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Entanglement in recreational fishing gear poses a threat to estuarine and coastal dolphins: Animal welfare and population level impacts should guide intervention decision making

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ABSTRACT

Derelict and active fishing gear poses a threat to marine wildlife. This study details Indo-Pacific bottlenose dolphin entanglements in recreational fishing gear in the Peel-Harvey Estuary, Western Australia between 2016 and 2022. Eight entanglements were recorded, three resulted in death. While concerning from an animal welfare perspective, the impact of entanglements on the viability of the local dolphin population was low. This is as majority of affected individuals were juvenile males. Should entanglements result in the loss of reproductive females, or impact their reproductive success, the population trajectory could quickly change. As such, management decision making should consider population level impacts as well as the welfare of entangled individuals. Government agencies, together with relevant stakeholders, should work together to maintain preparedness to respond to entanglements and take preventative action that lowers the risk of interactions with recreational fishing gear.

Interactions with fishing gear pose a threat to marine wildlife such as turtles, sharks, seabirds and marine mammals (Butterworth et al., 2012; Nelms et al., 2016; Parton et al., 2019). Individuals are directly affected through entanglement or ingestion of fishing gear that may lead to drowning, amputation of body parts, systemic infection, restricted movement and an inability to forage, feed or engage in other normal behaviour (Butterworth et al., 2012). Beyond the clear welfare implications to individuals, interactions with both derelict and active fishing gear have been identified as one of the main threats to cetaceans globally (Read, 2008; Reeves et al., 2003; Stelfox et al., 2016; Jog et al., 2022). Incidental catches and entanglements in commercial fishing gear are well documented for many populations and species (Silvani et al., 1999; Wade et al., 2007; Børge et al., 2013; van der Hoop et al., 2013; Thomas et al., 2016; Peltier et al., 2016; Braulik et al., 2019; How et al., 2021; Manlik et al., 2022) and have played a significant contributory role in driving the Yangtze River dolphin (*Lipotes vexillifer*) to extinction (Turvey et al., 2007) and the vaquita (*Phocoena sinus*) to the brink of extinction (Rojas-Bracho et al., 2006; Taylor et al., 2017). While interactions with recreational fishing gear have received less attention, it is recognised that these also pose a threat to coastal species (e.g., Mann et al., 1995; Wells et al., 2008; Marks et al., 2020; McHugh et al., 2021; Carretta et al., 2022).

Coastal and estuarine dolphins are particularly vulnerable to interactions with recreational fishing gear as they often occupy areas that are also heavily used by recreational fishers (Nicholson et al., 2021a). Entanglements or ingestion of fishing gear may result from animals attempting to capture prey from active fishing gear (i.e., prey that has already been caught by fishing gear) (Powell and Wells, 2011) or from dolphins interacting with lost or inappropriately discarded fishing gear in their environment. Commonly reported recreational fishing gear involved in dolphin entanglements include monofilament and braided fishing line, crab trap float lines, fishing hooks and other debris (Wells et al., 2008; Barco et al., 2010; Butterworth et al., 2012).

Entanglements in fishing gear may be sub-lethal or lead to an individual's death. Fishing line or rope can cause tissue damage and constriction that result in amputation of distal body parts (i.e., dorsal and pectoral fins or tail flukes) and laceration of blood vessels (Wells et al., 2008; Cassoff et al., 2011). Additionally, open wounds pose a risk of infection that may further compromise individuals' health (see below). Ingested fishing gear, such as line and hooks, can cause internal damage and affect an individual's ability to feed, leading to loss of body condition and eventually death (Wells et al., 2008; Byard et al., 2020). Entangled dolphins may also be restricted in their movements and are known to spend less time foraging (Miketa et al., 2017). They also spend

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more time on their own (Wells et al., 1998; Miketa et al., 2017), which may disrupt their social relationships (Greenfield et al., 2021). As such, whether resulting in death or not, fishing gear interactions are a significant threat to animals' physical and social welfare (Butterworth et al., 2012; Dolman and Brakes, 2018).

The viability of a population may also be affected by fishing gear related increases in mortality rates. Many estuaries and coastal waters are occupied by socially distinct communities of dolphins with high site fidelity, or residency, to an area (e.g., Urian et al., 2009; Wiszniewski et al., 2009; Titcomb et al., 2015; Chabanne et al., 2017; Nicholson et al., 2021b). Some of these communities can be considered populations where population size is mainly driven by death and birth processes and/or where immigration and emigration offset each other (Lacy et al., 2021; Nicholson et al., 2023). In such cases, for example, a human caused loss of just one mature female may result in population decline over time (Lacy et al., 2021). As such, to ensure adequate management response to dolphin entanglements, it is important to quantify their occurrence and contribution to population mortality rates.

