A Trait-Based Risk Assessment for Ranking Relative Vulnerabilities of Marine Mammal Populations to Macroplastic Entanglement and Ingestion

by

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ABSTRACT

Plastic pollution poses a threat to the health and well-being of marine mammals across the globe. This paper takes a previously developed trait-based risk assessment framework and applies it to all 118 species of marine mammals worldwide, to help create a relative ranking of vulnerability of species to plastic ingestion and entanglement. After extensive data collection on 13 traits related to each species' relative likelihood of exposure to plastics, species sensitivity to plastic ingestion and entanglement, and overall population resiliency, the initial trait framework was adapted and scored to calculate the relative vulnerability of marine mammals to marine microplastic pollution. Results indicate that the Hawaiian Monk Seal has one of the highest relative vulnerabilities to macroplastic pollution among all marine mammals. Furthermore, this exercise highlighted several areas where future research is needed, including expanding the framework to microplastics, applying the framework to coastal human populations, and further investigation of unknown life history traits of various marine mammals.

DEDICATION

I would like to dedicate this thesis to my friends and family who stood by my side and supported me through every step of this process. My parents have been my primary support system and have provided me with such a loving environment to learn and grow in. My siblings have been very helpful and have always served as motivators in my life. My best friend, Megan Phillips, has been an amazing asset to have in my life. She and I traveled to Costa Rica, allowing me to conduct fieldwork with Olive Ridley Sea Turtles. Without her companionship, I never would have had this experience. My other friends have also been incredibly supportive and loving throughout the process of writing and defending my thesis.

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TABLE OF CONTENTS

Page

APPENDIX

As of 2014, it was estimated that over 250,000 tons of plastic were in the oceans (Eriksen et al., 2014). There has been an exponential increase in oceanic plastic pollution since the start of widespread plastic use in the 1950s due to consumer products as well as plastic fishing gear (Ostle et al., 2019). Because of the rising examples of marine mammals becoming entangled in plastics, and escalation of reports of plastic ingestion, the marine plastic pollution is call for serious concern (Gregory, 2009). Furthermore, rather than macroplastics decomposing over time, they fragment into smaller pieces until they are less than 5 mm in diameter, at which point they are deemed microplastics (Piehl et al., 2018). Marine mammals are negatively impacted by both micro- and macroplastics (Piehl et al., 2018). There have been accounts of marine mammals washing up on shores after ingesting copious amounts of plastics, causing death (Nelms et al., 2019). There have also been reports of marine mammals becoming entangled in oceanic plastics, causing death or serious injury (Gregory, 2009). Although many accounts of interactions with plastics have been recorded the population level impacts of marine mammals being exposed to plastics is unknown (Butterworth, 2016). Empirical studies to determine the individual- and population-level impacts of macroplastics on marine mammals are difficult, largely because of the ethical and practical challenges that come with keeping marine mammals in captivity and exposing them to plastics. Therefore, a more theoretical, relative risk assessment approach can be used to identify those species that may be more vulnerable to plastic pollution, in order to prioritize management and mitigation actions for specific species and geographic areas.

Trait-based risk assessments are used in conservation science to provide theoretical answers to the questions, without interfering with the ecosystem or causing stress to study species. Trait-based risk assessments have been used in the past to evaluate the risk of invasive species, better understand the effects of environmental toxins, and to measure the risk of oil spills on different species (Chan et al., 2021) (Brink et al., 2013) (Woodyard et al., 2022). Trait-based risk assessments can also be used as projections for the impact a threat, such as global warming, poses to species in the future (Sandin et al., 2014, Foden et al. 2014). In this case, a recently developed, multi-taxonomic trait-based risk assessment framework was applied (Murphy et al. 2022) specifically to marine mammals, to score and rank each species' relative vulnerability to macroplastic entanglement and ingestion. This non-invasive approach is necessary to prioritize interventions and inform policy, especially as oceanic plastic pollution increases globally (Vered and Shenkar, 2021).

The goal of this trait-based risk assessment is to provide guidance as to which species may currently be at highest risk of negative population impacts from exposure to marine macroplastics. This study serves as the first application of a trait-based risk assessment of plastic pollution to be applied to marine mammals. The focus of this relative vulnerability ranking exercise is solely on the population-level impacts to marine mammals due to entanglement and/or ingestion of macroplastics. It is recognized that microplastics, too, are often ingested by marine mammals and pose a serious threat to ocean health (Nelms et al., 2019). However, given the chemical complexity of microplastics, and the lack of toxicological data, (Coffin et al., 2021) microplastics risk assessment is beyond the scope of this study and the adapted framework (Murphy et al., 2022).

METHODS

FRAMEWORK USE AND SCOPE OF APPLICATION

A multi-taxonomic, trait-based approach was recently developed to assess the relative vulnerability of different marine animals to the ingestion of and entanglement in oceanic macroplastics (Murphy et al., 2022). The framework covers a vast scope and can be applied to multiple taxa in a single area, a particular taxonomic group worldwide, or any intermediate variation (Murphy et al., 2022). Ultimately the framework was developed as an all-encompassing basis for ranking animals by vulnerability to macroplastic exposure. Here, this framework was adapted specifically to assess the relative vulnerability of the world's marine mammals to ingestion of and entanglement in macroplastics. Specific traits from the original framework were removed when i) the resulting score would be the same for all marine mammals, ii) there were many species with unknown information, iii) there were many assumptions to be made that would potentially skew or bias the data, and iv) two traits captured the same trend, causing an accidental over-weighting of a trait. Because the original framework was meant to be applied to multiple taxa, some traits were added to the framework to distinguish between taxa. However, when applied to a single taxa, the trait was universal, causing it to be useless in distinguishing between marine mammal species. Typically, if a characteristic was unknown, the species would receive a score of 3 in most cases, as most traits were scored on a 1 to 5 scale. However, if many of the species had unknown characteristics, by giving a large portion of species a score of 3, certain species that should have received a lower score could become ranked more highly than more at risk animals solely due to a lack of knowledge, causing randomness to assume a larger role in the relative trait-based risk assessment than desired. Certain trait categories require too many assumptions to be made and are not objective enough to use in the relative trait-based risk assessment at this time. This could lead to inaccuracy, results that are difficult to replicate, and opinions to factor into decision making.

APPLICATION OF MULTI-TAXONOMIC FRAMEWORK TO MARINE MAMMALS GLOBALLY

An initial list of the world's 125 marine mammals was gathered from the International Union for the Conservation of Nature (IUCN, n.d.). Of these 125 species, only 118 were used, as 7 were aquatic, semi-aquatic, or spent much of their time on land (e.g. most otters, hippopotamuses, etc.). The original framework identified 22 traits, falling into 3 groupings. There were 7 traits related to a species' likelihood of microplastic exposure, 9 traits related to individual species sensitivity to entanglement or ingestion, and 6 traits related to species' overall population resilience (Murphy et al., 2022). Motility, egestion potential, behavior of the most sensitive pre-adult stage, and respiration mode were all removed from the framework, as they were uniform across all marine mammals. Longevity of most sensitive pre-adult stage was also removed because of lack of information. Relative physiological sensitivity of pre-adult stages, reduced fitness from other stressors, population connectivity, and proportion of most sensitive life stage impacted were also removed because too many assumptions would have been made regarding which life stage was most sensitive, which stressors have the biggest impact across all marine mammals, and in which situations population connectivity is harmful versus helpful. Finally, distribution of most sensitive pre-adult stage was also removed, as marine mammals usually stay with their mothers as pre-adults, and therefore the pre-adult distribution was assumed to be the same as adults. Foraging Habitat was also very similar to water column position, as many habitats are defined by water column position, causing us to remove foraging habitat from the relative trait-based risk assessment. Initially, Habitat was divided into the 9 categories of Pelagic, Benthic, Surface, Coastal waters, Sandy bottomed benthic, Seagrass Benthic, Kelp forests, Intertidal zones, and estuaries/lakes/rivers/ponds, which were then aggregated into 4 categories of pelagic, benthic, surface, and aquatic. As these generalized habitat zones were better described as water column positions, to prevent double counting of water column position, Habitat was eventually removed from the assessment.

Eleven traits remained after the removal of the above redundant, unknown, or not-applicable traits. These included 3 traits regarding likelihood of exposure: distribution, water column position of feeding, and longevity; 4 traits regarding species sensitivity: body morphology, feeding and foraging behavior, prey preference, and non-foraging behaviors; and 4 traits regarding species sensitivity: abundance, reproductive turnover rate, feeding and habitat specialization, and species extinction risk.

For each of the 11 remaining traits, indicators were selected to categorize and then score the different trait values. To select and collate trait data, a literature search was performed to determine the appropriate indicators that also had sufficient data available. Where data for a given trait was quantitative, rather than categorical or nonparametric, the species trait was scored based on quintiles corresponding to a score of between 1 and 5, with 5 representing the most relative vulnerability and 1 the least relative vulnerability. Quintiles were used because the goal was to calculate the risk of the species regarding one another rather than an overall score with little context. For categorical or nonparametric traits, a literature review was conducted to determine which trait category was associated with an increased vulnerability to exposure, sensitivity, or population resilience. Scoring methods for each trait and indicator are explained in detail below.

EXPLANATION OF SPECIFIC SCORING METHODS

Likelihood of exposure

Distribution. A Raster file of global plastic density was used from a paper focusing on the distribution and density of oceanic plastics (Eriksen et al., 2014). This Raster file was converted into a polygon with size 3 polygons and 10 different levels of plastic density in pieces per square kilometer. All marine mammal generalized range distribution maps were downloaded from the IUCN Red List of Threatened Species (IUCN, n.d.). The geometry of each species map was repaired individually, as well as the plastic map. From there, each map was individually dissolved. Each species map was then intersected with the plastic density map and the projection was changed to Cylindrical Equal Area. Average plastic density for each species' distribution was then calculated. Species with an average plastic density less than 1.902 received a score of 1, species with an average plastic density of 1.9021-2.339 received a score of 2, species with an average plastic density of 2.340-2.524 received a score of 3, species with an average plastic density of 2.5241-2.673 received a score of 4, and species with an average plastic density greater than 2.6731 received a score of 5.

Water column position of feeding. Many plastics settle to the ocean floor, especially as they are broken apart and lose buoyant characteristics over time (Choy et al., 2019). These plastics can become incorporated into the sand at the ocean floor and can be ingested by bottom feeders, putting benthic feeders at the greatest risk of plastic ingestion. Plastics can also accumulate at the surface of the ocean, putting surface feeders at risk of plastic ingestion (Reisser et al., 2015). Plastics exist throughout the water column, however, given the great distance that exists in the pelagic section of the ocean, the density of plastics is greatest in the benthic region, followed by the surface. It is important to note that all marine mammals surface to respire. Therefore, to distinguish between different water column rankings, the position of feeding was used. Considering animals can feed in multiple locations of the water column, the species were assigned the point value of the highest risk area in which they feed. Species that feed in the benthic zone received a score of 5, species that feed on the surface received a score of 3, and species that solely feed in the pelagic zone received a score of 1.

Longevity. Longevity of an organism greatly impacts an individual’s likelihood of exposure (Nabi et al., 2022). The longer the lifespan of the individual, the more likely they are to encounter and therefore ingest or become entangled in plastics (Nabi et al., 2022). Species with an average lifespan of less than 20 years were given a score of 1, species with an average lifespan of 20-25 years received a score of 2, species with an average lifespan of 25.1-37 years received a score of 3, species with an average lifespan of 37.1-60.3 years received a score of 4, and species with an average lifespan of 60.4 years or greater received a score of 5. Species with unknown lifespans received a score of 3.

Species sensitivity

Body morphology. Body mass drastically impacts whether an entangled marine mammal drowns (Murphy et al., 2022). Based on the literature review (Murphy et al., 2022), heavier animals are more likely to break free from entangling plastics, allowing them to resurface and breath rather than drown, putting them at a lower risk. Species with an average mass greater than 2726.94 kg received a score of 1, species with an average mass of 424.69-2726.93 kg received a score of 2, species with an average mass of 172-424.7 kg received a score of 3, species with an average mass of 92-171.9 kg received a score of 4, and species with an average mass less than 92 kg received a score of 5. Any species with an unknown mass received a score of 3. It was also assumed that marine mammals that have a dorsal fin are also more likely to become entangled in plastics. Therefore, any species with dorsal fins received an extra 1 point.

Feeding and foraging behaviors. After completing the literature review, it was determined the four categories of foraging behaviors to be filter feeding, grazing, swallowing food whole, and biting food into pieces prior to ingestion (Berta and Lanzetti, 2020). Because filter feeders are not specialists, they can incidentally ingest plastics (Fossi et al., 2021). Therefore, filter feeding species received a score of 5. Grazers often feed on the bottom of the ocean on vegetation that resembles plastic, putting them at a great risk for plastic ingestion (Reynolds et al., 2018). Therefore, grazing species received a score of 4. Marine mammals, such as pinnipeds, that swallow their food whole are described as specialized filter feeders (Hocking et al., 2017), showing that although they have more control over the contents they are ingesting, incidental ingestion of plastics is still possible. Therefore, swallowers received a score of 3. Few marine mammals have been shown to tear their food apart or chew it. This increased awareness of food being ingested may decrease likelihood of plastic ingestion (Werth, 2000).

Therefore, species that bite and tear their food up received a score of 2. If species had a combination of feeding mechanisms, they received the highest score that applied to them.

Prey preference. Prey preference was scored on a binary scale of 0 or 2, based on a literature review of trends that increased likelihood of ingestion or entanglement. For example, it is well-known that species whose prey resembles plastic are more likely to ingest plastics (Ozturk and Altinok, 2020). Therefore, species that consumed either cephalopods, vegetation, or both received 2 points. Similarly, it has been shown that marine mammals interact strongly with fisheries and can become entangled in fishing gear when competing for food (Read, 2008). Therefore, any species that consumed fish also received an additional 2 points.

