The Analysis of Whale-watching Impacts

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ABSTRACT:

The majority of studies investigating the impacts of whale-watching have focused on small cetaceans such as dolphins and porpoises. However, many other species, for example humpback whales and fin whales, are also exposed to this form of environmental tourism. While the short-term effects of whale-watching on some species' behaviour and physiology have been quantified, there is still considerable uncertainty regarding the long-term effects of this anthropogenic interaction. Here we seek to summarize those modelling tools currently being used to investigate and analyse the impacts of whale-watching, as well as discuss some of those under development.

INTRODUCTION

At the 2013 meeting of the International Whaling Commission Scientific Committee meeting the creation of an intersessional working group to investigate the modelling and assessment of whale-watching impacts (MAWI) was proposed. It was agreed that the group would seek to define the specific research questions and hypotheses that will most benefit our understanding of the impact of whale-watching, identify those whale-watching locations that would be most suitable and amenable for targeted studies addressing these questions, and summarise the current modelling tools available to analyse the data that will be collected. Here we aim to address the final point. While the research questions and hypotheses to be considered are still under discussion, the other action outlined for MAWI is to identify potential locations and species of large whales for targeted studies. Ideally these locations would be in accessible areas where: the potential for whale-watching exists, has not yet started or is in its infancy; control areas can be established; these is an elevated site in near proximity allowing for land-based observations; and some data on the target species exists. Such sites could include Isla de Chiloe (blue whales), Haiti (sperm whales), Oman (humpback whales) and American Samoa (humpback whales). To better determine sites, a grid detailing all criteria by potential sites will be developed and presented at the 2015 Scientific Committee meeting.

MODELLING

A variety of different approaches have been taken to analysing the impacts of whale-watching and vessel traffic on cetaceans. As with all statistics, the chosen method depends both on the type of data available and the question to be answered with the analysis. The majority of whale-watching studies are observational, taking advantage of existing situations to record information on how different species respond to factors such as the presence, speed, size and orientation of whale-watching vessels (e.g., Lusseau, 2003a; Constantine *et al*., 2004; Lusseau *et al*., 2009; Stamation *et al*., 2010; Tseng *et al*., 2011; Lundquist *et al*., 2013). However, there have also been controlled experiments examining marine mammals' response anthropogenic disturbances related to whale-watching (e.g., Jahoda *et al*., 2003; Hodgeson & Marsh, 2007). Studies also differ in whether they are interested in the short-term (e.g., Lundquist *et al*., 2013) or long-term (e.g., Bejder *et al*., 2006a) impacts of whale-watching.

By far the most common data collection method is the use of focal-follows (e.g., Constantine *et al*., 2004; Bejder *et al*., 2006a; Christensen *et al*., 2010; Steckenreuter *et al*., 2012; Lindquist *et al*., 2013). However, stationary platforms, either in the form of land-based observation points or anchored boats, are also used for data gathering (e.g., van Parjis & Corkeron, 2001; Hodgson & Marsh, 2007; Tosi & Ferreira, 2009). In addition, the whale-watching vessels themselves can provide a unique platform of opportunity from which data on cetacean's response to human activities can be recorded (e.g., Weinrich & Corbelli, 2009; Stamation *et al*., 2010). Regardless of the method of data collection, certain covariates are common across studies. These include, but are not limited to, the number and type of boats in proximity to the species of concern (e.g., Bejder *et al*., 2006b; Anwar *et al*., 2007; Lundquist *et al*., 2013), focal species' behaviour (e.g., Constantine *et al*., 2004; Christiansen *et al*., 2010; Steckenreuter *et al*., 2012; Lundquist *et al*., 2013) and respiration rate (e.g., Jahoda *et al*., 2003; Lusseau, 2003b).

Despite the similarity in data collection methods and covariates, a wide variety of statistical approaches have been used to estimate the effects of whale-watching on cetaceans. The approaches taken have not closely followed statistical developments, but instead appear to have been determined by a combination of the researchers' skill sets, the question under consideration and the exact nature of the data collected. By no means exclusive, the approaches taken can be divided into roughly four categories; 1) comparison of groups (e.g., van Parjis & Corkeron, 2001; Hodgson & March, 2007; Tosi & Ferreria, 2009), 2) regression methods (e.g., Bejder *et al*., 2006a; Weinrich & Corbelli, 2009; Stechenrueter *et al*., 2011), 3) Markov-chains (e.g., Lusseau, 2003c; Lusseau *et al*., 2009; Christiansen *et al*., 2010; Lundquist *et al*., 2013) and 4) modelling and simulation (e.g., Anwar *et al*., 2007; Pirotta *et al*., 2014).