Here I detail Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) entanglements in recreational fishing gear in the Peel-Harvey Estuary in

Western Australia between 2016 and 2022. The data presented were collected during regular boat-based population monitoring surveys (Nicholson et al., 2021b; Nicholson et al., 2023) with additional observational data provided by the Mandurah Volunteer Dolphin Rescue Group. The estuary is occupied by a resident community (Peel-Harvey: PH) of ca. 90 Indo-Pacific bottlenose dolphins (Nicholson et al., 2021b). Based on census level data, this community is considered stable with a slightly negative mean population growth rate, which makes it vulnerable to any external stressors that may lead to increased mortality or decreased reproductive rates (Nicholson et al., 2023). Another community of ca. 40 coastal dolphins show high site fidelity to one of the entrance channels to the estuary, the Dawesville Channel (DW) (Nicholson et al., 2021b). As such, the entire system is important year-round habitat to at least 130 dolphins. The estuary is heavily used by recreational fishers and supports finfish and blue swimmer crab (*Portunus armatus*) commercial fisheries (Gaughan et al., 2019; Obregón et al., 2020).

Eight incidents involving separate individual dolphins entangled in recreational fishing gear were recorded during this study (Table 1). There were no reports or observations of dolphin interactions with

Table 1

Summary of Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) entanglements in the Peel-Harvey Estuary, Western Australia between 2016 and 2022. Notations: PH = Peel-Harvey Estuary, DW = Dawesville Cut, M = male, F = female, N = neonate (<6 months old), C = calf dependent on mother, J = juvenile, A = adult, DBCA = Department of Biodiversity, Conservation and Attractions (Western Australia).

Dolphin ID	Community	Sex	Age (at the time of entanglement)	Date 1st seen entangled	Intervention date	Entanglement type	Fate
Halo	PH	M	N (3 months)	06/05/2016	10/05/2016	Rope around body and through the mouth	Disentangled during boat approach by senior wildlife officer. Seen alive ~2 years post entanglement. Halo was last seen 24/08/2018. It is not uncommon for calves to wean at two years old in this community, therefore Halo could have emigrated when weaned or has died.
Joy	DW	F	A	10/05/2016	–	Monofilament line around dorsal fin	The line cleared without intervention within two days of observation.
Goose	DW	F	J	02/05/2017	–	Line/rope cutting into left fluke	No intervention. Observed without line 28/03/2018. Entanglement did not result in amputation of any part of the fluke.
Luca (Fig. 2)	DW	M	C (11 months)	10/02/2019 18/04/2019 (pectoral fin) 14/06/2019 (dorsal fin) 11/08/2019	26/02/2019 08/08/2019 23/08/2019	Monofilament line around body, dorsal and pectoral fins. Second entanglement much worse than first and amputating dorsal fin from both sides.	Luca died during the last intervention while given a sedative while surgically removing his dorsal fin to prevent re-entanglement. X-rays and post-mortem exam revealed that right pectoral fin was significantly more damaged than first suspected. The shoulder joint had an infection that spread to adjacent bones causing septic arthritis and osteomyelitis. DBCA came on site (PH) to assess the entanglement on 20 and 22/05/2020 but no intervention.
Brave	PH	M	C (13 months)	09/05/2020	–	Monofilament line in right pectoral fin.	River was with her first-born calf, Merak, born in May/June 2019 at the time of entanglement. DBCA came on site 21/08/2020 to assess entanglement but no intervention. Remains entangled (23/01/2023).
River (Fig. 1)	PH	F	A	08/06/2020	–	Monofilament line in right pectoral fin.	Disentangled by DBCA but not seen since. Presumed dead.
Jemo	PH	M	C (9 months)	22/11/2020	27/11/2020	Braided fishing line on both sides of the body, travelling through the mouth and cutting into dorsal fin.	Reported by professional fishermen as 'a baby dolphin weighted down by line and hooks'. On the day of reporting DBCA and fisheries officers looked for the calf. 7/10/2021 DBCA officers attended the Peel-Harvey Estuary to look for the entangled calf with other staff on standby. No further disentanglement attempts were made and the calf is presumed dead as the mother has been observed without Meelan and has produced a new calf.
Meelan	PH	M	C (18 months)	28/09/2021	–	Braided fishing line around right tail fluke.	

