higher trophic positions, while gudgeon and barbel were at slightly lower trophic levels. In the highest trophic position was dace (*Leuciscus leuciscus*), which had the highest enrichment in the nitrogen isotope $\delta^{15}N$ (Fig. 2). The most pronounced niche overlap was recorded between bleak and chub (46%). The trophic niche of roach (SEAc = 1.146, $p < 0.05$) overlapped with chub (11%), bleak (6%), bullhead (13%), and, to a small extent, barbel (2%). The niche of nase (SEAc = 3.253, $p < 0.05$) was significantly larger than those of chub, roach, bleak, and did not overlap with any other species (Fig. 1). Values of SEA, SEAc, and TA for the fish species at this site are presented in Table 1.

Discussion

Using isotopic values $\delta^{15}N$ and $\delta^{13}C$, the extent of the niche breadth of individual species and their placement along the overall isotopic mixing axis was determined. The trophic niche size was determined using SEAc, as this measure provides accurate estimates even when only a small number of individuals are included in the analysis (Jackson et al. 2011; Philips et al. 2014). In the upper part of the Vltava river, eurytopic and omnivorous species such as chub (*Squalius cephalus*), roach (*Rutilus rutilus*) and bleak (*Alburnus alburnus*) had the largest SEA and SEAc values, indicating broad trophic niches and use of many resources. Also, the most pronounced niche overlap was recorded between bleak and chub (46%). Chub is a typically omnivorous species inhabiting a wide range

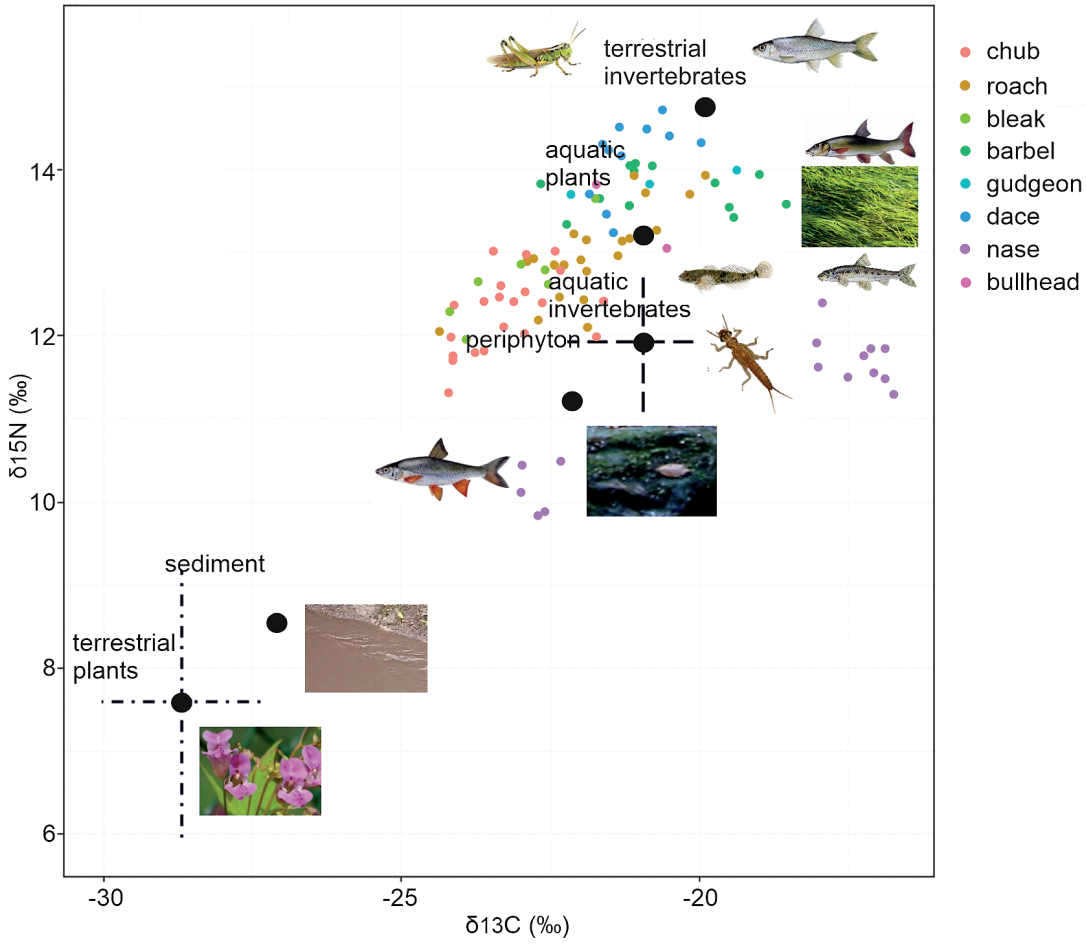

Fig. 3 MixSIAR model estimates of resource contributions to fish diets in the upper Vltava river. Posterior probability distributions based on the Bayesian mixing model (MixSIAR) show estimated percentage contributions of resources to the diet of each species. Species-specific isotope values ($\delta^{13}C$, $\delta^{15}N$) are plotted in isotopic space alongside modelled mean source signatures.

of habitats. In adulthood, it may even consume small fish, but its diet is primarily composed of insects, and it also feeds on plant material collected throughout the water column (Allouche et al. 1999). Chub occupies an intermediate position in the food web, with $\delta^{15}N$ values around 12 ‰ and wide trophic niche space. Chub is often described in the literature as a rheophilic species (Aarts et al. 2003; Capra et al. 2018). However, it may be considered a eurytopic species with a very broad habitat and dietary requirements. Chub occupied a broader niche than the other species, indicating a high degree of dietary plasticity. Roach is a typical generalist (Svanbäck et al. 2008; Hayden et al. 2014; Nahon et al. 2020), utilizing a wide range of food including detritus (Persson 1983), zooplankton, macrophytes and benthic invertebrates (Persson and Hansson 1999). Its niche may expand with increasing eutrophication of an aquatic environment (Olin et al. 2002). According to Hayden et al. (2014), the main components of roach diet are aquatic snails and chironomid larvae. In this study, the trophic niche of roach was slightly higher than that of chub and bleak, possibly reflecting higher proportion of aquatic plants in its diet. $\delta^{15}N$ values ranged from 12–14‰, confirming its feeding generalisation.

Bleak is shoal-forming, visually orientated pelagic fish considered an obligate zoophage (Kottelat and Freyhof 2007; Horka and Vlachova 2024). They occupy a key trophic role as plankton consumers and are essential prey of predators (e.g., asp *Leuciscus aspius*, Linnaeus 1758) in river ecosystems (Krpo-Cetkovic et al. 2010). Their diet primarily consists of plankton, larvae and adult aquatic invertebrates, as well as of terrestrial insects that fall into the water or fly above the surface, which the fish can capture by leaping (Haberlehner 1988; Chappaz et al., 1998). These prey items provide a high caloric and protein content (Giller and Malmqvist 2000). The trophic position of bleak ranged from 12–13‰ $\delta^{15}N$, and was comparable to that of chub, indicating that aquatic invertebrates, and periphyton was the main dietary source. Bleak, chub, and roach which are exhibiting the widest trophic niches are also among the most widely distributed in the Elbe river basin (Horky et al. 2013). This implies that an omnivorous feeding strategy may enhance population development, since effective assimilation of food resources is critical to population dynamics.

In contrast, species with more specific habitat requirements, such as barbel (*Barbus barbus*) and bullhead (*Cottus gobio*), had smaller SEA and TA values, reflecting

narrower isotopic niches and diets dominated by aquatic invertebrates. At the study site, gudgeon and barbel occupied higher trophic positions, with gudgeon having the smallest trophic niche. This may be explained by their diet, which consists mainly of insect larvae and benthic invertebrates (Hanel and Lusk 2005; Nunn et al. 2012). The trophic level of gudgeon, as indicated by $\delta^{15}N$, ranged between 13–14 ‰. The high trophic position of gudgeon and barbel can be attributed to two main factors. First, it may reflect the relatively high trophic level of its prey, such as insect larvae and benthic invertebrates. Second, its trophic position may be influenced by benthic feeding, where nitrogen in the food sources is enriched due to decomposition in detrital-pathway occurring at the sediment-water interface (Steffan et al. 2017). A slightly lower trophic niche was occupied by European bullhead, reflecting its benthophagous diet. According to Hyslop (1982), bullhead primarily consume algae and aquatic insect larvae, including chironomids, simuliids, Trichoptera and Ephemeroptera.

Dace (*Leuciscus leuciscus*) occupied the highest trophic position within the assemblage, which indicates high percentage of terrestrial prey, such as insects in its diet (Weatherley 1987). This is also consistent with its placement along the overall isotopic mixing axis. Nase (*Chondrostoma nasus*) had a wide but distinct niche, separate from other species, consistent with its specialized feeding on periphyton and sediment-associated organic matter (Reckendorfer et al. 2001). This fish feeds primarily by scraping periphyton from the streambed. These periphyton layers contain not only plant material, but also animal components, including various insect larvae, chironomids and other invertebrates. At the site studied, its $\delta^{15}N$ values were 10–12 ‰. Compared to all other species, nase occupied a lower trophic position. This lower trophic position could be influenced by the absence of animal components in the periphyton scraped from stones. In addition, two relatively distinct groups were recorded in the diet of nase, which may indicate that fishery managers introduce two distinct size classes of fish during regular stocking (Horky et al. 2013; Lyach 2021), resulting in the variation in its diet, or that the isotopic signatures reflect the feed they received in fish farms. Its low trophic position suggests that its unique feeding strategy may reduce competition with other species, and to provide a competitive advantage of this species in the assemblage.

In anthropogenically affected rivers, fish with low environmental requirements are supposed to have an advantage over more specialised species. Such features include, for example, limited migration and habitat requirements, unspecialised breeding strategies and flexible use of food resources (Musil et al. 2012; Horky et al. 2013). In European rivers, several species belong to the eurytopic ecological group, often exhibiting omnivorous feeding habits. It is suggested that these species benefit from omnivory, in contrast to more specialized rheophilic fish species, particularly in ecosystems affected by nutrient loading (Horka et al. 2023). In this study, chub, roach and bleak had the widest trophic niches, confirming their omnivorous feeding strategies. In addition, nase occupied a niche in a low trophic position largely separated from other fish, which may indicate reduced competition and a potential competitive advantage over co-occurring species. Knowledge of trophic niches is essential for effective management of freshwater ecosystems and for the restoration of habitats (Fráguas et al. 2025). The arrangement and position of the trophic niches of individual species provides critical insights into community food web structure and resource use, and can be especially valuable in managing biodiversity conservation for eutrophic ecosystems (Di Prinzio et al. 2024; Luo et al. 2025). Future research should employ a more detailed categorization of food resources together with Bayesian mixing models to improve our understanding of resource use and trophic differentiation among fish in freshwater ecosystems exposed to different types and intensities of anthropogenic pressures.

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EXPERIMENTAL TEST OF THE HYPOTHESIS THAT NITROGEN INPUT INHIBITS GROWTH AND NODULATION OF *ALNUS GLUTINOSA* GROWING ON SOILS IN MINING AREAS

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ABSTRACT

Alder (*Alnus glutinosa*) is a nitrogen-fixing species commonly used in the reclamation of mining sites. Nitrogen supply is assumed to be beneficial for soil development, soil carbon storage and overall ecosystem recovery. However, earlier studies show that in old alder plantations, growth is slow. The experiment reported here was done to test the hypothesis that a surplus of nitrogen can suppress the nitrogen fixing activity of *Frankia*, which is the nitrogen-fixing symbiont of alder, resulting in a reduction in the growth of alder. Potted alder seedlings were grown in a greenhouse into two types of non-sterilised spoil heap soils from the Sokolov brown coal mining district in Czechia. Two different concentrations of ammonium nitrate were tested, which mimic the addition of 25 and 50 kg N.ha^{-1}, together with a control in which no nitrogen was added. The addition of nitrogen to the soil significantly reduced both alder growth and the formation of *Frankia* tubers. This indicates that once there is sufficient nitrogen in soil, alder growth will be suppressed even in the absence of competition from other plants, which has implications for using alder in reclamation.

