

Predator-recognition training of hatchery-reared walleye (*Stizostedion vitreum*) and a field test of a training method using yellow perch (*Perca flavescens*)

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Abstract: Fishes reared in captivity are predator-naïve and suffer large predation mortality when stocked into lakes with a full complement of predators. We tested the potential of predator training to enhance post-stocking survival of hatchery-reared walleye (*Stizostedion vitreum*). In the first part of the study, we found that walleye (*i*) use chemical cues for assessing predation risk, (*ii*) do not have innate recognition of the odor of northern pike (*Esox lucius*) as an indicator of predation, and (*iii*) associate predation risk with pike odor after a single simultaneous encounter with pike odor and chemical alarm cues from walleye skin. In the second part of the study, we attempted to mass-train yellow perch, *Perca flavescens* (as a surrogate for walleye), to fear pike odor. Perch response to pike odor was not changed by placing sponge blocks containing pike odor and perch alarm cues around the perimeter of a pond. On pre- and post-training assays, perch avoided traps scented with perch alarm cues, but did not avoid traps labeled with pike odor or water. We conclude that recognition training offers potential as a management tool for walleye, but significant logistic challenges must be solved before it can be implemented.

Résumé : Les poissons élevés en captivité n'ont pas l'expérience de la prédation et ils subissent une forte mortalité due à la prédation lorsqu'ils sont introduits dans des lacs qui contiennent une gamme complète de prédateurs. Nous évaluons ici le potentiel d'un entraînement aux prédateurs pour augmenter la survie après l'empeisonnement chez des dorés jaunes (*Stizostedion vitreum*) élevés en pisciculture. Dans la première partie de l'étude, nous avons trouvé (*i*) que les dorés utilisent des signaux chimiques pour évaluer les risques de prédation, (*ii*) qu'ils ne reconnaissent pas de façon innée l'odeur du grand brochet (*Esox lucius*) comme indicateur du risque de prédation et (*iii*) qu'il suffit d'une seule exposition simultanée à l'odeur de brochet et aux substances d'alerte de peau de dorés pour qu'ils associent l'odeur de brochet au risque de prédation. Dans la seconde partie de l'étude, nous avons essayé d'entraîner des groupes de perchaudes, *Perca flavescens* (en remplacement des dorés) à craindre l'odeur des brochets. La réaction des perchaudes à l'odeur de brochets ne change pas lorsqu'on place des blocs d'éponges contenant l'odeur de brochet et les signaux d'alerte de la perchaude sur le périmètre d'un étang. Dans les tests avant et après l'entraînement, les perchaudes évitent les pièges marqués de signaux d'alerte de perchaudes, mais pas ceux marqués d'odeur de brochet ou d'eau. Nous concluons que l'entraînement à la reconnaissance d'odeurs peut avoir un potentiel comme outil d'aménagement des dorés, mais qu'il y a des problèmes logistiques importants à résoudre avant son utilisation.

[Traduit par la Rédaction]

Introduction

Chemical cues are ubiquitous in aquatic environments (Wisenden 2003). Olfaction is the most ancient of the senses and provides information for such critical activities as finding food, avoiding predators, and cueing reproductive behav-

ior (Hara 1993; Kats and Dill 1998; Stacey and Sorensen 2002). Several classes of chemical cues are used for detecting predation risk. Alarm cues are chemicals released when tissue is damaged by a predatory attack (Chivers and Smith 1998). These cues are released only in this context and thereby reliably indicate risk to conspecifics and ecologically similar heterospecific prey (Mathis and Smith 1993c; Chivers and Smith 1998). Behavioral responses to these cues reduce the probability of predation (Mathis and Smith 1993a; Mirza and Chivers 2000; Gadzewich and Chivers 2002).

