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Protecting marine top predators through adaptive and dynamic management

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ABSTRACT

Anthropogenic disturbances are altering the functioning and provisioning of marine ecosystem services, and as such, affect marine wildlife profoundly. A major problem in this context is resource competition between marine predators and fisheries. Marine protected areas (MPAs) can be a powerful tool to provide protection to predators and their prey; however, effective management strategies are required. A case study of African penguin conservation in South Africa was used to illustrate the benefits of embracing adaptive and dynamic management in the marine environment. The South African government plans to implement 22 new MPAs, which will maximise socio-economic benefits, while ensuring adequate ocean environmental protection. In Algoa Bay, the main purpose of the proposed MPA is to increase populations of the endangered African penguin *Spheniscus demersus*. We used the results of a seven-year experiment, in which purse-seine fisheries were closed around penguin colonies in that area, and concluded that the new MPA would provide a legal improvement to the current situation, but would not be sufficient to increase numbers of African penguin populations. For this, larger no-take zones are necessary when prey availability is low. At the moment, ongoing acoustic surveys could provide recommendations on prey availability to design flexible MPA boundaries. More advanced surveys will be necessary in the future to allow for the MPA's criteria to be adapted, and fully benefit penguins and the coastal community. As such, this study illustrates the usefulness of an adaptive and dynamic management approach for the conservation of marine resources and endangered top predators.

1. Introduction

1.1. Why marine protected areas with no-take zones are needed

Coastal ecosystems are under increasing pressure due to human population growth and the socio-economic importance of these areas [1]. Furthermore, they contain many endangered species, such as dugongs and turtles, and key habitats (e.g., wetlands, seagrasses, mangroves) [2]. It is therefore important to manage these ecosystems effectively. To attenuate the negative anthropogenic effects on coastal areas, marine protected areas (MPAs) have been recommended as a valuable tool [3,4]. At present, only 2.1% of the world's oceans are protected within the framework of MPAs, and of those, only 1% are no-take marine reserves [5]. No-take reserves or zones are defined as areas in the ocean where fishing and all other types of extraction are prohibited [6]. Approximately 94% of all MPAs allow fishing, hence cannot protect all aspects of biodiversity [7]. As a result, concerns are being raised that the MPA label creates an illusion of marine conservation. Costello & Ballantine [7] suggest three reasons as to why so many MPAs allow fishing: (i) people still underestimate the global amount of overfishing and the consequences of shifting baselines; thus, they do not believe that fishing affects biodiversity; (ii) in some cases, trade-offs are necessary to protect biodiversity, which involves allowing some fishing to take place; and (iii) protecting terrestrial and freshwater biodiversity may be given a higher priority, because extinction rates have been indicated to be higher in these environments [8,9]. However, the latter has been contested by recent assessments that concluded there are actually more threatened marine than non-marine species [10]. In all cases, educating and informing people can help to change their general view on fishing. Nevertheless, conservation planning will always be a process of deciding where, when and how to allocate limited funds to minimize the loss of biodiversity and ecosystem services [11]. When various stakeholders in coastal areas need to be accommodated, zoning for multiple-use MPAs can be a strategic alternative [12]. While MPAs with partial protection confer advantages compared to areas with no restrictions, the greatest increase in fish density and biomass occur for areas with total exclusion [13]. Nevertheless, MPAs with a combination of protection levels are a valuable spatial management tool, particularly

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in areas where exclusion of all activities is not a socio-economically or politically viable option [13]. In general, zoned MPAs with no-take reserves at their core, combined with limited fishing in the surrounding areas, show significant effects in rebuilding depleted fish stocks [3,14].

1.2. Role of seabirds in marine conservation

Seabirds are widely regarded as potential qualitative indicators of the health and status of marine ecosystems [15–17], which is convenient due to their relative ease of study. Seabirds' responses to changes in their environment can be measured through different features with their corresponding methods, for example, foraging behaviour (with global positioning systems (GPS) and time-depth recorders), energy expenditure (use of double-labelled water), stress levels (measuring corticosteroid hormone concentrations), and diet trends (stable isotopes and fatty acid analyses) [16]. Since seabirds are top predators, their losses inflict trophic downgrading, which has far reaching consequences on the structure and dynamics of marine ecosystems [18,19]. They belong to the most threatened bird groups and their conservation status has deteriorated faster than any other over recent decades [20,21].

Seabird population dynamics are conditioned by the availability of food and suitable breeding habitat on land. As such, seabirds are protected at numerous breeding colonies, but despite major known impacts of industrial fisheries on seabirds, few sites at sea have received protection [22]. Most direct effects of fisheries involve entanglement in fishing gear and disturbance [23]. Indirect effects include changing the structure of marine communities, depleting stocks of fish species fed upon by seabirds, and discards, which may increase the supply of previously less used food sources [23]. In essence, historical overfishing precedes all other pervasive anthropogenic disturbances to the marine environment [24]. Resource competition between marine predators and fisheries has been described as largely unfavourable to marine predator populations [23,25–28]. As such, reproduction in seabirds is limited when food availability is scarce or fluctuating [29,30], since during poor breeding conditions, maximum fitness is achieved either by not initiating breeding at all, or by abandoning the brood [31].

