Disentangling entanglement in Cape fur seals for better management of plastic pollution impacts

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February 2023

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Abstract

Marine litter is a widespread issue threatening marine biodiversity and coastal economies. Entanglements and ingestion are among the most common impacts of marine litter on wildlife. While most marine litter is assumed to come from land-based sources, marine items such as fishing gear tend to be responsible for most entanglement incidents. Entanglement is a frequent threat to pinniped species leading to suffering and potential death of affected individuals. I use a long-term dataset to investigate temporal trends in entanglement rates as well as to describe the most common material, type and probable source of entanglements of Cape fur seals (*Arctocephalus pusillus pusillus*) in the Victoria and Alfred (V&A) Waterfront and broader Cape Town harbour area. Between 1986-2018, 5843 entanglements (annual mean and standard deviation: 177±166) were recorded through systematic surveys, of which 5530 contained descriptive data relating to entanglement type. From 1994-2018 the number of seals checked, as well as the number of entangled seals were recorded. The mean entanglement rate, calculated as the total number of entanglements observed divided by the total number of seals checked, was 8% (range per year: 3–17%, n= 4488 entangled seals). This is the highest entanglement rate reported for a pinniped, albeit in a highly modified environment. Entanglement rates increased from 2007-2009, with a peak in 2009, and decreased to below 1990s levels in 2016. Significantly more seals were entangled in winter (rainy season) than in summer. Most entanglement items were made of plastic, with fishing line, rope and packing straps most commonly observed. The proportion of packing straps and rope decreased slightly in recent years, whereas the proportion of fishing line was relatively constant. Items associated with fishing and/or shipping activities accounted for 67% of entanglement cases, with fishing gear alone responsible for 33%. Offshore activities as well as the harbour itself were probable sources of most entanglement items, although a large storm drain that enters the harbour from central Cape Town probably also contributes to the problem. Key management interventions include education programmes targeting harbour employees and fishermen about the adverse impacts of marine litter, and implementing guidelines on appropriate waste disposal in the harbour. Putting up signage where seals commonly haul out highlighting the entanglement problem may also improve waste disposal habits. The V&A Waterfront is one of South Africa’s leading tourist destinations and provides an opportunity to reach a large audience about the negative impacts of littering.

Introduction

Global annual plastic production has increased from 1.5 million tonnes to over 350 million tonnes in the past 70 years (Plastics Europe, 2015; Li et al., 2016; Tiseo, 2022). Due to its high production, poor waste management and longevity, plastic debris now makes up the majority of all marine litter, which is a global environmental issue with significant impacts on both marine life and the economy (Barnes et al., 2009; Bergmann et al., 2015; Derraik, 2002). Their versatility, durability and low weight make plastics attractive materials both for domestic and industrial uses (Franco-Trecu et al., 2017; Ryan et al., 2009). Since the 1960s plastics have replaced most of the natural fibres that were used for fishing gear, making recreational and commercial fishing activities a major source of plastic pollution in the ocean (Derraik, 2002; Kim et al., 2016). An estimated 640 000 tonnes of fishing gear is discarded and/or lost into the ocean yearly (Li et al., 2016). Fishing gear like fishing lines, ropes and nets are extremely long-lived and robust and are able to both persist in the marine environment and be transported through ocean currents far from their original source (Butterworth, 2016; Ryan et al., 2009). This leaves even the most remote areas in the world vulnerable to marine litter and its associated threats, with entanglement and ingestion the most common impacts (Barnes et al., 2009; Kühn et al., 2015).

Marine litter enters the ocean from both land-based and ocean-based sources but it is assumed that currently most marine litter stems from inappropriately discarded land-based domestic and industrial waste (Beiras, 2018; Galgani et al., 2015). Rivers and stormwater drains transport a large proportion of land-based waste to the sea and the predicted increase in extreme weather events such as floods due to climate change may intensify the amount of litter entering the ocean, further threatening marine ecosystems (Ford et al., 2022; Wagner et al., 2019). Floods flush a large amount of litter down rivers and into the ocean (Van Emmerik et al., 2019). Ocean-based sources include intentional and/or unintentional waste disposal from ships and recreational and commercial fishing activities (Derraik, 2002; Sheavly & Register, 2007). However, non-fishery waste is difficult to assign to shipping/offshore sources which may limit mitigative action (Ryan et al., 2019). Annex V of the International Convention for the Prevention of Pollution from Ships (Marine Pollution 1973 and 1978 (MARPOL 73/78)) aims to reduce litter from ships and prohibits disposal of all plastics in the ocean (Gold et al., 2013; Henderson, 2001). In spite of its implementation in 1989 and it being ratified by over 139 countries, the source of entanglements continue to be dominated by fishing gear, indicating that large amounts of gear is still being lost into the ocean (Chen & Liu, 2013; Derraik, 2002; Waluda & Staniland, 2013).

Documented effects of marine litter have been reported for at least 800 species, however this is clearly a minimum estimate because ingestion is increasingly pervasive due to the abundance of microplastics (especially microfibres) in marine environments (Cole et al., 2011; Gago et al., 2018; Kühn et al., 2015). Several of the species impacted by marine litter are listed as threatened by the IUCN Red List (Gall & Thompson, 2015; Jepsen & de Bruyn, 2019). The number of species affected by entanglement more than doubled from 136 species to 344 species between 1997 and 2015, with seals (pinnipeds) among the groups most frequently affected by entanglements (Butterworth, 2016; Jepsen & de Bruyn, 2019; Kühn et al., 2015; Laist, 1997). If animals are unable to free themselves of the entanglement, their welfare and survival rates are greatly reduced (Fowler, 1987). In addition to the individual level impacts, increased mortality due to entanglements can have population-level effects (Senko et al., 2020). However, this is typically only in species already impacted by other threats or who have very small populations, such as the Mediterranean (*Monachus monachus*) and Hawaiian (*M. schauinslandi*) monk seals (Henderson, 2001; Karamanlidis et al., 2008).

The vulnerability of seals to entanglement may be due to their curious and playful nature, which is especially prevalent in juveniles (Butterworth, 2016). In addition to juveniles interacting more (through play) with marine debris, they are smaller, which can increase their chance of getting entangled because there are more small than large litter items, so larger animals have a lower risk because they are too big to be easily entangled in small items (Feldkamp & Costa, 1971; Lawson et al., 2015). While both phocid (earless) and otariid (eared) seals are susceptible to entanglement, otariid seals are more vulnerable (Butterworth, 2016), which may be due to their thicker fur (increasing the chance of objects getting stuck) as well as their swimming action (Curtis et al., 2021). Otariids use their fore flippers more than phocids when swimming, increasing their chance of getting entangled (Adam, 2009).

Fishing gear such as fishing lines, ropes and fishing nets make up the majority of entanglement items (Allen et al., 2012; Franco-Trecu et al., 2017; Li et al., 2016). Animals can get caught as bycatch (in active fishing gear) as well as get entangled in Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG) and it can be difficult to distinguish entanglement from bycatch (Laist, 1997). A particular concern with ALDFG is that it has the ability to be displaced long distances by currents and continue to entangle individuals for a prolonged period (Randall, 2020). Packing straps, which are used on containers such as packages and bait boxes, are also commonly found entangling marine animals (Hogan & Warlick, 2017). Looped items (such as packing straps and some fishing lines when tied into loops) are especially problematic as they are more likely to entangle animals if not cut before disposal (Butterworth, 2016).

Seals typically are entangled around the neck and upper body, which may alter their behaviour and movement (Curtis et al., 2021). Because their movement may be impeded (e.g. through increased drag), entangled animals tend to have reduced foraging efficiency and therefore have to spend longer foraging for food (Allen et al., 2012; Feldkamp & Costa, 1971). Additionally, entangled seals may have a higher predation risk as they are less able to escape predators (Laist, 1987). They also have a greater chance of getting stuck on fixed objects and the entanglements themselves may cause wounds, which can lead to severe infections (Laist, 1997).

Long-term monitoring of entanglements helps to identify trends in the type and source of material which most commonly entangles marine animals. This can be used to understand the abundance of marine litter that is particularly prone to cause entanglement (Kuzin & Trukhin, 2019). By identifying the source of the entanglement material we can implement targeted and effective mitigation efforts (Lawson et al., 2015). In addition, we can investigate the effectiveness of mitigation efforts through long-term monitoring (Henderson, 2001). Seals can be used as indicator species to monitor the effects and trends of marine litter as they spend more time on land relative to other marine animals and can therefore be easier to observe (Kirkman et al., 2016). Long-term monitoring also increases our understanding of the spatial and temporal trends in global entanglement rates, which are currently lacking due to skewed research effort, unsystematic and restricted monitoring and reporting bias as well as sampling bias (Butterworth, 2016; Jepsen & de Bruyn, 2019). Thus, to understand the magnitude of entanglement and its effect on seal populations, contributions to this area of research is encouraged when data are available.

Entanglement rates differ depending on the overlap between marine litter, fishery activity and seal abundance (Boren et al., 2006; Page et al., 2004). Seal species that live in areas close to human activity (e.g. urban areas and fishing grounds) or areas that have high litter accumulation rates (due to ocean currents and shallow reefs) tend to have higher entanglement rates (Boren et al., 2006; Harcourt et al., 1994). Challenges to monitoring entanglement rates in seals include the difficulty in detecting entanglements because 1) entangled seals underwater will not be counted (Raum-Suryan & Suryan, 2022); 2) dead animals often will be unaccounted for (Laist, 1987); and 3) it can be difficult to detect entanglements in large aggregations of seals (e.g. in breeding colonies) (Curtis et al., 2021). In terms of reporting entanglements, 1) rates are often underestimated due to the above difficulties in detecting them (Boren et al., 2006); 2) entanglement rates are sensitive to the number of seals as well as the amount of litter (McIntosh et al., 2015) and 3) it is difficult to distinguish entanglements from bycatch (Ryan, 2018). In addition, methods of reporting entanglements and calculating entanglement rates vary, complicating comparisons among studies (McIntosh et al., 2015). Calculations of entanglement rates often exclude search effort or assume a consistent effort over time, which may lead to inaccurate estimates of long-term trends (Arnould & Croxall, 1995; Fowler, 1987; McIntosh et al., 2015).