Because of the steep selection gradient imposed by predation, a significant fitness benefit accrues from recognition of risk from indirect indicators. Many prey species use the presence of conspecific chemical alarm cues to extend the range of stimuli that indicate risk (Chivers and Smith 1998). When alarm cues are released, chemical and visual stimuli correlated with the event, such as predator odor, diet of the

Received 6 May 2004. Accepted 2 July 2004. Published on the NRC Research Press Web site at <http://cjfas.nrc.ca> on 25 January 2005.
J18112

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predator, smell of the habitat, and appearance of the predator, become associated with predation risk (Suboski 1990; Chivers and Smith 1998). As testimony to the extreme importance of predator recognition, a single simultaneous exposure to alarm cues and a novel stimulus is sufficient for learned recognition to occur, persisting for at least 4 months in fathead minnows (*Pimephales promelas*; Chivers and Smith 1994), at least 10 days in brook char (*Salvelinus fontinalis*; Mirza and Chivers 2000), and 21 days in rainbow trout (*Oncorhynchus mykiss*; Brown and Smith 1998). By attending to correlates of alarm-cue release, prey species quickly track temporal and spatial shifts in predator identity and abundance.

This learning paradigm has application to fisheries management in instances where fish are reared in predator-free environments and subsequently released into natural waters that contain predators (Suboski and Templeton 1989). Mortality of stocked fish due to predators is a perennial problem for stocking programs (Santucci and Wahl 1993; Szendrey and Wahl 1996). Recognition training could improve the survival rate of stocked fish and thereby improve the cost-effectiveness of hatchery programs, enhance fishery quality, and contribute to the economic benefits associated with the recreational sport fishery and related tourism industry. Recognition training has been shown to be effective for several species of hatchery-reared salmonids (Brown and Smith 1998; Berejikian et al. 1999; Mirza and Chivers 2000).

To successfully apply predator-recognition training to hatchery-based stocking programs, four conditions must be met. The first three are (1) that the game species use chemical cues for assessing predation risk, (2) that they do not already have an internal cognitive recognition of the predator odor (or sight) as an indicator of danger, and (3) that they associate predation risk with predator odor (or sight) after a single simultaneous exposure to conspecific chemical alarm cues and stimuli from predators. The fourth condition is feasibility of implementation (see below).

In the first part of this study we explore the potential application of predator-recognition training to hatchery-reared walleye (*Stizostedion vitreum*). The Minnesota Department of Natural Resources intercept spawning walleye in the spring spawning run, strip their gametes, incubate fertilized eggs in a hatchery, and transfer the resulting larvae to small prairie pothole lakes that serve as rearing ponds. The combination of shallow water (mean depth 2.8 m) and frequent low winter concentrations of dissolved oxygen ensure that large piscivorous fish usually do not survive over winter ("carryover") to prey upon the next crop of walleye the following year. In the fall, as temperatures begin to cool, walleye fingerlings, by now approximately 15–20 cm in length, are harvested from the rearing ponds and transferred to area lakes for fishery enhancement. Although walleye are efficient predators as adults, as juveniles they are subject to the same predation pressures as other similar-sized fish. Mortality over the first 2 weeks after stocking can be high, and a large proportion is thought to be due to predation, northern pike (*Esox lucius*) being the dominant predator. Here we test if walleye fall fingerlings can be trained to recognize pike odor, thereby satisfying the first three conditions outlined above.

Following the establishment of the potential for recogni-

tion training, there remains the significant logistical problem of developing a mechanism of training walleye on a scale typical of fisheries stocking programs. Whereas laboratory studies typically train fish on an individual-by-individual basis, the state of Minnesota alone stocks 1.2 million walleye fingerlings annually. To be a practical tool for fisheries management, the method of recognition training must be simple and rapid, and not demand additional facilities or personnel (i.e., inexpensive). This is the fourth condition for the successful implementation of predator-recognition training in fisheries management.

In the second part of this study, we attempted to train a whole population of yellow perch, *Perca flavescens* (as a surrogate for walleye), by applying alarm cues and pike odor directly to the small lake in which they lived. Perch are an appropriate surrogate for walleye because both possess percid club cells in the epidermis (darters, Smith 1982; walleye, Wisenden 2003; perch, Shireen Alemadi and Brian Wisenden, Minnesota State University Moorhead unpublished data), which are a likely component of alarm cues in the Percidae.

