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Investigator disturbance does not reduce annual breeding success or lifetime reproductive success in a vulnerable long-lived species, the yellow-eyed penguin

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ABSTRACT

Well-studied, long-lived species, such as seabirds, can be exposed to decades of investigator interventions, and if the species is of conservation concern, intensive monitoring and management as well. Most evaluations of impacts of investigator disturbance have been relatively short-term. We evaluated both short- and long-term impacts of investigator disturbance on the yellow-eyed penguin (*Megadyptes antipodes*) by focusing on both the breeding season during which the impact occurred and lifetime reproductive success (LRS). In long-lived species, reproductive decisions are often trade-offs between current and future reproductive success, and lifetime reproductive success (LRS) can be influenced by many life- history and environmental parameters, including investigator disturbance. Yellow-eyed penguins, a long-lived seabird that has been intensively studied on the Otago Peninsula of South Island, New Zealand for three decades, are known to be vulnerable to human intrusion. Research and monitoring has required banding and band maintenance, handling, blood sampling, stomach flushing, and device deployment. We found no negative effects associated with any investigator disturbance type on breeding success or LRS. Monitoring disturbances (egg, chick and adult handling, band maintenance) that occurred during the egg and chick phases showed a positive association with breeding success and LRS, probably because the longer a nest survived the more likely eggs, chicks, or adults would be handled. There appeared to be a core of resilient individuals with long lifespans and high LRS that may buffer the population despite being exposed to many investigator disturbance events.

1. Introduction

Most conservation practitioners probably wonder at some point in their careers whether the interventions they carry out to better understand and protect their study populations are in fact contributing to any decline. Is the gain in knowledge achieved at the cost of detrimental effects associated with research and monitoring activities? Ecological and behavioural studies and long-term conservation monitoring of bird populations often require the handling of adults, eggs, and chicks. We visit nests, capture birds to mark them, measure them, take blood and diet samples, and attach instruments to measure behaviour. In most cases handling is performed efficiently and manipulations follow accepted animal ethics guidelines, however it is important to evaluate the levels of disturbance a study species can tolerate, and the nature of possible adverse effects, to minimise impacts on study animals and ensure the parameters being measured are not biased (Carey, 2009). Animal ethics protocols might fail to take into account potential accumulated impacts over individuals' lifetimes in long-lived species, especially when considerable research attention has been focused on a particular population. Although longitudinal studies of populations yield valuable information, this might be at the expense of individuals that experience multiple investigator disturbances.

Investigator disturbance is defined by Carey (2009) as "all activities affecting individual birds or nests (marking nests, trapping, banding, and handling of adults and their young)". Some activities occur as a result of monitoring and others are associated with specific research projects. There are many studies evaluating investigator disturbance in birds, however most focus on impacts during one or two seasons or years. Impacts examined include visitation and handling frequency on colonial species during the reproductive season (e.g. Rodway and Montevecchi, 1996; Shealer and Haverland, 2000; O'Dwyer et al., 2006), nest predation rates (Ibáñez-Álamo et al., 2012), and effects of instrumentation and deployments on the behaviour and ecology of birds (Barron et al., 2010; Elliott et al., 2012; Ludynia et al., 2012). The

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most likely reason for animals to respond negatively to human interaction is because they perceive humans as potential predators (Frid and Dill, 2002; Watson et al., 2014), which triggers both physical and physiological responses. For this reason, some investigators have monitored levels of corticosterone in response to handling and instrumentation stress, recording elevated levels after long-term deployments of geolocators (Brewer et al., 2008; Elliott et al., 2012).

Evidence indicates that investigator disturbance has negatively affected some species of birds, even influencing the parameters being measured (Götmark, 1992; Nisbet, 2000; Ludynia et al., 2012). Effects include increased predation of eggs and young (Hockey and Hallinan, 1981; Götmark and Ahlund, 1984), and decreased breeding success (Pierce and Simons, 1986; Blackmer et al., 2004; Giese, 1996). A meta-analysis of 84 studies of instrumentation effects on wildlife, including capture and handling, found evidence for negative effects, the most substantial being increased energy expenditure and reduced propensity to breed (Barron et al., 2010). An investigation of the role of a number of extrinsic and intrinsic factors affecting population dynamics in a metapopulation of 17 sociable weaver (*Philetairus socius*) colonies over 17 years showed that investigator disturbance measured as capture events contributed to the decline of the meta-population by lowering survival (Altwegg et al., 2014). However, a number of studies did not document any negative effects on reproductive (Shealer and Haverland, 2000; O'Dwyer et al., 2006) or physiological parameters (Ludynia et al., 2012), or reported only small negative effects (Ludynia et al., 2012) that were short-term (Rodway and Montevecchi, 1996; Gómez et al., 2014).