The few long-term studies of seal entanglement rates show variable trends, but studies mostly show a decrease over the last two decades (Table 1). Kuzin & Trukhin (2019) reported a varied trend in entanglement rates of Northern fur seals (*Callorhinus ursinus*) during their study period. However, entanglement data had been collected on Tyuleniy Island in the Sea of Okhotsk since 1975 and compared to entanglement rates reported (and previously published) from the 1970s to the 1990s the current entanglement rates show a decreasing trend (Table 1). They also noted a reduction in the proportion of entanglements caused by drift nets after their ban in 1992 (66% pre-ban, 44% between 1998-2013). Hofmeyr (2002) noted an increase in entanglement rates of Subantarctic (*Arctocephalus tropicalis*) and Antarctic (*A. gazella*) fur seals once longline fishing started around Marion Island in the mid-1990s, which is also when entanglements in fishing line were first recorded. However, packing straps accounted for most entanglements throughout the study period, suggesting that the increase in entanglement rates may have been attributed to the use of packing straps (around bait boxes) by longliners.

Table 1: *The author(s), location, study period (listed in order of end year), species and entanglement trend from long-term entanglement studies of seals.*

Author	**Location**	**Study period**	**Species**	**Entanglement trend**
Stewart and Yochem (1987)	San Nicolas and San Miguel Islands	1978-1986	Northern elephant seal[1]	Increasing
Stewart and Yochem (1987)	San Nicolas and San Miguel Islands	1978-1986	California sea lions[2]	Increasing
Stewart and Yochem (1987)	San Nicolas and San Miguel Islands	1978-1986	Harbour seal[3]	Increasing
Hanni and Pyle (2000)	Farallon Island, California	1976-1998	Northern elephant seal	Decreasing
Henderson (2001)	North-western Hawaiian Islands	1982-1998	Hawaiian monk seal	Decreasing
Hofmeyr et al. (2002)	Marion Island	1991-1999	Subantarctic fur seals	Increasing
Hofmeyr et al. (2002)	Marion Island	1991-1999	Antarctic fur seal	Increasing
Boren et al. (2006)	Kaikoura, New Zealand	1995-2005	New Zealand fur seal[4]	Decreasing
Waluda and Staniland (2013)	Bird Island, South Georgia	1989-2013	Antarctic fur seal	Decreasing
McIntosh et al. (2015)	Seal Rocks, Australia	1997-2013	Australian fur seal[5]	Decreasing
Kuzin & Trukhin (2019)	Tyuleniy Island, Russia	1998-2013	Northern fur seal	Decreasing

[1] *Mirounga angustirostris*
[2] *Zalophus californianus*
[3] *Phoca vitulina*
[4] *Arctocephalus forsteri*
[5] *Arctocephalus pusillus doriferus*

Cape fur seals (*Arctocephalus pusillus pusillus*) are endemic to southern Africa, with a range spanning from southern Angola, along the Namibian coast to south-eastern South Africa (Miller et al., 1996). Their breeding colonies have increased from 23 in 1973 to 40 in 2009 with an estimated population size of 1.7 million individuals (Hofmeyr, 2015; Kirkman et al., 2013). Although their breeding range has expanded, their population size has remained stable since the 1990s (Kirkman et al., 2016). The 16 breeding colonies in South Africa support about 40% of the total population (~680 000 individuals) (Kirkman et al., 2013). Cape fur seals are generalist predators that forage in both pelagic and benthic waters, feeding on a variety of fish species, seabirds, cephalopods and marine arthropods (Botha, 2022; De Bruyn et al., 2005; Mecenero et al., 2006). Roughly two thirds of their prey consists of commercially important fish species, resulting in a distributional overlap between fishing vessels and Cape fur seals (Kirkman et al., 2019; Mecenero et al., 2006).

The only published articles on entanglements of Cape fur seals are 41 years apart: Shaughnessy (1980) reported entanglement rates ranging from 0.34% (Seal Island, False Bay, South Africa) to 0.66% (Cape Cross, Namibia) among immature Cape fur seals harvested at breeding colonies in 1979. Entanglements resulted from fishing line, string, packing straps, rope, fishing nets, wire and rubber O-rings. Curtis et al. (2021) based entanglement rates on field observations between 2018-2019 at two Namibian colonies, and were similar at Cape Cross (0.15%) and Pelican Point (0.17%). Fishing line, rope and packing straps were identified as the most common entanglement types. Additionally, a recent study based on observations of entanglements at six Cape fur seal colonies in South Africa between 2019-2022 recorded entanglement rates between 0.05%-0.24%, with a rate of 0.12% at Seal Island, False Bay (Maguiña, 2022, unpublished work). Although sampling methods differ between the studies, there may have been, if anything, a decrease in entanglement rates over the four decades since 1979 at both Cape Cross and Seal Island.

I use a long-term dataset (1986-2018) to investigate temporal trends in the types and rates of entanglement of Cape fur seals in Cape Town harbour. The area is used as a haul out location for a group of almost exclusively young males avoiding being harassed by territorial bulls at breeding colonies (Kirkman et al., 2016; Shaughnessy & Chapman, 1984). The objectives of this study are to: 1) investigate the long-term trends in entanglement rates of Cape fur seals in the Cape Town harbour area; 2) test if entanglement rates increase in winter, when seasonal rains increase litter loads in coastal waters; and 3) characterise and identify entanglement items, assess whether their composition has changed over time, and infer the main sources of entangling litter. I also make management recommendations to reduce entanglement rates and protect the welfare of Cape fur seals.

Methods

Study site

Entanglement of Cape fur seals was investigated in the Cape Town harbour area between 1986-2022 (Figure 1). Most observations come from the V&A Waterfront (-33.9067, 18.4216), a 123 ha-area in South Africa's oldest working harbour developed for recreational and commercial purposes (Nombembe, 2015). The V&A Waterfront is one of South Africa's top tourist destinations (Ferreira & Visser, 2007). Public awareness has primarily enabled the long-term monitoring of entanglements because they are both a visible form of pollution and animal suffering. The Port of Cape Town sits on a busy trade route around the tip of Africa (Troch et al., 2021). It is a large container port and important economic activities include fresh fruit export, maintenance- and repair facilities (for fishing fleets and the West African oil industry) and both recreational and commercial fishing (Kilian & Dodson, 1996; Okoro et al., 2013). Despite being heavily urbanised, Cape fur seals, Cape clawless otters (*Aonyx capensis*), humpback whales (*Megaptera novaeangliae*), Dusky (*Lagenorhynchus obscurus*), Heaviside's (*Cephalorhynchus heavisidii*) and common (*Delphinus delphis*) dolphins as well as many sea- and coastal birds frequent the area.

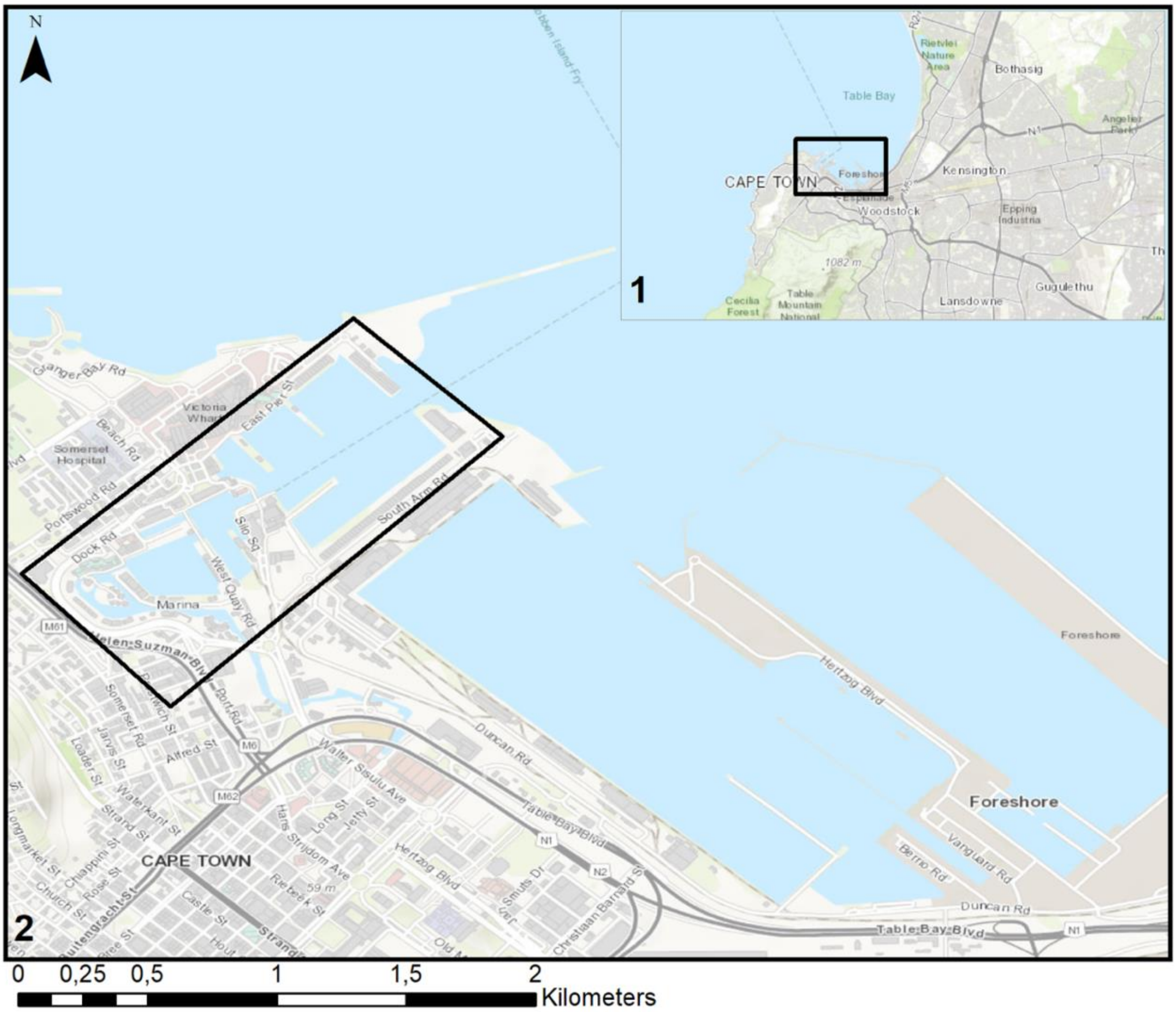


Figure 1: *Site map of 1) study site location within the city of Cape Town and 2) specific survey location (within boundary) in the Cape Town harbour.*

Data collection

As a part of their seal monitoring programme, the Marine Mammal Research Group of the Department of Forestry, Fisheries and the Environment (DFFE) and Two Oceans Aquarium (TOA) have collected data on Cape fur seal entanglements in the Cape Town harbour since the 1980s. Sampling first started in 1983, but effort was patchy and reporting unsystematic, so I excluded data from 1983-1985. From 2019 entanglement events were only recorded if the entanglement was removed (as opposed to recording all entanglements observed). Due to this change in reporting protocols, I only used data up to 2018. Surveys were conducted year round, on average 12.0±4.7 (SD) days per month. Surveys were run by a small group of staff members that had extensive experience in assigning seals to age classes. Surveys were conducted on foot, visiting haul-out locations of Cape fur seals and scanning from lookout points around the harbour. Entanglements were identified through direct observation, using binoculars, of hauled out seals. Entanglements were classified as such if the seal had a physical entanglement around its body; wounds and/or scars were not recorded as an entanglement. Hooks and spikes were excluded unless attached to a line and/or rope wrapped around a seal's body.

