Chemical sensing in recognition and avoidance of novel predator

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Abstract

Chemical cues are important for predator recognition and avoidance in aquatic environments, where visual cues are not always substantial. Learning, rather than instinct, is important to assessing threat levels, generally requiring the pairing of a predator with an alarm cue of a conspecific. Detection of a novel scent often results in predator inspection to determine motives of the organism. Exposing fish in Deming Lake to two treatments of novel leech species, a visual cue and chemical/visual cue, the experiment shows that redbelly dace (*phoxinus eos*) preferentially inspect the chemical/visual treatment over the control.

Introduction

Recognition and avoidance of predators is a cornerstone of fitness in aquatic environments. In shoaling species, visual cues are important for initiating anti-predatory behaviors. However, a fish's habitat may restrict visual cues due to vegetation or dark waters, requiring other adaptations to avoid predation. Detecting predator scents then becomes a significant secondary avoidance mechanism (Kats and Dill 1998).

Visual and chemical cues are more complicated than only recognizing the identity of nearby organisms. Prey species need to be able to assess each threat accurately and quickly. Reacting unnecessarily results in lost time that could have been spent on foraging and mating, but not reacting in the right scenario results in an increased rate of predation (Kusch et al. 2004). It is well known that odors travel well through an aquatic medium, making scent recognition a useful mechanism for detecting threats in the environment, much like any terrestrial animal, especially mammals such as mice and voles.

Learning is vital to recognition of threat level because novel organisms have unknown behaviors and motives cannot be established instantly. Therefore, it is not until the scent is conditioned with alarm cues from conspecifics that a behavioral response is initiated. Additionally, these learned responses require only one experience of the paired odor signals (Korpi and Wisenden 2001). It is well known that these anti predator responses include reduced activity, hiding, fleeing, increased shoaling, and inspecting.

Redbelly dace shoal in the littoral zone during the day and spend time of darkness as individuals in the pelagic zone. This behavior serves to maximize foraging of zooplankton. While shoaling in the littoral zone, redbelly dace prefer heavily vegetated areas for protection from predation (Naud and Magnan 1988). Inspection of predators would not be surprising since related European minnows (*Phoxinus phoxinus*), a close relative, use inspection as an important behavioral response (Brown et al. 2000).

Brook stickleback (*Culaea inconstans*) and fathead minnows (*Pimephales promelas*) often share the same habitat where brook stickleback react to fathead minnow alarm cues to avoid predation (Wisenden et al. 1994). It is widely known that the preferred habitat is heavily weeded, implying a greater need for chemical cues to avoid predation due to limited visual cues. Pollock et al. (2003) further shows that fathead minnows can learn to detect stickleback alarm cues, meaning that an alarm cue from any fish should result in antipredatory behavior.

My experiment explored the behavioral reactions of these three species of fish to bait leeches based on chemical and visual cues. This procedure was designed to test the reaction to chemical cues given by a novel predatory species. Anecdotal evidence has previously shown that leeches from within the lake are avoided. Although of different species, recognition should elicit similar responses. My hypothesis is that all fish species would avoid all leech traps, especially when exposed to a chemical cue along with the chemical odor. When given only a visual cue, I hypothesized the catch would be higher for all three species, especially for the brook stickleback and fathead minnows, which rely more on a chemical cue than the visual.

Methods

The study area used for the experiment was Deming Lake, located inside Itasca State Park in Minnesota. Deming Lake is primarily home to three types of fish: red-belly dace, fathead minnows, and brook sticklebacks. Population density in this lake is high, allowing for higher trap catches and controlling for density dependent results.

The experiment was conducted using two treatments and a control. The control was created by placing an empty, .946 L mason jar in a small fish trap. The first treatment was made by placing four leeches in a mason jar with a screen covering it to allow for the presence of both visual and chemical cues. The second treatment used four leeches with a solid cap to suppress the chemical cue so fish could only see them. Leeches were bought from the Itasca bait shop and ranged from two to five inches long.

Sixteen sets of data were acquired for the experiment. Traps were set in approximately 6 meter intervals along the shore of Deming Lake. Each trap was submerged for two hours and then data was collected by counting the number of redbelly dace, fathead minnows, and brook sticklebacks in each trap.

In Microsoft Excel, data for each trap type was sorted by fish species from least caught to most. A trendline was found expressing the rate the natural log of the catch increased per trap number. Ancovas were done using Statistics Program for the Social Sciences (SPSS) to determine significance values between the trap types.

