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Influence of Time Interval on Estimations of Movement and Habitat Use

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Abstract.—Although biotelemetry has been widely used in fisheries science, the standardization of methods is uncommon. Researchers often use more than one time interval (frequency of recording locations) in a study, and different researchers frequently use different time intervals. There is a paucity of information describing the relationship between time interval used and movement observed or the proportion of time associated with habitat type. The objectives of this study were to evaluate the effects of varying time intervals on fine-scale (i.e., minutes-to-hours) diel movement and habitat use by spotted bass *Micropterus punctulatus*. To evaluate such effects, we tracked spotted bass ($n = 11$) every 15 min for a 24-h period. Using these data we simulated tracking at 30-min, 1-h, and 2-h intervals. The mean percent error of time interval simulations for total daily movement varied from 24.3% to 64.3% for 30-min and 2-h intervals, respectively. Loss of movement information (i.e., detecting less movement with simulated time intervals compared with the original data set) increased with increasing time intervals, and the 2-h interval poorly estimated diel movement. Conversely, habitat use was well-represented by each time interval. These results illustrate the importance of standardizing the use of time intervals and the need to consider time intervals when comparing results among biotelemetry studies.

Despite the common use of biotelemetry to study the movement and habitat use of fishes, there is little standardization among studies regarding tracking interval. Many authors recognize that the frequency of locating fishes may influence study results (Hawkins and Urqhuart 1983; Todd and Rabeni 1989; Clapp et al. 1990), but few have quantitatively determined the effect of varying time intervals on results. For example, Jones and Rogers (1998) stated that their methods provided a minimum estimate of movement because individual fish were not monitored continuously. We are not aware of any studies that evaluate the relationship between time interval and habitat results, but some authors have alluded qualitatively to the sufficiency of their time interval in describing habitat use. For example, Quist et al. (1999) suggested that weekly positioning was sufficient to describe the habitat use of shovelnose sturgeon *Scaphirhynchus platorynchus* during the winter.

Biotelemetry studies often use more than one time interval to describe movement or habitat use, sometimes on different scales (e.g., diel movement or seasonal). For example, James and Kelso (1995) located rainbow trout *Oncorhynchus mykiss* once every 2 weeks to describe long-term movements, once every 1 to 3 h to describe diel movements, and continuously (approximately every 10 min) for several hours on two consecutive days to determine swimming speeds and short-term patterns of movement. Making comparisons within or among studies can be difficult or invalid if fisheries scientists do not understand the effect of the time interval used on their results (Baras 1998; Ovidio et al. 2000).

Cooke et al. (2001) compared movement results among different research methods including mark–recapture, fixed-antenna telemetry, and electromyogram (EMG*i*) telemetry. The authors found that mark–recapture and fixed-antenna telemetry significantly underestimated movement relative to the results of EMG*i* telemetry. Baras (1998) demonstrated that varying daily time intervals from 1 to 7 and 28 d increased the mean error in total

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movement by 40% and 70%, respectively, for barbel *Barbus barbus*. Ovidio et al. (2000) investigated the influence of varying daily time interval (from 1 to 28 d) on estimates of brown trout *Salmo trutta* movement. The authors demonstrated a loss of accuracy of 92% when they simulated tracking brown trout with a 2-week interval compared with daily positioning. These results illustrate the effects of different time intervals on the interpretation of movement on a coarse scale (i.e., daily to monthly); however, we are aware of no information on a finer scale (i.e., minutes to hour) or the effects of different time interval on habitat use estimates. The objectives of this study were to assess the effects of different time intervals (15 min, 30 min, 1 h, and 2 h) between successive locations on the movement and habitat use estimates for spotted bass *Micropterus punctulatus*. We predicted that different time intervals would influence movement estimates since we did not expect movement to be unidirectional (i.e., migrations). We also predicted that different time intervals would have less of an influence on habitat use results since habitat use is discrete and not cumulative in nature.