Non-foraging behaviors. Research has shown that curiosity and aggression increase marine mammal interactions with plastics (Laist, 1987). Each species that is known to display curious and/or aggressive behavior also received an additional 2 points. However, information was not available for all species on whether they were aggressive or curious. As a result, when curious and aggressive behaviors of a species were not mentioned as being present or absent, it was assumed these behaviors were not common within the species and the species did not have the two points added to their score.

Population resilience

Population abundance. Species with larger population sizes are more resilient (Murphy et al., 2022). Species with a population size between 0-9,976 received a score of 5, species with a population size between 9,977-40,000 received a score of 4, species with a population size between 40,001-116,700 received a score of 3, species with a population size between 116,701-342,000 received a score of 2, and species with a population size greater than 342,000 received a score of 1. Any species with an unknown population size received a score of 3.

Reproductive turnover rate. The reproductive turnover rate can be useful in measuring the resilience of a population, as a species with a lower population turnover rate are considered to have slower recovery rates (Renaud et al., 2018). To measure reproductive turnover rate, the IUCN definition of generation length was used, which is defined as the average age of reproducing adults. In general, the longer the generation length of a species, the lower the reproductive turnover rate and lower annual fecundity, which can lead to slower recovery from major threats (Renaud et al., 2018). Species with a generation length between 0-10.56 years received a score of 1, species with a generation length between 10.57-14.06 years received a score of 2, species with a generation length between 14.07-17.88 years received a score of 3, species with a generation length between 17.89-22.72 years received a score of 4, and species with a generation length of at least 22.72 years received a score of 5. Any species with an unknown generation length received a score of 3.

Feeding or habitat specialization. Feeding and habitat specialization is a strong indicator of population resilience. If one habitat or food source becomes unavailable because of climate change, oil spills, or other factors, a more resilient population will have an alternative option.

Seven different prey type categories including fish, cephalopods, krill/plankton, other invertebrates, vegetation, mammals, and other food types were created. Species that eat 1 prey type were assigned a score of 5, species that eat 2 prey types were assigned a score of 4, species that eat 3 prey types were assigned a score of 3, species that eat 4 prey types were assigned a score of 2, and species that eat at least 5 prey types were assigned a score of 1.

A list of IUCN habitat preferences was gathered through the SIS database. Considering this list was more inclusive than the list this project developed above for likelihood of exposure, it was known that it would be more likely to capture marginal differences between number of livable habitats for each species. Species that can only live in 1 habitat type received a score of 5, species that can live in 2 habitat types received a score of 4, species that can live in 3 habitat types received a score of 3, species that can live in 4 habitat types received a score of 2, and species that can live in at least 5 habitat types received a score of 1.

To prevent the potential of earning 10 points in a single trait category, the scores from feeding specialization and habitat specialization were averaged, resulting in a number between 1 to 5. This number was used in the final calculation.

Species extinction risk. The relative existing likelihood of each species extinction risk was gathered from the IUCN Red List of Threatened Species data. Species extinction risk, as expressed by the categories and criteria of the IUCN Red List, is considered a reliable measure of each species' estimated or projected global population decline (Rodriguez et al., 2015). Species listed as least concern received a score of 1, species listed as near threatened received a score of 2, species listed as vulnerable received a score of 3, species listed as endangered received a score of 4, species listed as critically endangered received a score of 5, and species that were listed as data deficient received a score of 3.

FINAL SCORE EVALUATION

After each of the 11 traits was scored for all species, each species was assigned an overall score by summing the scores of all individual traits. From there, species were divided into 5 categories, based on overall scores, for their relative population vulnerability to adverse impacts from plastic ingestion and entanglement. Species with scores between 40.5-47.5 were assigned to the relatively high risk category, species with scores between 36-40 were assigned to the moderately high risk category, species with scores between 33.5-35.5 were assigned to the moderate risk category, species with scores between 31.5-33 were assigned to the moderately low risk category, and species with scores between 24-31 were assigned to the relatively low risk category. The categories were created by dividing the scores into approximate quintiles, ensuring that no two species with the same score would end in different risk categories.

STATISTICAL ANALYSIS

After all scoring was complete, Pearson correlation coefficients were calculated using Excel for the rating of each trait. In addition, the average overall vulnerability score was calculated as well as the average vulnerability score for cetaceans, mysticetes, odontocetes, pinnipeds, sirenians, and fissipeds. Using Excel, two-tailed T-tests were conducted between every combination of animal groups to see if there was a significant difference between the scores of different animal groups. Because the variance was not assumed to be uniform, Two-sample unequal variance tests were used.

RESULTS

Among the 118 species of marine mammals, final plastic vulnerability scores ranged from 20 to 42.5 with an average score of 30.4. The average score for likelihood of exposure was 8.03 with the highest possible score of 15 points, the average score for species sensitivity was 11.31 with the highest possible score of 17 points, and the average score for population resilience was 11.04 with the highest possible score of 20 points. Twenty-one species had scores between 21 and 26.5, placing them in the lowest vulnerability category, and twenty-three species had scores between 34 and 39.5, placing them in the highest vulnerability category. All individual species scores as well as score breakdowns can be found in the Supplemental table (Table 1).

As shown in Figure 1, the overall distribution of scores resembled a bell-curve as expected, showing fewer species with scores on the extreme ends of the range. Due to the normal distribution and the risk categories being calculated by quintiles, the point ranges for the different risk categories were not uniform.

The average vulnerability scores for different taxonomic groups are shown in Figure 2. The average vulnerability index for cetaceans was 32.6. Broken down even further, odontocetes had an average index of 31.5 while mysticetes had an average index of 37.8, showing a significant difference (a=0.05). Pinnipeds, sirenians, and fissipeds all had averages indices below the overall average with scores of 26.2, 22.1, and 28.5 respectively.

The distribution of scores for individual traits are shown in Figure 3a and b. Figure 3a shows the quantitative traits that were scored by quintile. Considering the quintiles were as even as possible, scores 1, 2, 4, and 5 all have very similar frequencies. However, because any unknowns were assigned a value of 3, all categories with unknowns have the highest frequency of 3 scores. Figure 3b shows the categorical traits. Considering most species have prey types that resemble plastic, have prey types that cause interactions with plastics, and display either curious or aggressive behaviors, species that scored low in those categories have an advantage with regard to their vulnerability index. On the other hand, filter feeders, grazers, and those considered critically endangered by the IUCN were relatively rare within the dataset.

The 11 species with the highest final vulnerability scores are shown in Table 3. All 11 species scored the most points in the population resilience category, illustrating the importance of understanding population dynamics vs sporadic or patchy impacts to individuals. For example, all 11 species are listed in globally threatened IUCN Red List categories (e.g. 4 as vulnerable, 5 as endangered, and 2 are critically endangered). Additionally, the 11 species with the highest vulnerabilities scored particularly high in overlap with plastic distribution and water column position demonstrating the particular importance of geography and habitat on plastic exposure risk.

The Pearson correlation coefficients of all possible trait score combinations were calculated and can be seen in Table 4. Furthermore, any traits with correlations higher than 0.15 are shown in Figure 4. The species that scored highest in the top two correlated categories (generation length and lifespan and IUCN status and population size) are outlined in Figure 4. In addition, Figure 2 highlights which animal groups had significantly different vulnerability score averages from one another. Pinnipeds and Fissipeds were not significantly different from each other but were significantly different from all other animal groups, including the overall average of all animal groups. Sirenians were significantly different than all other animal groups including the overall average.

DISCUSSION

Although trait-based risk assessments can be a useful approach to determining which species populations have the highest vulnerability to specific threats, there are many gaps in knowledge regarding species' exposure and sensitivity to plastics as well as population resilience of different animals. As more knowledge is incorporated into the framework, the scores will become more accurate. Higher accuracy can be achieved by adding data to cells in the framework that are currently scored as 'unknown' or by adding new traits to the framework entirely. For example, if new data was gathered regarding population connectivity or additional stressors different species face, those traits could be added to the framework, and scores could be adjusted to incorporate this new information. As the framework integrates more traits, the scores should become more accurate. However, even with more data, all trait-based risk assessments have limitations as not all traits will have an equal impact on vulnerability, and a single trait cannot be isolated in an environment to determine the most accurate impact that it has on vulnerability (Hamilton et al., 2019)

LIKELIHOOD OF EXPOSURE

A species that does not encounter plastics over the entirety of its lifetime is at no risk of losing individuals to plastic related deaths. Therefore, a community that is not exposed to plastics is not vulnerable to death via plastic pollution. Considering plastics are not uniformly distributed across the globe, species living in certain areas will be more likely to encounter plastics, putting them at a greater risk of exposure (Erikson et al., 2014). Furthermore, because we have species distribution maps, the average plastic density in a species' range could be calculated using GIS (IUCN, n.d.). This was important because it allowed the area that the species occupied to be averaged out, preventing species distribution from double counting as habitat specificity. It is acknowledged that the calculation of plastic density allows probability to play a role in the TBA, as some animals with lower plastic density ranges may encounter plastics at a higher rate due to random chance. However, there was no accurate way to account for this randomness in the framework. Rather, the most accurate depiction of overlap with plastic accumulation depended on average plastic density in a specie's range. For example, the Hawaiian Monk Seal occupies a very small range of land (IUCN, n.d.). However, the plastic density is very high in the Hawaiian Monk Seal's range, causing it to rank in the highest quintile in the overlap with plastic accumulation trait.

A similar approach was taken with water column position. Considering all mammals surface to breathe, this paper focused on the water column position where a species feeds. This is important, as plastics are often ingested accidentally during feeding (Nelms et al., 2019). However, the distribution for water column position feeding was not uniform. Most marine mammals are pelagic feeders and very few are surface feeders. Because most of the marine mammals received a score of 1, water column feeding position was an area where few species increased their scores significantly relative to other species. However, this was deemed a necessary trait to include due to the research showing different plastic densities in different areas of the water column, demonstrating a trait that could lead to differential likelihood of exposure to plastics (Lenaker et al., 2019).

The longer the lifespan of a marine mammal, the more opportunities for potential exposure events arise (Nabi et al., 2022). If an animal has a short lifespan, there is a greater chance that they will not encounter plastics, or as many plastics over the course of their life. In addition, the longer the lifespan of a species, the more plastic encounters an individual is likely to have. This is important because cumulations of ingested plastics are more likely to cause a gastro-intestinal blockage than ingestion of a single plastic (Fossi et al., 2018). In addition, entanglement in plastics increases chances of lacerations that can lead to injuries and infections, as well as starvation due to lack of ability to catch food (Luo et al., 2022). Entanglements in plastics can also lead to drowning considering all marine mammals need to surface for air in regular intervals. The longer the lifespan of the species, the more potentially deadly encounters with plastics the individuals will face.

SPECIES SENSITIVITY

If all individual marine mammals were exposed to the same levels of plastics, some would be more likely to be impacted than others, due to their sensitivity to plastics. Rather than accounting for the number of plastics that a species is exposed to, as seen in the likelihood of exposure section, species sensitivity is more of a hypothetical, allowing how different life history traits would cause differential physiological impacts between all marine mammal species if exposed to plastics to be evaluated.

The mass of an individual animal exposed to macroplastics can have a significant impact on the animal’s survival. While developing the framework, it was found that more massive animals entangled in plastics are more likely to break free from said plastics, preventing starvation and suffocation, ultimately increasing the odds of survival (Murphy et al., 2022). However, it is important to note that the mass used in the trait-based risk assessment was the average adult mass of the species. This could lead to limitations in the framework for species that have long juvenile life stages where they weigh significantly less than the average mass as well as species that display sexual dimorphism, where males and females weigh significantly different amounts. Sexual dimorphism can be seen in cases such as elephant seals, where males are much larger than females, as well as in baleen whales where females are much larger than males (Mesnick and Ralls, 2018). The framework initially attempted to include the length of time of the most sensitive lifestage (time as a juvenile) as an attempt to raise the scores of animals that have a smaller than average mass for a longer period. However, not enough information currently exists regarding the time each species is a juvenile for, limiting the accuracy of the framework and highlighting an area where more research is needed. With regard to the species that demonstrate sexual dimorphism because the trait-based risk assessment does not rank species by both sex and species, a male and a female of the same species will always receive the same score. Therefore, although individuals in a species may have differential survival depending on sex, the average sensitivity of a species can be calculated using average mass.

There have been findings of plastics wrapped around marine mammals' flippers and dorsal fins (Parton et al., 2019). Because the dorsal fin provides an additional anchor for plastics to wrap around, it was hypothesized that presence of a dorsal fin will increase a species' sensitivity, as an individual with a dorsal fin is more likely to be entangled in a plastic than one without.

Prey type plays a role with regards to species sensitivity because active feeders are more likely to ingest plastics depending on the prey type they typically consume (Jamieson et al., 2019). The two specific prey characteristics that were researched were prey that resembles plastics and prey that would cause a marine mammal to encounter fishing gear. It was assumed that if species has a prey item that resembles a plastic bag, they are more likely to ingest a plastic bag than a species that does not eat prey that resemble plastic bags. In addition, both active and ghost fishing gear pose a major threat to marine mammals with regard to entanglement (NOAA, n.d.). Since commercial fish are often eaten by marine mammals, these marine mammals are more likely to become entangled in fishing gear due to their direct competition with fisheries. Because prey type was divided into two subcategories, each subcategory was limited to a maximum of two points to prevent prey type from being weighted more strongly than other categories.

Feeding mechanism can impact species sensitivity, because if one feeding mechanism leads to a higher rate of ingestion of plastics that an animal is exposed to, the animal is more likely to be impacted from ingestion of too many plastics. Because filter feeders cannot filter small plastics out of their food source, they are most likely to ingest large amounts of plastic accidentally while feeding (Scherer et al., 2017). Considering grazers such as manatees and dugongs feed at the bottom of the ocean and stir up benthic sand while eating, they are likely to accidentally disturb and ingest plastics that have settled on the ocean floor (Budiarsa et al., 2021). On the other hand, animals that swallow their food whole but do not filter feed are less likely to ingest plastics, as they are more likely to catch individual prey and eat one piece of prey at a time (Guerrero et al., 2020). They are more specific foragers, allowing them to distinguish more easily between plastic and prey. Finally, marine mammals, such as otters, who use their teeth to chew through their food are least likely to ingest plastics, in part because they hunt for specific types of food. It was also assumed that by chewing their food, they are less likely to become victims to secondary ingestion of plastics, as they may have a mechanism in place to remove plastics from their food during the chewing process.