commercial fishing gear. Five of the entangled dolphins belonged to the PH community and three to the DW community. Five individuals were calves, one a juvenile and two adults at the time of becoming entangled. Four individuals (i.e., Joy, Goose, Brave and River) had an entanglement only involving distal body parts of which three were confirmed to have resolved without intervention (i.e., line confirmed no longer to be present). The fourth, an adult female, remains entangled (confirmed 16 April 2023) with line embedded in her right pectoral fin since June 2020 (Fig. 1). One individual, a three-month-old male calf (Halo), had rope around his body with his mouth also engaged in the entanglement. This was considered a life-threatening entanglement due to the potentially impaired ability of the calf to feed (Wells et al., 2008). Intervention in this case was successful with the calf observed alive and apparently well more than six weeks post intervention, a threshold suggested for short term success (Wells et al., 2013). In 2020, another male calf, Jemo, was observed entangled in braided fishing line with intervention to remove the line occurring five days later. This calf was reported to be in poor body condition and has not been observed since the disentanglement. Given regular monitoring of the dolphin community, if an individual is not observed for six months it is assumed to have died or permanently emigrated. As such, given the circumstances prior to Jemo's disappearance, he is now considered deceased. Another male calf, Meelan,

was reported entangled in fishing line and hooks, but was not located for intervention and has not been seen since. He is also now considered deceased.

The most complex fishing line entanglement was a year-old male calf, Luca, who was observed entangled in fishing line on 10 February 2019 (Table 1, Fig. 2). On 26 February, Luca was captured, and the line successfully removed from around his body. Unfortunately, two months after the intervention, Luca was observed entangled again on his pectoral fin. Two months on, without intervention, his dorsal fin became engaged in the entanglement. A second intervention took place to remove the line with the fishing line showing extensive biofouling. Only days after the removal of the second entanglement, Luca was entangled again. The previous entanglements had resulted in a deep notch in the leading edge of the dorsal fin, which was prone to catching more line and other debris (Fig. 2). A decision was made to amputate the dorsal fin to prevent further entanglement. Unfortunately, during this intervention, Luca died. The post-mortem exam revealed that the damaged pectoral fin had resulted in a shoulder joint infection that had spread into adjacent bones (Table 1). This infection would have led to Luca's eventual death (Personal communication, Dr. Nahiid Stephens).

My observations indicate that fishing line entanglements that only engage distal body parts are likely to resolve without intervention or are



Fig. 1. An adult female resident to the Peel-Harvey Estuary in Western Australia was observed entangled in fishing line on 8 June 2020. There has been no intervention and she was confirmed still entangled on 16 April 2023. Photograph, taken 29 July 2020, courtesy of Mandurah Volunteer Dolphin Rescue Group.

