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Plastics and pusillus - Investigating the impact of plastic pollution on Cape Fur Seals (*Arctocephalus pusillus pusillus*) at colonies in central Namibia

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“I understand the nature of plagiarism and am aware of the University’s policy. I confirm that this dissertation is my own work. I confirm that I received any required ethical approval.”

SLCurtis   13th April 2020.

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Keywords: *Plastic, pollution, Cape fur seal, entanglement, Namibia*

Abstract

The impacts of macro pollution in the marine environment are well publicised. Entanglement in waste material is a conservation concern, welfare issue and call to action. In Pinnipeds, entangling material commonly originates from fishing-related sources, but a significant quantity of other materials could also cause entanglements. Here we explored entanglement occurrence within colonies of Cape fur seals (*Arctocephalus pusillus pusillus*) at two locations along the Namibian coastline, Pelican Point (PP) in Walvis Bay and Cape Cross (CC) between April 2018 and December 2019. We aimed to establish the most common type of entanglement material as well as the demographic profile of animals affected. As this is the first stage in a long-term monitoring program we critically compared methods involving *in situ* binocular scans and ground-based photographic surveys of seal groups. Data from local marine tour operators and conservationists involved in disentanglement were also reviewed. Overall 217 cases of entanglement were observed with 17% more entanglements identified through photographic surveys than in situ scans. Entanglement rates were 0.14 % and 0.04 % for PP and CC respectively. Fishing-related materials accounted for 52% of the observed cases of entanglement, with juveniles most commonly affected, and 5% of recorded seals exhibited 'severe' injuries caused by entangling materials. Seventy three individuals were successfully disentangled, highlighting the important role that disentanglement efforts by tour guides can play in supporting animal welfare. In summary, we identified photographic surveys as the optimal method for assessing entanglement, the common entanglement materials and demographic of affected animals.

Introduction

The presence of plastic in our oceans is not a new concept; for decades plastic has been produced and distributed around the world on a large scale without appropriate disposal. In 2015 alone, an estimated 407 million tonnes of plastic was produced globally (Geyer et al. 2017), and whilst rates of recycling are on the rise in many countries including South Africa, (Plastics SA 2019), the percentage of total plastic used worldwide up to 2015 which has been recycled is only 9% (Geyer et al. 2017). An accurate assessment of the quantity of plastic currently in the sea is difficult, but it is estimated that a minimum of 5.25 trillion particles as small as 0.33mm are currently afloat (Eriksen et al. 2014). The ability of plastic to resist degradation is why it is such a popular material in a wide range of applications, but this quality is also the reason why plastic is hazardous to the marine environment. In the sea, plastic fragments at even slower rates than on land due to decreased exposure to UV radiation and colder temperatures (Andrady 2011).

The full-scale impact of ocean-dwelling plastics is still to be assessed, but it is clear that smaller fragments known as microplastics (<5mm) have the ability to enter and progress up the food chain (Thompson et al. 2004). Larger macro-plastics (>5mm) which are resistant to digestion have been discovered in the stomachs of many marine birds including shearwaters. For example, in a study of short-tailed shearwaters (*Puffinus tenuirostris*) the stomachs of all individuals analysed were found to contain plastics, with a total weight ranging between 0.04–0.59g for each bird (Tanaka et al. 2013). Similar instances and fatalities have been observed in larger marine mammals such as whales and dolphins, where plastic ingestion has led to starvation due to a decrease in stomach capacity and appetite, and even gastric ruptures (de Stephanis et al. 2013).

A more visible impact of plastic pollution comes in the form of animal entanglement, most commonly caused by discarded or damaged fishing gear, classed as plastics. To date, 344 marine species worldwide have been documented as having been entangled by marine waste (Bergmann et al. 2015). Pinnipeds, generally known as seals, are among the most commonly found entangled. Entanglement in seals occurs primarily around the neck, but can occur on other parts of the body, causing constrictive wounds (Allen et al. 2012). This can impact foraging behaviour by causing inefficient movement through water, resulting in an increased energy demand (Laist 1997). This has been identified as a significant impact for the Californian sea lion (*Zalophus californianus*, Feldkamp 1985). It is likely that observed entanglements are an underestimate of the true rate, due to an unknown quantity of seals drowning in waste at sea, making it difficult to accurately assess the scale of this issue and the impact entanglement has on survivorship (Laist 1997). Studies conducted on the Australian fur seal (*Arctocephalus pusillus doriferus*) and other species such as the Hawaiian monk seal (*Monachus schauinslandi*) show that high rates of localised entanglements can have severe impacts on population numbers due to increased mortality rates (Henderson 2001; Pemberton et al. 1992). The Hawaiian monk seal has some of the highest recorded rates of entanglement with 0.7% of their small population entangled in 2004 (Donohue and Foley 2007; USEPA 2011).

Whilst difficult to accurately assess mortality and the long-term impact entanglement may have on individual seals, it is widely recognised as an animal welfare issue, with an estimated survival rate of seals entangled in light-weight waste almost half that of non-entangled seals (Fowler et al. 1990). In Northern fur seals (*Callorhinus ursinus*), it has been suggested that the annual mortality for entangled seals could be as much as 14% (Fowler et al. 1990). Pups have a higher mortality rate should their mother become entangled (DeLong et al. 1988), likely due to the mother's decreased foraging ability and increased energy expenditure. Entangled seals may also be more susceptible to predation, as impaired movement and infection may hinder their response to predators such as Brown Hyena (*Hyaena brunnea*) and Black-backed Jackals (*Canis mesomelas*), particularly younger seals which are smaller and more naïve in nature (Wiesel 2006).

Although fishing-associated materials are the common cause of entanglement in plastic materials (Butterworth 2016), it is unclear whether seals are interacting more with active fishing material or ghost gear abandoned at sea which moves with the currents into seal foraging ground (Hanni and Pyle 2000). In addition, seals have commonly been found entangled with plastic waste material such as packaging straps and bags, with other more unusual materials such as clothing and rubber O-rings also at fault (Butterworth 2016). These are likely disposed of and carried by ocean currents to different parts of the world (Butterworth 2016). A recent global review outlines key gaps in seal entanglement data including age and an in-depth account of entanglement severity based on world-wide studies (Jepsen and de Bruyn 2019). This review also highlights discrepancies in published pinniped-plastic relationships in parts of the world where fishing activity is high, such as Southern Africa, therefore further proving the urgent requirement for this to be explored.

The Cape fur seal (*Arctocephalus pusillus pusillus*) is found along the coastline of Namibia and western Southern Africa, with a total population size estimated to be around 1.5-2 million (Kirkman et al. 2007). Adult fur seals can live for up to 21 years of age, with adult males weighing up to 360kg and females 113kg (Kirkman and Arnould 2013). Cape fur seals are gregarious income breeders (Houston et al. 2007), meaning nursing females operate a cyclic foraging strategy, spending three-four days at sea and three days on land nursing her pup. The breeding season occurs between October and December, with males arriving first at the breeding colonies in October to fight for territory, in which they will later establish harems with an average twenty-eight females (Hiller 2002). Pups are born between November and January and soon after they are born, their mothers will mate with territory holding males (Kirkman et al. 2016). To avoid instant pregnancy, female fur seals have a delayed implantation strategy, whereby the embryo remains dormant for up to 4 months (Daniel 1981). There is little dedicated research on Cape fur seal weaning age, but this occurs at around 8-12 months (Kirkman et al. 2016).

In Namibia there are an estimated 1.2 million Cape fur seals distributed across 26 different colonies (Ministry of Fisheries and Marine Resources 2013). Information on marine litter and seal entanglements along Namibia's coastline is severely lacking, with no recent data on entanglement rates recorded in Cape Cross, or the recently established colony at Pelican Point, Walvis Bay. Entanglement figures from 1979 are based on harvested male juveniles alone, and show that Cape Cross had the highest incidence of entanglement, with 0.66% of harvested seals found entangled (Shaughnessy 1980). These data did not include Pelican Point which is an emerging colony and, where no harvesting takes place. This study aims to update the information on entanglement in Cape fur seals, using data collected from Pelican

Point and Cape Cross in Namibia. Within this study, I aim to identify and compare rate of entanglement and common causative materials at these two colonies, identifying severity and investigating the demographic of seals most commonly entangled. A critical comparison of the two methods for entanglement assessment: photographic surveys and in situ binocular scans is conducted to determine the optimal method for assessing rates of entanglement within colonies.

Methods

Study sites

Standardised systematic surveys to investigate entanglement in Cape fur seals were carried out at Pelican point and Cape Cross seal colonies between April 2018 and December 2019. The Pelican Point colony of Cape fur seals is situated close to Walvis Bay in central Namibia (22°57'30.4"S, 14°30'24.1"E). Pelican Point is a dynamic sandy peninsula habitat with an estimated year round population of 30,000, increasing to around 100,000 seals during the breeding season (Dreyer 2020, personal communication, 11 April). Directly adjacent to this colony is the largest commercial port in Namibia, easily accessed from major shipping routes and a popular landing site for local fishing boats and international trade due to its processing facilities. Pelican Point was considered the principal site for data collection, due to both logistical constraints (proximity to the field station and co-ordination with marine tour operators) and its proximity to human activity.

The second site for comparison, Cape Cross (21°46'18.6"S, 13°57'08.5"E), is located 164km north of Walvis Bay. Here, Cape fur seals are estimated to exceed numbers of 200,000 during the breeding season (Ministry of Fisheries and Marine Resources 2013). In contrast to Pelican Point, Cape Cross is more exposed, with seals densely packed amongst the rockier terrain.

Tourism has a major presence at both sites, though boat based tourism only takes place within Walvis Bay where seven boat tour companies and four kayak tour companies operate. Using vehicles to access Pelican Point, these companies launch multiple kayaks from here on a daily basis throughout the year. The Cape Cross Marine Reserve is operated by the Ministry of Environment and Tourism, and here tourists visit the colony on purpose built walkways to view the seal colony at close proximity. In 2011 alone 49,000 tourists visited the reserve (Leeney 2014).

