LOCOMOTORY DYNAMICS AS INDICATORS OF STRESS IN FISH – REMOTE MEASURES UTILIZING ACTIVITY TRANSMITTERS

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Abstract

Stress related physiological disturbances can result in either locomotory impairments or hyperactivity. These behavior-altering disturbances, however, are difficult to quantify. Undoubtedly, for free-swimming fish in non-laboratory settings, it is these sub-lethal disturbances that result in changes in activity that can increase the susceptibility to predation, elevate energy expenditure, and generally disrupt the ecology of the species. Devices capable of remotely monitoring and quantifying the locomotory activity of free-swimming fish have been developed and have been applied widely within fisheries science, particularly for the determination of activity patterns and the calibration of bioenergetics models. The application of these devices to the measurement of environmental or anthropogenic stressors provides the opportunity to link behavior and physiology in an effort to understand the influences of these stressors from both an energetic and ecological framework. We present examples of data generated from several novel uses of activity transmitters in the areas of aquaculture production research, thermal effluent monitoring, and handling and angling related disturbances. The approach of coupling behavior

and physiology as outlined in this paper, is particularly robust, providing what we believe to be an important component of our comprehension of how stress manifests itself at the organismal level.

Introduction

Aquatic organisms, and in particular, fish, pose several challenges to scientists interested in assessing the behavioral and physiological responses to stress under both natural and artificial conditions. Ideal approaches to data collection would be generally non-invasive and would permit evaluation of *in situ* conditions without repeatedly handling or terminally sampling individuals. Approaches used to assess the locomotory activity of free-ranging fish have included videography and locational telemetry. These approaches are undoubtedly useful, but both have limitations in many situations that either make it difficult to obtain continuous time series data or to collect data at appropriate temporal and spatial scales for detailed assessments of locomotory activity.

Activity transmitters capable of remotely measuring the activity of free-swimming fish have been developed over the past 20 years and can operate on either radio or ultrasonic frequencies. There is large variation in the transmitter configurations and how the data are actually collected (see Cooke 1999 for review). For example, some devices rely on electromyographic signals that are detected by electrodes implanted in musculature, relaying either raw or integrated muscular activity correlates. Other configurations rely on pressure transducers capable of detecting changes in the frequency and amplitude of caudal fin beats. Some devices do not directly measure any biological information from the fish, but instead inferr swimming activity from changes in detected water velocities. Many of these devices have been described in detail in the literature, including both the technical details concerning their design and operation, as well as laboratory and field applications of the technologies. Some of these devices have come into commercial production. Although commercially produced devices minimize the creative energies required to develop new technologies, thus restricting further advances, it is perhaps time that researchers attempt to use a series of standardized devices to facilitate interstudy and interspecific comparisons. Initially, if a researcher was interested in obtaining remote activity measures, it required the assistance of electrical engineers among others, as well as time and financial resources. Now a researcher can order devices from several companies specializing in physiological telemetry.

Activity as a surrogate measure of stress

Generally, activity transmitters are an accepted method for the assessment of the activity of free ranging fish. One area of research where activity transmitters could make a valuable contribution is in the measurement of stress. Changes in the activity levels of fish have recently been observed to be sensitive indicators of stress (Schreck 1990; Scherer 1992; Schreck et al. 1997). Swimming requires the integration of numerous physiological processes that if quantified, could provide information on the general health and stress of the fish (Schreck 1990). As a result, efforts to understand the behavioral and physiological impacts of various stressors could include a focus on activity levels. Stressors that have the potential to disrupt activity patterns or either elevate or impair swimming activity are perhaps the applications best suited for activity transmitters. Behavioral changes in free swimming fish however, have been difficult to obtain *in situ* (Beamish 1978) until the recent development of activity transmitters.