Curiosity and aggression increase species sensitivity to plastics and have been noted as the cause of ingestion and entanglement in past cases (NOAA, 2014). This can be because aggressive marine mammals are more likely to attack plastics and curious marine mammals are more likely to play with plastics and swim close to fishing vessels, increasing their sensitivity (Whale and Dolphin Conservation Society, 2005). However, curiosity and aggression of marine mammals is hard to measure. If no specific mention of a species having curious or aggressive tendencies was found, they were scored as not aggressive/curious. There were also species that specifically mentioned docile and calm behavior, however. Therefore, there was no distinction in scores between species where information regarding curiosity and aggression was omitted and species that were notable not curious and aggressive, posing a potential limitation in the framework. Another complication that came about when ranking species based off curiosity and aggression was that there was no spectrum or quantitative ranking associated with different levels of curiosity and aggression. A species that is slightly curious as a juvenile would, therefore, receive the same score as a species that is very curious and aggressive over the course of its entire life. There was not enough detailed research for the species to be ranked on a finer scale about curiosity and aggression, but the literature implied it was a very important trait. It was decided that it was better to include curiosity and aggression with an understanding that detail was missing, rather than omitting the category altogether.

POPULATION RESILIENCE

Different populations of marine mammals may be more likely to rebound from, or have more resilience to, population reductions associated with plastic impacts (e.g. death, reduced reproduction or fitness, etc.)

Although population size had many unknowns, it was still included in the final framework. Population size was important because, when comparing a species such as the spinner dolphin, that has a million individuals to a species such as the vaquita that only has 18 individuals (IUCN, n.d.), losing a single vaquita would cost a significantly higher proportion of the population than losing a single spinner dolphin would. It has also been explained that a larger population size allows for more fluctuations in population without a rise for concern (Mace et al., 2008).

Generation length also had many unknowns but plays a significant role when it comes to population resilience. Species with a smaller generation length, the length of time from birth to reproductive maturity, can reproduce more quickly and their populations are more likely to rebound from a decrease in population size more quickly than species that have a longer generation length (Mace et al., 2008). A shorter generation length ultimately leads to a shorter population turnover rate which is generally used by ecologists as a measure of population resilience (Renaud et al., 2018).

The habitat and food specificity of a species can be related to species' resilience overtime. As threats such as climate change impact the ocean, habitats and food resources that are available can be rapidly changing (Poloczanska et al., 2016). Therefore, animals with more food preferences and habitat preferences are more resilient to change in general and are less at risk of extinction (Mace et al., 2008). Although this does not relate to plastic exposure specifically, overall resilience is important to determining vulnerability to a specific threat such as plastics.

Finally, the current state of a species' global population, based on cumulative impacts of multiple stressors, can be accounted for in the trait-based risk assessment by also scoring each species current level of extinction risk, expressed as an IUCN Red List Category (www.iucnredlist.org). IUCN Red List Categories were ranked by current level of extinction risk to account for species that may already be less resilient (Mace et al., 2008), due to higher risk of extinction, and therefore harm from plastics could occur at a disproportionately higher rate. Although IUCN status can be based in part on certain traits such as population size that may have already been accounted for in the trait-based risk assessment, it was important to include a measure of the current impact of various stressors and a snap shot of the current status of each species global population status.

CORRELATIONS BETWEEN CATEGORIES

By conducting various data analysis and looking at correlations specifically, this project attempted to look for relatedness between various traits. The highest correlation coefficient was between generation length and lifespan, with an r^2 value of 0.5174. This is a common correlation that has been observed in other species including algae species (Sarma et al., 2005). This phemomenon has also been observed in bivalves and marine mammals (Moss et al., 2016) (Staerk et al., 2019). In an extreme case, a strong correlation coefficient could indicate a flaw in the framework, demonstrating a trait being double counted. However, because lifespan was used to capture likelihood of exposure and generation length was used to capture population resilience, it was deemed appropriate to leave both traits in the TBA, as they demonstrate different categories that could impact vulnerability. However, this correlation between lifespan and generation length should draw special attention to species that have particularly long lifespans and long generation lengths (Staerk et al., 2019), as these species are more likely to be exposed to plastics over their lifetimes and reproduce at slower rates, limiting population regeneration. Therefore, these species should be of particular interest to researchers, as they are more likely to be exposed and less likely to recover as a population due solely to their life history traits. Researchers should be making efforts to learn more about North Atlantic right whales, Sei whales, dugongs, and North Pacific right whales, as they were the top four overall ranked species that scored the maximum possible score in both generation length and lifespan.

Another correlation was between lifespan and mass. This correlation has been observed before in a variety of animals (Speakman, 2005). The r^2 value between lifespan and mass was 0.3682. Considering toxins can adhere to the surface of plastics, massive animals can have a significant amount of toxins incorporated into their blubber over the course of their lifetime (Routti et al., 2021). Blubber is used for insulation and body temperature control but can also be broken down and used for food when an animal is under pressure and unable to hunt for enough calories (Guerrero, 2017). When blubber is broken down, these toxins can be released into the animal's bloodstream. Furthermore, animals with longer lifespans are more likely to endure more harsh periods of time where accumulated toxins could be released from blubber, showing that the correlation between mass and lifespan causes a compounding impact on the vulnerability of a large, long-lived species by increasing likelihood of exposure as well as specie's sensitivity. However, it is important to note that the initial framework was developed to evaluate the risk posed by macroplastics specifically and plasticizers and toxins adhering to plastic surfaces become a more amplified problem with microplastics, showing that this speculation has its limitations. Rather than dismiss the correlation between lifespan and mass, more research should be conducted to determine the true strength of this correlation.

ETHICAL IMPLICATIONS AND BROADER IMPACTS

Although society expresses negative feelings towards plastics and the negative environmental impacts they cause, plastics are still widely used and little is being done to correct the negative impacts that plastics have caused. It has been found that the public does view plastics as a bio-ecological threat (Soares et al., 2021). This raises two questions: Whose responsibility is it to prevent plastic use and pollution, and if plastic pollution is only impacting individual animals rather than entire populations is it an urgent concern?

Who is responsible? As previously mentioned, plastics have become a widespread and frequently used material because of their cheap manufacturing costs, durability, and versatility (Thompson et al., 2009). However, as demonstrated by animals dying from exposure to plastics, plastic usage and disposal has become ecologically harmful. It is important to note that both individuals and corporations are responsible for plastic pollution, as both groups use and dispose of plastics. However, it should be considered that individuals are at the mercy of corporations to produce plastic alternatives. Nevertheless, individuals do have the power to make different purchasing choices, demonstrating their responsibility and influence in the matter.

If an average person is out shopping and wants a bottle of water, they are likely to grab the cheapest option available, which would likely be a plastic water bottle. Although there are glass water bottles available for sale, they are costlier. However, if only glass water bottles were available, not only would the consumer be forced to avoid plastic, but competition between different water bottling companies would also drive the cost of glass water bottles down, making it a practical alternative for consumers. Currently, because plastic is notoriously cheap to produce, it is used so widely and, disregarding environmental concerns, there is no motivation for a corporation to stray from plastic products. Therefore, to see change in plastic usage, government intervention and new plastic manufacturing policies are needed.

It has been argued that, because plastics can travel so far and because the ocean health is a global concern, global governance is needed to prevent plastic usage and manage proper disposal (Dauvergne, 2018). Global management of plastics is needed. Also, smaller, local efforts to get individuals to take responsibility regarding their plastic usage should be made because, if the consumers feel ethically compelled to use an alternative material, they can also put a pressure on corporations for an alternative, more environmentally friendly material.

With all things considered, plastic pollution impacts everyone and therefore, everyone who uses plastics, whether it be individuals, organizations, fisheries, or corporations is responsible for limiting plastic pollution. However, for decades numerous attempts have been made to get the public to care enough about plastic pollution to limit their usage. Regardless, 300 million tons of plastics can easily be produced in a single year (Thompson et al., 2009). Therefore, the grassroots movement has proven to be ineffective, and government intervention revolving around holding corporations responsible is needed.

Individualism vs holism. When conducting a trait-based risk assessment, the good of the individual is overlooked for the benefit of the community. For example, it may be more beneficial for the community to save a single vaquita rather than 100 common dolphins. The trait-based risk assessment, that is, undervalues the individual organism, as many ecological research methods do. In much of ecology and sustainability science, the good of the community (i.e., population, species, ecosystem) is prioritized over the good of the individual organism (Shrader-Frechette, 1996).

However, the growing movement of compassionate conservation argues that the individual matters just as much, if not more than the whole. Therefore, it could be argued that a trait-based risk assessment places too much value on the good of the community and ecosystem rather than on individual organisms. It is important to note that this tool should be used in situations with limited resources. If there were a situation where thousands of marine mammals are washed up, having been entangled in or ingested plastics and resources are only available to save fifty of the animals, species need to be prioritized. The overall good of the community should be considered and the most vulnerable species should be prioritized by using a trait-based risk assessment.

FUTURE DIRECTIONS

As mentioned above, there is research that could be conducted to increase the accuracy of this trait-based risk assessment, to better understand which marine mammal species need to be monitored more closely, and to increase the applicability of this framework.

To increase the accuracy of the framework, traits that were removed because of too many unknowns, as explained in the methods, should be further researched. This would include population connectivity of marine mammals, determining the length of the pre-adult stage, determining and evaluating the direst threats to marine mammals besides plastic pollution.

Considering the correlation between mass and lifespan, massive, long lived marine mammals should be monitored closely, as well as the species ranked as high risk. Both ways to help limit entanglement and ingestion of plastics by these animals should be researched as well as ways to assist the animals after exposure events have occurred.

Finally, this trait-based risk assessment has the potential to be applied in different ways. A similar framework should be developed for the ingestion of microplastics specifically, allowing for the investigation of the risk of toxins and plasticizers that are augmented with an increased surface area to volume ratio that comes with smaller plastics. The initial framework could be applied to other taxa and could be applied to multiple taxa at once. Similarly, a trait-based risk assessment could be applied to human populations that consume commercial fish. By applying the framework to human populations, we could determine which coastal populations are consuming the most plastic by eating fish as well as which people are at the greatest health risk from eating fish with these plastics.

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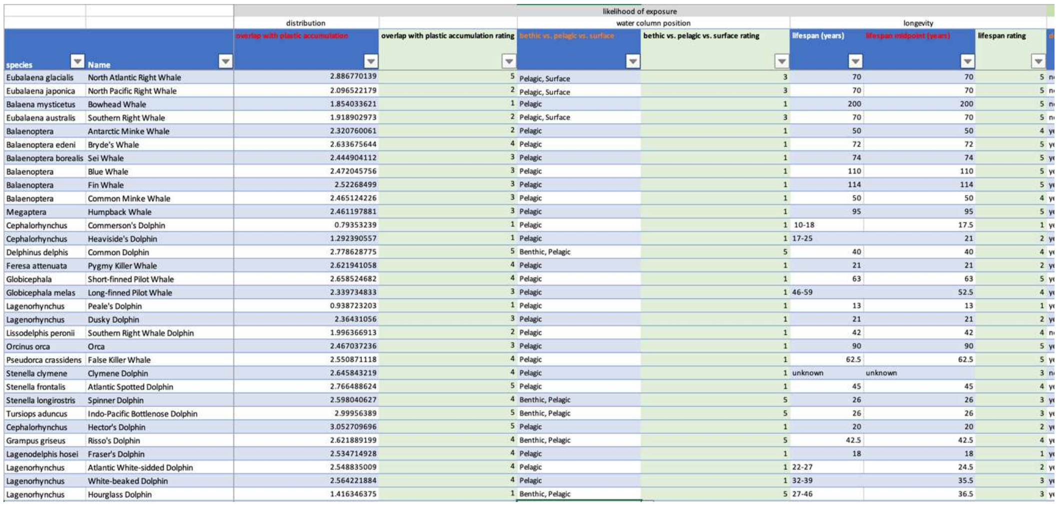
APPENDIX A