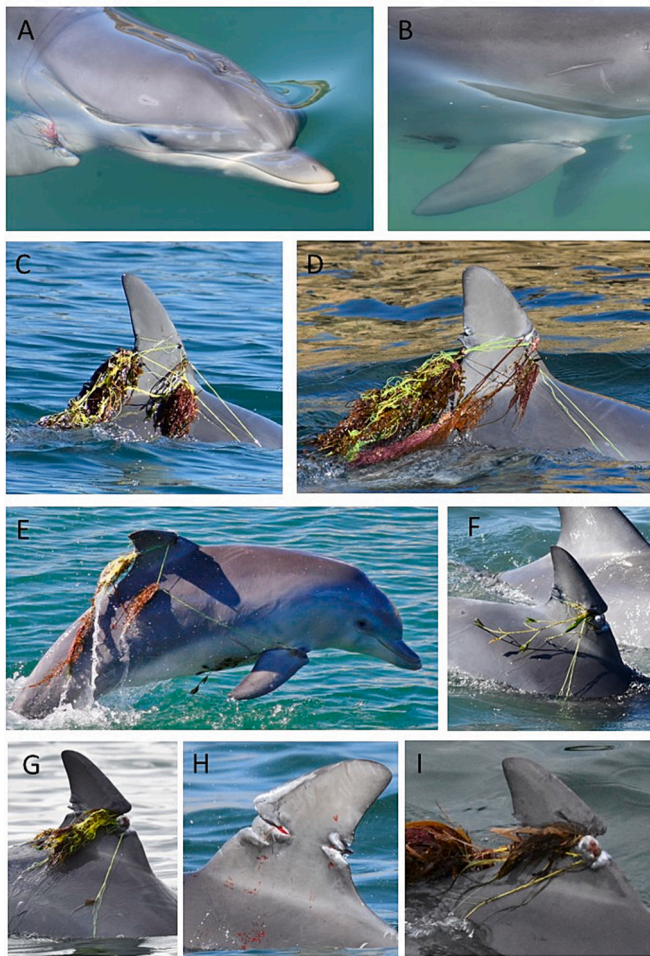


Fig. 2. Progression of fishing line entanglement on a male calf, Luca, who has high site fidelity with his mother to one of the entrance channels to the Peel-Harvey Estuary in Western Australia. Luca was first observed entangled in fishing line on 10 February 2019. Given he was a growing calf, and the entanglement circumvented the body and engaged the mouth (panel A, taken 26 February), an intervention took place to remove the fishing line. He was entangled again on his pectoral fin on 18 April 2019 (panel B, taken 18 April). On 14 June 2016, the entanglement engaged the dorsal fin (panel C, taken 18 June) causing tissue damage that progressively got worse (panel D, taken 8 July; panel E, taken 14 July; panel F, taken 31 July). Between June and August, extensive biofouling was observed on the line resulting in further damage to the pectoral and dorsal fins (panel G, taken 4 August). Luca was captured and disentangled again on 8 August (panel H, taken 8 August) only to be observed entangled yet again on 12 August (panel I, taken 14 August). He was captured again to remove the entanglement and to amputate the dorsal fin to decrease the risk of re-entanglement. Unfortunately, Luca passed away during the third intervention. All photos courtesy of Mandurah Volunteer Dolphin Rescue Group.

unlikely to result in mortality. Wells et al. (2008) made similar conclusions from their observations of dolphin entanglements in Florida, USA. However, as seen in this study, if the entanglement is causing tissue damage close to the shoulder joint, the joint and adjacent bones are susceptible to infection that may further compromise the individual's health and lead to death. Although not observed in this study, restrictive entanglements involving both tail flukes and/or the tail stock should also be considered life threatening (Wells et al., 2008). It is also noteworthy, as observed in Luca's entanglement, that if the entanglement results in deep notches in the dorsal or pectoral fins, the probability of re-entanglement is high. As such, a quick disentangling response is crucial, especially when braided fishing line, which cuts through tissue faster than monofilament line, is involved (see Barco et al., 2010).

The immediate threat from recreational fishing gear entanglements documented during this study to the viability of the Peel-Harvey Estuary dolphin population is low. This is as the individuals whose deaths were attributed to entanglements were immature males. Should entanglements result in mortality of reproductive females, there would be a more direct threat to the estuarine community's long-term viability. Modelled population trajectories with varying demographic parameter values showed that a 10 % decrease in adult female mortality (i.e., no more than an average of one adult female mortality each year), or 5 % in adult female and 10 % in calf (less than one-year-old) mortality will still achieve a positive population growth rate and maintain the Peel-Harvey Estuary dolphin community at approximately 90 individuals (Nicholson et al., 2023). As such, there is concern for the adult female who remains entangled. Although not confirmed whether related to her ongoing entanglement, her male calf at the time of entanglement has not been observed in the population since October 2021 (when he was two years old) and she lost her second calf a few months after giving birth in late 2022. Wildlife managers should apply a precautionary approach in entanglement intervention decision making. This is as mortalities may quickly change the trajectory to a declining population over time (Manlik et al., 2016; Lacy et al., 2021; Nicholson et al., 2023) while successful interventions directly lead to higher population growth rates due to mature females successfully breeding post intervention (McHugh et al., 2021).

Even when entanglements do not pose a risk to population or species viability, or it is unknown whether they do, the welfare implications for entangled individuals need to be considered (Butterworth et al., 2012). Fishing gear entanglements and ingestion have shown to cause injury, pain, starvation and disruption to normal behaviour patterns of affected individuals who commonly suffer amputation of distal body parts (Wells et al., 2008; Cassoff et al., 2011) and infection arising from entanglement wounds (e.g., this study). They may also have restricted ability to forage or feed normally (Miketa et al., 2017) and experience disrupted social relationships (Wells et al., 1998; Miketa et al., 2017; Greenfield et al., 2021). As such, entangled dolphins are often in a state of poor welfare.