Keywords: alder; ecosystem; *Frankia*; reclamation; symbiosis

Introduction

Post-mining sites are often poor in available nitrogen (N) (Bradshaw 1996). Planting N-fixing trees is a common approach to improving soils and increasing the N pool in soil organic matter (Batterman et al. 2013; Brookshire et al. 2019; Levy-Baron et al. 2019; Kou-Giesbrecht and Menge 2021). Alders are a genus of actinorhizal plants, which are often used for afforestation of post-mining sites in central Europe. This is due to their pioneer status (Pietrzykowski et al. 2018; Perakis and Pett-Ridge 2019) and nitrogen-fixing ability of their bacterial symbionts of genus *Frankia*, which fix atmospheric nitrogen. *Frankia* are Gram-positive bacteria belonging to the *Actinobacteria phylum*. Among them, *Frankia alni* is the only formally identified species known to form a symbiotic relationship with actinorhizal plants of the genus *Alnus*. In associations with members of the Betulaceae family, *Frankia* typically initiate intracellular infections (Santi et al. 2013). These bacteria possess the ability to fix atmospheric nitrogen (N_2), both while residing within plant root tubers and as free-living organisms in the soil (Sellstedt and Richau 2013). Nitrogen fixation is facilitated by nitrogenase, an enzyme complex that is highly sensitive to oxygen (Jang et al. 2000). The process of nitrogen fixation in root nodules can demand up to 12% of the host plant's total photosynthetic input, making the symbiotic relationship particularly beneficial in environments where nitrogen availability islow.

Earlier studies at the Sokolov post-mining sites (Frouz et al. 2015) show that the growth of 30-year old alder, *A. glutinosa*, is stunted. A plausible explanation is that there is already sufficent nitrogen in the soil and this reduces *Frankia* performance, consequently negatively affecting the growth of alder. This assumption is supported by several laboratory experiments, as well as field observations on other alder species.

A greenhouse experiment using hydroponic culture, Bélanger et al. 2011, reports that if exogenous nitrogen (potassium nitrate) concentrations are increased they gradually inhibit the symbiosis between *Alnus glutinosa*, *A. viridis*, *A. incana* and *Frankia*. In another greenhouse study, different concentrations of ammonium nitrate reduced nodulation and nitrogen fixation in *Alnus sieboldiana* (Yamanaka et al. 2016). Tiffany Laws and Graves (2005) report that ammonium nitrate negatively affects nodule (tuber) activity in *Alnus maritima* and *Frankia*, and growth of alder.

In addition, field studies with various species of alder, namely *Alnus rubra, A. incana* and *A. alnobetula* spp. *crispa*, report that the addition of N in the form of organic or inorganic fertilizer reduces *Frankia* infestation and nitrogenase activity, and consequently tree growth (Hurd et al. 2005; Gaulke et al. 2006; Markham and Anderson 2021).

The aim of this study was to test the hypothesis that nitrogen addition will reduce *Frankia* infestation and alder growth at post-mining sites. It is also expected that this

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effect will be more pronounced in old spoil soils where the natural background of nitrogen is already high.

Materials and Methods

Materials

Alder [*Alnus glutinosa* (L.) Gaertn.] seeds were obtained from Lesy České republiky Company (Czech Republic).

Soils used in this study came from the Sokolov mining district (Czech Republic), specifically sites that are located at 450–550 m above sea level, where average annual rainfall is 650 mm and average annual temperature is 6.8 °C. Soils used in this experiment originated from clay-rich tertiary mudstone deposits in post-mining spoil heaps after brown coal mining. The material consists mainly of clays (kaolinite, illite and montmorillonite), quartz and calcium carbonate. Two soils were used in this study, both coming from a chrono sequence of alder plantations (Frouz et al. 2001). The first soil, hereafter called young, came from an 18-year old alder plantation, while the other called old, came from a 70 years old plantation. Carbon content in the young soil was 4% and 10% in the old soil. N content was 0.2 and 0.6%, and pH was 8.5 and 6.5 in young and old soil, respectively (Bartuška and Frouz 2015).

Pot experiment

Seeds of *Alnus glutinosa* (L.) Gaertn. were washed in distilled water and then allowed to germinate for one week. Once germinated, similarly developed seedlings were chosen and planted individually in 150 ml pots filled with post-mining spoil heap soils from the Sokolov mining district in Czechia.

The pots were then treated with the equivalent 0 kg/ha, 25 kg/ha and 50 kg/ha ammonium nitrate and each treatment was replicated 7 times.

In addition to irrigation and providing fertilizer, which was provided by top-watering, plants were checked every other day and watered from the bottom with pure water as needed.

The experimental plants were then placed in a greenhouse kept at an average temperature of 20 °C and under a light regime of 14/10 LD, 600 $W.m^{-2}$ for four months.

After this period, the plants were carefully extracted from the pots, dried at room temperature and weighed.

Data analysis

Tree biomass and *Frankia* infestation were tested using two-way ANOVA using soil age and N fertilization level as factors. In addition, one-way ANOVA was used to test the effect of the N fertilizer on both soils separately. If the ANOVA showed significant results, LSD post hoc test was used. Computation was done using Statistica 13.0.

Results

Over the course of the experiment the effect of the fertilizer on plant growth was obvious. Dry aboveground biomass of alder seedlings was significantly affected by both soil age and application of nitrogen fertilizer (Table 1). The growth of seedlings was strongly negatively affected by the nitrogen fertilizer, with seedlings growing in the nonfertilizer treatment having a significantly higher dry mass than those growing in both fertilizer treatments, with no significant difference between the latter two (Fig. 1). Seedlings in the old soil grew slightly and significantly better than in young soil (Fig. 1, Table 1).

Production of *Frankia* tubers was significantly (Table 1) affected by nitrogen fertilizer; no tubers were formed in any of the fertilizer treatments, thus tuber production in non-fertilizer treatments were significantly higher than in those treated with fertilizer (Fig. 2). In terms of

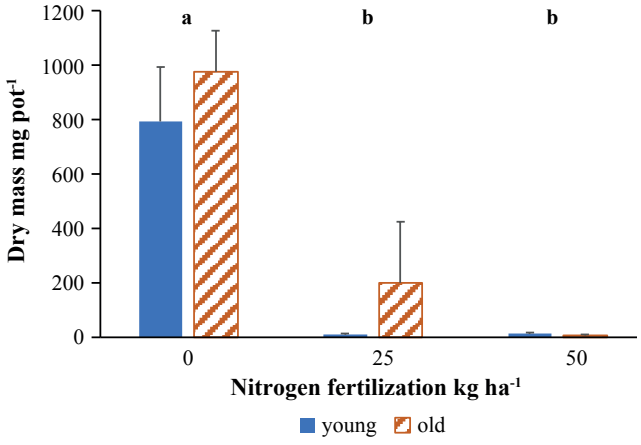

Fig. 1 Aboveground dry mass of alder in young and old soil exposed to various levels of N fertilization (mean and SD). Statistically homogeneous groups of fertilization treatments are marked by the same letter (LSD post hoc test $p < 0.05$).

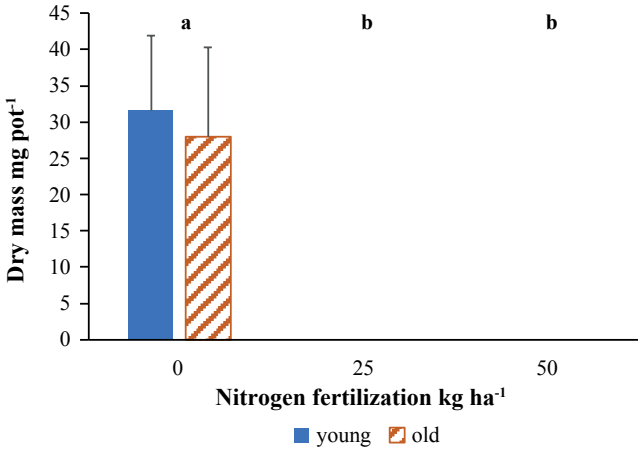

Fig. 2 Mass of *Frankia* tubers on alder roots in young and old soils (mean and SD) exposed to various levels of N fertilization. Statistically homogeneous groups of fertilization treatments are marked by the same letter (LSD post hoc test $p < 0.05$).

Table 1 Output of two-way ANOVA (p values) exploring effect of soil age and nitrogen fertilization and their interaction on aboveground biomass of alders and mass of *Frankia* tubers.

Parameter	Soil age	N fertilization	Interaction
aboveground biomass	0.0123	> 0.0001	ns
mass of tubers	ns	> 0.0001	ns

tuber production, there was no significant difference between the two soils (Fig. 2, Table 1).

Discussion

In agreement with the hypothesis and previous research (Hurd et al. 2005; Gaulke et al. 2006; Bélanger et al. 2011; Yamanaka et al. 2016; Markham and Anderson 2021), the addition of nitrogen affects the symbiotic relationship between alders and *Frankia*. This indicates that the poor growth of alder trees in old soils (Frouz et al. 2015) may be at least partly associated with surplus nitrogen.

Contrary to the hypothesis, alder seedlings grew better in old than young soil, this however, was not recorded for the *Frankia* tubers. In the present experiment, soils from alder plantations which were already inoculated with *Frankia* strains that had time to establish on the local spoil heap soils, so it is unlikely that there were any problems with colonization or mismatch between alder and *Frankia* strains (Balkan et al. 2019; Wolfe et al. 2022; Yuan et al. 2023). Colonization of trees by *Frankia* in young soil can be negatively affected by the availability of phosphorus and micronutrients as the soil was alkaline (Buchbauerová et al. 2024). Slightly better performance of alder seedlings in old soil can be due to better availability of nutrients in these soils. Also, the symbiotic relationship is further affected by the presence and activity of other symbionts, like mycorrhizal fungi and rhizobacteria (Yamanaka et al. 2005), which may be better developed in old soil.

Conclusion

Results clearly show that surplus of nitrogen suppresses colonization of alder roots by the N-fixing symbiont *Frankia* and have a negative effect on alder growth. This indicates that accumulation of nitrogen in soil due to the activity of alders and their symbionts may have negative effect on these symbiotic interactions and eventually impair performance of alder trees. These findings have a clear implication for the restoration of spoil heap soils. While planting nitrogen-fixing trees can speed up soil development, their long- term persistence at a site is unlikely.

Acknowledgements

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REPORT ON THE SPECIES DIVERSITY OF FISH IN ALBANIA'S MAJOR LAKES

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ABSTRACT

Lake Shkodra, between Albania and Montenegro; Lake Ohrid, between Albania and North Macedonia; and the two Prespa Lakes that span the borders of Albania, North Macedonia and Greece, together form the largest lake complex in Europe in terms of habitats, species and genetic diversity. This paper presents the unique characteristics that sustain the stable and resilient condition of each lake, as well as one of their most important features: the diversity of their fish populations.

Keywords: fish; genetic diversity; Lake Shkodra; Lake Ohrid; Prespa Lakes; species diversity

Introduction

The hydrological complex formed by the Drin and Buna rivers and associated lakes (Shkodra, Ohrid, Great Prespa, and Small Prespa), is on the Balkan Peninsula, in a region characterized by active tectonic, hydrographic, geomorphological, biogeographical and evolutionary processes. This complex is in part of the Adriatic Sea Basin, which is one of the most ecologically and scientifically intriguing in the Mediterranean area, as the water in the South Adriatic–Ionian zoogeographic region is noted for its distinct features (Dhora 2017).

Although the four lakes are hydrologically interconnected each has unique characteristics that determine their ecological individuality and importance.

Among the most important features of these lakes is the genetics and species diversity of their fish populations. Genetic diversity refers to the genes in each population of a species varying and diversity of the variety of species present and their relative abundance (Biba et al. 2013).

This article outlines, for each lake, the key characteristics that sustain the ecological stability and resilience of the ecosystem, as well as the genetic and species diversity of their ichthyofauna.

Materials and Methods

The characteristics of the lakes were mainly obtained from Dhora (2016, 2017), Dhora et al. (2016) and Group authors (2015). These characteristics were revised and adapted according to two main aspects: the stable condition of the lakes and the genetics and species diversity of their fish.

The updated list of fish in Albania's major lakes is based on Talevski et al. (2009), Crivelli and Catsadorakis (2012), Barbieri et al. (2015), Marić (2018) and Dhora (2020).

Species diversity was based on comparing data for each lake on the number of species of fish, the number of species of Cyprinidae, the number of species of Salmonidae, the number of species migrating to the sea, the number of introduced species and the number of endemic species.

The genetic diversity of the fish is based on data presented in Dhora (2024) and several aspects of the species of salmon in the Moraça River, three species of salmon in Lake Ohrid, *Alosa agone* in Lake Shkodra, two species of *Rutilus* in Lakes Shkodra and Ohrid, and the indigenous common carp in Lake Shkodra, which are in genetic equilibrium (Biba et al. 2013).

Results and Discussion

Characteristics of each lake

Below are the characteristics of Albania's major lakes that support the stable and resilient condition in these ecosystems, as well as the genetic and species diversity of their fish populations.

