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Letter

Preliminary telemetry data on the movement patterns and habitat use of European catfish (*Silurus glanis*) in a reservoir of the River Ebro, Spain

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Abstract – Knowledge of the movements and diel behaviour of the European catfish (*Silurus glanis*), the largest European freshwater fish, is limited to anecdotal information. In a preliminary telemetry study of European catfish, the spring diel movement patterns of five adult catfish were examined. After intraperitoneal insertion of the acoustic tags, the positions of the fish were recorded automatically in the Flix Reservoir (River Ebro, NE Spain). A marked nocturnal mobility pattern was observed throughout the study. During daytime, the catfish were consistently located in the littoral zone and spent extended periods of the day hidden in concealed habitats. Catfish movements were in a radial pattern, with upstream and downstream excursions followed by returns to a previously occupied location. Significant individual variations in movement pattern were observed among the tagged fish and within the 24 h cycle for each fish. Mean instantaneous swimming speed was 0.17 body lengths per second (BL·s^{-1}) at night but 0.09 BL·s^{-1} during the daytime.

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Key words: ultrasonic telemetry; swimming activity; mobility; wels

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Introduction

The European catfish (*Silurus glanis*), also known as wels catfish or sheatfish, is the largest European freshwater fish, being native to Eastern Europe and western Asia and most abundant in the Danube and Volga river basins. The European catfish inhabits the lower reaches of large rivers and muddy lakes, tends to prey on fish smaller than could be expected for its size and mouth gape (Adámek et al. 1999; Wysujack & Mehner 2005) and males grow faster than females (Dogan & Gul 2004). Catfish is nowadays popular among European anglers and has been introduced in many European countries, including France, Italy, the Netherlands, Spain, and the UK (Elvira 2001; Keith & Allardi 2001). Catfish is also an increasingly important aquaculture resource in Central and Eastern Europe and most research has been devoted to aquaculture development (Adámek et al. 1999; Alp et al. 2004). The ecology of natural populations of European catfish is poorly known, probably because of the difficulty of sampling such a large species in large rivers or lentic ecosystems. The ecological impact of European catfish on native biota is also unknown, although the introduction of some parasites has been noted (Blanc 1997).

The European catfish was introduced in the lower River Ebro (NE Spain) 30 years ago and is now considered abundant, although there is no scientific literature on this species for the Iberian Peninsula.

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Similarly, there are no known published telemetry studies of European catfish anywhere, with a single telemetry study of the congener, Biwa catfish *Silurus biwaensis* in Japan (Takai et al. 1997), being the sole reference point. Inforrmation on European catfish is therefore urgently needed to understand better the environmental biology of the species and its impacts on native biota. The aim of the present paper is to present preliminary telemetry data on the diel movements of adult European catfish, which were tagged and tracked during spring 2005.

Study area and methods

The study was undertaken in the Flix Reservoir (41°23′N, 0°55′E), which is an artificial in-stream water body of the River Ebro (NE Spain), the river with the highest water flow in the Iberian Peninsula (annual mean = 255–424 $m^3 \cdot s^{-1}$; area ≈ 85,820 km^2). Flix Reservoir is relatively small (surface area = 320 ha, capacity = 11 hm^3) and has a very short residence time (0.15 days), which preserves some of the river natural properties but not upstream connectivity. Mean water discharge in the reservoir was 100 $m^3 \cdot s^{-1}$ in summer and up to 500–700 $m^3 \cdot s^{-1}$ in winter. Wetted width ranges from 300 to 400 m, with maximum depth in the study area usually being 9.5 m in summer. Water temperature throughout the year ranged from 8 to 28 °C. The littoral area presents a poor diversity of substratum types characterised by smooth, weakly sloped banks, with abundant vegetation, particularly common reeds *Phragmites australis*. In summer, submerged macrophytes (mainly *Chara* sp. and *Potamogeton* spp.) grow extensively, except in the deepest parts. The fish assemblage is dominated by introduced cyprinids, such as bleak *Alburnus alburnus*, common carp *Cyprinus carpio*, and roach *Rutilus rutilus* (see Carol et al. 2006 for further details).