TABLES CREATED FOR THIS THESIS

TABLES

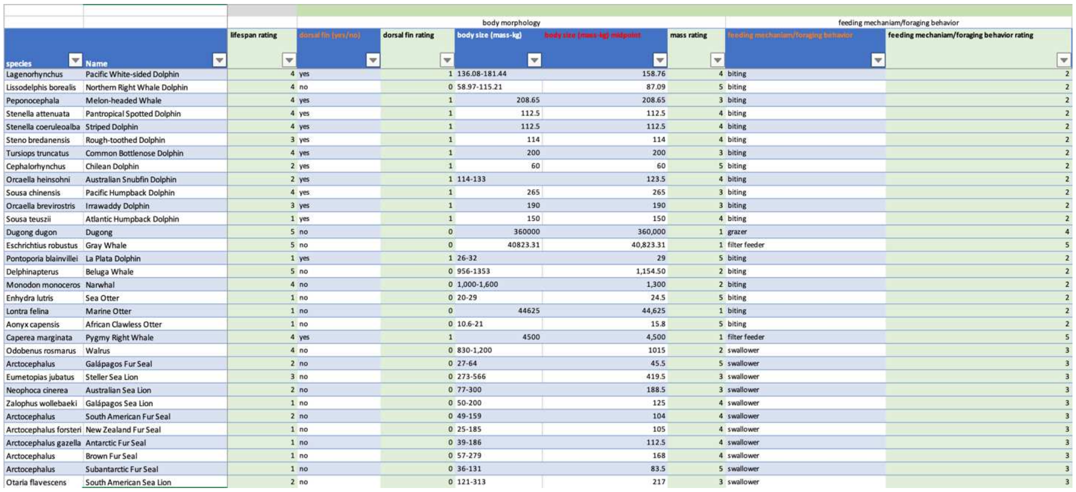
Table 1

Table 1 shows all of the supplementary data gathered from the literature review

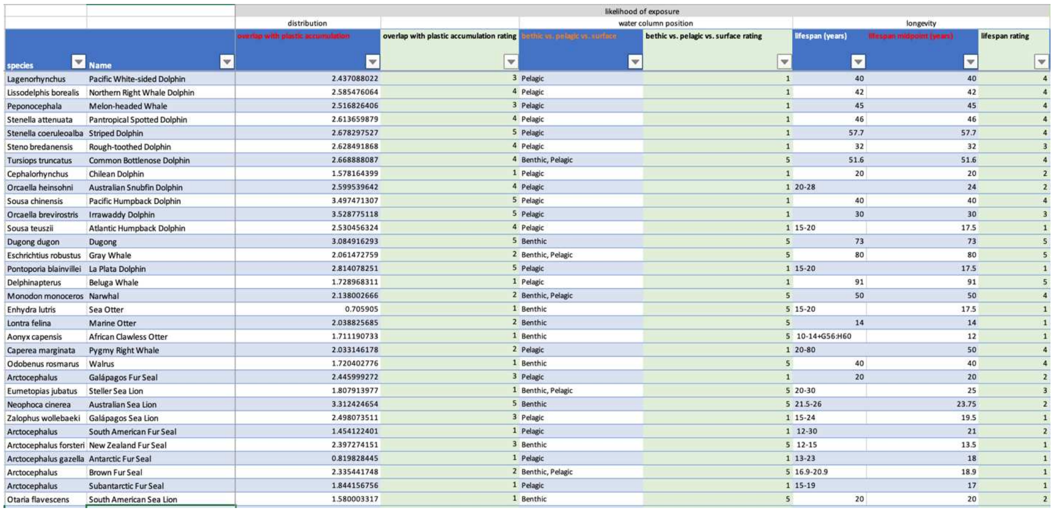


		likelihood of exposure						
		distribution		water column position		longevity		
species	Name	overlap with plastic accumulation	overlap with plastic accumulation rating	bethic vs. pelagic vs. surface	bethic vs. pelagic vs. surface rating	lifespan (years)	lifespan midpoint (years)	lifespan rating
Eubalaena glacialis	North Atlantic Right Whale	2.886770139	5	Pelagic, Surface	3	70	70	5
Eubalaena japonica	North Pacific Right Whale	2.096522179	2	Pelagic, Surface	3	70	70	5
Balaena mysticetus	Bowhead Whale	1.854033621	1	Pelagic	1	200	200	5
Eubalaena australis	Southern Right Whale	1.918902973	2	Pelagic, Surface	3	70	70	5
Balaenoptera	Antarctic Minke Whale	2.320760061	2	Pelagic	1	50	50	4
Balaenoptera edeni	Bryde's Whale	2.633675644	4	Pelagic	1	72	72	5
Balaenoptera borealis	Sei Whale	2.444904112	3	Pelagic	1	74	74	5
Balaenoptera	Blue Whale	2.472045756	3	Pelagic	1	110	110	5
Balaenoptera	Fin Whale	2.52268499	3	Pelagic	1	114	114	5
Balaenoptera	Common Minke Whale	2.465124226	3	Pelagic	1	50	50	4
Megaptera	Humpback Whale	2.461197881	3	Pelagic	1	95	95	5
Cephalorhynchus	Commerson's Dolphin	0.79353239	1	Pelagic	1	10-18	17.5	1
Cephalorhynchus	Heaviside's Dolphin	1.292390557	1	Pelagic	1	17-25	21	2
Delphinus delphis	Common Dolphin	2.778628775	5	Benthic, Pelagic	5	40	40	4
Feresa attenuata	Pygmy Killer Whale	2.621941058	4	Pelagic	1	21	21	2
Globicephala	Short-finned Pilot Whale	2.658524682	4	Pelagic	1	63	63	5
Globicephala melas	Long-finned Pilot Whale	2.339734833	3	Pelagic	1	46-59	52.5	4
Lagenorhynchus	Peale's Dolphin	0.938723203	1	Pelagic	1	13	13	1
Lagenorhynchus	Dusky Dolphin	2.36431056	3	Pelagic	1	21	21	2
Lissodelphis peronii	Southern Right Whale Dolphin	1.996366913	2	Pelagic	1	42	42	4
Orcinus orca	Orca	2.467037236	3	Pelagic	1	90	90	5
Pseudorca crassidens	False Killer Whale	2.550871118	4	Pelagic	1	62.5	62.5	5
Stenella clymene	Clymene Dolphin	2.645843219	4	Pelagic	1	unknown	unknown	3
Stenella frontalis	Atlantic Spotted Dolphin	2.766488624	5	Pelagic	1	45	45	4
Stenella longirostris	Spinner Dolphin	2.598040627	4	Benthic, Pelagic	5	26	26	3
Tursiops aduncus	Indo-Pacific Bottlenose Dolphin	2.99956389	5	Benthic, Pelagic	5	26	26	3
Cephalorhynchus	Hector's Dolphin	3.052709696	5	Pelagic	1	20	20	2
Grampus griseus	Risso's Dolphin	2.621889199	4	Benthic, Pelagic	5	42.5	42.5	4
Lagenodelphis hosei	Fraser's Dolphin	2.534714928	4	Pelagic	1	18	18	1
Lagenorhynchus	Atlantic White-sidded Dolphin	2.548835009	4	Pelagic	1	22-27	24.5	2
Lagenorhynchus	White-beaked Dolphin	2.564221884	4	Pelagic	1	32-39	35.5	3
Lagenorhynchus	Hourglass Dolphin	1.416346375	1	Benthic, Pelagic	5	27-46	36.5	3

		body morphology					feeding mechaniam/foraging behavior	
species	Name	dorsal fin (yes/no)	dorsal fin rating	body size (mass-kg)	body size (mass-kg) midpoint	mass rating	feeding mechaniam/foraging behavior	feeding mechaniam/foraging behavior rating
Eubalaena glacialis	North Atlantic Right Whale	no	0	67,000-107,000	87,000	1	filter feeder	5
Eubalaena japonica	North Pacific Right Whale	no	0	90718.5	90,718.50	1	filter feeder	5
Balaena mysticetus	Bowhead Whale	no	0	90718.47	90,718.47	1	filter feeder	5
Eubalaena australis	Southern Right Whale	no	0	79832.257	79,832.26	1	filter feeder	5
Balaenoptera	Antarctic Minke Whale	yes	1	9071.85	9,071.85	1	filter feeder	5
Balaenoptera edeni	Bryde's Whale	yes	1	16000	16,000	1	filter feeder	5
Balaenoptera borealis	Sei Whale	yes	1	16,000-22,000	19,000	1	filter feeder	5
Balaenoptera	Blue Whale	yes	1	136000	136,000	1	filter feeder	5
Balaenoptera	Fin Whale	yes	1	36,287.4-72,574.8	54,431.10	1	filter feeder	5
Balaenoptera	Common Minke Whale	yes	1	9000	9,000	1	filter feeder	5
Megaptera	Humpback Whale	yes	1	28,000-41,000	34,500	1	filter feeder	5
Cephalorhynchus	Commerson's Dolphin	yes	1	35-65	50	5	biting	2
Cephalorhynchus	Heaviside's Dolphin	yes	1	60-75	67.5	5	biting	2
Delphinus delphis	Common Dolphin	yes	1	100	100	4	biting	2
Feresa attenuata	Pygmy Killer Whale	yes	1	224.982	224.982	3	biting	2
Globicephala	Short-finned Pilot Whale	yes	1	2200	2,200	2	biting	2
Globicephala melas	Long-finned Pilot Whale	yes	1	1,800-3,800	2,800	1	biting	2
Lagenorhynchus	Peale's Dolphin	yes	1	115	115	4	biting	2
Lagenorhynchus	Dusky Dolphin	yes	1	100	100	4	biting	2
Lissodelphis peronii	Southern Right Whale Dolphin	no	0	59-100	79.5	5	biting	2
Orcinus orca	Orca	yes	1	7200	7,200	1	biting	2
Pseudorca crassidens	False Killer Whale	yes	1	916.26-1841.59	1,378.90	2	biting	2
Stenella clymene	Clymene Dolphin	no	0	74.84-90.72	82.78	5	biting	2
Stenella frontalis	Atlantic Spotted Dolphin	yes	1	99.70-142.88	121.29	4	biting	2
Stenella longirostris	Spinner Dolphin	yes	1	51.5	51.5	5	biting	2
Tursiops aduncus	Indo-Pacific Bottlenose Dolphin	yes	1	280	280	3	biting	2
Cephalorhynchus	Hector's Dolphin	yes	1	49.9	49.9	5	biting	2
Grampus griseus	Risso's Dolphin	yes	1	425	425	2	biting	2
Lagenodelphis hosei	Fraser's Dolphin	yes	1	164	164	4	biting	2
Lagenorhynchus	Atlantic White-sidded Dolphin	yes	1	182-234	208	3	biting	2
Lagenorhynchus	White-beaked Dolphin	yes	1	77.11	77.11	5	biting	2
Lagenorhynchus	Hourglass Dolphin	yes	1	73.5-94	83.75	5	biting	2

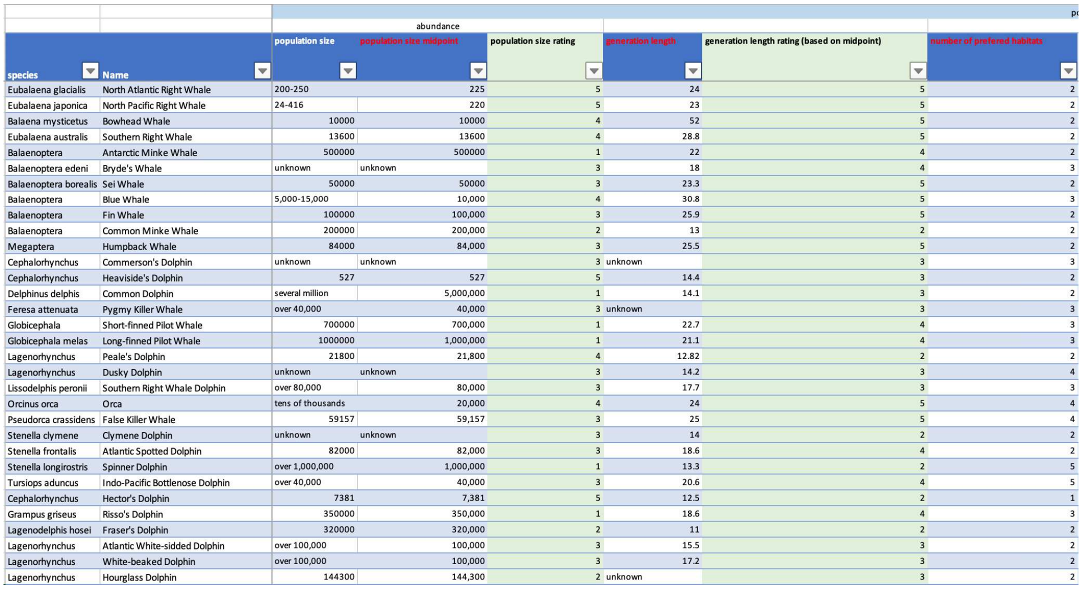


			body morphology					feeding mechaniam/foraging behavior	
species	Name	lifespan rating	dorsal fin (yes/no)	dorsal fin rating	body size (mass-kg)	body size (mass-kg) midpoint	mass rating	feeding mechaniam/foraging behavior	feeding mechaniam/foraging behavior rating
Lagenorhynchus	Pacific White-sided Dolphin	4	yes	1	136.08-181.44	158.76	4	biting	2
Lissodelphis borealis	Northern Right Whale Dolphin	4	no	0	58.97-115.21	87.09	5	biting	2
Peponocephala	Melon-headed Whale	4	yes	1	208.65	208.65	3	biting	2
Stenella attenuata	Pantropical Spotted Dolphin	4	yes	1	112.5	112.5	4	biting	2
Stenella coeruleoalba	Striped Dolphin	4	yes	1	112.5	112.5	4	biting	2
Steno bredanensis	Rough-toothed Dolphin	3	yes	1	114	114	4	biting	2
Tursiops truncatus	Common Bottlenose Dolphin	4	yes	1	200	200	3	biting	2
Cephalorhynchus	Chilean Dolphin	2	yes	1	60	60	5	biting	2
Orcaella heinsohni	Australian Snubfin Dolphin	2	yes	1	114-133	123.5	4	biting	2
Sousa chinensis	Pacific Humpback Dolphin	4	yes	1	265	265	3	biting	2
Orcaella brevirostris	Irrawaddy Dolphin	3	yes	1	190	190	3	biting	2
Sousa teuszii	Atlantic Humpback Dolphin	1	yes	1	150	150	4	biting	2
Dugong dugon	Dugong	5	no	0	360000	360,000	1	grazer	4
Eschrichtius robustus	Gray Whale	5	no	0	40823.31	40,823.31	1	filter feeder	5
Pontoporia blainvillei	La Plata Dolphin	1	yes	1	26-32	29	5	biting	2
Delphinapterus	Beluga Whale	5	no	0	956-1353	1,154.50	2	biting	2
Monodon monoceros	Narwhal	4	no	0	1,000-1,600	1,300	2	biting	2
Enhydra lutris	Sea Otter	1	no	0	20-29	24.5	5	biting	2
Lontra felina	Marine Otter	1	no	0	44625	44,625	1	biting	2
Aonyx capensis	African Clawless Otter	1	no	0	10.6-21	15.8	5	biting	2
Caperea marginata	Pygmy Right Whale	4	yes	1	4500	4,500	1	filter feeder	5
Odobenus rosmarus	Walrus	4	no	0	830-1,200	1015	2	swallower	3
Arctocephalus	Galápagos Fur Seal	2	no	0	27-64	45.5	5	swallower	3
Eumetopias jubatus	Steller Sea Lion	3	no	0	273-566	419.5	3	swallower	3
Neophoca cinerea	Australian Sea Lion	2	no	0	77-300	188.5	3	swallower	3
Zalophus wollebaeki	Galápagos Sea Lion	1	no	0	50-200	125	4	swallower	3
Arctocephalus	South American Fur Seal	2	no	0	49-159	104	4	swallower	3
Arctocephalus forsteri	New Zealand Fur Seal	1	no	0	25-185	105	4	swallower	3
Arctocephalus gazella	Antarctic Fur Seal	1	no	0	39-186	112.5	4	swallower	3
Arctocephalus	Brown Fur Seal	1	no	0	57-279	168	4	swallower	3
Arctocephalus	Subantarctic Fur Seal	1	no	0	36-131	83.5	5	swallower	3
Otaria flavescens	South American Sea Lion	2	no	0	121-313	217	3	swallower	3