The number of entanglements were recorded throughout the study period (1986-2018) but the total number of seals checked was only recorded on each survey from 1994 (see Appendix 1 for supplemental text). For most sightings of an entangled seal the estimated age, entanglement item and whether the entanglement was removed was recorded. Seals were assigned to three age categories: juveniles (1-3 years); subadults (4-8 years); and adults (>8 years). Age classes are reported in results but since I have no population level age distribution to use to test whether one age class is more likely to be entangled, age classes were not included in any further data analyses. Entanglement items were divided into two categories; entanglement type (Table 2) and the inferred source of entanglement items. There are concerns about inferring source for many entanglement items. Fishing lines and nets are clearly derived from fishing activities but packing straps could be from either onshore or offshore sources, although shipping and fishing (for bait boxes) are both major users (Hogan & Warlick, 2017). Rope is probably mostly for marine use but can also be from onshore sources (Jang et al., 2014). Both single-use and multiple-use items are difficult to confidently assign to source (Jang et al., 2014; Ryan, 2020).

Efforts were made to remove entanglements whenever possible. Disentanglement methods changed over time with a move towards less invasive methods (from restraining the seal with a hoop net to cut off the entanglement, to swiftly removing entanglements with a long pole with a hook at the end used to cut and remove the entanglement). Most removed entanglement items were archived. Archived items were analysed separately to record the following data: entanglement material; the number of entanglements per seal; the type of entanglement item and its mass, length, width, thickness and buoyancy. Mass was recorded with an electronic scale to the nearest 0.1 g. Length was measured as the total length of the cut entanglement and recorded to the nearest 10 mm; width and thickness were recorded to the nearest 1 mm with Vernier callipers (for fishing line and rope, width and thickness did not differ). Buoyancy was tested by placing the entanglement item in a bowl of freshwater.

Table 2: *Categories and description of entanglement type.*

Type	Description
Fishing	Plastic fibre fishing line, loops and braided lines
Net	Meshed material used for fishing
Rope	All cord, string, twine and rope
Packing straps	Polypropylene plastic strap
Single-use items	Disposable items such as plastic bags, mesh, cable ties and tape
Multiple-use items	Items designed for multiple use such as clothing, rubber O-rings and gaskets

Data validation

To ensure standardised naming of entanglement type across such a long time-series, collected by multiple observers, the people that were involved in collecting the data were asked to name images of common entanglement items to ensure consistency of scoring. Repeat sightings of the same individual seal and whether multiple entanglements belonged to the same seal or not was sometimes noted in the data, but there were inconsistencies which made it unclear whether data entries of entangled individuals were unique or a repeated sighting and whether entanglements belonged to the same seal or not (see Appendix 1 for supplemental text). Therefore, duplicates were removed from the dataset where these were clearly indicated, however, I acknowledge that duplicates almost certainly remain.

Data analyses

Data handling and analyses were conducted in Microsoft Excel (version 16.58, 2022) and R version 4.2.2 (R Development Core Team, 2022) using R studio. Models were run in the 'emmeans' (Lenth, 2022) package and 'tidyverse' (Wickham et al., 2019) was used to create boxplots. Maps were made using ArcGIS software (Redlands, 2011). A significance level of <0.05 was used for all statistical tests.

Number of entanglements and number of removed entanglements

The total number of entanglements and the number of removed entanglements were used to investigate whether removals correlated with the number of entangled seals in each year as well as to calculate the proportion of entanglements removed.

Entanglement rate

Methods of calculating entanglement rates vary, which complicates comparisons between studies (McIntosh et al., 2015). I calculated entanglement rate from 1994-2018 by dividing the number of seals entangled per year by the total number of seals checked per year (rate = n_e/n_c), which is the standard method used to calculate entanglement rates (Allen et al., 2012; Curtis et al., 2021; Hanni & Pyle, 2000; McIntosh et al., 2015; Raum-Suryan & Suryan, 2022). Henderson (2001) reported an index of entanglement as opposed to a rate where he included search effort in his calculation of annual entanglements. Donohue and Foley (2007) and McIntosh et al. (2015) used the same index. Although this index corrects for variable search effort, it results in a much smaller number and is thus not comparable to the percentage of entangled animals (Henderson, 2001).

To test the effects of long-term trends in entanglement rates, years were divided into eight three-year blocks (except the first block, which was four years: 1994-1997). A generalised linear model with a quasi-binomial family was used to test for a long-term trend. Year block one, 1994-1997 was used as the baseline against which to compare other year blocks. I used post hoc pairwise comparisons using Tukey's HSD to test for significant differences among year blocks. I also tested whether there was any temporal auto-correlation between year blocks using the acf() function in R. A quasi-binomial family was chosen over binomial due to overdispersion (found by dividing the residual deviance by the degrees of freedom). To check whether season had an effect on the entanglement rate, records were divided into summer (November-April) and winter (May-October) in the same generalised linear model. Standard error was estimated following a binomial distribution.

Entanglement composition

A Pearson's χ^2 test for independence was used to test for differences in entanglement type between three-year blocks for the whole study period (1986-2018). Subsequently, the entanglement rate per type was used to investigate long-term trends in the composition of entanglements (1994-2018 only). Nets were grouped with rope in the analyses. "Other" items represented 0.5% of all entanglement items and were excluded from further analyses.

Entanglement material and measurements

I used the archived items to classify entanglement material and to characterise the dimensions of entangling items. Entanglement material was grouped into plastic, rubber and cloth. Length was reported for all entanglements as well as for the most common entanglement types. Mass, width and thickness were only reported for the most common entanglement types. Fishing lines tied into loops typically are thicker than non-looped fishing lines. Therefore, fishing lines were split into two groups (lines <1 mm and lines >1 mm in diameter) and the proportion of each group was recorded. To test if there was a significant difference in length, mass, width and thickness between entanglement types (fishing line, packing straps and rope), I used a Kruskal-Wallis test. This non-parametric test was chosen over a one-way ANOVA because the data were not normally distributed (histograms were used to check for normality). I used post-hoc pairwise Wilcoxon tests with correction for multiple testing (p.adjust.method is Benjamini-Hochberg) to see which groups differed.

Results

Number of entanglements and number of removed entanglements

A maximum of 5843 entanglements (annual mean and standard deviation: 177±166) were recorded through systematic surveys between 1986-2018 in the Cape Town harbour (Figure 2). Of these, 5530 contained descriptive data relating to entanglement type. The mean number of entanglements removed per year was 49±27, representing 28% (n=1615) of all entanglements. The percentage removed each year was weakly correlated with the annual number of entangled seals (R^2=0.2; Figure 3).

