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Abiotic and fishing-related correlates of angling catch rates in pike (*Esox lucius*)

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ABSTRACT

Understanding how angling catch rates vary between environments is of interest from ecological and fisheries management perspectives, but this has rarely been investigated in detail. Using experimental catch-and-release angling records for northern pike (*Esox lucius*) from a small natural lake in Germany and a generalized linear model we investigated how abiotic and fishing-related environmental variables as well as time of day affect pike catch per unit effort (CPUE; fish per hour). Catch rates of pike were significantly increased at low temperatures, high wind speeds and around full and new moon as well as during dusk. Large fishing effort during the past two days reduced catch rates significantly, indicating the combined influence of abiotic and human-induced variables on the catch rates of pike with angling gear. Of all the significant covariates, fishing effort had the most pronounced effect on catch rates. Our results indicate that anglers can increase catch rates by choosing appropriate weather conditions and lunar phases, but that continuously intensive fishing negatively affects future catch rates even in the absence of harvest. This has implications for the choice of sampling effort using angling gear when attempting to assess fish stocks.

1. Introduction

Angling is a popular recreational and commercial fishing method. While angling methods usually involve rod-and-reel in recreational fisheries, long-lining is the most important angling technique in commercial fisheries. Understanding how angling catch rates vary with environmental variables is of interest from ecological and fisheries management's perspectives. Angling requires fish to attack/ingest the bait or the artificial lure, so that angling catch rates provide insights into the activity and feeding patterns in fish and potentially level of aggressive attacks in predatory fish. In particular, catch rates in angling fisheries should depend on the foraging activity and hunger level of fish as well as their ability to locate or avoid the bait or lure (Uusi-Heikkilä et al., 2008). These processes, in turn, are likely affected by environmental cues correlated with activity and metabolism such as water temperature (Stoner, 2004). Therefore, quantifying the vulnerability of fish to angling gear necessitates identifying environmental variation in angling catch rates, but this has rarely been investigated in detail using rod-and-reel-type angling. Moreover, as stock assessments are sometimes conducted using angling methods (e.g., Myers and Worm, 2003; Pierce and Tomcko, 2003; Hansen et al., 2005; Lehtonen et al., 2009), distinguishing environmental variations in angling catch per unit effort (CPUE; an index of relative abundance) from variation arising from differences in population density is vital for obtaining reliable information about the population size (Stoner, 2004).

Out of the potential abiotic factors affecting angling catch rates water temperature appears to be the variable most commonly reported in the literature (e.g., Bigelow et al., 1999; Stoner, 2004; Stoner et al., 2006; Damalas et al., 2007; Ortega-Garcia et al., 2008). This is presumably due to its pervasive influence on movement activity, metabolism, and foraging activity in all poikilothermic aquatic animals (Brown et al., 2004). Other abiotic environmental variables such as wind speed, light, barometric air pressure, day length, time of day and air temperature have also been shown to affect catch rates in angling fisheries (e.g., Millar et al., 1997; Bigelow et al., 1999; Margenau et al., 2003; Stoner, 2004; Wall et al., 2009). However, particularly in recreational fisheries, analyses of such relationships are sparse, presumably due to the lack of datasets providing high resolution measurements of abiotic environmental variables along catch records (Stoner, 2004). This lack of knowledge contrasts with a wealth of anecdotal information about correlations between abiotic environmental variables and angling catch rates, culminating in fishing 'calendars' that are commonly applied by anglers to predict future fishing success.

A particularly intriguing aspect related to abiotic environmental variations in catch per unit effort (CPUE) is the potential role of lunar cycles. Namely, it is a common belief among professional and recreational anglers that catch rates depend on the moon

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phase, with catches being highest around full and new moon (e.g., http://www.solunarforecast.com/). In the context of baited fishing gears, this hypothesis has rarely been investigated and the available evidence is mixed. In some longline fisheries for marine species, catches have been seen to peak around full or new moon (Bigelow et al., 1999; Lowry et al., 2007; Damalas et al., 2007), while other studies have reported lack of correlations between lunar phases and catch rates (Millar et al., 1997; Ortega-Garcia et al., 2008). Overall, the extent to which lunar cycles might affect CPUE in angling is still largely unknown and may be species-specific. Moreover, as pointed out by deBruyn and Meeuwig (2001), weak lunar cycles in catch rates easily remain undetected if the statistical methods that are applied are not appropriate.

In addition to abiotic environmental variables, it is undisputed that a number of biotic features affect catch rates of angling gears. For example, food abundance and the density of conspecifics generally increase competition for food or induce social stress in cannibalistic species (Edeline et al., in press), which may affect food intake rates, foraging activity and hunger levels. Not surprisingly, density-dependent factors have been reported to substantially affect catchability in angling fisheries (Raat, 1986, 1991; Hansen et al., 2005). In some species, angling catchability also depends on learning to avoid capture, particularly if catch-and-release fishing is widespread (Raat, 1985; van Poorten and Post, 2005; Askey et al., 2006), but the same pattern can also emerge as a result of high angling effort with easily-identifiable lures as was demonstrated by Beukema (1970). In his catch-and-release experiment conducted in ponds, northern pike (*Esox lucius*) learned to avoid future capture by artificial lures regardless of whether individuals were hooked previously, but similar learning effect did not occur for natural baits (Beukema, 1970). This finding along with other studies in freshwater fisheries conducted with artificial lures (van Poorten and Post, 2005; Askey et al., 2006) suggests that fishing effort might affect angling catch rates negatively (Cox and Walters, 2002; Young and Hayes, 2004). Thus, fishing effort must be accounted for when investigating the impact of environmental factors on catch rates in angling fisheries.