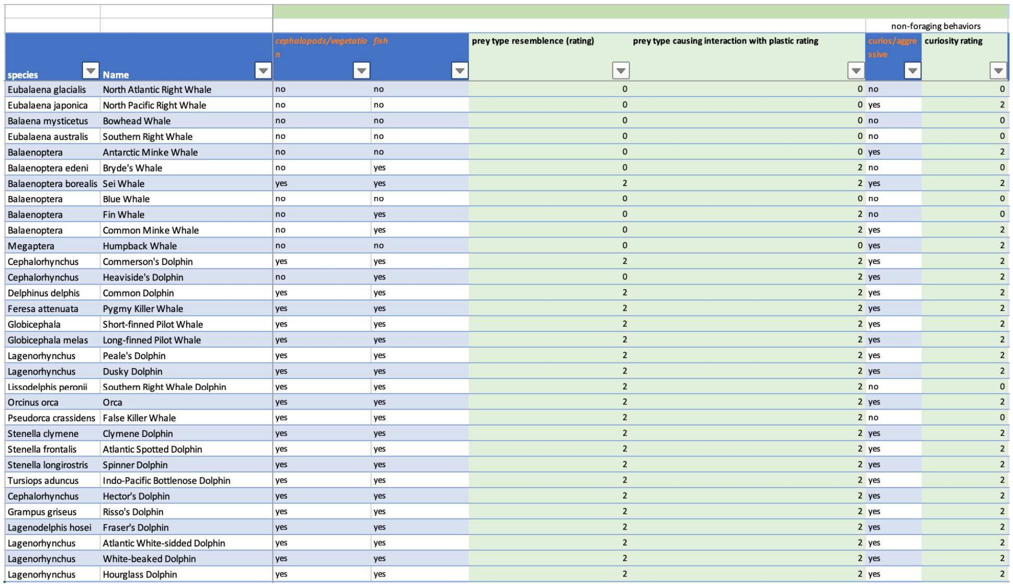


		likelihood of exposure						
		distribution		water column position		longevity		
species	Name	overlap with plastic accumulation	overlap with plastic accumulation rating	bethic vs. pelagic vs. surface	bethic vs. pelagic vs. surface rating	lifespan (years)	lifespan midpoint (years)	lifespan rating
Lagenorhynchus	Pacific White-sided Dolphin	2.437088022	3	Pelagic	1	40	40	4
Lissodelphis borealis	Northern Right Whale Dolphin	2.585476064	4	Pelagic	1	42	42	4
Peponocephala	Melon-headed Whale	2.516826406	3	Pelagic	1	45	45	4
Stenella attenuata	Pantropical Spotted Dolphin	2.613659879	4	Pelagic	1	46	46	4
Stenella coeruleoalba	Striped Dolphin	2.678297527	5	Pelagic	1	57.7	57.7	4
Steno bredanensis	Rough-toothed Dolphin	2.628491868	4	Pelagic	1	32	32	3
Tursiops truncatus	Common Bottlenose Dolphin	2.668888087	4	Benthic, Pelagic	5	51.6	51.6	4
Cephalorhynchus	Chilean Dolphin	1.578164399	1	Pelagic	1	20	20	2
Orcaella heinsohni	Australian Snubfin Dolphin	2.599539642	4	Pelagic	1	20-28	24	2
Sousa chinensis	Pacific Humpback Dolphin	3.497471307	5	Pelagic	1	40	40	4
Orcaella brevirostris	Irrawaddy Dolphin	3.528775118	5	Pelagic	1	30	30	3
Sousa teuszii	Atlantic Humpback Dolphin	2.530456324	4	Pelagic	1	15-20	17.5	1
Dugong dugon	Dugong	3.084916293	5	Benthic	5	73	73	5
Eschrichtius robustus	Gray Whale	2.061472759	2	Benthic, Pelagic	5	80	80	5
Pontoporia blainvillei	La Plata Dolphin	2.814078251	5	Pelagic	1	15-20	17.5	1
Delphinapterus	Beluga Whale	1.728968311	1	Pelagic	1	91	91	5
Monodon monoceros	Narwhal	2.138002666	2	Benthic, Pelagic	5	50	50	4
Enhydra lutris	Sea Otter	0.705905	1	Benthic	5	15-20	17.5	1
Lontra felina	Marine Otter	2.038825685	2	Benthic	5	14	14	1
Aonyx capensis	African Clawless Otter	1.711190733	1	Benthic	5	10-14+G56:H60	12	1
Caperea marginata	Pygmy Right Whale	2.033146178	2	Pelagic	1	20-80	50	4
Odobenus rosmarus	Walrus	1.720402776	1	Benthic	5	40	40	4
Arctocephalus	Galápagos Fur Seal	2.445999272	3	Pelagic	1	20	20	2
Eumetopias jubatus	Steller Sea Lion	1.807913977	1	Benthic, Pelagic	5	20-30	25	3
Neophoca cinerea	Australian Sea Lion	3.312424654	5	Benthic	5	21.5-26	23.75	2
Zalophus wollebaeki	Galápagos Sea Lion	2.498073511	3	Pelagic	1	15-24	19.5	1
Arctocephalus	South American Fur Seal	1.454122401	1	Pelagic	1	12-30	21	2
Arctocephalus forsteri	New Zealand Fur Seal	2.397274151	3	Benthic	5	12-15	13.5	1
Arctocephalus gazella	Antarctic Fur Seal	0.819828445	1	Pelagic	1	13-23	18	1
Arctocephalus	Brown Fur Seal	2.335441748	2	Benthic, Pelagic	5	16.9-20.9	18.9	1
Arctocephalus	Subantarctic Fur Seal	1.844156756	1	Pelagic	1	15-19	17	1
Otaria flavescens	South American Sea Lion	1.580003317	1	Benthic	5	20	20	2

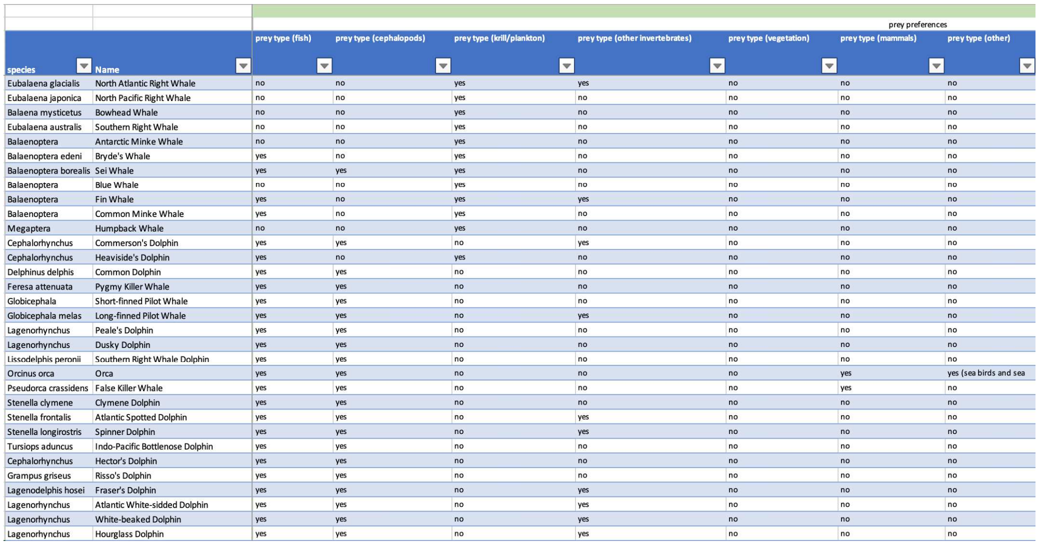
		opulation resilience						
		feeding or habitat specialization				extinction risk		total score
species	Name	number of prefered habitats rating	number of food preferences	number of food preferences rating	average of food preferences and habitat preferences rating	IUCN status	IUCN status Rating	Total
Eubalaena glacialis	North Atlantic Right Whale	4	2	4	4	CR	5	38
Eubalaena japonica	North Pacific Right Whale	4	1	5	4.5	EN	4	36.5
Balaena mysticetus	Bowhead Whale	4	1	5	4.5	VU	3	29.5
Eubalaena australis	Southern Right Whale	4	1	5	4.5	LC	1	30.5
Balaenoptera	Antarctic Minke Whale	4	1	5	4.5	NT	2	27.5
Balaenoptera edeni	Bryde's Whale	3	2	4	3.5	DD	3	32.5
Balaenoptera borealis	Sei Whale	4	3	3	3.5	EN	4	37.5
Balaenoptera	Blue Whale	3	1	5	4	EN	4	33
Balaenoptera	Fin Whale	4	3	3	3.5	VU	3	32.5
Balaenoptera	Common Minke Whale	4	2	4	4	LC	1	28
Megaptera	Humpback Whale	4	1	5	4.5	LC	1	31.5
Cephalorhynchus	Commerson's Dolphin	3	3	3	3	LC	1	27
Cephalorhynchus	Heaviside's Dolphin	4	2	4	4	NT	2	30
Delphinus delphis	Common Dolphin	4	2	4	4	LC	1	36
Feresa attenuata	Pygmy Killer Whale	3	2	4	3.5	LC	1	29.5
Globicephala	Short-finned Pilot Whale	3	2	4	3.5	LC	1	30.5
Globicephala melas	Long-finned Pilot Whale	3	3	3	3	LC	1	27
Lagenorhynchus	Peale's Dolphin	4	2	4	4	LC	1	27
Lagenorhynchus	Dusky Dolphin	2	2	4	3	LC	1	29
Lissodelphis peronii	Southern Right Whale Dolphin	3	2	4	3.5	LC	1	28.5
Orcinus orca	Orca	2	4	2	2	DD	3	33
Pseudorca crassidens	False Killer Whale	2	3	3	2.5	NT	2	31.5
Stenella clymene	Clymene Dolphin	4	2	4	4	DD	3	33
Stenella frontalis	Atlantic Spotted Dolphin	4	3	3	3.5	LC	1	34.5
Stenella longirostris	Spinner Dolphin	1	3	3	2	LC	1	32
Tursiops aduncus	Indo-Pacific Bottlenose Dolphin	1	2	4	2.5	NT	2	36.5
Cephalorhynchus	Hector's Dolphin	5	2	4	4.5	EN	4	37.5
Grampus griseus	Risso's Dolphin	3	2	4	3.5	LC	1	33.5
Lagenodelphis hosei	Fraser's Dolphin	4	3	3	3.5	LC	1	27.5
Lagenorhynchus	Atlantic White-sidded Dolphin	4	3	3	3.5	LC	1	29.5
Lagenorhynchus	White-beaked Dolphin	4	3	3	3.5	LC	1	32.5
Lagenorhynchus	Hourglass Dolphin	4	3	3	3.5	LC	1	32.5



		abundance					
species	Name	population size	population size midpoint	population size rating	generation length	generation length rating (based on midpoint)	number of prefered habitats
Eubalaena glacialis	North Atlantic Right Whale	200-250	225	5	24	5	2
Eubalaena japonica	North Pacific Right Whale	24-416	220	5	23	5	2
Balaena mysticetus	Bowhead Whale	10000	10000	4	52	5	2
Eubalaena australis	Southern Right Whale	13600	13600	4	28.8	5	2
Balaenoptera	Antarctic Minke Whale	500000	500000	1	22	4	2
Balaenoptera edeni	Bryde's Whale	unknown	unknown	3	18	4	3
Balaenoptera borealis	Sei Whale	50000	50000	3	23.3	5	2
Balaenoptera	Blue Whale	5,000-15,000	10,000	4	30.8	5	3
Balaenoptera	Fin Whale	100000	100,000	3	25.9	5	2
Balaenoptera	Common Minke Whale	200000	200,000	2	13	2	2
Megaptera	Humpback Whale	84000	84,000	3	25.5	5	2
Cephalorhynchus	Commerson's Dolphin	unknown	unknown	3	unknown	3	3
Cephalorhynchus	Heaviside's Dolphin	527	527	5	14.4	3	2
Delphinus delphis	Common Dolphin	several million	5,000,000	1	14.1	3	2
Feresa attenuata	Pygmy Killer Whale	over 40,000	40,000	3	unknown	3	3
Globicephala	Short-finned Pilot Whale	700000	700,000	1	22.7	4	3
Globicephala melas	Long-finned Pilot Whale	1000000	1,000,000	1	21.1	4	3
Lagenorhynchus	Peale's Dolphin	21800	21,800	4	12.82	2	2
Lagenorhynchus	Dusky Dolphin	unknown	unknown	3	14.2	3	4
Lissodelphis peronii	Southern Right Whale Dolphin	over 80,000	80,000	3	17.7	3	3
Orcinus orca	Orca	tens of thousands	20,000	4	24	5	4
Pseudorca crassidens	False Killer Whale	59157	59,157	3	25	5	4
Stenella clymene	Clymene Dolphin	unknown	unknown	3	14	2	2
Stenella frontalis	Atlantic Spotted Dolphin	82000	82,000	3	18.6	4	2
Stenella longirostris	Spinner Dolphin	over 1,000,000	1,000,000	1	13.3	2	5
Tursiops aduncus	Indo-Pacific Bottlenose Dolphin	over 40,000	40,000	3	20.6	4	5
Cephalorhynchus	Hector's Dolphin	7381	7,381	5	12.5	2	1
Grampus griseus	Risso's Dolphin	350000	350,000	1	18.6	4	3
Lagenodelphis hosei	Fraser's Dolphin	320000	320,000	2	11	2	2
Lagenorhynchus	Atlantic White-sidded Dolphin	over 100,000	100,000	3	15.5	3	2
Lagenorhynchus	White-beaked Dolphin	over 100,000	100,000	3	17.2	3	2
Lagenorhynchus	Hourglass Dolphin	144300	144,300	2	unknown	3	2