Study Site

Spotted bass were tracked in Otter Creek, Kansas. Otter Creek is a fourth-order stream located 90 km south of Emporia, Kansas, within the Flint Hills physiographic region. Flint Hills streams are characterized by deep channels lined with rock ledges and substrate dominated by limestone and chert fragments (Schoewe 1949). Discharge in a typical Flint Hills stream is highly variable, and a stream may receive 75% or more of its total annual flow during 2 months of the year (Metzler 1966). Watersheds within the Flint Hills region are dominated by tall-grass prairie in the uplands and deciduous riparian forests (Küchler 1969). Otter Creek drains a 334.1-km^2 watershed and converges with the Fall River 5 km upstream of the Fall River Reservoir. Two study areas were delineated. Site 1 was 1,000 m long (starting 8.4 km upstream from the mouth of Otter Creek), and site 2 was 450 m long (starting 500 m upstream of site 1). Site 2 was only used during the summer of 1998.

Methods

Spotted bass were sampled using boat-mounted electrofishing equipment. Shortly after capture, spotted bass were tagged following the procedures outlined by Hart and Summerfelt (1975) and Schramm and Black (1984). An incision was made lateral to the midventral line to avoid blood vessels (Winter 1996), and posterior to the pelvic girdle. Three simple interrupted sutures were used to close the incision. Each radio transmitter (model 357; Advanced Telemetry Systems) measured 13 mm wide, 7 mm deep, and 24 mm long, and weighed 3.6 g in air (see Horton and Guy [2002] for more details on transmitter implantation). By reducing the signal strength and pulse rate from 55 pulses per minute to 40, transmitters had a minimum life span of 140 d.

Transect spacing for habitat mapping was based on habitat heterogeneity and varied from 7 m to 25 m. Measurements of substrate and velocity were taken at 1-m intervals across each transect. Habitat was mapped at site 1 during the summers of 1998 and 1999, and at site 2 during 1998. Substrate composition was determined visually where possible or by feeling the substrate with an extremity (i.e., hand, foot, or pole; Hamilton and Bergersen 1984). Any object able to provide protection from predators or adverse environmental conditions (e.g., high velocity) was classified as cover habitat (McMahon et al. 1996). This classification included overhanging vegetation, undercut banks, log complexes, and rootwads. Stream area more than 1 m away from any of the above cover types was classified as open-water habitat (see Horton and Guy [2002] for more details on habitat measurements).

Biweekly during the summers of 1998 and 1999, spotted bass with transmitters were tracked to provide detailed information on diel movement and habitat use. We located one or two randomly selected spotted bass every 15 min for a 24-h period. Each time we located a spotted bass, we recorded the macrohabitat and cover habitat associated with the location. After each tracking period, substrate use was determined by referencing transect data (White and Garrott 1990). The straight-line distance (m; within the stream boundaries) between consecutive locations was recorded for each spotted bass to obtain an estimate of movement. To simulate tracking spotted bass at 30-min, 1-h, and 2-h intervals, we removed locations from the 15-min data set to reflect data that would have been collected had we tracked the spotted bass at the simulated interval. Next, we measured the linear distance between locations and determined the percent of locations associated with each habitat. Percent error was defined as the difference of the 15-min data set compared with the simulated time interval (i.e., percent error = $[x - x']/x \cdot 100$, where x equals the 15-min data set and x' equals

TABLE 1.—Total daily movement (m) of spotted bass in Otter Creek, Kansas (24-h period) determined by locating spotted bass once every 15 min (15 min), and by time interval simulations (30 min, 1 h, and 2 h) by fish. Numbers in parentheses represent the percent difference when compared with 15-min data (i.e., percent error = $[(x - x')/x] \cdot 100$, where x equals the 15-min data set and x' equals the simulated interval [30 min, 1 h, or 2 h]).

	Time interval			
Fish	15 min	30 min	1 h	2 h
1	1,395	951 (31.8)	565 (59.5)	323 (76.8)
2	1,193	992 (16.8)	463 (61.2)	230 (80.7)
3	255	1,999 (22.0)	149 (41.6)	133 (47.8)
4	1,939	1,534 (20.9)	994 (48.8)	675 (65.2)
5	324	193 (40.4)	134 (58.6)	111 (65.9)
6	2,724	2,408 (11.6)	1,302 (52.2)	680 (75.1)
7	2,815	2,372 (15.7)	1,694 (39.8)	1,434 (49.1)
8	497	321 (35.5)	184 (63.1)	149 (70.1)
9	808	534 (33.9)	300 (62.9)	191 (76.4)
10	1,588	1,477 (7.0)	1,094 (31.1)	933 (41.3)
11	356	244 (31.5)	206 (42.3)	147 (58.7)
Mean percent error [SE]		24.3 [44.9]	51.0 [21.6]	64.3 [20.1]

the simulated [30-min, 1-h, or 2-h] interval; Baras 1998).