Materials and methods

Walleye training experiment

Approximately 200 juvenile walleye were obtained from Axberg Pond, a walleye rearing pond located in western Minnesota near Moorhead (46°50'N, 96°10'W). Fish were transferred to the aquatic research facilities at Minnesota State University Moorhead (MSUM) and held in four 570-L holding tanks (88 cm × 75 cm × 82 cm high) at 21 °C. Each tank was fitted with two biological filtration columns, and partial water changes (about 15% of tank volume) were conducted weekly. Walleye were fed fathead minnows purchased from a bait dealer.

Ten test aquaria were set up in two rows along one wall in a room in the MSUM aquatic-research facility. Test aquaria were 190 L in volume (91 cm × 46 cm × 48 cm high) with a thin layer of naturally colored gravel and a large-capacity power filter hanging on the outside of the short pane. A sponge filter in the center of the tank received two tubes of airline tubing; one delivered compressed air, while the other served as a means by which chemical stimuli could be injected surreptitiously. A grid with cell dimensions of 10 cm × 10 cm was drawn on the front (long) viewing pane to be used for scoring vertical distribution and activity (described below). The outer surfaces of the back and sides were painted blue to preclude visual contact among fish in the test aquaria. The solid appearance of painted glass seemed to promote a sense of security in walleye and help them adjust to captivity. Dim ambient lighting also helped walleye adjust to captivity. Room lighting was limited to two partially shaded 25-W floor lamps. We placed three juvenile walleye in each test aquarium. We found that social interactions among a group of three stimulated activity and normal foraging behavior. Normal feeding on fathead minnows commenced almost immediately after the walleye were netted and transferred from the holding tanks to test aquaria, but resumption of normal swimming activity required about a week of acclimation to the test tank.

Chemical alarm cues were collected from 17 juvenile

walleye (total length (TL) = 18.7 ± 0.62 cm (mean \pm SE)). Each fish was killed humanely by cervical dislocation with a knife blade and measured, and skin fillets were removed from each side. The skin fillets were measured (length and average width) to calculate the area of skin removed, and placed in a beaker of chilled dechlorinated tap water. A total of 1006.06 cm² of walleye skin was collected from the 17 walleye. The fillet area collected per fish was 59.1 ± 4.8 cm². A kitchen hand blender was used to rupture percid epidermal club cells and simulate the release of chemical cues during a predatory attack. The resulting solution was filtered through a loose wad of polyester wool to remove scales and connective tissue and diluted to a final volume of 1200 mL. Aliquots of 60 mL were frozen at -20 °C until needed. At the same time, we froze 60-mL aliquots of blank dechlorinated tap water that had been passed through a wad of polyester fiber. Each 60-mL dose contained 50 cm² of walleye skin, approximately equivalent to one donor fish.

Predator odor was collected from a northern pike (TL = 50.6 cm) collected from Boyer Lake, Minnesota ($46^{\circ}52'N$, $96^{\circ}03'W$). The pike was held for 7 days in a 75-L aquarium containing dechlorinated tap water. Tank water was removed in 120-mL aliquots and frozen at -20 °C until needed.

Each group of three fish was tested twice. On the first (conditioning) day, walleye were given 120 mL of pike odor + 60 mL of water (control treatment) or 120 mL of pike odor + 60 mL walleye skin extract (experimental treatment). These trials served to (i) test for preexisting recognition of pike odor as dangerous (control treatment) and (ii) determine if walleye respond to injury-released alarm cues with antipredator behavior (experimental treatment). Ultimately, the first trial provided walleye the opportunity to associate alarm cues with pike odor. After each batch of conditioning trials was completed (several hours), tank water was siphoned out of each tank until just the backs of the walleye were exposed (a depth of about 5 cm). Each test tank was immediately refilled with fresh dechlorinated tap water. Thus, test stimuli were mostly removed from the test tank, and any cues that remained were greatly diluted. We did not capture the walleye and move them to a new tank to completely exchange the water because walleye become highly stressed when handled. This stress may have inadvertently caused walleye in control trials (pike odor + water) to associate pike odor with the stress of handling. On the second (test) day, about 2–5 days later, each group of three walleye was retested with 120 mL of pike odor alone. This trial tested for a learned association between pike odor and predation risk. We predicted that walleye previously exposed to walleye skin and pike odor would now recognize pike odor as an indicator of predation risk, whereas control walleye would continue to be indifferent to pike odor.

