Dear Dr. Wells and Reviewers,

This document is the “Response to Reviewers” for the manuscript titled “Entanglement rates and haulout abundance trends of Steller (*Eumetopias jubatus*) and California (*Zalophus californianus*) sea lions on the north coast of Washington state”. Thank you for your thorough and helpful review.

In this document we copy each reviewer comment and address them individually in the order they were received. Our responses are provided below each bolded comment. Line numbers referring to the revised draft “Manuscript” are provided where each change or section can be found.

Editor Comments

**Namely, while the work you have presented is comprehensive, in my reading, I simply think that some discussion on its application to mitigation measures (e.g., what specifically can we do to slow the rate of entanglement managerially) and a bit of context regarding the role of environment would be interesting.  For example, in the paper, it is stated that during 2014 and 15 there was an uptick.  While you may not have support for the reasons why this may have occurred, we do know that these were years of serious perturbation (ie, heatwave) with, in some areas, habitat compression. Simply contextualizing in a small way this may be interesting.**

We discussed potential mitigation measures in the last paragraph of the discussion. Entanglement has so many sources and influencing factors (many of which were also addressed in the discussion) that this discussion was more about pros and cons of various options than a declaration of what should be done. See line 452 to the end. Additional tangential discussion of mitigation with regards to the need to better understand entangling materials and their distribution and relative risk to the individual are scattered throughout the paper.

We addressed the 2014-2015 heatwave and habitat compression specifically on line 433:

“Studies have shown that warm anomaly ocean conditions, usually associated with an El Niño event, can cause changes to the distribution of marine debris, fishing effort, and pinniped prey items, all of which can impact rates of entanglement [14,15,38]. In summer 2014, high sea surface temperatures associated with the warm anomaly referred to as “the Blob” reached the coast, causing the shortest upwelling season for the northern California Current on record [72], the impacts of which were seen well into 2016 [73]. Both California and Steller sea lions exhibited high rates of entanglement in our study area in 2014 and 2015, and 2014 - 2016 were also years of elevated large whale entanglements in the area [17,74]. It is possible that these anomalous ocean conditions changed the distribution of fishing effort, entangling materials, and prey items important to cetaceans and pinnipeds, causing habitat compression and contributing to the high levels of entanglement seen for both taxa. Entanglement rates therefore seem to be driven somewhat by normal ocean currents and abnormal ocean conditions. However, the way that ocean conditions impact entanglements may depend on the type of entangling material, as actively fished and derelict gear are more likely to be impacted by conditions that shift fishing effort, prey distributions, and sea lion abundance, while marine debris is more likely to be linked to conditions that directly change currents and circulation.”

**2. In your Methods section, please provide additional location information of the study sites, including geographic coordinates for the data set if available.**

Coordinates for each of the four major haulout sites were added to the methods.

**Equation Line 99: The assumption being that differences related to entanglements?**

No, the intent of this section of the paper is just to describe the haulout abundance trends in the study area to better understand how they compare to the overall populations and to provide context around the potential impact of such high entanglement rates.

**Line 124: What is the value in testing directly between these species? Is there an associated hypothesis? Seems may be better to just examine them and not compare them.**

We agree that a direct comparison between species does not add substantial value to the paper and has been removed in favor of independently describing what was seen for each species.

**Line 192: LMH? Forage inshore? Later fishery dynamics that lead to issues?**

The intent of this comment was unclear, and we do not know what “LMH?” refers to. However, we believe the editor is looking for a clearer explanation of why the entanglement rates are so much higher for California sea lions than for Steller sea lions. We believe this is explained as an effect of the seasonal variation in California rates on line 408:

“Entanglement may also have an impact on pinniped life history and population dynamics. Most California sea lions migrate away from our survey area to their breeding grounds to the south during June and July, but the few animals that stayed in our survey area during those months exhibited a much higher entanglement rate than in other months, largely driving the high overall rate of entanglement seen for California sea lions (Fig 5). In our study area, it is possible that entangled male California sea lions observed in the summer months chose not to migrate to their breeding grounds due to compromised body condition caused by entanglement, which would likely also compromise their ability to establish and hold a breeding territory.”

**Line 244: The percentages seem pretty random. The question is do those stranded ones have a higher rate of entanglement? Perhaps I missed this.**

**Line 277: This answers a previous question on line 244 I had and perhaps should be put in results.**

A table comparing entanglement rates for each species between the stranding record and live counts was added on line 270 and in-text context was added on line 260:

“The rate of dead strandings exhibiting evidence of entanglement (1.6% for Steller sea lions and 0.38% for California sea lions) was of a similar magnitude to the rate of entanglement among live sea lions observed on the haulouts (Table 2).”

