Biological Conservation 199 (2016) 172–184

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/bioc

Satellite tracking in sea turtles: How do we find our way to the conservation dividends?

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ARTICLE INFO

Article history:
Received 16 November 2015
Received in revised form 3 April 2016
Accepted 28 April 2016
Available online xxxx

Keywords:
Review
Telemetry
Impact
Questionnaires
Marine vertebrates
Collaboration
Communication

ABSTRACT

As species of conservation concern, sea turtles have historically been difficult to study because of their elusive nature and extensive ranges, but improvements in telemetry have facilitated insights into life histories and behaviours which can potentially inform conservation policies. To date, there have been few assessments of the impact of satellite tracking data on species conservation, and it is difficult to clearly gauge whether the dividends justify the costs. Through an extensive review of the literature (369 papers, 1982–2014) and a questionnaire-based survey of 171 sea turtle tracking researchers, we evaluate the conservation dividends gained thus far from tracking and highlight conservation successes. We discuss who is tracking and where, where biases in effort exist, and evaluate the impact of tracking data on conservation. Conservation issues are increasingly being considered. Where research recommends policy change, the quality of advice varies and the level of uptake is still uncertain, with few clearly described examples of tracking-data actually influencing policy. The means to increase the conservation impact are discussed, including: disseminating findings more widely; communicating and collaborating with colleagues and stakeholders for more effective data sharing; community liaison, and endeavouring to close the gaps between researchers and conservation practitioners.

1. Introduction

Marine megavertebrates have historically been difficult to study due to their extensive ranges and many such species, including sea turtles, face numerous threats (e.g. bycatch: Lewison et al., 2014) and consequently are of profound conservation concern. Despite debate over their conservation status (Godfrey and Godley, 2008; Seminoff and Shanker, 2008), sea turtles ('turtles' hereafter) are considered important as potential ecosystem engineers, keystone, or flagship species, instrumental in raising awareness about wider marine ecosystems and their conservation (Coleman and Williams, 2002; Eckert and Hemphill, 2005; Moran and Bjorndal, 2006; Butler et al., 2012). Their management and protection is therefore important and depends on an accurate understanding of both their distribution and how they interact with their environment, including anthropogenic stressors.

Tracking of marine turtles by satellite has evolved significantly since the first published study, in which researchers tethered turtles to floating buoys (Stoneburner, 1982). Subsequent developments in tracking have enabled researchers to gain valuable insights into turtle ecology and behaviour, particularly via satellite tracking (including Argos-linked GPS units) (Rees et al., 2010; Marcovaldi et al., 2010; Arendt et al., 2011; Bailey et al., 2012a; Casale et al., 2012; Gaos et al., 2012a; Witt et al., 2010). Tracking units are now typically quite small , ranging from ca. 30–490 g, with the most commonly used tags approximately 130 g in air (pers comm Kevin Lay, Wildlife Computers). Reduced size has enabled this method to overcome some of the barriers to tracking multiple life stages of these migratory species such as wide ranging dispersal and occupation of remote areas. This has great potential to inform conservation science. It is now possible to track multiple species in near real-time over great distances (Frydman and Gales, 2007; Block et al., 2011).

Consequently, satellite tracking data can help provide the information necessary to inform management policies and mitigate against anthropogenic threats (Hart et al., 2012; Maxwell et al., 2013). It has been suggested, however, that researchers sometimes focus on the results rather than the implications (Hammerschlag et al., 2011) and data might not be used to their full potential. To date, there are few assessments of the conservation impact of satellite tracking (e.g. Godley et al., 2008) and no studies assess the overall impacts on policy. Without evaluation it is difficult to measure the tangible benefits of tracking, or determine if the expenditure and potential animal welfare issues are justified (McMahon et al., 2011; Jones et al., 2013; Hammerschlag et al., 2014).

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http://dx.doi.org/10.1016/j.biocon.2016.04.032

Using data from an extensive literature review and a questionnaire-based survey of researchers tracking turtles, we sought to investigate: *To what extent are data from satellite tracked turtles ('tracking data' hereafter) influencing relevant conservation policies and practices to protect turtles and/or their habitats?* Answering this is imperative to discern the benefits to conservation and help counter any criticisms that workers are guilty of a *'tagging reflex'* (when tags are applied without clear objectives or strong experimental design; Mrosovsky, 1983).

2. Methods

2.1. Reviewing the literature

We searched Web of Science and Google Scholar using the terms 'marine turtle' or 'sea turtle', plus either 'telemetry' or 'satellite tracking'. All Web of Science results and the first 200 results from each Google Scholar search were included for all papers published until end 2014 (final searches carried out 24 Sept. 2015). The archive of the *Marine Turtle Newsletter* (vol 1–139) was also searched using the term 'satellite' to check for any further relevant papers. We removed duplicates, false positives and non-peer reviewed 'grey' literature based on title and abstract, or main text if relevance was unclear from the abstract (without duplicates n = 350). Papers reviewed described work that either directly tracked turtles, or used third-party satellite tracking data. Review papers using turtle tracking case studies, methodologies directly related to satellite tracking turtles, or comments related to tracking (e.g. Chaloupka et al., 2004a) were included as they may inform future tracking practice (e.g. Sperling and Guinea, 2004; Pilcher, 2013). These were cross-checked with citations in a similar review (Godley et al., 2008) and those cited by recent papers. As a further check, peer-review and contribution of new or missing papers was invited at three stages when the original list of literature was sent to: all sea turtle researchers at the University of Exeter; members of the www.seaturtle.org satellite tracking e-mail list; and all authors contacted as part of the questionnaire. This process resulted in 19, mostly new, papers coming to our attention leading to an overall sample size of 369 papers.