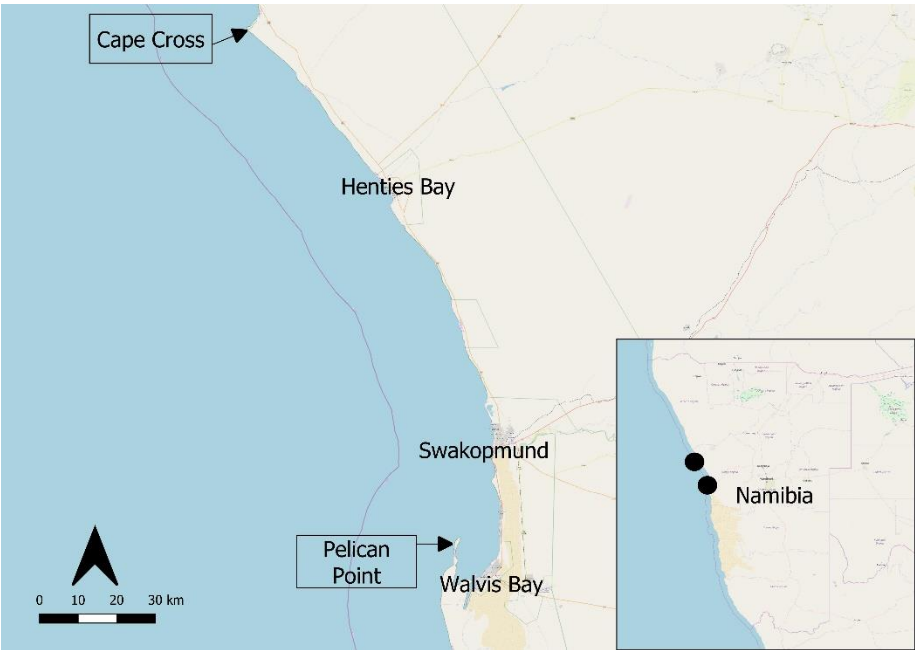

Fig. 1. Map representing two survey locations along Namibian coastline.

Data collection

Entanglement surveys at colonies focused on sub-colonies (groups) of seals, excluding seals that were in the water, using binocular searches and photographic surveys. Surveys at Pelican Point (PP) were conducted from a 4x4 vehicle to minimise disturbance to colonies, as seals here are more habituated to vehicle presence. At Cape Cross (CC), surveys were conducted on foot from the walkways, due to habituation to human presence. Sub-colonies (groups) were defined as discrete groupings with inter animal spacing less than that of between each sub colony. Once a sub-colony was identified an estimation of group size, age, and sex ratio was made alongside an estimated distance to the colony from surveying position. For each survey, binoculars were used to scan seals for entanglements. Entanglements were logged with corresponding severity, material type and seal demographic. Simultaneously to binocular surveys, photographic surveys consisting of a series of photographs of the sub-colony, using varying zoom and focal point, were taken for subsequent analysis. Photographic surveys used Canon Digital SLR cameras with either 300 or 400mm lenses. If during either the binocular scans or photographic surveys an entanglement was sighted, the animal was observed and a detailed series of photographs taken to help identify the animals age class, severity, location of entanglement, and material involved.

In addition to dedicated research survey, opportunistic data and citizen science data of entanglements were utilised. Opportunistic data were collected by the research team at all times other than dedicated surveys (i.e. when undertaking bio-acoustic research). Citizen science data collection was conducted through local marine tour operators during the study period (2018-2019). Entanglements seen in the latter were logged between August 2018 and August 2019, and were recorded differently to surveys, with more detailed information on seal demographic, severity and material type due to animal proximity (Appendix C for data form). Entanglement data were recorded by eight individuals over the study period, with disentanglement being performed by one individual or a group of up to three individuals. As tour guides, the citizen scientists recording these data were experienced in seal ecology, due to their daily interaction with the Pelican Point colony. Entangled seals recorded through citizen science sightings were disentangled and released where possible, and recorded as such. Although all demographics of entangled seals were documented by citizen scientists, the disentangled seals was biased to animals easier to catch - juveniles and subadults. Entanglements recorded through opportunistic and citizen scientists sightings did not include information on sub-colony size or demographics.

Data analysis

i) Systematic surveys: Temporal and Spatial variation in rates of entanglement

To assess the effectiveness of the different survey methods, the number of observed entanglements was compared between in situ binocular searches and photography data. Entanglement rates were then calculated using the number of entanglements found per group divided by the estimated group size. Where values for binocular scans differed from photographic scans, the greater was chosen. Data were crosschecked to ensure every entanglement recorded was unique, however due to similarities in entangling material and low distinctiveness between individual seals, there was potential for double counting between survey days, particularly those close in time or location. Similarly, with data containing wounded seals, seals recently disentangled by the citizen science team may have been represented twice in the dataset, recorded once with material and once as a wound. Unfortunately, there was no reasonable way to correct for this in the data series.

To assess changes over time, entanglement rate per month was calculated for Pelican Point and Cape Cross, by dividing the number of entanglements seen by the number of seals surveyed in each month.

Geographic differences in entanglement rate were compared between the two sites: Pelican Point and Cape cross. It was hypothesised that there would be a greater rate of entanglement at the Pelican Point site due to its proximity to human activities. Survey data containing group size and entanglement rate were tested for normality using SPSS and found to be not normally distributed ($p=0.000$ Kolmogorov-Smirnov). Logistic regression models were produced in R statistical software (RStudio 2015) using location data and calculated entanglement rates to estimate probability of seals being entangled at either location. Entanglement rate and location data were submitted to R using ggplot2 (Wickham 2016) and the associated glm function, and tested using quasibinomial logistic regression. The coefficients were converted into probabilities using the below logistic equation:

1/(1+exp(-x))

ii) Demographic of entanglement and disentanglement

The demographic characteristics of entangled animals were investigated using data from dedicated surveys, opportunistic data and citizen science data. Number of entanglements were compared across likely age and sex classes. To minimise potential bias arising from double counting between data collection methods, results from dedicated surveys and opportunistic/ citizen science data are presented separately.

Accurately assessing the age and sex of fur seals can be incredibly difficult by sight, and so data were cautiously interpreted. During field surveys the age categories pup, juvenile, sub-adult, and adult were used. However, during analysis it became apparent that pup and juveniles were frequently interchanged, and so in order to display accurate results, the age class pups and juvenile were pooled to represent the 'young seal' age co-hort. Sub-adults are intermediate in size, but not yet sexually mature (small, and with no associated pup) and adults were seals that had reached sexual maturity, identified by presence of pup in females (~4 years) or large size with distinctive head shape in males, both with or without an established harem (~8 years). A literature review aimed at establishing a protocol for accurately ageing and sexing seals when carrying out future monitoring was conducted as part of this study (See Appendix A). A full list of recommendations can be seen in Appendix F.

iii) Entanglement severity, material and site differences

To investigate severity of both entanglements and wounds, referring to wounded seals where previous entanglements may have occurred, these were first categorised into scaled severity types (Table 1). The same severity categories were applied to both entanglements and wounds in order to standardise results. Entangling materials were standardised into 14 main types based on available data. Where known, fishing gear was separated into different categories whilst unknown fishing line types remained under 'Other Fishing Gear'. The majority of fishing gear is made from plastic (Deshpande et al. 2020), and thus is classified as such in this study. Examples of material types and associated categories are presented in Appendix B, with example photographs in Appendix D.

Geographical differences in the entangling materials between the two study sites was investigated. For this, quasibinomial logistic regression models were produced for each entanglement material at both locations. Material categories were entered as fractions of the total entanglements from each survey. This included opportunistic and citizen science data for a full assessment of entanglements from both locations. Calculations of probabilities were made as per entanglement rate comparison above.

Table 1. Categories of entanglement severity and corresponding images. (Photo credit Namibian Dolphin Project).

Severity	**Description**	**Image**
No Injury	Newly entangled seals with little current constriction. Also refers to entanglement wounds which appear healed or mostly healed, with no cuts or exposed flesh.	
Minor Injury	Physical constriction resulting from entanglement, shallow cuts/wounds.	
Major Injury	Possible restricted movement (either due to extent of wound or trailing entanglement material, e.g. large ropes or netting which may get caught or drag), deep cuts and visible open wounds and tight constrictions.	
Severe	Extreme constrictions, open fleshy wounds, seal unable to move either as a result of wound and/or restriction from entanglement (e.g. connected to another seal).	

Carcass	Entangled seal or wounded seal from previous entanglement is dead, likely due to entanglement.	

Results

General summary of entanglement data

Between April 2018 and December 2019, 285 dedicated surveys were conducted over 50 dates at both Pelican Point (Walvis Bay), and Cape Cross on fur seal sub-colonies, with a total of 133 entanglements seen in either field surveys or post-survey photographic analysis. Entanglement numbers used in analysis was the greatest value found in the two methods. Unless otherwise stated, presented rates for dedicated surveys are based on this value. Sampling was more consistent and frequent during 2019, and the number of entanglements per month for this year is shown in Figure 3. Surveys were conducted on only 5 dates in 2018 at Pelican Point in April, July, August and September with an average frequency of 1 per month. In 2019, surveys were conducted over 45 days between January and December (excluding March) with an average frequency of 4 days per month and 24 individual group surveys per month.

Of the total 285 group surveys conducted during the study period, 244 were at Pelican Point (PP) and 41 at Cape Cross (CC) (Figure 2). Total entanglements, including opportunistic and citizen science data, were 183 and 34 for Pelican Point and Cape Cross, respectively. Sampling was more regular between the months of May – December, with data lacking between the January – April for both locations. August exhibited the highest rate of entanglement, as shown in Figure 4.

Of the total 285 surveys conducted, 30% (n=85) identified at least one entangled seal, with an average entanglement rate per survey effort in 2019 of 0.4%. Surveyed groups containing at least one entangled or wounded seal accounted for 32% (n=92) of total survey data. Of total entanglements, 114 were recorded with detailed information on seal age and sex, as well as entangling material type and severity of entanglement.

Additional entanglements observed opportunistically and by citizen scientists totalled 103 over the study period, with most data being recorded in 2019. These were entanglements observed through opportunistic sightings (n=57) or citizen scientists (n=46)(Figure 3). Of the total recorded entangled individuals, 31% (n=67) were successfully disentangled (Table 2). The majority of these disentanglements (n= 46) were carried out by the Pelican Point kayaking team and logged as citizen science data, whilst the remaining disentanglements (n=21) were carried out whilst off survey effort and logged as opportunistic. The majority of disentanglements were carried out on juveniles, accounting for 76% of disentanglement data. A total of 6 disentanglements were attempted during systematic surveys and opportunistic sightings, but were unsuccessful. These seals could have been later disentangled by the Pelican Point kayaking team.