For group comparisons, the statistical tests used have included parametric tests such as ANOVA (e.g., Hodgson & March, 2007), MANOVA (e.g. Lusseau, 2006), *t*-test (e.g., Tosi & Ferriera, 2009) and non-parametric tests such as the Kruskal-Wallis and Mann Whitney U test (e.g., van Parjis & Corkeron, 2001). Given the relevant assumptions of each test (e.g., distribution of the data), these allow researchers to determine whether there is a statistically significant difference in aspects (e.g., mean, variance) of the groups when considered in light of the whale-watching disturbance. For regression analyses, approaches have included generalized linear models (GLM) (e.g., Lusseau, 2006; Weinrich & Corbelli, 2009) and generalized additive models (GAM) (e.g., Lundquist *et al*., 2013), allowing researchers to look at whether explanatory variables such as the type of vessels or time of day can help predict response variables such as behaviour or survival. It is important to note that when considering regression methods for analysing whale-watching data approaches such as GLMs or GAMs are almost always going to be more appropriate than standard linear regression because of model assumptions. Given the time-dependent nature of much of whale-watching data (e.g., focal follows) Markov chains are well suited to their analysis. This approach permits researchers to investigate the change in states of interest (e.g. behaviour) over time and whether the transitions between the states are dependent on influences such as whale-watching (e.g., Lusseau, 2003c; Lusseau *et al*., 2009; Christiansen *et al*., 2010; Lundquist *et al*., 2013). Lastly, tools such as agent based modelling (e.g., Anwar *et al*., 2007; Pirotta *et al*., 2014) can be very powerful, as they allow researchers to investigate how species of concern and whale-watching vessels interact with one another and then predict how these agents may respond to changes in the system (e.g., an increasing in the number of whale-watching vessels). These models can be challenged with data (e.g., Pirotta *et al*., 2014), further increasing their utility.

Agent based models can be a powerful tool when seeking to understand species interactions with each other (e.g., Srinivasan *et al.*, 2010) and different vessel types (e.g., Anwar *et al*., 2007; Pirotta *et al*., 2014), as well as the long-term impacts of disturbance. However, the type of data currently being collected on species impacted by whale-watching may not be sufficient to answer the questions of research and conservation interest (Pirotta *et al.*, 2014). Therefore, if we seek to improve our understanding of the impact of whale-watching on marine mammal species, it is necessary to reassess the current standard of data collection for whale-watching studies. This reassessment is not in terms of the quality, but rather the type of data to ensure its relevancy to a wider range of research questions than has been fully considered to date. For example, for some species it is possible to record visual health assessments (e.g., Pettis *et al.*, 2004) or stress levels (e.g., Rolland *et al*., 2012), which could help inform questions on the long-term impact of whale-watching.

Although an important question, the long-term impacts of whale-watching have rarely been quantified (e.g., Bejder *et al*., 2006a). This is due, in part because traditional approaches to the question of long-term impacts require that data be available from long-term monitoring (e.g., Schick *et al*., 2013). However, there are new approaches being developed, such as the population consequences of disturbance (PCoD) framework (New *et al*., 2014), which have the potential to assess the long-term impacts of disturbance from short-term measures, allowing for more pro-active management and conservation action. However, this means using more than a single statistical test or regression and having a solid understanding of the species biology and ecology, both of which can be limiting in some situations.

CONCLUSIONS

Overall, the methods used to assess whether a species shows a short-term response to disturbance are well established and should be used in conjunction with the appropriate data and hypotheses. Of increasing interest are the mechanisms by which whale-watching impacts individuals, as well as the effects this can have on the long-term health and persistence of a population. This last is of particular importance, since a short-term change in behaviour should not be automatically associated with a long-term impact on the species of concern (e.g., Bejder *et al*., 2006b; New *et al*., 2013). It is therefore imperative that the types of data collected in whale-watching studies be broadened and that new statistical and modelling developments be integrated into whale-watching research to ensure that a wider array of research questions can be answered with the most appropriate and powerful tools. To facilitate this aim, the MAWI intersessional working group will be presenting a symposium and focus group at the 2014 International Marine Conservation Congress in Glasgow, with the aim of receiving input and feedback from the wider marine conservation community. The outcome of these presentations and discussions will be published in a special issue of *Ocean and Coastal Management.*

REFERENCES

Anwar, S.M., Jeanneret, C.A., Parrott, L. and Marceau, D.J. 2007. Conceptualization and implementation of a multi-agent model to simulate whale-watching tours in the St. Lawrence Estuary in Quebec, Canada. *Environ. Mod. Soft.* 22: 1775-1787.

Bejder, L., Samuals, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C. and Krützen, M. 2006a Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Cons. Bio.* 20:1791-1798.

Bejder, L., Samuals, A., Whitehead, H. and Gales, N. 2006b. Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. *Ani. Behav.* 72:1149-1158.

Christiansen, F., Lusseau, D., Stensland, E. and Berggren, P. 2010. Effects of tourist boats on the behaviour of Indo-Pacific bottlenose dolphins off the south coast of Zanzibar. *Endang. Species Res.* 11: 91-99.

Constantine, R., Brunton, D.H. and Dennis, T. 2004. Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Bio. Cons.* 117:299-307.

Hodgson, A.J. and March, H. 2007. Response of dudongs to boat traffic: The risk of disturbance and displacement. *J. Exp. Mar. Bio. Eco.* 340**:**50-61.