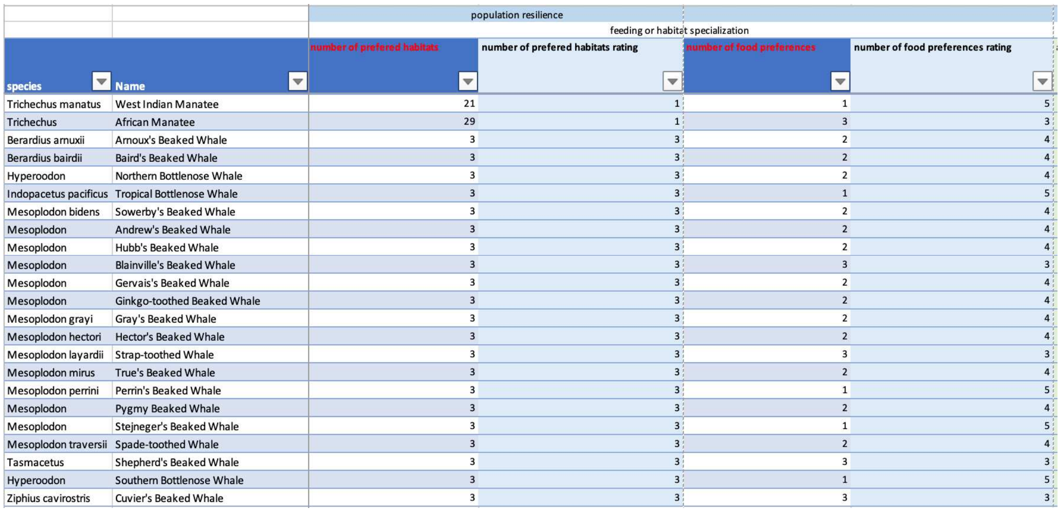


						non-foraging behaviors	
species	Name	cephalopods/vegetation	fish	prey type resemblence (rating)	prey type causing interaction with plastic rating	curios/aggressive	curiosity rating
Eubalaena glacialis	North Atlantic Right Whale	no	no	0	0	no	0
Eubalaena japonica	North Pacific Right Whale	no	no	0	0	yes	2
Balaena mysticetus	Bowhead Whale	no	no	0	0	no	0
Eubalaena australis	Southern Right Whale	no	no	0	0	no	0
Balaenoptera	Antarctic Minke Whale	no	no	0	0	yes	2
Balaenoptera edeni	Bryde's Whale	no	yes	0	2	no	0
Balaenoptera borealis	Sei Whale	yes	yes	2	2	yes	2
Balaenoptera	Blue Whale	no	no	0	0	no	0
Balaenoptera	Fin Whale	no	yes	0	2	no	0
Balaenoptera	Common Minke Whale	no	yes	0	2	yes	2
Megaptera	Humpback Whale	no	no	0	0	yes	2
Cephalorhynchus	Commerson's Dolphin	yes	yes	2	2	yes	2
Cephalorhynchus	Heaviside's Dolphin	no	yes	0	2	yes	2
Delphinus delphis	Common Dolphin	yes	yes	2	2	yes	2
Feresa attenuata	Pygmy Killer Whale	yes	yes	2	2	yes	2
Globicephala	Short-finned Pilot Whale	yes	yes	2	2	yes	2
Globicephala melas	Long-finned Pilot Whale	yes	yes	2	2	yes	2
Lagenorhynchus	Peale's Dolphin	yes	yes	2	2	yes	2
Lagenorhynchus	Dusky Dolphin	yes	yes	2	2	yes	2
Lissodelphis peronii	Southern Right Whale Dolphin	yes	yes	2	2	no	0
Orcinus orca	Orca	yes	yes	2	2	yes	2
Pseudorca crassidens	False Killer Whale	yes	yes	2	2	no	0
Stenella clymene	Clymene Dolphin	yes	yes	2	2	yes	2
Stenella frontalis	Atlantic Spotted Dolphin	yes	yes	2	2	yes	2
Stenella longirostris	Spinner Dolphin	yes	yes	2	2	yes	2
Tursiops aduncus	Indo-Pacific Bottlenose Dolphin	yes	yes	2	2	yes	2
Cephalorhynchus	Hector's Dolphin	yes	yes	2	2	yes	2
Grampus griseus	Risso's Dolphin	yes	yes	2	2	yes	2
Lagenodelphis hosei	Fraser's Dolphin	yes	yes	2	2	yes	2
Lagenorhynchus	Atlantic White-sidded Dolphin	yes	yes	2	2	yes	2
Lagenorhynchus	White-beaked Dolphin	yes	yes	2	2	yes	2
Lagenorhynchus	Hourglass Dolphin	yes	yes	2	2	yes	2



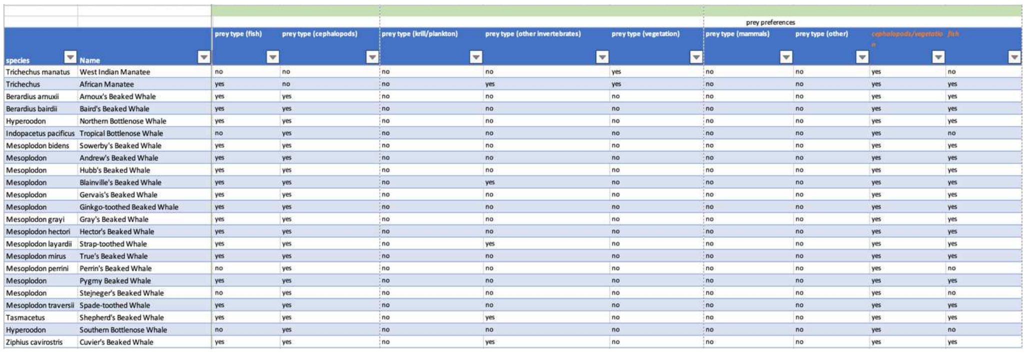
							prey preferences	
species	Name	prey type (fish)	prey type (cephalopods)	prey type (krill/plankton)	prey type (other invertebrates)	prey type (vegetation)	prey type (mammals)	prey type (other)
Eubalaena glacialis	North Atlantic Right Whale	no	no	yes	yes	no	no	no
Eubalaena japonica	North Pacific Right Whale	no	no	yes	no	no	no	no
Balaena mysticetus	Bowhead Whale	no	no	yes	no	no	no	no
Eubalaena australis	Southern Right Whale	no	no	yes	no	no	no	no
Balaenoptera	Antarctic Minke Whale	no	no	yes	no	no	no	no
Balaenoptera edeni	Bryde's Whale	yes	no	yes	no	no	no	no
Balaenoptera borealis	Sei Whale	yes	yes	yes	no	no	no	no
Balaenoptera	Blue Whale	no	no	yes	no	no	no	no
Balaenoptera	Fin Whale	yes	no	yes	yes	no	no	no
Balaenoptera	Common Minke Whale	yes	no	yes	no	no	no	no
Megaptera	Humpback Whale	no	no	yes	no	no	no	no
Cephalorhynchus	Commerson's Dolphin	yes	yes	no	yes	no	no	no
Cephalorhynchus	Heaviside's Dolphin	yes	no	yes	no	no	no	no
Delphinus delphis	Common Dolphin	yes	yes	no	no	no	no	no
Feresa attenuata	Pygmy Killer Whale	yes	yes	no	no	no	no	no
Globicephala	Short-finned Pilot Whale	yes	yes	no	no	no	no	no
Globicephala melas	Long-finned Pilot Whale	yes	yes	no	yes	no	no	no
Lagenorhynchus	Peale's Dolphin	yes	yes	no	no	no	no	no
Lagenorhynchus	Dusky Dolphin	yes	yes	no	no	no	no	no
Lissodelphis peronii	Southern Right Whale Dolphin	yes	yes	no	no	no	no	no
Orcinus orca	Orca	yes	yes	no	no	no	yes	yes (sea birds and sea
Pseudorca crassidens	False Killer Whale	yes	yes	no	no	no	yes	no
Stenella clymene	Clymene Dolphin	yes	yes	no	no	no	no	no
Stenella frontalis	Atlantic Spotted Dolphin	yes	yes	no	yes	no	no	no
Stenella longirostris	Spinner Dolphin	yes	yes	no	yes	no	no	no
Tursiops aduncus	Indo-Pacific Bottlenose Dolphin	yes	yes	no	no	no	no	no
Cephalorhynchus	Hector's Dolphin	yes	yes	no	no	no	no	no
Grampus griseus	Risso's Dolphin	yes	yes	no	no	no	no	no
Lagenodelphis hosei	Fraser's Dolphin	yes	yes	no	yes	no	no	no
Lagenorhynchus	Atlantic White-sidded Dolphin	yes	yes	no	yes	no	no	no
Lagenorhynchus	White-beaked Dolphin	yes	yes	no	yes	no	no	no
Lagenorhynchus	Hourglass Dolphin	yes	yes	no	yes	no	no	no

			extinction risk		total score
species	Name	average of food preferences and habitat preferences rating	IUCN status	IUCN status Rating	Total
Trichechus manatus	West Indian Manatee	3	VU	3	38
Trichechus	African Manatee	2	VU	3	39
Berardius arnuxii	Arnoux's Beaked Whale	3.5	LC	1	34.5
Berardius bairdii	Baird's Beaked Whale	3.5	DD	3	34.5
Hyperoodon	Northern Bottlenose Whale	3.5	NT	2	32.5
Indopacetus pacificus	Tropical Bottlenose Whale	4	LC	1	29
Mesoplodon bidens	Sowerby's Beaked Whale	3.5	LC	1	33.5
Mesoplodon	Andrew's Beaked Whale	3.5	DD	3	31.5
Mesoplodon	Hubb's Beaked Whale	3.5	DD	3	32.5
Mesoplodon	Blainville's Beaked Whale	3	LC	1	29
Mesoplodon	Gervais's Beaked Whale	3.5	LC	1	30.5
Mesoplodon	Ginkgo-toothed Beaked Whale	3.5	DD	3	30.5
Mesoplodon grayi	Gray's Beaked Whale	3.5	LC	1	28.5
Mesoplodon hectori	Hector's Beaked Whale	3.5	DD	3	29.5
Mesoplodon layardii	Strap-toothed Whale	3	LC	1	29
Mesoplodon mirus	True's Beaked Whale	3.5	LC	1	28.5
Mesoplodon perrini	Perrin's Beaked Whale	4	EN	4	33
Mesoplodon	Pygmy Beaked Whale	3.5	LC	1	30.5
Mesoplodon	Stejneger's Beaked Whale	4	NT	2	25
Mesoplodon traversii	Spade-toothed Whale	3.5	DD	3	31.5
Tasmacetus	Shepherd's Beaked Whale	3	DD	3	28
Hyperoodon	Southern Bottlenose Whale	4	LC	1	24
Ziphius cavirostris	Cuvier's Beaked Whale	3	LC	1	31



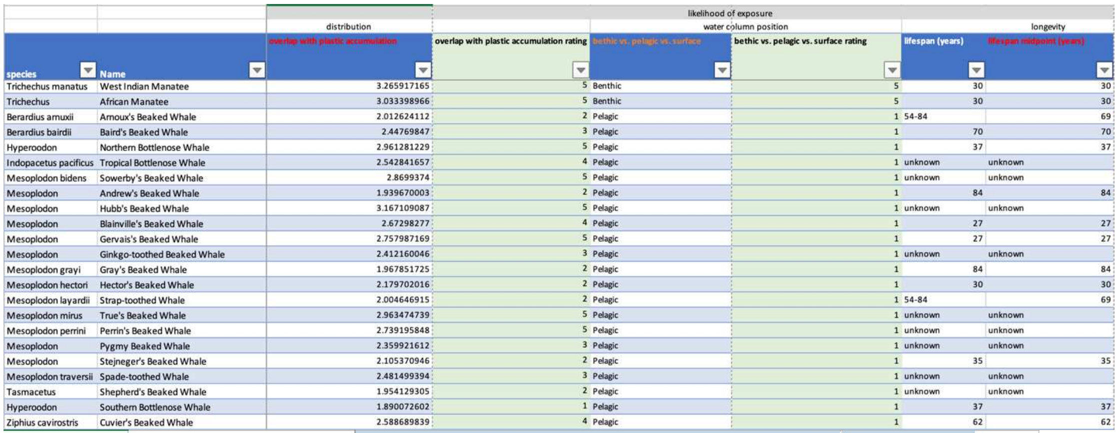
		population resilience			
		feeding or habitat specialization			
species	Name	number of prefered habitats	number of prefered habitats rating	number of food preferences	number of food preferences rating
Trichechus manatus	West Indian Manatee	21	1	1	5
Trichechus	African Manatee	29	1	3	3
Berardius arnuxii	Arnoux's Beaked Whale	3	3	2	4
Berardius bairdii	Baird's Beaked Whale	3	3	2	4
Hyperoodon	Northern Bottlenose Whale	3	3	2	4
Indopacetus pacificus	Tropical Bottlenose Whale	3	3	1	5
Mesoplodon bidens	Sowerby's Beaked Whale	3	3	2	4
Mesoplodon	Andrew's Beaked Whale	3	3	2	4
Mesoplodon	Hubb's Beaked Whale	3	3	2	4
Mesoplodon	Blainville's Beaked Whale	3	3	3	3
Mesoplodon	Gervais's Beaked Whale	3	3	2	4
Mesoplodon	Ginkgo-toothed Beaked Whale	3	3	2	4
Mesoplodon grayi	Gray's Beaked Whale	3	3	2	4
Mesoplodon hectori	Hector's Beaked Whale	3	3	2	4
Mesoplodon layardii	Strap-toothed Whale	3	3	3	3
Mesoplodon mirus	True's Beaked Whale	3	3	2	4
Mesoplodon perrini	Perrin's Beaked Whale	3	3	1	5
Mesoplodon	Pygmy Beaked Whale	3	3	2	4
Mesoplodon	Stejneger's Beaked Whale	3	3	1	5
Mesoplodon traversii	Spade-toothed Whale	3	3	2	4
Tasmacetus	Shepherd's Beaked Whale	3	3	3	3
Hyperoodon	Southern Bottlenose Whale	3	3	1	5
Ziphius cavirostris	Cuvier's Beaked Whale	3	3	3	3

