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The modelling and assessment of whale-watching impacts

Leslie F. New [a, i, *], Ailsa J. Hall [b], Robert Harcourt [c], Greg Kaufman [d], E.C.M. Parsons [e], Heidi C. Pearson [f], A. Mel Cosentino [g], Robert S. Schick [h]

[a] US Geological Survey, Patuxent Wildlife Research Center, 12100 Beech Forest Rd, Laurel, MD, 20708, USA
[b] Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews, Fife, KY16 8LB, UK
[c] Department of Biological Sciences, Faculty of Science and Engineering, Macquarie University, Sydney, NSW 2109, Australia
[d] Pacific Whale Foundation, 300 Ma'alaea Road, Suite 211, Wailuku, Maui, HI, 96793, USA
[e] Department of Environmental Science & Policy, George Mason University, Fairfax, VA, 22030, USA
[f] Department of Natural Sciences, University of Alaska Southeast, Juneau, AK, 99801, USA
[g] Wild Earth Foundation, Av de las Ballenas 9500, Puerto Piramides, Peninsula Valdes, Chubut, Argentina
[h] Centre for Research into Ecological and Environmental Modelling, University of St Andrews, The Observatory, Buchanan Gardens, St Andrews, Fife, KY19 9LZ, UK
[i] Department of Mathematics, Washington State University Vancouver, 14204 NE Salmon Creek Avenue, Vancouver, WA, 98686, USA

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ABSTRACT

In recent years there has been significant interest in modelling cumulative effects and the population consequences of individual changes in cetacean behaviour and physiology due to disturbance. One potential source of disturbance that has garnered particular interest is whale-watching. Though perceived as ‘green’ or eco-friendly tourism, there is evidence that whale-watching can result in statistically significant and biologically meaningful changes in cetacean behaviour, raising the question whether whale-watching is in fact a long term sustainable activity. However, an assessment of the impacts of whale-watching on cetaceans requires an understanding of the potential behavioural and physiological effects, data to effectively address the question and suitable modelling techniques. Here, we review the current state of knowledge on the viability of long-term whale-watching, as well as logistical limitations and potential opportunities. We conclude that an integrated, coordinated approach will be needed to further understanding of the possible effects of whale-watching on cetaceans.

1. Introduction

In the last few decades businesses and NGOs have touted whale-watching as a sustainable alternative to commercial whaling. The public's desire to see and interact with large cetaceans has grown (O'Connor et al., 2009), and with this burgeoning interest comes a responsibility to ensure that this new source of exploitation does not harm the very populations it purports to protect. In many areas, rapid industry development has outpaced management, resulting in concerns over the industry's long-term sustainability (Garrod and Fennell, 2004). The desire to reduce the potential for disturbance has led to the development of guidelines (e.g., IWC, 1996) that have been adopted by over 100 countries and numerous commercial whale-watching operations around the globe. However, these guidelines are often voluntary, which reduces their effectiveness (e.g., Allen et al., 2007; Wiley et al., 2008). Furthermore, even when the guidelines are mandatory it is difficult to enforce them, and thus non-compliance by both commercial and recreational vessels is common (e.g. Kessler and Harcourt, 2013; Lusseau, 2004; Scarpaci et al., 2004). This has given rise to the concern that whale-watching in all its forms, be it commercial, opportunistic (e.g., sightseeing cruise, scuba diving), private recreational vessels, or others, may negatively impact the exposed populations over time (e.g., Parsons, 2012). Of these, the majority of the focus has been on commercial whale-watching, due to the greater ability to assess and regulate it as an industry.

There is a large body of evidence documenting the short-term response of cetaceans to disturbance caused by whale-watching vessels (e.g., Corkeron, 1995; Lundquist et al., 2013; Lusseau,

* Corresponding author. Current address: Department of Mathematics, Washington State University Vancouver, 14204 NE Salmon Creek Avenue, Vancouver, WA, 98686, USA.

E-mail addresses: lnew@usgs.gov, leslie.new@wsu.edu (L.F. New), ajh7@st-andrews.ac.uk (A.J. Hall), robert.harcourt@mq.edu.au (R. Harcourt), greg@pacificwhale.org (G. Kaufman), ecm-parsons@earthlink.net (E.C.M. Parsons), heidi.pearson@uas.alaska.edu (H.C. Pearson), orcinus.orca.1758@gmail.com (A.M. Cosentino), rss5@st-andrews.ac.uk (R.S. Schick).

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2006; Richter et al., 2006; Stamation et al., 2010; Steckenreuter et al., 2012; Williams et al., 2002b). However, any potential long-term effect of these short-term responses remains unclear (e.g., Bejder et al., 2006a; Magalhães et al., 2002) and may be dependent on the context, type, severity and frequency of the short-term response (e.g., Jelinski et al., 2002; Pirotta et al., 2015; Williams et al., 2009). As a result, there is a need to better assess the impacts of whale-watching on the target species in order to determine whether, and in what context (e.g., population size, level of isolation), there may be a long-term impact, or if the short-term responses to disturbance are just that: short-term (e.g., Weinrich and Corbelli, 2009). To begin to understand and address this issue we need a framework that incorporates the history of whale-watching, its behavioural and physiological effects, the development and application of modelling techniques to link short-term changes to long-term impacts and the industry itself. Each of these topics is covered here and we then seek to bring these components together to begin the formation of a unified platform for moving forward with the modelling and assessment of whale-watching impacts.

