Chemosensory Communication Systems Research Theme

Addendum 1

Repellents: A class of odorants that may prove useful in sea lamprey control

Recent discoveries in light of previously reported anecdotal behavioral observations suggest the existence of a powerful sea lamprey alarm response to an undescribed semiochemical. Here, we briefly set forth a rationale and an initial set of research questions to guide the implementation of new research into this phenomenon and thereby extend the GLFC Pheromone Theme (Li et al. 2007).

Background

Previously thought to have a single olfactory sensory neuron (OSN) morphotype (Thornhill 1967; VanDenbossche et al. 1995; Zielinski et al. 2005), Lamframboise et al. (2007) recently described three distinct OSN morphotypes intermingled in the lamprey olfactory organ. This arrangement closely parallels that of teleost fishes where the axons of each morphotype converge to a specific region of the olfactory bulb, enjoy three distinct connections to the brain, and thereby mediate three fundamental behavioral processes (Hamdani and Doving 2007). In teleosts, one pathway is tuned to reproductive pheromones, another to food odors, and the third to social cues and alarm substances. The similarities revealed in the sea lamprey olfactory architecture imply a reliance on odors for fundamental processes beyond reproduction (i.e, the acquisition of food and the avoidance of harm).

It has frequently been observed, although only anecdotally reported, that exposure to the odor from putrefying conspecifics can induce a spectacular alarm response in sea lampreys. Such avoidance is typically thought to be an indirect response to the threat of predation, revealed through the odor emitting from ruptured or decaying conspecifics (reviewed by Chivers and Smith 1998, Yao et al. 2009). These odors are variously termed alarm pheromones, injury-released cues, endogenously produced repellents, or necromones (Yao et al. 2009). It is currently unknown whether the operating semiochemical is a conspecific signal (an innate response to a compound released upon attack or death), or a common catabolite mixture produced by decomposition. However, because predation is one of the most pervasive and powerful selection pressures on individual fitness (Lima and Dill 1990, Wisenden 2000, Brown 2003), recognition and avoidance of the odor of dead or injured conspecifics may serve to reduce risks that are reliably associated with such signals (e.g., Turner 1997, Stout et al. 1998, Peacor 2003, Nilsson and Bengtsson 2004, Wilson-Rich et al. 2009).

Opportunities for Use of a Repellent in Sea Lamprey Control

A variety of possibilities for using sea lamprey semiochemicals in pest management, including luring adults into traps, diverting migrations into habitats where other opportunities for control are facilitated, or directly disrupting reproduction, have been proposed (e.g., Twohey et al. 2003; Sorensen and Vrieze 2003; Li et al. 2007; Johnson et al. 2009). A repellent holds particular promise for use in redistribution-based management strategies – approaches that rely on re-directing migrants into streams where the efficacy of traditional control is enhanced. For example, one such strategy developed for use in managing agricultural pests, the Push-Pull

Approach, involves the simultaneous use of attractive and repulsive chemical stimuli to guide pests away from crops and into target areas occupied by natural enemies (Miller and Cowles 1990, Cook et al. 2007). The confluence between a geographic feature of the sea lamprey migration (transition from lakes to streams) and reliance on innately acquired responses to olfactory stimuli reveals a unique opportunity to achieve a push-pull manipulation in the Great Lakes.

During the annual spawning migration, a pheromone emitted by larvae living in stream sediments attracts migrating adults into high quality larval rearing habitats (Sorensen et al. 2005, Wagner et al. 2006). Thus, as migrants move upstream, the proper path forward at each branch in the network is informed by the presence of larval odor; if both channels are activated, migrants are typically not choosy (Wagner et al. 2009). Consequently, we may divert migrating lampreys away from a repellent-treated stream (e.g., one that is either difficult or expensive to treat with lampricides) and into one that does not suffer these operational weaknesses, if activated with larval odor. Because successful blockage at any point low in the network protects all areas upstream of the node, a large fraction of the water shed may be blocked off with applications at a few sites, greatly limiting the amount of spawning area available, and thereby the area in need of subsequent lampricide treatment. The push-pull manipulation, whether perpetrated at the river mouth or at a branch higher in the watershed, relies on always providing the lampreys with two simple choices: one noxious, one attractive. With a repellent successfully identified, this manipulation will become immediately available to the control program in streams already infested with sea lampreys (i.e., it will not require full elucidation of the larval pheromone to proceed).

Initial Research Needs

Because the desired effect is the disruption or manipulation of the chemical communication system employed by the sea lamprey to complete its life history, potentially useful repellents fall into one of two classes: 1) natural repellents emitted by or from sea lamprey and used as chemical communication (e.g., alarm substances or necromones); and, 2) generally noxious substances (natural or manmade) that are repellent to sea lampreys and modify their responses to pheromone cues (particularly attractants). The primary research needs are as follows and generally extend Research Need #18 identified in the Pheromone Research Theme per Li et al. (2007), "*Are there environmentally benign compounds that repel lampreys from a stream or tributary?*"

1. Identify and elucidate the chemical structure of natural and man-made repellents that strongly modify the behavior of sea lamprey.
2. Ascertain the physiological factors (e.g., habituation and adaptation) and contextual stimuli (including physical, chemical, and social circumstances) that augment, impede, or otherwise modify sea lamprey responses to repellents.
3. Discover cost-effective procedures to either chemically synthesize or collect sufficient repellents for basin-scale delivery in the integrated pest management program.
4. Determine the non-target effects of proposed repellents, particularly on species of lamprey native to the Great Lakes basin and additional species of concern identified by the governments of the United States and Canada.