

Activity Patterns of Largemouth and Smallmouth Bass Determined with Electromyogram Biotelemetry

ERIC DEMERS

Department of Biology, York University
4700 Keele Street, North York, Ontario M3J 1P3, Canada

R. SCOTT MCKINLEY

Department of Biology, University of Waterloo
Waterloo, Ontario N2L 3G1, Canada

ALLAN H. WEATHERLEY

Life Sciences Division, Scarborough College, University of Toronto
Scarborough, Ontario M1C 1A4, Canada

DONALD J. MCQUEEN

Department of Biology, York University

Abstract.—Electromyogram (EMG) biotelemetry was used to assess activity patterns for adult free-swimming largemouth bass *Micropterus salmoides* and smallmouth bass *Micropterus dolomieu*. We first conducted laboratory respirometry trials and found a strong association between EMG signal and swimming activity which indicated that EMG biotelemetry could be used to assess activity of wild fish. A field study confirmed that both species exhibit diurnal activity patterns. When EMG activity was compared with estimates of swimming activity from location tracking, elevated EMG activity was often recorded for apparently stationary fish. These observations suggested that fish activity at spatial and temporal scales too small for detection by location tracking may account for a significant proportion of daily activity. We argue that EMG biotelemetry, combined with location tracking, may be a versatile tool for application to a wide variety of problems in fisheries biology, including the study of physiological energetics and spatial and temporal habitat use.

Direct assessment of the amount and nature of locomotory activity displayed by wild fish has long been a goal for fishery scientists (Fry 1947; Brett and Groves 1979). Location tracking of radio-tagged fish (reviewed by Winter 1983) has been used to monitor activity in the natural environment. Recently, the development of telemetry of activity indicators such as heart rate (Priede 1983), ventilation rates (Rogers and Weatherley 1983), tailbeat frequency (Ross et al. 1981), and locomotor muscle electromyograms, EMGs (Weatherley et al. 1982; Kaseloo et al. 1992), provides new tools to measure physiological activity of free-living fish directly (Lucas et al. 1993). Among these procedures, the biotelemetry of EMGs from the axial musculature has been successful for long-term monitoring of locomotory activity in the field (Rogers et al. 1984; McKinley and Power 1992).

For largemouth bass *Micropterus salmoides* and smallmouth bass *Micropterus dolomieu*, previous location-tracking work has provided useful information on habitat and home range use (Savitz et

al. 1983; Mesing and Wicker 1986; Todd and Rabeni 1989) and activity levels (Savitz et al. 1983). However, we are aware of no study in which physiological biotelemetry was used to describe short- or long-term activity levels and patterns for these fish. In our study, we assessed the applicability of EMG biotelemetry to indicate activity patterns of largemouth bass and smallmouth bass. We conducted a laboratory study to examine the relation between EMG values and swimming activity. A field study provided us with an assessment of daily activity profiles and a comparison of EMG biotelemetry with location tracking.

Methods

Laboratory study.—The EMG transmitters (Lottek Engineering, Newmarket, Ontario), were 5 cm long and 1.5 cm in diameter and weighed 20 g in air. The EMG signals emitted from contracting musculature were detected by a pair of flexible, teflon-coated, stainless steel microelectrodes. The transmitter emitted a signal pulse when the voltage difference between the two electrodes reached a

TABLE 1.—Size, release date, and duration of monitoring of smallmouth bass (SMB) and largemouth bass (LMB) implanted with electromyogram transmitters during the laboratory and field phase of the study.

Location and fish number	Total length (cm)	Weight (kg)	Release date (1992)	Duration of monitoring (d)
Laboratory				
SMB A	40.5	1.05		
SMB B	42.0	1.26		
Field				
SMB 1	40.0	0.94	6 Jun	46
SMB 2	41.3	1.13	21 Sep	44
LMB 1	42.1	1.30	25 Jun	129
LMB 2	45.5	1.54	15 Sep	50

manufacturer's predetermined threshold (150 μ V). Thus, the interval between pulses (in ms) was correlated with the frequency of muscle contractions. Pulse intervals were transmitted to a signal receiver data logger (model SRX-400; Lotek) on a radio frequency unique to each transmitter. Pulse intervals were subsequently converted to pulse rates per minute for analyses. Thus, an increase in muscle contractions resulted in a higher pulse rate. Further details on the transmitters are given in Kaseloo et al. (1992).