Long-term impacts on survival and reproductive success have been detected over several breeding seasons in relation to flipper bands in some (Saraux et al., 2011; Dann et al., 2014) but not all species of penguin (Boersma and Rebstock, 2009, 2010). Responses to investigator disturbance seem to vary depending on the species and the stage of reproduction, but also on the season, with negative effects on reproduction or survival sometimes expressed only in unfavourable environmental conditions that result in poorer body condition (O'Dwyer et al., 2006; Ludynia et al., 2012; Goldsworthy et al., 2016). Long-lived species such as penguins might be particularly susceptible to investigator disturbance (Blackmer et al., 2004) since birds that have many opportunities to breed should adopt a strategy of minimising risks during a given breeding attempt in favour of investment in future reproductive attempts (Stearns, 1992). Consequently, they are more likely to abandon breeding efforts during unfavourable conditions (Stearns, 1992). Therefore, an important measure of the overall effect of investigator disturbance on these species would be lifetime reproductive success (LRS). Individuals of long-lived species could also be exposed to investigator disturbance over multiple seasons and in many forms if their population is under intensive or long-term monitoring. To date, disturbance studies on penguins have been dominated by shorter-term behavioural and physiological responses with little or no connection to population demography. LRS is one of the closest metrics to fitness that is available. This study is the first to evaluate the impacts of multiple investigator disturbance events on the LRS of individuals.

The yellow-eyed penguin or hōiho (*Megadyptes antipodes*) is a well-studied, long-lived species that is endemic to New Zealand and listed as 'Endangered' on the IUCN Red List (Birdlife International, 2016) and 'Nationally Vulnerable' under the New Zealand Threat Classification System (Robertson et al., 2013). Yellow-eyed penguins at some localities are subject to disturbance in the form of intensive handling by investigators and regular monitoring as part of their conservation management. There is evidence that they are sensitive to disturbance, with individuals breeding at heavily visited tourist sites having elevated stress responses to human interaction compared to birds at undisturbed control sites, indicating that these birds had become sensitised to human disturbance (Ellenberg et al., 2007). Penguins exposed to unregulated visitor access had reduced breeding success and fledged chicks at lower weights compared to adjacent, less-visited sites (McClung et al., 2004; Ellenberg et al., 2007). Individual yellow-eyed penguins vary in their ability to habituate to disturbance, but the type of disturbance is also important, with habituation more likely to occur in response to short and consistent approaches. However, some interventions, such as blood sampling, appear to have had long-term negative impacts on the time taken for penguins to recover from approaches by researchers (Ellenberg et al., 2009).

Lifetime reproductive success in this species varies widely between individuals, ranging from zero to 24 fledged offspring, but with mean values of 5.07 for males and 6.82 for females, or 5.91 overall (Stein et al., in press). We determined whether the frequency of investigator disturbance events, defined as research and monitoring, affected the probability of annual breeding success in the season during which the disturbance occurred, or on the LRS of birds for which we have complete reproductive histories. We explored a range of types of investigator disturbance (including band maintenance, double banding, stomach flushing, blood sampling, device deployment, and egg, chick, and adult handling) to determine whether the frequency of particular disturbance events resulted in reductions in immediate breeding success or in LRS, and whether the timing of investigator disturbance within a season influenced breeding success or LRS.

2. Methods

We used data from the Boulder Beach complex on the Otago Peninsula (45°500 S and 170°300 E; Fig. 1), a site that has supported between 80 and 280 adult yellow-eyed penguins and where intensive long-term population monitoring and research has been carried out since 1980. It has been the study site for nearly 30 postgraduate research student projects, and has the longest history of adult and chick marking of all yellow-eyed penguin breeding sites, with almost all chicks fledged at this site having been marked since 1981.

Yellow-eyed penguins lay clutches of up to two eggs (Richdale, 1957; Seddon and Darby, 1989) and incubation is shared by both parents. During the guard stage, when chicks are young, at least one adult is constantly present at the nest, but chicks older than *c.* 6 weeks are left alone as both adults forage during the day until fledging, which occurs in late January to early March (Darby and Seddon, 1990; Seddon et al., 2013). Yellow-eyed penguins are sedentary, long-lived, highly philopatric and monogamous, and demonstrate a high degree of nesting site fidelity once they establish breeding (Richdale, 1957; Seddon et al., 2013): all of these traits allow for accurate measurement of LRS. A small proportion of individuals have exceeded 20 years of age, but lifespan for most individuals has been estimated at *c.* 10–12 years by Richdale (1957), and *c.* 8–9 years by Stein et al. (in press).

2.1. Data source and sample parameters

We extracted breeding data from the Yellow-eyed Penguin Database, which comprises marking, nesting, re-sighting, captivity, and death records from 1979 onwards. We checked original records from data contributors against the electronic database to ensure that all investigator disturbance events had been recorded appropriately.

We defined LRS as the total number of offspring that survived to fledge-age (*c.* 90 days) over an individual bird's lifetime, using only data recorded from birds marked as chicks or as juveniles (one-year olds) to ensure all birds in the sample were of known age. Birds in their juvenile year are distinct from adults because the plumage on their heads and their eye colour are dull grey, and they lack the post-ocular yellow eye stripe. Yellow-eyed penguins are typically marked when they are at the pre-fledge stage and have reached their morphometric asymptotes (*c.* 80–90 days). Juvenile birds were from the previous year's cohort of chicks. We defined a breeding attempt as the cohabitation of a nest by two birds where at least one egg was laid.