The capture and tagging of European catfish took place from 4 to 14 April 2005 in the littoral zone of Flix reservoir using a boat-mounted electrofishing unit (5000 W pulsed-DC current). Five European catfish were tagged with acoustic tags (VEMCO V16: length = 92 mm, mass in water = 16 g) with a minimum expected battery life of 9 months. Fish were individually anaesthetised by immersion in MS222 (60 $mg \cdot l^{-1}$) for 5 min, when a surgical level of anaesthesia was achieved. Individuals were then measured for mass (nearest 10 g) and total length (nearest 1 mm) and placed ventral side up on an operating table. Fish specimens 1–5 measured 1030, 1075, 1150, 1380 and 1430 mm and weighed 6850, 6910, 8050, 13400, and 16150 g, respectively, thus yielding tag-to-body mass ratios ranging 0.099–0.234. The transmitter was inserted into the peritoneal cavity through a 5-cm long, mid-ventral incision, which was closed using surgical sutures (3–0 Polydioxanone, Ethicon Inc., Piscataway, NJ, USA) placed 5 mm apart. No experiments have been undertaken on European catfish to examine the potential impact of this procedure, but the tags were ≤0.24% of the fish's total body mass, which is well below the recommended maximum of 5%. The sex of the specimens was impossible to determine during tag implantation, so a sample of fin tissue was extracted for subsequent sex determination by genetic analysis. Following suture placement, the fish were transferred to a recovery tank, where they were continually observed until the visible effects of the anaesthesia had disappeared. Prior to release in their capture zone, and 1 h after tag implantation, all specimens were tagged externally with a T-bar anchor (Floy Tag Inc., Seattle, WA, USA) to facilitate their identification in future recaptures.

Tracking of the tagged specimens began on 9 May 2005 and lasted 9–12 days, yielding 210–1679 valid locations per fish. We used a fixed, radio-linked acoustic hydrophone array (VRAP; Vemco^{TM}, Halifax, Canada), deployed at the fish capture location and consisting of three buoys and a computer-controlled base station installed on shore (see Zamora & Moreno-Amich 2002 for further details). The buoys, which communicated with the base station via VHF radio modems, were tightly anchored ca. 1 km upstream from the dam in a triangular pattern, with approximately 400–700 m distance between each buoy. The accuracy of the positioning system, which was verified by placing transmitters at known locations within the triangle, was >1 m inside the array and decreased to 10 m within a 300 m radius of the array's centre; this is consistent with other studies (Bégout Anras et al. 1999; Zamora & Moreno-Amich 2002). Signal detection declined to zero near the littoral zone because of attenuation by vegetation. Therefore, when tagged fish were close to shore, manual tracking was conducted using an acoustic receiver (VR100, VEMCO) and a directional hydrophone.

Prior to analysis, the data were subjected to a cleaning process to remove noise due to refraction (e.g., temperature, deep contour), which affects tag detection range (Voegeli & Pincock 1996). Only positions that fulfilled two criteria were kept in the analysis: (i) that the time between positions had not exceeded 10 min., and (ii) the standard deviation (SD) of estimated position was <5 (see Skajaa et al. 1998).

A series of descriptive statistics of fish movement, including the distance travelled and the bearing between locations, were calculated using the Animal Movement Analysis Arcview® Extension (Hooge & Eichenlaub 1997) to determine basic movement patterns. Eccentricity is the ratio between the major and minor axes of range and indicates whether the range shape is circular (close to 1) or increasingly elongate (>1). Linearity is the ratio between the travel path endpoints and the total distance travelled and ranges from 1 (perfect linearity) to 0. Site fidelity was analysed using a Monte Carlo simulation to test whether the trajectories (so-called "walks") followed a random pattern; the test creates random angles and uses distances between existing sequential points to determine walk points so as to examine if the observed movement pattern has more site fidelity than should occur randomly. The orientation of

