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Anthropogenic threat assessment of marine-associated fauna in Spencer Gulf, South Australia

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ABSTRACT

Assessing the vulnerability of species to anthropogenic threats is an essential step when developing management strategies for wild populations. With industrial development forecasted to increase in Spencer Gulf, South Australia, it is crucial to assess the ongoing effects of anthropogenic threats to resident and migratory species. Expert elicitation was used to assess 27 threats against 38 threatened, protected, and iconic marine-associated species. Species and threat interactions were assessed individually, and as taxonomic or functional groups. Climate change had the greatest overall exposure (c.f. risk) across species, followed by disturbance, pollution, disease/invasive species, and fishing/aquaculture threats. The largest overall sensitivities (c.f. consequences) were pollution and disease/invasive species, followed by climate change, disturbance and fishing/aquaculture threats. Vulnerability scores (exposure x sensitivity) showed the climate change group posing the greatest overall threat in Spencer Gulf, with individual climatic threats ranking as three of the top four biggest threats to most animal groups. Noise, shipping, and net fishing were considered the greatest region-specific individual threats to marine mammals; as were trawl fishing, line fishing, and coastal activities to fish/cuttlefish; trawl fishing, line fishing, and net fishing to elasmobranchs; and oil spill, disease, and coastal activities to sea/shorebirds. Eighteen of the 20 highest vulnerability scores involved the short-beaked common dolphin, Indo-Pacific bottlenose dolphin, and Australian sea lion, highlighting the particular susceptibility of these species to specific threats. These findings provide a synthesis of key threats and vulnerable species, and give management a basis to direct future monitoring and threat mitigation efforts in the region.

1. Introduction

Anthropogenic threat assessments are an essential consideration during the development of management strategies for marine and terrestrial populations. While direct assessments provide quantitative data on the impacts of specific threats to species (i.e. [1,2]), collection of such data on wide ranging and patchily-distributed species is time consuming, costly, and often impractical. In the absence of targeted quantitative data, expert elicitation can provide an alternative means to predict likely outcomes. Expert elicitation relies on informed experts providing their best estimates of the likely outcomes of scenarios, such as the effects of different threats on species. Opinions can be gathered independently from a panel of selected experts through structured questionnaires, known as the *Delphi* method, or obtained as the consensus of round-table discussions. Expert elicitation has been used to estimate the effects of threats on mammals and birds [3,4], seagrass [5], invertebrates and fishes [6], and to examine human threats to marine ecosystems on a global scale [7,8].

South Australia's Spencer Gulf (Fig. 1) is an ecologically significant region for many bird, mammal, fish, shark, and invertebrate species. It provides an important feeding area for migratory northern hemisphere shorebirds, whose numbers have declined in eastern Australia over recent decades [9], and encompasses significant portions of South Australia's breeding and foraging habitats for *endangered* raptor species [10]. Spencer Gulf similarly provides foraging and/or breeding grounds for resident dolphins such as bottlenose dolphins (*Tursiops* sp.), and

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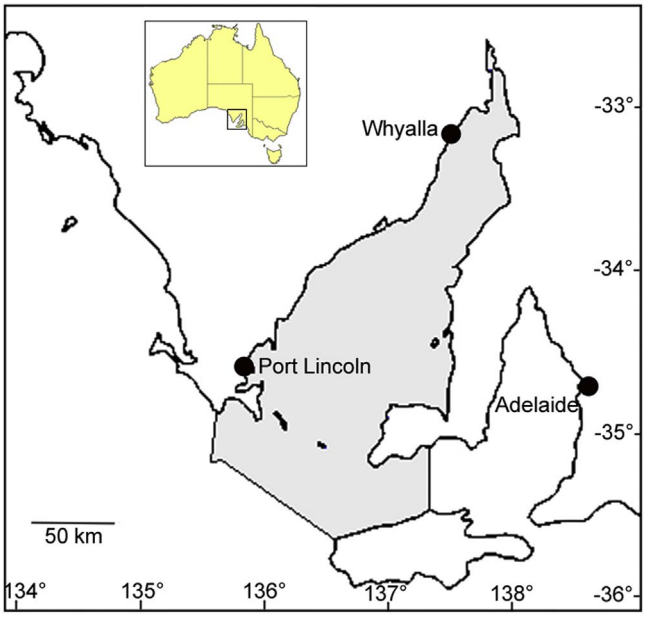

Fig. 1. Spencer Gulf and surrounding Investigator Strait in South Australia. Shading indicates the area considered in this study.

short-beaked common dolphins (*Delphinus delphis*); and migratory whales such as southern right whales (*Eubalaena australis*), and humpback whales (*Megaptera novaeangliae*) [11,12]. The region also contains important breeding and rookery areas for Australian sea lions (*Neophoca cinerea*) and long-nosed fur seals (*Arctocephalus forsteri*) [13,14]. Numerous shark and ray species inhabit Spencer Gulf [15], and important aggregation areas for white sharks (*Carcharodon carcharias*) and giant Australian cuttlefish (*Sepia apama*) are found in the region [16,17]. Spencer Gulf also contains a range of federally-protected syngnathid species [18].

