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Measuring burst movements of smallmouth bass (*Micropterus dolomieu*) in Lake Kizaki, Japan, using micro-acceleration data loggers

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Abstract: This study used micro-acceleration data loggers to measure burst movements, such as feeding behavior, of smallmouth bass (*Micropterus dolomieu*). Data loggers were attached to the dorsal side of seven bass released into Lake Kizaki, Japan, during summer 2007–2008. From 220.7 total hours of data, the burst movement rate was 0.7 ± 0.3 events/hour (mean ± s.d.) (range: 0.4–1.1 events/hour). All bass showed burst movements during both daytime and nighttime, but four fish had higher event rates during the day. For two individuals, the mean event depth was significantly deeper during the daytime than the nighttime.

Keywords : *invasions, fish behavior, bio-logging, micro-acceleration data logger*

Introduction

Smallmouth bass (*Micropterus dolomieu*) are freshwater fish native to North America that were introduced to Japanese lakes in the mid-1990s and have been successfully reproducing since then (IGUCHI *et al.*, 2001). The introduction of this competitive species likely has serious consequences for native species (IGUCHI *et al.*, 2004).

Bio-logging tools have proven useful for behavioral ecology research, specifically to assess behavior in marine mammals, seabirds, and other free-living species that are difficult to study (KATO *et al.*, 1996; SUZUKI *et al.*, 2009; NAITO *et al.*, 2010). Micro-accelerometer tags are efficient tools to remotely quantify rates of behaviors such as resting, swimming, or migrating, and can

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Table 1. Logger data of burst movements of smallmouth bass in Lake Kizaki. Data were collected from 130.3 nighttime and 90.4 daytime hours.

ID	Capture date	TL (cm)	BW (g)	Water temp. (℃)	Daytime			Nighttime			Total		
					N	RT (h)	Rate	N	RT (h)	Rate	N	RT (h)	Rate
F	2007/5/20	34.1	640	14.3 ± 0.1	14	13.7	1.0	5	9.7	0.5	19	23.4	0.8
I	2007/8/10	42.1	-	26.3 ± 0.3	18	27.5	0.7	12	20.2	0.6	30	47.7	0.6
Q	2008/6/12	40.4	-	18.8 ± 0.2	12	14.5	0.8	5	9.2	0.5	17	23.6	0.7
R	2008/6/12	40.3	1080	19.0 ± 0.1	5	14.3	0.4	4	9.2	0.4	9	23.5	0.4
S	2008/6/16	38.2	-	20.2 ± 0.5	6	14.6	0.4	5	9.2	0.6	11	23.7	0.5
U	2008/8/13	38.3	-	26.5 ± 0.2	15	26.5	0.6	13	20.5	0.6	28	47.0	0.6
X	2008/8/24	40.1	-	25.0 ± 0.3	23	19.2	1.2	13	12.4	1.1	36	31.6	1.1
Mean ± s.d.		39.1 ± 2.6	-	21.4 ± 0.2	13.3 ± 6.4	18.6 ± 6.0	0.7 ± 0.3	8.1 ± 4.3	12.9 ± 5.2	0.6 ± 0.2	21.4 ± 10.2	31.5 ± 11.2	0.7 ± 0.3

TL: total length, BW: body weight, N: number of burst movements, RT: record time, Rate: burst movement rate per hour, -: no data

be used to estimate activity and energy budgets (Føre *et al.*, 2011; Alabsi *et al.*, 2011; Broell *et al.*, 2013). These devices allow the measurement of swimming intensity and active events (Aoki *et al.*, 2012), which can be used to estimate the quantity of food eaten (Tanoue *et al.*, 2012) and indicate the ecology of fish species.

This study explored the activity of smallmouth bass and investigated the potential of biologging devices for acquiring data on their burst movements such as feeding behavior. We also collected data on spatiotemporal swimming behavior of smallmouth bass to extrapolate their potential threats to native fish populations in Lake Kizaki.

Materials and methods

Smallmouth bass were caught by lure fishing from Lake Kizaki (36°32–34'N, 137°49–50'E, shoreline length: 7 km, surface area: 1.4 km^2, volume: 0.02 km^3, height: 764 m, maximum water depth: 29.5 m, transparency: 4 m,) in Nagano Prefecture, Japan, during the summers of 2007–2008. In May, nests of smallmouth bass were visually located. Individuals with IDs A-I were caught in in 2007, and IDs J-X were caught in 2008.

They were housed in a fish cage (3 × 3 × 1 m) in the lake to identify burst movements including feeding events via direct visual observation and video camera put from the cage side. Individuals (n = 7) were tagged with a micro-acceleration data logger M190–D2GT (Little Leonardo Co., Tokyo, Japan) to measure burst movements and other variables. Less than 24 h after the logger was tagged, three or five live loach (*Misgurnus* spp.), goldfish (*Carassius auratus*), and Japanese smelt (*Hypomesus nipponensis*) were introduced to the cage to allow the tagged fish to feed *ad libitum*. After the caged experiments, the tagged fish (n = 2 in 2007, n = 5 in 2008) were released into Lake Kizaki (Table 1).