Most trials were conducted in the morning (0700–1100), when walleye were most active. Activity was scored as the total number of grid lines crossed by the three walleye. Vertical distribution was recorded by noting which of the four horizontal zones each fish occupied at 10-s intervals over the 10-min observation period. Vertical distribution ranged from a maximum value of 720 (all fish on the bottom for the entire observation period). We recorded activity and vertical distribution for 10 min (prestimulus observation period). Then, for 90 s, we injected test stimuli. Behavioral recording

resumed for another 10 min (post-stimulus observation period). After a batch of test trials was finished the fish were killed by cervical dislocation with a knife blade and measured. To clean test tanks, we stirred the gravel to suspend fecal pellets and drained all the water by siphon.

We used Wilcoxon–Mann–Whitney tests (Siegel and Castellan 1988) to compare the magnitude of behavioral change between the treatments, followed by Wilcoxon's matched-pairs signed-ranks tests to test for deviation from zero for individual treatments (Siegel and Castellan 1988). We used one-tailed probability distributions because dozens of previous studies had indicated that antipredator behavior in response to chemical alarm cues is manifested as a reduction in activity and movement to the bottom (for reviews see Lima and Dill 1990; Chivers and Smith 1998; Wisenden 2003).

Field population training of yellow perch

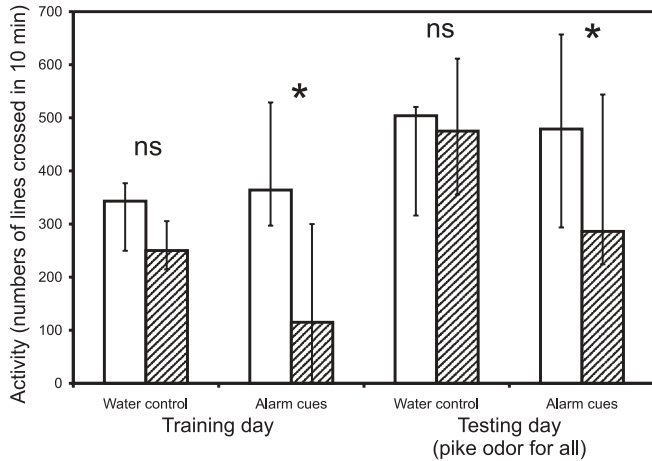
This experiment was conducted in Deming Lake, Minnesota ($47^{\circ}10'N$, $95^{\circ}10'W$), within the boundaries of Itasca State Park. This lake is 5.5 ha in area and contains yellow perch, pumpkinseed sunfish (*Lepomis gibbosus*), fathead minnows, northern redbelly dace (*Phoxinus eos*), golden shiners (*Notemigonus crysoleucus*), blacknose shiners (*Notropis heterolepis*), brook stickleback (*Culaea inconstans*), Iowa darters (*Etheostoma exile*), and black bullhead (*Ameiurus melas*). Large piscivorous species are not known to occur in this lake.

Alarm cues of perch were prepared by killing 28 perch (TL = 7.98 ± 0.81 cm) by decapitation and removing skin fillets from each flank. A total of 271.25 cm² of perch skin was collected and placed in well water resting on a bed of ice. A conventional kitchen hand blender was used to rupture percid club cells and simulate the release of chemical cues due to a predatory attack. The solution was diluted to 2700 mL and filtered through a wad of polyester wool. The concentration of perch skin extract was 0.1 cm² of skin per 1 mL of solution.

We prepared pike odor from a northern pike (TL = 38.6 cm) seined from Lake Itasca, Minnesota ($47^{\circ}13'N$, $95^{\circ}12'W$). The pike was placed in a 75-L aquarium for 3 days to allow dietary cues to pass out of the pike's gut (Mathis and Smith 1993b). The water was replaced with 37 L of fresh lake water and another 3 days were allowed to pass. We used this aquarium water as pike odor.

