NOTE

MEASURING PREDATION WITH A NEW DESIGN OF SUBMERSIBLE CHRONOGRAPHIC TIMER

Riikka I Puntila, Charles W Martin, and John F Valentine

ABSTRACT

While predation has been widely acknowledged to have important, ecosystem-wide impacts, measuring the rate of this process has been difficult. Tethering is a popular technique used by ecologists to compare predation potential among different areas, although it has also been criticized for its limitations. Chronographic tethering devices eliminate some of these perceived limitations by removing the binary data used in statistical tests and artifacts from experimental duration. Here, we provide details for the construction of a new submersible chronographic tethering device. The new design allows deployment at greater depths (up to 8 m), minimizes the addition of “new” structure on the benthos due to the chronograph itself, and any consumed prey can easily be replaced and the timer reset without retrieval of the device. Furthermore, we present the results of a short field experiment demonstrating use of the timers. This experiment was designed to determine if differences in the survival of *Mithraculus sculptus* (Lamarck, 1818) crabs exist on fore and back reef environments in the Florida Keys. These results are then used to compare and contrast the results of chronographic tethering with traditional tethering experiments.

Predation is arguably one of the most important processes in the ocean, affecting community structure (Brooks and Dodson 1965, Paine 1966), recruitment success (Beets 1997), and transfer of energy among adjacent trophic levels (Valentine et al. 2008). Therefore, measuring predation rates in habitats of varying composition and structural complexity can be useful for a variety of reasons, including estimation of habitat nursery values (Costanza et al. 1997) and the cross-habitat energy transfer (Valentine et al. 2008).

Measuring processes such as predation in the ocean can be a complicated task. While mesocosm and laboratory studies allow the researcher to exert more control over environmental variables of interest in experiments, results can be ecologically unrealistic (Carpenter 1996, Kraufvelin 1999). Less powerful, indirect measurements of such processes (such as changes in relative abundances of predators and their prey combined with gut content analyses) can provide important qualitative insights into food web interactions, although they are not usually measurements of rate. Tethering experiments, on the other hand, directly measure rates of predation in the field (Heck and Thoman 1981, Heck and Wilson 1987, Lipcius et al. 1998, Valentine et al. 2008). The method, despite its drawbacks, mainly due to artifacts of intervention (Peterson and Black 1994, Kneib and Scheele 2000, Mills et al. 2008), can be a suitable approach for estimating predation potential when slow-moving animals, such as crabs, urchins, and snails, are used as prey (Aronson and Heck 1995, Aronson et al. 2001).
One of the concerns about using tethering to measure predation potential is that the resulting data are either binary or proportional in nature and are integrated over the entire experimental duration (Minello 1993, Haywood and Pendrey 1996, Peterson et al. 2001). Chronographic tethering devices can quantify such rates more accurately by recording the exact moment of predation. This is especially important in areas where consumption is intense and the typical 24-hr assessments are too long to detect true differences in predation potential (Peterson and Renaud 1989, Bolser and Hay 1996). In such cases, the analysis of a continuous variable, survival time (instead of mortality or survivorship), can increase the power of statistical comparisons made between or among habitats (Minello 1993, Haywood and Pendrey 1996). As such, survival time can estimate differences in predation pressure more accurately than the more traditional approach of relying on an integrated measure of tether survival during experiments of excessively long duration (Minello 1993).

A number of chronographic tethering device designs have been proposed over the years, all using an inexpensive digital watch to record the moment of predation (Minello 1993, Haywood and Pendrey 1996, Oliver et al. 2005). Minello (1993) introduced a simple, non-submersible design suitable for use in very shallow waters with small tidal ranges. Haywood and Pendrey (1996) later introduced a waterproof timer, which was triggered by movement of a magnetic switch at the moment of predation. However, the latter design involved complex assembly and operation, and required retrieval of the device from the field to record prey survival time. Other designs have included the use of a resin to reduce water inundation of the timer (Ha 1996, Danilowicz and Sale 1999). Here, we present an alternative submersible chronograph design with several key improvements and present the results of a field test on coral reefs in the Florida Keys.

**Methods**

**Design and Construction of the Chronographic Tethering Device.**—The technical schematic of this new device is shown in Figure 1. Components used in the construction of this device are widely available and were obtained from local hardware, electronics, and automotive accessory stores. The assembled device was attached vertically to a 0.5 m long PVC pipe (Fig. 2) and secured in place in the field with an iron re-enforcement bar, driven into the sediment. The device was located approximately 25 cm above the bottom (Fig. 2A), adding minimal artificial structure to the benthic environment.

