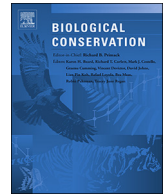




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## Somewhere between acceptable and sustainable: When do impacts to resources become too large in protected areas?



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## ABSTRACT

Utilization of marine and terrestrial protected areas is fundamentally important for their acceptance and success. Yet even appropriate uses can negatively impact resources requiring managers to make decisions as to when the impacts become unacceptably large. These decisions can be difficult because the level at which impacts occur may be far below the level at which resource persistence is threatened. In Glacier Bay National Park, Alaska, managers must make a recurring decision regarding the number of cruise ships that are allowed to enter the park each year. Cruise ships bring > 95% of all visitors to the park but have been involved in several lethal collisions (ship strikes) with humpback whales. Using an individual-based simulation model, we demonstrate that increasing the annual ship volume from current to maximum allowable levels would have negligible impacts on population growth of whales. Over the next 30 years the median number of collisions would likely increase from 3 (95% CI: 0–7) to 4 (1–8) or, worst case scenario, from 5 (0–7) to 8 (3–13), while median annual growth rates would, at most, shift from 4.4% (3.7%–5.2%) to 4.2% (3.5%–4.9%), depending upon assumptions. By comparison, a median of 67 (50–82) ship strikes would need to occur over the next 30 years to threaten the persistence of whales. Confronted with an impact level that is far below what would threaten the conservation of whales, managers are tasked with the decision of placing values on 2 million additional visitors for every additional dead whale. We argue that decision-making related to use-impact trade-offs for protected areas could be more consistent and effective if site-values are defined explicitly, clearly communicated among stakeholders, and linked to biological metrics. Protected areas managers can then utilize monitoring programs to evaluate management effectiveness when the objective is conserving both resources and values.

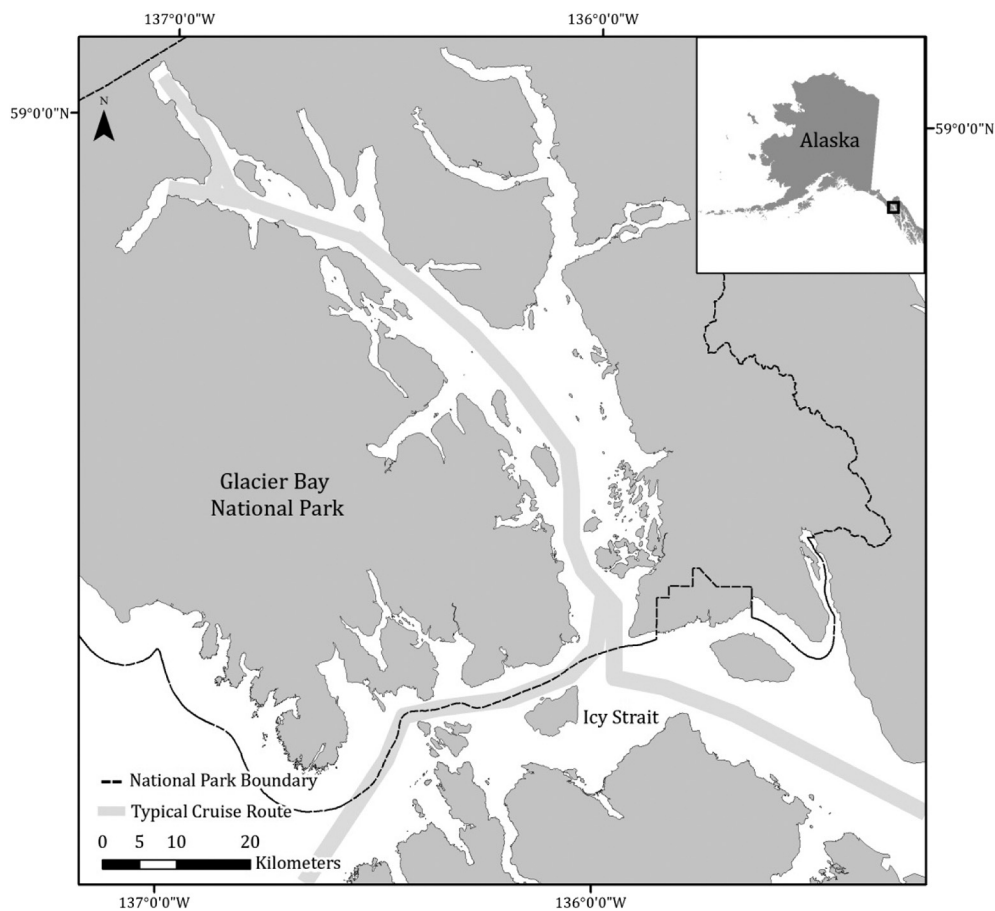
### 1. Introduction

Reserves, parks, conservation zones, and other types of protected areas around the world are established primarily to conserve natural resources considered to be ecologically, historically, or culturally important. Both internal and external stressors can negatively impact resources within these areas (Thurstan et al., 2012; Hansen et al., 2014), but the magnitude of those impacts, and thus the need for management action, varies considerably. In some cases, such as when an existential threat develops that would lead to permanent loss of large areas of habitat and/or extirpation of biodiversity (e.g., damming a river in a protected area; e.g., Laranjeiras et al., 2014) the need for management action is obvious because it represents a clear violation of the goals and objectives of the protected area. More frequently, however, impacts are sufficiently limited such that the need for management action is equivocal. Confounding management uncertainty, these impacts may derive

from appropriate, and perhaps necessary, uses of the protected area.