In January and February 1992, two smallmouth bass (Table 1) were implanted with EMG transmitters by the method developed by Kaseloo et al. (1992) and were held in the laboratory. Each individual was anesthetized with tricaine methanesulfonate (MS-222). Transmitters were surgically implanted into the abdominal cavity through a 2.5-cm ventrolateral longitudinal incision caudal to the posterior end of the pectoral fins. Electrode wires were passed through the axial musculature from the inside out, and they were anchored with epoxy-cemented plastic disks (0.5 cm in diameter and 0.1 cm thick). The antenna was threaded through the body wall dorsal to the cloaca with a hypodermic needle. After the transmitter was placed inside the body cavity, the incision was closed with five individual PDS-II monofilament absorbable (3–0 Ethicon) sutures. The antibiotic oxytetracycline HCl was injected intraperitoneally, and malachite green was applied as a fungicide to the closed incision. Apparent recovery was rapid and both fish resumed normal swimming within 30 min. External healing and suture absorption was complete after 4 weeks at 20°C.

We used a 48-L Blazka–Fry respirometer to measure the relation between EMG activity and swimming activity (i.e., swimming speed) follow-

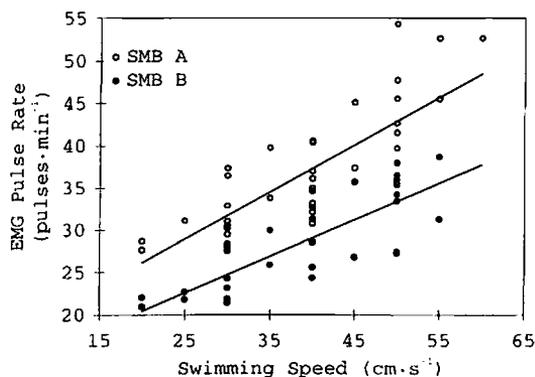


FIGURE 1.—Relation between electromyogram (EMG) pulse rate and swimming speed in laboratory respirometry trials for two smallmouth bass.

ing the protocol described in Kaseloo et al. (1992). Individual fish were acclimated to low water velocity in the chamber for 1 h (20 cm/s). For each trial, fish swam in the chamber for 20 min at speeds from 20 to 60 cm/s, with increments of 5 cm/s. The EMG signals were recorded continuously and averaged for each 20-min period. All swimming trials were carried out in 20°C water.

Field study.—Between May and September 1992, two largemouth bass and two smallmouth bass (Table 1) were captured with trap nets in Ranger Lake, south-central Ontario, Canada (45°09'N, 78°52'W). Physical, chemical, and biological descriptions of the lake are provided in Ramcharan et al. (1995). Each fish was measured (cm; total length, TL), weighed (kg), anesthetized, and surgically implanted with an EMG transmitter by the procedure used in the laboratory. Each fish was held for 1 week after surgery and then released. Two fish, one of each species, were released in June and two others in September. The signal for SMB 1 was lost on 31 July when the fish was caught by an angler and the external electrode anchors were damaged. A shore-based five-element Yagi antenna received the EMG signals for the whole lake.

To establish daily EMG activity patterns of individual fish, EMG signals were averaged hourly. We constructed daily profiles by plotting the 5th, 25th, 50th, 75th, and 95th percentiles of the distribution of EMG values for each hour across days. Periodically, another Lotek SRX-400 receiver was used to locate the EMG-tagged fish. Fish were tracked during the daylight hours for several 8–12-h periods. During each tracking, each tagged fish present in the lake was located every 30 min. Mapped movements were then compared to EMG

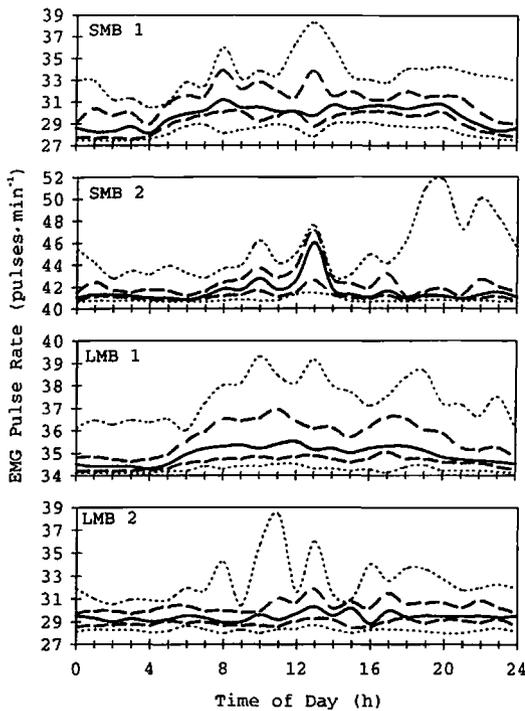


FIGURE 2.—Daily electromyogram (EMG) profiles for two smallmouth bass (SMB) and two largemouth bass (LMB) in the field, June–October 1992. The EMG signals were averaged for each hour, and the 5th, 25th, 50th, 75th, and 95th percentiles of the distribution of hourly means across days are shown (from top to bottom). The number of days included for each fish are reported in Table 1.

signals recorded simultaneously. Correlation analysis was used to assess the relation between apparent swimming speed (cm/s), which we estimated by dividing the distance between two consecutive locations by the time between those locations, and average EMG pulse rate recorded during the corresponding tracking interval.