The context for the rates of entanglement seen in stranded individuals is provided on line 301:

“While the entanglement rates we observed were high, the low number of recorded mortalities from entanglement in the literature and in the local stranding record highlights our poor understanding of the effects of entanglement on sea lion health and survival. In the stranding record for the Washington and Oregon coast only thirteen California and Steller sea lions were found dead with signs of entanglement from 2010-2018 out of 1,599 total strandings. The rate of dead stranded sea lions that exhibited evidence of entanglement (0.81%) was of a similar order of magnitude to the rate of live sea lions observed with signs of entanglement from survey effort (0.41% Steller, 2.13% California). In the literature there are also very few records of animals observed dead with signs of entanglement [19,44]. Since dead stranded animals are a subset of the mortality experienced by a population, it is logical that if entanglement always had a significant negative effect on the sea lion’s health and survival, the proportion of dead individuals with evidence of entanglement would be greater than for the live population at large. Since recorded mortality due to entanglement was lower than expected, it suggests that this was not the case.”

Reviewer #1 Comments

Major comments:

**(1) The introduction sets up a conflation of entanglements in marine debris and in active fishing gear, which continues throughout the paper. Fishing gear is generally only considered marine debris once it has become derelict, and has different management implications, so a reframing of the introduction and rewording throughout is needed to "disentangle" these sources of entanglement, even though the animals affected by each source may not always be visually distinguishable in photographs.**

Thank you for this comment. We agree that disentangling the sources of entangling materials is crucial to the clarity and usefulness of this paper. All instances of “marine debris” that were used to describe general entangling materials have been replaced with “entangling materials”. Additionally, language was added to the introduction to emphasize this important distinction on line 45:

“The mechanisms by which an animal becomes entangled are almost as varied as the entangling materials themselves. Entangling materials can come from terrestrial and marine pollution, and from derelict and active fishing gear. Any materials that form loops that can ensnare or sharp edges that can embed pose an entanglement risk. The mechanism of entanglement can often be determined by identifying the entangling material. Packing bands and rubber bands are likely encountered passively as debris, while monofilament line, rope, and net fragments can be a sign of either passive encounters with derelict gear or a sign of interaction with an active set. Salmon flashers and other hook and line setups are likely encountered as actively fished gear and are evidence of fishery depredation behaviors, which cause harm both to the entangled animal and to the fisher’s catch [10,11]. Otariids are especially curious of novel objects, and can become entangled in materials while attempting to explore or play with them [12,13]. The frequency and nature of entangling interactions with marine debris might be governed by ocean currents, upwelling patterns, and marine traffic patterns, while interactions with active or derelict fishing gear are driven by fishing effort, gear types, and prey distribution [9,14–17]. Each type of entangling material poses different challenges and opportunities for mitigation, so identifying the source of entangling materials is crucial to building effective and targeted prevention plans.”

This distinction was also reiterated in the discussion on the impact of ocean conditions on entanglement rates on line 444:

“However, the way that ocean conditions impact entanglements may depend on the type of entangling material, as actively fished and derelict gear are more likely to be impacted by conditions that shift fishing effort, prey distributions, and sea lion abundance, while marine debris is more likely to be linked to conditions that directly change currents and circulation.”

**(2) The paper should spend less space and emphasis on the population growth rate observations to leave more space for discussion of the more interesting entanglement observations. For both species studied, the study region only contains a fraction of a demographically independent population. The abundance of animals hauling out in this region will therefore not be driven primarily by processes occurring within the region. This is particularly true for California sea lions, of which only males occur in the study region. The manuscript needs to set up this context from the abstract onward, rather than attempting to directly link local sources of mortality to local population index counts, and discuss how observed growth rates in abundance based on partial counts might be expected to be biased relative to the dynamics of the populations as a whole (Holmes 2001). To what extent might local mortality affect overall population growth rates, and what magnitude of lags might be expected in the response of local abundance to changes in local mortality rates?**

We took the advice of reviewers #1 and #2 and reframed our “population trends” as “haulout abundance trends as an index for local abundance”. We also removed language attempting to directly link high haulout abundance growth rates with an absence of negative impacts from high entanglement rates. However, we still think it is important to point out this relationship between such high entanglement rates, which would be high enough to cause visible population declines in some populations, and the high rates of increase we are seeing in local area use by the two sea lion species as context for our statements that entanglement is likely not a conservation issue requiring immediate action or concern. We understand that we are unable to make conclusions regarding the population as a whole, and have added language to that effect on line 285:

“While local haulout abundance trends alone cannot be used to make conclusions regarding the trajectory of the population as a whole, or the impact that entanglement might be having range-wide, it is important to note that use of the study area continues to increase despite such high entanglement rates, and that both populations as a whole are healthy and growing. Future studies that incorporate entanglement data from the whole range of each species could illuminate the full impact that entanglements may be having on the two species. Furthermore, a longer-termed study could detect delayed impacts of entanglements on local abundance trends that might have been outside the timeframe of this study.

