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Data loggers to monitor activity in wild freshwater turtles

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A data logger originally developed for the study of homing routes in birds was adapted for monitoring the activity patterns of the European pond turtle *Emys orbicularis* and tested on wild specimens from a Central Italian population. The set of sensors included a compass, water switches, an activity sensor and a thermocouple. The compass allowed us to record the orientation of the turtle's body axis, but also provided information on the temporal pattern of activity, thus adding to the information from the activity sensor. The water switches allowed us to distinguish between immersion and complete or partial emersion, while the thermocouple furnished data on surface temperature. The system provided new detailed information on the behaviour of wild *E. orbicularis*, in particular the daily patterns of activity, including basking, and overwintering habits.

KEY WORDS: activity patterns, basking, data logger, freshwater turtles, *Emys*.

INTRODUCTION

The family Emydidae includes many species of turtles differently adapted to a range of habitats, from aquatic to terrestrial (ERNST & BARBOUR 1989). Interest in the evolution and biology of this family, and the increasing concern for the conservation of wild populations, has motivated many studies on the spatio-temporal

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organisation of their behaviour and their social organisation (GIBBONS 1970; KAUFMANN 1992, 1995; KENNETH DODD et al. 1994; LINDEMAN 1999; ROVERO et al. 1999).

Traditionally, field methods for the study of the spatial and temporal patterns of activity and the social interactions of these turtles included individual marking and resighting (GIBBONS 1970), thread-trailing techniques (BREDER 1927, STRANG 1983) and radiotracking (e.g. ROWE & MOLL 1991, BUHLMANN 1995). However, these methods provide only partial, often discontinuous, information and generally involve some interference with normal behaviours. The limitations of the traditional methods are even more severe in aquatic species, on account of their low detectability in water.

A different approach to the behavioural study of free-ranging animals is based on the use of animal-borne data loggers to store information on different aspects of their activity and on the surrounding micro-environmental conditions (e.g. SATO et al. 1998). In the case of freshwater turtles, this technique can provide detailed short-term information on such aspects as swimming activity, submerged/emerged status and basking behaviour, but it can also be useful for the long-term study of environmental determinants of activity patterns.

For this purpose, a data logger originally developed for the study of homing routes in birds (BRAMANTI et al. 1988) was adapted for monitoring the activity patterns of the European pond turtle *Emys orbicularis* and tested on wild specimens from a Central Italian population. This species is one of the most strictly aquatic among the Emydidae, mainly inhabiting in Italy lowland ponds and streams (LANZA 1983). *E. orbicularis* spends most of its time in the water, from which it emerges only on three occasions: on a daily basis for basking, in late spring for nesting and during summer for overland movements related to pond drought (LEBBORONI & CHELAZZI 1991, ROVERO & CHELAZZI 1996). Behavioural investigations of this species in the natural habitat are particularly important in relation to its conservation, since it is disappearing from several areas once inhabited by natural populations.

MATERIALS AND METHODS

The data loggers

The instruments used for *E. orbicularis* were basically similar to those designed for the study of the spatial habits of various species of birds (DALL'ANTONIA et al. 1993, 1995; BENVENUTI et al. 1998). Each data logger included a microcontroller, a set of sensors, solid state memory and a battery. The microcontroller, memory and battery were enclosed in a waterproof container glued dorsally on the turtle's carapace, while the sensors were placed on the turtle's shell. The microcontroller (MC68HC705B6) included an 8 bit A/D converter and was programmed to acquire data from the different sensors at set intervals, depending on the monitoring protocol. The duration of recording is limited by the capacity of the memory (128 Kbytes) and thus depends on the sampling frequency and the number of sensors deployed. Data stored in the memory can be downloaded to a computer and analysed with original software (A. RIBOLINI unpublished).