Case Studies – Diverse Examples

As noted above, activity transmitters have the potential to contribute to our understanding of whole organism responses to stress. Below we provide several examples of the types of applications for which activity transmitters may be particularly suited and some data generated using this approach. The applications that we describe are diverse and include aquaculture production research, environmental monitoring and handling and angling disturbances. The data that we provide were all generated using "electromyogram" activity transmitters that emit an integrated signal (Lotek Engineering Inc, Newmarket, ON). We are not endorsing this product specifically, however, alternative technologies such as pressure transducer based activity transmitters (Vemco Inc, Shad Bay, NS) have become commercially available only recently.

*Activity Transmitters in Aquaculture Production Research***:**

Activity transmitters provide opportunities to develop quantitative animal welfare correlates for fish exposed to different husbandry practices. For example, Cooke et al. (2000) exposed adult rainbow trout (*Oncorhynchus mykiss*) to a series of increasing density treatments (15-low, 30-medium, 45-high kg/m^3) and associated disturbances. Fish were first exercised in respirometers to

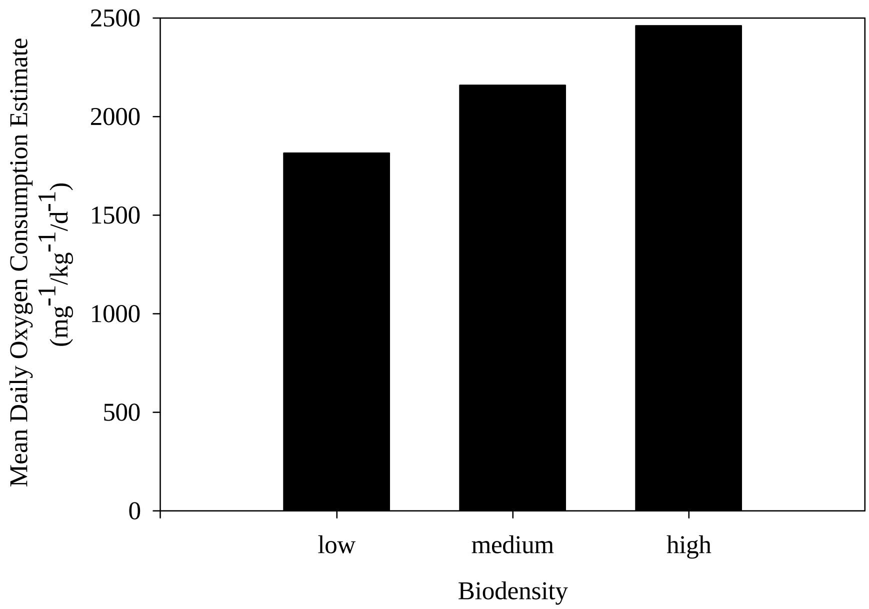

Figure 1. Effects of increasing density treatments on daily oxygen consumption rates of adult rainbow trout.

establish relationships between swimming speed, telemetered activity signals, and oxygen consumption. Signals recorded during the increasing density treatments could then be used to estimate the *in situ* energetic expenditure of fish. Overall, there was an overwhelming trend of increased activity and energetic expenditure that corresponded to the increasing densities (Figure 1).

A second example involves the assessment of fish behavior during transport while fish were being held in varying concentrations of clove oil anesthetic. It has been postulated that at low concentrations, clove oil may serve as a means of minimizing fish activity during transport (Keene et al. 1998), thus reducing physiological disturbance and stress. We transported adult rainbow trout for a period of three hours in separate 60 l containers. Concentrations of clove oil (0, 2.5, 5, 10 PPM) were maintained during this period. Interestingly, the lowest concentration of clove oil (2.5 PPM) resulted in the lowest activity levels during