2. History

The first officially recorded whale-watching trip occurred in California in 1955, when an enterprising entrepreneur charged $1 for individuals to go out on his fishing boat to see grey whales (*Eschrichtius robustus*) (Hoyt, 1984, 2009). Whale-watching has since grown into a global industry occurring in over 119 countries and is worth more than $2.1 billion year^{-1} (Hoyt, 2011 *unpublished presentation*; O'Connor et al., 2009). As of 2011, the number of individuals participating in whale-watching worldwide had reached over 15 million (Hoyt, 2011 *unpublished presentation*). This represents a rate of increase greater than 18% year^{-1} (O'Connor et al., 2009), and resulted in a potential economic growth of $0.4 billion year^{-1} (Cisneros-Montemayor et al., 2010). In developing countries whale-watching can be a major contributor to gross domestic product (e.g., Tonga (Kessler and Harcourt, 2010; Orams, 2013)). In addition to the monetary value of whale-watching, there is evidence for more intangible benefits, including education and the promotion of conservation ethics in participating tourists (e.g., Filby et al., 2015; Forestell, 2007; Kessler et al., 2014; Mayes and Richins, 2008; Orams et al., 2014; Zeppel and Muloin, 2008). Therefore, when weighing the potential downsides of whale-watching against its positives, it is necessary to take more than just its monetary value into account.

3. Behavioural and physiological effects

Species ranging from bottlenose dolphins (*Tursiops* sp.) (e.g., Filby et al., 2014; Lusseau, 2003a: Matsuda et al., 2011) to killer whales (*Orcinus orca*) (e.g., Williams et al., 2009, 2002b) to humpback whales (*Megaptera novaeangliae*) (Corkeron, 1995; Stamation et al., 2010) and many others, have demonstrated a behavioural response to the presence of whale-watching vessels. These behavioural responses take different forms, including changes in surfacing and diving patterns (e.g., Corkeron, 1995; Lusseau, 2003a; Matsuda et al., 2011), swimming speed and direction (e.g., Matsuda et al., 2011; Williams et al., 2002b) and decreased time spent feeding and/or resting (e.g., Christiansen et al., 2010; Lusseau, 2003a; Stamation et al., 2010; Visser et al., 2011). Group size and cohesion has also been observed to change when whale-watching vessels are present (Arcangeli and Crosti, 2009; Bejder et al., 2006a). However, these responses are not ubiquitous across species, nor are they consistent within a species across all contexts (e.g., responses when feeding may differ from when resting, breeding or migrating). Furthermore, whether a behavioural response is observed often depends on the number of vessels present (e.g., Constantine et al., 2004; Williams and Ashe, 2007; Williams et al., 2009), the type of vessel (e.g., Goodwin and Cotton, 2004), and the manner in which and how closely vessels approach the animal(s) being observed (e.g., Hodgson and Marsh, 2007; Lemon et al., 2006; Lundquist et al., 2013; Williams et al., 2009, 2002a). It is typically concern about these short-term responses, along with precautionary principles, that have given rise to the various regulations and guidelines implemented by government agencies and used by the commercial whale-watching industry.

In contrast to behavioural responses, there have been fewer studies looking at the physiological effects of whale-watching. Vessel noise is known to affect the acoustic behaviour of marine mammals (e.g., Buckstaff, 2004; Foote et al., 2004; Luís et al., 2014; Richter et al., 2006; Sousa-Lima and Clark, 2008), which can be mediated through their physiology (Tougaard et al., 2015). The noise of whale-watching boats can cause masking and temporary threshold shifts in hearing under certain circumstances (Erbe, 2002). This can affect species' ability to perform auditory scene analysis, and thus their ability to detect predators and to communicate, as well as to locate prey, which in turn may have energetic consequences. As before, the response depends on the type of vessel and its behaviour (e.g., Au and Green, 2000; Erbe, 2002). Pollution, in the form of the exhaust emissions from whale-watching vessels, can also potentially affect the physiology of the exposed individuals (Lachmuth et al., 2011), as can operational oil leaks, passenger rubbish and other forms of pollutants resulting from the interaction of vessels with the marine environment. In some cases, following whale-watching guidelines limit individual exposure to these emitted pollutants to safe levels, whereas guideline violations can potentially lead to adverse health effects (Lachmuth et al., 2011). There is also concern about the effects of stress anthropogenic activities place on marine mammals (e.g., Fair and Becker, 2000; Rolland et al., 2012; Simmonds et al., 2014; Wright et al., 2007b), to which whale-watching likely contributes. More insidiously, disturbance may cause chronic stress. While short-term stress responses are often beneficial, allowing individuals to better respond to perceived threats or dangers (Reeder and Kramer, 2005; Wright et al., 2007a), chronic stress is maladaptive (Martineau, 2007; Rich and Romero, 2005; Rolland et al., 2012; Romero and Butler, 2007; Wright et al., 2007a). When individuals are chronically exposed to stressors, the resulting hormonal response can suppress growth, limit reproduction and result in compromised immune system function (Romero and Butler, 2007; Sapolsky et al., 2000). This can have serious negative implications for both individuals and populations (Rolland et al., 2012; Romero and Butler, 2007; Weilgart, 2007; Wright et al., 2007b).

A difficulty in assessing the behavioural and physiological impacts of disturbance in cetaceans is that these changes may not be directly observable or properly interpreted. Additionally, habituation may occur such that an individual no longer responds outwardly to a disturbance, but still has an unobserved stress response (Lusseau and Bejder, 2007; Weilgart, 2007; Wright et al., 2007a, b). As a result, the lack of an observed response cannot be assumed to indicate a lack of impact (e.g., Tougaard et al., 2015). Important effects may also be secondary to the initial stimulus, as demonstrated by the evidence, across taxa, that distraction due to noise has the potential to interfere with an individual's ability to make biologically important decisions, such as those regarding predator detection (e.g., Chan and Blumstein, 2011).