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The Thermochron: A Truly Miniature and Inexpensive Temperature-Logger

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Miniature temperature-loggers (e.g., HOBO, Watchdog) have become valuable tools for herpetologists, and biologists in general. Being lightweight and self-contained, miniature temperature-loggers make it easy to simultaneously record temperatures at separate sites. Certain models are waterproof and can be attached to or implanted in large organisms, providing detailed profiles of body temperature that are otherwise difficult to obtain (e.g., Butler and Woakes 2001; Litzgus et al. 1999). In some microhabitats, temperature-loggers can even be used to estimate operative environmental temperatures (Vitt and Sartorius 1999). Miniature temperature-loggers are accurate and reliable under field conditions and are generally easier to program and deploy than larger, more expensive systems (Mueller and Rakestraw 1995). Although the use of miniature temperature-loggers has increased rapidly in the last decade, reductions in the size and cost of these devices have not kept pace.

Recently, a novel temperature-logging device has emerged that could enhance studies of behavioral and physiological ecology. The Thermochron iButton, manufactured by Dallas Semiconductors (Dallas, Texas, USA), is a remarkably small and light temperature-logger than meets or exceeds the specifications of temperature-loggers that are commonly used by biologists. Each Thermochron is a mere 5.9 mm thick and 17.4 mm in diameter, and has a mass of 3.1 g. The outer casing is stainless steel, permitting the unit to function normally during complete submersion in water. The Thermochron is powered by an non-replaceable, internal battery that provides approximately 10 years of service (or one million readings). The manufacturer specifies a resolution of 0.5°C and an accuracy of ± 1°C within the operating range of –20° to 85°C. The Thermochron was developed primarily as an inexpensive tool for commercial shipping companies to document that perishable goods have been stored and transported within an acceptable range of temperatures. Current pricing is approximately US $14 per unit, and discounts are available for purchases of 25 or more units. Thus, the Thermochron is a high-performance temperature-logger that is approximately 10% of the cost of similar products.

Thermochrons are launched (or “missioned”) using free software downloaded from the manufacturer’s website and hardware included in a startup kit (US $25). The interface between a computer (Macintosh or PC) and a Thermochron is established with an iButton reader (Blue Dot Receptor, Model DS1402D-DR8), which attaches to a serial port. The software (32-Bit iButton-TMEX Runtime Environment) provides an intuitive interface that allows one to toggle among windows enabling one to mission a logger, display the status of the current mission, and report output from a mission in progress. A mission “wizard” provides an easy to follow, step-by-step process of starting a mission. Advanced features and ranges of settings are almost identical to those offered for competing brands of temperature-loggers (e.g., HOBO Temp loggers used with BoxCar Pro 4.5, Onset Computer Corporation). For example, the output can be obtained in the form of a text file or a histogram of temperatures, and each file is marked with a 48 bit serial number that identifies the logger generating the data. Each mission can record up to 2048 data points, at rates ranging from one point per min to one point per 255 min. The start of the mission can be delayed up to 45 days, so that the user has time to position the thermochron prior to the onset of data collection.

Thermochrons also possess several unique features. First, the thermochron can add temperatures to the histogram after the maximum number of time-stamped data points have been stored; therefore, the mean temperature and its variance can be obtained for durations that far exceed the duration of the mission. Second, thermochrons are equipped with an alarm feature that permits one to monitor the number and duration of deviations from minimum and maximum temperatures (set by the user). The alarm feature is extremely useful for applications such as monitoring the occurrence of lethal temperatures in nests or hibernacula. Finally, the thermochron features 512 bytes of memory that enables the user to create directories and store the results of a mission. The memory feature of the thermochron is based on EPROM technology, meaning that data can be accessed even after subsequent missions have been launched and completed.