In 1998, we tracked six spotted bass for a 24-h period (two of six were tracked twice during the summer and mean movement for each time period was used in the analyses). In 1999, five spotted bass were tracked for a 24-h period (one spotted bass was tracked twice and mean movement for each time period was used in the analyses). On three occasions, the tracking of an individual spotted bass was suspended for 1.5–5.75 h. Therefore, for three time periods (1900–2015, 2130–2145, and 630–1200 hours) sample size was ten spotted bass, and for one time period (2030–2145 hours) sample size was nine. All other time periods were represented by 11 spotted bass in the analyses.

Results

The total daily movement of spotted bass varied from 255 to 2,815 m using a 15-min interval (Table 1). Mean percent error of total daily movement was 24% for the 30-min simulation, 51% for the 1-h simulation, and 64% for the 2-h simulation. Diel movements determined by the 15-min interval were always higher than other time interval simulations (Figure 1). For example, the average movement of spotted bass during the morning crepuscular period was 200 m when tracking on a 15-min interval, and decreased to less than 100 m when simulated with a 2-h interval. Overall, each of the time intervals followed a similar pattern of diel movement where no movement occurred at night, followed by a morning crepuscular peak and relatively constant movement throughout the daylight hours.

Average daily habitat use (the average of all time categories) determined by the 15-min interval and the simulated time intervals showed little variation in percent use, and most habitats were equally represented by each of the simulated time intervals (Table 2). For example, the mean percent use of log complexes was 31% (15 min), 31% (30 min), 31% (1 h), and 30% (2 h). Diel patterns of habitat use were well-represented by each of the simulated time intervals. For example, the diel patterns of mean percent use of log complex (determined by each time interval) showed little variation (Figure 2). Each time interval showed a similar trend, where spotted bass used log complexes more during the night and less (20–35% less) during the day.

Discussion

Despite the simple objectives of most biotelemetry studies, data analyses are often complex and performed inappropriately. For example, the experimental units in biotelemetry projects often are not reported or are reported as the number of locations, whereas the experimental units should be the number of randomly selected fish that were tracked (Aebischer et al. 1993; Winter 1996). Problems with independence and autocorrelation among successive locations are an artifact of the data being analyzed incorrectly (Aebischer et al. 1993). If sampling is frequent enough to record the use of infrequently used habitats, then the proportion of locations associated with a habitat is a reasonable representation of the time the animal used the habitat. The number of times a fish is located within a given time period does not relate

