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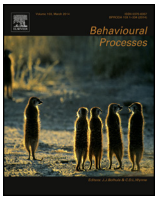

An experimental test of in-season homing mechanisms used by nest-guarding male Largemouth Bass following displacement

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ABSTRACT

Through manipulations of sensory functions, researchers have evaluated the various mechanisms by which migratory fish, particularly in lotic systems, locate natal spawning grounds. Comparatively less work has occurred on the ways by which fish in lentic systems locate spawning sites, and more specifically, the ways by which displaced fish in these systems locate their broods post spawning. The primary goal of this research was to determine the sensory mechanisms used by nesting, male Largemouth Bass to navigate back to their brood following displacement. This was accomplished by comparing the ability of visually impaired, olfactory impaired and geomagnetically impaired individuals to return to their nests after a 200 m displacement, relative to control males. All treatments were designed to be temporary and harmless. We analyzed the data using a generalized linear mixed model, and found that the probability of an olfactory impaired individual returning to his nest within a given time interval was significantly lower than the probability of a geomagnetically impaired individual returning. Overall, it appears as though olfaction is the most important sensory mechanism used for homing in Largemouth Bass.

1. Introduction

Largemouth Bass, *Micropterus salmoides*, are the most popular sportfish in North America (Quinn and Paukert, 2009). In early spring, males are particularly susceptible to angling due to their parental care strategies (Jennings, 1997; Philipp et al., 1997; Suski and Philipp, 2004). When water temperatures rise to approximately 14 °C, male Largemouth Bass move to shallow waters, where they build a nest and attract a female for spawning (Kramer and Smith, 1962). The nest-building process typically takes place in a sandy or muddy substrate, and involves sweeping a 60–90 cm circular region clean of vegetation and debris. Largemouth Bass eggs can also simply be deposited on a log or a patch of vegetation (Kramer and Smith, 1962). After the deposition and fertilization of the eggs, the female departs, but the male remains, sometimes for over a month after the eggs hatch, in order to provide parental care. He does so by fanning his tail over the nest to prevent sediment from smothering eggs and fry, and by actively and aggressively defending the nest against predators (Kramer and Smith, 1962). This period of parental care is key to the survival of offspring and thus to the persistence of the species. However, these aggressive males readily attack fishing lures that land in their nest, making them more vulnerable to angling during the parental care period (Jennings, 1997; Philipp et al., 1997; Suski and Philipp, 2004).

If a fish is caught, and returned to the water, it is not uncommon for the fishing boat to drift away from the initial location as the fish is removed from the hook. This means that fish are often not returned exactly at their capture location. Competitive angling events exacerbate this problem, since fish are not released immediately after capture; they can be temporarily held and transported in livewell confinements, and then released great distances (even greater than a kilometer) away from their capture site (Wilde, 2003). For a male, nest-guarding Largemouth Bass, both scenarios result in the fish not being returned to the water exactly above his nest. However, many studies have reported that male Largemouth Bass are capable of finding and returning to their nest location, even after being displaced by as much as 1 km (e.g.: Hanson et al., 2007; Hanson et al., 2007). Moreover, the bass' return, assuming that they are not exhausted from the capture event, is relatively rapid, suggesting that there is some level of directed swimming as opposed to fish encountering the nests by chance alone (Hanson et al., 2007). This journey back to the nest is vital for the success of the brood,

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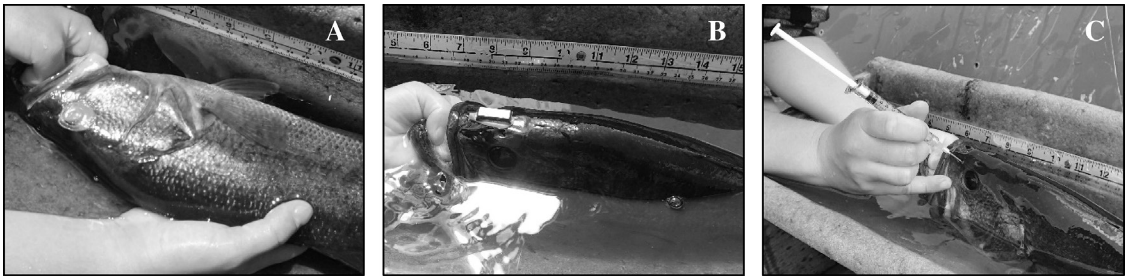