The set of sensors used for *E. orbicularis* included a compass, one or two water switches, an activity sensor and a thermocouple. The compass consisted of a traditional compass equipped with a transducer to convert the angular values into electrical resistance values (see BRAMANTI et al. 1988, DALL'ANTONIA et al. 1993). It allowed us to measure the angle between the horizontal component of the earth's magnetic field and the instrument's main axis (resolution ~ 2°). Since the device was mounted axially on the turtle's carapace, it provided instanta-

neous data on the direction of the body axis; however, the directional variations between successive readings, due to the turtle's movements, also provided information about the temporal pattern of activity. The water switch (ws) consisted of an electric bridge external to the instrument package: two conducting wires glued to the turtle's carapace formed a circuit which was open during emersion (dry carapace) but closed when the animal was in the water. One or two wss were connected to the data logger: when there were two, the first wss was placed on the top of the turtle's carapace and the second on the lateral margin. This allowed us to distinguish between complete emersion (both wss in the off status) and the periods when the turtle was totally submerged (both wss in the on state) or partially submerged (top ws off, lateral ws on). The activity sensor consisted of a microphonic capsule containing a small lead sphere (diameter 1 mm), which sent an on/off signal to the data logger when the turtle was moving. The thermocouple was based on a thermistor (1 k) with 0.5 °C resolution.

Two different versions of the logger were tested on *E. orbicularis*, each with a different set of sensors. Type 1 was equipped with a compass and two wss positioned at different levels on the carapace. The time between successive recordings was 30 sec for the compass and 20 sec for the wss. This sampling schedule permitted data recording for 18.2 days. The type 1 logger, including the batteries and the container, weighed (in air) 33 g and its external dimensions (length, width, height) were 85, 25, 18 mm, respectively. The type 2 logger was equipped with one ws, the activity sensor and a thermocouple. Signals from the ws and activity sensor were recorded every 192 sec and those from the thermocouple every 576 sec, allowing recording for over 5 months. The type 2 instrument weighed 19 g and its external dimensions (length, width, height) were 62, 24, 15 mm, respectively.

Study area and tests

The population selected for the field tests inhabits a group of ponds in a hilly protected area in central Italy (Riserva Naturale Monte Rufeno, North Latium). Adult turtles use both permanent and temporary ponds throughout the year (Lebboroni & Chelazzi 1999), while overland activity is performed in June by females moving towards nesting areas in bushy clearings (Rovero & Chelazzi 1996). Turtles (total carapace length > 13 cm) were captured and individually marked with a numbered plastic tag on each side of the carapace, allowing resighting from a distance. The data loggers were glued dorsally on the turtle's carapace, with the long axis parallel to the animal's main body axis; the use of a two-component glue (Sintolit, Bandini) allowed easy removal of the device without injury to the animal. Various adult turtles equipped with type 1 data loggers were monitored in the post-reproductive period (late June-July 1997), while a second group, bearing type 2 data loggers, was monitored during the cold season (November 1997-April 1998). In the same periods, several visual observations of the logger-equipped turtles were conducted to provide direct information on their behaviour.

RESULTS

Direct observation of *E. orbicularis* can hardly provide detailed information on the daily pattern of activity, and its seasonal variation, since the turtles can move or rest while submerged or in dense vegetation. Radiotransmitters, even when equipped with activity sensors, are not suitable for the detection of discontinuous movements. In contrast, a detailed reconstruction of activity can be obtained by means of data loggers equipped with an activity sensor or, in particular, with a compass. In the latter case, one can precisely assess the activity by inferring the movements from variations of the body axis direction, computed as the hourly fraction of non-coincident pairs of frequently sampled bearings (120 times per hour in the present tests). Some examples of daily activity patterns obtained by this method (type 1

data logger) for two females monitored in late June-July are shown in Fig. 1A-B. The most common pattern is bimodal, with one period of activity in the morning and another in the afternoon, separated by a midday rest phase and nocturnal inactivity. However, on several occasions, intense nocturnal activity was recorded as well. This is not an artefact of the recording device as shown by the fact that there was nocturnal activity by different animals during the same night, probably related