The experiment compared the numbers of fish captured in minnow traps scented by sponge blocks soaked in either water (control), pike odor (predator odor), or perch skin extract (chemical alarm cues). We used conventional cellulose kitchen sponge (unscented) cut into cubes (2 cm \times 2 cm \times 3 cm) that could hold 5 mL of test stimulus. Thus, each sponge holding perch skin extract contained the equivalent 0.5 cm² of skin. On the first day of the experiment we set 45 traps around the perimeter of Deming Lake. We set the traps in groups of three, each trio containing one of each stimulus type. The three traps in each group were placed in the water simultaneously, then we waited 5 min before setting the next trio. Traps were left in the water for 2 h, after which we pulled trios individually at 5-min intervals. This protocol maintained a constant fishing time of 2 h for every trap and provided 5 min per trio to process the catch.

Fig. 1. Median (\pm quartiles) walleye (*Stizostedion vitreum*) activity before (open bars) and after (hatched bars) the introduction of test stimuli. On the training day, walleye received pike (*Esox lucius*) odor plus either water (control) or walleye skin extract (alarm cues). On testing day, the same walleye were retested with pike odor only (*, $P < 0.05$; ns, nonsignificant, $P > 0.05$.)



We waited 3 days and then placed 60 pairs of scented sponges around the perimeter of the lake at intervals of about 5 m. Sponges were attached together in pike odor – perch alarm cue pairs. Sponges were larger for the second day of the experiment. Sponge blocks (2.6 cm \times 2.6 cm \times 3.9 cm) were each infused with 15 mL of skin extract, thus holding the equivalent of 1.5 cm² of perch skin area. Sponge blocks holding pike odor were 3.5 cm \times 3.5 cm \times 3.8 cm and each held 30 mL of pike odor. These sponges were left in the lake for 2 h. After another 4 days (7 days since the first trapping experiment), we reset 45 traps in trios as before, with sponge blocks of the same dimensions as on the first day. Trap trios, as before, contained either water, pike odor, or perch skin extract.

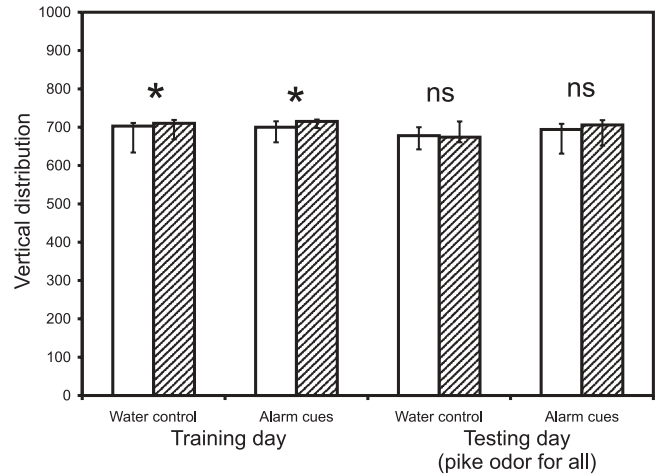
We used Kruskal–Wallis one-way analyses of variance (KW) to test for differences among sponge treatments followed by post-hoc α -adjusted pairwise comparisons among treatments (Siegel and Castellan 1988).