Fig. 1. Nesting, male Largemouth Bass subjected to A) visual impairment, B) geomagnetic impairment and C) olfactory impairment.

since any time spent away from the nest increases the exposure of eggs and fry to predation, which in turn increases the likelihood of a male abandoning his nest (Philipp et al., 1997). However, in spite of the importance of this return to the nest, the mechanisms behind the phenomenon have not previously been studied.

The tendency for Largemouth Bass to navigate back to their nests following displacement can be considered in-season homing, since the journeys are made within a given breeding season (Gerking, 1959). Aside from black bass (which includes Largemouth Bass and the closely-related Smallmouth Bass, *Micropterus dolomieu*), several other fish species, including Brook Trout (*Salvelinus fontinalis*; O'Connor and Power, 1973), Pink Salmon (*Oncorhynchus gorbuscha*; Helle, 1966), and Cutthroat Trout (*Oncorhynchus clarkia*; McCleave, 1967) are known to perform in-season homing. However, their journeys differ in the sense that displaced fish can return to a particular spawning region within a given lake or stream, but not necessarily to a designated nest containing eggs or fry. While the navigational mechanisms used by these fish are unclear in most cases, Cutthroat Trout have been found to use a combination of olfaction and vision (McCleave, 1967; Jahn, 1969; McCleave and Labar, 1972).

In some fish species, homing can also occur when adults return to their natal hatching location to spawn. This is referred to as reproductive homing (Gerking, 1959). Reproductive homing is common and well-studied in many anadromous salmonid species, who navigate to the sea as juveniles, and then return to their natal site as adults to reproduce. There is mounting evidence that the oceanic portion of the migrations is guided by the sun's position, polarized light patterns and the geomagnetic field (Quinn, 1980; Hawryshyn et al., 1990; Walker et al., 1988; Dittman and Quinn, 1996; Putman et al., 2013, 2014), while the freshwater portion of the journeys appears to be primarily guided by olfactory cues (see reviews by: Nevitt and Dittman, 1999; Hino et al., 2009; Ueda, 2011, 2012), with vision playing a secondary role in some cases (e.g.: Jahn, 1968; Groves et al., 1968; LaBar, 1971 Groves et al., 1968; LaBar, 1971).

The objective of this experiment was to determine how nest-guarding, male Largemouth Bass return to their nests after displacement. This was accomplished by assessing the homing ability of sensory-impaired fish (i.e., visual, olfactory and geomagnetic impairments) relative to appropriate controls. Some of the sensory impairment techniques in past studies have been quite invasive and sometimes even permanent. For example, olfactory occlusion has been accomplished by cutting the olfactory nerve (Bertmar and Toft, 1969), cauterizing the nasal rosettes (Lorz and Northcote, 1965), or suturing across the nares after packing them with cotton, wax, petroleum jelly or a combination of the three (Groves et al., 1968). Blinding has been accomplished by cutting the optic nerve (Bardach, 1958), by removing the optic lens and replacing it with petroleum jelly and carbon toner (Groves et al., 1968), by injecting formalin into the pupil (Lorz and Northcote, 1965) or by injecting aqueous benzethonium chloride into the eyeball (McCleave, 1967; Jahn, 1969; LaBar, 1971). A major requirement of our study was to design all treatments to be temporary and as harmless as possible given that animal welfare norms have changed considerably since the time when many of these sensory impairment strategies were first developed. Thus, we developed a novel visual impairment method, namely the application of dental adhesive. This experiment also represents one of the first tests of in-season homing mechanisms where displacement involves moving fish from a spe-