**(4) While stranding records indeed include only a small number of entanglement-related deaths, the paucity of entanglement scars relative to active entanglements suggest either entanglements are very long-lasting, post-removal scars disappear rapidly, or entangled animals are winnowed from the population quickly whether through direct mortality or increased susceptibility to other mortality sources such as predation. The apparent correspondence between entanglement and failure to migrate to rookeries in the breeding season also suggests either serious implications of entanglement to individuals (or greater susceptibility of non-migrating animals to entanglement?). On what basis do the authors conclude that entanglements are mostly not deadly? This conclusion should either be reconsidered or further evidence provided to bolster it.**

**Lines 310-312: Wouldn't the authors expect more scarred individuals than active entanglements if most shed and survive?**

We disagree that there is a “paucity of entanglement scars relative to active entanglements”. Only the most severe, wide neck entanglements leave scars that are visible, and even then, scars are only visible until they heal, so our scarring rate likely reflects a large amount of survival from entanglement, and more specifically from very severe entanglement wounds. However, we decided to reframe the discussion to capture the idea that any individual surviving entanglement is contrary to many of the assumptions made by managers today instead of seeming to argue that entanglement is not a serious and deadly issue, which we agree it can be in many cases. We added on line 314:

“The definition of serious injury developed and used by the National Oceanic and Atmospheric Administration (NOAA) is “an injury that will likely result in mortality” [45]. According to the guidelines, which categorize most entanglements as serious injuries, including “Ingestion of gear or hook” and “﻿Gear constricted on any body part, or likely to become constricting as the animal grows”, most active entanglements observed in this study would be classified as serious injuries, with the exception of two Steller sea lions who exhibited hooks externally on the flank and side of the head [45]. In assessments by NOAA of data from 2010-2017, all entanglements categorized as serious injuries with descriptions similar to what we observed and that did not receive rehabilitation or disentanglement assistance were recorded as mortalities [46–57]. However, this study presents multiple lines of evidence refuting the idea that entanglement without intervention is always a death sentence for the affected individual.”

The language for the rest of the discussion was largely kept the same but reorganized to better match the new logical flow.

**Abstract: The abstract could be substantially shortened.**

Much of the abstract was edited to improve efficiency of language, but it ended up at the same length, still under the limit imposed by the journal.

**Line 25: Specify temporal correlation.**

We feel that more information can be conveyed by describing the nature of the temporal correlation instead of just labelling it.

**Lines 68-70: This sentence is a key point and could be highlighted elsewhere in the manuscript too: "Understanding the patterns behind entanglement occurrence will enable the development of more targeted prevention and response efforts"**

An attempt was made to echo this sentiment elsewhere in the paper, see also our response to major comment 1.

**Line 93: The authors should note that this trend is for the population of animals using the area, not a demographically independent unit, and that this is a minimum estimate, as some proportion of individuals are in the water at any given time.**

We only report the haulout abundance as a trend, so it should not matter that it is a minimum estimate as the assumption that a similar proportion of animals is hauled at each count is likely valid.

**Lines 114-119: All entanglement and animal counts should be pooled over a full survey before calculating a survey rate, rather than using a daily rate. Based on some simple simulations I ran, this approach should tend to be less biased even if individuals move among sites between days.**

We believe this comment stems from a misunderstanding about our methods. Full surveys were only ever conducted over a single day, we never pooled counts from multiple days into a single survey, so there should be no issues with individuals moving between haulout sites between counts in a single survey. The language was clarified on line 85:

“Surveys often did not include all haulouts due to logistical challenges such as sea conditions and daylight, but only complete survey days where all four major haulouts were visited were included in haulout abundance calculations.”

**Lines 123-124: Averaging entanglement rates within month and then year and using annual averages for paired comparison should provide greater independence among samples, though this hardly matters since it would likely further decrease statistical power and the authors already did not detect a difference between species. The authors could explore patterns among species, with season, etc with something like an auto-regressive logit-link GLM at the individual month level, to deal with both autocorrelation and proportions. Personally, though, I think descriptive stats would suffice here.**

We agree that describing each species separately and eliminating any direct comparison is the best way forward. Descriptive stats regarding seasonal and annual patterns and material occurrences are presented in Fig 4 and 5.