Results

The median number of fish caught did not differ significantly among trap types for redbelly dace ($KW_2 = 3.776$, $P = 0.151$), fathead minnows ($KW_2 = 787$, $P = 0.675$) or brook stickleback ($KW_2 = 1.022$, $P = 0.600$). A linear scatter plot was created by taking the natural log of each trap's catch

Redbelly dace

There was a significant difference in slopes of cumulative number caught over trap number among the three treatments (ANCOVA treatment $F_{2,42} = 1.25$, $P = 0.296$; trap number $F_{1,42} = 491.0$, $P < 0.001$; Interaction $F_{2,42} = 4.207$; $P = 0.022$, Fig 1). Further analysis shows that the significant data exists comparing slopes of the control and screened treatment ($F_{1,28} = 7.542$, $P = 0.010$). A comparison of the control versus the capped treatment yields no significant data but have almost different slopes ($F_{1,28} = 4.051$, $P = 0.054$). Comparing the two treatments shows that no difference exists in the slopes ($F_{1,28} = .177$, $P = 0.677$) but there is almost a significant difference in the elevation of the parallel lines ($F_{1,28} = 3.398$, $P = 0.076$).

Fathead minnows

No significant data was found comparing trendline slopes and elevations for fathead minnows (ANCOVA slope $F = 0.745$, $P = 0.532$; elevation $F = 1.289$, $P = 0.286$, Fig 2).

Brook Stickleback

The treatment with chemical and visual cues is the only data with fewer fish than the control for all three species of fish (Fig 3). No significant data was found for comparing either slopes or elevations (ANCOVA slope F = 2.953, P = 0.063; elevation F = 0.418, P = 0.661).