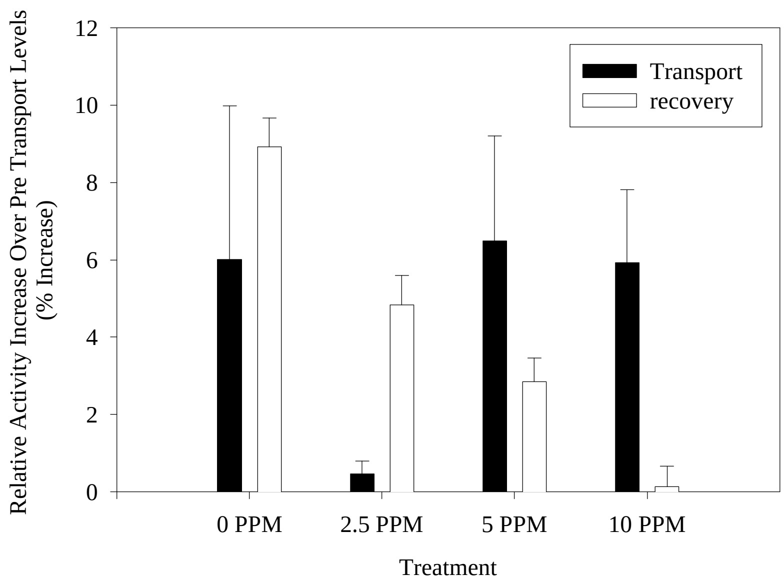

Figure 2. Effects of clove oil on activity of adult rainbow trout during transport.

transport. At higher concentrations fish lost equilibrium and spent the majority of the time struggling while upside down (Figure 2). Upon release, fish from the two highest concentrations were the least active. Control fish were the most active, with the lowest concentration showing intermediate activity levels. Activity of all fish following release was higher than prior to transport for at least 24 hours. Activity transmitters provided behavioral insights, that can be used to explain differences obtained using conventional physiological measures.

Activity Transmitters and Environmental Monitoring

Environmental variations and site-specific conditions experienced by fish in the wild are sometimes difficult to replicate in laboratory settings. Knowledge of the *in situ* response of fish to environmental fluctuations can provide managers with opportunities to minimize anthropogenic disturbances. We have used activity transmitters to monitor the locomotory activity of fish residing in a

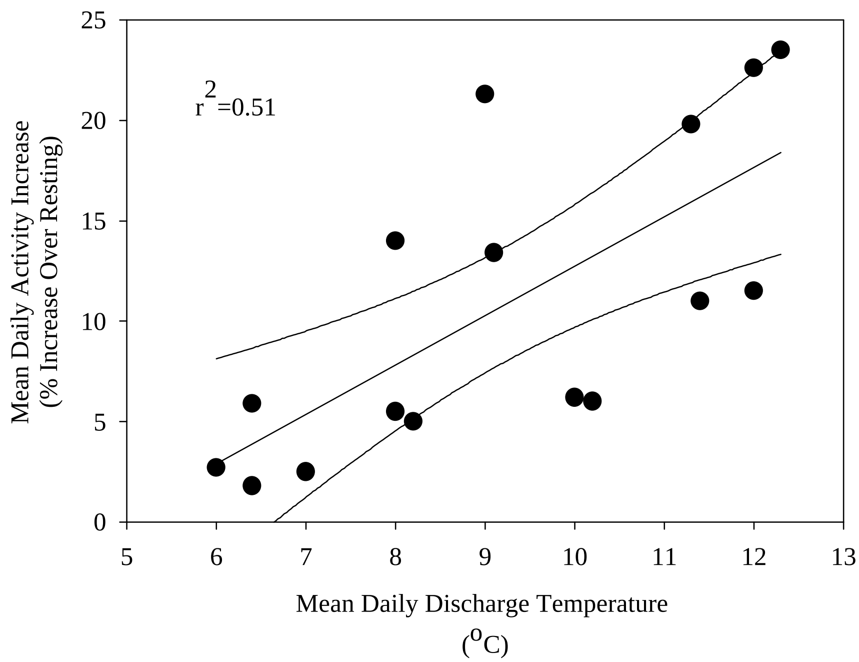

Figure 3. Relationship between mean daily water temperature and locomotory activity of adult channel catfish in a thermal discharge canal.

thermal discharge canal on Lake Erie. Here, we show data (Figure 3) for an adult channel catfish (*Ictalurus punctatus*) residing in a thermal effluent during March. In this case, we see a moderate correlation between mean daily water temperature and mean daily swimming activity. Data from activity transmitters can also be examined on a finer time scale (seconds) to detect more immediate responses to temperature fluctuations or other environmental variables (i.e., Rand and Hinch 1998).

