Abstract

Anthropogenic activities alter turbidity level and light availability in freshwater ecosystems through anthropogenic climate change and deforestation. Changes in turbidity and light availability often influence fish foraging, predator response, and mate selection, which can shift community composition and alter ecosystem dynamics. In this study, we investigated the influence of a range of turbidity levels (0, 3.5, 6, 10, 20, 22, 25, and 35 NTU) and light levels (400 lx and 1000 lx) on prey consumption in *Rhinichthys atratulus* (Eastern blacknose dace), and we ran a preliminary study on reactive distance, comparing the reactive distance between the 0 NTU low light and 6 NTU low light conditions. We found differences in prey consumption as a function of turbidity under both high light and low light conditions. Within each turbidity level, prey consumption only varied based on light level at 25 NTU, with increased consumption under
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freshwater systems, as these land-use practices result in increased soil erosion (Wolanski et al. 2004).

Turbidity has been shown to alter community structure through benthic smothering, reduced penetration of light for photosynthesis, and reduced visual range of sighted organisms (Vogel and Beauchamp 1999). Diminished visual range can have various behavioral effects on individuals, including altered foraging, predator response, and mate selection (Gregory 1993; Vogel and Beauchamp 1999; Seehausen et al. 1997).

Along with turbidity, light availability also influences an organism's visual range

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Methods

Rhinichthys atratulus (Cypriniformes, Cyprinidae; common name: Eastern blacknose

distance. Reactive distance was measured as the distance between the blacknose dace and its prey (a bloodworm) when the individual first oriented itself toward a bloodworm before continuing forward to consume it in one continuous motion. Then, using ImageJ, we measured the reactive distance in centimeters. We focused on measuring reactive distances in the 0 NTU and 6 NTU treatments under low light conditions as a preliminary study on blacknose dace reactive distance.

Since our consumption data was not normally distributed (Shapiro-Wilks: $p > 0.05$), we analyzed this data using nonparametric statistics. Using Kruskal-Wallis tests, we analyzed bloodworms consumed as a function of turbidity level under both high light and low light conditions. Additionally, we ran Mann-Whitney paired tests at each turbidity level to test for differences in consumption between the high light condition and the low light condition. A Kendall's Tau-b was used to analyze whether there was a correlation between the average length of the two fish in the trial and the number of bloodworms consumed. For this test, we used the average length of the two fish present in the trial. Finally, we ran a T-test to analyze whether reactive distance varied significantly between the 0 NTU low light conditions and the 6 NTU low light conditions. The T-test and Kruskal-Wallis tests were conducted on JMP Pro 11.0.0, while the Mann-Whitney paired tests and Kendall's Tau-b test were conducted on SPSS.

Results

Consumption of bloodworms varied significantly under low light conditions ($X^2_{7, 95}$ =