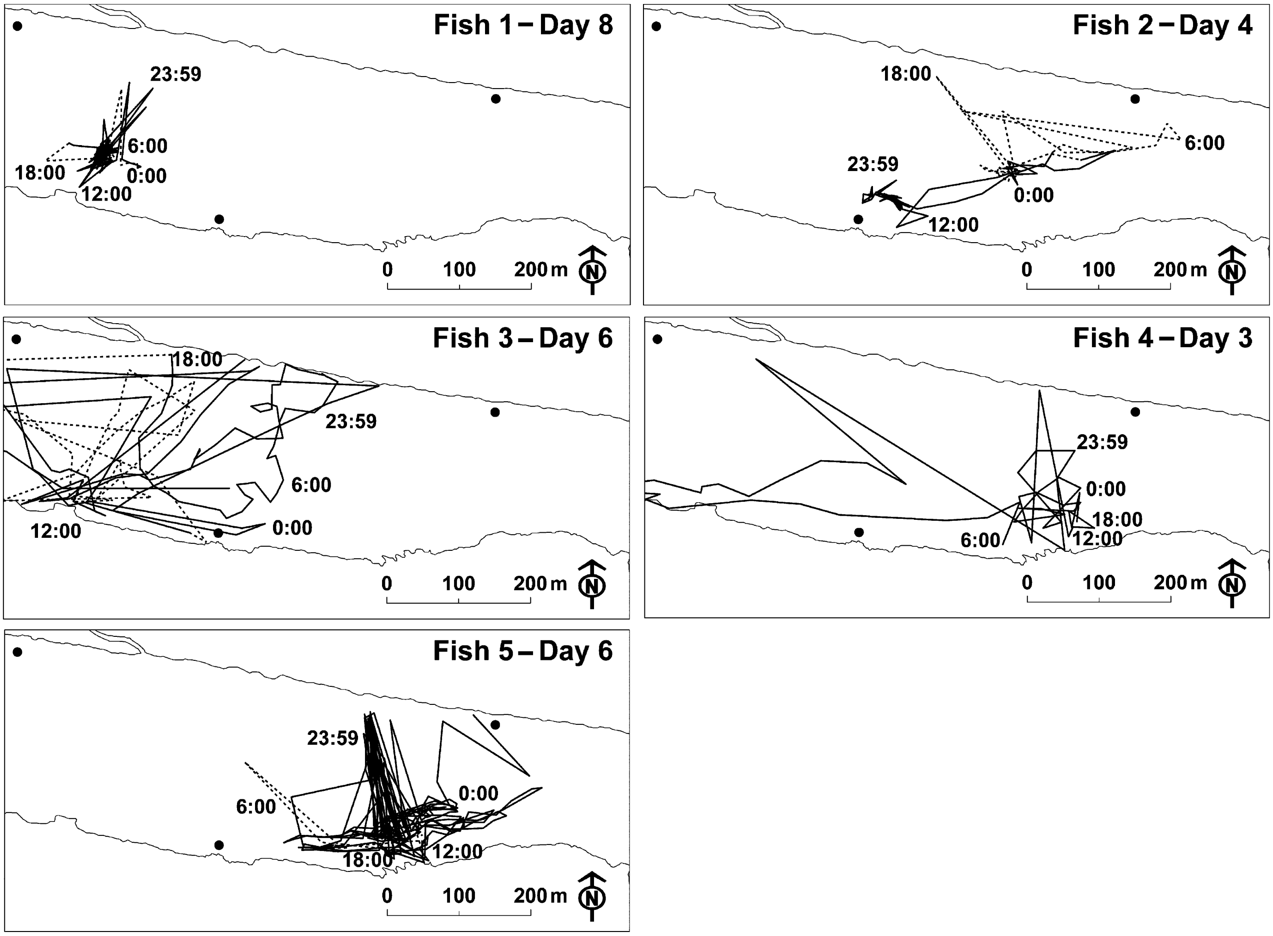

Fig. 1. Examples of trajectories undertaken by five European catfish at Flix Reservoir during daytime (dashed lines) and night (continuous lines) in different days (numbered from the beginning of tracking study; times given are GMT + 2). Location of the three recording buoys (●) is also given.

Table 1. Statistics of movements by tagged specimens (Spec.) of European catfish in Flix reservoir (River Ebro, Spain).

	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
Linear statistics					
No. valid locations	1298	1462	1679	219	1171
Total distance (km)	24.1	27.1	76.7	11.9	56.3
Mean daily distance (m)	18.58	18.55	45.72	54.59	48.10
L (Linearity)	0.00	0.01	0.01	0.01	0.00
Primary axis length (m)	158.9	530.3	851.7	1133.8	493.7
Secondary axis length (m)	127.9	119.3	344.9	267.2	332.8
Eccentricity	1.11	2.11	1.57	2.06	1.22
Circular statistics					
Rao's spacing test (*U*)	150.7	144.4	139.7	169.2	140.5
Rao's spacing test (*P*-value)	<0.01	<0.01	<0.01	<0.01	<0.01

See Study area and methods for the statistics used.

movements was tested for uniformity of bearings distribution using Rao's spacing test (Batschelet 1981). Pairwise Watson U^2 tests were used to compare the bearing distributions of fish pairs (Zar 1984); Watson tests analyse whether the mean angle of bearings for two fish is the same. Finally, mean hourly instantaneous swimming speed was calculated for each fish and the relationship between this mobility measure and time was tested using the circular-linear correlation coefficient (Mardia & Jupp 2000). Analysis of variance (ANOVA) was used to compare mean swimming speed between individuals. Linear statistical analyses were performed with SPSS 11.5 and circular statistics with the software Oriana (Kovach Computing Services, Anglesey, UK).