**Line 187: It would be more correct to say "entanglement observation" as they may not represent independent individual entanglements.**

Agreed and fixed.

**Lines 230-232: "and the remaining adult males exhibited entanglements in the same proportions as what was seen for California sea lions overall in the survey area" can be omitted - this is self-evident based on the first part of the sentence.**

Agreed and removed.

**It would be helpful to know how the age-sex composition of entanglements compare to that of all hauled-out animals - are those data available?**

These data are available for a short overlapping time period, but we feel that they are not applicable to later years due to observed, but poorly documented, changes in the age-sex structure of individuals hauling out and thus would not provide helpful, current context.

**In Figs. 3-5 it would be helpful to add sample sizes to the tops of the proportion plots.**

We agree, sample sizes were added to figures 4-6.

**The discussion would be improved by touching on some additional key points:**

**- how the growth phase of an animal may influence the eventual severity of an entanglement**

This was already covered on line 397:

“The age, size, and foraging experience of the sea lion may dictate the materials they become entangled in, and therefore the outcome and observability of the entanglement [9,67,68]. The high proportion of entangled Steller juveniles exhibiting flashers and rubber bands may be a function of their age: rubber bands may be too small to entangle a large adult, and flasher entanglement is a sign of a risky foraging behavior - depredating salmon troll fisheries. The small number of unidentifiable entangling materials on juveniles may be because of their smaller size, which causes the material to sit on the surface of the skin where it can be easily identified. This may also explain the large number of unidentifiable entangling materials on adult males, whose considerable seasonal growth [69] could have caused entanglements to bury deep into the flesh where they are not readily observed [61]. Age and body size therefore impact both the entangling materials an individual is likely to encounter, and the severity of the wound caused by that entanglement.”

**- whether any entanglement materials are associated with more severe entanglements, lead to mortality more or degrade or break off animal sooner, etc, to inform how observations of relative rates among materials may be biased. For example, the authors discuss that salmon flashers are more deadly and/or shed more quickly. If that is the case, they must also cause a higher proportion of the entanglements than observed in photo surveys.**

**Lines 310-312: Wouldn't the authors expect more scarred individuals than active entanglements if most shed and survive? How quickly do such scars disappear?**

A paragraph was added to the discussion to address these important points about observation bias and length of entanglement or scar healing on line 375:

“The type of entangling material can also potentially impact the likelihood of observing an entanglement. If sea lions entangled by a salmon flasher are likely to either shed the gear quickly or die, the window to observe and document that entanglement might be much shorter than for a material more prone to long entanglements, like a packing band. The shape and color of the entangling material could also contribute to the probability that it is observed. Packing bands, rope, and monofilament line all mostly cause neck collar entanglements, but monofilament line, which is thin and usually somewhat translucent, is likely to be quickly embedded in a deep wound, disappearing from view faster than a thicker packing band or rope loop would. Packing bands also have a distinctive fraying pattern which causes thin curly strands to be visible above the edges of a deep wound where the band itself is otherwise invisible, making them much more likely to be identified than a material without such clear identifying features. For the most part, it was impossible to identify the entangling material in cases of severe entanglement wounds because the material was embedded so deeply in the flesh, and therefore also impossible to make any conclusions about which materials might be associated with the most severe wounds or highest potential risk of mortality to the affected individual. Additionally, only the most severe, deep, wide wounds are likely to create lasting and readily observable scars, meaning certain entangling materials are better represented among scarring rates than others. This complicates the search for the most damaging entangling materials on which to focus targeted mitigation and forces any management efforts to rely on other metrics of impact, such as the prevalence of an entangling material within the population in question. Further studies that track the fate of individually identifiable entangled individuals would help clarify important questions about scar healing rates and time to death or shedding that are crucial for understanding the full long- and short-term impact of entanglement on individuals and populations.”

**- the association of rubber band entanglements with Steller's and spring months - does this reflect a difference in foraging habitat from California sea lions?**

We do not feel that this is a strong enough trend to comment on. Rubber bands are present in most months, with no clear bump in the spring, and are not the only material to show up in Steller entanglements but not Californias. There were fewer California entanglements documented in our study, which likely led to fewer materials being documented.