The data loggers (53 mm × 15 mm, 6 g in water) measured depth and temperature in 1 s intervals, and both static and dynamic acceleration along the lateral 'sway' and longitudinal 'surge' axes at 32 Hz. A soft nylon mesh (6 × 4 cm) was sewed onto the dorsal side of each fish using biodegradable thread made of polyglycolic acid (Matsuda Medical Technology Co., Tokyo, Japan). The data logger was wrapped in copolymer foam to keep it slight positive buoyancy in the water (Komatsu *et al.*, 2011), and was attached to the nylon mesh with plastic bands. Data loggers had an automatic scheduled release system included VHF radio transmitter to detach from the nylon mesh and float to the surface (Watanabe *et al.*, 2008), where they were

Table 2. Activity patterns obtained by the data logger of smallmouth bass in a fish cage

Types of behavior	Criteria		
	High-pass filtering the swaying acceleration (m/s^2)	Beat frequency (Hz)	Change in body angles (degrees)
Feeding	≧ 2.0	≧ 3.0	≧ 20
Escaping	≧ 1.0	≧ 2.5	
Swimming	≧ 0.3	≧ 1.5	
Resting	< 0.3	< 1.5	

retrieved by the signal. One of the loggers tagged to nesting individuals (F) was detached in the same nest where the fish was caught.

Data were downloaded from the data loggers and analyzed using Igor Pro (v.6.0 J, WaveMetricks, Lake Oswego, OR, USA) and Igor Filtering Design Laboratory (IFDL: v. 4, WaveMetrics). Ethographer v. 1. 2 was used to detect specific waveforms among the large dataset of acceleration records (Sakamoto *et al.*, 2009). Power spectral densities (PSD) were calculated from swaying acceleration records from loggers to determine the dominant stroke cycle frequency using fast Fourier transformation. Tail beats were derived by high-pass filtering the swaying acceleration (Tanaka *et al.*, 2001). The body angle was extracted by low-pass filtering the surge acceleration. To remove higher frequency acceleration caused by tail beats, a low-pass filter was applied, with the threshold being the predominant frequency of tail beats to surging acceleration.

Results

Caged experiments

There were no observed differences in behavior between tagged and untagged fish in the cage 1 h after tagging. During the daytime, fish alternated between slow and rapid (burst) swimming events that characterize chase and predation behaviors. During feeding events, 95 % of high-pass filtering the swaying accelerations were more than 2 m/s^2, beat frequencies were more than 3 Hz, and changes in body angles were more than 20 degrees based on the acceleration waveforms measured using the logger (Table 2). As such, burst movements were defined as high-pass filtering the swaying acceleration ≧ 2 m/s^2, beat frequency ≧ 3 Hz, and changes in body angle ≧ 20 degrees in this study.

Field experiments

All loggers fitted to free-swimming fish were retrieved, and 220.7 data hours were collected (Table 1). The bass were more active in August (0.8 ± 0.3 burst movements per hour (mean ± s.d.)) than in June (0.5 ± 0.2). On average, burst movements occurred 0.7 ± 0.3 times per hour (range: 0.4–1.1; Table 1). All fish appeared to exhibit burst movements during both daytime and nighttime. The fish often swam before and after burst movements during the day but were inactive at night (Fig. 1). Four individuals (F, I, Q and X) showed a significantly higher rate of burst movements during the day than at night (Table 1). Two individuals (F and X) showed burst movements at a mean depth that was significantly deeper during the day than at night (*t*-test, $p < 0.01$). There were no significant differences among other individuals (Fig. 2).

