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Comparison of industry-based data to monitor white shark cage-dive tourism

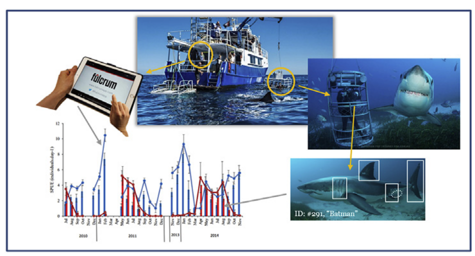
Leila Nazimi [a], William David Robbins [b, c, d], Adam Schilds [a], Charlie Huveneers [a, *]

[a] College of Science and Engineering, Flinders University, Bedford Park, South Australia 5042, Australia
[b] Wildlife Marine, Perth, Western Australia 6020, Australia
[c] School of Science, Curtin University, Perth, Western Australia, 6102 Australia
[d] School of Life Sciences, University of Technology Sydney, Sydney, New South Wales 2007, Australia

HIGHLIGHTS

- Logbook and photo-ID both revealed seasonal sex-biased changes in shark abundance.
- Photo-ID reports lower numbers of sharks, but provides additional parameters.
- We suggest that logbook reporting is the optimum long-term monitoring method.
- A combination of methods will enable an ongoing adaptive management framework.

GRAPHICAL ABSTRACT



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ABSTRACT

Although wildlife tourism is becoming increasingly popular worldwide, the industry has a potential to affect the fauna it targets. A variety of methods are used to monitor the activities and impacts of wildlife tourism. In South Australia, mandatory logbook reporting and the ability to photograph and identify individual sharks provides two industry-based data sources to monitor how cage-diving tourism may impact white sharks. Findings show that both methods can assess shark populations, and detect seasonal sex-biased changes in white shark abundance. Photo-ID significantly underestimates effort days and number of sharks sighted, and is considerably more labour-intensive, but allows accurate identification of individual sharks, facilitating additional analysis. The continued use of logbook reporting is the optimum long-term monitoring method, although we recommend the maintenance of a photographic database for periodic extraction of individual information. Combining these methods will facilitate an ongoing adaptive management framework, aiding the long-term sustainability of the industry.

1. Introduction

The white shark (*Carcharodon carcharias*; family: Lamnidae) is a generally solitary species which can travel thousands of kilometres per year (Bonfil, Francis, Duffy, Manning, & O'Brien, 2010; Bruce, Stevens, & Malcolm, 2006; Domeier & Nasby-Lucas, 2008). However, individuals periodically aggregate in some locations in response to seasonal increases in resource availability (Bruce & Bradford, 2012; Domeier & Nasby-Lucas, 2007; Klimley, Anderson, Pyle, & Henderson, 1992). White shark aggregations occur at several locations throughout the world, including mainland U.S.A.

* Corresponding author.
E-mail address: Charlie.huveneers@flinders.edu.au (C. Huveneers).

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(Chapple et al., 2011), Mexico (Domeier & Nasby-Lucas, 2007), Hawaii (Weng & Honebrink, 2013), South Africa (Kock, O'Riain, Mauff, Kotze, & Griffiths, 2013), Australia (Bruce & Bradford, 2015; Robbins, Enarson, Bradford, Robbins, & Fox, 2015), and New Zealand (Francis, Duffy, & Lyon, 2015). The predictability of white shark aggregations has resulted in targeted wildlife tourism industries in places such as Australia (Bruce & Bradford, 2013; Huveneers et al., 2013), South Africa (Laroche, Kock, Dill, & Oosthuizen, 2007), the USA, Mexico (Nasby-Lucas & Domeier, 2012, pp. 381–392), and New Zealand (Francis et al., 2015). These industries allow close underwater encounters with white sharks in custom-built cages.

Wildlife tourism is often cited to facilitate increase public education and promote conservation awareness (Wilson & Tisdell, 2003; Zeppel, 2008), provide local economic benefits (Dwyer, Forsyth, & Dwyer, 2010; Wells, 1997), and increase psychological health benefits (Ballantyne, Packer, & Falk, 2011; Curtin, 2009). However, the industry can also threaten the wildlife and ecosystems it targets (for reviews see: Burgin & Hardiman, 2015; Green & Giese, 2004; Green & Higginbottom, 2001; Orams, 2002; Robbins, Huveneers, Parra, Möller, & Gillanders, 2017). With these concerns in mind, researchers have investigated a range of potential impacts on sharks, including physiological changes (Maljković & Côté, 2011; Semeniuk, Bourgron, Smith, & Rothley, 2009), behavioural changes (Barker, Peddemors, & Williamson, 2011a, 2011b; Smith, Scarpaci, & Otway, 2016), changes in seasonality, residency, or abundance (Bruce & Bradford, 2013; Laroche et al., 2007; Meyer, Dale, Papastamatiou, Whitney, & Holland, 2009), and disruptions to movement and space use (Corcoran et al., 2013; Fitzpatrick, Abrantes, Seymour, & Barnett, 2011; Huveneers et al., 2013) (for a review see: Brena, Mourier, Planes, & Clua, 2015; Gallagher et al., 2015). These studies have invariably concluded that anthropogenic impacts can be detrimental to sharks if unregulated or too frequent.