Results and discussion

Two months after the tagging exercise, all tagged catfish were detected in motion, which indicated no post-tagging mortality, no tag expulsion, and no tag failure. After 45 days, one fish was recaptured to assess the incision, which had healed well and the sutures had fallen out. During the observation period, all tagged fish remained within detection range of the acoustic array, which registered 27,479 tag detections. However, spatial position could be calculated for only 7.3% of the records because of signal attenuation due to vegetation, the tag-to-receiver distance, tag position relative to the buoys (i.e., in the shadow areas outside the array and behind the

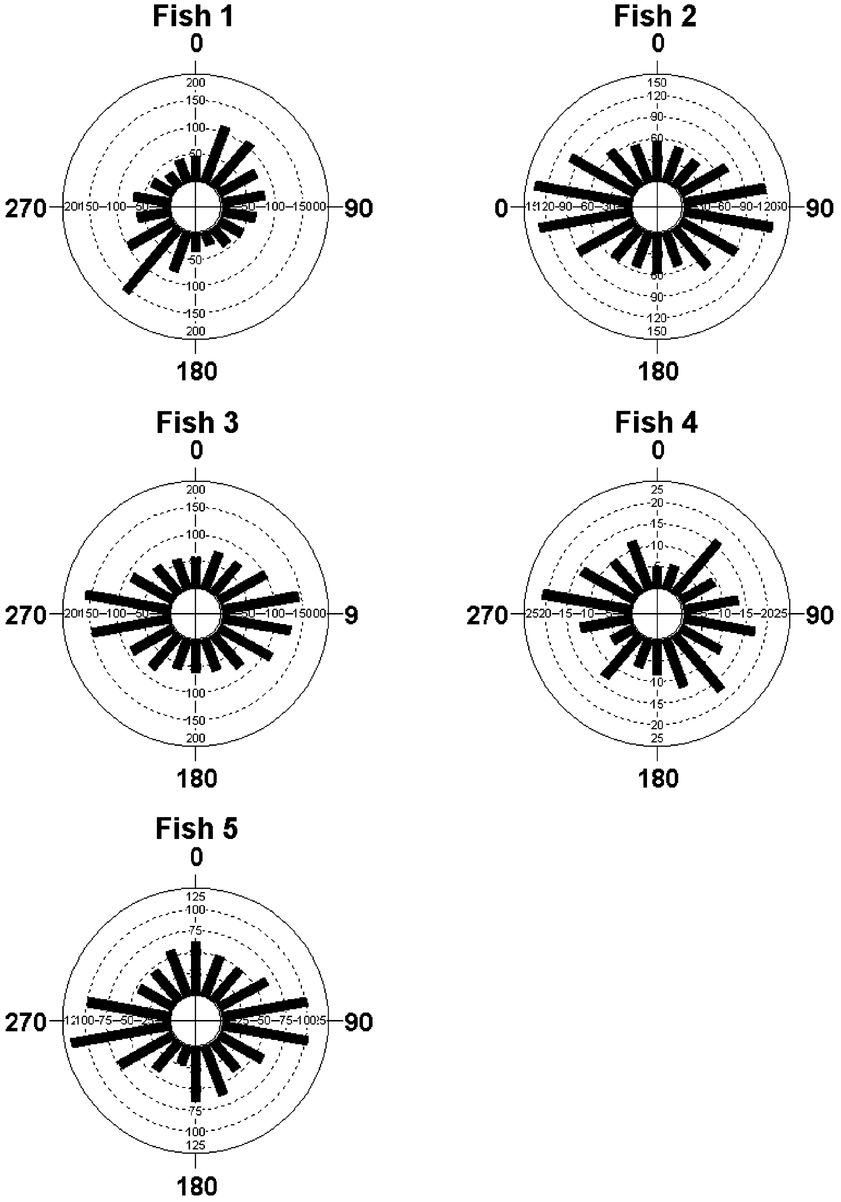

Fig. 2. Circular histograms for the five European catfish showing the number of bearings for each direction class. The rings are at 50-unit intervals, beginning from the inner circle, which is zero.

buoys), or high noise levels. Indeed, 77.9% of the failures in triangulation were related to the presence of the experimental fish within the littoral vegetation, where detection range decreased to 50 m and portable equipment had to be used to detect the tagged catfish.