Lake Shkodra

Lake Shkodra is one of the biggest lakes in the world (100–10,000 km²) and is the largest lake on the Balkan Peninsula in terms of surface area.

The subsiding movement of the plate on which Lake Shkodra lies began at the end of the Paleogene and the beginning of the Neogene. It is believed that this downward movement has been offset by the deposition of sediment from inflowing rivers, an important geological factor contributing to the lake's long-term stability.

Karst modelling revealed hydrographic features, lake morphology and high catchment potential.

Approximately 44.3% of the lake's minimum surface area lies below sea level. This feature classifies the lake as a crypto depression, which is a rare phenomenon in Europe and globally. This aspect contributes to its classifi-

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cation as a stereotypical lake, with unique natural values, regenerative capacity and longevity.

Lake Shkodra is a lowland lake, yet it is supplied with rainwater from high-altitude areas in its extensive catchment basin.

The lake functions as a hydrological stabilizer. When the flow of water in the Drin River is low, Lake Shkodra discharges water into the Buna River, but when the flow is high it impedes the normal outflow of the Buna and blocks the discharge from the lake. As a result, the water level, surface area and volume of the lake increase.

Historically, Lake Shkodra is described as both a riverine system (lotic system) in which the lake is the potamic segment of the Morača-Buna River, and a marsh system (lentic, palustrine) along the lowland stretch of the river. Currently, Lake Shkodra is a lake (lentic, lacustrine), with a large, permanent water surface, which distinguishes it from marshland.

As the lake's water temperature very rarely drops below 0 °C its thermal regime is subtropical. It contains more water during the wet seasons and less in the summer months.

There are significant seasonal fluctuations in water level of this lake, which can reach up to 5 meters. These fluctuations are important ecologically as during the warm seasons when the water level is low, aquatic macrophytes flourish and reproduction and migration occur.

As autumn approaches, macrophytes die back and decompose in the lakebed sediments, some of which are carried via the Buna River to the sea, which results in the natural cleansing of the lake.

In the cold seasons, when water levels are at their maximum, the lake undergoes a reversal in ecological dynamics. The number of habitats decreases, and the fauna seeks shelter for overwintering.

Lake Shkodra is a littoral-type environment as its shallowness and fluctuations in water level prevent the development of a well-defined vertical zonation within the lake.

The lake is characterized by clear, oligotrophic waters with a low phytoplankton biomass. The feedback mechanisms that maintain water quality include: the nutrient concentrations in the water versus humic production in wetlands; nutrient levels versus the productivity of riparian forest habitats; and food web structures that transfer phosphorus from littoral to pelagic zones versus biogeochemical processes that inhibit phosphorus recycling from sediments.

There are three main habitats in Lake Shkodra:

- The lacustrine system, which includes limnetic and littoral habitats.
- The palustrine system, consisting of habitats that vary in vegetation and the presence or absence of standing water,
- The riverine system, which includes both permanently and seasonally flooded habitats.

Aquatic macrophytes are the most characteristic feature of the littoral zone and, to a certain extent, the entire Lake Shkodra ecosystem.

The lake is notable for its high species diversity. It also has significant ornithological value at a regional scale. In and around Lake Shkodra and its catchment area, a total of 283 species of birds are recorded, 168 of which are associated with aquatic habitats.

Lake Ohrid

Lake Ohrid is situated at an altitude of 693 metres above sea level, nestled between the Mokra Mountains to the west and Galicica Mountains to the east.

This lake is listed among the nine most ancient lakes worldwide and is considered the oldest in Europe.

It is one of the largest lakes in the world and with an average depth of 167 metres and a maximum depth of 288.7 metres, it is one of the deepest in Europe and second in terms of average depth and volume the largest in the Balkans.

Lake Ohrid and Lake Prespa are part of the Dessaret basin group, formed by a geotectonic depression during the Pliocene

Uniquely Lake Ohrid is primarily spring-fed. Approximately 50% of its inflow originates from underground sources coming from Lake Prespa, which lies about 10 km to the southeast and is roughly 150 meters higher in altitude

There are three thermal zones in this lake:

- The epilimnion, the uppermost water layer, extends to a depth of about 20 meters and can reach temperatures of 24–27 °C.
- The metalimnion lies beneath the above, where temperature decreases by approximately 0.5 °C per metre of depth.
- The hypolimnion is the deepest, coldest layer, which does not receive heat from sunlight or oxygen from the atmosphere. At 150 metres depth, the temperature is about 6 °C.

The open waters in this lake are oligotrophic, whereas the nearshore zones are considered mesotrophic.

Lake Ohrid has an outstanding biodiversity, including:

- Habitat diversity, often physically and/or ecologically isolated,
- Species diversity, particularly of endemic taxa,
- And genetic diversity in several biological groups.

The lake's biota is unique, not only because of its physical isolation, but also because its biocenosis is homogeneous, stable and a product of long-term evolutionary processes.

Lake Ohrid has the highest density of endemic species per surface area of any lake in the world.

The presence of cold, oxygen-rich underwater springs, combined with both horizontal and vertical isolation, are the main reasons for the lake's unique evolutionary pathways, high level of endemism and ecological stability.

Lake Ohrid is often described as a "museum of relict species" or a "repository of living fossils," as many of the species there that were once widespread millions of years ago and are now extinct elsewhere, but survived in this lake. The most notable relict groups include Diatoms, Gastropods and Salmonids, with the benthic community being among the most interesting.

Zooplankton plays a vital role in the lake's food web, serving as the primary food source for small fish, which in turn sustain predatory fish, including trout.

A total of 270 bird species is recorded in Lake Ohrid and its surrounding catchment.

The Prespa Lakes

The Prespa Lakes**,** both Great and Small, form part of the Dessaret basin group, which originated from a geotectonic depression during the Pliocene. Great Prespa Lake is included on the list of the 21 oldest lakes in the world.

Located at altitudes ranging from 844 to 852 metres above sea level, they are the highest tectonic lakes in the Balkans.

Great Prespa Lake

This Lake is among the largest globally (100–10,000 km^2). It receives water primarily via surface inflows, while its outflows are subterranean, passing through the karstic systems beneath Mount Galicica and Mount Mali i Thate, and emerging as springs in Tushemisht and Saint Naum, which subsequently feed Lake Ohrid.

The lake has a maximum depth of 52 metres. Over the past few decades, the water level has dropped by approximately 8 meters, which is most likely due to changes in the underground karstic water flow, or other natural or anthropogenic reasons.

Unlike Lake Ohrid, thermal stratification in Great Prespa Lake is less distinct, although a general layering does exist.

For most of the year, the open waters of Great Prespa are oligotrophic, shifting towards mesotrophic during the summer months.

Ecological stability of this lake is attributed to its clean water and two primary production systems: phytoplankton, which thrives in the surface thermal layer and rooted macrophytes in the littoral zone.

Small Prespa Lake

Small Prespa Lake is shallow, with a maximum depth of only 7.7 meters and is eutrophic due to high concentrations of phosphorus. It is rich in emergent vegetation and wetland habitats, making it especially important for birdlife.

Landscape and Biodiversity

There are many habitats in the surroundings of this lake, scenic bays, and islands such as Golem Grad, Maligrad, Agios Achillios and Vidronisi, which, together with the pristine nature and clear waters, contribute to the lakes' beauty and ecological value.

The habitat diversity, species richness, and presence of endemic taxa, particularly in terms of gastropods and fish, means this lake should have priority for conservation. In total, over 200 bird species are recorded there and recently the overwintering water-bird populations have reached up to 50,000 individuals.

In terms of biogeographical classification, this lake is generally grouped in the Adriatic–Ionian lake system, which also includes Lake Ohrid. However, it can also be considered ecologically distinct from Lake Ohrid and the broader Eastern Lake Group, which includes two Balkan and three Anatolian lakes.

To date, 28 species of aquatic macrophytes are recorded there along with over 200 species of birds. In the past two decades, the maximum number of waterbird individuals counted during the winter period has approached 50,000.

Genetics and species diversity of fish

Genetic diversity of fish

Salmo obtusirostris is a complex species, which includes *Salmo zetensis* in the Zeta River, which some authors regard as a subspecies of *S. obtusirostris*. Two other species, *Salmo montenigrinus* Karaman 1933 in the Morača River, is considered by some authors as a synonym of *S. obtusirostris*, and *Salmo taleri* Karaman, 1933 in the upper course of the Zeta River that morphologically resembles *S. cf. farioides*, has so far been recorded only at a single locality. Therefore, the *Salmo* species in the Morača River basin, which includes the Zeta and Cem tributaries, are still not well known, although six species are reported. It is important to accurately determine these species or subspecies, using genetic analyses.

A thorough study of the non-migratory *Alosa agone* population in Lake Shkodra is needed, which should also determine whether migration to the sea occurs. For years, a portion of individuals older than three years may not have migrated and over time, a non-migratory population may have formed, adapted to life along the northeastern shore of the Albanian part of this lake, and possibly reproducing there. Individuals in this population are smaller than the migratory ones, have smaller heads and fewer spots on both sides of the body (Kottelat and Freyhof 2007). This long-established population is *Alosa agone*, living in sympatry with *Alosa fallax* (Rakaj and Crivelli 2001). The above is also discussed in Dhora (2024).

The common carp (*Cyprinus carpio*) was introduced into Albania by the Romans, who cultivated it. Considering its adaptive capacity, the carp population in Lake Shkoder can be regarded as an autochthonous species. Microsatellites have been used as molecular markers to assess genetic variability at the DNA level in carp populations of Lake Shkodra and Lake Ohrid. This study re-

vealed that only the carp population in Lake Shkodra is at genetic equilibrium (Biba et al. 2013). The conservation of the native common carp in Lake Ohrid, and possibly also in the Prespa Lakes, should be ensured by careful stock enhancement based on selected individuals.

Rutilus karamani and *Rutilus ohridanus*, previously considered distinct species in Lake Shkodra, are regarded by Bianco and Ketmaier (2014) as synonyms of a single species, *Leucos basak* Heckel, 1843 and were once classified as subspecies: *karamani* the yellow roach and *ohridanus* the white roach (Dhora et al. 2008). Dhora (2024) suggests that this variation may represent intraspecific diversity, possibly in terms of colour morphs adapted to particular aquatic habitats.

Equally important are the trout, particularly the species in Lake Ohrid: *Salmo aphelios* Kottelat, 1997; *Salmo balcanicus* Karaman, 1927; *Salmo lumi* Poljakov, Filipi and Basho, 1958, and *Salmo ohridanus* Steindachner, 1892. In many cases, trout populations are on the brink of collapse due to pollution, declining water levels and unregulated fishing.

Species diversity of fish

The list of freshwater fish in Albania, according to Dhora (2020), comprises 100 species. The two most significant families in terms of species are Cyprinidae with 40 species and Salmonidae with 15 species. The table below provides, for each lake, the following data: the number of species, the number of species of Cyprinidae, the number of species of Salmonidae, the number of migratory species, number of introduced species and number of endemic species.

As shown in Table 1, Lake Shkodra has the highest number of species with 45, followed by Great Prespa Lake with 30 species, then Lake Ohrid with 28 species and finally Small Prespa Lake with 18 species.

The number of species in the family Cyprinidae is as follows: Lake Shkodra has 26 species, Great Prespa Lake 19 species, Lake Ohrid 15 species and Small Prespa Lake 14 species. The total number of species and those of the Cyprinidae family is greatest in Lake Shkodra due to its subtropical characteristics, large surface area, and shallowness over most of its extent. After Lake Shkodra, Great Prespa Lake follows with considerable fewer species and Cyprinidae species. This is because it is shallower and more eutrophic, especially along the gently sloping shores with abundant vegetation. The difference becomes more pronounced in the other lakes.

Lake Shkodra also has the greatest number of species of Salmonidae, as this count includes the trout in the Morača River, which flows into the lake and contributes over 60% of the lake's total water inflow. Lake Ohrid is deep and the water comes from both surface and subterranean springs, which favours salmonids.

Due to its close proximity and connection to the Adriatic Sea via the Buna River, Lake Shkodra also hosts numerous migratory species.

Both Lake Shkodra and Large Prespa Lake have many introduced species, numbering 16 and 14 respectively. Many of these species were introduced to increase fish production for human consumption. By contrast, Lake Ohrid has 4 introduced species, while Small Prespa Lake has 8. The latter is a shallow and eutrophic.

Each lake hosts endemic species. The endemic species in the two Prespa lakes are almost identical due to their close hydrological connection. Lake Shkodra shares some endemic species with the Morača River. Whereas, Lake Ohrid's endemic species have developed within the lake itself, primarily due to geographical and ecological isolation.