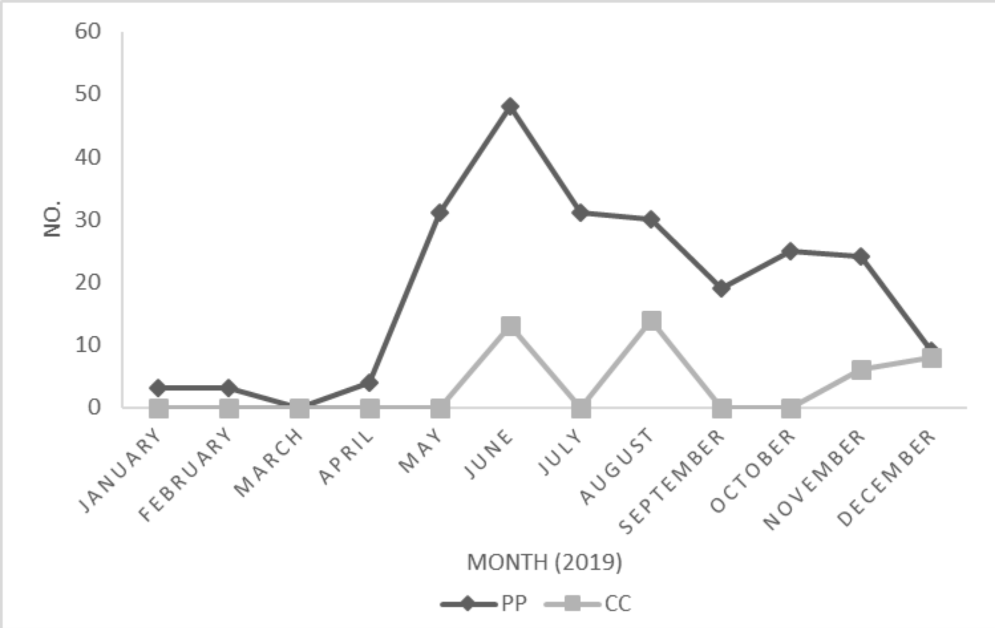

Fig. 2. The number of dedicated surveys conducted at Pelican Point (PP) and Cape Cross (CC) in 2019.

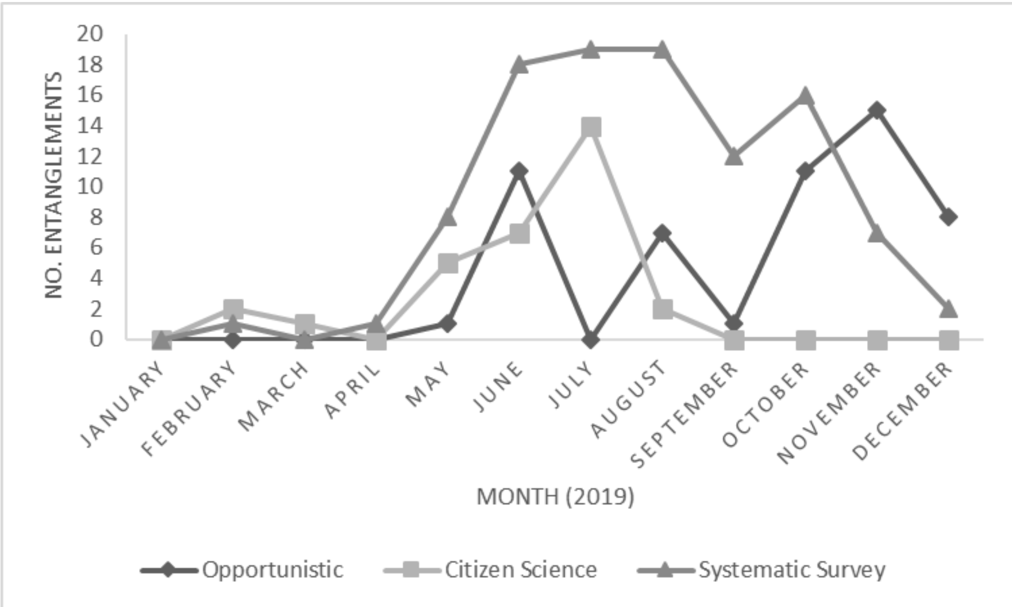

Fig. 3. Number of entanglements observed across all sources of data from Pelican Point and Cape Cross, in each month in 2019.

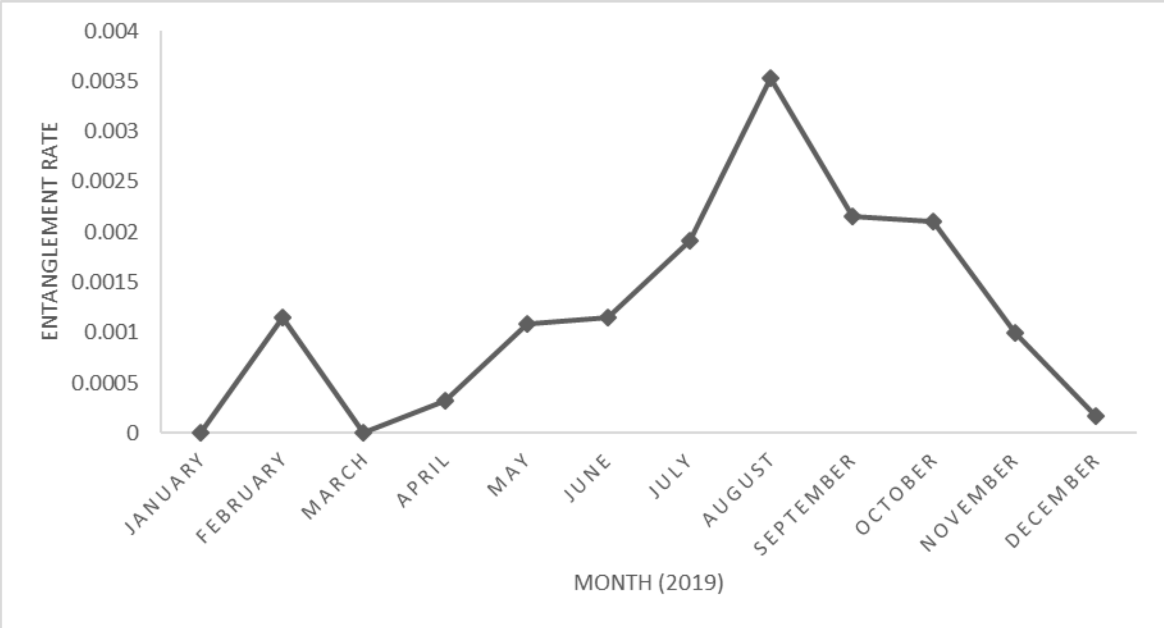

Fig. 4. Average entanglement rate per month in 2019, using dedicated survey data from Pelican Point and Cape Cross.

Table 2. Number of seals successfully disentangled in different age and sex categories through opportunistic sightings and the citizen scientist team between August 2018 and December 2019.

Sex	Age Group			Total (%)
	Juvenile	Sub-Adult	Adult	
Male	8	5	1	21
Female	5	5	3	19
Unknown	38	2	0	60
Total(%)	76	18	6	

Methodology review

The total number of entanglements seen from field surveys and through post-survey photo analysis from 2019 are shown in Figure 5, with counts from photo surveys 22% (n=110) greater than that of those recorded in binocular scans (n=90). Data from 2018 was not as consistent, but showed that binocular scans identified 33% more entanglements (n=12) than what could be seen in photo surveys (n=9). Overall, photo surveys were more successful in identifying entanglements, with 17% (n=17) more entanglements seen using this method. Number of entanglements seen in either methods were tested using Pearson correlation, and found to be significantly positively correlated (Pearson = 0.779, p = 0.000, R^2 = 0.64, 273 degrees of freedom).

During data collection, estimated distance to sub-colony of interest from surveying position ranged between 2-120m (mean 33 +/- SD 19), with a mean distance of 31m (+/- SD 17) at PP and a mean distance of 42m (+/- SD 28) at CC. The average time taken to conduct a binocular survey in addition to taking photographs was nine minutes (+/- 8 mins) . Additional time was taken to analyse photographs, usually no more than five minutes per selection of photos (scan), however this depended largely on the number of photographs taken.

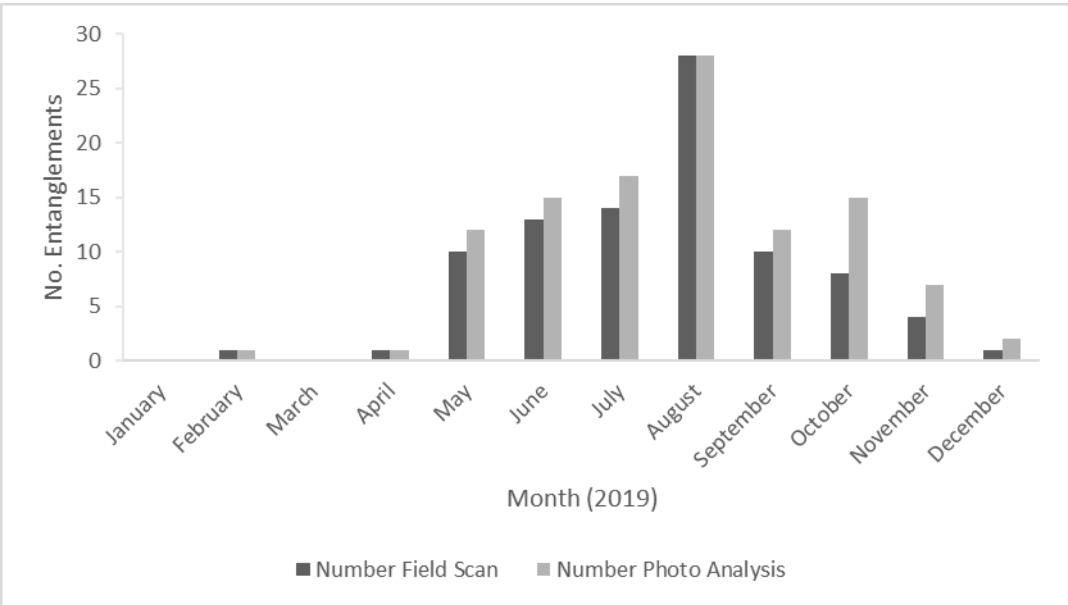

Fig. 5. Number of entanglements seen during dedicated binocular scans versus number seen during post-survey photo analysis in 2019, excluding less active months (January-April).

The total number of photographs analysed from photograph surveys was 6511, ranging between 1-125 photographs (mean 23 +/ SD 18). The amount of photos taken per group size can be seen in Figure 6, with smaller groups often having more photos to analyse than larger groups. Photo numbers appear to be 5-10% of the estimated group size in many of the smaller group surveys, with many outliers.