Given the individual welfare considerations and the potential population level impacts that entanglements in fishing gear may have, it is important that incidents are managed by government agencies that administer biodiversity conservation and animal welfare legislation. In Australia, state and territory governments are responsible for conservation and protection of whales and dolphins in coastal waters (< 3 nm offshore). The National Guidance on the Management of Whale and Dolphin Incidents in Australian Waters (2013) provides for an overarching framework for dolphin incident (i.e., strandings and entanglements) management. This framework is intended to be used together with local standard operating procedures (SOPs) and places responsibility to state and territory governments to maintain a state of preparedness to whale and dolphin incidents. In Western Australia, at the time of writing, the relevant public offices for incident management are the Department of Biodiversity, Conservation and Attractions (DBCA), that administers the *Biodiversity Conservation Act 2016*, and the Department of Primary Industries and Regional Development (DPIRD) that administers the *Animal Welfare Act 2002*. DPIRD and DBCA have worked together for decades to mitigate and respond to whales entangled in commercial rock lobster gear off the coast of Western Australia (Groom and Coughran, 2012; How et al., 2021). In comparison, the number of mortalities and the lack of response, or relatively long response times, for known entangled individuals that are resident to an area, well-studied and observed regularly, gives the impression that preparedness to dolphin entanglements is not adequately resourced in Western Australia. A proactive and concerted effort is required from the state government to adequately resource dolphin entanglement response. This includes developing informed policy and decision-making tools that incorporate animal welfare (e.g., Nicol et al., 2020) and ensuring enough personnel is appropriately trained and given the

correct tools to successfully disentangle dolphins. DBCA is currently preparing Marine Fauna Incident Standard Operating Procedures (Personal communications, Mark Cugley, DBCA), which will guide dolphin incident response in the state. I acknowledge that responding to dolphin entanglements is a complex task where human safety must remain the highest priority. As such, it is evident that interventions are not always possible (e.g., offshore or in deeper waters). However, when entangled individuals are well-known and frequently sighted in shallow and calm waters (e.g., estuaries) and their entanglement warrants intervention (e.g., entanglement involves the mouth), incident response should be immediate, follow established protocols and involve adequately trained personnel with appropriate equipment.

Beyond responding to dolphin entanglements, it is vital to identify the source of fishing gear involved in entanglements and to work on preventative measures. Here, the source of the problem could be either derelict or active fishing gear. Currently, the Western Australian government with stakeholders run a 'Reel it in' program, launched in 2013, which educates the public in responsible use and discarding of fishing gear. This campaign has provided sixty-five dedicated fishing line bins in popular fishing locations in the Perth metropolitan area and in Mandurah. The government also engages the public on impacts of discarded fishing gear on wildlife through a citizen science program, Dolphin Watch, launched in 2010, and supports regular coastal and waterways clean-ups. Unfortunately, even with this effort, the number of entangled dolphins and those resulting in mortality are still relatively high. As such, I propose further collaboration between DBCA and DPIRD, who manages recreational fisheries, and RecFishWest, the main body representing recreational fishers in Western Australia, to find solutions to reduce not only dolphin, but other wildlife entanglements in recreational fishing gear. Fishers need to be continually engaged and educated (e.g., Cowx et al., 2010), for example to reel their lines in where non-target wildlife is present and to appropriately discard of their fishing gear. Education on using gear that biodegrades faster and causes less severe injuries to wildlife (e.g., using monofilament instead of braided fishing line, see Barco et al., 2010) is also required.

This study shows that entanglements in recreational fishing gear are a threat to estuarine and coastal dolphins, and their welfare, in Australia. Management decision making should consider entanglements involving dolphin's mouth, shoulder joint(s), both tail flukes and/or the tail stock as life threatening. It should also be noted that quick response times lower the risk of re-entanglement by preventing the formation of deep wounds that would repeatedly catch more line or debris. Management action should be triggered not only by species conservation status or when there is a threat to population or species viability, but also by the threat to individuals' health and welfare. Government agencies responsible for wildlife management and welfare, with appropriate stakeholders, should work together to maintain a state of preparedness. This involves responding to dolphin entanglements and taking preventative action, such as educating fishers, conducting regular clean-ups and advocating for altered gear use, to lower the risk of dolphin entanglements in recreational fishing gear.

CRedit authorship contribution statement

Krista Nicholson: Conceptualization, Investigation, Data curation, Writing – original draft, Writing – review & editing, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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