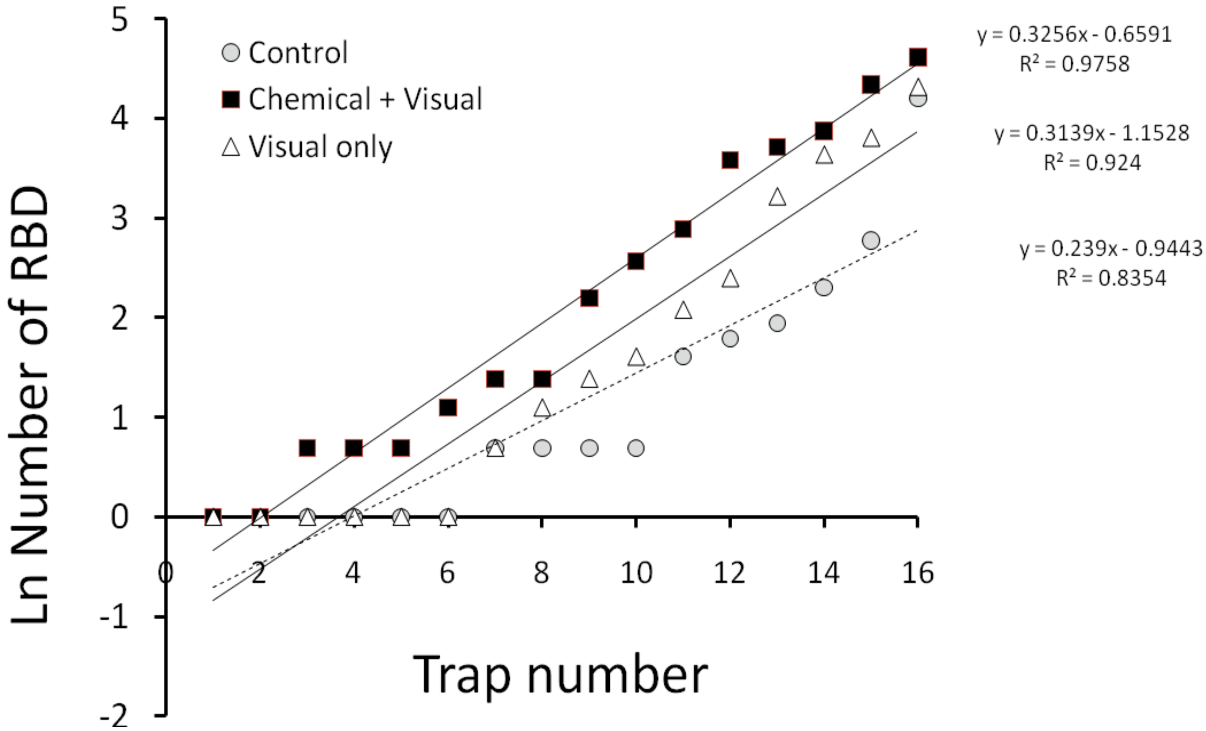

Fig 1: Natural log of redbelly dace catch per trap number

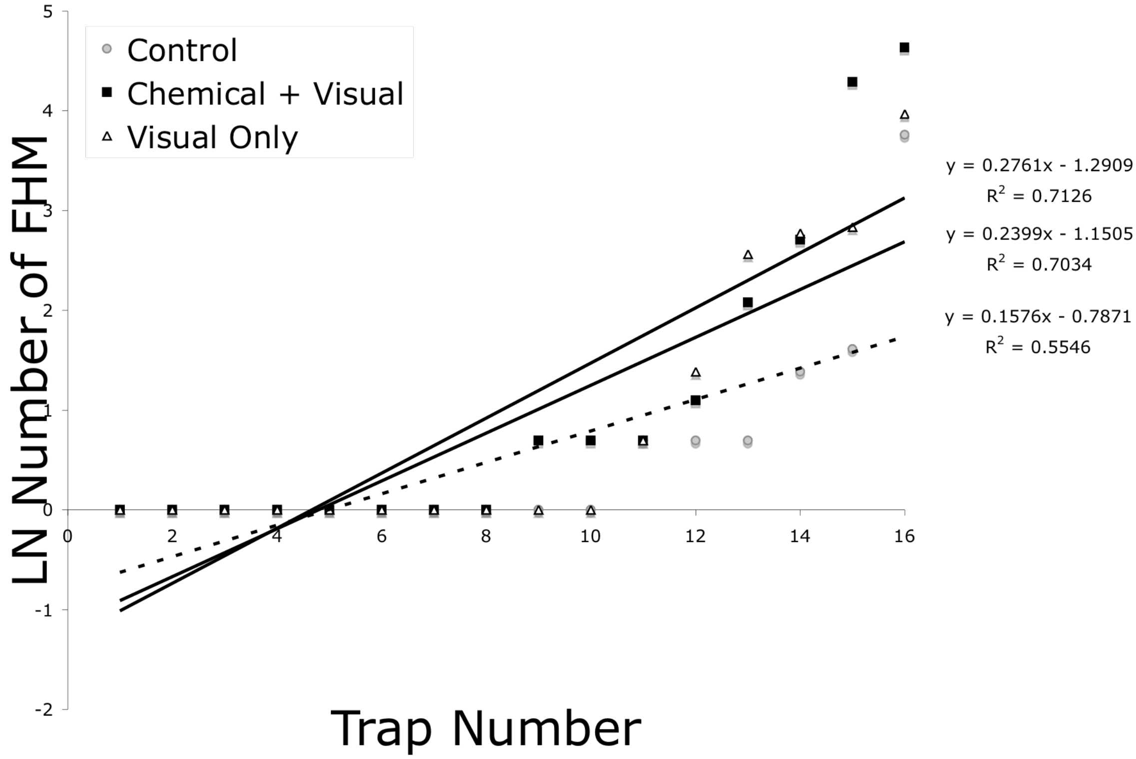

Fig 2: Natural log of fathead minnow catch per trap number

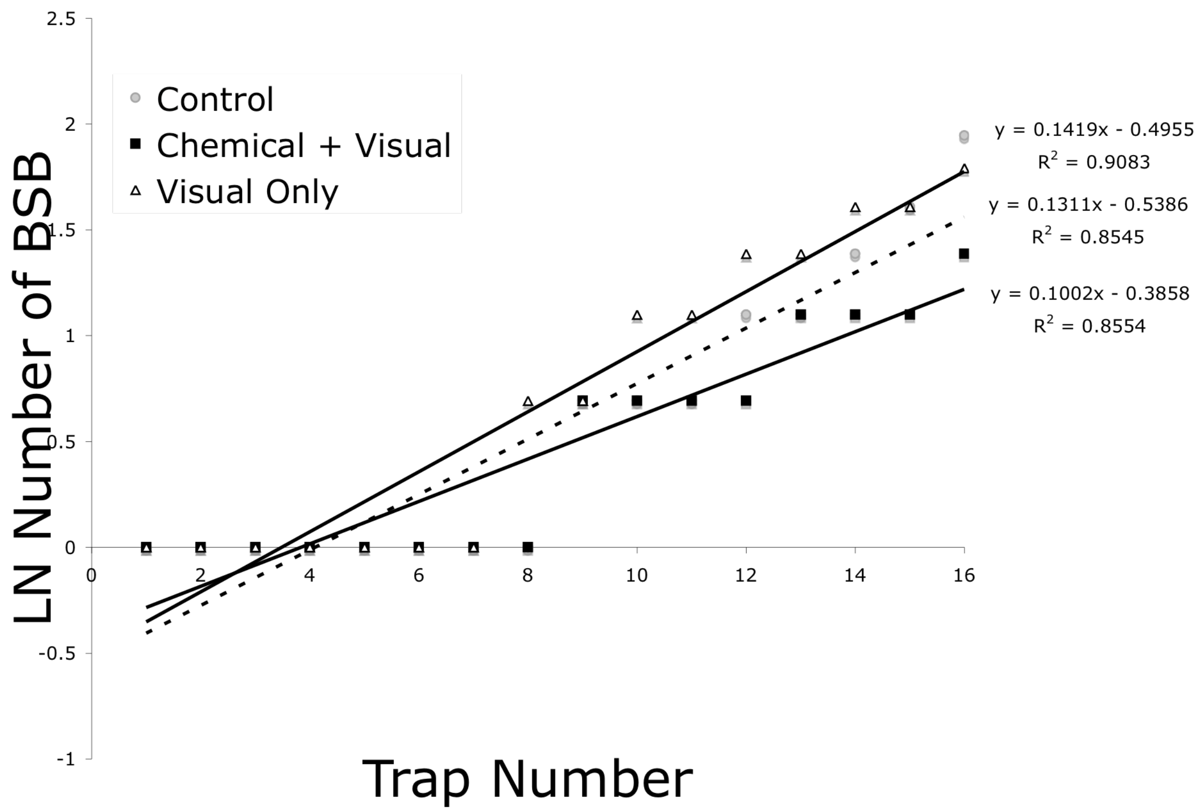

Fig 3: Natural log of brook stickleback catch pr trap number

Discussion

Data collected failed to support the hypothesis that fish would avoid traps containing novel leeches. The only significant data shows the opposite affect with redbelly dace preferring the traps with both visual and chemical cues. Trends in the redbelly dace data do show the importance of chemical cues in recognition of other organisms.

Data obtained from the experiment supports ideas that the predatorial nature of an organism is not conditioned until paired with alarm cues from conspecifics. Novel predator inspection is likely the reason a significant number of redbelly dace were found in the chemical/visual treatment compared to the control. Although nearing a novel organism has high risks involved, studies have shown inspection results in valuable benefits including visual assessment, chemical assessment, deterrence, and preferred mate selection (Brown et al. 2000). Further studies by Brown et al. (2001) show the importance of other odor cues paired with the predator explaining that fish are more likely to inspect predators without alarm cue scents of conspecifics. This may be due to the alarm cue being present on the predator after a meal (Jachner 1997). Results obtained support this idea because novel leeches had not been feeding and showed no immediate threat to the fish shoals.

Raw data supports existing ideas that heterospecifics are able to sense alarm cues (Wisenden 1994). Excluding brook stickleback, which had low and similar catches, it was rare to find a high number of redbelly dace without a high number of fathead minnows and vice versa. One could infer from this data that some benefits exist in shoaling with heterospecific species. Especially in a lake with few aquatic predators (mostly birds), similar phenotype would be less important and larger numbers alone are effective in lessening predation risk.