Results and Discussion

Laboratory Study

Electromyogram pulse rate was positively correlated with swimming speed (Figure 1) for both fish (SMB A: $r = 0.797$, $df = 35$, $P < 0.001$; SMB B: $r = 0.795$, $df = 29$, $P < 0.001$). Analysis of covariance showed that the slopes of the regression relations did not differ ($P = 0.198$), but intercepts did ($P < 0.001$). The similar slopes indicate that changes in swimming speed were reflected by proportional changes in EMG signal between fish. Likely causes for the difference in intercepts include electronic variability within each transmitter,

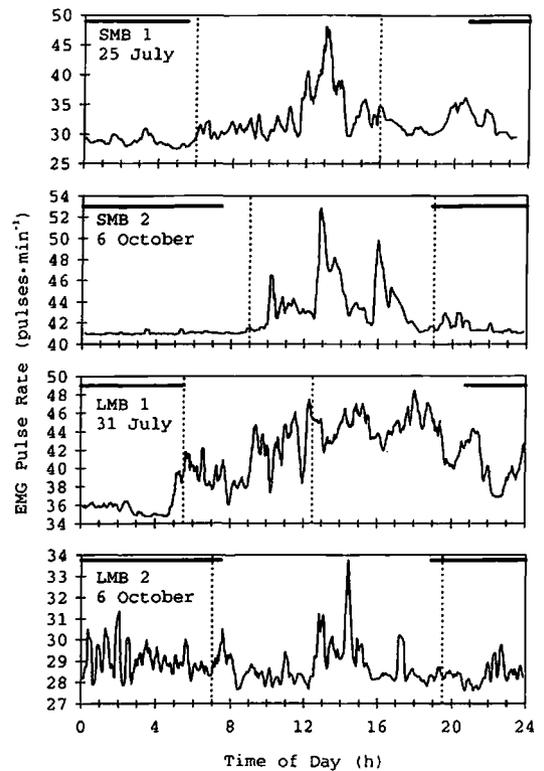


FIGURE 3.—Daily records of electromyogram (EMG) pulse rate for two smallmouth bass (SMB) and two largemouth bass (LMB) in the field in 1992. Solid horizontal lines represent nighttime. Dashed vertical lines delimit the daytime interval during which fish were tracked (see Figure 4).

electrode placement within the axial musculature, and fish-induced variability, and further investigation on the importance of these factors is needed.

Field Study

Our experiments suggested that EMG transmitters can be implanted successfully into both species of bass. All fish survived through and beyond the monitoring period. We captured SMB 2 in early May 1993 (8 months after release) to assess long-term tolerance of the transmitter. By that time, all sutures had been absorbed, the incision was fully bridged, and skin coloration was even around the incision area. No internal damage was apparent and the transmitter was fully encapsulated in connective tissue. We also observed LMB 1 guarding nests during the 1993, 1994, and 1995 nesting seasons. Kaseloo et al. (1992) observed similar successful long-term tolerance of EMG transmitters by rainbow trout *Oncorhynchus mykiss*.