White shark cage-diving began in the late 1970s and has become a popular recreational activity, with opportunities in only a few countries where these sharks can be reliably observed (Apps, Dimmock, Lloyd, & Huveneers, 2016). Management of white shark cage-diving worldwide is guided by management plans and various legislative and regulatory instruments in each jurisdiction within which it occurs. These regulations mostly focus on limiting effort (i.e., number of operators), restricting the activity to certain sites and time periods), controls on equipment or other operational restrictions, and all have mandatory reporting and logbook requirements that monitors the activity of the industry (Bruce, 2015). The management objectives relating to cage-diving operations generally reflect legislative requirements to minimise possible deleterious effects on white sharks and the local marine environment.

In Australia, white shark cage-diving has occurred since the late 1970s in South Australia's Spencer Gulf and has become an economically important industry (Huveneers et al., 2017). However, the potential for cage-diving activities to negatively impact white sharks represents a concern in some jurisdictions (DSEWPaC, 2013; Robbins et al., 2017). For example, the increase in cage-diving effort in 2007 coincided with increases in white shark sighting rates and residency periods, and altered the fine-scale distribution of white sharks (Bruce & Bradford, 2013; Huveneers et al., 2013).

In order to monitor white shark numbers, all South Australian shark cage-diving operators (SCDOs) have logged the daily number and sex of sharks sighted since 1999, including null values (Bruce & Bradford, 2015). These logs were originally managed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), but were transferred to the South Australian Research and Development Institute (SARDI) in November 2013, when they implemented a new electronic system allowing online data entry (Fulcrum™). This electronic logbook uses an phone application (app) that allows data to be entered and uploaded by operators, removing the need to collect paper forms and manually enter data recorded by the operators. It also allows almost immediate access to the data.

An alternative method being considered to monitor white shark numbers in South Australia is photographic identification (photo-ID). Photo-ID has been widely used to monitor and describe elasmobranch populations, and is considered robust at identifying individual white sharks over for at least 22 years (Anderson, Chapple, Jorgensen, Klimley, & Block, 2011; Marshall & Pierce, 2012). Photo-ID can be used to determine habitat use (Klimley & Anderson, 1996), describe population composition (Domeier & Nasby-Lucas, 2007; Jorgensen et al., 2009), and assess individual residency or site fidelity (Delaney, Johnson, Bester, & Gennari, 2012). The high number of photographic records regularly available from SCDOs makes this a viable alternative method to monitor white shark population.

The simultaneous availability of mandatory logbook reporting and photo-ID provides two alternative means to monitor aggregating white sharks. However, the suitability and value of information available from these methods has yet to be compared. This study examines the data obtained by both methods, and determines which is most suitable for ongoing monitoring and tourism management of white sharks at their Australian aggregation site. The study will achieve this by comparing: (1) the number of sampling days and number of sharks sighted per day; (2) the sex ratio of visiting sharks; (3) temporal trends in the number of sharks visiting the aggregation site; and (4) the number of days individual sharks were sighted (as a proxy for residency). The variables used to compare the two methods were selected based on the information recorded by the operators, and information used to regulate the cage-diving industry. We further included ecologically-relevant variables (e.g., sighting differences between sexes) commonly used to assess shark populations (e.g., Bruce & Bradford, 2015; Domeier & Nasby-Lucas, 2007; Kock et al., 2013; Robbins, 2007; Robbins & Booth, 2012).

2. Methods

2.1. Study area

Photographic and logbook data was collected at the Neptune Islands Group (Ron and Valerie Taylor) Marine Park, South Australia. These islands are situated ~60 km south of Port Lincoln on the Eyre Peninsula, and consist of the North Neptune Islands (35°149 S; 136°049 E) and South Neptune Islands (35°201 S; 136°060 E) (Fig. 1). This is the only Australian location where white shark commercial cage-diving operations are permitted, as described in Bruce and Bradford (2013) and Huveneers et al. (2013).

2.2. Photographic images

Photographic images were obtained from one of the three cage-diving operators permitted in the area, with the principal aim of capturing images of all sharks present each day. Underwater images were taken throughout the day from cages on the surface and close to the seabed by a single experienced crew member using a digital single-lens reflex (DLSR) camera with strobes. This operator was chosen due to their reliability in taking daily high-quality images. All images were taken during normal tourism operations between June 2010–December 2011 and July 2013–November 2014 (Table 1). Sufficient images from other periods were not available due to the photographer's absence on trips during those periods.