For example, visitation (and visitor activities) is one of the most common sources of direct and indirect impact to resources in protected areas. In the U.S. visitation to national parks has been linked to wildlife disturbance (e.g., Coleman et al., 2013; Young et al., 2014), incidental deaths of wildlife (e.g., animal-vehicle collisions; Ament et al., 2008), degradation of air or water quality from pollutants or human waste (e.g., Reed and Rasnake, 2016), noise pollution (e.g., Kaplan and Mooney, 2015), and destruction of fish or wildlife habitat (e.g., Hallac et al., 2012), among others. Yet these impacts may be highly localized, temporary, involve only a small fraction of animals or sites within the area, or produce conditions nearly identical to background (unimpacted) levels (Martin et al., 2009; Clow et al., 2011; Mölders and Gende, 2015; Marcella et al., 2016; Eagleston and Marion, 2017). What's more, providing opportunities for visitor use and enjoyment of park resources represents a fundamental management goal of the

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**Fig. 1.** Glacier Bay National Park and adjacent Icy Strait showing the area used by cruise ships when entering, within, and exiting park waters (light shaded area). Ship routes rarely deviate from outside of this area.

National Park Service (NPS, 2006; p 10), mirroring the goals of parks in other countries or World Heritage Sites. These conflicting issues also commonly apply to marine protected areas because management success is often contingent upon support from local communities whose members may rely on extractive uses of the area, such as for subsistence and artisanal fishing (Guidetti and Claudet, 2010). The conflicting incentives complicate the decision-making process because, absent clear definitions or guidance, managers must decide when the impacts from mandated and important uses of the area become unacceptably large.

As an applied example, we consider the tradeoffs between cruise ship traffic and the associated impacts to humpback whales (*Megaptera novaeangliae*) in Glacier Bay National Park, Alaska (hereafter ‘Glacier Bay’ or ‘the park’). Glacier Bay is one of the largest marine protected areas in the northern hemisphere, and large cruise ships ( $\bar{x}$  length of ships visiting in 2012 = 273 m; Webb and Gende, 2015) have been visiting the area regularly since the early 1970s. While consistently conveying > 95% of the visitors to the park annually, cruise ships, like other marine vessels, can negatively impact marine wildlife (Young et al., 2014; Marcella et al., 2016), including humpback whales that aggregate within the park and adjacent waters to feed during the summer months (Saracco et al., 2013). Ship routes overlap temporally and spatially with heavy whale-use areas (Webb and Gende, 2015) resulting in frequent surfacing events near the bow of the transiting ships (Gende et al., 2011; Harris et al., 2012; Williams et al., 2016). Consequently, collisions between ships and whales (ship strikes) have been documented within the park (Neilson et al., 2012), despite speed restrictions on vessels where whales aggregate and requirements for vessels to maintain a mid-channel course to minimize overlap with near-shore habitat used by whales. While relatively rare, ship strikes have been demonstrated to negatively impact the dynamics of some

populations of whales (Fujiwara and Caswell, 2001) particularly when they involve adult females because the collision not only removes her from the population but also results in a loss of her future offspring in the area owing to high levels of maternally-driven site fidelity (Baker et al., 2013; Pierszalowski et al., 2016). The relationship between cruise ship volume and risk of whale deaths (in addition to risk of impacts to other resources such as to air quality from ship pollution) forces managers to make decisions regarding appropriate tradeoffs between increased visitation and the associated probability that an increased number of whales will be killed.

While a dead whale washing up on the shore of a national park is clearly undesirable, the fundamental aspect of this issue reflects the common and recurring issue faced by nearly all protected area managers: at what level does an impact from an appropriate use of the area become unacceptably large? An obvious first approach, such as that commonly used in evaluating by-catch in fisheries (Underwood et al., 2008) is to ask whether the impact threatens the persistence of the resource. If so, the need for management intervention is clear. However, should the impact level be deemed biologically sustainable, managers are still tasked with deciding if and when the impact level becomes sufficiently large that use or visitation needs to be curtailed. The point at which management actions are invoked is important to define and communicate because conflict can arise from stakeholders who may not understand the criteria upon which decisions are made (e.g., Borkowski et al., 2006), or adhere to different values about how protected areas should be managed (Sarewitz, 2004) particularly if management is based on factors other than sustainability. Ambiguity can also lead to loss of support for the conservation areas (DiFranco et al., 2016).

Here we quantify the potential impacts of changes in cruise ship

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