Daily EMG profiles for these fish revealed di-

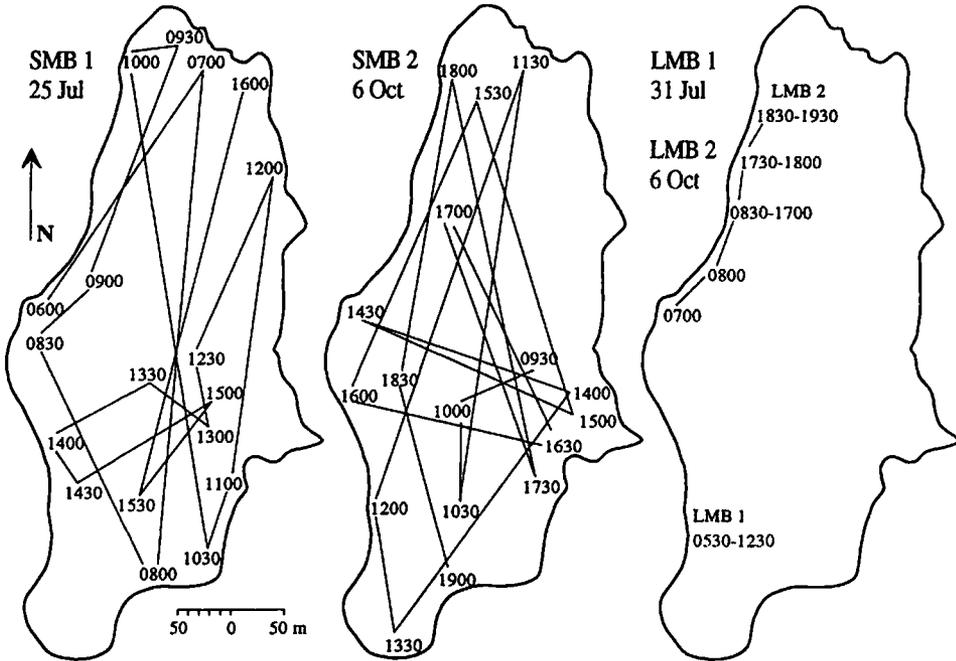


FIGURE 4.—Daytime tracks of two smallmouth bass (SMB) and two largemouth bass (LMB) in 1992. Dates and positions at time are indicated.

urnal patterns of muscle activity (Figure 2). On approximately 75% of days monitored, SMB 1 and LMB 1 maintained EMG signals that were higher through the daytime. Rises and falls in EMG signals coincided with the onset and end of daylight. In contrast, daytime EMG levels for SMB 2 and LMB 2 were not maintained, but they were dominated by periods of both high and low muscle activity. These differences in daytime EMG may be attributable to the time of year during which these fish were monitored. For example, the elevated EMG activity of LMB 1 during daytime was strongest between July and September but resembled that of LMB 2 in October as water temperature and day length decreased. Diurnal patterns of activity for largemouth and smallmouth bass were expected because both species are mainly visual predators (Emery 1973). All fish displayed some level of nighttime EMG activity on at least 5% of days monitored, and the lowest EMG signals were usually recorded at 0400 hours.

On most days, EMG-tagged smallmouth bass were tracked over the entire lake surface. For example, on 25 July, SMB 1 was repeatedly located along the lake perimeter between 0600 and 1200 hours and offshore for the remainder of the tracking period. The movements tracked in the pelagic area corresponded to intense EMG activity (Fig-

ures 3, 4). On 6 October, we observed three peaks of EMG activity for SMB 2: the first, a smaller peak, occurred while the fish was offshore, and the second and third peaks corresponded to successive inshore locations. Our tracking time interval did not allow us to determine whether movements between successive littoral locations were made through the pelagic zone or along the lake perimeter.

Most of the movements of EMG-tagged largemouth bass occurred within the littoral area, and these fish rarely covered large distances. In addition, on many occasions, elevated EMG signals suggested significant muscular activity that did not correspond with any changes in location (Figures 3, 4). For example, on 31 July, LMB 1 showed elevated EMG activity from 0530 to 1230 hours but remained within a small littoral area (<100 m²). Similar observations occurred with LMB 2 on 6 October—EMG peaked between 1230 and 1530 hours but no movement was recorded. Although our data may suggest a species-specific activity pattern, these patterns remain speculative, given our small sample size.

In some studies, tracking-based swimming speed estimates have been used to assess metabolic costs of activity for wild fish (Diana 1983; Rice et al. 1983). Relations of oxygen consumption to

swimming speed generated with respirometers are then directly applied to field situations. In these studies, investigators assumed that tracking-based swimming speeds were correlated with muscular activity (i.e., swimming requires muscle activity), and thus, with metabolic costs. We found no correlation between apparent swimming speeds and average EMG pulse rates recorded during corresponding tracking-time intervals ($P > 0.10$). This lack of a correlation suggests that using tracking-based swimming speeds alone as an index of fish activity could underestimate the true intensity of muscular activity and its related metabolic cost, as was also concluded by Lucas et al. (1991). In addition, fish movements at spatial and temporal scales too small to detect by location tracking may in fact account for a significant portion of daily activity metabolism. For example, the activity level of a guarding male that occurs over a few weeks and within a small territory may constitute a significant fraction of activity metabolism (Hinch and Collins 1991; Ridgway et al. 1991), yet apparent tracking-based swimming speeds would be negligible because the fish remains within a small area. This type of activity may be very important over short time intervals such as over minutes, hours, or days, but effects over longer time periods are unknown and consequences for seasonal or annual energy budgets remain to be determined (Lucas et al. 1991). Perhaps combining EMG biotelemetry and location tracking can provide indices of fish activity for a wide range of spatial and temporal scales.

Despite the apparent success of electromyogram biotelemetry in this study, EMG studies of wild fish are still preliminary. The large minimal size of the transmitters limits their application to small-bodied individuals and species, and therefore miniaturization would greatly enhance their applicability. An ultimate application of this technique is its potential to establish activity patterns and their associated bioenergetic costs for free-ranging fish (Rogers et al. 1984; McKinley and Power 1992). Behavioral observations in the laboratory should also allow a better interpretation of the EMG output from the field.

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