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No differences between littoral fish community structure of small natural and gravel pit lakes in the northern German lowlands

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ABSTRACT

Habitat loss has been identified as a major contributor to declining freshwater biodiversity, resulting in a high threat level among European fishes. Non-natural ecosystems such as pit lakes may compensate habitat loss by providing new habitat for aquatic organisms. We compared the structure of the littoral fish communities of 18 natural and 19 gravel pit lakes located in the northern German lowlands to evaluate whether artificial lakes managed by angling clubs host similar communities as typically observed in natural lakes. The fish community structure was analyzed between the lake types and along gradients of lake morphometry, productivity and littoral complexity. Although the gravel pit lakes differed in morphology (characterized by steeper littoral slopes and less structured littoral habitat), differences in fish community structure between the natural and gravel pit lakes were weak and mainly related to differences in the abundance of the dominant species perch, roach and rudd. Both lake types had similar species richness, community diversity and hosted several small-bodied and endangered species. To conclude, fish communities characteristic of small natural lakes may serve as reference for the development of gravel pit lakes. Moreover, our study reveals that recreational-fisheries management of gravel pit lakes does not result in artificial communities that deviate strongly from the communities present in natural lakes. Therefore, nature conservation and fisheries management goals can be reconciled in relation to fish in small artificial lakes managed by angling clubs.

Introduction

Lentic freshwaters are among the world's most threatened ecosystems experiencing a disproportionate rapid biodiversity decline over recent times (Sala et al., 2000; Abell, 2002). Habitat loss has been identified as one of the major threats, which has contributed to the present-day freshwater biodiversity crisis (Dudgeon et al., 2006). Today, about 41% of all native freshwater fish species have been classified as threatened or are considered as near threatened, one of the highest threat level for any major taxonomic group in Europe (Freyhof and Brooks, 2011). Particularly, species that depend on small and temporary stagnant waters have declined in abundance and distribution throughout central Europe (Freyhof, 2002; Aarts and Nienhuis, 2003).

Lentic freshwater ecosystems of natural and non-natural origin (such as reservoirs, gravel pits and ponds) provide valuable habitat for many European fish species. In particular large, deep lentic ecosystems support diverse fish communities (e.g., Irz et al., 2002; Brucet et al., 2013). Such ecosystems have attracted scientific attention for generations (Wetzel, 2001), and also recent legal demands stemming from the European Water Framework Directive (European Union, 2000) safeguard repeated sampling of fish communities in natural lakes and reservoirs larger than 50 ha. Surprisingly, only few studies have compared the structure of fish communities between natural and non-natural large lakes, and the few available studies have been mainly confined to reservoirs (e.g., Whittier et al., 2002; Irz et al., 2006; Launois et al., 2011). As would be expected due to variation in genesis, morphology, hydrology and water chemistry among natural lakes and non-natural systems (Thornton et al., 1990; Castro and Moore, 2000; Schultze et al., 2010), reservoirs have been found to host different fish communities with a greater number and proportion of non-native and tolerant species (Whittier et al., 2002; Launois et al., 2011). Despite these differences also many commonalities in fish community structure including the number of common and rare species

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and the same dominating species have been observed among natural lakes and reservoirs in Europe (Godinho et al., 1998; Irz et al., 2006).

Compared to large lentic systems, much less research effort on fish community structure has been devoted to small European and German lakes (for exceptions see Tonn et al., 1990; Eckmann, 1995). Across the world, small lakes <10 ha are numerically dominant (Oertli et al., 2002; Downing et al., 2006), and small artificial lakes stemming from soil extraction have become main elements of the landscape in many water-scarce areas (Gee, 1978; Schagerl et al., 2010) such as the west German lowlands. The lack of dedicated attention to fish communities in small non-natural lakes has been repeatedly noted (Gee, 1978; Bartmann et al., 1990) and is surprising given its importance for recreational fisheries and its potential to host relevant aquatic biodiversity. Small lentic surface waters may potentially compensate for the loss of natural habitat for many aquatic biota as shown for several aquatic invertebrates, amphibians and macrophytes (Biggs et al., 1994; Gee et al., 1997; Williams et al., 2008). The degree to which non-natural water bodies provide refuges for diverse fish communities and the question how fish communities in small non-natural lakes differ from natural lakes has hitherto not been studied.

Recreational fishing is a popular pastime in Germany, with about 3.3 million active anglers living in the country (Arlinghaus, 2004). In Germany many artificially created lakes are managed by about 10,000 angling clubs who are obliged, according to state-specific inland fisheries laws, to maintain and support natural fish communities in terms of species and age/size structure commensurate with the ecological conditions of a given water body (Daedlow et al., 2011). Legal terminology in German fisheries legislation acknowledges that many aquatic ecosystems have been heavily modified or are entirely artificially created. Accordingly, fishing rights holders are demanded to maintain near-natural ("*naturnah*") fish communities while using and managing fish stocks for recreational purposes. However, a near-natural status for fish communities in small non-natural lakes has as yet not been defined. In the absence of comparative studies, fish communities in small natural lakes have served as reference communities and targets for non-natural lakes, but whether this agrees with ecological reality is an open empirical question.