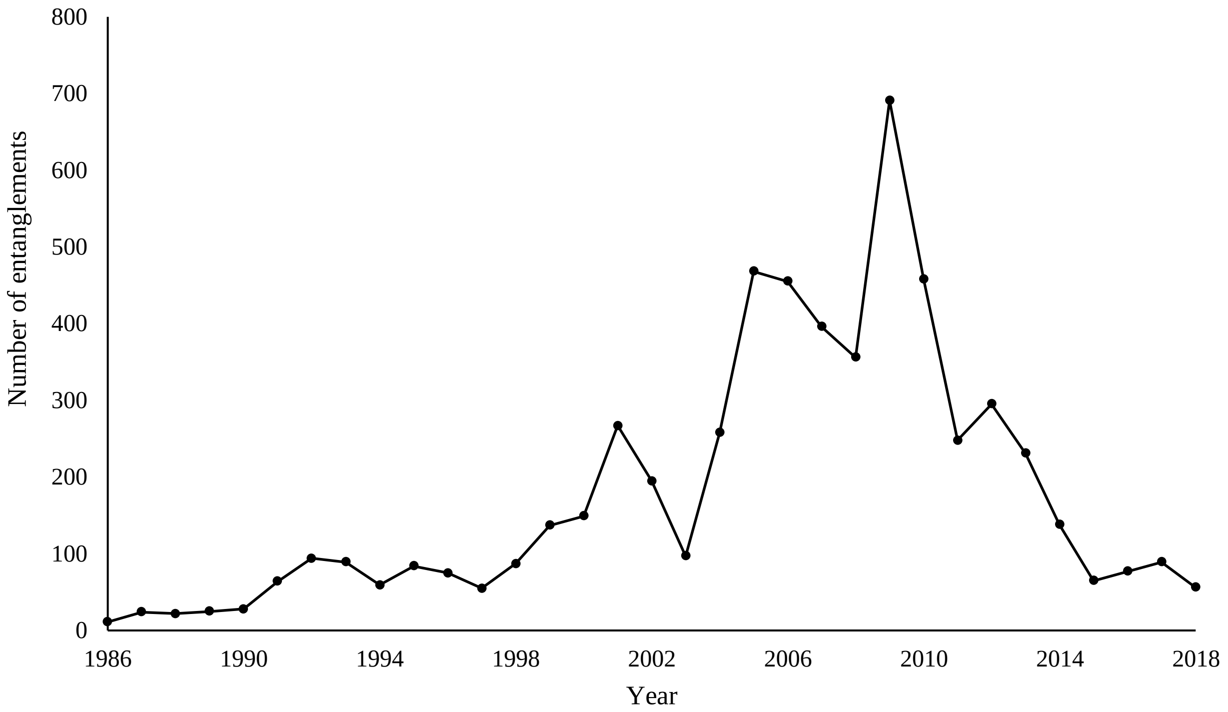


***Figure 2**: The number of entanglements of Cape fur seals in Cape Town harbour from 1986-2018.*

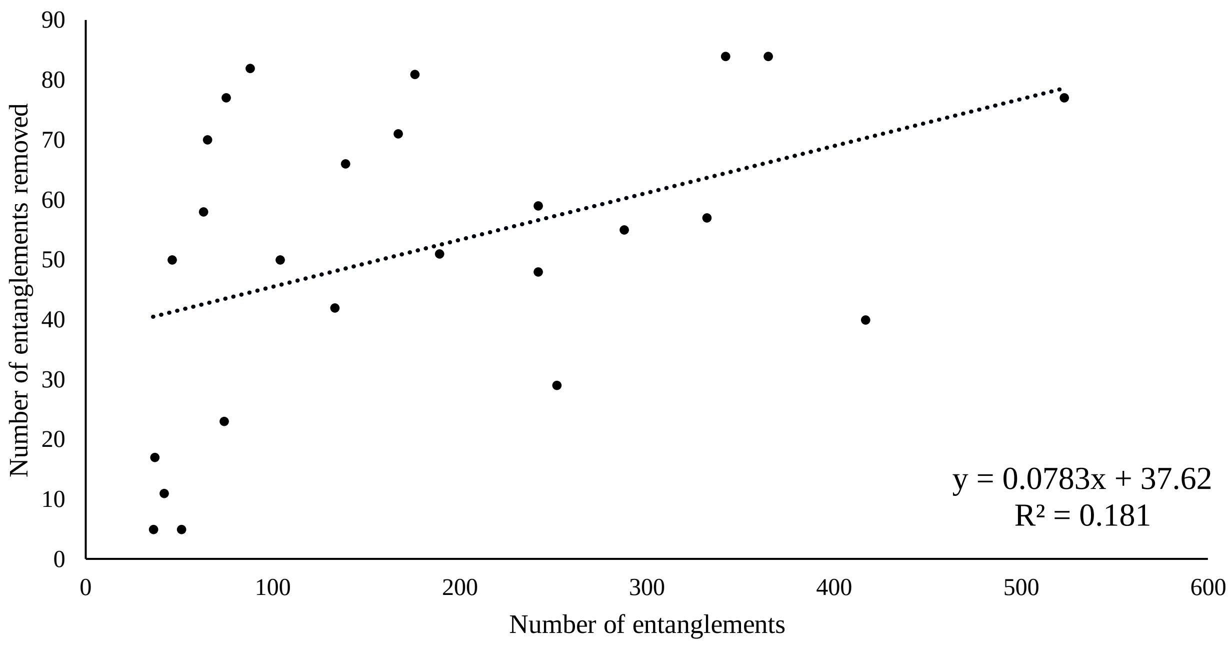


***Figure 3:** The annual percentage of removed entanglements versus the annual number of entanglements of Cape fur seals in Cape Town harbour between 1986-2018.*

Entanglement rate

Between 1994 and 2018, 4488 seals (180±136 per year) out of 56865 checked were recorded entangled through systematic surveys in the Cape Town harbour. The average number of Cape fur seals checked in the study area varied yearly (2275±1135) as well as monthly (4739±1792). On average, there were more seals in summer months (5471±93) than in winter months (4007±20) (Figure 4). Age of seals was recorded in 5245 cases between 1986-2018: 9% (n=482) juveniles, 66% (n=3440) subadults and 25% (n=1323) adults.

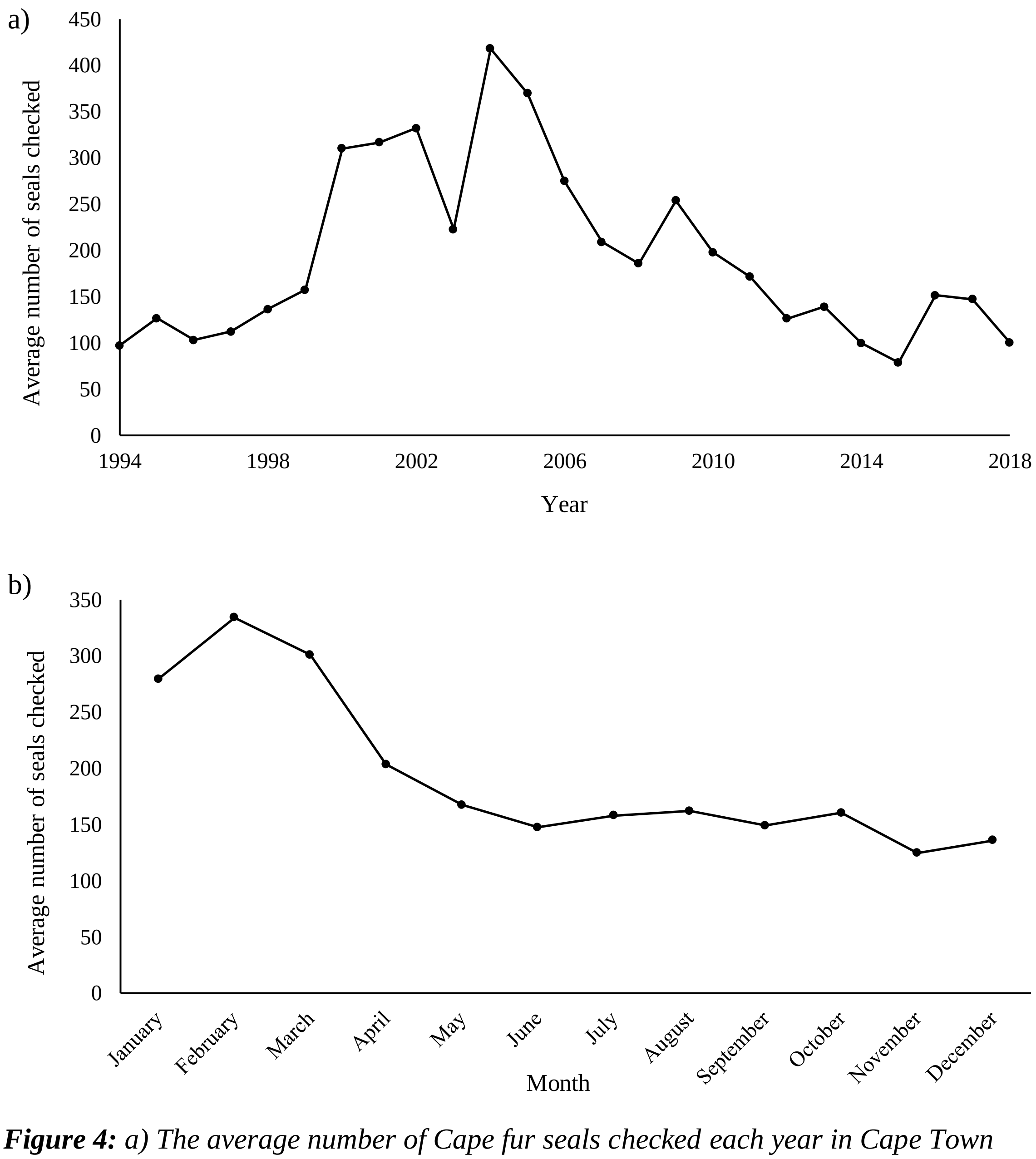


Figure 4: *a) The average number of Cape fur seals checked each year in Cape Town harbour between 1994-2018 and b) the average number checked each month.*

Entanglement rates of all three-year blocks ranged from 3% to 17%, with a mean of 8±4% (Figure 5, see Appendix 2 for yearly entanglement rates). The entanglement rate remained relatively constant between 1994 and 2006, more than doubled in 2007-2009, then declined (Figure 5). Entanglement rates were significantly higher from 2007-2015 than 1994-1997 (Table 3). The only time the rate was lower than between 1994-1997 was between 2016-2018 ($p<0.05$,Table 3). Post-hoc pairwise comparisons showed that entanglement rates were significantly higher between 2007-2012 than in other year blocks ($p<0.05$). Rates were also significantly higher between 2013-2015 than 1998-2000 and 2007-2009 ($p<0.05$). There was no temporal autocorrelation among year blocks (lags stayed within the 95% confidence interval indicating values significantly close to zero: -0.58 to 0.44). Season had a significant effect on entanglement rates, with higher entanglement rates in winter than in summer (Table 3).

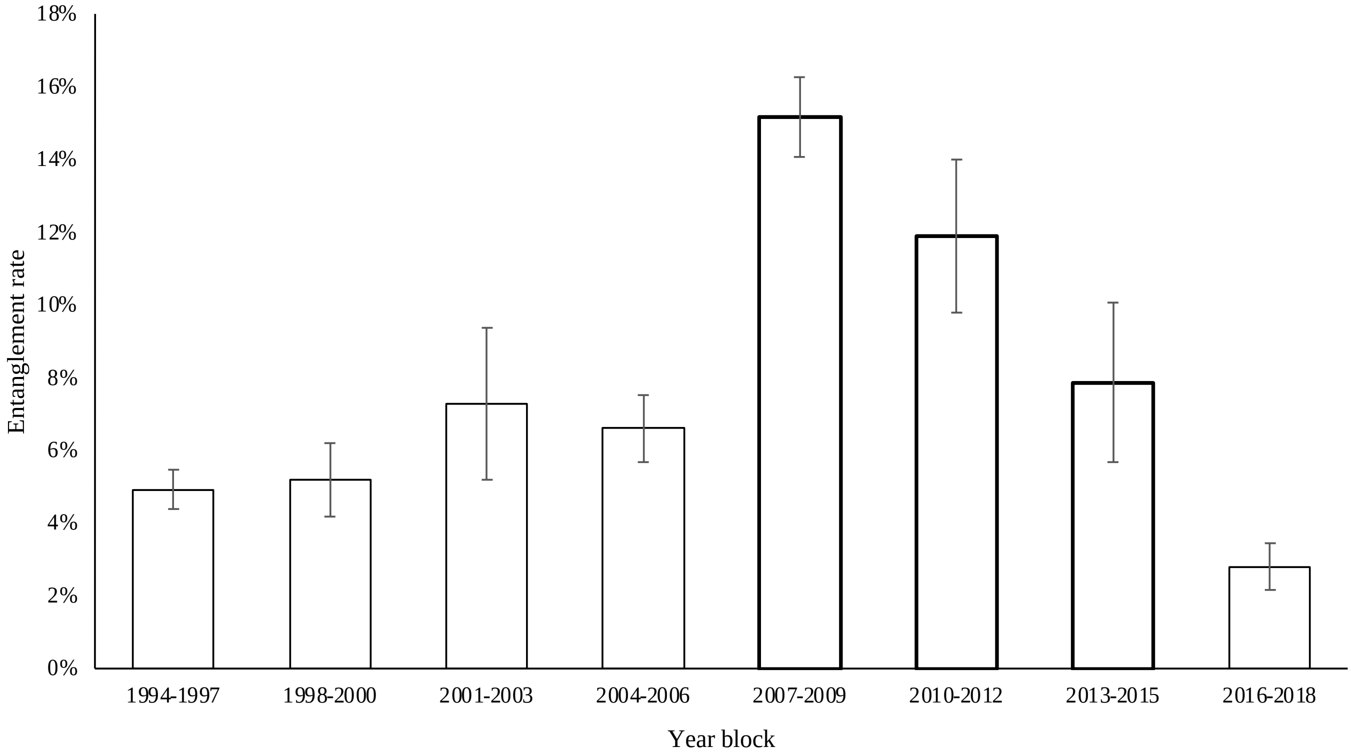


Figure 5: *Entanglement rates of Cape fur seals in the Cape Town harbour between the eight year blocks from 1994 and 2018. Bars in bold indicate year blocks where rates were significantly higher than in other year blocks. Error bars represent standard error.*