The movement patterns of European catfish were distinctly nocturnal throughout the study (Fig. 1). During daytime, the fish remained primarily in the littoral zone, spending extended periods in a concealed 'resting place'. At night, large displacements were undertaken but these swimming excursions were of

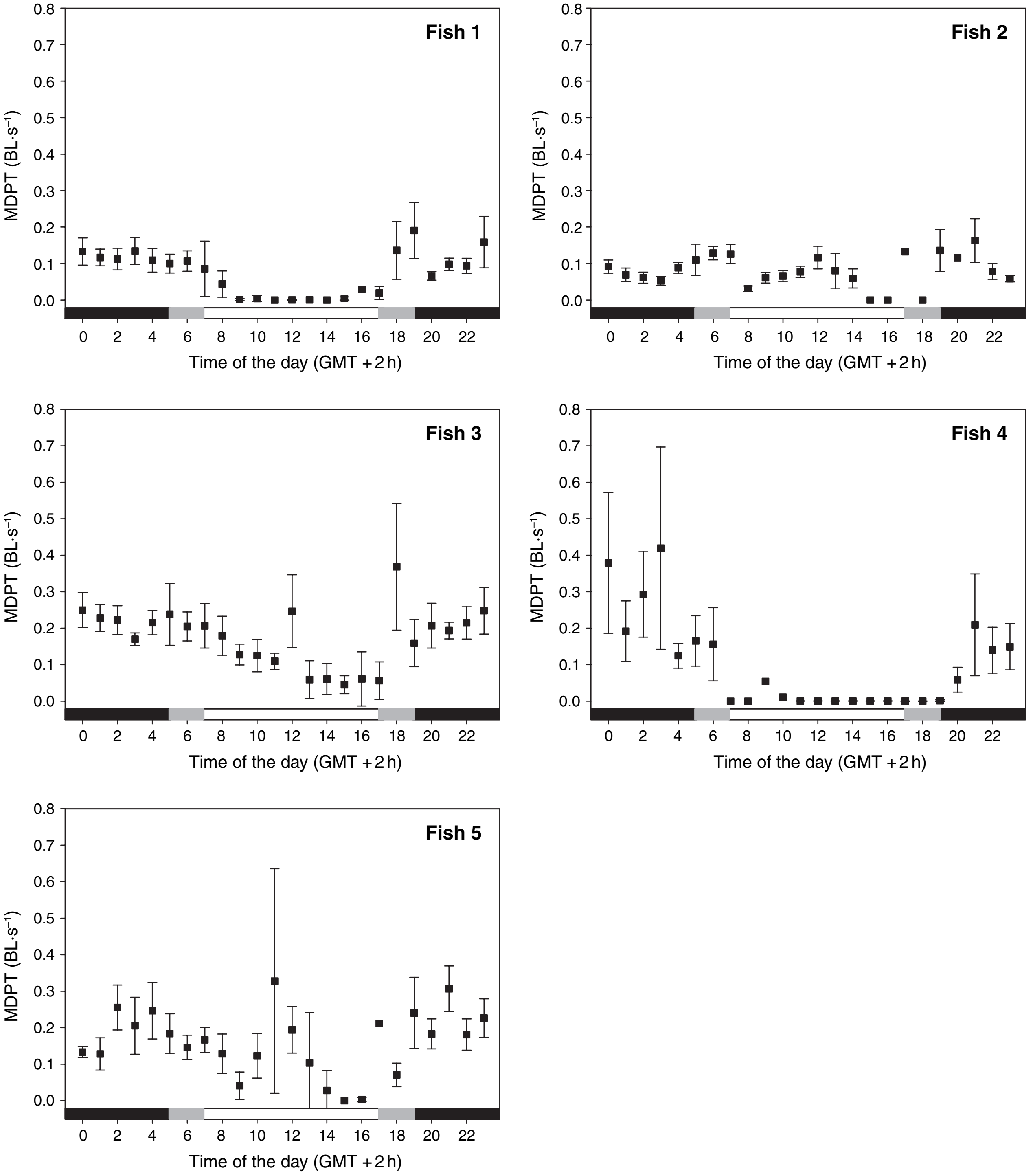

Fig. 3. Diel mean swimming speed during the 24 h (+2 h GMT) cycle. MDPT: minimum displacement per time unit (Body lengths·s^{-1}). Vertical bars denote standard error. The dark and light sections indicate night and day, respectively. Grey sections indicate dawn and dusk.