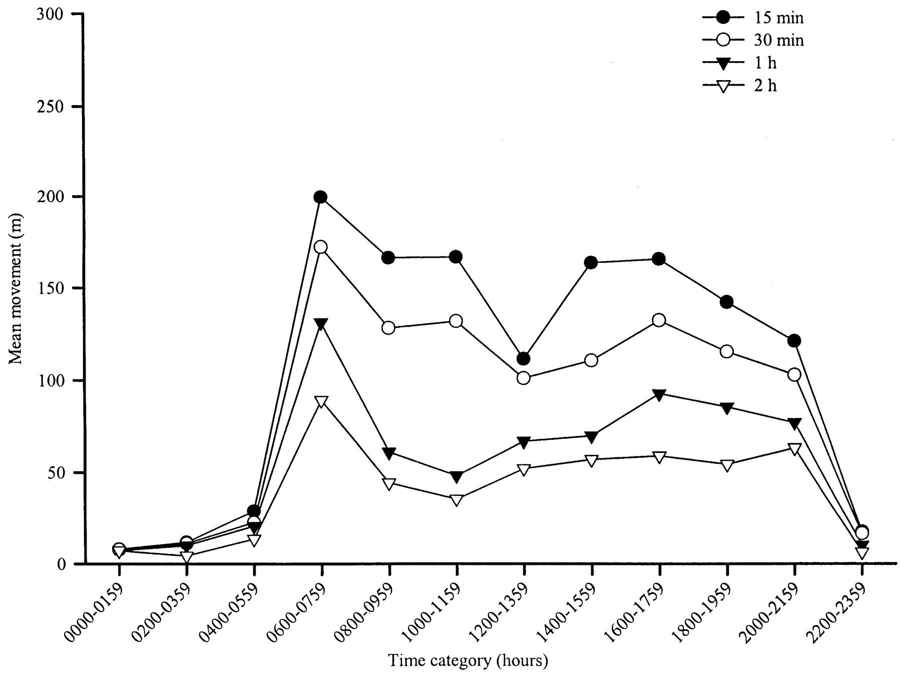

FIGURE 1.—Diel movement patterns by spotted bass tracked in Otter Creek, Kansas (n = 11) as determined by locations at 15-min intervals and simulated time intervals (i.e., 30 min, 1 h, and 2 h).

TABLE 2.—Mean percent of locations associated with habitat type determined by locating spotted bass (n = 11) once every 15 min for a 24-h period and by time interval simulations (30 min, 1 h, and 2 h) for spotted bass tracked in Otter Creek, Kansas.

Habitat level	Time intervals			
	15 min	30 min	1 h	2 h
Macro habitat				
Pool	92.2	99.1	99.4	99.6
Run	0.3	0.4	0.2	0.4
Riffle	0.5	0.6	0.4	0.0
Cover habitat				
Open water	49.5	45.5	43.4	46.4
Overhanging vegetation	20.1	20.5	22.9	22.6
Log complex	31.1	31.1	31.0	30.3
Rootwad	9.8	10.3	10.0	9.2
Undercut bank	4.6	4.5	3.9	3.6
Substrate				
Clay	15.1	15.1	15.5	12.5
Silt	20.4	21.2	20.8	19.6
Sand	1.0	1.0	1.3	2.1
Gravel	8.8	9.2	8.8	7.5
Pebble	11.6	11.9	12.3	14.6
Cobble	10.5	10.8	11.0	12.5
Boulder	4.0	2.8	2.9	3.3
Bedrock	28.5	27.1	26.5	27.1

to sample size, but relates to the precision of describing the movement trajectory (Aebischer et al. 1993). As the number of observed locations for an individual fish increases in a finite time period, its movement trajectory becomes more precise. Thus, the frequency of recording locations should reflect study objectives (e.g., diel or seasonal movement patterns).

Baras (1998) and Ovidio et al. (2000) demonstrated the loss of movement information on a coarse scale (i.e., days to months), and our study illustrates the loss of movement information on a finer scale (i.e., minutes to hours) by simulating movement at different time intervals. Future studies on movement patterns of fishes should clearly define what level of information is of interest, and then use a time interval sufficient to accomplish the objective. Ideally to satisfy one study objective (e.g., diel movement or seasonal habitat use) and to ensure consistent results, researchers should select one time interval and use that time interval for the duration of the study. Baras (1998) and Ovidio et al. (2000) suggested the use of one time interval throughout a study in order to collect consistent results, and suggested caution when making comparisons of movement patterns between or among fish tracked at different time intervals.