Results

Walleye training experiment

Upon first exposure to pike odor, walleye given pike odor + walleye skin extract (alarm cue) decreased activity significantly more than walleye given pike odor + water (Wilcoxon–Mann–Whitney test, $z = 2.821$, $P = 0.002$; Fig. 1). A comparison of activity before and after introduction of stimuli showed no change for walleye given pike odor + water (Wilcoxon’s matched-pairs signed-ranks test, $T^+ = 78$, $n = 15$, $P = 0.165$) but a significant decrease for walleye given pike odor + walleye skin extract ($T^- = 119$, $n = 15$, $P < 0.001$; Fig. 1). Walleye in both treatments increased vertical distribution (time near bottom) (pike odor + water: $T^+ = 96$, $n = 14$, $P = 0.002$; pike odor + walleye skin extract: $T^+ = 80$, $n = 13$, $P = 0.007$; Fig. 2), suggesting a general apprehensiveness in response to novel stimuli. Vertical distribution did not differ between treatments ($z = 0.29$, $P = 0.386$). Overall, walleye did not respond strongly on first exposure

Fig. 2. Median (\pm quartiles) walleye vertical distribution (i.e., which of the four horizontal zones each fish occupied at 10-s intervals over the 10-min observation period) before (open bars) and after (hatched bars) the introduction of test stimuli. On the training day, walleye received pike odor plus either water (control) or walleye skin extract (alarm cues). On testing day, the same walleye were retested with pike odor only (*, $P < 0.05$; ns, nonsignificant, $P > 0.05$).



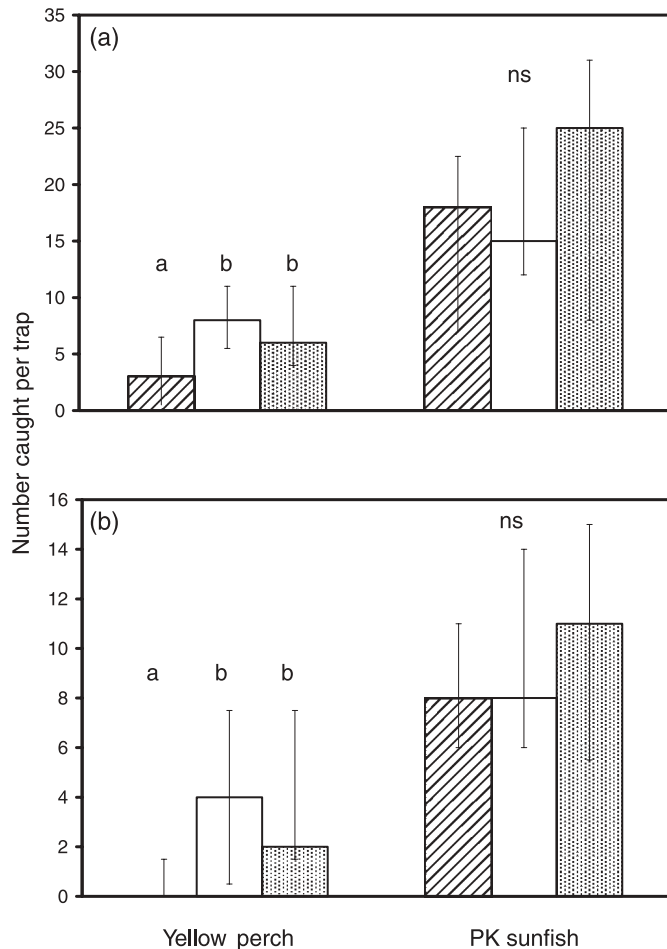
to pike odor alone, but did respond to the combination of pike odor and walleye skin extract.

When retested with pike odor, walleye previously given pike odor + water did not change activity ($T^- = 58$, $n = 15$, $P = 0.467$); however, walleye previously given pike odor + walleye skin extract significantly decreased activity ($T^- = 113$, $n = 15$, $P < 0.001$; Fig. 1). The change in activity differed significantly between the treatments ($z = 1.91$, $P = 0.028$). Thus, after a single, simultaneous exposure to pike odor and conspecific alarm cues, walleye later responded to pike odor alone in the same way as to walleye skin extract on the first day — with the antipredator response of reduced activity. Although vertical distribution shifted in the predicted direction, there were no statistically significant changes in vertical distribution for either treatment on the second day (pike odor + water: $T^+ = 78$, $n = 15$, $P = 0.165$; pike odor + walleye skin extract: $T^+ = 55$, $n = 13$, $P = 0.271$; Fig. 2). There was no significant difference between treatments in vertical distribution ($z = 0.145$, $P = 0.444$).