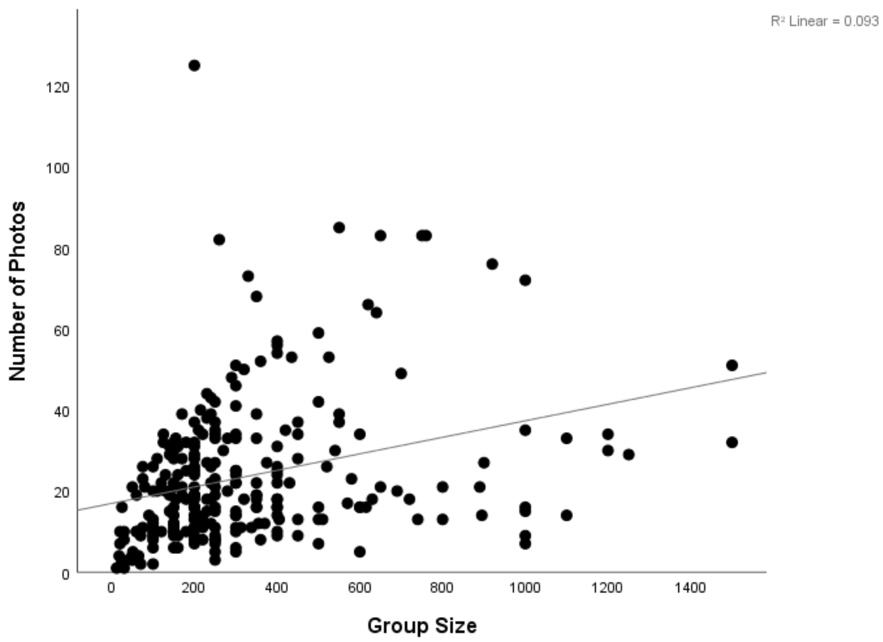

Fig. 6. Number of photos taken per sub-colony survey. Based on group sizes between 12-1500 individuals.

The distribution of survey effort of sub-colonies/groups at Pelican Point and the number of entanglements observed indicates a spatial trend in entanglements (Figure 7). The majority of sub-colonies at Pelican Point reside on the eastern side of the peninsula, which accounts for the greater number of surveys being conducted there. Most of the entanglements sighted during surveys are on the eastern side of the peninsula.

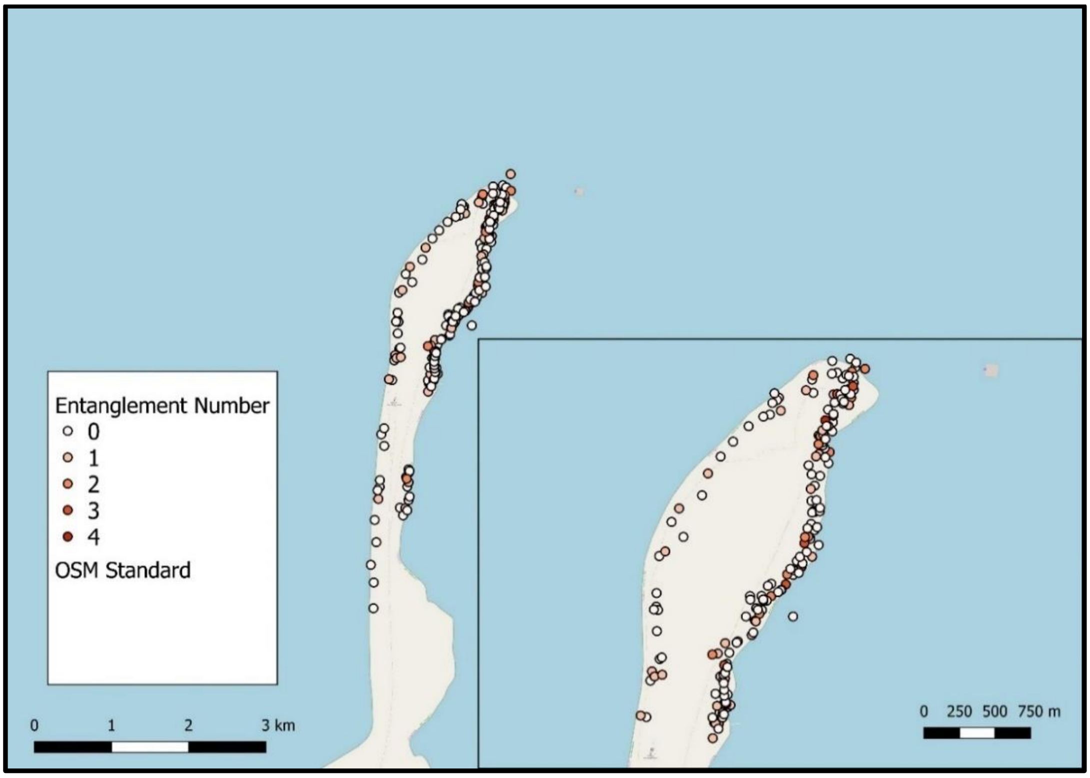

Fig. 7. Map of Pelican Point, Walvis Bay. Circles represent individual group surveys, with colours indicating number of entanglements present within each survey, based on the highest number observed in either field or photo survey. The majority of surveys were conducted further up the point, which is shown in more detail on the right.

i) Systematic surveys: Temporal and Spatial variation in rates of entanglement

The rate of entanglement (%) at PP was higher than Cape Cross (CC), with one in 715 (0.14%) surveyed seals being entangled over the study period here compared to one in 2437 (0.04%) at CC (Table 3). Between 2018 and 2019, the entanglement rate for Pelican Point (PP) remained the same (0.14%) , indicating no inter-annual change between surveys years. The percentage increase in the number of seals surveyed at PP between 2018 – 2019 was identical to the percentage increase in the number of observed entanglements. To check for independence in the rate data, these data consisting of number of seals surveyed and associated rate of entanglement from each survey, were subsequently tested using Pearson correlation coefficient to determine whether a correlation existed. There was found to be no significant correlation (Pearson = 0.073, p= 0.227, 273 degrees of freedom), Indicating that the rates are independent from survey effort. The correlation plot for these data (Figure 8) indicates that more entanglements are seen in smaller group sizes, which could correspond with ease of surveying; the fewer the seals, the less likely seals will be hidden amongst large numbers. As the data were highly zero inflated, a second analysis investigating the correlation between group size and rate was conducted, using scan data which contained at least one observed entanglement. This resulted in a significant negative correlation at the 0.01 level (Pearson = -.298, p= 0.000, 76 degrees of freedom).

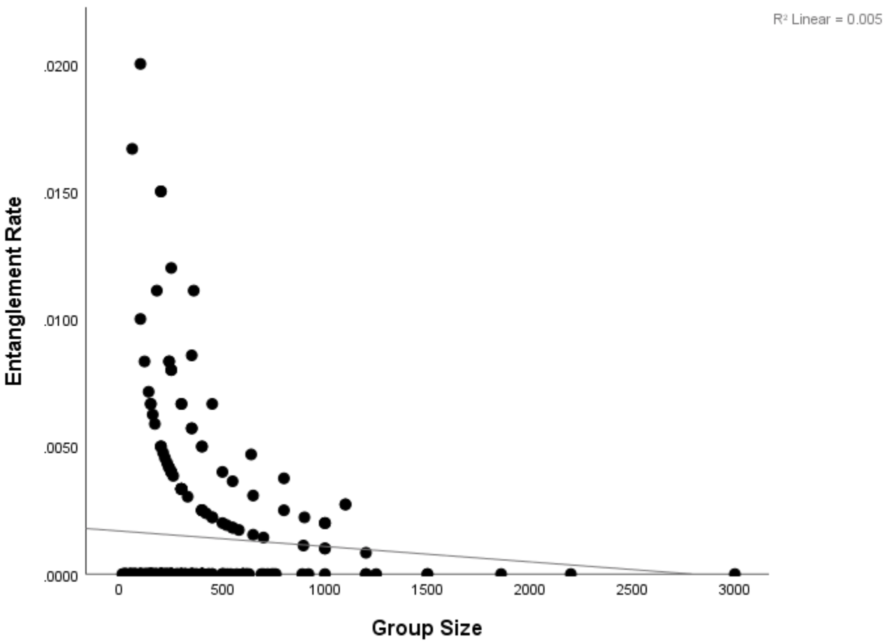

Fig. 8. Correlation plot of number of seals surveyed (group size) and associated entanglement rate from Pelican Point and Cape Cross, using survey data.

A higher monthly entanglement rate was observed between the months of July and October (Figure 4) corresponding with an increased survey effort during this time period. Greater survey effort would be required at either end of the year for seasonal trends to be fully assessed. A higher number of entanglements were also observed in these months from opportunistic and citizen science data (Figure 3).

Table 3. Rate (%) of entangled seals in 2018 and 2019, excluding surveys without group size data (n=23), and opportunistic/citizen scientist sightings.

Year	Location	Total seals	Total Entanglements	% Entangled
2018	PP	10 728	15	0.14
2019	PP	70111	98	0.14
	CC	12 188	5	0.04
% Increase 2018-2019	PP	553	553	
Total	PP	80 839	113	0.14
Total	PP + CC	93 027	118	0.13

ii) Demographic of entanglement and disentanglement

Juvenile seals were found to be the most commonly entangled (n= 131) across both systematic surveys and opportunistic data (Figure 9; Figure 10). Most disentanglements by the citizen scientist team were carried out on juveniles (Table 2), corresponding with the greater number of entanglements observed in this age group. Sex was difficult to establish in the majority of entanglement cases, with 60% (n=135) of total recorded entanglements categorised as ‘Unknown’. However, in cases where sex could be determined, males were

12% more commonly entangled than females. Identified males were also 10% more commonly found entangled and subsequently disentangled by citizen scientists.