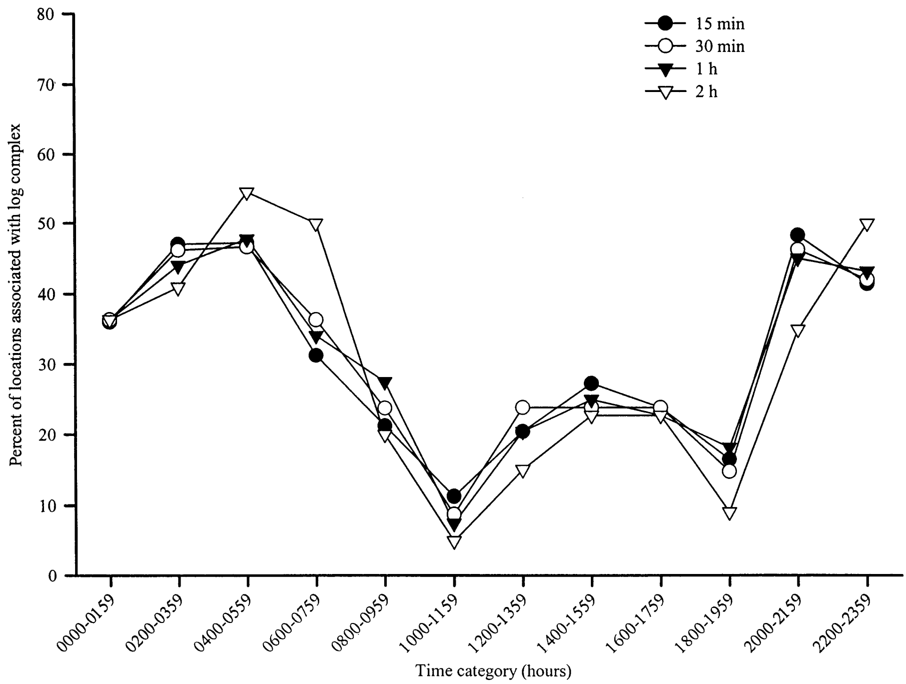

FIGURE 2.—Diel use of log complex by spotted bass tracked in Otter Creek, Kansas (n = 11) as determined by locations at 15-min intervals and simulated time intervals (i.e., 30 min, 1 h, and 2 h).

Some researchers have realized this problem and used standardized time intervals to allow comparisons of results among studies and species (Holland et al. 1993; Nelson et al. 1997; Gruber et al. 1998). For example, Morrissey and Gruber (1993) used a 15-min interval for tracking juvenile lemon sharks *Negaprion brevirostris* to assure that their results were comparable with previous biotelemetry studies on lemon sharks.

The loss of movement information due to longer time intervals may vary among species. Baras (1998) and Ovidio et al. (2000) hypothesized that the frequency of recording locations may have less of an effect on movement results for species that make more unidirectional migrations (e.g., salmonids), at least during certain seasons. In addition, the relationship between time interval and loss of movement information may vary among seasons and time of day. In our study, when spotted bass were not moving during the night, each time interval approximated movement equally. Some species may move less during particular seasons and little would be gained by frequent tracking. The loss of movement information may also be affected by differences in environments (e.g., lotic and lentic environments). The relationship between tracking frequency and the loss of movement information needs to be evaluated for other situations (including different species, time periods, seasons, and environments).

In our study, habitat use by spotted bass was well-represented by each of the time intervals. However, we only examined up to 2 h intervals. Intervals longer than 2 h may cause higher variability in percent use. In addition, longer time intervals may misrepresent the use of some habitats. Specifically, the use of infrequently used habitats may be misrepresented. In this case, fish may use a habitat for a short time during a particular part of the day (e.g., riffle areas for feeding in the morning), and less frequent tracking may cause researchers to misrepresent the actual use and, therefore, the importance of the habitat. We are not aware of any other studies examining the relationship between time interval and habitat use results. Subsequently, more research is needed to determine the relationship between time interval and habitat use.

The results of this study elucidate potential problems with biotelemetry studies. First, fisheries scientists researching movement must be careful when comparing results among studies using different time intervals, or within a study using multiple time intervals. In addition, the time interval used in a study may not be sufficient to describe diel patterns of movement. Our study illustrates how fine-scale and diel movement information is lost when time intervals are increased. These results introduce the possibility for a more dichotomous approach to biotelemetry studies. In the past, researchers may have decided to examine the movement of a fish species since they were already studying habitat use. However, the time interval selected to represent one objective may not be sufficient to accurately represent another (e.g., habitat use and movement). Therefore, the tradeoffs between accuracy and time interval (and associated factors) must be evaluated in each situation, and more focused approaches (e.g., habitat use only) may be necessary.

Data from telemetry studies are frequently used in fisheries management. For example, habitat use is often defined from telemetry studies so natural resource agencies can enhance or restore habitat. Further, relations between movement patterns and abiotic variables such as discharge are critical to understanding the effects of anthropogenic modifications on fish behavior. Proper management decisions need to be based on sound science and data analysis techniques. Thus, understanding the effects of tracking interval on telemetry data are critical. This study provides evidence for standardizing the tracking interval and the need for caution when making comparisons among telemetry studies with different tracking intervals.

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