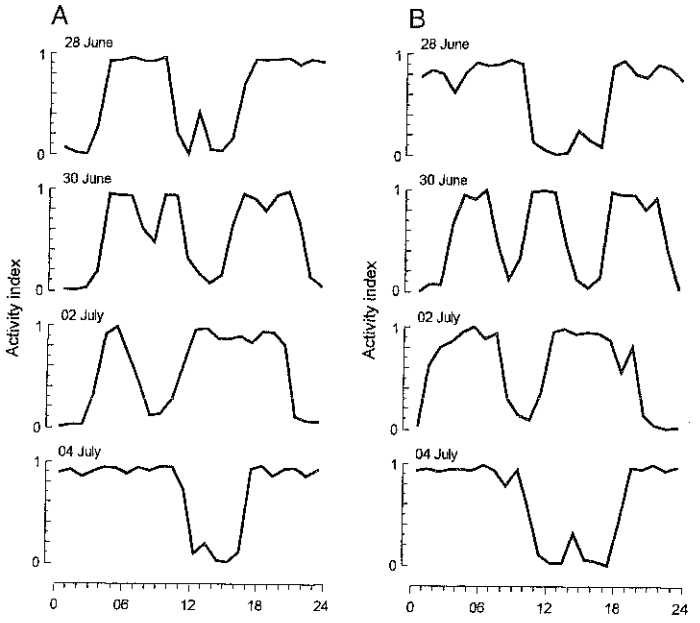

Fig. 1. — Daily activity patterns obtained from two females (A and B) during the post-reproductive period. Activity index (ordinate) was computed as the hourly fraction of non-coincident body axis directions, from data provided by the automatic compass connected to the data logger (type 1).

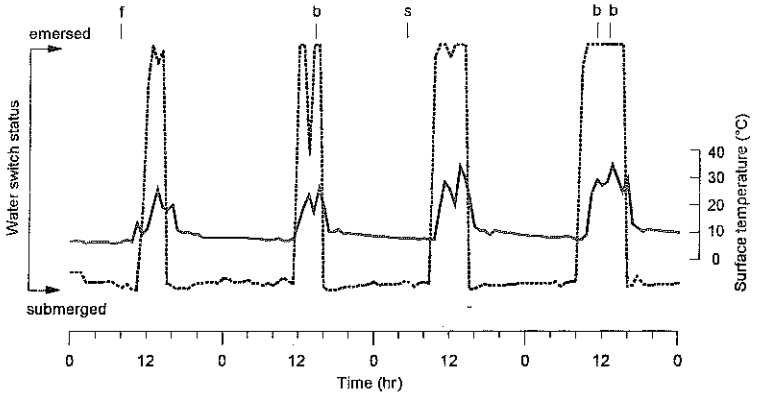

Fig. 2. — Example of in-water/on-land time series obtained from the water switches (dotted line) and body surface temperature obtained from the thermocouple (solid line) connected to the data logger (type 2) mounted on a male (15-18 March 1998). The letters on top report behaviours of the turtle during visual observations: *f*, foraging; *s*, swimming; *b*, basking.

to high water temperature. Although nocturnal activity in *E. orbicularis* is known to occur during overland reproductive migrations (ROVERO & CHELAZZI 1996), movements within the pond during the night had not been recorded in this species by visual observations or radiotracking (LEBBORONI & CHELAZZI 1991).

Direct observation of basking behaviour is also not easy in this species, since it may occur in small clearings within dense vegetation and the turtles readily submerge when approached and/or disturbed. However, very detailed information on the daily basking schedule of individual turtles can be obtained from the data provided by the water switches and thermocouple connected to the data logger. Fig. 2A shows a 4-day time series of in-water/on-land status and surface temperature, downloaded from a type 2 logger mounted on a male. There is an obvious regular daily alternation of periods spent in the water and those spent on land, with clear transitions between the two conditions. Variations of surface temperature from 10-12 °C to 25-35 °C corresponded to the aquatic and terrestrial periods, respectively. Contemporaneous visual observations of the turtle confirmed that the overland periods coincided with basking.

The data from the water switches provided evidence of variations in the duration and temporal organisation of basking performed by the same individual on successive days (Fig. 3). Although in the period considered (end of June-July) basking was confined to the central part of the day, its duration varied in the same individual from < 1 to > 8 hr per day (within a total of about 16 hr of daylight) and long basking phases were interrupted by dips in the water.

Another limitation of field studies based on direct observation and radiotracking is the difficulty of monitoring several individuals for long periods, particularly during the cold season when *E. orbicularis* remains submerged in the pond, under roots or buried in the bottom mud. The long-term use of loggers (type 2) provided data on the cessation and resumption of activity during the cold season, as well as a record of the temperatures experienced by individual turtles (Fig. 4). Activity almost completely ceased in early November, when the surface temperature was steadily around 10 °C. A sudden recovery of activity was observed in February, in concomitance with a definite rise in the external temperature. Nonetheless, occasional activity, including short phases of emergence on land, also occurred in the

