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The endangered Australian sea lion extensively overlaps with and regularly becomes by-catch in demersal shark gill-nets in South Australian shelf waters

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ABSTRACT

Australian sea lions (*Neophoca cinerea*) have typically small breeding colonies, many of which are genetically distinct populations due to female philopatry (i.e. breeding site fidelity). This situation may increase the vulnerability of the species to decline when anthropogenic influences increase levels of mortality, even by small amounts. Anecdotal reports from South Australian shelf waters suggest Australian sea lions become by-caught and drown in demersal gill-nets used to catch sharks, or escape with life threatening entanglements. This study explored the potential impact of the operational interaction by estimating the (i) extent of geographic overlap and (ii) level of by-catch. Monitoring of Australian sea lion at-sea movements and of the demersal gill-net fishery confirmed spatial overlap between the two in 68.7% of 4 km^2 grid cells across South Australian shelf waters and by-catch of 283–333 Australian sea lions each breeding cycle (193–227 each year). Recent changes to the management arrangements of demersal gill-netting in South Australian shelf waters are likely to have improved the situation for Australian sea lions, although it may be necessary to further refine aspects relating to (i) the effectiveness of untested electronic fishery monitoring methods, (ii) the efficacy of relatively small permanent fishery closures around breeding colonies and (iii) the efficiency in receiving, processing and responding to by-catch reports to ensure by-catch limits are not exceeded. Long-term monitoring at representative breeding colonies would be useful for determining if and where research and management should be prioritised. A recent report suggests a similar problem may exist in Western Australia, where approximately 14% of the species resides.

1. Introduction

A growing body of research conducted since the early 1990s indicates that Australian sea lions (*Neophoca cinerea*) have low fecundity and their breeding colonies are typically small and unlikely to receive female immigrants due to philopatry (Higgins, 1993; Gales et al., 1994; Gales and Costa, 1997; Goldsworthy et al., 2009; Lowther et al., 2012). These characteristics may increase the species vulnerability to decline or extinction when even small increases to the level of mortality occur (Caughley, 1994; Goldsworthy et al., 2010; Hamer et al., 2011). Since the late 1960s, a demersal gill-net fishery has operated along the southern Australian coastline (BRS, 2004; Walker et al., 2005), overlapping with Australian sea lions most apparently in waters adjacent to South Australia (SA) where the greater proportion of the species resides and forages (Fowler et al., 2007; Hamer et al., 2011; Woodhams et al., 2011; DSEWPaC, 2012a). Available reports suggest that Australian sea lions may become by-caught and drown, or occasionally become entangled and eventually succumb from related injuries (Shaughnessy et al., 2003; Page et al., 2004; Goldsworthy et al., 2010; Hamer et al., 2011). The nature, extent and impact of these events remain unclear, thus providing the impetus for this study.

1.1. Pinniped by-catch: a global perspective

Since the 1960s, the Southern Ocean has witnessed the recovery and expansion of many pinniped populations, due to the widespread cessation of commercial sealing by the mid 1800s (e.g. Taylor, 1982; Roux, 1987; Wickens, 1995; Kirkwood et al., 2010).

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Commercial fishing effort has also expanded during the same period, due to advancements in fishing technology and increased demand for fish (FAO, 2009; UN, 2009). Consequently, increased overlap between these two marine consumers has resulted in the increased occurrence of direct or 'operational interactions' (e.g. Beverton, 1985; Woodley and Lavigne, 1991; Pemberton et al., 1994; Wickens, 1995; Northridge and Hofman, 1999; Hückstädt and Antezana, 2003; Shaughnessy et al., 2003; Hamer and Goldsworthy, 2006; Hamer et al., 2011). These events occur when marine mammals come into direct or close contact with fishing gear, either intentionally when depredating caught fish, or accidentally when foraging naturally (Northridge and Hofman, 1999; Shaughnessy et al., 2003; Read, 2005).

Pinnipeds may benefit energetically from depredating fish caught in the fishing gear, although they may also become by-caught and drown when doing so (Northridge and Hofman, 1999; Hamer and Goldsworthy, 2006), or may escape with life threatening entanglements from which they later succumb (Fowler et al., 1990; Page et al., 2004). The occurrence of these events in demersal gill-nets is widespread and may be the greatest contemporary anthropogenic threat to pinnipeds (Woodley and Lavigne, 1991; Wickens, 1995; Read et al., 2006; Read, 2008). In California, two gill-net fisheries have reported by-catch of four pinniped species (Californian sea lion *Zalophus californianus*, Steller sea lions *Eumetopias jubatus*, harbour seal *Phoca vitulina* and northern elephant seal *Mirounga angustirostris*; Julian and Beeson, 1998). A recent study estimated 98% of all pinniped by-catch in the United States of America (USA) commercial fisheries occurs in gill-nets (Read et al., 2006), while another estimated 9% of all California sea lions at one Mexican breeding colony exhibited gill-net entanglements (Aurioles-Gamboa et al., 2003).