Perch population training in Deming Lake

Upon first exposure to test cues, perch avoided traps labeled with perch skin extract but gave no indication that they recognized pike odor as dangerous (KW = 8.59, $P < 0.020$; Fig. 3a). The numbers of perch captured in the three trap types were 127, 125, and 57 for pike odor, water, and perch skin extract, respectively. Alpha-adjusted post-hoc pairwise comparisons showed that traps labeled with perch alarm cues caught significantly fewer perch than traps labeled with either pike odor or water. Pike-odor- and water-labeled traps did not differ in perch catches (Fig. 3a). Following seeding of Deming Lake with sponges of perch skin and pike odor, the response of perch to the test stimuli remained virtually unchanged from the first day of trapping (KW = 8.16, $P = 0.02$), with 88, 84, and 16 perch caught in

Fig. 3. Median (\pm quartiles) number of yellow perch (*Perca flavescens*) and pumpkinseed (PK) sunfish (*Lepomis gibbosus*) caught per trap in Deming Lake, Minnesota, on the first day (a) and the second day (b) of the experiment. Traps were scented with either perch skin extract (hatched bars), water (open bars), or pike odor (stippled bars) (ns, nonsignificant, $P > 0.05$). The letters above the bars denote statistical significance in pairwise comparisons at $P < 0.05$.



traps scented with pike odor, water, and perch alarm cues, respectively (Fig. 3b). Simultaneous addition of alarm cues and novel predator odor did not result in demonstrable acquired recognition by perch of pike odor as an indicator of risk.

Density of pumpkinseed sunfish was sufficient to test for a cross-species reaction to perch alarm cues (Chivers and Smith 1998; Pollock et al. 2003) and the potential of a learned association of predation risk with pike odor via a cross-species alarm cue. On first exposure, pumpkinseed sunfish did not show differential catch numbers based on chemical stimuli in each trap ($KW = 1.43$, $P = 0.488$). On the first day, 316, 320, and 229 sunfish were captured in traps labeled with pike odor, water, and perch skin, respectively (Fig. 3a). After the lake was seeded with pike odor and perch alarm cues, sunfish on the second exposure continued to ignore both perch alarm cues and pike odor ($KW = 0.74$, $P = 0.691$). We caught 162, 176, and 129 pumpkinseed

sunfish for pike odor, water, and perch alarm cue treatments, respectively (Fig. 3b).

Discussion

We succeeded in establishing the potential for predator-recognition training of hatchery-reared walleye (conditions 1–3 above), but we did not succeed in demonstrating a method for implementing it on a large scale (condition 4 above). Juvenile walleye in our study used chemical cues for assessing predation risk, did not have a preexisting genetic template for recognizing pike odor, and used alarm cues to acquire recognition of pike odor as an indicator of predation risk. Therefore, there exists the potential to train hatchery-reared walleye to recognize significant sources of predation risk before they are stocked into established fish communities. Through predator-recognition training, predator-naïve hatchery-reared fish gain some of the survival skills normally acquired in the wild. This, in turn, could lead to better post-stocking survival of walleye, improve the cost-efficiency of stocking programs, enhance fishery quality, and stimulate economic benefits associated with it.

Several hatchery-reared salmonid species are able to acquire predator recognition through releser-induced training (rainbow trout, Brown and Smith 1998; chinook salmon (*Oncorhynchus tshawytscha*), Berejikian et al. 1999; brook char, Mirza and Chivers 2000). Antipredator behavioral response to predator odors translates into survival benefits when trained hatchery-reared fish encounter predators (Berejikian et al. 1999; Mirza and Chivers 2000). Our study is the first to apply recognition training to a hatchery-reared percid game species.

To our knowledge, our data represent the first field demonstration of perch avoidance of conspecific alarm cues; thus, this study provides an important field verification of earlier laboratory results (Mirza et al. 2003). This is also the first field test for a response to predator kairomones. Because we were able to detect avoidance of perch alarm cues, it seems likely that we would have detected avoidance of pike odor if acquired recognition had occurred. We cannot say from our data whether our inability to detect an effect was caused by inadequacies in the method of training (seeding), in the method of testing (scented traps), or both. We can only speculate whether predator recognition may have been achieved with a more intensive seeding of alarm and predator cues. We added a total of 1.8 L of pike odor and 75 cm² of perch skin (equivalent to slightly more than eight perch) distributed along about 300 m of shoreline.