Table 3: *Generalized linear model output with a quasi-binomial family testing the effect of long-term and seasonal effects on entanglement rates of Cape fur seals in Cape Town harbour relative to 1994-1997 and summer. Values in bold indicate significant effects.*

Factor	Estimate	SE	t-value	P-value
Intercept	**-5.70**	**0.17**	**-32.10**	**<0.05**
winter	**0.32**	**0.08**	**3.83**	**<0.05**
1998-2000	0.00	0.21	0.01	0.98
2001-2003	0.26	0.19	1.36	0.17
2004-2006	0.26	0.19	1.36	0.17
2007-2009	**1.28**	**0.18**	**6.89**	**<0.05**
2010-2012	**0.92**	**0.19**	**4.70**	**<0.05**
2013-2015	**0.63**	**0.22**	**2.78**	**<0.05**
2016-2018	**-0.79**	**0.28**	**-2.80**	**<0.05**

Entanglement composition

Between 1986-2018, 5530 entanglements were described and classified according to type. Of all entanglement items the proportions of each type were: 37.1% (n=2052) rope, 32.5% (n=1797) fishing line, 29.6% (n=1635) packing straps, 0.3% (=16) net, and 0.5% (n=30) other items (12 multiple-use and 18 single-use items). Although there was a significant difference in the composition of entanglement type between year blocks (χ^2=305.1, df=20, p<0.05), there was no consistent pattern over time when investigating the entanglement rate per type (between 1994-2018, Figure 6). There was a slight reduction in rope and packing straps between 2016-2018 relative to other year blocks (Figure 6).

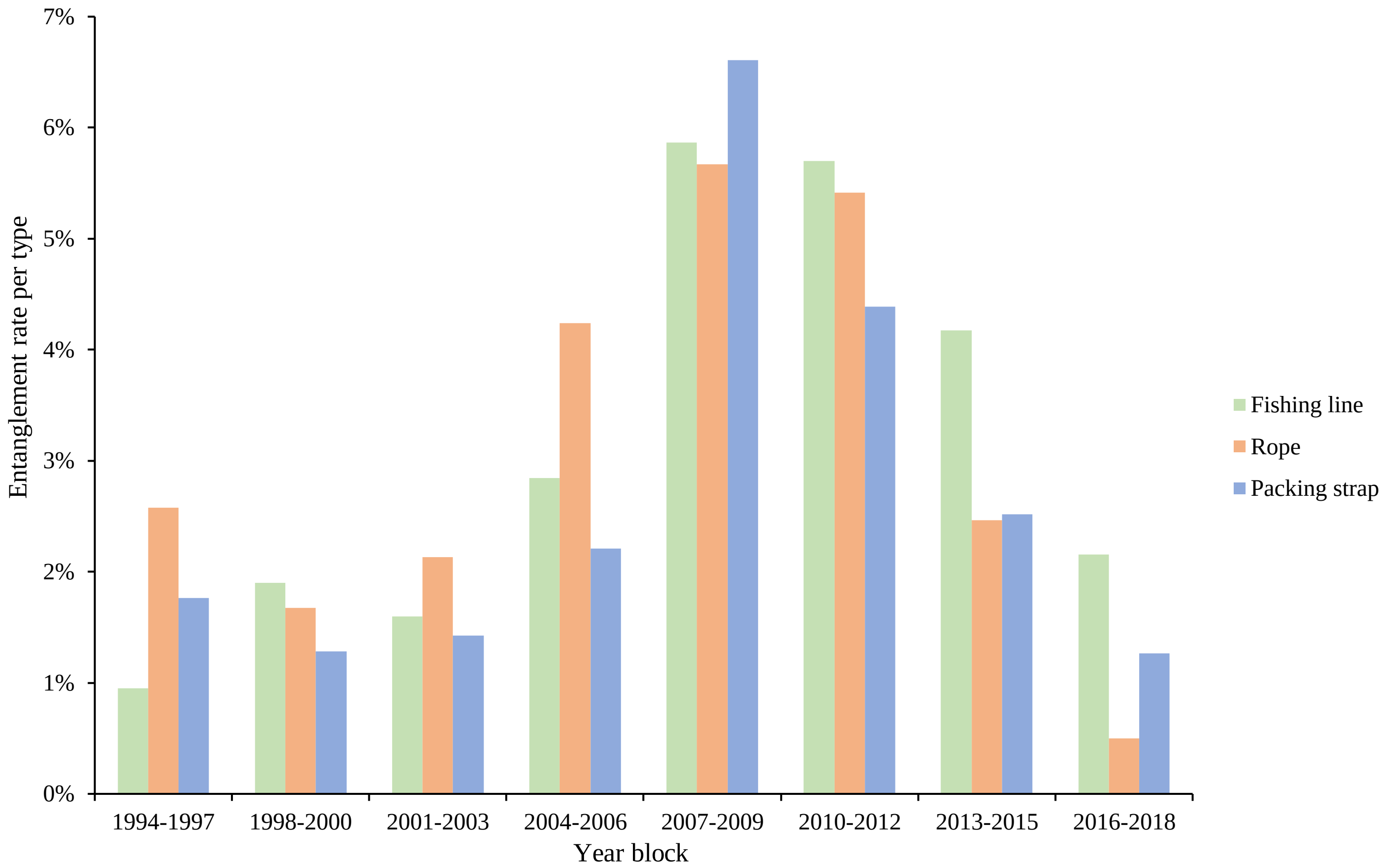


Figure 6: *Cape fur seal entanglement rate per type in Cape Town harbour by three-year blocks from 1994-2018. Error bars represent standard error.*

Number of entanglements carried

A total of 865 entanglements were available from 678 seals (mean 1.3 entanglements per seal): 85% (n=575) had one entanglement, 9.7% (n=66) had two, 2.2% (n=15) had three, 2.1% (n=14) had four, 0.4% (n=3) had five, 0.3% (n=2) had six, 0.1% (n=1 each) had eight, nine and 13 entanglements.

Entanglement material and measurements

Plastic was the most common entanglement material overall (98.8%, n=855), with the remainder (1.2%, n=10) rubber and clothing (also likely synthetic). There was a significant difference in length (Kruskal-Wallis χ^2 =223.2,df=2, $p<0.05$), width (Kruskal-Wallis χ^2=586.75, df=2, p-value <0.05, thickness (Kruskal-Wallis χ^2=570.8, df=2, $p<0.05$) and mass (Kruskal-Wallis χ^2=50.4, df=2, $p<0.05$) between entanglement types. The mean length of entanglement items was 987±941 mm, Figure 7). On average, packing straps (1055±234 mm) were longer than fishing line (985±1393 mm) and rope (885±592 mm) ($p<0.05$, Figure 7). The mean mass of items was 5.1±5.7 g, with little difference between rope (5.5±8.3 g), fishing line (4.9±6.3 g) or packing straps (5.0±2.6 g) ($p<0.05$, Figure 8c). Most fishing lines (95%, n=329) were >1 mm in diameter. Most lines >1 mm were looped, whereas most lines <1 mm (5%, n=17) were thin fishing lines that were not looped. Packing straps were wider than fishing line and rope ($p<0.01$, Figure 8a) and rope was thicker than fishing line and packing straps ($p<0.01$, Figure 8b). Of the 865 entanglement items, 53% (n=462) sank and 47% (n=403) floated in fresh water.