The lake littoral is a zone of high productivity and essential in the life-cycle of most fish species (e.g., Winfield, 2004). Shallow and diversely structured littoral habitats provide spawning and nursery grounds, foraging areas and shelter against predation (reviewed in Winfield, 2004; Smokorowski and Pratt, 2007; Strayer and Findlay, 2010). The high meso- and microhabitat diversity of the littoral zones in lakes promotes higher species diversity and fish abundances compared to profundal and pelagic habitats (Diekmann et al., 2005; Menezes et al., 2013). Littoral sampling is therefore particularly important for the characterization of fish communities and the assessment of biodiversity in lakes (Diekmann et al., 2005; Menezes et al., 2013).

The fish species composition of littoral zones is influenced by a range of abiotic (e.g., morphometry, productivity) and biotic factors (e.g., predator–prey dynamics), which often interact simultaneously in non-linear ways. For example, with increasing lake productivity and water turbidity littoral fish abundance may increase (Jeppesen et al., 2006; Lewin et al., 2014) but only up to a maximum point after which it decreases due to oxygen limitations (Hartmann, 1977). The presence of macrophytes and coarse woody debris is thought to increase species richness and abundance of juvenile fishes (Lewin et al., 2004, 2014; Helmus and Sass, 2008) by providing refuges against predation by piscivorous fish and birds and by elevating feeding opportunities (Eklöv, 1997; Russell et al., 2005). Although this statement is rarely questioned, experimental manipulations of littoral zones have either strongly affected fish communities (Sass et al., 2006; Helmus and Sass, 2008) or have no measurable impact at all (Sass et al., 2012). In US ecosystems, correlations among shoreline development and fish communities have been reported (Scheuerell and Schindler, 2004), while no such strong impacts were detected across lakes studied in northern Germany, which have typically less structurally degraded shorelines (Mehner et al., 2005; Lewin et al., 2014). More studies on lentic fish communities in systems, which have less structural elements in the littoral (e.g., non-natural waterbodies), are needed to further improve our understanding of the abiotic and biotic factors that structure lake fish communities in littoral zones.

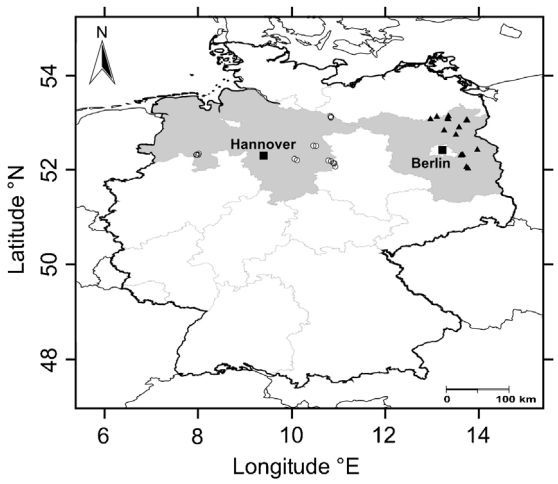

Fig. 1. Location of the 37 study lakes in northern Germany. Triangles indicate location of the natural lakes in Brandenburg (grayish area); open circles indicate location of the gravel pit lakes in Lower Saxony (grayish area).

In this study we compared the structure of littoral fish communities in small and relatively shallow natural and non-natural lowland lakes (hereafter called gravel pit lakes) located within northern Germany along gradients of lake morphology, productivity and littoral complexity. We aimed at identifying to what extend fish communities in gravel pit lakes that are managed by local angling clubs differ from fish communities in natural lakes in terms of fish community composition, species richness, community diversity, proportion of predators, and the abundance of threatened and alien species. The results were meant to inform whether small gravel pit lakes can provide valuable habitat that support diverse fish communities similar to those observed in small natural lakes. We further wanted to elucidate whether fish communities in natural lakes can serve as management targets for the rehabilitation and management of non-natural systems by angling clubs and other stakeholders. Due to the younger age of gravel pit lakes and the potentially more intensive fisheries management via stocking we hypothesized that gravel pit lakes would host less threatened species but a greater proportion of non-native and predatory fishes due to their importance for recreational fisheries. We also expected gravel pit lakes to be less structured in terms of the habitat diversity in the littoral zone with steeper littoral zones, and hence that fish communities should be different compared to natural lakes of similar size.

Methods

Study lakes

Littoral fish communities of 37 small (mean surface area: 17 ha, SD = 22.9, range = 0.4–61.4 ha) lakes located in the lowlands of northern Germany (<200 m a.s.l., European "Central Plains" Ecoregion, Illies, 1978) were analyzed (Fig. 1). A total of 18 lakes located