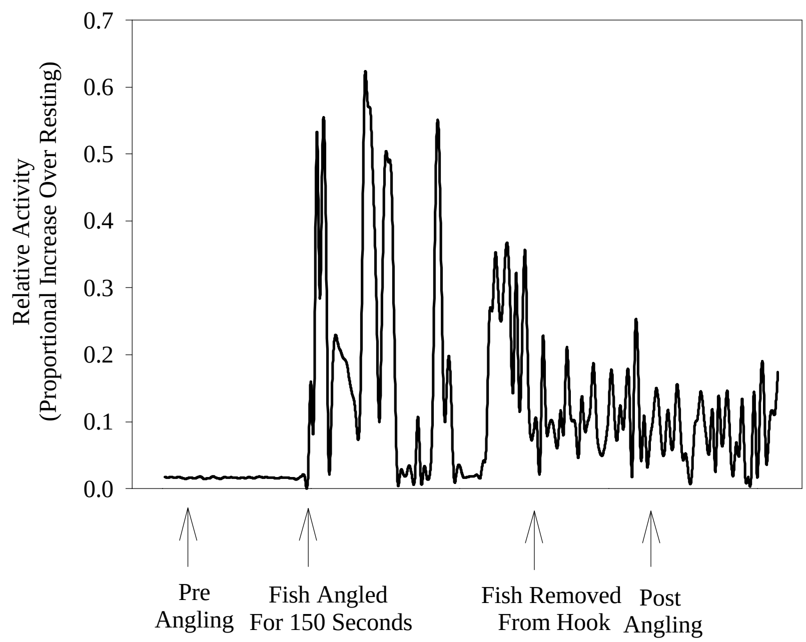

Figure 4. Pattern of adult smallmouth bass locomotory activity before, during, and after exhaustive angling.

Measurements of the activity associated with catch-and-release angling, as well as behavior and activity of fish during the recovery period, would be useful in further understanding how this practice may affect free swimming fish. To this

end, we have conducted several studies examining locomotory activity before, during, and after angling. Here we present an example of an adult smallmouth bass (*Micropterus dolomieu*) angled at 14°C for a period of 150 seconds (Figure 4). The fish was observed to be inactive and under cover prior to angling. Activity increased dramatically upon hooking the fish. During the angling period, there was a decrease in activity as the fish became exhausted. The fish exhibited somewhat heightened activity relative to pre angling levels after release.

Conclusion

We are strong proponents of continued research and development on the remote collection of indices of locomotory activity (and other relevant measures). We also urge more researchers to begin adopting some of these techniques. Because numerous studies utilizing activity transmitters now exist illustrating a variety of different techniques for surgical implantation (see Beddow and McKinley 1999; Bunt 1999), data collection, and data analysis, it is intuitive to encourage the standardization of approaches to facilitate comparisons across studies. We also encourage the adoption of approaches that incorporate other indicators of an organisms physiology and behavior. In this paper we have provided several novel examples of how commercially available activity transmitters can be used to generate useful data. When this technique is combined with other more conventional methodologies, scientists will have a robust set of tools to integrate both behavior and physiology in understanding how fish respond to stress. Behavioral studies only provide information on what animals are doing. An understanding of the proximate basis for a given behavior, i.e. how they are physiologically able to perform the activity, is essential to understand ultimate questions of why they behave as they do.

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