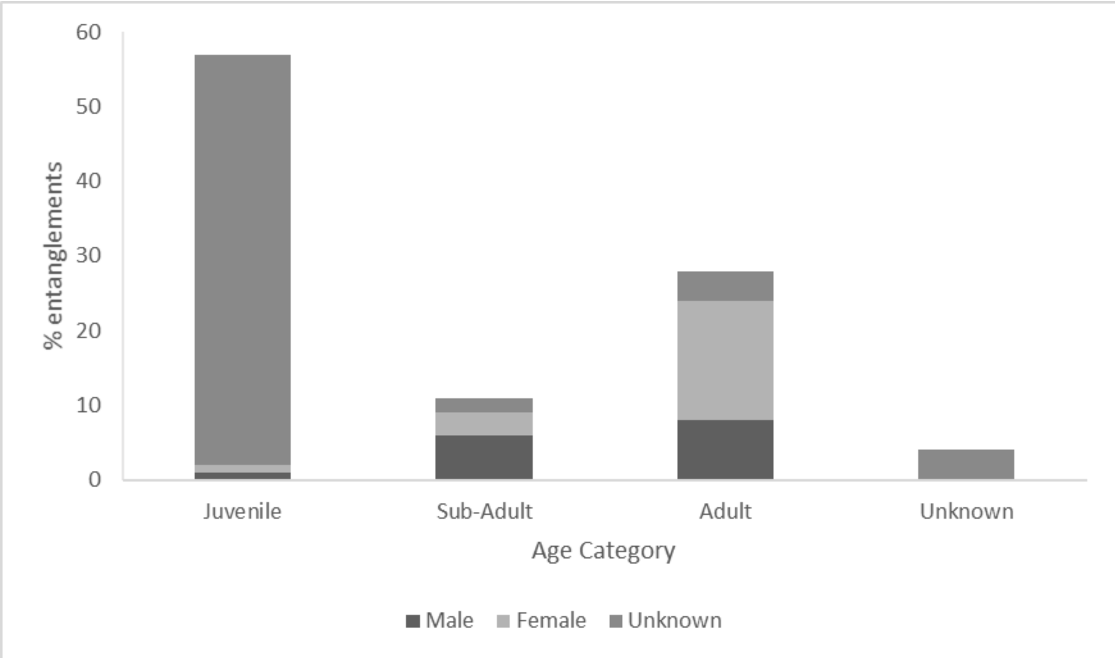

Fig. 9. Percentage of entanglements observed in each age and sex category, based on dedicated surveys

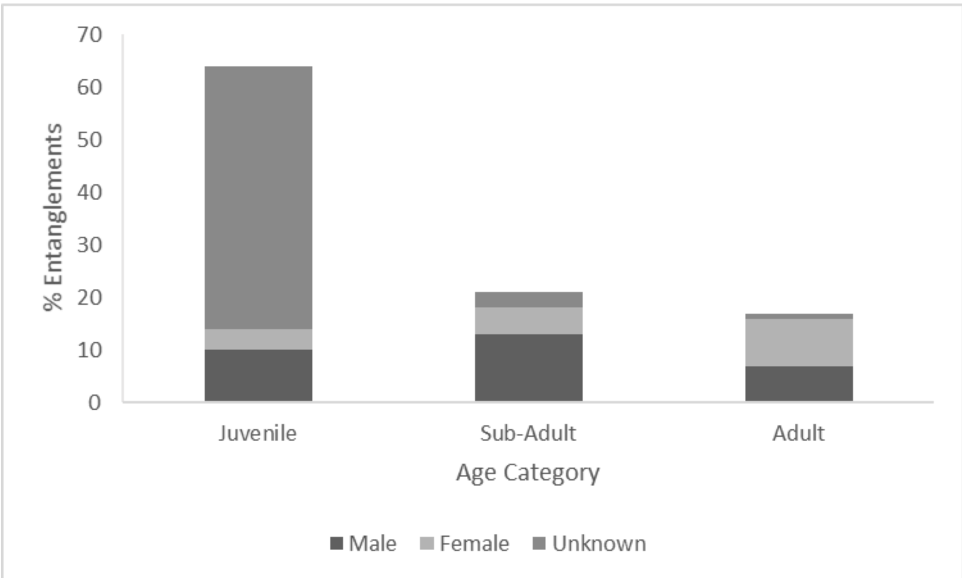

Fig. 10. Percentage of entanglements observed in each age and sex category, based on opportunistic and citizen science data.

iii) Entanglement severity, material and site differences

The most commonly observed effects of entanglement were Minor and Major injury, accounting for 41% and 35% of the survey data respectively. Whilst cases of 'Severe' and 'No Injury' were much less common overall, entanglements of these severities were observed more at PP than at CC (Figure 11; Figure 12). Only one carcass was recorded - a juvenile seal attached to a female by a single material type. Ten percent of entanglements were categorised as 'unknown' severity, due to difficulties assessing severity from a distance and/or in poor visibility. Data from wounded seals are shown in Table 4, with 'No Injury' being the most frequently observed severity type. Where documented (85% of cases) the location of entangling materials were commonly observed around the neck of affected seals, accounting for 74% of total recorded entanglements. Other affected areas included the head, mid body and shoulders (10%), and jaw (1%).

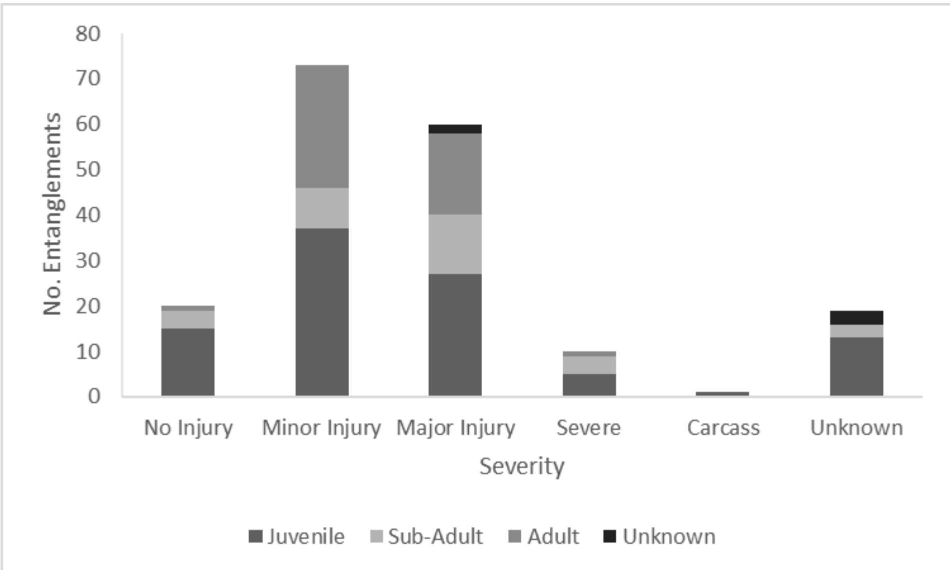

Fig. 11. Number of entanglements observed in each severity category across all data sources for Pelican Point.

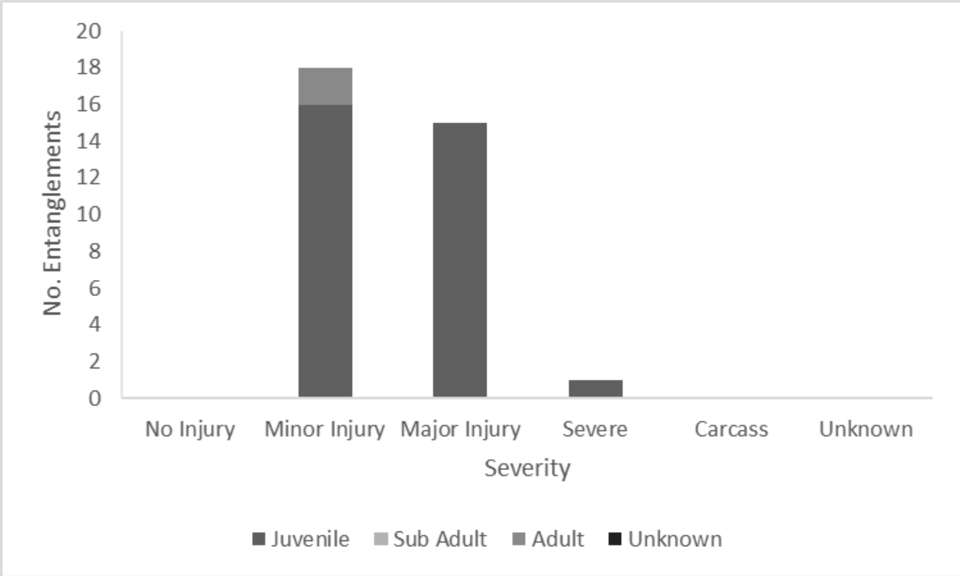

Fig. 12. Number of entanglements observed in each severity category across all systematic, citizen science and opportunistic data at Cape Cross.

Table 4. Number of wounds observed in each age category with their corresponding severity rating, across all systematic, opportunistic, and citizen science data at both Pelican Point and Cape Cross.

SEVERITY OF WOUND	AGE				TOTAL
	Juvenile	Sub-Adult	Adult	Unknown	
NO INJURY	4	3	8	1	16
MINOR INJURY	3	0	8	1	12
MAJOR INJURY	3	0	6	0	9
SEVERE	1	0	0	0	1

Overall results (Figure 13), indicate that fishing-related materials are collectively the main cause of entanglement in fur seals at both Pelican Point and Cape Cross. This includes known fishing material such as snoek line and gill net but also other unidentifiable fishing material. A high percentage of unknown materials (31%) caused entanglements, and these were categorised as such due to difficulties in identifying from a distance or in poor quality images. Other common entangling materials included shipping material (13%), consisting of packing strap, and other plastics (5%).

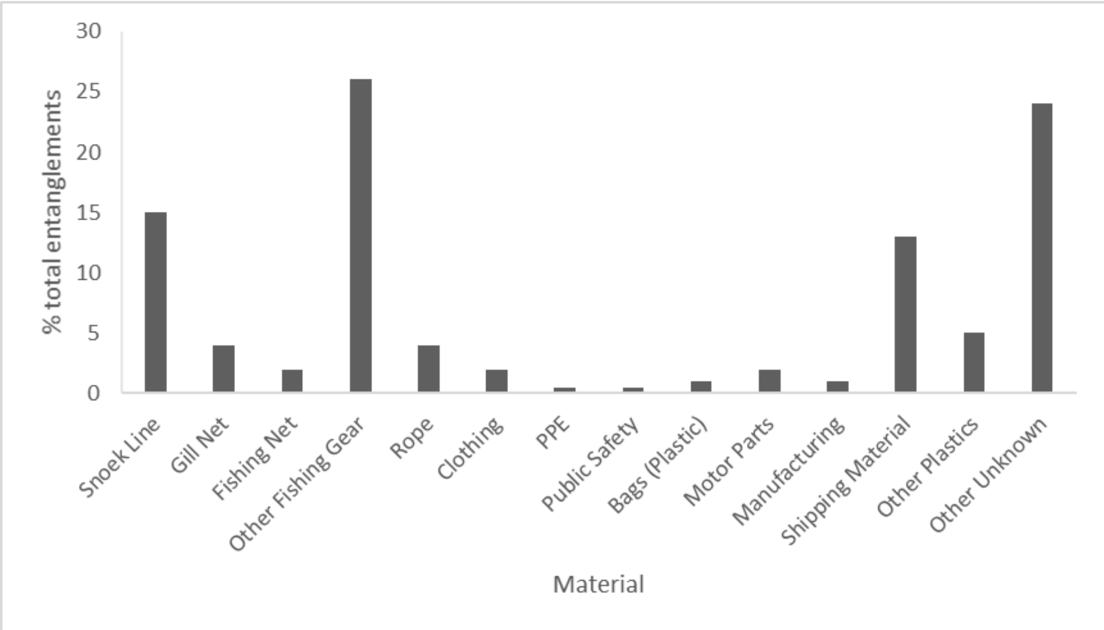

Fig. 13. Percentage of total recorded entanglements from different material categories across dedicated survey, opportunistic and citizen science data.