Conclusion

Many of the features of these lakes are unique. Lake Shkodra, is a rare cryptodepression in Europe and worldwide. Lake Ohrid is primarily fed by springs and is the richest lake in terms of endemic species relative to its surface area. The Prespa Lakes are at an altitude of 852 meters and are the highest lakes in the Balkans. Water enters these lakes via surface flow, disappears beneath Mount Galicica and Mount Thate, re-emerging as springs at Tushemisht and Saint Naum, which feed Lake Ohrid.

In terms of management the main characteristics of Albania's large lakes are particularly important as the endemic species are threatened by pollution and unregulated fishing.

The high species diversity of fish in these lakes needs to be recognized. The three supposed endemic species of trout in Lake Ohrid need to be genetically confirmed as distinct species. In the case of the six species of trout in the Morača River, there is a need for genetic studies

Table 1 Numbers of species that belong to different taxonomic groups in different lakes.

Lake	Species					
	Total no. of species	Cyprinidae	Salmonidae	Migratory species	Introduced	Endemic
Lake Shkodra	45	26	7	8	16	6
Lake Ohrid	28	15	6	2	4	5
Great Prespa lake	30	19	3	1	14	7
Small Prespa lake	18	14	?	1	8	7

aimed at differentiating species and subspecies. A comprehensive study of the non-migratory *Alosa* population in Lake Shkodra is required, including morphological, genetic, embryological, ecological and evolutionary analyses. *Rutilus karamani* and *Rutilus ohridanus* are currently thought to be one species; however, further population and genetic studies are needed in both Lake Shkodra and Lake Ohrid to clarify whether they are subspecies or distinct forms.

Lake Shkodra, Lake Ohrid and the Prespa Lakes are protected areas in their respective countries. In the future, the entire hydrological complex and its catchment basin should be declared a protected area. This would involve an integrated approach by five countries if the management is to be successful.

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THE ROLE OF E-MAIL IN INCREASING OUR CARBON FOOTPRINT

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ABSTRACT

Digital technologies are part of our daily lives, and they have a carbon footprint. This paper explores the effect of sending e-mails for business purposes, a supposedly green means of communication, in two workplaces, home and office. Quantitative data of the e-mailing activities of staff was collected and the CO_2e calculated. The survey included the perceptions of the uses of the cost in terms of CO_2e. Based on the data collected, e-mail is an integral part of modern communication within an organisation. A statistically significantly higher percentage of e-mails were sent/received in the office ($p < 0.001$) and the percentage of long e-mails with attachments/images is statistically significantly higher in the office than from home ($p = 0.0194$). The number of standard e-mails is statistically significantly higher in the office than from a cubicle within an office ($p = 0.020$). E-mail seems to be a relatively eco-oriented business and private channel, but the results of this study indicate that it results in the emission of CO_2e.

Keywords: carbon footprint; digital footprint; e-communication; e-mail; workplace

Introduction

Each industrial revolution gives rise to a different way of doing things (Beno 2019). Nowadays everything can be accessed via the Internet (Wook 2019). Different options are chosen by people with little or no consideration of the effect it has on emissions. Currently, global climate change is a topic of great interest. Humans were confined to their residences for a long time during the covid-19 pandemic.

Undoubtedly, one's place of work has undergone a massive change from a business environment to home (De Vincenzi 2022; Beno et al. 2023). This transformation, mainly due to the Covid-19 pandemic, resulted in a transition from a traditional cubicle settings to more flexible settings. In the pre-pandemic period, the use of e-mails was already increasing slowly but steadily (Felstead 2021; Beňo 2022). Hence, a large share of workforce activity globally is fully remote, hybrid or in-office. Ignoring productivity, this raises the question of which option is the most sustainable, sending e-mails from home or a cubicle in an office. Commuting is a necessary but usually disliked daily routine (Beňo 2022) and sending e-mails from home reduces the time spent travelling (Beno and Caganova 2023), leading to a reduction in transportation emissions, but an increase in use of energy at home (Cicala 2023; Shi et al. 2023) and alters ones' style of living (Oda and Kanegae 2023). While time spent travelling decreases, as expected, the overall number of trips in vehicles actually increases (de Vos et al. 2018; Zhu et al. 2018; Caldarola and Sorrell 2022). A recent study demonstrates that the "pandemic upended old routines by creating new ones such as pseudo-commuting" (Beňo 2023, p. 131). In contrast, working from a cubicle is viewed as less environmentally friendly and has its own environmental implications. Therefore, this paper explores this complex situation and its effect in two workplaces, namely working from home and an office.

A digital footprint is the data left behind after every digital service action or whenever others post information to you (actively or passively). There are many harmless everyday actions that contribute to emissions of carbon dioxide (CO_2e). These activities include the so-called "digital footprint." E-mails are still an important means of communication for both people in general and business. In 2022, there were a total of 4.26 billion e-mail users globally (Statista 2024). The greenhouse gas (GHG) emissions of the average digital user in 2019 were approximately equivalent to 356 kg CO_2 (Bordage 2019). Average e-mail traffic is equivalent to driving 10–128 miles in a small petrol-driven car (Berners-Lee 2020). As a consequence, the following question was addressed:

- What is the estimated CO_2e produced by e-communication in homes and offices?

Quantitative data were collected from staff of a particular business about their e-communication activities, and the CO_2e calculated. This survey determined the perceptions of CO_2e in the workplace.

The following section briefly explains the meaning of the digital CO_2 footprint. The third section describes the collection and analysis of the data. The results are presented in the next section, followed by a review of the findings and an outline of the meaning and relevance of the study. The last section summarises the arguments/findings of this study, discusses the implications and presents an overview of what remains to be done in the future.

Footprint of digital CO_2

According to Sharma and Dash (2022), there are CO_2 emissions associated with various human and natural activities. Digitisation "designates the analogue information conversion into digital information" (Beno and Saxunova

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2018). The use of Internet results in a high percentage of CO_2e emitted (Sharma and Dash 2022). "The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product" (Wiedmann and Minx 2007, p. 4). Grinstein et al. (2018, p. 1) typify "carbon numeracy as one's ability to approximate a correct value of one's carbon footprint without resorting to an explicit calculation." Digital footprint simply means all data left behind when going online (passive or active (Lutz and Hoffmann 2017) or all direct and indirect emissions (Wiedmann and Minx 2007). The digital carbon footprint, simply stated, is the effect on the environment associated with digital online activities, measured as the sum of all greenhouse gas emissions. In 2022, Austria's total greenhouse gas (GHG) emission (other than land use, land use change and forestry – LULUCF) amounted to 72.8 Mt CO_2 equivalents (CO_2e) (UB 2024, p. 9). The average person in Austria emitted 6.9 t CO_2 in 2022 (Ritchie and Roser 2024) compared with German's 12 t (Gröger 2020). According to Gröger (2020), the estimated CO_2e of digital activities totals 850 kg CO_2e per year. Based on LocaliQ data (Marino 2023), a lot can happen in a minute in today's hyper-connected Internet era, e.g. 231 million e-mails can be sent; in a day, 6 billion are sent and received. Daily e-mail traffic (of both business and public) exceeded 362 billion in 2024 (Radicati 2023). In 2019, the global digital CO_2 was equal to that of a country two to five times the size of France (Bordage 2019). Digital communications accounts for 2% to 4% of greenhouse gas emissions (EC 2024).

Wissner-Gross report that it takes on average about 20 milligrams of CO_2 per second to visit a website (Simpson 2009). An Apple iPhone13 produces 64 kg of carbon emissions (Apple 2021). Streaming 35 hours of video a month is equivalent to 2.68 metric tons of CO_2 (Marks et al. 2020). Berners-Lee (2020, p. 16) provides the average carbon footprints of different e-mails as follows:

- 0.03 g CO_2e for spam e-mail picked up by a filter;
- 0.2 g CO_2e for short e-mail sent/received on a phone;
- 0.3 g CO_2e for short e-mail sent/received on a laptop;
- 17 g CO_2e for long e-mail that takes 10 minutes to write and 3 minutes to read, sent/received on a laptop;
- 26 g CO_2e for an e-mail that takes 10 minutes to write and is sent to 100 people, of whom one reads it and the other 99 glances at it for 3 seconds and decide to ignore it.

The average business e-mails account for 131 kg of CO_2e per year, 22% of which is spam-related (McAfee 2009). If every person in the UK sent one e-mail less per day it would save 16.433 t of CO_2 per year (OVO 2019).

Materials and Methods

In this paper, evaluative (McDonough and McDonough 1997) and instrumental (Stake 1995) research methods were utilised. For purposes of evaluation, the data were divided into two parts: dependent (received per day, sent per day, standard e-mails, long e-mails with attachments/images, desktop/mobile) and independent variables (business and public). Data was collected for six months from September 2023 to February 2024 using both variables.

In order to satisfy this requirement, a quantitative study was conducted. The methodology used was that cited by Beno et al. (2022) and consisted of an ad hoc questionnaire in a real workplace environment in an Austrian company (in the region of Lower Austria) with workers at home (n = 10) and in the office (n = 10). The author has business contacts with organisation selected and the agreement to participate was given during an interview with the manager. This organisation was chosen as its staff either worked from home or office. A consent form between the researcher and research participants was agreed, which stipulated their roles and responsibilities towards one another throughout the entire research process.

A quantitative data collection was appropriate for this study because it allows a vast volume of data to be obtained from respondents. This was done using a search folder for incoming and outgoing e-mails for each participant and creation of a VBA code in Outlook. In addition, the organisation's own record of the total number of e-mails received/sent per day in a month was used. The respondents only noted the number of attachment/image e-mails in an Excel sheet on a daily basis. E-mails opened/sent using mobile phones were recorded and noted in an Excel sheet by the respondents. Finally, the data were analysed using Excel, statistical tools and SPSS, and a correlation analysis. In addition, Berners-Lee's (2020) and Fighiera's (2024) average CO_2e data was used to determine the @CO_2e. For this purpose, the following formula was used:

$$\mathbf{@CO_2e = a@ \times GWP \times sCO_2e}$$

where:

@CO_2e = e-mail carbon footprint

a@ = average number of types of e-mail (standard/long e-mails with attachments/images)

GWP (global warming potential) = **1** (Eurostat 2023)

sCO_2e = standard values of carbon footprint generated by different types of e-mail (the values were as follows: standard e-mail 0.4 g CO_2e, and long e-mail with attachments/images 50 g CO_2e (CWJOBS, n.d.))

Results

Carbon literacy is "an awareness of the carbon costs and impacts of everyday activities and the ability and motivation to reduce emissions on an individual, community and organisational basis" (CLP 2020, p. 2). As reported in the literature, receiving/sending e-mails re-

sults in a wide range of values of CO_2e. In order to protect the world, every step taken to reduce the production of CO2 is important. What about e-mails? It is important to know the amount of CO_2e generated using e-mails in business?

First, just like any digital channel, e-mailing relies on energy. Normally, e-mail is viewed as relatively eco-oriented. But, as there are enormous numbers of e-mail users, billions of e-mails are sent every day, all of which produce CO_2. The @CO_2e depends on various factors, e.g. weight, attachments, images, videos, recipient residence and storage. Generally, e-mails are not counted and used in mass as a tool in business and home environments to communicate in order improve mutual cooperation and relationships.

Based on the data collected in this study, e-mail is an integral part of modern communication in and within an organisation. On average, each day the in-house workforce received 35 and sent 118 e-mails via computers and received 10 and sent 45 e-mails via smartphones. At home, each day the workforce received 56 and sent 164 e-mails using computers and received 10 and sent 45 e-mails using smartphones. In terms of size: on average, the in-house employees received/sent 56 standard and 97 long e-mails with attachments/images each day. Those working from home received/sent 104 standard and 116 long e-mails with attachments/images each day.

In the cubicle in the office, the average number of e-mails (sent/received) is 153, consisting of 56 (36.6%) standard and 97 (63.4%) long e-mails with attachments/images. For business, the average daily number of e-mails (sent/received) is 220, consisting of 104 (47.3%) standard and 116 (52.7%) long e-mails with attachments/images. In order to determine whether there is a difference between the percentage of e-mails received/sent, the difference between the percentages was tested. The software only provides the p-value for these tests. There was a statistically significantly higher percentage of e-mails sent/received in the office than in the cubicle ($p < 0.001$), but the percentage of long e-mails with attachments/images for the cubicle is statistically significantly higher than for the office ($p = 0.0194$). The percentage of standard e-mails is statistically significantly higher for the office than the cubicle ($p = 0.020$).