The objective of this study was to investigate the impacts of a wide range of abiotic and fishing-related environmental variables including lunar cycles and fishing effort on CPUE in northern pike (hereafter termed pike) rod-and-reel angling. Pike is a fast growing, early maturing and strongly cannibalistic top piscivore in freshwater and brackish ecosystems; it was chosen as the model species for the present study because it has great value for both commercial and recreational fisheries throughout its circumpolar natural range in the northern hemisphere (Paukert et al., 2001; Arlinghaus and Mehner, 2004). Field data were collected by experimental catch-and-release fishing in a natural lake. The study site was protected from any other forms of fishing and was confined to a short period of intensive sampling within one season. Therefore, variations in CPUE were likely not associated with large changes in population density, which would otherwise confine the analyses of abiotic and fishing-related variations in catch rates (Hansen et al., 2005; VanDeValk et al., 2005).

2. Materials and methods

2.1. Data

Experimental pike angling took place in the Kleiner Döllnsee during the spring to autumn of 2005. This small (25 ha), dimictic, shallow (mean depth 4.1 m, maximum depth 7.8 m) natural lake is located in north-east Germany (N52°59′, E13°34′). Kleiner Döllnsee is mesotrophic to slightly eutrophic (P concentration at string overturn 28 $\mu g\,l^{-1}$) sustaining a natural pike population protected from any form of commercial or public recreational fishing (Klefoth et al., 2008; Kobler et al., 2008a). In spring of 2005, abundance of age 1 year and older pike was estimated as 544 individuals (95% CI: 194–1088) (Kobler et al., 2008a,b). Within the study period from 27th May to 17th September 2005 pike were angled on a total catch-and-release basis using 25 skilled anglers (3 fishing regularly on each sampling day, occasionally supplemented by in total 22 additional experimental anglers). Most the anglers were part of the research team and all employed standard recreational pike angling fishing techniques described in detail in Arlinghaus et al. (2008a). Briefly, each angler was instructed to use a personal choice of artificial lures using medium-action rods for spinning or trolling and, when occasionally using organic bait, to set the hook quickly to avoid deep hooking (Arlinghaus et al., 2008a). Anglers were asked to fish all habitats during a fishing day, but for logistical reasons and to add realism anglers were not assigned to randomly selected fishing sites. Due to the small size of the lake all available habitats were sampled on a given angling day, but some more productive fishing sites (e.g. dense macrophyte patches) known by anglers to host particularly high abundances of pike (see Kobler et al., 2008a,b, 2009) might have been more intensively fished on particular days. However, this is typical for any recreational fishing sites and, hence, managers would normally have aggregated daily catches over a sample of anglers. Once a pike was landed, it was quickly de-hooked, checked for any signs of marks or tags, and its length and weight were measured after which the individual was released. Immediate hooking mortality was low and estimated as 3.9% (see Arlinghaus et al., 2008a for details). For each angling day, the cumulative number of pike caught and the cumulative duration of fishing over all anglers was recorded, separately for daytime and the hours of dusk, yielding 169 observations in total (93 during daytime and 76 during dusk spread over 94 fishing days; Fig. 1). For more ecological details about the study system, see Klefoth et al. (2008) and Kobler et al. (2008a,b, 2009).

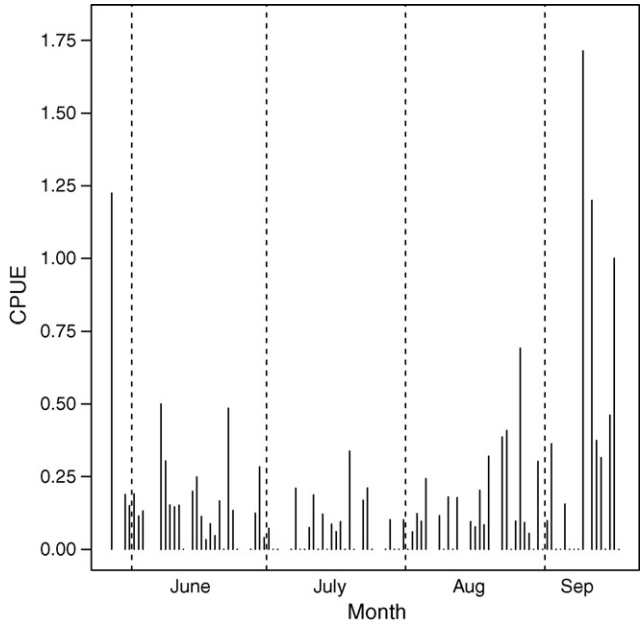

Fig. 1. Pike catch per unit effort (CPUE; fish per hour) at daily intervals over the study period from 27th May to 17th September 2005.

Abiotic environmental conditions were measured on a daily basis. Variables measured (and their ranges) were water temperature (14.7–24.1 °C), wind speed (0.7–6.9 $m\,s^{-1}$), wind direction [categories (frequencies of observation): east (14), south (38), west (40), north (2)], air humidity (58–98%), rain