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# Telemetry as a tool for improving estimates of marine turtle abundance

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ABSTRACT

Accurate estimates of abundance are fundamental to the conservation of threatened species, but are often difficult to obtain directly. Population size assessments of marine turtles are often based on counts of nests, which are then related to abundance using the mean number of clutches laid by individuals within a season. Due to low re-encounter probabilities, clutch frequency has proven difficult to estimate reliably, particularly for large populations that make a major contribution to global stock assessments. We use a combination of VHF radio-telemetry and Argos-linked Fastloc™ GPS devices to improve clutch frequency estimates for one of the world's largest green turtle rookeries at Ascension Island. Females fitted with VHF tags at the start of the season ($n = 40$) were re-encountered with a probability of 85% and laid a minimum average of 5.8 clutches. Three of these turtles were fitted with VHF and GPS devices and using the data collected by the latter, were found to lay an average of 6.3 clutches. GPS-telemetry detected emergences observed using radio-telemetry, and confirmed that some radio-tagged turtles laid again after their last observed emergence. Correcting for missed nesting events yielded a mean clutch frequency of 6.3, more than doubling the previous estimate of 3.0 for this population. Applying this revised assessment to annual nest counts reduces the estimated size of this population by 52%. Conventional tagging approaches may considerably underestimate annual fecundity of turtles, resulting in inflated population size estimates. We call for urgent reassessment of baseline abundance values for regionally important populations.



## 1. Introduction

Reliable estimates of population size are essential in many biological fields and particularly for the conservation and management of threatened species (e.g. Flather et al., 2011; Hare et al., 2011). To be able to monitor and predict population trends it is first necessary to establish a reliable baseline of distribution and abundance. Unfortunately, however, for the vast majority of species it is not possible to directly census the number of individuals in a population, placing reliance on sampling-based approaches (e.g. distance transects and capture-mark-recapture) or indirect indices of abundance (Williams et al., 2002). Such indices can include camera-trapping (e.g. Garrote et al., 2011), scat sampling (e.g. Kindberg et al., 2011) or track counts (e.g. Balme et al., 2010). Although these methods are useful for assessing trends, for many applications absolute estimates of population size are needed (e.g. when setting harvesting limits and assessing extinction risk). Indirect approaches also assume that the scaling factors that relate them to absolute population size are well defined and remain constant over time, which may not be the case. Evaluations of the reliability of indirect survey methods with cross-validation studies are therefore necessary as technologies advance in order that more accurate population size estimates can be derived.

Due to the inherent difficulties of quantifying wide-ranging, marine species, global assessments of marine turtle abundance are generally based on studies of the annual nesting activity and egg production of adult females at nesting aggregations (Gerrodette and Taylor, 1999; Witt et al., 2009; National Research Council, 2010). Marine turtles are of global conservation concern following centuries of overexploitation that has seen many stocks reduced to a fraction of their former size (e.g. McClenachan et al., 2006; Tomillo et al., 2008; Dethmers and Baxter, 2011). Incidental capture in fisheries, habitat loss and marine pollution also continue to threaten the survival of many stocks (Seminoff, 2004). However, while some marine turtle populations are in rapid decline, others are stabilizing or increasing following sustained conservation

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efforts (reviewed in Wallace et al., 2011). Accurate estimates of abundance are therefore necessary to inform relevant conservation action. For most populations, such estimates are obtained indirectly from annual counts of the number of tracks and/or successful nests at nesting beaches (e.g. Gerrodette and Taylor, 1999; Bjorndal et al., 1999; Broderick et al., 2006; Witt et al., 2009; Witherington et al., 2009). Since all species of marine turtles nest more than once within a nesting season (Miller, 1997), this value must then be divided by the mean number of clutches laid per female per season ('clutch frequency') to estimate the annual number of nesters (Gerodette and Taylor, 1999; National Research Council, 2010). Small changes in average clutch frequency therefore have large effects on estimated population size, making it one of the most important demographic parameters in marine turtle biology and conservation (National Research Council, 2010). However, for most populations, it is also one of the least well defined.

For the vast majority of marine turtle populations, clutch frequency has been estimated using a standard mark-recapture design, whereby nesting females are tagged with uniquely numbered flipper tags or PIT (Personal Integrated Transponder) tags and relocated during nocturnal beach patrols as they come ashore to lay additional clutches (e.g. Frazer and Richardson, 1985; Johnson and Ehrhart, 1996; Broderick et al., 2002; Tomás et al., 2010). However, as this method relies on directly observing individual females, there is a tendency to underestimate the average clutch frequency value and hence overestimate population size (Schroeder et al., 2003; Rivalan et al., 2006; Briane et al., 2007; Tucker, 2010). Inaccuracies in the observed clutch frequency (OCF) arise when tagged females are either missed due to incomplete survey coverage or move to different beaches for some or all of their subsequent clutches. The measure of estimated clutch frequency (ECF) goes some way to remedying this by using the length of the intervals between observed clutches to infer whether any nesting events were missed (Frazer and Richardson, 1985; Johnson and Ehrhart, 1996). Since the time taken to produce a clutch of eggs (the 'inter-clutch interval') is physiologically constrained by water temperature (Weber et al., 2011), dividing the time elapsed between observed clutches by the known inter-clutch interval yields a reasonable estimate of the number of missed nesting events. However, inaccuracies are still introduced when a turtle is not observed for her first and/or last clutch(es), or when she is observed only once on the study beach (Rivalan et al., 2006; Girondot et al., 2007). Due to difficulties in re-identification and often more temporally extensive breeding seasons, these errors are likely to be exacerbated in large, high-density populations which make the greatest contributions to global stock assessments.