**- in reference to Table 2, how dates (i.e., years) of entanglement studies potentially affect estimated rates. When all else is equal (particularly region), might more recent years be expected to correspond to higher entanglement rates?**

Yes, later years might be expected to correspond to higher entanglement, but not due to the year itself, and not universally, which makes that trend still interesting to document. Additionally, this was the first paper we found that provided a review of documented rates, hopefully aiding future studies in performing more interesting comparisons between years, regions, new data, etc.

**Line 257: "second highest rate" - of entanglement or growth?**

This line refers to entanglement and was clarified.

**Line 284: What was the expectation for the entanglement rate in the stranding record, and what was it based on?**

The expectation was that the rate of entanglement would be higher in the stranding record than for live haulout observations, as was explained in the discussion in line 301:

“While the entanglement rates we observed were high, the low number of recorded mortalities from entanglement in the literature and in the local stranding record highlights our poor understanding of the effects of entanglement on sea lion health and survival. In the stranding record for the Washington and Oregon coast only thirteen California and Steller sea lions were found dead with signs of entanglement from 2010-2018 out of 1,599 total strandings. The rate of dead stranded sea lions that exhibited evidence of entanglement (0.81%) was of a similar order of magnitude to the rate of live sea lions observed with signs of entanglement from survey effort (0.41% Steller, 2.13% California). In the literature there are also very few records of animals observed dead with signs of entanglement [19,44]. Since dead stranded animals are a subset of the mortality experienced by a population, it is logical that if entanglement always had a significant negative effect on the sea lion’s health and survival, the proportion of dead individuals with evidence of entanglement would be greater than for the live population at large. Since recorded mortality due to entanglement was lower than expected, it suggests that this was not the case. ”

**Lines 340-345: This pattern is an important observation and should be highlighted, perhaps in the abstract.**

This observation was added to the abstract on line 18:

“The rate of entanglement for California sea lions was 2.13%, almost entirely composed of adult males, with a peak rate during June and July potentially due to some entangled individuals not migrating to their breeding grounds.”

**A key reference that is missing and should be incorporated reports on packing band entanglements of pinnipeds globally (Hogan and Warlick 2017). Are other important references missing? Conduct another search for recent relevant literature.**

The authors conducted a very thorough search of the literature and did find this paper. However, the presence of an incorrect citation (to Cole et al., 2006 in the introduction when it should be either Fowler 1988 or Laist 1997 or other similar review) and inconclusive results made it difficult to incorporate appropriately into our paper. It is not relevant to us that packing bands of different material, color, and size can be found in different places, especially because the cause of these material, color, and size differences could not be related definitively either to manufacturing differences or increased entanglement risk.

Reviewer #2 Comments

**- Recommend toning down the language around the claim that this study assesses entanglement rates for sea lions in relation to population trends. The trend data from this study are based on haulouts and so recommend that the language around ‘population trends’ is changed to ‘haulout abundance’ throughout manuscript. Particularly given the geographic range of these species, haulout counts provide an index of abundance but not a robust assessment of population size or population dynamics.**

We greatly appreciate this phrasing suggestion and have incorporated it wherever relevant. See response to reviewer #1 comments related to toning down language around population trends otherwise.

**- Suggest commenting on whether there may be a delay in any observed population impacts from the high rates of entanglement observed for these two species in this study. e.g. individuals may be entangled for a number of years, the impacts of entanglement may occur over a long time period and the effect of entanglement on individuals and populations may not be apparent in the short term.**

This was addressed in the new paragraph about observation bias added on line 375, including the following statement on line 393:

“Further studies that track the fate of individually identifiable entangled individuals would help clarify important questions about scar healing rates and time to death or shedding that are crucial for understanding the full long- and short-term impact of entanglement on individuals and populations.”

And on line 289:

“Future studies that incorporate entanglement data from the whole range of each species could illuminate the full impact that entanglements may be having on the two species. Furthermore, a longer-termed study could detect delayed impacts of entanglements on local abundance trends that might have been outside the timeframe of this study.”

**- Suggest commenting on different potential impacts relating to the sex bias in entanglement, particularly for California sea lions where you reported almost all entanglements were adult males e.g. less likely to have impacts on population dynamics (if this was measured) compared to a bias towards adult, breeding females.**

We decline to comment on this potential impact because the sex bias is entirely due to the fact that in our area males are seen almost exclusively and sightings of females are extremely rare, not due to any increased likelihood of entanglement on the part of males.

**- Suggest title change to “Entanglement rates and haulout abundance trends of…”**

Agreed and changed. All other wording changes were also adopted from this list of specific comments.

Thank you again for putting your time and effort into this review. We appreciate your help in improving this manuscript and hopefully readying it for publication.

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