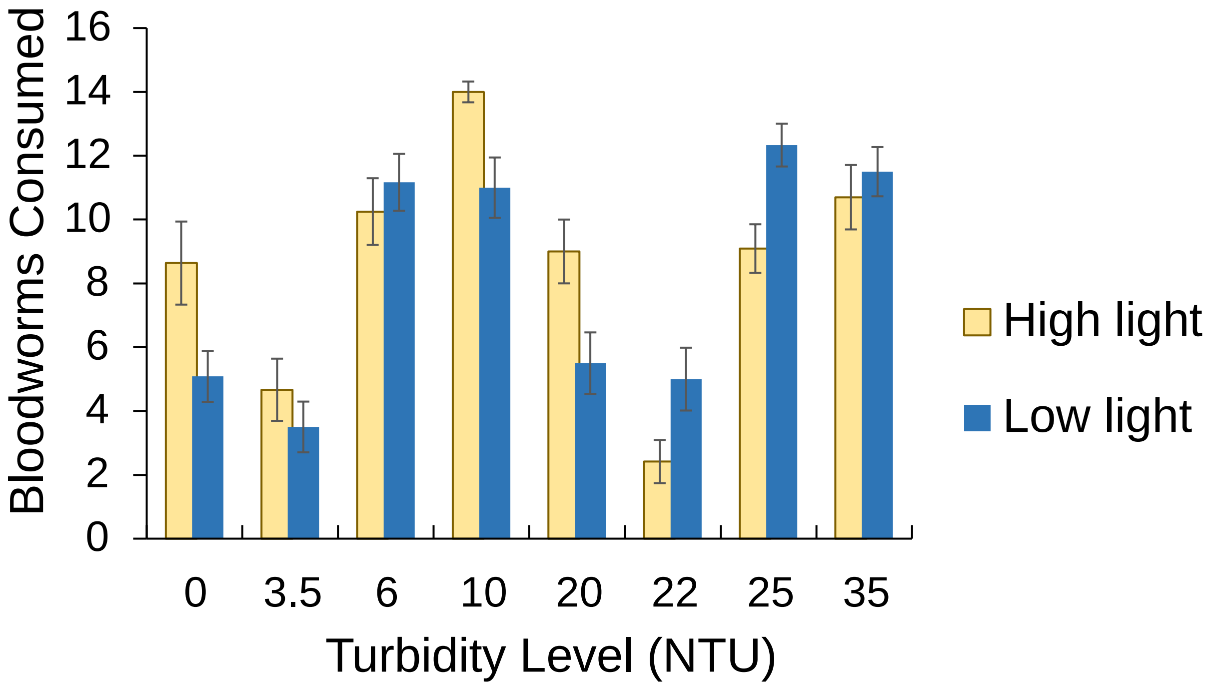

Figure 1. The number of prey consumed by blacknose dace varied based on turbidity level under both high light ($X^2_{7,\,90} = 33.302$, $p < 0.001$) and low light ($X^2_{7,\,95} = 39.198$, $p < 0.001$) conditions. At every turbidity level, the number of prey consumed was statistically similar between the low light and high light treatments ($p > 0.05$), except at 25 NTU, with more prey consumed in the low light treatment than in the high light treatment ($T_b = 0.257$; N = 185; $p < 0.001$). Error bars represent one standard error.

Figure 2. Reactive distance of blacknose dace was greater under the 0 NTU low light treatment compared to 6 NTU low light treatment ($T_{18.6, 35}$ = -2.05, p = 0.027). Error bars represent one standard error.

Discussion:

As shown in this study, light level had no significant impact on foraging in almost all circumstances; however, consumption varied significantly based on turbidity and length of blacknose dace. Our results showed the highest consumption for blacknose dace being at moderate (6 NTU, 10 NTU) and extreme (25 NTU, 35 NTU) turbidity levels. These findings somewhat vary from results found on the impact of turbidity on foraging in other species. In fact, increase in consumption at 6 NTU and 10 NTU found in our study can potentially be explained by this heightened perception of predator protection; these levels of turbidity may still be clear enough to allow for effective foraging, however the fish may also perceive this level of cloudiness to be a refuge from predators. In some cases, increased turbidity can also increase the contrast between prey and its background, also known as the “physical effect hypothesis” (Hinshaw 1985). If this is acting in our system with the blacknose dace, it is plausible that we see an uptick in foraging at 6 and 10 NTU as a result of increased contrast, and therefore a heightened ability for the fish to see the prey.

The increase in consumption at 25 NTU and 35 NTU is also notable for being unlike the results found among other species. Many studies on juvenile and adult aquatic species show the lowest consumption being at the highest turbidity levels (Vinyard and Yuan 1996; Wellington et al. 2010; Zamor and Grossman 2007). We hypothesize that the increase in foraging in blacknose dace at these extreme turbidity levels may be the result of switching from visual foraging techniques to other sensory systems, such as a lateral line system or olfactory cues. Non-visual cues, particularly the lateral line system, have proven to be critical to foraging success in species such as torrentfish, mottled sculpin, and common bullies in habitats with either extremely low light availability or high turbidity (Montgomery and Milton 1993; Hoekstra and Janssen 1985; Rowe and Dean 1998). Our results support this trend where after the water passes a threshold of

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problematic. In order for a fish to see its prey, the fish must be able to distinguish the prey from its background. Therefore, there must be high contrast between the prey and its surroundings (Utne-Palm 2002). This contrast is drastically reduced when backscattering increases (Ranaker et al. 2012); it is likely that at 22 NTU and above, a higher light setting is disadvantageous for the blacknose dace due to increased backscattering off bentonite particles, making the low light setting more successful for individuals at the higher turbidity.

In our preliminary study of reactive distance at 0 and 6 NTU we found that at higher turbidities, the reactive distance of the fish decreased. These results were exactly as expected because visual range in aquatic species is often predicted to decrease following a non-

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