In general, recent studies have shown that the combined effect of overfishing and climate change [32] cause a spatio-temporal mismatch between seabirds and their prey [22], which results in the observed decline in global seabird populations [21]. Given their imperilled conservation status [20], many seabirds have been highlighted for special conservation status and measures [33]. One way to account for this, is to use data (*e.g.*, distribution, abundance, behaviour, seasonality and pressures), collected via the important bird area (IBA) identification process, in the design process of protective measures for seabirds [34]. The IBA Programme uses objective and transparent data-driven criteria to define key conservation areas at global and regional scales [35]. These criteria have been used to identify more than 10,000 terrestrial sites worldwide (including wetlands), and proved to be a useful tool in conservation efforts for the past 40 years [36]. In 2004, methodologies were developed to identify IBAs in the marine environment [36]. Consequently, the IBA programme also has quantitative data available of seabird distributions at sea, which can contribute significantly to identify representative networks of MPAs. If such data is not available for a specific region, priority should be given to collect these with the methods that are locally available (e.g., GPS loggers, boat surveys, ringing data). Using these data, sites can be protected effectively as they would then be large enough to consider temporal and spatial variations — to allow adaptive management to minimize effects of any pressures — and to capture critical behaviour [34]. The latter is necessary to ensure the inclusion of key breeding sites, the marine areas around them, and more distant feeding and aggregation sites [34].

1.3. Aim

Agardy et al. (2003) stated that “MPAs should be designed so one can learn from their application and adjust their management strategies as needed, in the true spirit of adaptive management” [37]. Therefore, the boundaries of no-take zones can be designed in a flexible way when all anthropogenic threats to the marine ecosystem and human socio-economic needs are considered in integrated management plans. In addition, dynamic management can procure the best solution for all stakeholders at a specific moment. This publication addresses the importance of adaptive, dynamic management as a prerequisite for conservation of marine endangered species and marine ecosystems as a whole. By using African penguin as a model species, we present a practical guide to adaptive, dynamic management.

2. Adaptive management

At present, the majority of marine management approaches (e.g., quota setting, total allowable catches, and MPAs) are relatively static in contrast to the ocean itself and the majority of ocean uses (e.g., fishing, shipping, wildlife viewing) [38–40]. Therefore, to effectively manage this highly dynamic marine system, conservation measures must become flexible in space and time in the same way as are both the environment and the resource uses [38].

Two solutions have been put forward to address this dilemma: (i) Adaptive management, and (ii) effective stakeholder engagement [41]. By combining these two processes, effective environmental management can be achieved [42]. Some studies adopt the term 'adaptive governance', which seems to be in agreement with a flexible and learning-based ecosystem approach [43]. However, since the result is the same, the term ‘adaptive management’ will be used for all iterative processes of decision making, whereby management strategies are progressively changed or adjusted in response to new information [44,45]. This makes it an attractive strategy to use in the marine environment, where climate change and other anthropogenic threats cause high levels of uncertainty on the possible outcome of conservation plans.

Despite the many obvious benefits of adaptive management, spatial management for marine resources has been largely static so far [46]. Generally, designing a management plan is considered as a task to be done only once, which results in it being quickly outdated. As such, it can fail to be implemented or to completely achieve its objectives. Yet, to fully take advantage of the available information, plans must be seen as starting points for ongoing adaptation and refinement, even if this involves additional costs [46]. Adaptive management allows decisions to be improved with accumulating knowledge, and to be regularly fine-tuned to a constantly changing social-ecological system [47]. More specific, adaptive management ensures that spatial plans remain relevant. Furthermore, triggers determine when new adaptive planning cycles should begin. As such, they may consist of new information, altered political or socio-economical situations, revised objectives, or assessments of the effectiveness of implemented management actions [46,48–50]. These triggers need to be defined SMART (Specific, Measurable, Attainable, Realistic and Time-related; [51]), and linked to the social, economical, and ecological features that exist for each particular case. Thresholds for these triggers need to be determined, also taking climate change into account.

Once conservation measures are implemented, people can learn from the outcomes. Learning is an iterative process, in which gained knowledge results in better decisions [48]. Active adaptive management incorporates the possible learning outcomes from monitoring the management plans [52,53]. In contrast, passive adaptive management only includes learning that occurred by chance [54,55]. The reason why active adaptive management is not applied commonly is because it presents many challenges. A long-term vision is necessary to design conservation measures in such a way that managers can learn