Entanglement rates for both locations can be seen in Figure 14. Due to a large quantity of data containing 0 entanglements, or few entanglements seen in a large group size, the median value for both locations is 0, meaning the data are zero inflated. Logistic regression modelling using entanglement rates at both locations suggests that the probability of entanglement at CC was 0.0016, and at PP was 0.0007, with no significant difference between the two locations (p= 0.0956, 112 df). Thus, the probability of entanglement is the same for each location. However, the data was zero inflated, and so the statistical test did not have enough power based on sample size.

Juveniles were most commonly entangled at both locations (Figure 15), but at PP entanglements were observed in a wider range of age classes than at CC, with no sub-adults recorded at this location.

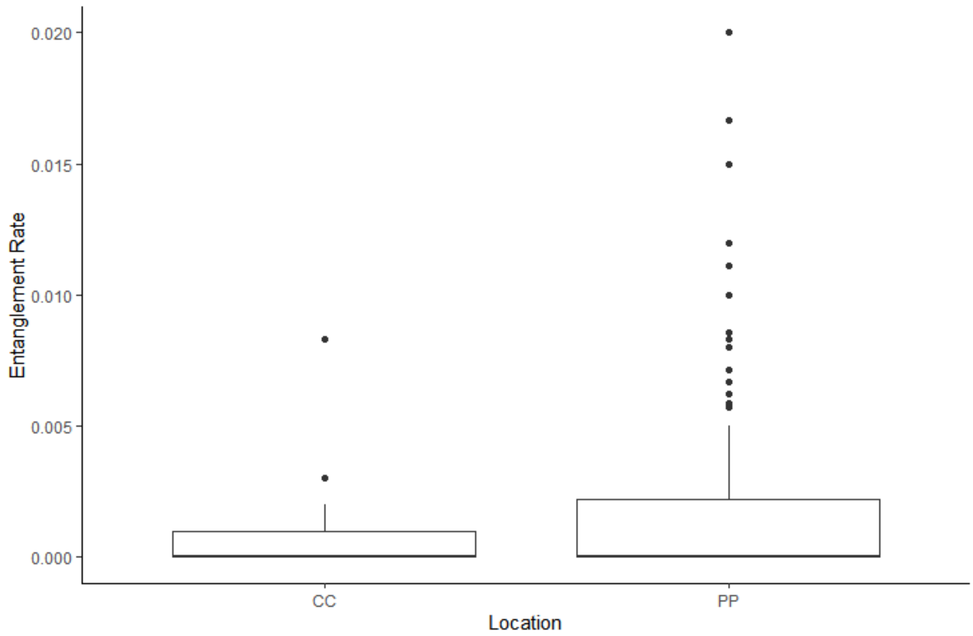

Fig. 14. Calculated entanglement rates for CC and PP, based on number of entanglements seen in dedicated surveys within an estimated group size.

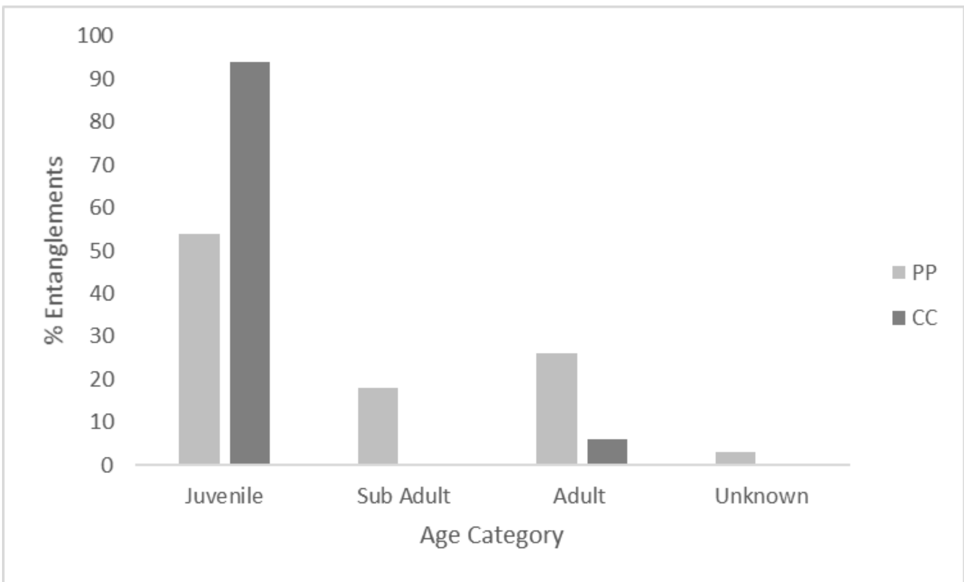

Fig. 15. Age demographic of entangled seals at Pelican Point (PP) and Cape Cross (CC), based on percentage of total recorded entanglements from each location.

Fishing-related materials accounted for 52% and 44% of entanglement data for PP and CC, respectively (Figure 16). A wider range of materials were found to cause entanglements at PP than at CC, involving more domestic materials such as clothing and plastic bags. A greater percentage of entanglements were caused by shipping material and motor parts at CC than PP. Logistic regression modelling was used to estimate the probability of each material causing an entanglement at either location (Table 5). Each material was more likely to cause entanglement at PP than CC, reflecting the greater rate of entanglement here.

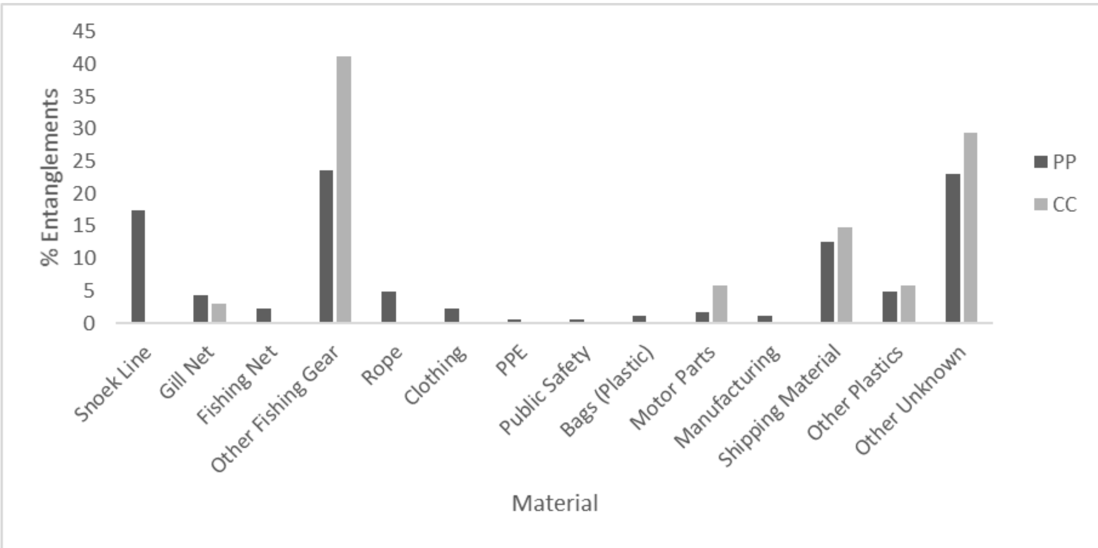

Fig. 16. Geographic comparison of entanglement materials at PP and CC from dedicated survey, opportunistic, and citizen science data, based on percentage of total entanglements recorded at each location.

Table 5. Probabilities of entanglement by most common material types at Pelican Point and Cape Cross, excluding unknown materials, and associated significance values (Pr). All other material types are classified as 'Other'.

Material	**Pelican Point**	**Pr(>|t|)**	**Cape Cross**	**Pr(>|t|)**
Snoek Line	0.255	0.99	0.001	0.99
Other Fishing Gear	0.419	0.591	0.325	0.308
Shipping	0.237	0.549	0.156	0.04 *
Other Plastics	0.073	0.69	0.047	0.007**
Other	0.163	0.429	0.065	0.039*

*significance level 0.01, 69 df
**significance level 0.001, 69 df

Discussion

This is the most recent and detailed assessment of plastic entanglement occurrence in Cape fur seals at Pelican Point and Cape Cross in Namibia. More entanglements were observed among the Pelican Point colony, however as this is the first study focusing on this colony, no pre-existing data exists for a comparison. Cape Cross entanglements could not be directly compared with pre-existing data due to differing surveying methods (Shaughnessy 1980).

A commonly used method in seal studies is that of aerial photography, either by drone or plane (Thomas et al. 2019; McIntosh et al. 2018). Whilst useful for assessing and monitoring seal population numbers, this method has associated financial implications and is usually conducted much less frequently than entanglement-focused surveys. *In situ* binocular scans are a low-cost method of data collection and allow for a detailed assessment of entanglements within fur seal colonies. Photographic surveys are an alternative method of entanglement analysis which enable a closer look at stationary seals and have previously been used in addition to field surveys (Zavadil et al. 2007). In this study, both methods were used to assess rate of entanglement in Cape fur seals. Significantly more entanglements were seen in photographs than in binocular scans, suggesting this is a more accurate method of assessment. Photograph surveys require additional time and both quality of photographs and seal positioning are major factors influencing the efficacy of entanglement assessment. Both weather and photographer ability can influence image quality (see examples in Appendix E). Unlike in the field, where seals move around and can be surveyed from different angles, photographs are two-dimensional and can capture seals in unfavourable positions such as behind others or lying down. A benefit of photographs are that seals are stationary and so can be studied more thoroughly. Good quality SLR cameras with adequate zoom allow seals to be scanned at closer range than in binocular surveys, with an additional zoom also available on photograph viewing software. A significant number of seal entanglements were missed in binocular scans, however there are some occasions where entanglements seen in binocular scans are not seen in photos, likely due to a lack of photos being taken or during large group surveys. The coefficient of determination (R^2) for these data indicated a high percentage of the entanglement numbers matched between methods (64%), with the remaining 36% of observed entanglements unaccounted for in either method. It is therefore highly recommended that both methods be used in future monitoring, to minimise errors from either method and enable an accurate assessment to be conducted.