Our chronographic tethering device was designed to be deployed at greater water depths than most of the earlier designs (but see Oliver et al. 2005). A waterproof housing, made from a clear 30 cm section of 5 cm diameter PVC pipe, was used to encase the timer. The housing was permanently sealed at one end with a glued PVC cap, while a threaded male PVC adapter was glued to the opposite end. Threads on this end were wrapped with Teflon tape and the inside of the cap was sealed with a silicone greased rubber gasket (approximately 13 mm thick piece of rubber cut to fit tightly inside the cap). The cap was firmly secured using adjustable pliers. The threaded cap allows the timer to remain accessible for battery replacement if needed, although in our study all batteries lasted throughout the duration of the trial period (3 wks).

The timer itself was an inexpensive digital watch (available from automobile accessory stores). The back cover of the watch was removed and copper wires were soldered to the battery holder terminal, to an external battery case, and then to a “normally closed” magnetic switch (Fig. 1). The magnetic switch was attached to the inside wall of the PVC housing using poster putty. A magnet, used to activate the timer, was placed inside a 3 cc plastic syringe.
Figure 1. Schematic of chronographic tethering device indicating the various components used to measure time of predation.

The syringe was secured to the outside of the housing using cable ties (Fig. 2B). Silicone rubber bands were then wrapped around the magnet to increase drag forces inside the syringe. The number of bands added around the magnet modifies the mechanism’s sensitivity and prevents tethered prey from triggering the timer. We set the tension needed to activate timers at $26 \pm 2.26$ g (95 CI), which was measured using a Lyman (R) trigger pull gauge (Martin and Valentine 2012). The selected tension was based on a preliminary trial, where we found 26 g to be the maximum tension our experimental prey could exert on the timer. Therefore, a minimal amount of “external force” (the predator) would result in the activation of the timer.

A 25-cm length of monofilament line (20-lb test) was then tied to the magnet and a fishing swivel snap was attached to the other end of the line. The snap allowed quick in situ replacement of the tethered prey.

The timer was triggered when enough external force (i.e., a predator consuming the tethered animal) was exerted on the monofilament line to move the magnet within the syringe. Once contact between the magnet and switch was broken, the unit was activated and digital watch began to record time. Since the watch was visible from outside the housing (Fig. 2C), time following attack could be recorded without removing the cap. The exact time of predation was calculated as: current time − time displayed on watch = time of predation event. The timer was reset by moving the magnet to its original position (up) in the syringe, by thus re-establishing contact with the “normally closed” switch. The watch resets automatically at 12:00 within one minute.

Field Test of Chronographic Tethering Device.—A field pilot study of the timer was conducted at locations of varying depths to ensure reliable operation. Twelve devices were constructed and 10 of them were used in the field test, five on the fore reefs (65 m depth) and five on the back reefs (2.5 m depth) on two reefs in the Florida Keys National Marine Sanctuary, Dry Rocks and Grecian Rocks. A total of 30 green clinging crabs [Mithraculus sculptus (Lamarck, 1818), carapace width $14.29 \pm 0.55$ mm (95 CI)] were tethered as prey and used to test the efficacy of the device from August 30 to September 1, 2009. Devices were checked periodically, approximately every 12 hrs. Tethers were replaced and devices reset each time.
A single crab was tethered to each device by looping one end of monofilament line tightly around the crab’s carapace and securing it in place with a slipknot and cyanoacrylate cement (Superglue™; Valentine et al. 2008). The remaining end was looped and attached to the snap swivel on the device.

We used a two-sample, unpaired \( t \)-test to compare the survival time (minutes) among the habitats (back reef and fore reef). Assumptions of the tests were checked and data were square-root transformed to comply with assumptions. We also compared these results to analyses conducted following the traditional survivorship [proportion of crabs surviving per day (arc sin square-root transformed)] and then compared these data using a two-sample, unpaired \( t \)-test. All tests were performed using XLSTAT 2009 and differences considered significant at \( P \leq 0.05 \).

Results

During the pilot study, we found a few initial problems including leaking caps and non-triggered timers. After adding additional Teflon tape to cap threads and re-adjusting tension between the magnet and syringe on the housing, devices performed without malfunction at depths down to 8 m.

