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Behavioral responses of sea lamprey (*Petromyzon marinus*) to a putative alarm cue derived from conspecific and heterospecific sources

Jason D. Bals and C. Michael Wagner *

Michigan State University, Department of Fisheries and Wildlife, 480 Wilson Road, 13 Natural Resources Building, East Lansing, MI, 48824, USA
*Corresponding author's e-mail address: mwagner@msu.edu

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Abstract

The sea lamprey, *Petromyzon marinus*, exhibits a spectacular alarm response to the odor emitted from decayed conspecifics that may differ substantially in function from the well-characterized system in ostariophysan fishes. Here, we report a series of three laboratory experiments designed to characterize the behavioral responses of migratory-phase lampreys to a set of odors derived from conspecific and heterospecific tissues, determine whether sex or sexual maturation alters these responses, and ascertain if the putative alarm substance derives from a particular region of the body. A number of the findings were consistent with the prevailing predator-avoidance paradigm for fish alarm substances released from the skin after predator attack in that: (1) dilute odors derived from freshly ground skin were highly repellent; (2) the substance is contained in the organism early in life; (3) the odor derived from a close relative was avoided whereas those of a distant relative were not; and (4) upon sexual maturity female response to the alarm substance was attenuated. Two interesting patterns arose that differed substantially from the prevailing paradigm: (1) conspecific odors remained repellent after 96 h of aerobic decay; and (2) the cue was emitted from multiple areas of the body, not just the skin, and the repellency of the odor derived from any tissue increased in accordance with its mass. A persistent cue emitted from several sources suggests a broader ecological function than the detection and avoidance of a predator.

Keywords

sea lamprey, *Petromyzon marinus*, alarm substance, risk, conspecific odor, heterospecific odor, public information, habitat selection, migration.

1. Introduction

Cues that reveal risk confer a fitness advantage to receivers capable of both accurately interpreting and properly responding to the information the cue

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contains. Consequently, alarm cues are ubiquitous constituents of animal public information strategies. Chemically-mediated risk assessment is particularly important in aquatic environments (Chivers & Smith, 1998; Kats & Dill, 1998; Ferrari et al., 2010). That fishes attend to alarm cues is implied by the organization of their olfactory system (Hamdani & Døving, 2007; Laframboise et al., 2007; Døving & Lastein, 2009) and evident in their behavioral responses to odors associated with predator presence (Mathis & Smith, 1993; Mirza & Chivers, 2001), predator attack and prey injury (Wisenden et al., 1999; Mirza & Chivers, 2003), startled prey (Wisenden et al., 1995; Bryer et al., 2001), and acquired predator recognition (Ferrari et al., 2006; Zhao et al., 2006; McLean et al., 2007). In fact, substantial effort has been expended to understand how a diverse array of vertebrates and invertebrates manage activity in space and time in response to predator-affiliated cues, and more recently, integrate that information into risk-informed decision-making (hereafter referred to as the predation-risk paradigm; McNamara & Dall, 2010; Schmidt et al., 2010). Considerably less attention has been paid to how alarm cues might be used to inform effective decision-making in important ecological circumstances that are not principally regulated by avoiding predation (e.g., the selection of reproductive habitat).

One particular class of alarm cues, the odors derived from dead and/or decayed conspecifics, may have originated as inadvertent social information released near the time of death that allows conspecifics to recognize risky circumstances (Yao et al., 2009; Wagner & Danchin, 2010). Animal decision-making typically involves an active trade-off between risk and opportunity, mediated by information received across multiple sensory modalities (Bouwma & Hazlett, 2001; Blanchet et al., 2007; Kim et al., 2009). Consequently, the elucidation of the ecological role of any single piece of information often requires knowledge of the ecological and social circumstances (Brown et al., 2006; Wisenden et al., 2010), an animal's internal state as it relates to signal reception/perception (Olsson et al., 2002; Rohr et al., 2002; Lastein et al., 2008; Webster & Laland, 2011), motivation to respond (Metcalfe et al., 1987), and the relevant currencies. Quantifying these trade-offs has proven difficult (Abrahams & Dill, 1989; Bednekoff, 1996). Wagner et al. (2011) recently demonstrated that sea lampreys (*Petromyzon marinus*) will avoid the odor emitted by dead conspecifics during the annual spawning migration. Several features of the sea lamprey reproductive migration relax a