The higher rate of entanglement at Pelican Point, and the combined rate from both locations corresponds with that of other seal species, with many being lower than 0.5% (Hofmeyr et al. 2002; Page et al. 2004). However, direct comparison with entanglement rates from similar studies should be carried out with caution, as surveying methods vary and rates estimated differently; for example being based on population size, or number of seals surveyed as per this study. The overall entanglement rate from both locations was relatively low (0.13%), however, the actual rate of entanglement including unseen mortalities and seals at sea could be significantly different. More entanglements were observed in smaller group sizes, indicating a bias in group size. This could be due to seals in smaller groups being more exposed, allowing entangled seals to be easily sighted. Size estimations are easier with smaller groups, meaning more reliable rates may exist in these data. This suggests surveys on smaller sub-colonies provide a more accurate assessment of entanglement numbers, and so should be the focus of future surveys. Dedicated surveys and citizen scientist disentanglements were often conducted close together in time and location, meaning entangled seals may be re-sighted or counted twice, thus inflating the entanglement data. Where possible, cross-checking can reduce this bias. Re-identifying seals both in the field and in photographs however, is difficult unless entanglement material is clearly unique and without tagging. Recent observations at Pelican Point indicate a high level of movement among seals, with bulls regularly moving between harems around the point and younger males using the area as a haul-out site in between long-distance sea trips (Martin 2020). It is thought that entangling material is not likely to be removed in fur seals without human intervention, indicating a frequent change in seal populations with short-lived entangled seals quickly being replaced by newly entangled seals (Fowler et al. 1990; Page et al. 2004). It is therefore necessary to continue conducting colony surveys on a regular basis, but focusing on smaller groups.

Spatial arrangement of entanglement occurrence and survey effort at Pelican Point (Figure 7) shows that the majority of entanglements were observed on the eastern side of the peninsula, directly adjacent to Walvis Bay town. It could be that entanglements on this side of the peninsula occur more frequently due to either: sub-colony composition consisting of more juveniles, an overall higher number of seals residing here, or an increased quantity of anthropogenic waste-interactions resulting from habitation on this side.

Disentanglements recorded as citizen science were largely carried out by marine tour operators, due to their adequate training and experience. Larger seals are much more difficult to disentangle, and so a bias in successful disentanglements leans towards younger juvenile seals. Pelican Point was the principal site for disentanglement, due to marine tour activity here. These actions will improve the chances of survival for entangled seals. Entangled seals forage at sea much longer than other seals, increasing their energy demands (Fowler et al. 1990). Whether this impacts their survival rate post-disentanglement would need to be determined to fully assess mortality in disentangled seals. Nevertheless, these efforts are helping improve the quality of life for this population and playing a vital role in data collection for future mitigation.

Long-term monitoring of these seal populations is necessary to establish whether there are seasonal trends in relation to entanglement rates, which cannot be fully identified from within this study alone. Dedicated surveys were largely conducted during the austral winter months (June-September), mainly due to an increase in the number of surveyors, and so these would need to be conducted more regularly at either end of the year for this to be assessed. The resulting increase in entanglement numbers found across all data sources during these months could be a result of increased effort; however this could also reflect changes in seal activity and behaviour with growing pups exploring further afield. Rate of entanglement at Pelican Point was identical in both 2018 and 2019, with the number of seals surveyed not influencing changes in annual rate. However, the identified group size bias may exist for both years. This also indicates that fewer surveys can be conducted in order to still gain colony-representative data. It is essential that entanglement rates in long-term monitoring be carefully interpreted, as rates could fluctuate due to an increase or decrease in the number of seals surveyed as opposed to changes in conservation efforts or waste management (Boren et al. 2006).

Within the life cycle of Cape fur seals, there are periods in which interaction with marine waste is likely to be higher. For example, observations indicate that pups usually begin swimming in deeper water after around 3-6 weeks (Erdsack et al. 2013), meaning at this age they would be more likely to interact with waste material close to their colony. Juveniles in this study exhibited a higher number of entanglements than other age categories, which corresponds with findings from similar studies (Croxall et al. 1990; Pemberton et al. 1992; Lawson et al. 2015). This can be likely attributed to a more curious nature in younger seals; smaller juveniles which do not yet have the dive capabilities of adults (Horning and Trillmich 1997) are more likely to interact with waste as they explore and develop their foraging skills, but can also fit into material with smaller mesh sizes due to their size (Fowler et al. 1990). The difference in entanglement occurrence between sexes was marginal, with males exhibiting slightly more entanglements than females. Much of the entanglement data consisted of unidentified sex, as whilst this is easier to establish in adults due to clear differences in physical appearance, in juveniles this is difficult without genital examination. A more regular and detailed assessment of sex would be needed to determine whether a trend exists between this and entanglement occurrence.

Whether entangling material in juveniles remains into adulthood, accounting for the number of adult entanglements seen, remains unclear. Due to the high annual mortality rate observed in Northern fur seals due to entanglement (14%) (Fowler et al. 1990), it could be assumed that this is not the case. Many entanglements caused deep constrictive cuts, with some individuals entangled in a single material in multiple locations, potentially impacting movement and foraging ability. Disentanglements at Pelican Point enabled a closer examination of causative materials and the damage they cause, resulting in a potential bias towards more accurate data stemming from citizen scientists with regard severity and material type. A bias may also exist in observed severities due to the fact that many severe entanglements may remain unrecorded as seals exhibiting these injuries with larger material are more likely to die and never return to shore (Fowler et al. 1990), resulting in an inflated number of milder injury cases.

The most common entangling materials were found to be related to the fishing industry, which corresponds with findings from similar studies (Hofmeyr et al. 2002; Campagna et al. 2007; Hanni and Pyle 2000). These fishing-related materials included snoek line, rope nets, gill netting, trawling line and braided line, often attached to other objects such as hooks and lures which can cause even greater damage and increased drag**.** Other common materials included shipping materials such as packing strap and motor parts such as rubber and metal gaskets. These materials have also been found to cause entanglements in many other species of seal, particularly packing strap (Hogan and Warlick 2007), indicating a world-wide issue with regard to inappropriate disposal. Packing straps used to seal bait boxes and other transported goods have previously been linked to longline vessels (Page et al. 2004; Pemberton et al. 1992). These may be disposed of in a similar manner to much fishing gear, either thrown overboard or lost (Sheavly and Register 2007). How seals then come to interact with these materials is unclear; they have the ability to travel through looped objects, but they may also play with these materials as part of their curious nature. Studies on cetacean entanglements have found that this may occur during depredation attempts (NOAA 2014), which could also be the case with seals and active fishing gear. Seals are often in competition for food with fisheries, particularly in Namibia and South Africa, where their diet of teleosts such as anchovy and horse mackerel are also the targets of fishery catches (Ministry of Fisheries and Marine Resources 2005). Historically they have impacted catch counts by general activity around fishing boats, but are also known to purposefully enter fishing nets to depredate fish, confirming their interactions with active fishing materials (Wickens 1994; Lyle et al. 2015). An important aspect of future study is to determine whether Cape fur seals are being entangled more in active or ghost fishing gear, allowing for more directed mitigation actions (NOAA 2014). In Namibia, seals forage mostly in the northern Benguela system but are known to travel further afield (Mauritzen et al. 2010), meaning foraging occurs on a much larger scale than intra-colony ranges. This behaviour means that seals are exposed to much more waste material than what may be present in their immediate colony feeding areas, making it difficult to establish sources of pollution. Female individuals have been shown to dive as deep as 450m when foraging, however this varies greatly within colonies with most foraging in the epipelagic zone (Kirkman et al. 2019), meaning seals can interact with both surface waste as well as deeper water fishing gear.

Probability of entanglement occurring in individuals was found to be similar at both locations. A wider range of materials were found to cause entanglements at Pelican Point than at Cape Cross; these included clothing, plastic bags, PPE such as hard hat straps, and other materials such as rubber and steel categorised as manufacturing. The presence of these other materials at Pelican Point could be linked to its proximity to habitation, which otherwise would not be found at a remote site such as Cape Cross. This could also explain the higher observed rate of entanglement and probability of entanglement by identified materials at this location. A greater range in age classes of entangled seals was also observed at Pelican Point, with data here including entangled sub-adults. This could be a result of disentanglements or proximity to seal groups from surveying position here, which both enable age to be more accurately assessed. Prior to and during data collection, construction of a new container terminal in Walvis Bay was underway, which aims to increase vessel and cargo handling capacity (Namport). This construction activity and associated increase in vessel traffic could explain an increased interaction with waste among the seal colony here. Snoek line was only observed at Pelican Point, which could be explained by the Snoek fishing activity that occurs around Walvis Bay (Ministry of Fisheries and Marine Resources 2013). Cape Cross entanglements were primarily fishing-related, however a higher percentage of entanglements were caused by shipping material and motor parts at this location. It's likely that many material types were not recorded or recorded as 'unknown' due to distance from surveyors or the quantity of entangled seals being in the sea at the time of surveying. Rock Lobster fishing activity has been linked to entanglement occurrence in Australia (Page et al. 2004), involving entanglements caused by packing strap and rope. Rock Lobsters are fished for between Walvis Bay and Cape Cross

(Batty et al. 2005), which could account for entanglements caused by these materials in these locations.

Future management and mitigation

Whilst difficult to fully assess the impact conservation efforts may have on localised entanglement rates, mainly due to marine debris originating from many different sources potentially miles away from a study site, efforts can still be made to help reduce entanglement occurrence. Mitigation methods already successfully identified include biodegradable packing materials, which are easily broken and offer seals a greater chance of escape (Page et al. 2004). These are currently not compulsory but should be actively encouraged in associated industries such as fishing and shipping. Other approaches involve net binding using organic materials; this has been implemented in Australia with an aim of reducing fur seal entanglement, however the success of this is difficult to determine (Hamilton and Baker 2019). Seal exclusion devices have been found to be highly effective in reducing net-related mortalities, with an increase in escape hole size significantly reducing entanglement occurrence (Lyle et al. 2015). Whichever method used, it is vital that future mitigation actions be carried out cooperatively between conservationists, local communities, and governing bodies.