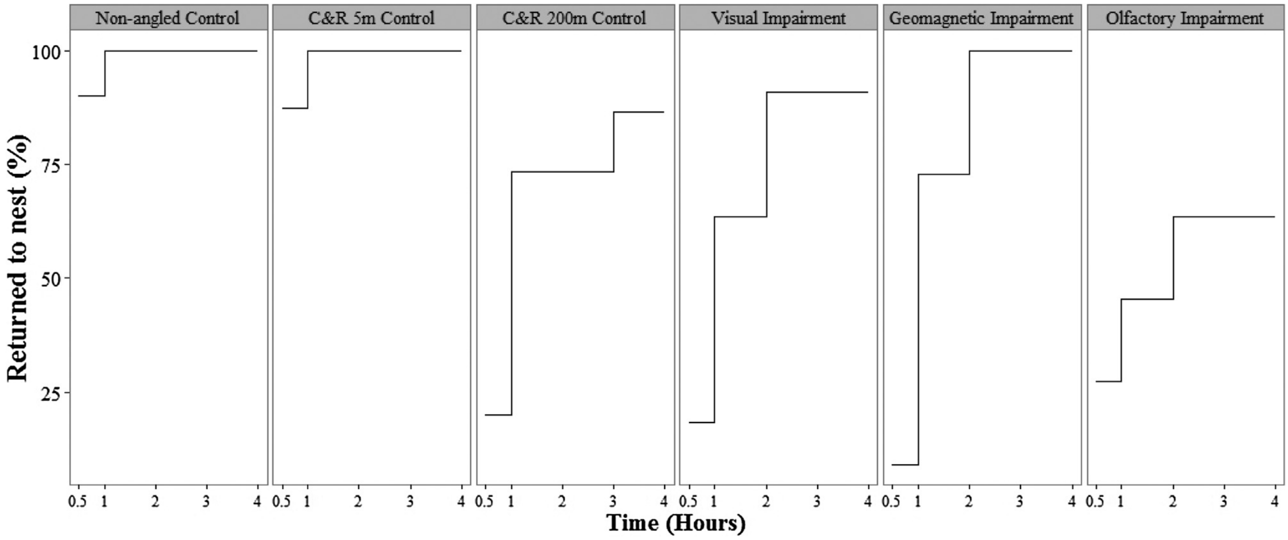

Fig. 2. The cumulative percentage of Largemouth Bass in each treatment group to return to their nests after 0.5 h, 1 h, 2 h, 3 h and 4 h.

cific active nesting site rather than a general summer home range, using temporary sensory impairment strategies.

2. Methods

2.1. Study site and experimental procedures

Data for this study were collected between May 11 and May 15, 2014 on Lake Opinicon in southeastern Ontario. Largemouth Bass nests containing newly-spawned eggs (<3 days old) were located in littoral regions by snorkel surveys and marked with polyvinyl chloride tags for future identification. The mating success of the male was determined by ranking the quantity of eggs in each nest on a scale from 1 to 5, with 1 representing a very small brood size and 5 representing a large brood (Kubacki, 1992; Philipp et al., 1997; Suski et al., 2002).

Nesting males (with the exception of the non-angled controls) were then angled off of the nests by a snorkeler and brought to a nearby boat to be measured (total length) and treated. Each male was randomly assigned one of the following treatments:

a Non-angled control: Non-angled control fish were not removed from their nests. Nests were simply located, and tagged like all other nests. Since an exact measurement could not be made, total length was estimated by the snorkeler to the nearest 2 cm.

b Catch-and-release (C&R) 5 m Control: All individuals in this group received simulated treatments for all three impairments involved in the study. The eyes were carefully padded dry with paper towel and gently rubbed for approximately 20 s (the same amount of time it took to treat visually impaired fish). A blunt-tipped 16 gauge needle was used to blow air through the nares. A strip of Fixodent® was applied above the cranial region. The fish were then released 5 m from their nests.