				non-foraging behaviors		abundance				
species	Name	prey type resemblence (rating)	prey type causing interaction with plastic rating	curios/aggressive	curiosity rating	population size	population size midpoint	population size rating	generation length	generation length rating (based on midpoint)
Trichechus manatus	West Indian Manatee	2	0	yes	2	over 3,300	3,300	5	20	4
Trichechus	African Manatee	2	2	yes	2	10000	10,000	4	30	5
Berardius arnuxii	Arnoux's Beaked Whale	2	2	yes	2	3,000-5,000	4,000	5	22.8	5
Berardius bairdii	Baird's Beaked Whale	2	2	yes	2	30000	30,000	4	23.4	5
Hyperoodon	Northern Bottlenose Whale	2	2	yes	2	over 20,000	20,000	4	17.8	3
Indopacetus pacificus	Tropical Bottlenose Whale	2	0	yes	2	unknown	unknown	3	unknown	3
Mesoplodon bidens	Sowerby's Beaked Whale	2	2	yes	2	3518	3,518	5	22.5	4
Mesoplodon	Andrew's Beaked Whale	2	2	yes	2	unknown	unknown	3	unknown	3
Mesoplodon	Hubb's Beaked Whale	2	2	yes	2	unknown	unknown	3	unknown	3
Mesoplodon	Blainville's Beaked Whale	2	2	yes	2	unknown	unknown	3	unknown	3
Mesoplodon	Gervais's Beaked Whale	2	2	yes	2	unknown	unknown	3	unknown	3
Mesoplodon	Ginkgo-toothed Beaked Whale	2	2	yes	2	unknown	unknown	3	unknown	3
Mesoplodon grayi	Gray's Beaked Whale	2	2	yes	2	unknown	unknown	3	15	3
Mesoplodon hectori	Hector's Beaked Whale	2	2	yes	2	unknown	unknown	3	unknown	3
Mesoplodon layardii	Strap-toothed Whale	2	2	yes	2	unknown	unknown	3	unknown	3
Mesoplodon mirus	True's Beaked Whale	2	2	no	0	unknown	unknown	3	unknown	3
Mesoplodon perrini	Perrin's Beaked Whale	2	0	no	0	500-1,164	832	5	unknown	3
Mesoplodon	Pygmy Beaked Whale	2	2	yes	2	tens of thousands	20,000	4	unknown	3
Mesoplodon	Stejneger's Beaked Whale	2	0	no	0	unknown	unknown	3	unknown	3
Mesoplodon traversii	Spade-toothed Whale	2	2	yes	2	unknown	unknown	3	unknown	3
Tasmacetus	Shepherd's Beaked Whale	2	2	yes	2	unknown	unknown	3	unknown	3
Hyperoodon	Southern Bottlenose Whale	2	0	no	0	54000	54,000	3	22.4	4
Ziphius cavirostris	Cuvier's Beaked Whale	2	2	yes	2	over 100,000	100,000	3	unknown	3

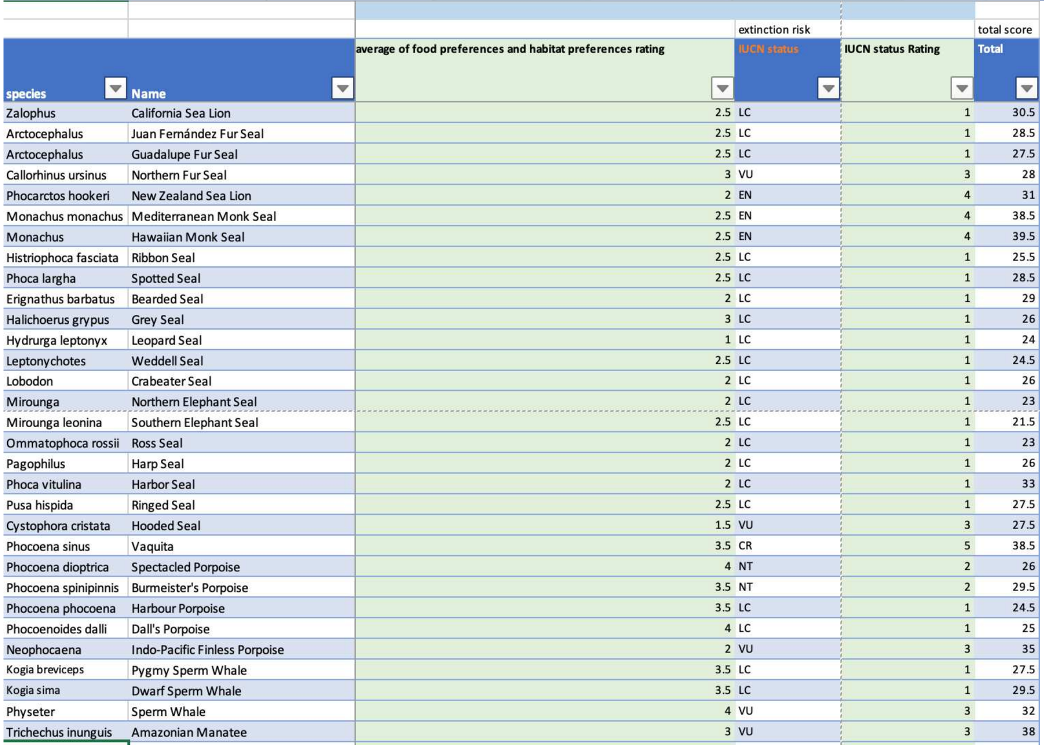


							prey preferences			
species	Name	prey type (fish)	prey type (cephalopods)	prey type (krill/plankton)	prey type (other invertebrates)	prey type (vegetation)	prey type (mammals)	prey type (other)	cephalopods/vegetation	fish
Trichechus manatus	West Indian Manatee	no	no	no	no	yes	no	no	yes	no
Trichechus	African Manatee	yes	no	no	yes	yes	no	no	yes	yes
Berardius arnuxii	Arnoux's Beaked Whale	yes	yes	no	no	no	no	no	yes	yes
Berardius bairdii	Baird's Beaked Whale	yes	yes	no	no	no	no	no	yes	yes
Hyperoodon	Northern Bottlenose Whale	yes	yes	no	no	no	no	no	yes	yes
Indopacetus pacificus	Tropical Bottlenose Whale	no	yes	no	no	no	no	no	yes	no
Mesoplodon bidens	Sowerby's Beaked Whale	yes	yes	no	no	no	no	no	yes	yes
Mesoplodon	Andrew's Beaked Whale	yes	yes	no	no	no	no	no	yes	yes
Mesoplodon	Hubb's Beaked Whale	yes	yes	no	no	no	no	no	yes	yes
Mesoplodon	Blainville's Beaked Whale	yes	yes	no	yes	no	no	no	yes	yes
Mesoplodon	Gervais's Beaked Whale	yes	yes	no	no	no	no	no	yes	yes
Mesoplodon	Ginkgo-toothed Beaked Whale	yes	yes	no	no	no	no	no	yes	yes
Mesoplodon grayi	Gray's Beaked Whale	yes	yes	no	no	no	no	no	yes	yes
Mesoplodon hectori	Hector's Beaked Whale	yes	yes	no	no	no	no	no	yes	yes
Mesoplodon layardii	Strap-toothed Whale	yes	yes	no	yes	no	no	no	yes	yes
Mesoplodon mirus	True's Beaked Whale	yes	yes	no	no	no	no	no	yes	yes
Mesoplodon perrini	Perrin's Beaked Whale	no	yes	no	no	no	no	no	yes	no
Mesoplodon	Pygmy Beaked Whale	yes	yes	no	no	no	no	no	yes	yes
Mesoplodon	Stejneger's Beaked Whale	no	yes	no	no	no	no	no	yes	no
Mesoplodon traversii	Spade-toothed Whale	yes	yes	no	no	no	no	no	yes	yes
Tasmacetus	Shepherd's Beaked Whale	yes	yes	no	yes	no	no	no	yes	yes
Hyperoodon	Southern Bottlenose Whale	no	yes	no	no	no	no	no	yes	no
Ziphius cavirostris	Cuvier's Beaked Whale	yes	yes	no	yes	no	no	no	yes	yes

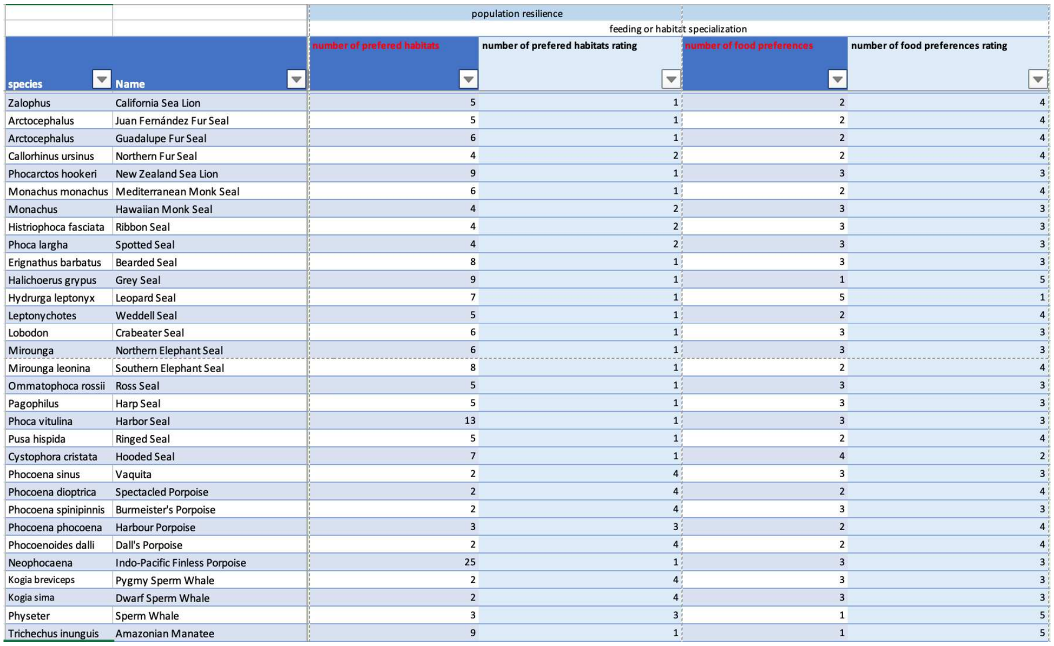
		body morphology					feeding mechaniam/foraging behavior	
species	Name	dorsal fin (yes/no)	dorsal fin rating	body size (mass-kg)	body size (mass-kg) midpoint	mass rating	feeding mechaniam/foraging behavior	feeding mechaniam/foraging behavior rating
Trichechus manatus	West Indian Manatee	no	0	500-685	592.5	2	grazer	4
Trichechus	African Manatee	no	0	500	500	2	grazer	4
Berardius arnuxii	Arnoux's Beaked Whale	yes	1	unknown	unknown	3	biting	2
Berardius bairdii	Baird's Beaked Whale	yes	1	8,000-10,000	9,000	1	biting	2
Hyperoodon	Northern Bottlenose Whale	yes	1	5,800-7,500	6,650	1	biting	2
Indopacetus pacificus	Tropical Bottlenose Whale	yes	1	unknown	unknown	3	biting	2
Mesoplodon bidens	Sowerby's Beaked Whale	yes	1	1,000-1,300	1,150	2	biting	2
Mesoplodon	Andrew's Beaked Whale	yes	1	2359	2359	2	biting	2
Mesoplodon	Hubb's Beaked Whale	yes	1	1500	1500	2	biting	2
Mesoplodon	Blainville's Beaked Whale	yes	1	925	925	2	biting	2
Mesoplodon	Gervais's Beaked Whale	yes	1	1197.48	1197.48	2	biting	2
Mesoplodon	Ginkgo-toothed Beaked Whale	yes	1	1,360.78-3,265.87	2313.325	2	biting	2
Mesoplodon grayi	Gray's Beaked Whale	yes	1	5000	5000	1	biting	2
Mesoplodon hectori	Hector's Beaked Whale	yes	1	800	800	2	biting	2
Mesoplodon layardii	Strap-toothed Whale	yes	1	901-2721	1811	2	biting	2
Mesoplodon mirus	True's Beaked Whale	yes	1	997.9-1,360.78	1179.34	2	biting	2
Mesoplodon perrini	Perrin's Beaked Whale	yes	1	unknown	unknown	3	biting	2
Mesoplodon	Pygmy Beaked Whale	yes	1	unknown	unknown	3	biting	2
Mesoplodon	Stejneger's Beaked Whale	yes	1	1599.82	1599.82	2	biting	2
Mesoplodon traversii	Spade-toothed Whale	yes	1	unknown	unknown	3	biting	2
Tasmacetus	Shepherd's Beaked Whale	yes	1	2,540.12-2,948.35	2744.235	1	biting	2
Hyperoodon	Southern Bottlenose Whale	yes	1	5443.11	5443.11	1	biting	2
Ziphius cavirostris	Cuvier's Beaked Whale	yes	1	2701	2701	2	biting	2