Jahoda, M., Lafortuna, C.L., Biasosoni, N., Almirante, C., Azzellino, A., Panigada, S., Zanardelli, M. and Notarbartolo di Sciara, G. 2003. Mediterranean fin whales (*Balaenoptera physalus*) response to small vessels and biopsy sampling assessed through passive tracking and timing of respiration. *Mar. Mam. Sci.* 19:96-110.

Lundquist, D., Gemmel, N.J., Würsig, B. and Markowitz, T. 2013. Dusky dolphin movement patterns: short-term effects of tourism. *Mar. Fresh. Res.* 47:430-449.

Lusseau, D. 2003a. Effects of tour boats on the behaviour of bottlenose dolphins: Using Markov chains to model anthropogenic impacts. *Cons. Bio.* 17:1785-1793.

Lusseau, D. 2003b. Male and female bottlenose dolphins *Tursiops* spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. *Mar. Eco. Prog. Ser.* 257:267-274.

Lusseau, D. 2003c. Effects of tour boats on the behavior of bottlenose dolphins: using Markov chains to model anthropogenic impacts. *Cons. Bio.* 17:1785-1793.

Lusseau, D. 2006. The short-term behavioral reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. *Mar. Mam. Sci.* 22:802-818.

Lusseau, D., Bain, D.E., Williams, R. and Smith, J.C. 2009. Vessel traffic disrupts the foraging behaviour of southern resident killer whales *Orcinus orca*. *Endang. Species Res.* 6:211-221.

New, L.F., Harwood, J., Thomas, L., Donovan, C., Clark, J.S., Hastie, G., Thompson, P.M., Cheney, B., Scott-Hayward, L. and Lusseau, D. 2013. Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. *Func. Eco.* 27:314-322.

New, L.F., Clark, J.S., Costa, D.P., Fleishman, E., Hindell, M.A., Klanjšček, T., Lussuau, D., Kraus, S., McMahon, C.R., Robinson, P.W., Schick, R.S., Schwarz, L.K., Simmons, S.E., Thomas, L., Tyack, P. and Harwood, J. 2014. Using short-term measures of behaviour to estimate long-term fitness of southern elephant seals. *Mar. Eco. Prog. Ser.* 496:99-108.

Pettis, H.M., Rolland, R.M., Hamilton, P.K., Brault, S., Knowlton, A.R. and Kraus, S.D. 2004. Visual health assessment of North Atlantic right whales (*Eubalanea glacialis*) using photographs. *Can. J. Zoo.* 82:8-19.

Pirotta, E., New, L., Harwood, J. and Lusseau, D. 2014. Activities, motivations and disturbance: An agent-based model of bottlenose dolphin behavioral dynamics and interactions with tourism in Doubtful Sound, New Zealand. *Eco. Mod.* 282:44-58.

Rolland, R.M., Parks, S.E., Hunt, K.E., Casetellote, M., Corkeron, P.J., Nowacek, D.P., Wasser, S.K. and Kraus, S.D. 2012. Evidence that ship noise increases stress in right whales. *Proc. R. Soc. Ser. B* 279:2363-2368.

Schick, R.S., Kraus, S.D., Rolland, R.M., Knowlton, A.R., Hamilton, P.K., Pettis, H.M., Kenney, R.D. and Clark. J.S. 2013. Using hierarchical Bayes to understand movement, health, and survival in the endangered North Atlantic right whale. *PLoS ONE,* 8:e64166.

Stamation, K.A., Croft, D.B., Shaughnessy, P.D., Waples, K.A. and Briggs, S.V. 2010. Behavioural response of humpback whales (*Megaptera novaengliae*) to whale-watching vessels on the southern eastern coast of Australia. *Mar. Mam. Sci.* 26:98-122.

Steckenreuter, A., Möller, L. and Harcourt, R. 2012. How does Australia's largest dolphin-watching industry affect the behaviour of a small and resident population of Indo-Pacific bottlenose dolphins? *J. Environ. Man.* 97:14-21.

Srinivasan, M., Grant, W.E., Swannack. T.M. and Rajan, J. 2010. Behavioral games involving a clever prey avoiding a clever predator: An individual-based model of dusky dolphins and killer whales. *Eco. Mod.* 221:2687-2698.

Tosi, C.H. and Ferreira, R.G. 2009. Behavior of estuarine dolphin, *Sotalia guianensis* (Cetacea, Delphinidae), in controlled boat traffic situation at southern coast of Rio Grande do Norte, Brazil. *Bio. Cons.* 18:67-78.

Tseng, Y.-P., Huang, Y.-C., Kyle, G.T. and Yang, M.-C. 2011. Modeling the impacts of cetacean-focused tourism in Taiwan: Observations from cetacean watching boats: 2002-2005. *Environ. Man.* 47:56-66.

van Parjis, S. M. and Corkeron, P.J. 2001. Boat traffic effects the acoustic behaviour of Pacific humpback dolphins, *Sousa chinensis*. *J. Mar. Bio. Assoc. U.K.* 81:533-538.

Weinrich, M. and Corbelli, C. 2009. Does whale watching in Southern New England impact humpback whale (*Megaptera novaeangliae*) calf production or calf survival? *Bio. Cons.* 142:2931-2940.