c Catch-and-release (C&R) 200 m Control: Fish were treated in the same way as the catch-and-release (5 m) control fish, but were released approximately 200 m away from their nests.

d Visual Impairment (Fig. 1A): Vision was impaired by drying the eyes with paper towel and applying a thin layer of Vaseline®, followed by a layer of pink, opaque Fixodent®. Based on observations made during preliminary trials, this method effectively blocked the vision of the fish for four to eight hours, after which time the Fixodent® began to flake off. There were no noticeable physical or behavioral impairments following eye treatments during laboratory trials. A variety of other approaches were attempted in preliminary trials, including the application of several brands of toothpaste, a mixture of toothpaste and Vaseline®, a mixture of Vaseline® and flour, opaque eye patches held in place by Fixodent® and a layer of Fixodent® with no Vaseline®. Out of all of the attempted approaches, the application of Vaseline® and then Fixodent® on dry lenses was most successful in terms of forming an eye patch of appropriate consistency to remain on the eyes for an extended, but temporary period of time. Treated fish were then transported 200 m away from their nests and released.

e Geomagnetic impairment (Fig. 1B): A strong bar magnet was fixed between the eyes of the bass, above the cranial region, using Fixodent®. Since strong bar magnets produce stronger magnetic fields than the Earth's natural field, placing a magnet above the fish's brain should compromise magnetic navigation (Avens and Lohmann, 2003). After the application of the magnet, fish were released 200 m away from their nests.

f Olfactory impairment (Fig. 1C): Olfaction was occluded by using a blunt-tipped 16 gauge needle to inject Vaseline® into the anterior nares until it came out of the posterior nares, indicating a full olfactory chamber (Jahn, 1969; LaBar, 1971). Again, olfactory impaired (anosmic) individuals were released 200 m away from their nest.

Note that all displacements were made at distances perpendicular to the shore. While a treatment was being administered to a nesting male, a snorkeler placed a cover over the nest to prevent brood predation and thus nest abandonment. Nest covers consisted of either flat sheets of chicken wire (25 mm hexagonal holes) or of hardware cloth (mesh size 12.7 mm; 19 gauge) folded at 90° angles to form bottomless cages, following the methods of Siepker et al. (2009). Nest covers of different dimensions were selected depending on the size and shape of the nest. Nest covers were either pressed into the substrate or held in place by rocks. Following the release of a treated fish, a snorkeler returned to the appropriate nest after 0.5, 1, 2, 3, and 4 h (or until the male returned) to note the presence or absence of the male.

The trials lasted a maximum of four hours because beyond four hours, preliminary trials indicated that vision was not occluded enough (as assessed visually) to be considered sensory impairment. The displacement distance was also carefully chosen; it had to be large enough to ensure that return to a nest was not a coincidence, but short enough such that control males could find their nests within the four hour trial. It was estimated that 200 m would be an appropriate distance (Hanson et al., 2007). After performing several trials, it became clear that individuals were able to return at various time intervals within the four hour period, confirming that 200 m was an appropriate distance.

Air exposure and handling time were kept to a minimum in this study in order to avoid unnecessary physiological stress. Hook removal and fish measurement were accomplished in less than 120 s. The treatment of a given male lasted an additional 120 s or less, during which time the fish was held in a trough full of water with his gills submerged. A treated fish was placed in a large cooler full of water while being transported 200 m away from the nest, which took approximately 8 min. The trough and the cooler were refilled with fresh, cool water between fish.

2.2. Analysis

2.2.1. Analysis of total length and egg scores

To test for between-group differences in body size and egg scores, Shapiro–Wilk statistics were generated to evaluate the assumption of normality, and the Levene's test was used to examine the assumption of homogeneity of variance. Due to non-normal distributions of data, Kruskal–Wallis rank sums tests were performed instead of ANOVAs.