As mentioned above, billions of e-mails are sent on a daily basis, all of which produce CO_2e. As shown in Table 1 (see figures in bold), e-mails from home emit more emissions than those from the office.

The average e-mail traffic recorded for the office and home emits more CO_2e per day than commuting by diesel car 27 km a day, as shown in Table 2 (see figure in bold).

E-mails sent/received in the office emit more CO_2e per year than heating/cooling, as demonstrated in Table 3 (see figures in bold).

Discussion

According to Huang and Shyu (2009), e-mailing is valuable for cultivating relationships. Comparable to the data recorded in this study (in terms of the average num-

Table 1 CO_2e.

Average /Day		Standard in kg	Long with attachment /image in kg	Average /Year	Long with attachment /image in kg	Standard in kg	Total in t
	Office	0.022	4.85		4.748	1028.2	**1.03**
	Home	0.041	5.80		8.819	1229.6	**1.24**

Table 2 Daily CO_2e of different modes of transport (Based on UNFCCC 2021; Statistics Austria 2024).

Mode	Factor	Average km	kg CO_2e/day	kg CO_2e/ year	Total in t
Bus	0.103	27	2.78	590.26	0.59
Diesel car	0.168		**4.55**	964.15	0.96
Metro	0.027		0.74	157.41	0.16
Railway	0.036		1.00	211.44	0.21

Table 3 Yearly CO_2e that was emitted heating the office (Based on UNFCCC 2021).

	Consumption kWh/hour	Working hours per day (141.33)	Factor 0.13	kg CO_2e	Total in t
Heating (2 months)	0.15	21.199	2.755	5.51	**0.01**
Cooling (3 months)	3.65	515.845	67.061	201.18	**0.20**
Heating (7 months)	5.15	727.849	94.620	662.34	**0.66**

ber of e-mails sent/received), e-mail promotes business and strengthens relationships in a variety of ways. This is similar to the situation in Australia, where at least 121 e-mails are sent/received every day (Jenkin 2014).

Generally, the sending of e-mails is not synchronized (Mick and Middlebrook 2015; Palupi 2022). But based on the data collected, the percentage of standard e-mails sent from the office is significantly higher than from the where at least 121 e-mails are sent/received every day (Jenkin 2014).

Generally, the sending of e-mails is notcubicle ($p = 0.020$). This means that e-mails sent/received in the office are synchronous because workers are expected to respond to an e-mail right away.

This study reports that e-mails emit CO_2e. Bordage (2019) highlights the carbon footprint has increased due to modern digital technology. Furthermore, consuming one euro of digital technology in 2018 induced direct and indirect energy consumption 37% higher than in 2010 (Theshiftproject 2019). In both work environments, CO_2e is higher than when commuting 27 km by a diesel car or even when heating/cooling an e-office. Digital technology can indirectly reduce CO_2e (Shen et al. 2023), but recent research indicates that nearly 72% of UK citizens are unfamiliar with the CO_2e associated with their inbox (OVO 2019). When determining the CO_2e of e-mails, size must be considered. For a long e-mail with an attachment/image, more electricity is needed, therefore the e-mail emits a greater weight of CO_2e (4.85 kg and 5.8 kg of CO_2e daily in the office and home respectively). As explained by Fighiera (2024), it is more impressive when the whole volume of CO_2 emitted by e-mails exchanged daily in the world is considered. As stated by Beňo (2021), despite the numerous benefits of digital technology, there is a need to emphasize its effect on the environment as reported in this study.

Conclusions

What appears to be a green activity, such as sending and receiving e-mails, can result in the emission of CO_2e. It is likely the online world will continue to expand. For this reason, it is necessary to have a better understanding of the digital contribution to global change due to e-mail CO_2e. This study collected the data necessary for answering the following research questions:

- What is the estimated CO_2e emission from e-communications sent from home and offices?

E-communication is an essential aspect of daily life, but it also affects the environment. Based on the data collected, sending e-mails is seen as eco-oriented, but it results in the emission of CO_2e. The volumes of 1.03 t for those sent from home and 1.24 t for those sent from offices per year are not very large, but if considered globally it is much greater. The weight of the emissions resulting from the use of e-mails is significant: 4.85 kg and 5.8 kg of CO_2e produced daily for home and office use, respectively. Although significant it is much less than from other sources of pollution. One should start by limiting the size of e-mails clean-up your mailbox. All in all, the effect of e-mails is smaller and greener than other sources, but this does not mean it should not be reduced.

This topic is complex and solutions to reduce CO_2e need collaboration between different stakeholders. A decrease of $@CO_2e$ may be achieved by encouraging the workforce to use eco-friendly practices.

A limitation of this research is that a retrospective measure of e-communication was used for estimating the $@CO_2e$ in only one department of one company in Lower Austria. Thus, it was not possible to test it. Further, it would be difficult to repeat this study due to various factors, e.g. the type of industry, the availability of data on home and office use of e-mails. Thirdly, the analysis was constrained by the data and limited time available.

Qualitative study needs to be part of future studies. In addition, it should include the hidden cost of spam e-mails, which could be significant as the spam folders of many computers contain very large numbers of e-mails.

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MATHEMATICAL STUDY OF THE EFFECT OF TUNED LIQUID DAMPERS IN MITIGATING THE EFFECTS OF VIBRATIONS ON BUILDINGS RESULTING FROM EARTHQUAKES AND EXPLOSIONS

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ABSTRACT

Recently, accidents at critical infrastructure facilities due to seismic activity, military explosions and accidents have become more frequent. The importance of studying such events in terms of the preservation and improvement of the environment and the sustainable development of any country is beyond doubt. These man-made effects negatively affect the environment. The hazardous materials released pollute soil, and surface and groundwater. Dust and emissions reduce the quality of the atmosphere. Destroyed objects could disrupt and degrade ecosystems resulting in a reduction in biodiversity. In this regard, a comprehensive analysis of the system to increase the environmental safety level of buildings and different technogenic objects under seismic loads, military explosions and emergencies, the development of theoretical models and practical solutions to ensure their stability and reduce environmental threats, is an urgent scientific task. The aim of this paper is to study the effectiveness of tuned liquid dampers in mitigating structural damage when subjected to vibrations. Tuned liquid dampers are strong tanks, partially filled with liquid, which are strongly integrated into a flexible structure. A numerical model that incorporates the interaction between a structure and a tuned liquid damper was developed. The structure is assumed to be a single degree of freedom system. To obtain the fundamental frequencies of a tuned liquid damper, the boundary element method was used. The novelty of the proposed method is that it defines the mitigation of vibrations in a structure with a tuned liquid damper.

Keywords: critical infrastructure; environmental safety; mitigation of vibrations; seismic loads; tuned liquid damper; vibration control

Introduction

Recently, damage to important facilities due to earthquakes, military explosions and accidents have become more frequent. The relevance of studying the effect of earthquakes on such facilities in order to preserve and improve the environment and ensure sustainable development of a country is beyond doubt.

Buildings and facilities destroyed by earthquakes negatively affect the environment as dangerous materials from these structures pollute the soil and surface and groundwater and dust reduce the quality of the atmosphere. In addition, they could disrupt and degrade ecosystems and adversely affect biodiversity.

Thus, it is important to increase the environmental safety level of buildings and other structures in areas subject to earthquakes and explosions, which can be done by developing theoretical models and practical solutions that ensure their stability and reduce the threat to the environment.

Problem Formulation

The increase in critical incidents has resulted in research on the vibration damping of elastic structures. A large number of damping devices have been developed to reduce vibrations (Ghaedi et al. 2017). Among them are membranes (Choudhary et al. 2021) and baffles (Zhang et al. 2020) in fuel tanks, as well as shock-absorbing suspensions in vehicles (Fang et al. 2024). Tuned liquid dampers (TLDs) are an effective means of suppressing vibrations that are currently widely used as passive or semi-active control devices for controlling vibrations of tall buildings and other high-rise structures with different dynamic loading conditions. These damping devices consist of rigid, thin-walled structures partially filled with liquids that are integrated into a structure. The inclusion of TLDs in structures can enhance their performance, particularly during high winds and earthquakes. The sloshing of the fluid in TLDs can generate pressures that alter both the dynamic characteristics of the structure and its response to vibrations. Tuning the sloshing frequency of the TLD to a structure's natural frequency results in sloshing and breaking waves at the resonant frequencies of the combined TLD-structure. Therefore, the problem of determining the fundamental frequencies of liquid sloshing in rigid tanks is important for research on problems of vibration damping.

The use of TLDs to reduce structural vibration in civil engineering was first proposed by Bauer (1984), who suggested the use of rectangular containers complete-

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ly filled with two immiscible liquids. Since then, many studies have resulted in control devices for stabilizing tall buildings (Wang et al. 2021; Wang et al. 2024), vehicle suspension (Fang et al. 2024), as well as more effective numerical methods for analyzing liquid sloshing (Gnitko et al. 2019; Saghi et al. 2021; Zheng et al. 2021) and structure stability (Zang et al. 2020; Smetankina et al. 2023). The finite element (Zaitsev et al. 2020; Konar and Ghosh 2023) and finite volume (Rusanov 2020) methods are highly efficient for solving problems related to fluid-structure interaction. The use of tuned liquid dampers with baffles is reported in Rusanov et al. (2020) and Konar (2024). The effect of horizontal and vertical baffles on sloshing frequencies in tanks used as liquid dampers, is reviewed by Strelnikova et al. (2020).

TLDs are especially effective in suppressing vibrations of structures during earthquakes (Gnitko et al. 2011), high winds (Liu et al. 2022) and explosions (Sierikova et al. 2023). However, these effects are often characterized by uncertainties. Sloshing in tanks of different forms is reviewed by Sierikova et al. (2022b). In addition, the improving of the Mechanical Properties of Liquid Hydrocarbon Storage Tanks is reported by Sierikova et al. (2022a) and strengthening of the steel of the tanks by chemical-thermal treatment is reported by Savchenko et al. (2022).

Problem Solution

The basic consideration is a single degree of freedom elastic system equipped with TLD, designed to control oscillations induced by external loads. The TLD absorbs energy by the liquid in the tank moving in the opposite direction to the movement in the structure. Fig. 1a illustrates this concept schematically, showing the motion of the liquid relative to the structure.

Equations of crisp boundary value problem for liquid motion

Rigid containers in TLDs are generally rectangular or circular. In this study an arbitrary shell of revolution is the TLD tank, Fig. 1). The liquid inside the tank is assumed to be incompressible. and are the time-dependent liquid free surface and shell wetted surface. Assuming that initially $S_0(0) = \Sigma_0$ and $S_1(0) = \Sigma_1$ and the free surface Σ_0 is located in the plane z = 0 when the system is in a state of rest.

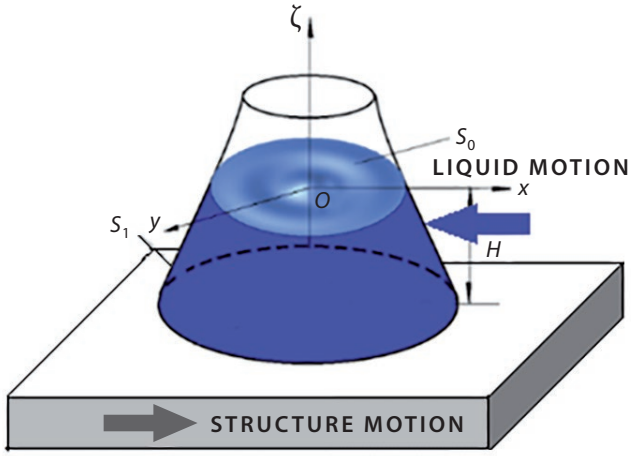

Fig. 1 Structure with tuned liquid damper.

The domain $Q(t)$, occupied by the liquid, in the cylindrical coordinate system (r, θ, z) is:

$$Q(t) = \{0 \le \theta \le 2\pi, 0 \le r \le r(z), -H \le z \le \zeta(r, \theta, t)\}.$$

In which describes the shell meridian, the unknown function ζ = ζ(θ, r, t) characterizes the time-dependent free surface elevation.