Spencer Gulf also has a long history of human activities. Resident populations are found in towns along both sides of the Gulf, with many seasonal visitors each year. Multiple commercial fisheries operate in Spencer Gulf, with the largest fishery landing up to 32,000 tonne per annum in the region prior to the implementation of catch restrictions [19]. Spencer Gulf also encompasses 37% of the State's recreational fishing effort [20]. Long-term aquaculture for shellfish and pelagic finfish operate within Spencer Gulf alongside multiple vessel-based ecotourism businesses offering wildlife interactions with pinnipeds and white sharks [2]. The region is important for shipping, with hundreds of domestic and international cargo ships transporting mineral and agricultural products each year (see [22]).

As with any environment, the potential exists for human use to cause detrimental impacts to Spencer Gulf. Anthropogenic impacts to the marine environment span a wide range of stressors, including (but not limited to) over-exploitation, urban and industrial habitat degradation, pollution, debris, biosecurity, shipping effects, wildlife disturbances, and the ubiquitous impacts of climate change [8,21]. However, the extent and impacts of such threats to Spencer Gulf species are largely unknown, and significant interest exists to expand resource exploitation and subsequent infrastructure and shipping in the region [22]. Such developments will increase present-day anthropogenic pressures on local fauna, necessitating the need to assess current threats prior to developments commencing. Although data are available on the population dynamics, genetic structure, movements, and anthropogenic interactions of numerous marine species in Spencer Gulf (i.e. [2,14,23–25]), many threats and species are critically lacking assessments.

This study used the *Delphi* method to investigate the likely impacts of multiple anthropogenic threats on selected *Threatened, Endangered*, protected, and iconic species (TEPS) in Spencer Gulf. Species included cetaceans, pinnipeds, seabirds, shorebirds, sharks, rays, fish, and cuttlefish. To investigate the ongoing effects of threats, the study (1) quantified the likely exposures (c.f. risks) and sensitivities (c.f. consequences) of TEPS to threats within Spencer Gulf; (2) used this information to determine the vulnerabilities of TEPS to specific Spencer Gulf threats; (3) examined broad trends among threat types and species groups, (4) identified which individual threats posed the most hazard to different TEP groups; and (5) highlighted threat/species combinations with the highest vulnerability scores. This information will provide management with direction for future monitoring and threat mitigation efforts in the region.

2. Materials and methods

2.1. Variable selection

Using a combination of literature searches, meetings with stakeholders, and discussions with local scientists and managers, a list of 27 anthropogenic or anthropogenically-exacerbated threats deemed most likely to affect marine-associated species in Spencer Gulf was developed. Each threat consisted of multiple components (e.g. Wildlife Disturbance included boating activities, shark cage–diving operations, kayaking and dolphin watching) (Supplementary 1). A list of 38 marine-associated TEP species occurring in the region was also determined across the major animal groups (marine mammals, fish/cuttlefish (including seahorses), sea/shorebirds, and elasmobranchs) (Supplementary 2). Species were limited to those listed as *Threatened* or *Endangered* by the International Union for Conservation of Nature (IUCN), and protected or iconic species with known anthropogenic interactions within Spencer Gulf. Species with comparative demographics were grouped, resulting in 32 species/species groups (Supplementary 2). Appropriate Australian-based experts were identified from searches of published literature, Google Scholar™, Research Gate™, Government and University websites, and suggestions from other participants, with participants invited through email and professional association lists. The research was conducted under Human Ethics approval from the Social and Behavioural Research Ethics Committee, Flinders University (#70930).

2.2. Survey design and implementation

Surveys were conducted in two tiers. Participants familiar with the Spencer Gulf region estimated the frequency and likelihood of threat interactions with species (exposure surveys) (tier 1), while a wider range of experts independently assessed the likely outcomes of such interactions (sensitivity surveys; Supplementary 3) (tier 2). Knowledge of Spencer Gulf was considered essential to assess the likely exposures of species to threats; however, as there was no reason to suspect that the outcomes of such interactions in Spencer Gulf differ from similar interactions occurring elsewhere, local knowledge was not required for sensitivity assessments. Exposure and sensitivity surveys were undertaken electronically, either as an MS Excel file or a SurveyMonkey™ online questionnaire, with the order in which threats were presented randomised in online surveys.

Both exposure and sensitivity participants could assess multiple species, however each species had to be assessed individually. Each exposure and sensitivity survey consisted of multiple questions pertaining to the interactions between the species and the 27 Spencer Gulf threats under investigation. Threats were individually assessed in most survey questions, however some questions asked for a single answer which was applied across all threats (Supplementary 3). Participants were asked to answer all questions and assess all threats, but could omit answers when unsure. Descriptions of threats were provided in all cases, and experts were asked to consider the current status of threats, with the exception of climate change which used 2030 forecast values