2.2.2. Analysis of treatment and time

To investigate whether bass returned to their nests following manipulation of their navigation systems, the proportion of bass that returned to their nests was modelled as a function of the 200 m control group and the three experimental impairment groups (included as fixed effects), and the timing of their return (included as a random effect) using a generalized linear mixed model. Note that the non-angled control group, and the C&R 5 m control group were included only in the graphical representation of the data for contextual purposes; they were not included in the model.

The random intercept provides estimates for a typical time interval (i.e., any of the five time intervals) over the 4 h period. Specifically, the model was:

$$Y_{ij} = \mathrm{Bin}(n_{ij}, \pi_{ij})$$

$$E(Y_{ij}) = \pi_{ij} \times n_{ij} \mathrm{andvar}(Y_{ij}) = n_{ij} \times \pi_{ij} \times (1 - \pi_{ij})$$

$$\mathrm{logit}(\pi_{ij}) = \propto + B_1 \times \mathrm{Treatment}_{ij} + \alpha_i + \epsilon_i$$

$$\alpha_{\mathrm{i}} \sim \mathrm{N}(0, \sigma_\alpha^2)$$

$$\alpha_{\mathrm{i}} \sim \mathrm{N}(0, \sigma_\epsilon^2)$$

Where Y_{ij} is the number of individual bass j that returned to their nest in the i^{th} time interval and n_{ij} is the total that could return. Y_{ij} is assumed to follow a binomial distribution where the probability that Y_{ij} is between 0 and 1 is π_{ij}. The expected mean and variance are given by E and var respectively. The random intercept for time interval is a_i. Both the random intercept and residual error ϵ_{i} are assumed to be normally distributed with a mean of zero and variance σ^2.

Here, higher parameter estimates indicate that more fish returned relative to fish in the other treatment groups. The model was fitted as a binomial logistic regression using the software package lme4 (Bates et al., 2014) in the R statistical environment (R Core Development Team, 2014). A Tukey's post-hoc test was performed to reveal pairwise treatment differences. The model was checked for overdispersion and validated by plotting the residuals against the fitted values and the explanatory variables. A value of 0.05 was used as the level of significance (α) for all statistical tests.

3. Results

In total, 10 individuals were subjected to the non-angled control treatment, 8 individuals were subjected to the catch-and-release 5 m control treatment, 15 individuals were subjected to the catch-and-release 200 m control treatment, and 11 individuals were subjected to each of the impairment treatments. Thus, 66 nests were sampled altogether.

According to Kruskal–Wallis rank sums tests, fish in all treatment groups were of similar total length (H = 6.5, p = 0.27) and had similar egg scores (H = 3.5, p = 0.63), which justified excluding these variables from the generalized linear mixed model. Individuals in the non-angled control and the 5 m displacement control groups were present on their nests across the entire monitoring period, aside from one individual in each group that was absent at the first time point (Fig. 2). This allowed us to isolate the effects of displacement and impairment.

Overall, the olfactory impairment group was found to be significant in the model (z = −2.1, p = 0.04, Table 1). In all but the olfactory impairment group, there was greater than a 70% probability that displaced Largemouth Bass would return to their nests during a typical time interval over the experimental period (Fig. 3). A Tukey's post-hoc test revealed that the olfactory impairment group was significantly different from the geomagnetic impairment group (z = −3.0, p = 0.016, Table 2) such that anosmic bass had a significantly lower probability of returning to their nests during a typical time interval (Table 2, Fig. 3).

Table 1

Results of a generalized linear mixed model, with experimental treatments included as fixed effects and return time included as a random effect (σ = 1.6). The intercept represents the 200 m displacement control group. Significant values, based on α = 0.05 are boldface.

Fixed effects	Estimate	Standard error	*z* value	Pr (>|z|)
(Intercept)	0.91	0.64	1.4	0.15
Visual	0.19	0.46	0.43	0.67
Geomagnetic	0.60	0.48	1.2	0.21
Olfactory	−0.88	0.43	−2.1	**0.039**

Table 2

The results of a Tukey's poc-hoc test, conducted for pairwise comparisons of the 200 m displacement control group (C&R200) and the three sensory impairment groups. Significant values, based on α = 0.05 are boldface.