Pumpkinseed sunfish in Deming Lake have never shown any response to chemical alarm cues from either conspecific sunfish (Jennifer Dehn, University of Minnesota, and Brian Wisenden, Minnesota State University Moorhead, unpublished data), heterospecific fathead minnows (Wisenden et al. 2003), or perch (this study). Centrarchid populations in other locations exhibit alarm reactions to alarm cues (e.g., Brown and Brennan 2000). We do not know why Deming Lake pumpkinseed sunfish appear to be unresponsive to these cues.

An alternative mechanism for recognition training is to seed the holding tanks used to transport walleye from the rearing ponds (or hatchery) to the destination lake. Holding

tanks have a relatively small volume and would require less alarm cues and less effort to achieve predator-recognition training. We are currently testing this method.

Another possible mechanism for mass training is to release a predator into the rearing pond a few weeks before harvest of the fingerlings. Previous work has shown that predator introduction causes chemical and visual recognition of the predator by entire populations of minnows in 1 week to a few weeks (Chivers and Smith 1995; Brown et al. 1997). Assuming that a large pike would not survive over winter in a small pond, predator stocking a week or two before walleye harvest might be an effective approach to transfer predator recognition to juvenile walleye. The loss of fingerling walleye to a single pike over a few weeks would be small compared with the potential increase in survival of remaining walleye once they were stocked into a large lake with a large pike population. There is inherent risk in this approach in that mild winters allow large fish in rearing ponds to survive to the following season. The resulting carry-over significantly reduces rates of harvesting walleye fingerlings.

Releaser-induced predator-recognition learning is a widely occurring phenomenon among taxa ranging from Platyhelminthes (Wisenden and Millard 2001) to Arthropoda (Wisenden et al. 1997), fishes (Göz 1941; Magurran 1989; Chivers and Smith 1994), birds (McLean et al. 1999), and mammals (McLean et al. 2000). The flexibility of this learning paradigm allows prey to adapt to predation landscapes that shift over ecological time and space. The application of this powerful ecologically selected learning mechanism to enhance resource management holds much promise for any species reared in a predator-free environment and later released into the wild. The outstanding challenge to this method is streamlining the logistics of the training process to accommodate the large numbers of animals typically involved in resource-enhancement programs.

Acknowledgements

Mariya Rzaszutak, Travis Thiel, and Tonya Overbo spent 2 years helping to develop the walleye training protocol. A Learning by Doing grant to B.D.W. from the Minnesota State Colleges and Universities Center for Teaching and Learning and a grant from the MSUM College of Social and Natural Sciences funded the expansion of the aquatic-research facility at MSUM that allowed us to accommodate this project. A research grant from the MSUM Biology Department to M. Rzaszutak helped fund the project in 2001, and grants from the MSUM Alumni Foundation bought the thousands of minnows needed to feed walleye during the final "data year" of the project. We thank Gary Huberty (Fisheries Specialist) and Mike Livingood (Fisheries Technician) of the Minnesota Department of Natural Resources at Detroit Lakes for field assistance in collecting juvenile walleye. The 2002 Animal Behavior class of the University of Minnesota Itasca Biological Field Station helped collect data for the perch training experiment. They are Annie Bakken, Sarah Compton, Trevor Estabrooks, Nate Foster, Erica Hansen, Nguyen Hoang, Nathan Hollenbeck, Jennifer McClain, David Pass, Kristen Seitz, Sopheak Srun, and Nicole Untener. This research was conducted under

MSUM's Institutional Animal Care and Use Committee protocol No. 99-T-BIOL-015-N-N-01 and University of Minnesota (Itasca Biological Field Station) Institutional Animal Care and Use Committee protocol No. 0005A51841.

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