This experiment could be refined to further assess the role of predator odors with regards to prey recognition and avoidance. Because the trendline for visual cues only in redbelly dace catch falls virtually in the middle of the chemical and visual and the control treatments, the extent that chemical cues are important cannot be inferred. An additional treatment with chemical cues only would remedy this unknown effect. Other studies could pair novel leeches with a redbelly dace alarm cue, or compare the effects of novel leeches with the effects of naturally occurring leeches. Conducting additional procedures with less inclusive variables could help to further understand the role of chemical scents in predator avoidance compared to visual cues.

The manner in which inspection occurs could also be tested within a laboratory setting. In a field setting, controlling for shoaling effects while ensuring that some fish will be caught is difficult. The quickness that a trap is discovered could be the lone variable determining whether 0, 10, or 100 fish are found in a certain trap because shoaling occurs when no alarm cue is released. Inspection is generally done by smaller groups of fish leaving the shoal momentarily (Dugatkin 1988). Therefore, large numbers in some traps seem unreasonable and reasons for finding larger shoals, the biggest being 100 redbelly dace and 102 fathead minnows, is unlikely. This experiment does not control for the chance that large catches may be due to the shoaling effect rather than the treatments.

Although no significant data was found for the brook sticklebacks, further studies could determine the reason that they tended towards visual cues and away from chemical/visual cues. No data was found to attempt to explain the trend of the control being in between the two sets of data, specifically the lower amount caught in the chemical and visual trap, but one could infer that chemical cues are more important to brook stickleback because of the heavily vegetated environments they live in. Although data for brook stickleback is not significant, the trend calls the reaction of the dace into question and poses new questions as to why brook stickleback would be attracted to visual cues alone but repelled from chemical/visual cues.

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