The continuity equation is , where **V** = 0 is the velocity of the liquid. If the fluid flow is free of vortices, a scalar velocity potential Φ = Φ(*x*,*y*,*z*,*t*) exists, and the continuity equation simplifies to the Laplace equation . When an external force $\mathbf{F}_Q$, with acceleration $\mathbf{a} = a_x(t)\mathbf{i}$ is applied to the liquid-filled shell in the horizontal direction, and the force of gravity in the vertical direction, the equation for liquid movement is derived using the law of momentum conservation as follows:

$$\rho_l \left(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{V} \cdot \nabla)\mathbf{V} + \mathbf{a} + \mathbf{g}\right) = -\nabla p, \quad (1)$$

where p is the liquid pressure, ρ_l is the liquid density, and g is the acceleration due to gravity. Thus, it follows from (1), that for potential flows

$$p - p_0 = -\rho_l \left[\frac{\partial \Phi}{\partial t} + gz + a_x(t)x + \frac{1}{2}(\nabla\Phi, \nabla\Phi)\right]. \quad (2)$$

Here p_0 is atmospheric pressure. Then boundary value problem for the Laplace equation in the time-dependent fluid domain $Q(t)$ is specified. At the wetted surface S_1 the impermeability condition is:

$$\partial\Phi / \partial\mathbf{n}|_{S_1} = 0, \quad (3)$$

where **n** is the normal external unit for a wet surface S_1. In addition to the no-slip condition (3) of the wet surface, dynamic and kinematic boundary conditions are imposed on the free surface S_0 as follows:

$$\frac{\partial\Phi}{\partial\mathbf{n}} = \left.\frac{\partial\zeta/\partial t}{\sqrt{1+|\nabla\zeta|^2}}\right|_{S_0},$$

$$\frac{\partial\Phi}{\partial t} + gz + a_x(t)x + \frac{1}{2}(\nabla\Phi, \nabla\Phi) = 0. \quad (4)$$

The solvability condition for Neumann's problem (3)–(4) is derived in Raynovskyy (2020) and takes the form:

$$\iiint_{Q(t)} dQ(t) = 0. \quad (5)$$

The initial data for the boundary value problem (3)–(5) are:

$$\zeta(x, y, 0) = \zeta_0(x, y) = 0, \quad \left.\frac{\partial\Phi}{\partial\mathbf{n}}\right|_{\Sigma_0} = \varphi(x, y, 0). \quad (6)$$

Thus, the problem of estimating pressure is reduced to determining the unknown functions Φ and ζ using the boundary value conditions (3)–(4) for the Laplace equation, along with initial data (6). To solve this problem, expansions in series using eigenfunctions of the spectral boundary problem (Strelnikova et al. 2020; Raynovskyy and Timokha 2020) were used. Thus, it is necessary to determine the fundamental frequencies and modes of oscillation of the fluid within the rigid shell.

Spectral boundary problem in the shell of revolution

The spectral boundary value problem (Raynovskyy and Timokha 2020) is the determining of the vibration modes and frequencies of liquids in partially filled rigid reservoirs in linear formulation. As the reservoir is assumed to have a rigid shell (Fig. 1b). According to (Raynovskyy and Timokha 2020), the unknown functions ζ i **Φ** in cylindrical coordinates (*r*,q,*z*) are represented by the following:

$$\zeta(r,\theta,t) = \sum_{k=1}^{n} d_k(t)\zeta_k(r,\theta), \tag{7}$$

$$\Phi(r,\theta,z,t) = \sum_{k=1}^{n} \dot{d}_k(t)\varphi_k(r,\theta,z). \tag{8}$$

Here n φ_k(r, θ) and n ζ_k(r, θ) are basic functions, and $d_k(t)$ are unknown time-dependant coefficients. For unknown basic functions in (7)–(8) the linear boundary value problems are (Strelnikova et al. 2020):

$$\nabla^2\varphi_k = 0, \mathbf{P}\in Q(0),\ \frac{\partial\varphi_k}{\partial\mathbf{n}} = 0\Big|_{\Sigma_1}, \frac{\partial\varphi_k(r,\theta,z)}{\partial\mathbf{n}} = \frac{\chi_k^2}{g}\varphi_k(r,\theta,H)\Big|_{\Sigma_0}, \tag{9}$$

where χ_k are the fundamental frequencies.

To solve the boundary problems (9), formulated above, the Green third formula is used as follows:

$$2\pi\varphi(\mathbf{P}_0) = \iint_S \frac{\partial\varphi}{\partial\mathbf{n}}\frac{1}{|\mathbf{P}-\mathbf{P}_0|}dS - \iint_S \varphi\frac{\partial}{\partial\mathbf{n}}\frac{1}{|\mathbf{P}-\mathbf{P}_0|}dS, S = \Sigma_0\cup\Sigma_1 \tag{10}$$

Here, the points **P** and $\mathbf{P}_0$ are located on the integration surface *S*, and $|\mathbf{P} - \mathbf{P}_0|$ are the Cartesian distance between these points and index *k* is omitted in (10) for simplicity. Applying boundary conditions of spectral boundary value problem (9), one obtains the following system of singular integral equations:

$$2\pi\varphi(\mathbf{P}_0) + \iint_{S_1}\varphi\frac{\partial}{\partial\mathbf{n}}\left(\frac{1}{|\mathbf{P}-\mathbf{P}_0|}\right)dS_1 - \frac{\chi^2}{g}\iint_{S_0}\frac{\varphi}{|\mathbf{P}-\mathbf{P}_0|}dS_0 + \iint_{S_0}\varphi\frac{\partial}{\partial\mathbf{n}}\left(\frac{1}{|\mathbf{P}-\mathbf{P}_0|}\right)dS_0 = 0,\ \mathbf{P}_0\in S_1, \tag{11}$$

$$2\pi\varphi(\mathbf{P}_0) + \iint_{S_1}\varphi\frac{\partial}{\partial\mathbf{n}}\left(\frac{1}{|\mathbf{P}-\mathbf{P}_0|}\right)dS_1 + \left(-\frac{\chi^2}{g}\right)\iint_{S_0}\frac{\varphi}{|\mathbf{P}-\mathbf{P}_0|}dS_0 = 0,\ \mathbf{P}_0\in S_0, \tag{12}$$

In the following, shells of revolution are considered. For this purpose, the series below are employed:

$$\zeta(r,\theta,t) = \sum_{k=1}^{n}\sum_{l=0}^{m} d_{kl}(t)\cos(l\theta)\zeta_k(r),$$
$$(r,\theta,z,t) = \sum_{k=1}^{n}\sum_{l=0}^{m}\dot{d}_{kl}(t)\cos(l\theta)\varphi_k(r,z),$$
$$\frac{\partial\varphi_k}{\partial\mathbf{n}} = \frac{\chi_k^2}{g}\varphi_k\Big|_{\Sigma_0} \tag{13}$$

where *l* is the wave number.

This leads to the next set of one-dimensional singular integral equations:

$$2\pi\varphi(r_0,z_0) + \int_\Gamma\varphi(r(z),z)\Theta(z,z_0)r(z)d\Gamma - \frac{\chi^2}{g}\int_0^R\varphi(\rho,H)\Xi(\mathbf{P},\mathbf{P}_0)\rho d\rho = 0.$$
$$2\pi\varphi(r_0,H) + \int_\Gamma\varphi(r(z),z)\Theta(z,z_0)r(z)d\Gamma - \frac{\chi^2}{g}\int_0^R\varphi(\rho,H)\,\Xi(\mathbf{P},\mathbf{P}_0)\rho d\rho = 0,\ \mathbf{P}_0\in S_0, \tag{14}$$

with the following kernels

$$\Theta(z,z_0) = \frac{4}{\sqrt{a+b}}\left\{\frac{1}{2r}\left[\frac{r^2-r_0^2+(z_0-z)^2}{a-b}E_l(k) - F_l(k)\right]n_r + + \frac{z_0-z}{a-b}E_l(k)n_z\right\},$$
$$\Xi(P,P_0) = \frac{4}{\sqrt{a+b}}F_l(k),\ a = r^2 + r_0^2 + (z-z_0)^2,$$
$$b = 2rr_0$$

The generalized elliptic integrals are introduced beforehand as

$$E_l(k) = (-1)^l(1-4l^2)\int_0^{\pi/2}\cos 2l\theta\sqrt{1-k^2\sin^2\theta}\,d\theta$$
$$F_l(k) = \int_0^{\pi/2}\frac{\cos 2l\theta d\theta}{\sqrt{1-k^2\sin^2\theta}}d\theta,\ k^2 = 2b/(a+b). \tag{15}$$

The numerical implementation of equations (14) was done using the boundary element method with constant approximation of the density (Brebbia et al. 1984), while the generalized elliptic integrals (15) were computed using the method of Karaiev and Strelnikova (2020).

After determining the basic functions and fundamental vibration frequencies, substitute functions $\cos(l\theta)\zeta_k(r)$ and $\cos(l\theta)\varphi_k(r, z)$ into linearized dynamic condition (4) of the free surface and used to derive differential equations for unknowns $d_{kl}(t)$. The acceleration **a** appearing in the dynamic boundary condition represents the acceleration of the elastic body, the vibrations of which need to be reduced using a tuned liquid damper.

Resolving system of differential equations

The coupled problem formulation of the vibration damping of an elastic structure using a tuned liquid damper can be presented in the following form (Gnitko et al. 2011):

$$[\mathbf{M}_S]\{\ddot{\mathbf{u}}^s\} + [\mathbf{C}_S]\{\dot{\mathbf{u}}^s\} + [\mathbf{K}_S]\{\mathbf{u}^s\} = \{\mathbf{f}_S\} + \{\mathbf{f}_{pr}\} \tag{16}$$

where $[\mathbf{M}_s]$, $[\mathbf{C}_s]$, $[\mathbf{K}_s]$, are matrices of masses, damping and stiffness, respectively, $\{\mathbf{f}_s\}$ is an unknown structure displacement vector, is the vector of applied forces acting on the elastic structure, and $\{\mathbf{f}_{pr}\}$ is the force vector

representing the fluid pressure from the TLD. To obtain the pressure vector $\{\mathbf{f}_{pr}\}$, the results of the previous section are used. Namely, the linearized dynamic boundary condition on the free surface is used for estimating the unknown coefficients $d_{kl}(t)$. This results in the following differential equations:

$$\left[\boldsymbol{M}_f\right]\{\ddot{\mathbf{d}}\} + \left[\boldsymbol{K}_f\right]\{\mathbf{d}\} + \rho_l\{\mathbf{a}\} = 0, \quad (17)$$

where **a** is the acceleration due the elastic movement of the structure.

Thus, the coupled system of differential equations (16)–(17) can be used to carry out a dynamic analysis of the behaviour of an elastic structure in the presence of TLD in the form

$$[\mathbf{M}_S]\{\ddot{\mathbf{u}}^s\} + [\mathbf{C}_S]\{\dot{\mathbf{u}}^s\} + [\mathbf{K}_S]\{\mathbf{u}^s\} = \{\boldsymbol{f}_S\},+ \{\mathbf{f}_{pr}\}\left[\boldsymbol{M}_f\right]\{\ddot{\mathbf{d}}\} + \left[\boldsymbol{K}_f\right]\{\mathbf{d}\} + \rho_l\{\ddot{\mathbf{u}}^s\} = 0. \quad (18)$$

To solve this zero was introduced into the initial conditions, ensuring that the "elastic structure-tuned liquid damper" system is initially at rest.

In the first stage, the problem of determining the frequencies and modes of the elastic structure is solved without considering the tuned liquid damper effect. If damping is not taken into account, the following equations are obtained:

$$[\boldsymbol{M}_S]\{\ddot{\mathbf{u}}^s\} + [\boldsymbol{K}_S]\{\mathbf{u}^s\} = 0. \quad (19)$$

By solving this problem, the natural vibration frequencies Ω_k and modes $\mathbf{u}_k(r, \theta, z)$ are obtained, which here after are the basic functions. Consequently, the displacements of the coupled problem are presented as a series

$$\mathbf{u}^s(x, y, z, t) = \sum_{k=1}^{N} c_k(t)\mathbf{u}_k(x, y, z), \quad (20)$$

where unknown coefficients $c_k(t)$ are treated as generalized coordinates.

Next, the spectral boundary value problem of determining the frequencies and modes of liquid vibrations in the rigid tank are solved (Gnitko et al. 2019; Raynovskyy and Timokha 2020).

With the basic functions $\varphi_k(r, z)$ and $\zeta_k(r)$ known, the vector $\{\mathbf{f}_{pr}\}$ will be obtained applying the pressure p derived from the relations

$$\mathbf{p} = p\,\mathbf{n}, p = \rho_l\left(\frac{\partial\Phi}{\partial t} + gz\right), p = \rho_l[\sum_{k=1}^{n}\ddot{d}_k(t)\varphi_k(r, z) + gH + \sum_{k=1}^{n} d_k(t)\zeta_k(r)]. \quad (21)$$

The value of $\{\mathbf{f}_{pr}\}$ is obtained by integrating the product of the pressure, given by equation (21), and the eigenmodes $\mathbf{u}_k(x, y, z)$ of the elastic structure over the wetted surface adjacent to the structure.