limited duration and characterised by numerous direction changes, which suggest the exploration of a small area. All of the tagged catfish showed a similar movement pattern, characterised by restricted mobility, short excursions and proximity to a fixed location, which was near the point of initial capture (Fig. 1). This daily site fidelity was statistically significant ($P < 0.001$ for all fish specimens), and locations where very few movements were recorded were considered to be 'resting places'. The maximum recorded daily distances from a resting place were: 736 m upstream and 767 m downstream. The mean distance travelled per day was 18.6 m·day^{-1} for smaller individuals and 49.5 m·day^{-1} for larger catfish (Table 1), although the relationship between swimming activity and body length was not quite significant ($r = 0.857$, $P = 0.063$).

The movements of European catfish were radial, with upstream and downstream excursions followed by a return to a previously occupied location (resting place). The linearity of movements was near 0 for all specimens, indicating that the tagged catfish did not follow a straight line; rather, a large area was used intensely during large displacements, which resulted in a wide range of eccentricity values (Table 1) and correspond to circular range shapes for specimens 1 and 5 and a near elliptical range shape for specimens 2, 3 and 4.

Circular bearing histograms (Fig. 2) showed that the movement distributions were bi-modal, with the two modes being in opposite direction from the point of origin (i.e., initial capture). Rao's test was significant for all fish (Table 1) and showed that bearings did not follow a uniform distribution and that angle concentration was low for all the fish. Most specimens registered the highest frequencies of movement upstream (90°) and downstream (270°) from the resting places (Fig. 2). Pairwise Watson's U^2 tests showed that only specimen 1 had significantly different ($P < 0.005$) movement directions from the rest of the specimens; specimen 1 had more movements perpendicular to the shore instead of upstream–downstream (Fig. 1).

The five catfish showed large variation in mobility, among individuals and throughout the 24 h cycle for each fish (Fig. 3; ANOVA, $P < 0.001$). Instantaneous swimming speed averaged for the five fish was 0.3 BL·s^{-1} (range = 0.09–0.21) at night and 0.15 BL·s^{-1} (range = 0.01–0.17) during the daytime. Specimens 1 and 2 were smaller and were less active. Specimens 1 and 4 presented significantly higher mobility within the 24 h cycle and basically showed nocturnal mobility and daytime inactivity. In contrast, specimens 2, 3 and 5 were also more active at night but made several displacements during the day. This resulted in an increase in mean swimming velocity from 6:00 to 18:00. The possibility that these results were due to fewer locations during the daytime was rejected with manual locations.

Experimental studies have shown the nocturnal movements of European catfish for feeding, although the species can be trained to feed by day (Boujard 1995). The site fidelity of European catfish resembles that of Biwa catfish, which returned quickly to their place of capture in Lake Biwa (Japan), where the species did not change its resting places throughout the year (Takai et al. 1997). The intensive daytime use of the littoral zone habitat was confirmed through comparison of the registered movements with random trajectories, which revealed use of a specific part of the littoral zone. The diurnal resting places of the tagged specimens were within very dense vegetation or near tree trunks or large stones. This habitat use is similar to that described in nontelemetry studies of European catfish in its native range, where the species is reported to inhabit lentic areas overgrown by bulrushes and under tree roots (Abdullayev et al. 1976). During late afternoon, swimming intensity increases to a night-time peak of activity, which is characterised by intermittent periods of high mobility and complete inactivity, either inside or outside the normal resting places. This early nocturnal peak in mobility appears to be motivated by hunger stimulus. Catfish have been shown to follow the paths of their prey (Pohlmann et al. 2001), most likely by detecting chemical (olfaction or sense of taste) or hydrodynamic cues (lateral line). Because European catfish demonstrate high site fidelity, occupying the same area throughout the year for feeding and for reproduction, this suggests some form of territoriality. Further data are needed to assess the seasonal and spatial variation in movement patterns and habitat use of catfish and to understand the ecological impact on native species.

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