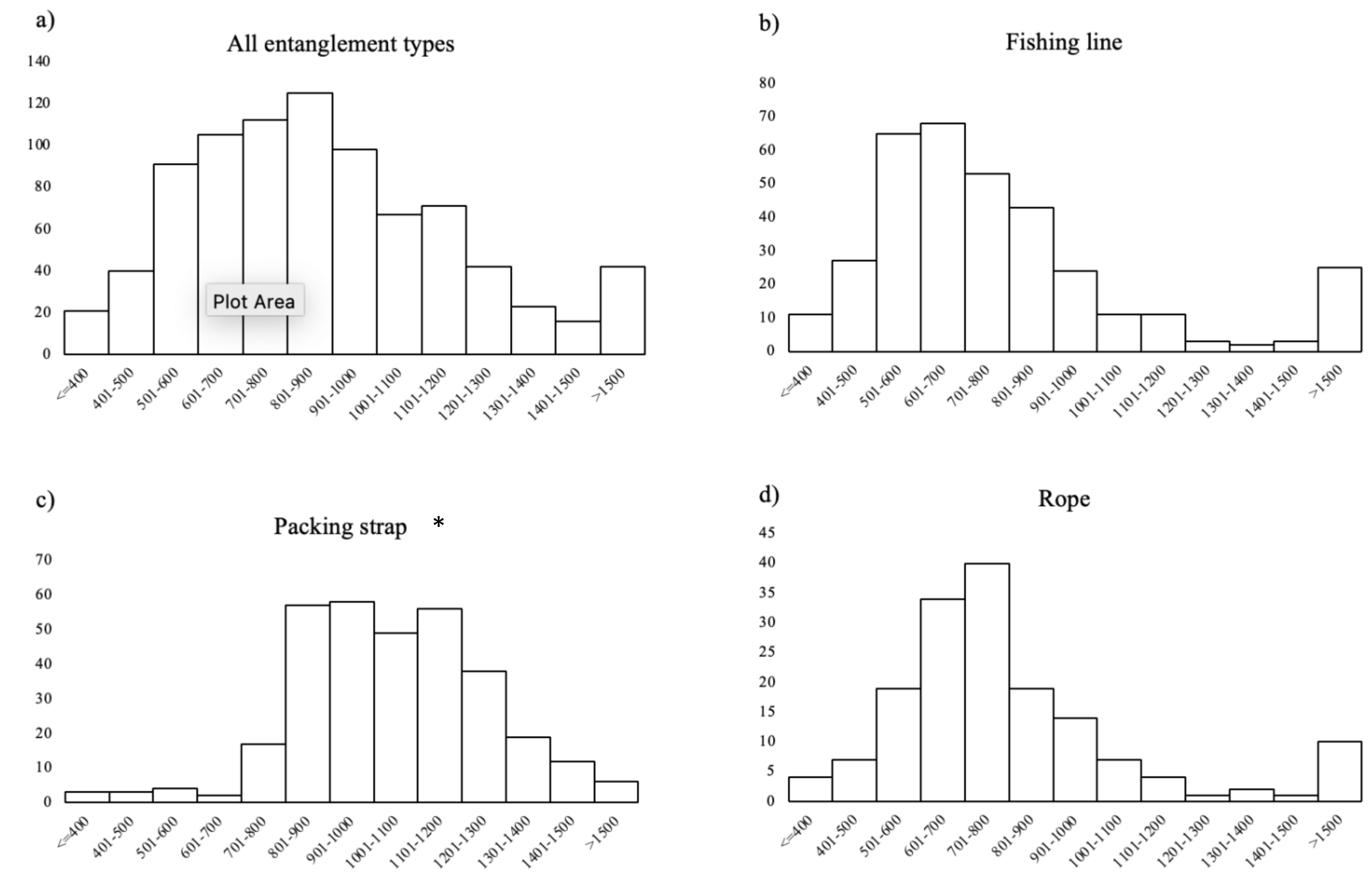
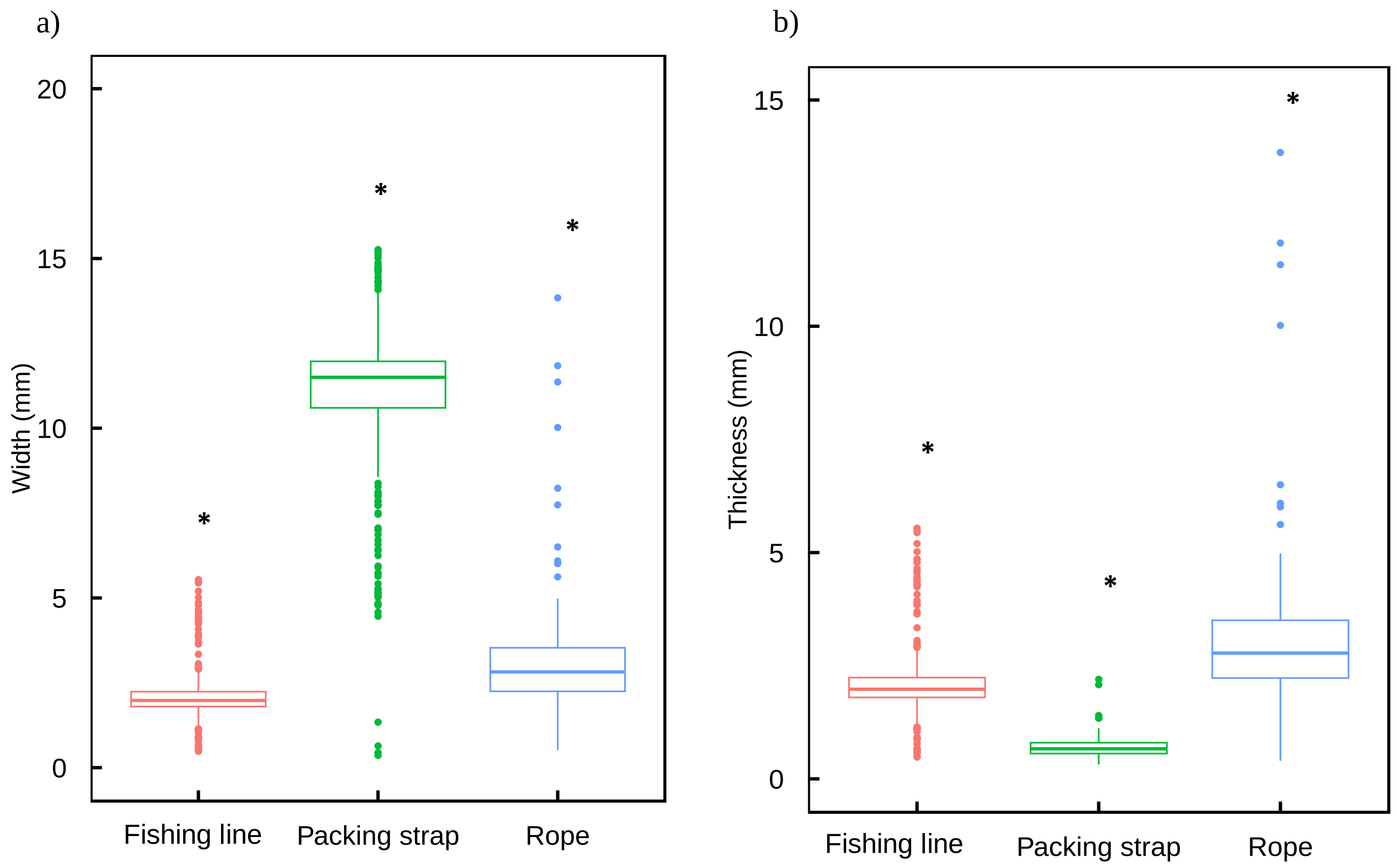


Figure 7: *Frequency distribution plots of length (in millimetres) for a) all entanglement types, b) fishing line, c) packing straps and d) rope. Significance ($p<0.05$) based on post-hoc pairwise comparisons are shown with *.*



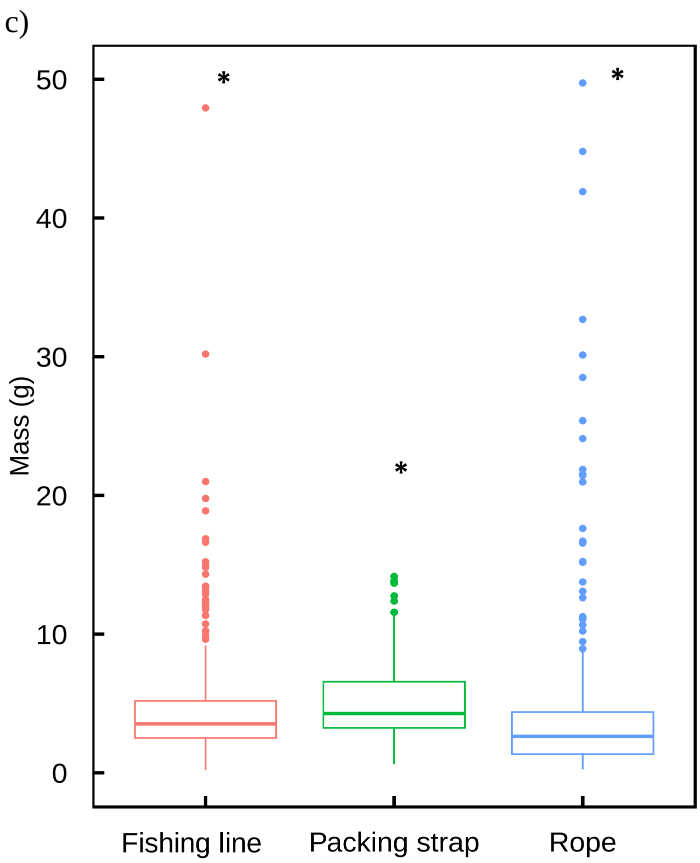


Figure 8: *Boxplots show the median (central line), IQR (edges of box), range (whiskers) and outliers (dots) of the a) width b) thickness and c) mass of the most common entanglement types; fishing line, packing straps and rope. Significance (p<0.05) based on post hoc pairwise comparisons are shown with *.*

Discussion

The highest number of entanglements of Cape fur seals was recorded in 2009. The proportion of entanglements removed was very weakly associated with the overall number of entangled seals recorded. Removing entanglements can affect reported entanglement rates as removals reduce the proportion of individuals entangled. While removing entanglements can be stressful and intrusive to the animal, the advantages in doing so greatly outweigh the costs (Hanni & Pyle, 2000). Boren et al. (2006) showed that disentanglement of New Zealand fur seals successfully mitigated the impacts of entanglements, even in cases where entanglement causes severe injury. van der Hoop et al. (2014) found that disentanglement of a North Atlantic right whale (*Eubalaena glacialis*) drastically increased diving time and depth. Disentanglement efforts are generally more accessible in or close to a human settlement like a harbour, as opposed to remote and inaccessible islands, and is a mitigation measure that should be considered where possible (Boland & Donohue, 2003; Boren et al., 2006).

This study describes the highest reported entanglement rate of Cape fur seals (mean: 8%, range: 3-17%) and overall highest rates reported for all species of seals (Raum-Suryan & Suryan, 2022). Compared to Shaughnessy (1980) entanglement rates of Cape fur seals have decreased at Seal Island in recent years (Maguiña, 2022). However, Maguiña (2022) showed that the location of colonies was an important factor explaining the differences in entanglement rates. Bird Island in Lamberts Bay had one of the highest entanglement rates in the survey which was attributed to it being close to the mainland and in proximity to a fishing harbour. Additionally, Seal Island in False Bay had the highest number of entanglements, most likely because 1) checks were carried out on Seal Island more frequently than the other colonies; and 2) in addition to False Bay being a popular fishing ground, 11 rivers feed into the bay which has been identified as the main source of plastic pollution in the area (Rundgren, 1992). The substantially higher rate identified in this study compared to previously recorded rates in colonies of Cape fur seals suggests that there are high levels of litter within the harbour (Curtis et al., 2021; Maguiña, 2022; Shaughnessy, 1980). In addition to the probable high abundance of litter in the harbour, the group of seals who frequent the harbour are mostly young males who tend to get entangled to a higher degree than adults (Butterworth, 2016). Finally, a relatively small number of seals frequent the Cape Town harbour which may yield higher entanglement rates than in areas where large aggregations of seals occur as it is harder to detect entangled seals in larger group sizes (Curtis et al., 2021). Fewer seals also increase the individual risk of entanglement (Boren et al., 2006).

Entanglement rates between 0.024% to 7.9% have been reported for different species and populations of seals (Table 4). Species that live close to areas of high human activity tend to have higher entanglement rates than seals that inhabit more remote areas (Harcourt et al., 1994; Hofmeyr et al., 2002). Such is the case for New Zealand fur seals, grey seals (*Halichoerus grypus*) and California sea lions, whose recorded entanglement rates are the most similar to the rates found in this study (Table 4) (Allen et al., 2012; Boren et al., 2006; Harcourt et al., 1994).