Conclusion

Being the first study to identify and compare rates of entanglement at Cape Cross and Pelican Point, results from this research will update pre-existing data as well as provide new information, acting as a baseline from which future monitoring can be compared with. It is hoped these findings will help encourage future management and mitigation actions with respect to conservation and waste reduction. Rate of entanglement was much higher at Pelican Point compared with Cape Cross, likely due to proximity to human habitation. Probability of entanglement was found to be not significantly different for either location. Further research is required to identify whether trends in entanglement exist at either location, both seasonally and annually. This, alongside efforts to determine whether entanglement by fishing gear, identified as the main cause of entanglement, occurs by interactions with active or ghost gear will help direct management decisions. The majority of materials found to cause entanglements were identified as plastic-derived, therefore it can be concluded that plastic pollution present in marine environments is negatively impacting the welfare of Cape fur seal individuals. Long-term monitoring of these populations and rates of entanglement is vital in assessing conservation impact; binocular scans should be continued in conjunction with photographic surveys for this to be accurately conducted.

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Appendices

Appendix A – Short literature review on accurately assessing age and sex in Cape fur seals, with recommendations for future approaches:

Oosthuizen and Bester (1997) found that the most effective method in determining age was to count dentine growth layer groups, however this is highly intrusive and not possible for large scale studies on live animals. McKenzie et al. (2007) conducted studies on Australian fur seals and found that females (on average) give birth to their first pup at around 5 years, whilst Cape fur seals give birth around the ages of 3-4 (Shaughnessy 1985). Ageing males can be more difficult, as they may be of age to mate, but have not yet established a harem, i.e. be 'socially sexually mature'. On average Australian fur seal males achieve social maturity at around 8 years. Studies differ in their approach to ageing and sexing seals; one study conducted on Northern fur seals identify males as either adults, sub-adults or juveniles based on size alone (Kiyota and Okamura 2005). However details on female ageing were not specified. Sexing can be achieved by physically examining the genital area; male pups have one hole, females have two. Harbour seals can be distinguished based on the width of the trail they leave in mud and are categorised as juveniles, sub-adults, and adults according to Naughton (2012), however this is difficult to examine in fur seal colonies. Jefferson et al. (2008) describes how sexing juveniles is impossible without examining genitals and separating adults, subadults and juveniles is difficult by sight.

A study by Erdsack et al. (2013) conducted on pup natal fur found that pups began swimming in deeper water after around 3-6 weeks. In the literature, the age of weaning is thought to be 8-12 months (Kirkman et al. 2016), but there is very little research focused on Cape fur seals with regards weaning age. An easy method of age assessment would be to categorise seals as either ‘adults’ or ‘juveniles’, with adults being seals of adult size and that have reached sexual maturity (with pup, large male mane and size), and juveniles being younger seals which have not yet reached sexual maturity (or social) which are significantly smaller in size and includes pups. The addition of ‘pup’ as a separate category would distinguish juveniles from pups, representing seals which have begun foraging for themselves and potentially interacting with entanglement material.

It can be argued that the age in which a seal becomes a juvenile is either the age at which it is weaned, or the age at which it begins swimming in deeper water. Considering many seals exhibit prolonged suckling (Kirkman and Arnould 2013) or have been found to exhibit early weaning as young as 6 months old (Oosthuizen 1991), the easier approach would be to age based on entry into the water. This would mean surveys conducted around March onwards would categorise these pups as Juveniles, to include any pups born in January. However, as weaned seals are more likely to cover a greater distance when foraging and migrate among colonies, it would be important to capture this age range to establish at which stage entanglements are occurring more. A recent study conducted on Northern fur seals categorised juveniles as seals being aged 1-2 (Zeppelin et al. 2019), and describes how these juvenile seals migrate away from breeding colonies and often don’t return until the age of 2. A similar age classification has been used in subantarctic fur seals (Beauplet et al. 2005), but also includes a ‘post-weaning’ life stage, which can be merged with ‘juvenile’ for easier identification.

Adult males can be easily distinguished from females due to their enlarged chest and shoulders and overall larger size. Whereas subadult males which are not yet fully sexually mature may easily be confused for adult females due to physical similarities. Staniland and Robinson (2008) uses four categories for ageing and sexing Antarctic fur seals; adult males are the males capable of dominating a territory, subadult (smaller) males which can be distinguished from adult females but do not yet hold territory, adult females, and juveniles which includes all smaller seals which are difficult to sex. This method was then also used in a study conducted by Staniland and Waluda (2013) but subadults were included in 'Juveniles'. Juvenile seals which have begun foraging for themselves exit the water darker than their natural fur colour and so could be mistaken for pups if size is not considered, and so an accurate assessment of the age of seals going forward can be carried out based on the time of year. With pupping season commencing around November, surveys conducted around this time will include pup data. Females present with pups can thus be classified as adults due to their sexual maturity, however this could potentially exclude any unsuccessful birthing females of which would still be classified as adults.

Conclusion and recommendations

Based on information found in the literature, the most logical method of age assessment would be to include pup, juvenile, and adult as age categories. Seals aged 10 months and under would be classified as 'pups' as they are still reliant on their mothers for suckling, and 10 months is thought to be the average age at which weaning occurs. Juveniles are seals aged between 10 months and sexual maturity (recognised either by size or presence of pup), of which they would then be classified as adults. Ease of categorising age when in the field was considered when assessing ageing methods, and it can be concluded that the time of year assists with identification. Surveys conducted at the beginning of the year will include new-born pups, the previous year's pups (now juveniles), and adults. Surveys conducted at the end of the year, before pupping season, will include mostly juveniles and adults, although it has been found that juveniles may still suckle for longer than a year this can still be assessed based on size. The terms juvenile and sub-adult seem to be used interchangeably in the literature, and so it would be necessary to exclude ‘sub-adult’ from the categories and instead use ‘Juvenile’, following the method used in Staniland and Waluda (2013). This is mainly due to subadult females being difficult to distinguish from subadult males. For sex assessments, accuracy is difficult for pups and juveniles without using invasive methods. It would have to be accepted that the sex is often ‘unknown’ for these age ranges. Adult females and males are easier to distinguish based on physical appearance and presence of nursing pups.

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Appendix B – Entangling material categories and associated descriptions

Category	Description and included materials
Other Fishing Gear	Unknown fishing line types, or known associated fishing gear such as hooks and lures.
Rope	Thick braided materials which could be either fishing-related or industrial. Includes braided fishing line.
Fishing Net	Netted fishing material, excluding gill net
Gill Net	Mono or multifilament netting with small mesh size
Snoek Line	Thick, plastic-like fishing line
Clothing	Clothing of all types apart from PPE.
PPE	Clothing and equipment worn and used as PPE
Bags (Plastic)	Plastic carrier bags and/or other plastic bag types
Shipping Material	Materials used for transporting goods, such as packing strap, string and polystyrene.
Motor Parts	Materials found in motor vehicles such as gaskets, tyres etc.
Manufacturing	Materials used in manufacturing processes such as rubber, steel etc.
Public Safety Equipment	Includes anything not used for personal protection, such as barrier tape.
Other Plastics	Plastics which do not fit above categories or unknown plastics
Other Unknown	Unknown materials

Appendix C – Example of form used in citizen science data recording. The data on the form shown were collected out-with the study period and thus not included in the results.

SEAL ENTANGLEMENT: Form for Recording all sightings and observations of seal entanglements

THANK YOU FOR YOUR OBSERVATIONS

Company: ____________________ Your email: ____________________

Please return to the NDP office or take a photograph and email to nam.dolphin.edu@gmail.com

Contact us to collect. Cell: 081 687 6461

	Date	Time	Location	Age of seal	Sex	Entanglement Material	Action	Behaviour or Comments Photograph image name	Observer Name
#30	19/03/20	09:30	P.P. Outside	Adult	F	Snoek line Loop	Freed	Severe Cut	Naude + Antoine
#31	19/03/20	10:00	Donkey Bay	Adult	F	HUGE white net	Freed	No damage	Naudé + Antoine
#32	20/02/20	09:30	PP outside	Sub Adult	M	Snoek line loop	Freed	Severe Cut 90% overgrown	Naude + Antoine
#33	22/02/20	08:30	P.P wreck	Adult	M	white Packing Strap	Freed	Severe Cut Approx 5cm deep	Naude + Antoine
#34	24/02/20	08:30	P.P near ledge	Adult	F	Snoek line	Freed	Moderate damage	Naudé + Antoine
#35	24/02/20	08:45	P.P Point	Sub Adult	F	white Packing Strap	Freed	Severe damage	Naudé + Antoine
#36	24/02/20	~~09:44~~ 09:15	P.P Point	Pup	?	Paint Bucket Ring	Freed	No damage	Naudé + Antoine

Location: GPS coordinates are great or distance and Bearing from a well established Landmark. **Eg. 4km South of Light house.**
Entanglement Material: What type of material (plastic bag, net, package strapping etc.) is entangling the animal.
Keep: Please keep this material if possible and log it with the date of the record. **PHOTOGRAPHS ARE USEFUL FOR EACH EVENT**
Action: What action was taken (left animal/ attempted disentanglement/ successful disentanglement)
Behaviour or Comments: Please note what is happening in the species interactiion (if applicable). Any comments or observations are welcome

Appendix D – Photographs of entangling materials, representing A) Fishing Net, B) Packing Strap, C) Snoek Line, D) Gill net, E) Rubber Gasket (Motor Parts), F) Rope

Appendix E - Group survey photographs exhibiting A: poor quality and B: good quality.

Appendix F – Full list of recommendations for future long-term monitoring and surveying.

Survey frequency PP

- Maximum of four sample days per month (once per week recommended)
- Surveys should be conducted around the whole point each time if possible, to include newly hauled out seals and seals which have moved around the peninsula.
- Surveys to be conducted throughout the year

Survey frequency CC

- Recommended to survey here throughout the year, on a bi-monthly basis if possible
- High chance of seals being re-sighted when surveys are conducted over two days, so strongly suggest careful examination of entanglements and eliminating potential re-counts, or surveying for one day only.

Study group

- Focus on smaller groups (<1000)
    - At Cape Cross, focus on seals closer to surveying position and split into sub-colonies where possible. Ensure photographs coincide with identified sub-colony.
- Standardise ageing/sexing protocol and accurately assess group composition (see below)
- Number of photos taken to equate to no more than 5% of the group size. (E.g. 500 seals, 25 photos maximum)

Age and sex assessment

- Suggest eliminating the age category 'sub-adult', as this can be interchanged with adult, or older juvenile.
- Using a standardised protocol and based on time of year, pups and juveniles can be accurately distinguished
- Males and females most likely to be accurate in adult entanglement data, and citizen science data

Method of surveying

- Both binocular scans and photographic surveys to be used
- Ensure photographs cover focal group panning from one side to the other, with duplicate photos of the group clearly labelled (should more entanglements be sighted in photo surveys, this could be a result of two photos of the same position in the group, interpreted as a different position)
- Try and avoid surveying in overly foggy days to enable photographs to be of good enough quality for analysing.