2.2. Literature analysis

We conducted a systematic review as outlined in previous studies (Khan et al., 2003; Pullin and Stewart, 2006). We examined papers using a list of criteria including: main theme: species/life-stage/sex of animals tracked; tracking location; sample size; inclusion/discussion of conservation issues; the nature of any recommendations and recognition of animal welfare concerns. To enable comparison with respondents' reasons for tracking, papers were assigned (by VJ) to a category using title and abstract, based on their main theme (1. biological or ecological; 2. conservation and management; 3. other. See Table 1 for categories). Papers were rated on a four point scale according to the extent that conservation/management issues were mentioned in the discussion sections using the following criteria: a) conservation/management issues formed the majority of the discussion, or the paper focussed on a particular issue or threat; b) some conservation/management issues were discussed in the context of the tracking results, or tracking results were applied to a conservation issue; c) conservation/management applications mentioned in passing, but no further explanation given; and d) no mention of conservation/management.

2.3. Expert opinion

We designed a mixed method (see Lobe and Vehovar, 2008) questionnaire (see supplementary material) using an online survey tool (www.surveymonkey.com) to obtain researchers' views on how tracking data contribute to policy and overall turtle conservation. The 12 questions combined a mix of question types and were designed to take a maximum 13 mins (the ideal length to obtain a good response rate; Fan and Yan, 2010). We sent a pilot version to several individuals for feedback, including a researcher with extensive experience in qualitative analysis and others who were experienced in turtle tracking.

Email addresses for first and last authors of the papers reviewed, plus anyone else with correspondence details were gathered from the published papers or, where possible, the internet (total 270 individuals). We sent personalised emails to obtain the best response rates (Sánchez-Fernández et al., 2012) and a reminder a week later. Around 60 remained unreachable due to expired email addresses. Additionally, we sent the questionnaire to the www.seaturtle.org tracking mailing list, comprising of 258 individuals involved in satellite tracking projects, including other taxa; the email was tailored to target those tracking turtles. Inevitably there was considerable overlap between these two groups, so as a conservative estimate, 300 people were contacted. Surveys were completed between 4 and 17 June 2014.

2.4. Data analysis

We conducted statistical analyses using the R statistical package (v. 3.0.2; http://www.r-project.org/). All percentages in the text were rounded to the nearest whole number. We used three different methods to analyse qualitative responses: 1. Qualitative responses justifying quantitative answers were selected to support statements based on quantitative data; 2. others were coded and analysed quantitatively; and 3. Despite some criticism of thematic content analysis, (see Jackson and Trochim, 2002 for a summary) we chose this method to analyse open-ended responses as a word-only based coding method would undermine the meaning of the comments, and a concept mapping approach was not feasible for this study (Jackson and Trochim, 2002).

3. Results

In total 369 papers were reviewed in full. Approximately 57% of people responded to the questionnaire, (n = 171, 90% fully completed. These are hereafter referred to as 'respondents'). Total responses for each question varied and where relevant, the number of responses is stated. The questionnaire reached a broad range of individuals; the largest group (n = 79) were from academic institutions, but a large number worked for government (n = 46), or non-government (n = 45) organisations. Additionally, 21 respondents selected two employment sectors, usually including an academic institution and a second institution (government: n = 10; non-government: n = 4; consultancy: n = 3; other: n = 1).

3.1. Who's tracking what and where?

Satellite tracking turtles is increasing, both in terms of the number of papers published and the number of nations hosting the work (Fig. 1, a & b). The majority of individuals use data that they have collected themselves (55%), 10% use only data collected by third-parties and 35% use a combination of their own and others' data.

Both the published data and the questionnaire responses (Fig. 2) show biases. As previously found (Godley et al., 2008), there was a bias towards tracking females, albeit slightly reduced (70% to 67%), with a small increase in males (7% to 10%) and juvenile numbers (both sexes) around the same (23%) The loggerhead (*Caretta caretta*) and green turtle (*Chelonia mydas*) were most commonly tracked but relatively few data exist for the flatback turtle (*Natator depressus*) and Kemp's ridley (*Lepidochelys kempii*) which are range restricted (Fig. 2a) (See supplementary Table 1 for a breakdown by species). Tracking was most common in the Atlantic and Pacific oceans (Fig. 2b). The USA was the highest ranked nation both by the number of individuals involved (42%) and number of turtle tracks (20%) (Fig. 2c). Geographical irregularities exist, with tracking hotspots such as the Caribbean (contributing 12% of study locations) and data