Table 4: *The author(s), study period (listed in order of end year) and entanglement rates for various seal species. Entanglement rates are listed as a range, mean or an annual rate depending on the length of study and available data in the literature. To enable comparisons, only the standard methods of calculating entanglement rate (number of entangled seals over the total number checked (n^e/n^c) or estimated population size (n^e/n^t)) are included in the table. The method used is indicated in brackets next to the entanglement rate.*

Author	Study period	Species	Entanglement rate
Fowler (1987)	1983-1986	Northern fur seal	0.4% (n^e/n^c)
Stewart and Yochem (1987)	1983-1986	California sea lion	0.08-0.16% (n^e/n^c)
Stewart and Yochem (1987)	1983-1987	Northern elephant seal	0.15-0.16% (n^e/n^c)
Stewart and Yochem (1987)	1983-1988	Harbour seal	0.05-0.09% (n^e/n^c)
Arnould and Croxall (1995)	1988-1989	Antarctic fur seal	0.4% (n^e/n^t)
Pemberton et al. (1992)	1989-1991	Australian fur seal	1.9% (n^e/n^c)
Croxall et al. (1995)	1990-1991	Antarctic fur seal	0.4-1.0% (n^e/n^t)
Harcourt et al. (1994)	1992	California sea lion	3.9-7.9% (n^e/n^t)
Prendergast and Johnson (1995)	1989-1994	Australian fur seal	0.78-1.2% (n^e/n^c)
Hofmeyr et al. (2002)	1991-1999	Subantarctic and Antarctic fur seals	0.15-0.24% (n^e/n^t)
Hofmeyr et al. (2006)	1996-2002	Antarctic fur seal	0.024-0.059% (n^e/n^t)
Page et al. (2004)	2002	New Zealand fur seal	0.9% (n^e/n^t)
Page et al. (2004)	2002	Australian sea lion	1.3% (n^e/n^t)
Campagna et al. (2007)	1995-2005	Southern elephant seal[6]	0.001% (n^e/n^c)
Boren et al. (2006)	1995-2005	New Zealand fur seal	0.16-6.74% (n^e/n^t)
Moore et al. (2009)	2001-2005	California sea lion	0.016-0.01% (n^e/n^c)
Raum-Suryan (2009)	2001-2007	Steller's sea lion	0.26% (n^e/n^t)
Allen et al. (2012)	2004-2008	Grey seal	3.6-5.0% (n^e/n^c)
Raum-Suryan and Suryan (2022)	2005-2009	Steller's sea lion[7]	0.34% (n^e/n^c)
McIntosh et al. (2015)	1997-2013	Australian fur seal	0.02-0.19% (n^e/n^t)
Curtis et al. (2021)	2019	Cape fur seal	0.17% (n^e/n^c)
Maguiña (2022)	2019-2022	Cape fur seal	0.05-0.24% (n^e/n^c)

[6] *Mirounga leonina*
[7] *Eumetopias jubatus*

Plastic accounts for most marine litter and is unsurprisingly identified as the most common entanglement material (Gall & Thompson, 2015; Li et al., 2016). It is thought that most marine plastic originate from land-based sources (Wepener & Degger, 2012). However, in this study the seals are mainly entangled in fishing gear and shipping-related items, indicating that these activities are the primary sources to the entanglement cases. Probable pollution sources around the Cape Town harbour are the ship-related activities in the harbour, the storm drain that enters the harbour from the central business district (CBD) in Cape Town and to a lesser degree the Diep River and Black River which drain into Table Bay 3-5 km east of the harbour (Lamprecht, 2013; Weideman et al., 2020). The Cape Town harbour and surrounding area lies on a busy trade route and next to an important fishing ground (DEFF, 2020; Kilian & Dodson, 1996; Okoro et al., 2016; Smith, 1999). Ryan et al. (2020) found that 19% and 27% of litter collected from demersal trawls were from fishing gear and packing straps respectively. Similarly, Buhl-Mortensen et al. (2022) found that fishing gear accounted for 69% of macro litter found on the seafloor in the South Atlantic region of Africa. Thus, it seems likely that offshore activities might have contributed to the entanglement incidences identified in this study.

Unlike entanglement rates, which vary with the density of litter at sea, the items that commonly entangle seals are relatively uniform worldwide (Harcourt et al., 1994; Hofmeyr et al., 2002; Jepsen & de Bruyn, 2019). Fishing, packing straps, synthetic rope and fishing nets are among the most common entanglement types (Arnould & Croxall, 1995; Boland & Donohue, 2003; Boren et al., 2006; Curtis et al., 2021; Franco-Trecu et al., 2017; Hanni & Pyle, 2000; Hofmeyr et al., 2002; Laist, 1997; McIntosh et al., 2015; Page et al., 2004; Shaughnessy, 1980; Waluda & Staniland, 2013). The proportion of items originating from the fishing industry in the Cape Town harbour is a conservative estimate. The fishing/shipping category likely contains a large proportion of fishing gear as synthetic rope is commonly used in the fishing industry and a large proportion of packing straps are from bait boxes, often used on longline, tuna pole and handline fishing vessels (Arnould & Croxall, 1995; Waluda & Staniland, 2013). Packing straps are from both onshore and offshore sources and are likely inappropriately discarded in the Cape Town harbour (on land and on ships in the harbour), while a proportion of packing straps are expected to be lost or discarded at sea from fishing vessels (Hogan & Warlick, 2017; Ryan, 2020). The preponderance of fishing line was odd because they sink and are not typically tied into loops when used for fishing. However, fishing lines are used by both the commercial and recreational fishing sectors (Jones, 1995).

The tuna pole line and pelagic longline sectors are a part of the commercial fishing sector targeting tuna and thick fishing lines >1 mm (as well as synthetic rope) are commonly tied into loops to hang tuna by its tail on racks when the fish is offloaded (and transported to freezer facilities) in the harbour (DEFF, 2020; S.McCue, DFFE, pers.comm; Pinnock, 2022). A surplus of fishing line loops are made in anticipation of the number of fish that may be caught (S. McCue, DFFE, pers. comm.). The use of fishing line loops in the Cape Town harbour could explain the large contribution of fishing line to entanglement incidences and points to a potential local entanglement source of Cape fur seals in the harbour.

While most entanglement items were relatively light in mass (<6g), they may still impact the animal through reducing streamlining, thus increasing drag (Feldkamp & Costa, 1971). The mean length of fishing, packing straps and rope were below that of the largest male Cape fur seal circumference (~1200 mm) suggesting that smaller seals are more commonly entangled. However, entanglement items that are not looped and found wrapped around the seal's body could entangle larger (and perhaps older) seals. Width and thickness of entanglements cannot be used to infer size, but wider and thicker items could potentially be easier for seals to remove themselves from (Waluda & Staniland, 2013). Nonetheless, packing straps are wider than both rope and fishing and have sharp edges which can cause more serious lacerations (Curtis et al., 2021).

Overall, the highest number of seals counted in the Cape Town harbour area during surveys were found in summer between December to March, with higher entanglement rates in winter. Opie (2021) found higher accumulation rates of beach litter in Table Bay in winter than in summer due to the predominantly winter rain in the Western Cape, flushing rivers and stormwater drains and thus transporting more litter into the sea. Although the influx of land-based litter could lead to higher entanglement rates it is not likely to have had a substantial effect as most items found entangling seals are fishing and shipping related. Additionally, fewer seals (in winter) can increase entanglement rates as there is more litter per seal even if the amount of litter is constant. Curtis et. al (2021) found entanglements to be highest in July and generally higher between June-October than November, December and April (January-March was not included). They also noted a clear decrease in the number of entanglements of seals with increasing group size, suggesting that seals are not adequately checked for entanglements in larger groups.

The entanglement trends in this study also follow a similar pattern to the beach accumulation rates identified in Opie (2021). Opie (2021) investigated changes in the daily accumulation of litter on two beaches in Table Bay (Milnerton and Koeberg) and found that summer beach accumulation rates (measured in December 1994, 2012 and 2019) doubled from 1994 to 2012 and then decreased by over a tenfold from 2012 to 2019. The decrease in litter accumulation rates in 2019 was likely a result of the implementation of consistent municipal cleaning incentives (at beach areas and rivers by Milnerton) as well as deploying litter booms in the Black and Diep rivers (both identified as key litter sources). Although the increased accumulation of beach litter may have affected the peak in entanglement rates in 2009, it is likely that harbour related activities have contributed more to the increase in entanglements. This is justified by the types of items found entangling seals in the harbour. The decrease in entanglement rates following 2009 may be partly attributed to an improvement in waste disposal in the harbour and on fishing vessels, efforts to reduce the amount of looped fishing lines washed into the water when offloading tuna is thought to have improved in recent years (D. Kotze, DFFE, pers. comm.). Somewhat contradicting are my findings indicating a consistent contribution of fishing line even in recent years (2016-2018) when entanglement rates overall fell.

From 2009 (and especially from 2016) entanglement rates show a decreasing trend, which has also been identified in several other long-term studies of seal entanglements (Boren et al., 2006; Hanni & Pyle, 2000; Kuzin & Trukhin, 2019; McIntosh et al., 2015; Waluda & Staniland, 2013). The entanglement rate of Cape fur seals in the colony at Cape Cross in Namibia in 2019 (0.15%; Curtis et al., 2021) is four times lower than it was 40 years ago (0.66% (Curtis et al., 2021; Shaughnessy, 1980). Similarly, a long-term study on ingestion rates in Atlantic fulmars (*Fulmarus glacialis*) in the North Sea showed a decreasing trend in the mass of ingested plastic post 2000 (van Franeker & Law, 2015). No change was identified in the concentration of microplastics in plankton samples and in the digestive tracts of Atlantic herring (*Clupea harengus*) and European sprat (*Sprattus sprattus*) in the Baltic sea between 1987-2015, in spite of the worldwide increase in plastic production (Beer et al., 2018). Whether this points to a potential reduction of litter in the marine environment, export to other oceanic areas (or beaches), degradation or just a change in the types of litter that gets discarded in the sea, is difficult to infer (Cózar et al., 2014; Eriksen et al., 2014; van Franeker & Law, 2015). However, the overall decreasing trend of entanglement and ingestion rates suggests that measures to reduce the loss of the types of plastic responsible for most entanglement and ingestion incidents at sea may have had some effect (McIntosh et al., 2015; Ryan, 2008; Waluda & Staniland, 2013).

The composition of entanglement types in the Cape Town harbour showed no clear differences over the study period when comparing it to entanglement rates. There was a slight decrease of rope and packing straps (between 2016-2018) whereas fishing line have stayed relatively consistent, despite the overall decrease in entanglement rates. Considering that fishing lines sink there may have been a build-up of these items in the water over time, suggesting a lag effect in the increase of fishing lines. Additionally, even if waste disposal habits have improved or remained unchanged in the harbour, a perhaps reduced but continued input of fishing lines may explain the consistent amount of items in later years. Synthetic rope and packing straps float, thus the minor reduction of these items could be due to localised cleaning efforts. In the V&A Waterfront there are daily cleaning efforts where all floating litter is collected (B. Glasby, TOA, pers. comm.). However, these cleaning efforts are not present on the commercial side of the harbour. In addition, seals may get entangled outside of the harbour area as well. Although there is limited knowledge on how often and how far the harbour-dwelling seals venture out of the Cape Town harbour, many individuals who frequent the V&A Waterfront come from Duiker Island (near Hout Bay), indicating that the movement patterns of these seals extend beyond the Cape Town harbour (B. Glasby, TOA, pers. comm.).

