Letter

Fin-flicking behaviour as a means of cryptic olfactory sampling under threat of predation

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Accepted for publication October 27, 2013

Risk of predation is a ubiquitous component of behavioural decision-making (Lima & Dill 1990). For small littoral fishes, chemical cues released from predators and/or injured conspecifics, comprise important sources of information about the presence and nature of predation risk (see Kelley 2008; Ferrari et al. 2010 for recent reviews). Behavioural responses to these chemical cues include area avoidance, increased shoal cohesion, reduction in activity, movement out of the water column, use of shelter and fin-flicking (Lawrence & Smith 1989; Ferrari et al. 2010). Collectively, these behavioural responses reduce the probability of predation (Mathis & Smith 1993).

Fin-flicking is a behaviour in which fish quickly sweep their pectoral fins anteriorly, matched with concomitant counterbalancing forward thrusts of the anal and caudal fin, resulting in no net movement. The function of fin-flicking has not received much attention in the context of antipredator behaviour. Fin-flicking by glowlight tetras (\textit{Hemigrammus erythrozonus}, Durbin 1909) in response to conspecific chemical alarm cues induced greater shoal cohesion in conspecifics and also deterred attack behaviour by a potential predator, the Jack Dempsey cichlid (\textit{Rocio octofasciata}, Regan 1903; Brown et al. 1999). Be that as it may, the precursor function of fin-flicking signals may be more utilitarian in nature and only later became co-opted into a visual signalling system. This brief communication presents a test of the hypothesis that fin-flicking by alarmed fish serves the selfish benefit of allowing individuals to sample chemical cues in the surrounding waters whilst remaining motionless to avoid attracting attention from predators.

Receptors that detect chemical alarm cues and predator odours are arranged in rosettes in the nares, which are blind pouches in the rostrum (Døving & Lastein 2009). Advection (mass water movement) of water to the nares is generated by ram ventilation as fish move through the water column. When risk is detected, fish are faced with a trade-off because the physical swimming movements needed to assess predation risk are conspicuous to predators. Fin-flicking behaviour may be a solution to this trade-off if it allows individuals to discreetly create microcurrents of water past the nares resulting in continuous sampling of chemical information of the surrounding water without the accompanying movements that would compromise crypsis.

Java moss (\textit{Taxiphyllum barbieri}) was chopped into 2-mm pieces to create small neutrally buoyant particles that would allow us to visualise water currents generated by fin-flicking. In one recording session, an adult fathead minnow (\textit{Pimephales promelas}, Rafinesque 1820) was placed in a shallow white plastic trough that afforded good visual contrast with the moss fragments. In a second recording session, an adult fathead minnow was placed into a narrow aquarium with a small amount of clay to visualise water currents. Skin extract was prepared by killing an adult fathead minnow by cervical dislocation and then lightly scoring its flanks with a clean razor blade. One minnow was killed for each session of filming. The minnow carcasses were then soaked in 100 ml of deionised water for 10 min. The test dose of alarm cue was 10 ml of minnow skin extract administered to the side of the container to induce fin-flicking behaviour. All procedures were approved by the Minnesota State University Moorhead Institutional Animal Care
and Use Committee (protocol number 10-T-Biol-009-N-N-C/D). Movements of moss fragments or clay particles were recorded by a video camera (Casio EX-F1) positioned directly overhead (moss) or in front of the aquarium (clay), which captured particle motion at a rate of 60 frames per second. Motion analysis was carried out using Logger Pro software (version 3.86).

Moss particles positioned on the sides of the minnow’s head, and flanks were swept forward and upward past the nares by water currents generated by flicking motions of the pectoral fins (Fig. 1). Viewed from the side, the thrust of water generated by the pectoral fins could be seen to create two vortices, one above and one below the snout, which drew water from the water column towards the nares. As predicted, fin-flicking behaviour resulted in making chemical information in the surrounding water available to olfactory receptors in the nares that would not otherwise be accessible without conspicuous swimming movements. Similar behaviour has been observed in other aquatic taxa (e.g., Breithaupt 2001). In fishes, there are three similar behavioural solutions to this trade-off reported in the literature. The first is buccal pumping, whereby fish remain motionless but increase rate of gill ventilation to generate water currents about the head and nares (Commens & Mathis 1999). Secondly, alarmed darters, a benthic percid that dwell primarily in the layer of laminar flow, engage in head-up behaviour in which the back is arched and the snout extended.

**Cryptic sampling of chemical alarm cues**

![Fig. 1. Top view and side view of path of individual particulars of java moss or clay as revealed from frame-to-frame motion tracking at 0.02-s intervals (generating a linear series of small dots). The particle tracks reveal water currents generated by flicking motions of the pectoral fins following exposure to chemical alarm cues. Arrows indicate direction of flow.](image-url)
upward into the overlying region of faster water flow (Wisenden et al. 1995). A third behavioural solution is head-bobbing behaviour by the starry goby Asteropteryx semipunctatus (Rüppell 1830) that may also serve to facilitate olfactory sampling of the water column (Smith 1989). In the field and in laboratory fluoravria, minnows in flowing water exploit flow to sample chemical information about predation risk from a safe distance downstream. In the absence of flow, fish sample chemical information from close range relatively near to the course of danger, illustrating the fitness value of access to chemical information about risk (Wisenden et al. 2010).

Some cichlids engage in fin-flicking as a warning signal to their young (Cole & Ward 1969; Shennan et al. 1994), but this signalling behaviour is maintained at least in part via kin selection by genes shared between parents and offspring. Minnows and characins form shoals of unrelated individuals. In this context, fin-flicking provides public information about the presence of predation risk (Wisenden & Chivers 2006) to both nearby conspecifics and predators (Brown et al. 1999). The most parsimonious account of the evolutionary sequence for visual signalling is that fin-flicking first arose as a means of cryptic sampling of chemical cues benefitting the fin-flicker and only secondarily became co-opted as a component of a visual signalling system.

References