Despite widespread occurrence of operational interactions between pinnipeds and fisheries, there have been few attempts to address the problem. Trawl fisheries have received some attention, with New Zealand sea lion (*Phocarctos hookeri*) by-catch mitigated to some extent by applying by-catch limits and temporary closures (Wilkinson et al., 2003), and Australian fur seal (*Arctocephalus pusillus doriferus*) by-catch mitigated by moving away when individuals were observed near the vessel and by including gear modifications (Tilzey et al., 2004; Hamer and Goldsworthy, 2006). One lobster trap fishery attempted to mitigate Australian sea lion by-catch by mandating the use of exclusion devices in some areas where the species foraged (Campbell et al., 2008). The apparent lack of effort committed to mitigating the impact of by-catch on marine mammals more widely may be in part due to resistance between the two main stakeholders, with conservationists aiming to protect marine mammals at the expense of the fisheries involved and fisheries aiming to exploit marine resources at the expense of other marine consumers. To date, there are few examples demonstrating a capacity or willingness to adopt a bipartisan approach.

1.2. Impact of demersal gill-nets on Australian sea lions

A demersal gill-net fishery has operated along the southern Australian coastline since the late 1960s, targeting benthic dwelling gummy shark (*Mustelus antarcticus*) and school shark (*Galeorhinus galeus*; BRS, 2004; Walker et al. 2005). The method used has remained virtually unchanged since its inception, with monofilament polypropylene gill-net hung between a weighted foot rope that holds it stationary on the benthos and a floated headline that holds it upright in the water column (Hamer et al., 2011). In waters adjacent to SA, Demersal gill-netting is managed by the Australian Fisheries Management Authority (AFMA) in state waters (i.e. from the coastline out to 5.56 km or 3 nm, under a bilateral agreement with the SA Government) and Australian Government waters (i.e. from 5.56 km out to a maximum depth of 183 m, pursuant to the management arrangements of the fishery), from the SA and Western Australian (WA) boarder, to the Victorian and New South Wales (NSW) border (AFMA, 2010; Woodhams et al., 2011). Waters adjacent to SA are particularly important to the fishery, with approximately 40% of effort by km of gill-net hauled occurring there in 2010 (Goldsworthy et al., 2010; Woodhams et al., 2011).

The same waters are also important for the Australian sea lion, with approximately 86% of the species by numbers of individuals and 63% by numbers of colonies residing there (Goldsworthy et al., 2009). This species is unique when compared with other pinnipeds, firstly by having slow maturation and extended breeding cycles of 17.4–17.8 months, that reduce overall fecundity by approximately 30% (Higgins, 1993; Gales et al., 1994; Gales and Costa, 1997). Secondly, colonies are generally small, with 66% of all breeding colonies in SA producing less than 30 pups. Thirdly, females exhibit philopatry, breeding exclusively at their own place of birth and thus unable to facilitate immigration at other sites, which may explain why many breeding colonies or clusters of breeding colonies are genetically distinct (Campbell et al., 2007; Lowther et al., 2012). These characteristics may increase the species vulnerability to decline or extinction when even small and unnatural increases in levels of mortality occur (Caughley, 1994; Goldsworthy et al., 2010; Hamer et al., 2011; Davidson et al., 2012).

Australia is home to three pinniped species (i.e. Australian fur seal, New Zealand fur seal *Arctocephalus forsteri* and Australian sea lion), all of which have had operational interactions with demersal gill-nets (Shaughnessy et al., 2003). A study during the early 1990s in Tasmania (Australia) found that 15% of entanglements on Australian fur seals involved demersal gill-net material (Pemberton et al., 1992). Entangled individuals may have been attracted to the benthic fish caught in the gill-nets that naturally occur in their diet (Arnould and Kirkwood, 2007; Deagle et al., 2009). During the early 2000s at Kangaroo Is (SA), 1% of entanglements observed on New Zealand fur seals involved demersal gill-net material (Page et al., 2004). The seemingly low incidence of entanglement may be reflect the pelagic foraging habit of the species (Baylis et al., 2008). In contrast, Australian sea lions are known to forage almost exclusively at or near the sea floor, mostly on benthic prey (Costa and Gales, 2003; Fowler et al., 2006). This may explain why the Kangaroo Is study found 55% of entanglements on Australian sea lions involved demersal gill-nets (Page et al., 2004). Given the severity of the wounds resulting from entanglement in demersal gill-nets and the low probability that the material would break away naturally (Peter Shaughnessy, personal communication), an estimated 36 Australian sea lions are likely to die from related injuries each year (modified from Page et al., 2004).

The impact of Australian sea lion by-catch in demersal gill-nets may be evident in population trends at some breeding colonies. Population growth at the Dangerous Reef breeding colony in Spencer Gulf (SA) increased from 0.6% each breeding cycle between 1975 and 2002 to 4.8% each breeding cycle between 2002 and 2007, after a moratorium of shark fishing was issued there in 2001 (SA Government Gazette, 22 March 2001, page 1060–1061; SA Government Gazette, 2 May 2001, page 1703). The Seal Bay population, which is close to an area where demersal gill-netting effort is high, declined at 1.1% each breeding cycle between 1985 and 2003 (Shaughnessy et al., 2006). These examples indicate that Australian sea lion populations are sensitive to the presence of demersal gill-netting activities, namely to the additional losses of individuals due to by-catch.

The empirical history of Australian sea lion by-catch in demersal gill-nets has been difficult to determine, because it was not mandatory to record such interactions prior to the enactment of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in 2000 (administered by the Australian Government Department of Sustainability, Environment, Water, Population