Accepting $c_{kl}(t)$ and $d_{kl}(t)$ as generalized coordinates enables the reduction of the resolving system of the differential equations for each wave number l to

$$[\mathbf{M}][\ddot{\mathbf{c}}] + [\mathbf{C}][\dot{\mathbf{c}}] + [\mathbf{K}][\mathbf{c}] + [\mathbf{R}]\left[\ddot{\mathbf{d}}\right] = \{\tilde{\mathbf{f}}_s\}[\mathbf{M}_f]\{\ddot{\mathbf{d}}\} + [\mathbf{K}_f]\{\mathbf{d}\} + \rho_l\{\ddot{\mathbf{c}}\} = 0. \quad (22)$$

Here

$$[\mathbf{M}] = \left\{\mathbf{M}_S\mathbf{u}_k, \mathbf{u}_j\right\}, [\mathbf{C}] = \{\boldsymbol{C}_S\mathbf{u}_k, \mathbf{u}_i\}, [\mathbf{K}] = \left\{\mathbf{K}_S\mathbf{u}_k, \mathbf{u}_j\right\}, [\mathbf{R}] = \left\{\mathbf{f}_{pr}, \mathbf{u}_j\right\}, \{\tilde{\mathbf{f}}_s\} = \left\{\mathbf{f}_s, \mathbf{u}_j\right\}.$$

In this study the analysis addresses horizontal external excitation was considered, focusing solely on the first wave component ($l = 1$) in the series expansions of Φ and ζ.

Results and Discussion

Benchmark test

The fundamental frequencies are calculated according to (Afsari et al. 2022) using the reduced boundary element method in linear formulation. The total number of boundary elements along the shell meridians and radii of the free surfaces is 240 for cylindrical shells.

The sloshing frequencies of the liquid in the rigid cylindrical shell with the filling level H = 1 m, and radius R = 1 m have been obtained.

A comparison of numerical and analytical results from (Raynovskyy and Timokha 2020) for $l = 0$ (axisymmetric modes) for different k is provided in Table 1.

Table 2 provides a comparison of numerical and analytical results (Raynovskyy and Timokha 2020) for $l = 1$ (non-axisymmetric modes) with varying k.

The above results demonstrate the accuracy of the proposed numerical method, exhibiting close agreement with the analytical solutions.

Table 1 Axisymmetric sloshing frequencies, Hz, $l = 0$.

k	Analytical solution	Numerical solution
1	3.828	3.828
2	7.015	7.015
3	10.173	10.176
4	13.323	13.326
5	16.470	16.475

Table 2 Non-axisymmetric sloshing frequencies, Hz, $l = 1$

k	Analytical solution	Numerical solution
1	1.667	1.667
2	5.330	5.330
3	8.536	8.536
4	11.706	11.709
5	14.863	14.866

Analysis of the tuned liquid damping

This study investigates the effect of a liquid damper in reducing the vibration amplitudes of an elastic plate under periodic loading. The analysis is restricted to a one degree of freedom elastic structure represented by the quadratic elastic steel plate, with following parameters: side length of 5 m, thickness of 0.1 m, Young's modulus $E = 210$ GPa, Poisson's ratio $\nu = 0.3$, and the material density $\rho_s = 7900\,\text{kg/m}^3$.

The following function is chosen as loading dependent in time $a_x(t) = a_0 \cos(f_0 t)$, with different frequencies $f_0 = (2.0, 5.9, 6.6)$, and amplitude $a_0 = (0.01, 0.05, 0.1)$. Using the method of Liu et al. (2022), the modes of free vibrations are obtained as beam functions that describe the displacements of a plate clamped on all edges.

The first frequency of the plate was estimated as

$$\Omega_1 = \frac{\pi^2 h}{a^2}\sqrt{\frac{EF}{6\rho_s(1-\nu^2)}} = 6.643\text{Hz}, \tag{23}$$

where for the first frequency parameter F 22.52 according to Liu (2022). The liquid tuned damper is a rigid cylindrical shell, partially filled with an ideal incompressible liquid. The cylinder radius R is 1m, and the filling level H is 1m. Figs 2–4 show the tuned liquid damper's mitigating effect on the plate vibrations.

In the figures, the navy lines are the displacements in the absence of damper and black lines the displacements considering the influence of damping. These results indicate that, despite detuning from the lower frequency of the plate vibrations, both a beat regime (Fig. 4) and a linear increase (Fig. 5) in vibration amplitude is recorded. It is important to note that the vibrations of the plate were considered without including damping [matrix $\mathbf{C} = 0$ in equations (21)]. However, the installation of the tuned liquid damper significantly reduced the amplitudes of the plate vibrations in all the cases considered (Grigorenko and Efimova 2005; Ahmadiani et al. 2018; Wang et al. 2020; Liu et al. 2022).

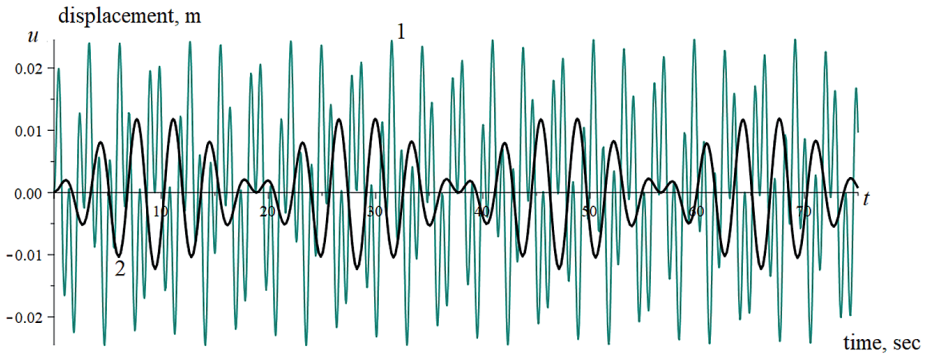

Fig. 2 Plate displacement over time at $f_0 = 2$Hz, $a_0 = 0.01$m.

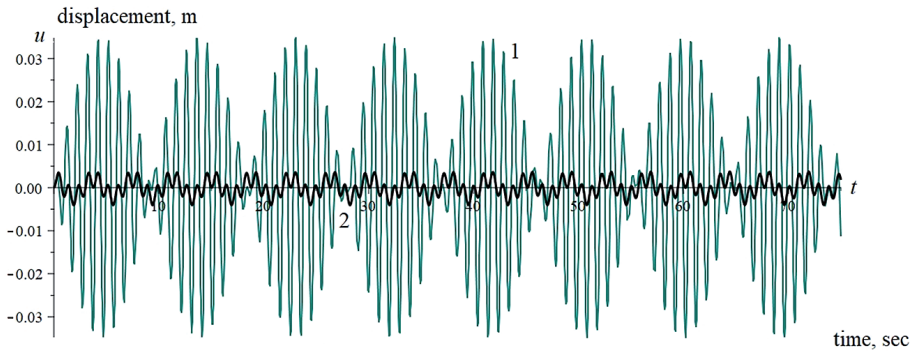

Fig. 3 Plate displacement over time at $f_0 = 5.9$Hz, $a_0 = 0.05$m.

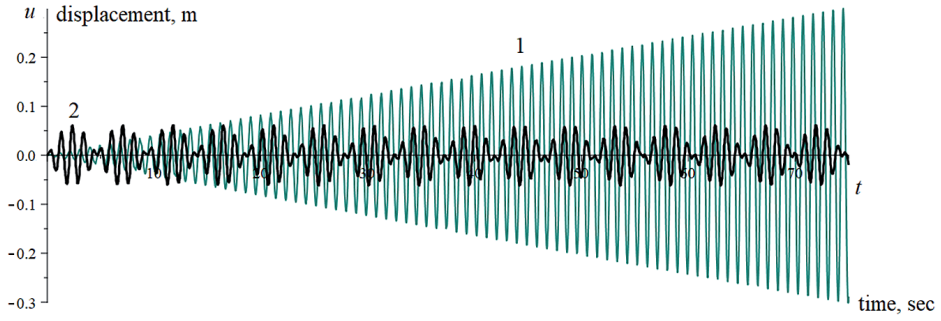

Fig. 4 Plate displacement over time at $f_0 = 6.6$Hz, $a_0 = 0.1$m.

Moreover, even in the case when the forcing frequency nearly coincides with the lowest natural frequency of the plate vibrations and the forcing amplitude is the largest among the studied cases, the tuned liquid damper still provides effective suppression of the plate oscillations.

Thus, the application of a tuned liquid damper consistently results in a substantial decrease in plate vibration amplitudes, in full agreement with the findings of other researchers.

Conclusion and further research

A method is developed for studying the influence of a tuned liquid damper in mitigating the vibration of an elastic structure. The method is based on the use of integral equations to determine the frequencies and vibration modes of a tuned liquid damper. The effective numerical procedure is elaborated to numerical estimation for the singular integrals.

The use of a liquid damper resulted in a significant reduction in the amplitude of vibration of an elastic element over the load range used. The use of liquid dampers will ensure the stability of buildings and critical infrastructure facilities and reduce environmental threats posed by earthquakes and explosions.

In the future work, the focus will be on developing the capability to account for uncertainties in the specification of external loads. Preliminary studies have already examined seismic excitations with different prevailing frequencies. In addition, the influence of other reservoir geometries will be investigated to extend the applicability of the proposed approach.

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HOW TO SAVE SITES CONTAINING PROTECTED PLANTS IN NATIONAL PARKS IN AREAS THAT BELONG TO PRIVATE OWNERS

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ABSTRACT

Biodiversity loss in national parks is increasingly due to private ownership of ecologically valuable land. This paper explores a critical yet under-discussed challenge: how to safeguard habitats hosting protected species of plants when these sites are privately owned. Focusing on Czech national parks, the legal frameworks, practical obstacles and real-world cases of land swapping, which is a promising but complex strategy that exchanges high-conservation plots for less sensitive areas, are analysed. While successful cases, such as that in Šumava, demonstrate that negotiated exchanges can prevent habitat destruction, other cases, including the long-running conflict at Jelení louky in Krkonoše National Park illustrates systemic weaknesses, from administrative loopholes to misleading narratives undermining plant protection. It is emphasized that proactive policies, rigorous enforcement and international knowledge-sharing are essential for preventing irreversible biodiversity loss. Based on lessons learned and proposing paths for dialogue, this study calls for collaborative solutions and opens a forum for a global dialogue on balancing development and nature conservation.

Keywords: developers; national parks; private ownership; protected plants; site swapping

Introduction

Species are disappearing worldwide, and the expectation is that this will increase in the future (Román-Palacios and Wiens 2020). The literature indicates that the most important factors responsible for this are changes in climate and land use (WWF 2020; Antonelli et al. 2023). As changes in land use result in the destruction of natural habitats they are likely to be the prime driver in the future. A particular emphasis should be placed not only on conserving specific species, but also the environment and communities they live in. There are, however, many other contributing factors and this paper concentrates on only one of them: the effect of private people, so called property developers, who buy land in National Parks (NPs) or close to their most important parts, the natural zones.

Loss of biodiversity in national parks caused by property developers

These people aim to convert acquired land into building areas, where they wish to build commercially used buildings for profit. It may be for example apartment houses containing dozens of flats for rent, restaurants etc. In other words, the property developers convert the most precious parts in the National Park into commercial property. This was very popular in the Czech Republic, maybe more than in other countries, because after the Velvet Revolution in 1989 the government nationalised a lot of undeveloped land that then became the property of the state (land vacated by the Germans after the war, or land converted into military areas). State then made money by selling this land to private people. Consequently, the problem was that if there were important habitats in these lands, the associated plants and animals were endangered, or even lost, because the private owners are rarely interested in them. The expectation was that nature protection organizations would buy the land, but they had very little money for this.

In theory, the solution of this problem could have been simple: just introduce laws forbidding private people from buying land where there are habitats that need to be conserved. There are such rules: in the National parks, most of them are likely to be in undeveloped land. Therefore, the legal position is: (1) if the undeveloped land belongs to the state, it cannot be privatized. (2) Any person who owns and wants to sell undeveloped land must first offer it to the state, who has to inform the vendor within 60 days whether it wants to buy it or not. This means that the state is interested in increasing the area of undeveloped areas in national parks.

However, as stated above, a substantial part of the state-owned undeveloped areas was sold to private people soon after WWII, i.e., long before the government realized that selling this land adversely affects local biodiversity. The simplest way to re-obtain this land is to buy it from the present owners, the developers. However, this is very costly, because developers want to make money and they are not legally bound to sell their land. In addition, in most cases the NP administration (hereinafter referred to as the Administration), has little money and it is very rarely used except to purchase small cheap sites, where botanically important plants grow.