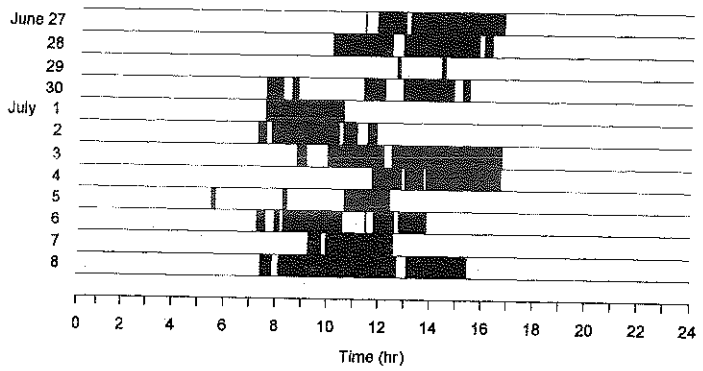

Fig. 3. — Daily duration of periods spent on land for basking, from data provided by water switches mounted on a continuously monitored female with a type 1 data logger (27 June-8 July 1997).

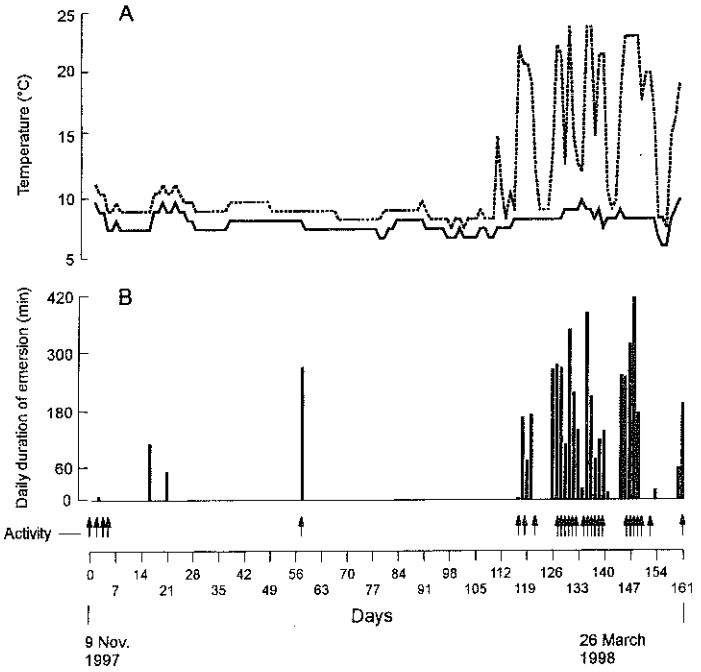

Fig. 4. — Example of the reconstruction of winter activity and surface temperature, based on data obtained from a type 2 data logger mounted on a female (9 November 1997-26 March 1998). A, Data from the thermocouple: average daily maximum (dotted line) and minimum (solid line) temperature. B, Data from the water switches: average daily time spent on land (bars). Bottom arrows indicate days with total activity lasting more than 60 min (data from the microphonic capsule).

middle of winter. This confirmed the absence of true hibernation in *E. orbicularis* (LEBBORONI & CHELAZZI 1991) and the capacity for short-term reactivation following temporary increases of the ambient temperature.

DISCUSSION

Although the present data are preliminary and mostly related to tests of the reliability of the data logger, the information about nocturnal activity, intra-individual variability of basking behaviour and overwintering is definitely original with respect to the information obtained from radiotracking and direct observation of wild *E. orbicularis*. Although at a prototype stage, the apparatus proved to be sufficiently reliable and no major faults of the electronic components were observed during the tests, even in the long-term trials. The major advantage of this method with respect to direct observation and radiotracking is the concomitant

recording of behavioural and physical information, particularly the temperature. This is crucial for the study of the environmental determinants of individual behaviour. Moreover, the compass-equipped data logger (type 1) can allow the reconstruction of postures maintained during basking. A possible disturbance of the normal behaviour — also a problem with the application of transmitters for radio-tracking — might be caused by the weight of the device and its size. The problem of weight, and the consequent interference with normal swimming, was resolved by setting the buoyancy of the device to a neutral level; a ballast and/or floating mass was included in the logger package. A major problem is the alteration of the turtle's profile (particularly with the larger type 1 recorder); this can make swimming within submerged vegetation difficult and can also interfere with normal mating (mounting of females by males) even when the package is made as streamlined as possible. In the present tests, this problem limited the application of the data logger to non-reproductive periods, particularly in females. However, this interference could be reduced in larger species by mounting the equipment on the postero-lateral portion of the carapace.

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