Linear Hypotheses	Estimate	Standard Error	*z* value	Pr (>|z|)
Visual–C&R200	0.19	0.46	0.43	0.97
Geomagnetic–C&R200	0.60	0.48	1.2	0.60
Olfactory–C&R200	−0.88	0.43	−2.1	0.17
Geomagnetic–Visual	0.40	0.52	0.78	0.86
Olfactory–Visual	−1.1	0.47	−2.3	0.10
Olfactory–Geomagnetic	−1.5	0.50	−3.0	**0.016**

4. Discussion

The only significant difference that we found was between the geomagnetic impairment group and the olfactory impairment group, with the probability of a male returning within a given time interval being significantly lower for the anosmic individuals (Table 2, Fig. 3). Several different forms of controls were used to isolate the effects of the sensory manipulations on the experimental fish. From the non-angled control group, we were able to conclude that neither the presence of snorkelers nor the presence of nest covers or nest tags caused males to abandon their nests; all fish in this group returned within thirty minutes of the nest visit, with the exception of one individual, who returned after one hour (Fig. 2). The same trend was observed for the 5 m displacement control group, confirming that the catch-and-release process in itself, without an added distance component, did not cause nest abandonment (Fig. 2).

Contrary to these first two control groups, not all of the 200 m displacement controls returned within the four hour time period. Rather, approximately 87% of males returned (Fig. 2). There are several potential reasons why a male without sensory impairment might not have been observed on the nest throughout the experimental period. First of all, there may be individual differences in the navigational abilities of bass. It is also possible that some males abandoned their nests due to energy expenditure during their homing journey, compounded by the stress and exercise associated with angling (Siepker et al., 2009; Cooke et al., 2000, 2004; Suski and Philipp, 2004), which make it altogether more difficult for males to resume their energetically costly parental care activities upon return (Gillooly and Baylis, 1999). It is also possible that some males abandoned their nests due to the depletion of eggs by nest predators. While nest covers may assist in reducing predation of Largemouth Bass eggs in the absence of a male, predators were observed underneath the nest covers of two nests: one nest belonging to a 200 m displacement control, who did not return within four hours, and one nest belonging to an anosmic male, who returned within one hour. It is possible that other cases of nest predation occurred between nest visits, and went unnoticed by snorkelers. Thus, some males might have in fact returned to a depleted nest and abandoned before being observed by a snorkeler. However, given the time scale of this study, and the fact that predation was directly observed on only two nests, it is unlikely that predation-induced abandonment was a major reason for the absence of males on their nests. More frequent nest visits by the snorkeler or use of videography could have provided more information about this issue. However, due to a combination of cold water temperatures, the length of the experimental period, time constraints for completing the study and a lack of underwater technology, none of these options were possible in the context of this project. Since bass were randomly assigned a treatment, all treatment groups should have been equally subjected to the individual variation in navigation as well as the possibility of exercise-induced or predation-induced abandonment. Therefore, a significantly lower return rate than the