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Fig. 1 General view of meadows on Zhůří (Šumava NP) saved by successful swapping (photo made by Z. Štípková).

There is another way of acquiring important sites: swapping land owned by private developers for land of little conservation importance. The NP Administration owns a large amount of land in the open countryside and in developed and built-up areas. If some of this land is not needed by the Administration, it may be offered to property developers in exchange for their land.

There is a lot of land that is not needed for conservation. For example, there are isolated plots of land belonging to private individuals who intend to use it in a way that is contrary to the objective of the national park. If the landowner knows that the land is not of great value but does not want to sell it there is the possibility of exchanging it for land of less conservation value. This is not always successful. Below one positive and one negative example of an outcome is presented.

Positive example of the way to save important sites

A good example is the director of the Šumava National Park, who was able to persuade property developers to exchange their land with important habitats for land of little conservation value. Thus, it is important to have somebody in the NP administration who is prepared to argue the case for swapping land for conservation purposes.

Swapping usually takes a long time and does not always end successfully. Currently there are at least 3 cases pending in Šumava. An exchange was successfully completed in Zhůří by Rejštejn (Figs. 1–3), but it took 8 years.

Negative example

In other regions, it has not been possible to prevent the loss of biodiversity caused by property developers. A good example of this is the Krkonoše National Park (KRNAP) and its valuable enclave Jelení louky ("Deer meadows").

There has been a decades long debate about the presence of commercial buildings at Jelení louky in a mountain meadow in an alpine landscape above Zelený důl in the Krkonoše National Park. The story begins with the buildings depicted in Figs. 4 and 5, and culminates in the current plan for the building of a new apartment-style resort called 'Bouda Jelení potok' (Figs. 6–9).

The biggest changes at this location occurred between 1989 and 2025:

- ***Beginning: an extension that was never built (1989–1994)***

  In 1989, documents were submitted for an extension to the existing recreational facility operated by ČSAD Praha 9. The building permit was issued in April 1990,

Fig. 2 Parts of meadows on Zhůří, ruins of old settlement in the right part (photos made by Z. Štípková).

but due to political changes only the basement was built. In 1992, the permit was extended with the condition that the building be the same size as the previous building, but the permit expired and work ceased in 1994. In 1998, this building ceased to be used.

- ***New planning: zoning regulation and sensitive locations (2011)***
  The 2011 land-use plan Pec pod Sněžkou classified Jelení louky as a green zone with isolated homesteads. In such areas, further construction was rarely allowed at sites where there were buildings in the past, and must respect the landscape character, scale, and limits of the infrastructure. The two small buildings at this site set the scale of any future buildings.
- ***Turning point: demolition of the historic buildings and the first large-scale project (2013–2014)***
  In 2013, the property was acquired by Salert a.s. who wanted to build a large building 'Nad Jelením potokem'. In the summer of 2014, the original building was demolished without permission. In the same

Fig. 3 Orchid species saved by successful swapping on the meadows in Zhůří – from left to right: *Pseudorchis albida*, *Dactylorhiza viridis*, *Dactylorhiza majalis* (photos made by Z. Štípková).

Fig. 4 Archive photograph of the meadow enclave Jelení louky.

year, a building permit was issued for a large apartment building (approx. 15,000 m^3), but after appeals from the town and National Park Administration (KRNAP), the regional building office cancelled it before it became effective. Subsequent attempts by the investor to overturn the decision were unsuccessful.

- ***Stricter nature protection (2020)***
  From July 1, 2020, the Ministry of the Environment designated 'quiet zones' within KRNAP. The boundary of one such protected area is just a few metres from the proposed construction site, and the most valuable natural zone (formerly Zone I) is within 100 metres.

Fig. 5 Company building in Jelení louky belonging to the ČSAD Prague company, photograph taken in the 1980s.

- ***New investor and a new design (2021–2023)***
  In 2021, Jakub Lovecký joined the company, and in December 2022 the company was renamed Bergalm a.s. In the spring of 2023, a new architectural plan 'Bouda Jelení potok' was presented that was four floors high and had a volume of 9,572 m³. The town's Regulatory Commission rejected the new proposal in January 2023. The KRNAP Care Principles, effective from July 17, 2023, emphasized the need to conserve the mountain landscape and the scale of typical local buildings.
- ***Administrative exemptions and increasing controversy (2023–2024)***
  In August and September 2023, the KRNAP Administration granted Bergalm a.s. exemptions: one for the effect on protected species of plants and another for permission for constructing buildings within a protected area. In March 2024, the town opposed the development, listing 23 reasons for rejection, which, however, was not included in the administrative file! In the summer of 2024, the case file was passed to the Trutnov building office, which on August 21 is-

Fig. 6 Visualization of the intended construction in Jelení louky – general view (according to OK Plan Architects).

Fig. 7 Visualization of the intended construction in Jelení louky – a common view of the adjacent shed (according to OK Plan Architects).

Fig. 8 Visualization of the intended construction in Jelení louky – side views (according to OK Plan Architects).

Fig. 9 Visualization of the proposed construction from across the access road in Jelení louky (according to OK Plan Architects).

sued a zoning decision for the location of a 9,572 m³ building. This resulted in reports in the media and criticisms of the misleading comparisons of the new building's volume with that of the original building, whose maximum size was around 3,200 m³.

- ***Civic response and administrative review (2024–2025)***
  At the end of 2024, the petition 'Let's save Jelení louky!' included thousands of signatures by spring 2025. In February 2025, the Aichelburg Castle Society filled a complaint with the regional authority. A demonstration took place outside the KRNAP headquarters, where its leadership defended its actions. On June 2, 2025, the Ministry of the Environment annulled four binding opinions of the KRNAP Administration for inconsistency with legal regulations and questioned six other documents. On June 16, 2025, the regional authority launched a review procedure of the zoning decision, which the developer appealed against. Nevertheless, on August 11, 2025, the Trutnov Municipal Office issued a building permit. The dispute thus entered a new phase where land-use and nature conservation regulations collide with the development plan and the public interest in protecting the mountain landscape.

A take home message from this historical overview

The story of Jelení louky illustrates how challenging it is to balance nature protection, the site's historical context and private investment plans. The key issues revolve

around the proposed scale of the building compared to the original building, compliance with the land-use plan and KRNAP care principles, effects on protected species, and the capacity of the narrow forest road at Zelený důl. Without access to documentation and a consistent respect of the rules, the situation may become a long-running conflict that weakens public trust in national institutions.

Examples of false defence by developers

Fooling the reader

Developers often attempt to fool the public in that protection of the site is not necessary because the plants growing there are either not rare or numerous enough to warrant their protection. Alternatively, they attempt to pretend that protected plants living at the site can be easily transplanted to another site, for example as reported by Říha (2025):

- In support of this, Říha (2025) claims that "In the case of orchids, it is a few individuals." However, the official Nature conservation database (NDOP) indicates that there were 543 flowering individuals of *Dactylorhiza fuchsii* and an unknown number of flowering individuals of *Listera ovata* present at the site on the 19. 7. 2025 (Málková 2025), which is certainly not "a few" as claimed by Říha (2025). The argument often used by developers is that this data is for the whole site and not only for the land to be built on, but if this house is built, many of the protected plants at Jelení louky will be destroyed by the movement of heavy machinery and later by people and cars, or by transfer of plants elsewhere (to be discussed in the next paragraph). Thus, it is unlikely that any of them will survive.
- Říha (2025) also states: "the other protected species found here are not irreplaceable like other endemics". This claim is based on a lack of knowledge on the rarity of the protected plants: NDOP indicates that the moonflower (*Botrychium lunaria*), Bohemian bellflower (*Campanula bohemica*, 169 clusters) and orange hairy plant (*Pilosella aurantiaca*) are present at Jelení louky (e.g., Grulich and Chobot 2017) and these plants are much rarer than the orchids at Jelení louky.
- The third misleading statement of Říha (2025) is the claim that "The KRNAP administration ordered the developer to ensure their professional transfer to another suitable location". However, the survival of transferred plants is very low (Reiter et al. 2016; Popovich et al. 2024), therefore, transferring plants is not used when it is possible to protect the original locality in which they live. In this case, the correct procedure is to swap such land for that which is of little conservational interest as outlined above.

Rescue transfers are only used in exceptional cases, such as when an entire locality will be destroyed by, e.g., building a dam or highway and the destruction of all the protected plants cannot be avoided (Reiter et al. 2016).

Needless to say, the desire of a developer to build a large house in order to make money is not an action of great public interest and must therefore be avoided, especially if it is in a National Park.

Failure of the KRNAP administration to defend public interest in nature conservation

In June 2025, the Ministry of the Environment issued a decision to a review the procedure for revoking four binding statements of the KRNAP Administration relevant to the Nature Conservation Act (Act No. 114/1992 Coll. on Nature and Landscape Protection), which were used as the basis for further project approval. The Ministry criticised, for example, the insufficient assessment of the effect on the character of the landscape (the KRNAP Administration essentially limited itself to stating that the building was to be built on the site of the former building and that its architecture was appropriate), the lack of detailed and comprehensive considerations of the possible effects on natural values in the given locality and the related national park area, the failure to take into account the requirements arising from the KRNAP Care Principles, and the fact that the transport solution and related effects needed to be assessed and evaluated in the binding statement, not sometime in the future.

Two decisions on exemptions from the Nature Conservation Act issued by the KRNAP Administration could not be revoked by the Ministry due to the expiry of the deadlines. Nevertheless, it at least criticised the fact that, for example, they did not justify the overriding public interest in favour of nature protection, which was a necessary prerequisite for granting an exemption from the protection of specially protected species under Section 56 of the Nature Conservation Act, or, in the case of an exemption under Section 43 of the Nature Conservation Act, there were insufficient arguments to support the claim that the authorised activity would not significantly affect the conservation status of the protected species.

Thus, even the Ministry disagreed with the procedures of the KRNAP Administration in its decision.

Similar flaws, which the Ministry criticised in previous actions of the KRNAP Administration, can also be found in the joint decision of the KRNAP Administration of 22 May 2025. It is noteworthy that ten days later, the Administration issued a corrective decision replacing the words "apartment building" with "mountain hut with accommodation units". Is there an effort here to mask the "apartment building", the construction of which is criticised based on the principles of care (for the KRNAP Administration, this should be a basic conceptual document), by using a different designation?

The KRNAP Administration can defend and promote the interests of nature and landscape conservation not only in its capacity as an administrative body that makes decisions, but also, for example, in its capacity as

an entity that manages state-owned land and represents the state as the owner. The KRNAP Administration was a participant in both the territorial proceedings and the subsequent proceedings for the approval of the project conducted by the building authority, with all the rights arising therefrom. The status of participant arises from the fact that the Bouda Jelení potok project is to be carried out in the vicinity of state-owned land and some parts of the entire project directly on it. Without the consent of the KRNAP Administration (as the owner), the building authority could not issue a decision in these proceedings, or the KRNAP Administration could have defended itself against such a decision. However, it did not appear to take advantage of the opportunity to influence the outcome of the proceedings conducted by the building authority in its capacity as a participant.

A number of ongoing administrative proceedings have apparently not yet been definitively concluded. In June 2025, for example, the regional authority initiated a review of the zoning decision issued by the building authority for the project. It will therefore be interesting to see how this case develops.

How to react to false defences and/or lack of defence of public interest by NP authorities?

It is very important to publicise the misleading statements of authors like Říha and present scientific rebuttals of these claims, if the objective is to avoid destroying local populations of protected plants. This could be done via public media.

Also lack of defence of public interest by NP authorities should be publicised and discussed and public media are a good tool for doing it.

The way forward: A discussion forum or maybe even a conference?

From the above it is clear that discussion between groups dealing with different sites based on scientific evidence is missing and/or not effective and therefore many precious sites are lost because of a wrong approach and/or wrong management. Also, inclusion of the experience of other countries should be considered and people from other countries invited to contribute.

Therefore, there is a need to establish a forum for discussion. The proposition is it will be published in the June issue of EJES with the deadline for submissions March 15th. It will be open access, and no APC will be required. This is based on the belief that this will facilitate the protection of habitats owned privately and improve the likelihood of survival of protected species of plants living there.

Please submit your manuscripts in the usual way. It can be anything from a paper or a short note, like a letter to the editor. It may be the experience of what has or is occurring at your locality or a comment on what is presented here or an attempt to present the specific features of a site that illustrates that sites are not all the same. Later (in 2027?) the intention is to organise a conference on this topic.

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