We obtained 170 Thermochrons (Model DS 1921-F51) to evaluate their performance under laboratory and field conditions. A certified thermometer and a circulating water bath were used to assess the accuracy of Thermochrons over a biologically-relevant range of temperatures (5–50°C). The clock of each thermochron and a digital watch were synchronized to ensure that our temperature readings from the thermometer corresponded temporally to the temperature readings of the Thermochrons. One hundred thermochrons were placed in a porous bag and suspended in the water bath with the thermometer. Prior to each temperature recording, the temperature of the water bath was stabilized for ten minutes. On average, Thermochrons deviated 0.3° C from the actual temperature. The magnitude of deviation from actual temperature was fairly consistent across the range of biologically-relevant temperatures (Fig. 1).

To evaluate the effects of prolonged submersion on the performance of Thermochrons, we placed 10 loggers in a water bath at 32°C for a period of one week. Each day we recorded the temperature of the water using a certified thermometer and compared this to the temperatures recorded by the Thermochrons. The average deviation from actual temperature on d 7 (0.3 ± 0.1°C) was not significantly different from that measured on d 1 ($t = 1.24$, df = 9, $P > 0.05$). Therefore, prolonged submergence did not affect the operation or accuracy of thermochrons.

To assess the reliability of Thermochrons under field conditions, 60 thermochrons were used to monitor soil temperatures in the Pine Barrens of New Jersey. In June of 2001, thermochrons were buried 6 cm deep at random sites. After 75 days, the loggers were exhumed and data were transferred to a laptop computer. None of the loggers failed during the study, and the data agreed with soil temperatures recorded previously with HOBO data loggers at the

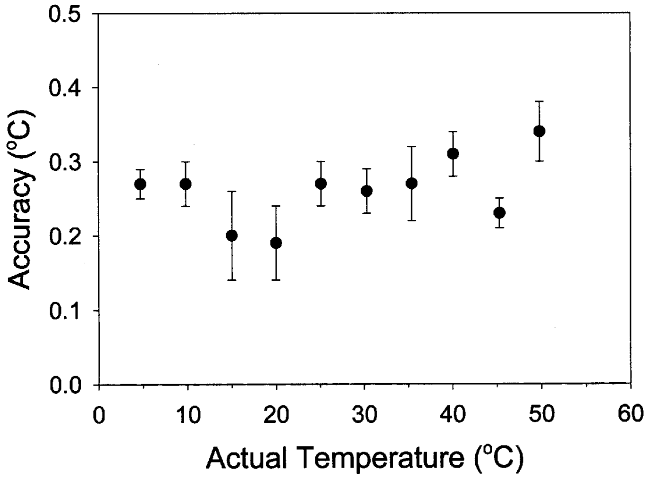

FIG. 1. Over the range of 5 to 50°C, the accuracy of the thermochron was always better than ± 0.5°C. Accuracy was estimated by calculating the absolute value of the difference between the temperature reported by a thermochron and the temperature measured with a certified thermometer. Error bars denote 95% confidence intervals.

same locality (Angilletta et al. 2000).

We found the iButton Thermochron to be an accurate and reliable device for monitoring temperatures in the laboratory and field. Because the Thermochron is much smaller than any other commercially available temperature-logger and can be purchased for a fraction of the cost, they will undoubtedly replace many existing loggers as the model of choice. Their diminutive size and stainless steel exterior enable direct implantation into small organisms (Wang and Adolph 1995), making it possible to monitor the body temperatures of species that could only be studied previously through difficult and time-consuming methods (e.g., cloacal thermometers, radiotelemetry). Their affordable price tag ensures that researchers with modest budgets can benefit from the advantages that Thermochrons provide. More importantly, researchers with ample budgets can ask questions that were logistically impossible to answer in the past. With a reasonable budget, one might afford to thermally "tag" a entire population of individuals. Similarly, environmental monitoring can be carried out at hundreds of random sites in addition to those sites of interest (e.g., nest sites), permitting powerful experimental designs. Based on our experience with the Thermochron, we anticipate that this technology will have a profound impact on the ways in which researchers study the thermal biology of organisms.

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