Management recommendations

The high entanglement rates identified in the Cape Town harbour compared to adjacent colonies suggests that local sources of pollution may be responsible for most entanglement incidents in this study (Maguiña, 2022). Thus, addressing the problem at a local scale is paramount. In the Cape Town harbour this can be done by discouraging the illegal dumping of litter, particularly packing straps, rope and looped fishing line. For packing straps that may be washed down the storm drain from the CBD, a litter trap could reduce the amount of straps entering the harbour, however the ultimate solution would be to prohibit the use of packing straps altogether. Educational programmes targeting commercial and recreational fishermen can improve disposal practices on vessels (Chen & Liu, 2013). Targeted educational programmes are something that could be extended to the land-based crews working in the harbour (especially targeting the workers who are involved in hanging tuna when offloading the fish). Raising awareness about the negative impacts of marine litter should also extend to the general public in an effort to change consumer behaviour, reduce the use of plastic and promote proper waste disposal (Sheavly & Register, 2007). This could be done by putting up posters where seals haul out that highlight the entanglement problem and the need to reduce leakage of plastic to the sea. Posters have the potential to reach many people due to the popularity and high visitation rates of the V&A Waterfront (Ferreira & Visser, 2007). Daily clean-up incentives could be implemented in the commercial part of the harbour. Lastly, appropriate litter bins (and/or recycling stations) should also be available in the harbour as well as on fishing vessels. Kusmanoff et al. (2022) evaluated the "bins for boats" programme implemented in Bass Strait in Victoria, Australia, which sought to reduce entanglement of Australian fur seals. After identifying that the net fragments responsible for most entanglements were from local sources and were often unintentionally discarded on vessels, convenient and appropriate (e.g. wind-proof) bins were installed on fishing vessels. The programme was successful in reducing the amount of litter lost from vessels and emphasised the importance of stakeholder involvement from the fishermen themselves as well as cross-sectoral collaboration.

ALDFG has been identified as especially problematic and efforts to reduce its occurrence include the use of biodegradable fishing gear (especially nets), developing technologies to reduce and/or recover gear loss (such as tracking tools), reducing fishing effort, implementing mandatory reporting of lost gear (to identify potential recovery areas) and continued documentation of entanglement rates (Laist, 1997; Randall, 2020; Richardson et al., 2019). Enforcing policies and legislation put in place to reduce marine litter is also important (Derraik, 2002). Studies measuring the success of MARPOL Annex V have been varied, for instance, a study on entanglements of the Hawaiian monk seals conducted from 1982-1998 found no change in either the amount of debris being washed ashore or the number of entanglements post implementation of MARPOL Annex V (Henderson, 2001). Similarly, the MARPOL legislation as well as other government implemented policies to reduce entanglement incidences showed no effect post implementation for New Zealand fur seals or Australian sea lions (*Neophoca cinerea*) (Page et al., 2004). However, some studies have identified a reduction in marine litter and a subsequent reduction in entanglement incidences post MARPOL (Arnould & Croxall, 1995; Edyvane et al., 2004; Waluda & Staniland, 2013).

Improving efforts to standardise methods of assessing entanglement rates can increase our understanding of the spatial and temporal trends in global entanglement rates as well as enable comparisons on a geographical and temporal scale (Jepsen & de Bruyn, 2019). Systematic and long-term monitoring can improve our ability to more confidently estimate entanglement rates and identify sources of marine litter, which will in turn better inform management interventions (Hanni & Pyle, 2000; Kuzin & Trukhin, 2019; Lawson et al., 2015). Combining the use of photography and binoculars during surveys has been found to be an effective method to capture entanglement data (Curtis et al., 2021).

Conclusions

The results of this study report the highest entanglement rates recorded for Cape fur seals, albeit in a heavily modified environment that may have high litter levels. While entanglement rates have decreased since a peak between 2007-2009, they are still among the highest reported rates for all seal species. Cape fur seals are currently listed as least concern on the IUCN red list and entanglements are thought not to have population level effects at this time (Kirkman et al., 2016). Additionally, since the seals involved in this study are mostly immature males (who are not a part of the breeding population), their loss will have diminished demographic impact. However, other demographic groups may be affected by entanglement in the broader region. Marine litter is caused by anthropogenic activities and measures to mitigate the negative impacts of marine litter are quite simple. In addition, entanglements cause animal suffering which should be prevented. Thus, the high rates identified in this study highlights the importance of focusing mitigative efforts in areas such as harbours and urban centres and presents the use of the entanglement problem as an educational opportunity to reduce and ultimately prevent litter from entering the sea. This study also supports previous findings identifying fishing gear as one of the largest sources of seal entanglements. Fishing lines, ropes and packing straps accounted for more than 99% of all entanglements in the Cape Town harbour. Locally, guidelines to improve waste practices in the Cape Town harbour should be implemented, which could also extend to harbours throughout the country. On a global scale, efforts should be focused on long-term monitoring to better understand the spatio-temporal trends in entanglement rates, enforcing policies to reduce marine litter and targeted educational programs to create change at the appropriate scale.

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Appendix 1

Three data sources were used to extract the data used in this study: raw data from notebooks and data captured in two excel spreadsheets from the Department of Forestry, Fisheries and the Environment (DFFE, 1986-2013) and Two Oceans Aquarium (TOA, 2014-2018). The DFFE team recorded their data in notebooks, which were later transferred into a spreadsheet. However, the total number of seals checked were not captured in the spreadsheet. Unfortunately, the notebooks necessary to extract the total number of seals checked were only available from 1994. Data on the number of entanglements, the type of entanglements and whether the entanglement was removed or not were available from 1983-2013. The notebooks recorded the number of seals entangled whereas the spreadsheet recorded each entanglement as a separate entry (i.e. if a seal had four entanglements on it, this was recorded as four entanglement entries as opposed to one). This resulted in a larger number of entanglements from the data in the spreadsheet versus the notebooks. The number of entangled seals (captured in the notebooks from 1994-2013 were used to calculate entanglement rates whereas the number of entanglements (captured in the spreadsheet from 1986-2013) were used to report on the number of entanglements and the number of removed entanglements throughout the study period and to investigate the entanglement rate per type. Using the number of entanglements when investigating type may be more appropriate than using the number of entangled seals as it precisely captures the contribution of each type of entanglement. TOA took over the seal monitoring programme in 2014 and recorded all data (number of seals present, number of entangled individuals as well as number of entanglements per seal, entanglement type and whether the entanglement was removed or not) in excel. Repeat sightings were also more clearly indicated in these data. A t-test showed no significant difference in search effort (=average number of survey days per month) between DFFE (12.2±4.8) and TOA (11.5±4.5) surveys ($t=1.1$, $df=121.5$, $p=0.3$).

Appendix 2

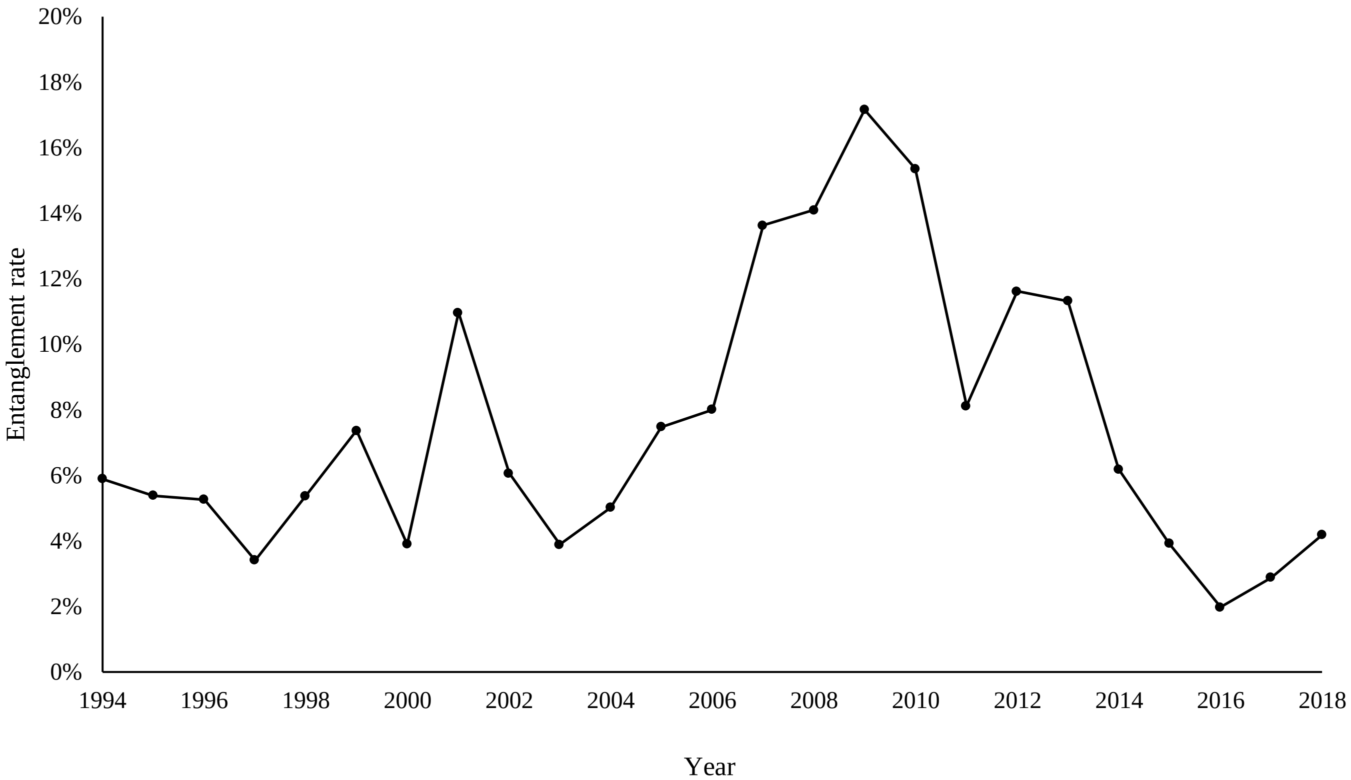

Figure A1: Yearly entanglement rates of Cape fur seals in Cape Town harbour.