In response to these limitations, several recent studies have explored the use of alternative technologies and statistical models to improve clutch frequency estimates, and have found significant discrepancies with ECF values obtained from conventional tag-recapture (Rivalan et al., 2006; Rees et al., 2008; Tucker, 2010; Blanco et al., 2011). For example, Tucker (2010) deployed satellite-telemetry tags on loggerhead turtles (*Caretta caretta*) nesting in Florida and derived an average clutch frequency of 5.4 nests per female in comparison to the 2.2 nests that was previously detected by monitoring patrols. Similarly, using ultrasonography of females' ovaries to supplement beach patrols, Blanco et al. (2011) estimated a clutch frequency of 5.1 ± 1.3 (mean ± SD) for green turtles (*Chelonia mydas*) in Costa Rica, compared to the value of 3.7 ± 1.8 obtained from beach patrols alone. As an alternative approach, Rivalan et al. (2006) used capture-mark-recapture models to extract more reliable estimates of clutch frequency from conventional tagging records of leatherback turtles in French Guiana, and concluded that true clutch frequency is considerably higher than the ECF for this population. If replicated across all regionally important populations, these findings have significant implications for marine turtle stock assessments. Unfortunately, however, the high cost of technologies such as satellite-telemetry limits their widespread use and restricts sample sizes, calling for cheaper and more accessible alternatives for accurately assessing clutch frequency (National Research Council, 2010). Doubts have also been expressed as to whether the spatial resolution of the Argos system that is most commonly used in satellite tracking of marine turtles is sufficient to allow detection of individual nesting events (National Research Council, 2010).

In this study we trial a combination of low-cost VHF transmitters and recently-developed, high acquisition, Argos-linked Fastloc™ GPS tags as a method for assessing clutch frequency, using the globally important green turtle nesting population at Ascension Island as a test case (Broderick et al., 2006). This population has been the subject of a long-term monitoring programme spanning more than 30 years (Mortimer and Carr, 1987; Broderick et al., 2006), and is showing promising signs of recovery following a period of heavy exploitation during the 19th and early 20th centuries (Broderick et al., 2006). It is also one of 34 index sites used by the IUCN to assess the global status of the green turtle (Seminoff, 2004), but the high density of nesting makes assessment of clutch frequency by conventional mark-recapture difficult. Indeed, the current estimate of 3 clutches per female based on flipper-tagging is likely to be an underestimate (as acknowledged by the authors; Mortimer and Carr, 1987), suggesting that the Ascension Island green turtle colony may be considerably smaller than currently thought.

## 2. Materials and methods

### *2.1. Study site and tagging methodology*

Ascension Island is an isolated volcanic peak on the mid-Atlantic ridge (14°20′W, 7°55′S), which, between December and June, hosts the second largest nesting aggregation of green turtles in the Atlantic Ocean (Broderick et al., 2006). Between 29th December 2011 and 12th January 2012 we deployed 40 VHF transmitters (Biotrack, Dorset, UK) and 3 Fastloc™ Argos-linked GPS tags (Wildlife Computers, Redmond, WA, USA) onto a randomly selected sample of females nesting on Long Beach ,which currently supports the highest density and numbers of nesting turtles on the island (Godley et al., 2001).

To allow cross-validation between methods, all turtles carrying a GPS tag were also fitted with a VHF transmitter. Telemetry devices were attached to the carapace using a two-part marine epoxy resin (Powers Fasteners, Brewster, NY, USA), and a metal flipper tag was applied to each female as a secondary means of identification. To reduce the chance of including an individual that had nested previously, the few females that were observed nesting on Long Beach for the 3 weeks prior to the start of the study were also fitted with metal flipper tags. This measure combined with the fact that <1% of nesting activity on Long Beach occurred prior to 29th December during the 2011–2012 nesting season (authors' unpublished data) gives a very high probability that VHF and Argos-linked GPS devices were fitted to females while they were depositing their first clutch. The mean curved carapace length (CCL) of study females was not significantly different than the mean of a random sample of $n = 40$ females measured during the peak of nesting between 20th February and 28th March ($t$-test, $t = 0.29$, $p = 0.77$; mean CCL ± SE, study females: 110.9 ± 1.0 cm; peak season females: 111.3 ± 0.8 cm), indicating that our clutch frequency estimates are unlikely to have been biased by seasonal variation in female size.

### *2.2. Radio-telemetry*

Nightly patrols of Long Beach to detect returning VHF-tagged females were carried out from 21:00 to 03:00 using an R1000