Significant differences in crab survival time between the two reef locations were detected \([t (12) = 3.691, P = 0.003]\). Crab survival on the fore reefs (approximately 1000 min) was an order of magnitude greater than on the back reefs (approximately 100 min, Fig. 3A). In contrast, when survival was analyzed as a daily proportion of tethers lost (the traditional 24 hr metric used in tethering studies), no significant difference was detected \([t (4) = 0.725, P = 0.509]\). Crab survival ranged from approximately 45% on back reef sites to around 75% on fore reef sites (Fig. 3B).
Tethering experiments have been used widely to document differences in the intensity of predation among a diversity of habitats (Aronson and Heck 1995, Heck and Thoman 1981, Valentine et al. 2008, among others). In some cases, differences were dramatic while in others they were not. It is unclear if, in cases where there was a lack of differences, a Type II error (sensu Zar 1999) was made due to a prolonged experimental duration. For this reason alone, the use of chronographic tethering devices can offer experimenters an improvement over historical approaches to tethering studies (Peterson et al. 2001, Baker and Sheaves 2007). Experimenters using the conventional approach to tethering have attempted to overcome this problem by checking tethers several times over the experimental period (Aronson 1987, Barbeau and Scheibling 1994), although this is often impractical in many environments (Minello 1993), and it remains unclear how the additional diver presence may affect estimates of predation (i.e., by scaring away/attracting potential predators to/from the tethered prey; Haywood and Pendrey 1996).

Tethering experiments have been criticized for artifacts of intervention, especially when comparing predation rates among different habitats (Peterson and Black 1994). They are, however, considered a suitable approach in measuring differences in predation intensity among similar sites, such as the coral reef environment used in our study (Aronson and Heck 1995, Aronson et al. 2001, Haywood et al. 2003). Tethering experiments have also been criticized in that they do not reflect natural predation intensity and overestimate consumption by providing predators with easily captured prey (Barbeau and Scheibling 1994, Kneib and Scheele 2000, Mills et al. 2008). This may be especially true when prey are highly mobile and rely on escape as a means of predator avoidance (i.e., shrimp and lobsters; Kneib and Scheele 2000, Mills et al. 2008). However, when prey items are slow moving and rely on hiding, such as the green clinging crabs used in our study, tethering experiments provide reasonable estimates of predation intensity among sites (Aronson et al. 2001).

While the use of tethering devices reduces or eliminates some criticisms of tethering, some noteworthy biases remain. For example, some predators (i.e., ambush predators) may be able to consume the prey without activating the timer (Haywood and Pendrey 1996). We did not notice this in our trials; however, in an attempt to
document this we focused an underwater video camera on a subset of tethers to identify predators and their foraging on tethered prey. In all cases, the timer was activated when the tethers were consumed. We suggest that alternate methods such as this could be useful supplementary information for experimenters. Moreover, knowledge of the foraging strategies of typical predators in the study area may provide useful in predicting when these biases may arise. Other problems, such as environmental conditions (strong currents resulting in timer activation) and prey behavior (such as burying) may also occur, although we did not encounter these problems in our study.

The results of our field pilot study illustrate the benefits and utility of using a chronographic tethering device. This example demonstrates how important differences in predation potential can be underestimated if rates of predation are high and the experimental duration is too long. We found significant differences in survival time of crabs at different reef locations; however, when the same data were analyzed in a manner consistent with traditional tethering studies (i.e., over a 24-hr period), significant differences were not detected.

Our design of a chronographic tethering device represents a marked improvement over the previous designs in that it: (1) is designed to be completely waterproof and can be deployed at greater depths than earlier devices (but see Oliver et al. 2005; to date, we have successfully deployed the device to depths of 8 m although we suspect greater depths are possible; Puntila and Valentine, University of South Alabama, unpubl data), (2) contains fewer parts, (3) minimizes bias due to introducing additional structure to the benthos since the device is well above the sediment-water interface, (4) contains an adjustable trigger mechanism allowing unique tension settings for prey with differing escape behaviors, and most importantly, (5) can be reset while underwater.

Our tests indicated that this design was effective in conducting replicated in situ measures of predation potential. The potential errors that can be encountered with this device are easy to troubleshoot. Over the course of our experiments, we found that properly constructed devices are highly waterproof and generated few errors, rendering this a useful design suitable for use in ecological studies of marine predation.

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ADDRESSES: (RP, CM, JV) 1: Department of Marine Sciences; University of South Alabama;
Mobile, Alabama 36688. 2: Dauphin Island Sea Lab, Dauphin Island, Alabama 36528.
PRESENT ADDRESS: (RP) Department of Aquatic Sciences, University of Helsinki; P.O. Box
56 00041 University of Helsinki. CORRESPONDING AUTHOR: (RP) Email: <riikka.puntila@
helsinki.fi>.