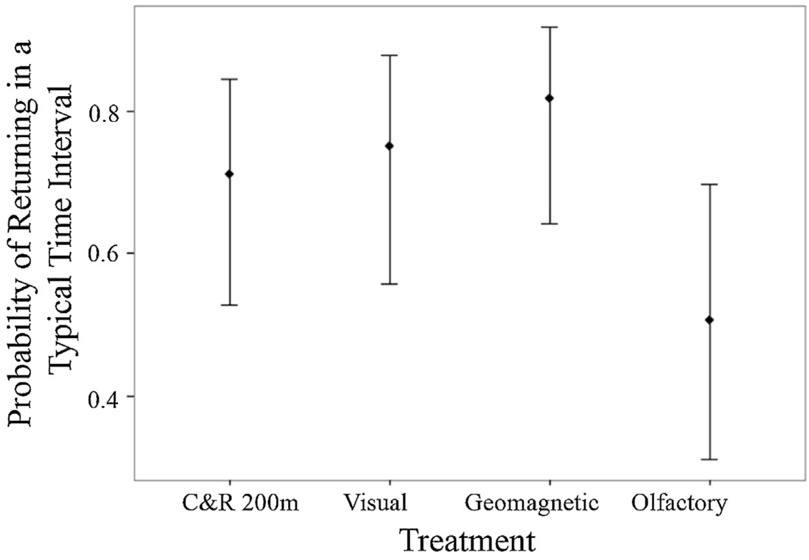

Fig. 3. The probability (±95% Confidence limits) of a male Largemouth Bass returning to his nest within a given time interval over the four hour experimental period when subjected to a 200 m control treatment (C&R) or one of the three sensory impairment treatments. The variance for the random time effect was 1.6. Confidence limits are shown for fixed effects only.

200 m displacement control group should reflect navigational difficulty relative to unimpaired individuals.

The visually impaired individuals had a very similar return pattern as the 200 m displacement controls, with approximately 91% of individuals returning within four hours (Fig. 2). It is important to note that the treatment broke down more quickly in the field than in the laboratory setting, and thus the eyes were not always completely covered with Fixodent® upon the return of males to their nests. We estimated a minimum of 80% visual occlusion among all visually impaired individuals at the end of the experimental period. If vision played a primary role in navigation, we contend that 80% occlusion should have been sufficient to yield noticeably lower return rates. Thus, it does not appear that vision is a sensory mechanism used by displaced male Largemouth Bass.

Aside from the non-angled controls and the 5 m displacement controls, the geomagnetic impairment group was the only treatment group with a 100% return rate within four hours. Although this is higher than the return rate of the 200 m displacement control group, the difference is not significant (Table 2, Fig. 2), which makes intuitive sense; placing a magnet above the cranial region of a fish, and thus exposing the individual to a new, stronger magnetic field would not improve navigational ability. However, it is possible that the more extensive handling of the control males (on the eyes and nares) relative to the geomagnetic impairment group contributed to the lower four hour return rate of the 200 m control group. This could have been verified by having a separate control group for each impairment treatment. Due to time constraints in our study, it was not possible to do so, but it can be considered as an improvement for future studies.

Interestingly, despite having the lowest four hour return rate, some individuals in the olfactory impairment group returned relatively quickly, within thirty minutes post release (Fig. 2). It is possible that this relatively high initial return rate was due to unsuccessful olfactory occlusion in some of the individuals. Although preliminary trials in the laboratory revealed that the nares remained blocked (as assessed visually) with Vaseline® for more than four hours, snorkelers were unable to verify occlusion in the wild due to a combination of murky water conditions and the subtle color of the Vaseline®. However, the differences between the various half hour return rates appear to be marginal overall (Fig. 2).

Overall, based on the sensory impairments used in the current experiment, it appears that olfaction is the most important sensory mechanism for homing in displaced nest-guarding male Largemouth Bass. Indeed, there is clearly a trend in the data that indicates that anosmic males have impaired navigational abilities. There is some limited evidence that other fish species that perform in-season homing may also use olfaction for navigation. For example, although they are not necessarily able to home to a particular active nest, Cutthroat Trout use in-season homing to navigate back to the general region from which they were displaced. However, unlike Largemouth Bass, Cutthroat Trout appear to sometimes use visual cues for additional navigational assistance (McCleave, 1967; Jahn, 1969; McCleave and Labar, 1972).