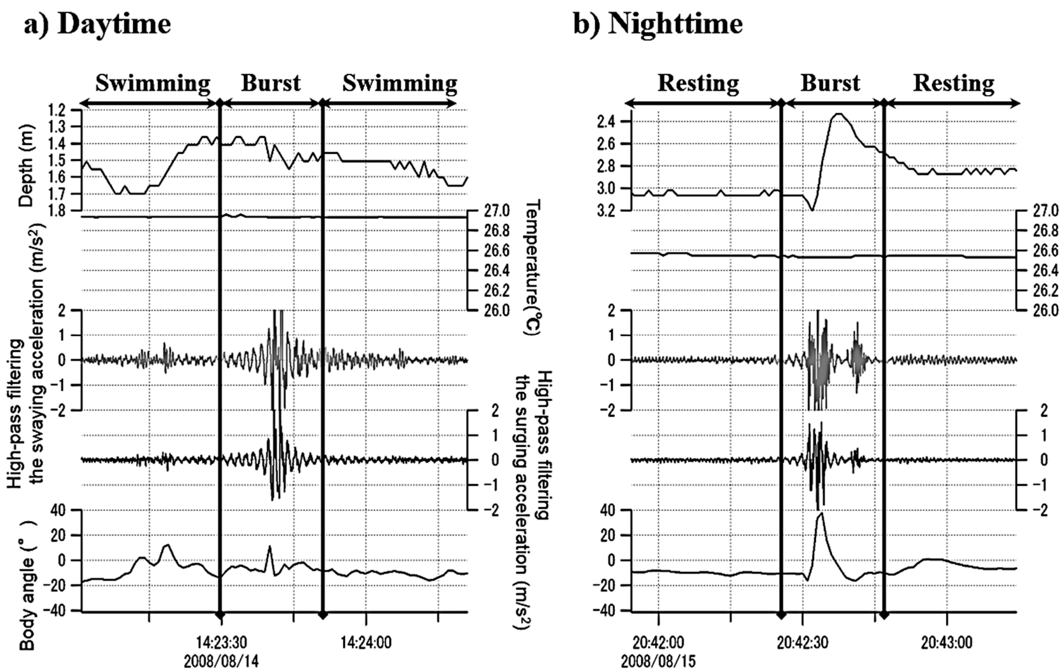

Fig. 1 Comparison of one fish's (ID: U) burst movements associated with swimming and resting behaviors between (a) daytime and (b) nighttime in Lake Kizaki.

Discussion

Micro-acceleration data loggers enabled us to monitor the swimming behavior and activity patterns of introduced smallmouth bass in Lake Kizaki. Smallmouth bass are generally diurnal, often inactive at night except during spawning season (EMERY *et al.*, 1973). The fish in our study were also more active during the day while in cages and free swimming (Fig. 1).

Smallmouth bass begin spawning once water temperatures exceed 14°C (RIDGWAY *et al.*, 1991). According to AZUMA and MOTOMURA (1998) a spawning fish is greater than 20 cm in length, which may be reached 1–2 years after hatching. In May, we caught nesting individual (F) that was more than 20 cm in length. After being tagged and released, the individual returned to the nest and displayed burst movements at 14.3 ± 0.1°C. These bursts may be indicative of defense behavior, as smallmouth bass defend their eggs both during the day and at night (SCOTT and NICHOLAS, 1991).

Introduced smallmouth bass can alter the habitat and reduce the abundance of many small-bodied species in freshwater environments (MACRAE *et al.*, 2001; JACKSON., 2002). Our study reveals the significant role that data-logging devices can play in researching fish behavior. Based on the behavior recorded in this study, we hypothesize that smallmouth bass display opportunistic and aggressive behaviors, and may act as competitors to other predators and stressors to small fish populations in Lake Kizaki. Future research should utilize micro-acceleration data loggers to study prey items and their capture, coupled with examinations of stomach contents.

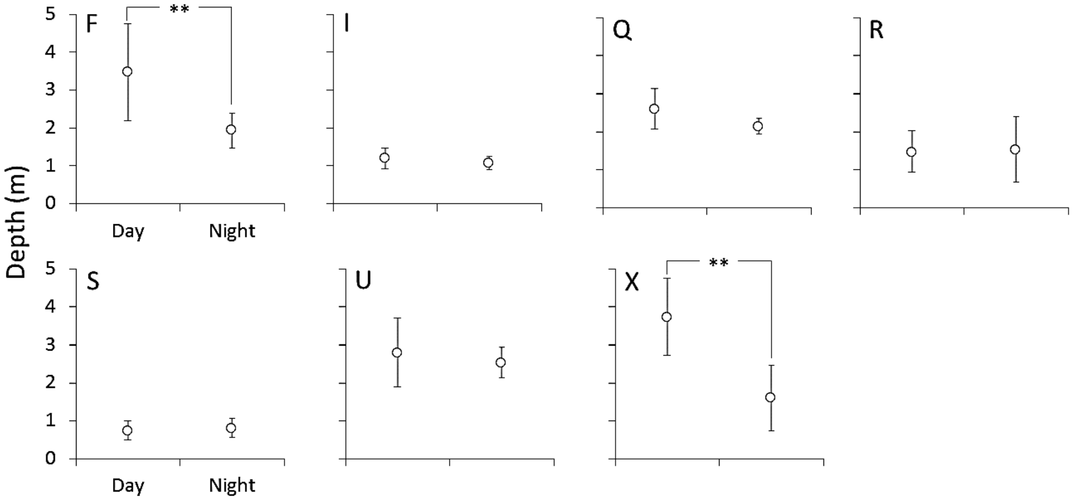

Fig. 2 Comparison of burst movement depth between daytime and nighttime in Lake Kizaki. Circles indicate mean. Error bars indicate standard deviation. Asterisks indicate significative difference between day and night (*t*-test results, $p < 0.01$).

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