Like the in-season homing journeys of Cutthroat Trout, the freshwater portion of the long, reproductive homing journeys of anadromous salmonids appears to be primarily guided by olfaction, with vision sometimes playing a secondary role (see reviews by: Leggett, 1977; Dittman and Quinn, 1996; Nevitt and Dittman, 1999; Hino et al., 2009; Ueda, 2011, 2012). This once again highlights the overall importance of olfaction in fish navigation. Before reaching a freshwater stream of interest, where visual and olfactory cues can be used, these anadromous fish must navigate on a larger scale through the open ocean. For this portion of their homing journey, they appear to use other cues, such as Earth's magnetic field (Quinn, 1980; Hawryshyn et al., 1990; Walker et al., 1988; Dittman and Quinn, 1996; Putman et al., 2013, 2014). Therefore, the fact that Largemouth Bass do not show evidence of geomagnetic navigation is likely related to the short distances of their homing journeys and thus the inability to detect such subtle spatial variation in the magnetic field.

Given that vision can aid in the journeys of other homing species, it would be worth exploring Largemouth Bass homing mechanisms further. While it is possible that there is simply variability in the mechanisms used by different fish species for homing, it is also possible that our study alone has not yet revealed all aspects of Largemouth Bass homing mechanisms. There is room, for example, to investigate how different combinations of sensory impairments affect displaced, nesting Largemouth Bass. Future research can also investigate whether or not displacement distance plays a role in the mechanisms used for homing, with visual cues possibly used at greater distances away from the nest.

Another area of future research might involve determining which specific olfactory cues are being used by the bass during navigation. There are several possible ways in which olfactory-recognition can occur. In the case of egg recognition in particular, chemical cues may be deposited on the nest by parents, or may originate from the eggs themselves (Loiselle, 1983). When site or kin recognition occurs post egg hatching, most evidence suggests that the chemical cues used for recognition are emitted by the large quantity of juvenile offspring via pheromones in urine or fecal matter (e.g.: Moore et al., 1994; Stabell, 1987). For example, Lake Trout, *Salvelinus namaycush*, who spawn perennially on rocky shoals, are able to differentiate, using olfaction alone, between substrata from perennial nesting sites and substrata from non-spawning shoals (Wasylenko et al., 2013). In Convict Cichlids (*Cichlasoma nigrofasciatum*), waterborne olfactory cues enable females to identify their own offspring (Lutnesky, 1989). Similarly, parental male Bluegill, *Lepomis macrochirus*, are able to recognize their young by means of chemical cues (Neff and Sherman, 2003). In all three cases, recognition is most likely facilitated by the build-up of pheromones released by juveniles. Since Largemouth Bass are known to home to nests containing either eggs or fry, it would be interesting to determine which olfactory cue(s) are used for these journeys, and whether or not these cues change depending on whether the males are homing to eggs or fry.

It would also be beneficial to determine if the olfactory signatures of different anthropogenic pollutants inhibit navigation. There is some evidence that suggests that water acidification, as well as trace amounts of substances such as copper or mercury can negatively affect olfactory-mediated behaviours of certain fish species (e.g.: Hara et al., 1976; Leduc et al., 2013). Although the extent to which nest abandonment in black bass affects bass populations as a whole remains unclear, there have still been steps taken to reduce the negative impacts of catch-and-release angling on nesting males. These steps include instating closed seasons during the reproductive period in certain regions (Paukert et al., 2007), establishing fish sanctuaries that prohibit fishing in specific, key nesting areas of lakes (Suski et al., 2002), and encouraging the use of barbless hooks and other best fishing practices (Cooke and Suski, 2005). An understanding of which water conditions inhibit olfactory-based navigation can potentially help to direct these conservation efforts to regions with compromised olfactory signatures, where bass displaced by angling events would be less likely to successfully return to their nests and resume parental care activities.

In summary, this study revealed that in-season homing of displaced Largemouth Bass appears to be primarily mediated by olfaction, yielding one of the few non-salmonid examples of such homing activity. Larger sample sizes would likely produce more conclusive results with respect to the relationship between the control groups and the olfactory impaired group. An additional contribution of this study was experimentation with temporary methods of impairing sensory apparatus of fish. The visual impairment treatment (i.e., use of a dental adhesive) in particular was novel, and can be used, modified and improved as needed for future studies.

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