		likelihood of exposure					
		distribution		water column position		longevity	
species	Name	overlap with plastic accumulation	overlap with plastic accumulation rating	bethic vs. pelagic vs. surface	bethic vs. pelagic vs. surface rating	lifespan (years)	lifespan midpoint (years)
Trichechus manatus	West Indian Manatee	3.265917165	5	Benthic	5	30	30
Trichechus	African Manatee	3.033398966	5	Benthic	5	30	30
Berardius arnuxii	Arnoux's Beaked Whale	2.012624112	2	Pelagic	1	54-84	69
Berardius bairdii	Baird's Beaked Whale	2.44769847	3	Pelagic	1	70	70
Hyperoodon	Northern Bottlenose Whale	2.961281229	5	Pelagic	1	37	37
Indopacetus pacificus	Tropical Bottlenose Whale	2.542841657	4	Pelagic	1	unknown	unknown
Mesoplodon bidens	Sowerby's Beaked Whale	2.8699374	5	Pelagic	1	unknown	unknown
Mesoplodon	Andrew's Beaked Whale	1.939670003	2	Pelagic	1	84	84
Mesoplodon	Hubb's Beaked Whale	3.167109087	5	Pelagic	1	unknown	unknown
Mesoplodon	Blainville's Beaked Whale	2.67298277	4	Pelagic	1	27	27
Mesoplodon	Gervais's Beaked Whale	2.757987169	5	Pelagic	1	27	27
Mesoplodon	Ginkgo-toothed Beaked Whale	2.412160046	3	Pelagic	1	unknown	unknown
Mesoplodon grayi	Gray's Beaked Whale	1.967851725	2	Pelagic	1	84	84
Mesoplodon hectori	Hector's Beaked Whale	2.179702016	2	Pelagic	1	30	30
Mesoplodon layardii	Strap-toothed Whale	2.004646915	2	Pelagic	1	54-84	69
Mesoplodon mirus	True's Beaked Whale	2.963474739	5	Pelagic	1	unknown	unknown
Mesoplodon perrini	Perrin's Beaked Whale	2.739195848	5	Pelagic	1	unknown	unknown
Mesoplodon	Pygmy Beaked Whale	2.359921612	3	Pelagic	1	unknown	unknown
Mesoplodon	Stejneger's Beaked Whale	2.105370946	2	Pelagic	1	35	35
Mesoplodon traversii	Spade-toothed Whale	2.481499394	3	Pelagic	1	unknown	unknown
Tasmacetus	Shepherd's Beaked Whale	1.954129305	2	Pelagic	1	unknown	unknown
Hyperoodon	Southern Bottlenose Whale	1.890072602	1	Pelagic	1	37	37
Ziphius cavirostris	Cuvier's Beaked Whale	2.588689839	4	Pelagic	1	62	62

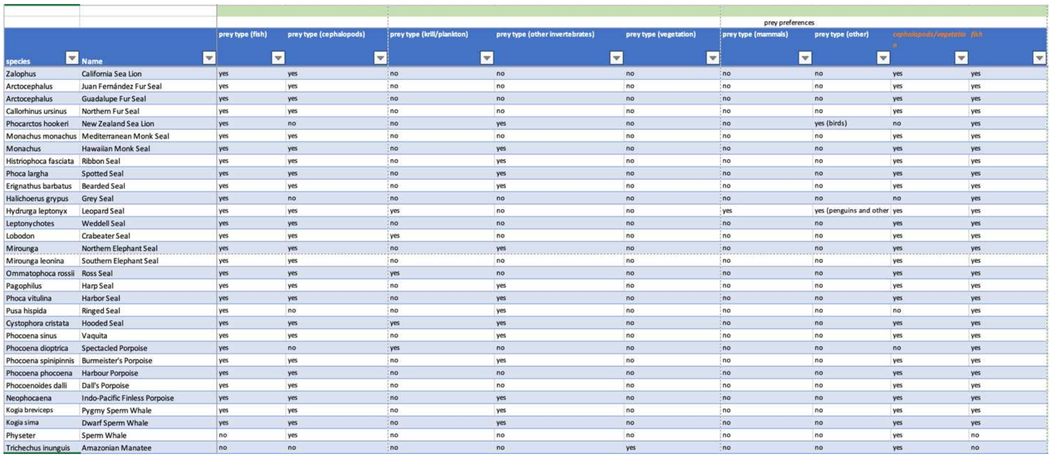


			extinction risk		total score
species	Name	average of food preferences and habitat preferences rating	IUCN status	IUCN status Rating	Total
Zalophus	California Sea Lion	2.5	LC	1	30.5
Arctocephalus	Juan Fernández Fur Seal	2.5	LC	1	28.5
Arctocephalus	Guadalupe Fur Seal	2.5	LC	1	27.5
Callorhinus ursinus	Northern Fur Seal	3	VU	3	28
Phocarctos hookeri	New Zealand Sea Lion	2	EN	4	31
Monachus monachus	Mediterranean Monk Seal	2.5	EN	4	38.5
Monachus	Hawaiian Monk Seal	2.5	EN	4	39.5
Histriophoca fasciata	Ribbon Seal	2.5	LC	1	25.5
Phoca largha	Spotted Seal	2.5	LC	1	28.5
Erignathus barbatus	Bearded Seal	2	LC	1	29
Halichoerus grypus	Grey Seal	3	LC	1	26
Hydrurga leptonyx	Leopard Seal	1	LC	1	24
Leptonychotes	Weddell Seal	2.5	LC	1	24.5
Lobodon	Crabeater Seal	2	LC	1	26
Mirounga	Northern Elephant Seal	2	LC	1	23
Mirounga leonina	Southern Elephant Seal	2.5	LC	1	21.5
Ommatophoca rossii	Ross Seal	2	LC	1	23
Pagophilus	Harp Seal	2	LC	1	26
Phoca vitulina	Harbor Seal	2	LC	1	33
Pusa hispida	Ringed Seal	2.5	LC	1	27.5
Cystophora cristata	Hooded Seal	1.5	VU	3	27.5
Phocoena sinus	Vaquita	3.5	CR	5	38.5
Phocoena dioptrica	Spectacled Porpoise	4	NT	2	26
Phocoena spinipinnis	Burmeister's Porpoise	3.5	NT	2	29.5
Phocoena phocoena	Harbour Porpoise	3.5	LC	1	24.5
Phocoenoides dalli	Dall's Porpoise	4	LC	1	25
Neophocaena	Indo-Pacific Finless Porpoise	2	VU	3	35
Kogia breviceps	Pygmy Sperm Whale	3.5	LC	1	27.5
Kogia sima	Dwarf Sperm Whale	3.5	LC	1	29.5
Physeter	Sperm Whale	4	VU	3	32
Trichechus inunguis	Amazonian Manatee	3	VU	3	38



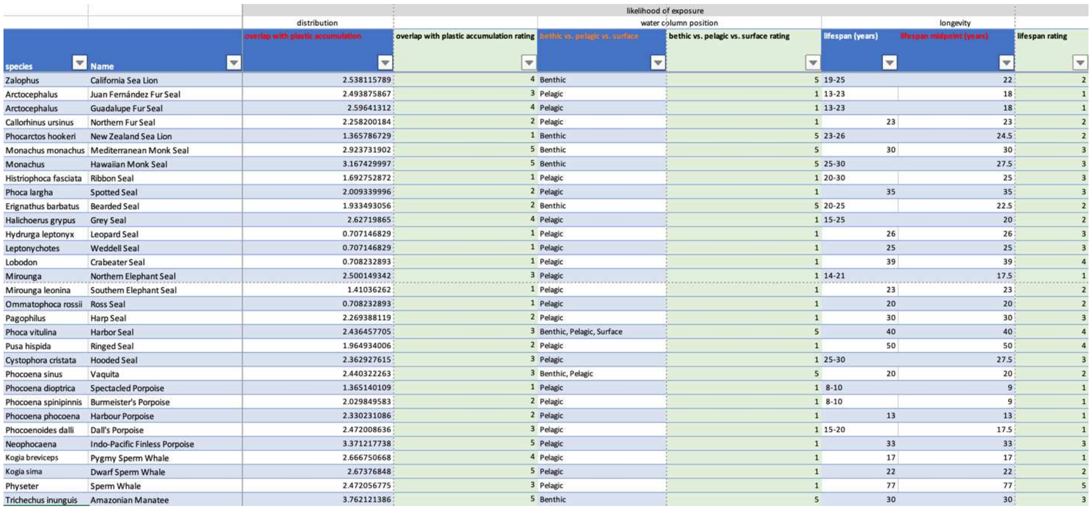
		population resilience			
		feeding or habitat specialization			
species	Name	number of prefered habitats	number of prefered habitats rating	number of food preferences	number of food preferences rating
Zalophus	California Sea Lion	5	1	2	4
Arctocephalus	Juan Fernández Fur Seal	5	1	2	4
Arctocephalus	Guadalupe Fur Seal	6	1	2	4
Callorhinus ursinus	Northern Fur Seal	4	2	2	4
Phocarctos hookeri	New Zealand Sea Lion	9	1	3	3
Monachus monachus	Mediterranean Monk Seal	6	1	2	4
Monachus	Hawaiian Monk Seal	4	2	3	3
Histriophoca fasciata	Ribbon Seal	4	2	3	3
Phoca largha	Spotted Seal	4	2	3	3
Erignathus barbatus	Bearded Seal	8	1	3	3
Halichoerus grypus	Grey Seal	9	1	1	5
Hydrurga leptonyx	Leopard Seal	7	1	5	1
Leptonychotes	Weddell Seal	5	1	2	4
Lobodon	Crabeater Seal	6	1	3	3
Mirounga	Northern Elephant Seal	6	1	3	3
Mirounga leonina	Southern Elephant Seal	8	1	2	4
Ommatophoca rossii	Ross Seal	5	1	3	3
Pagophilus	Harp Seal	5	1	3	3
Phoca vitulina	Harbor Seal	13	1	3	3
Pusa hispida	Ringed Seal	5	1	2	4
Cystophora cristata	Hooded Seal	7	1	4	2
Phocoena sinus	Vaquita	2	4	3	3
Phocoena dioptrica	Spectacled Porpoise	2	4	2	4
Phocoena spinipinnis	Burmeister's Porpoise	2	4	3	3
Phocoena phocoena	Harbour Porpoise	3	3	2	4
Phocoenoides dalli	Dall's Porpoise	2	4	2	4
Neophocaena	Indo-Pacific Finless Porpoise	25	1	3	3
Kogia breviceps	Pygmy Sperm Whale	2	4	3	3
Kogia sima	Dwarf Sperm Whale	2	4	3	3
Physeter	Sperm Whale	3	3	1	5
Trichechus inunguis	Amazonian Manatee	9	1	1	5

				non-foraging behaviors		abundance				
species	Name	prey type resemblence (rating)	prey type causing interaction with plastic rating	curios/aggressive	curiosity rating	population size	population size midpoint	population size rating	generation length	generation length rating (based on midpoint)
Zalophus	California Sea Lion	2	2	yes	2	180000	180,000	2	14	2
Arctocephalus	Juan Fernández Fur Seal	2	2	yes	2	16000	16,000	4	unknown	3
Arctocephalus	Guadalupe Fur Seal	2	2	yes	2	10000	10,000	4	10	1
Callorhinus ursinus	Northern Fur Seal	2	2	yes	2	650000	650,000	1	14.1	3
Phocarctos hookeri	New Zealand Sea Lion	0	2	yes	2	9880	9,880	5	10.75	2
Monachus monachus	Mediterranean Monk Seal	2	2	yes	2	600-700	650	5	11.2	2
Monachus	Hawaiian Monk Seal	2	2	yes	2	1209	1,209	5	15	3
Histriophoca fasciata	Ribbon Seal	2	2	yes	2	183000	183,000	2	10.4	1
Phoca largha	Spotted Seal	2	2	yes	2	320000	320,000	2	unknown	3
Erignathus barbatus	Bearded Seal	2	2	yes	2	unknown	unknown	3	13.4	2
Halichoerus grypus	Grey Seal	0	2	yes	2	316000	316,000	2	16.5	3
Hydrurga leptonyx	Leopard Seal	2	2	yes	2	18000	18,000	4	10.4	1
Leptonychotes	Weddell Seal	2	2	yes	2	300000	300,000	2	10.8	2
Lobodon	Crabeater Seal	2	2	yes	2	4000000	4,000,000	1	20	4
Mirounga	Northern Elephant Seal	2	2	yes	2	110000	110,000	3	8.7	1
Mirounga leonina	Southern Elephant Seal	2	2	yes	2	325000	325,000	2	9.5	1
Ommatophoca rossii	Ross Seal	2	2	yes	2	40000	40,000	3	8.6	1
Pagophilus	Harp Seal	2	2	yes	2	4500000	4,500,000	1	15.7	3
Phoca vitulina	Harbor Seal	2	2	yes	2	315000	315,000	2	14.8	3
Pusa hispida	Ringed Seal	0	2	yes	2	1500000	1,500,000	1	18.6	4
Cystophora cristata	Hooded Seal	2	2	yes	2	340000	340,000	2	12.8	2
Phocoena sinus	Vaquita	2	2	yes	2	18	18	5	10	1
Phocoena dioptrica	Spectacled Porpoise	0	2	yes	2	unknown	unknown	3	11	2
Phocoena spinipinnis	Burmeister's Porpoise	2	2	yes	2	unknown	unknown	3	14.4	3
Phocoena phocoena	Harbour Porpoise	2	2	yes	2	over 1,000,000	1,000,000	1	8.3	1
Phocoenoides dalli	Dall's Porpoise	2	2	yes	2	1200000	1,200,000	1	8.7	1
Neophocaena	Indo-Pacific Finless Porpoise	2	2	yes	2	2550	2,550	5	16	3
Kogia breviceps	Pygmy Sperm Whale	2	2	yes	2	unknown	unknown	3	10.8	2
Kogia sima	Dwarf Sperm Whale	2	2	yes	2	unknown	unknown	3	10.6	2
Physeter	Sperm Whale	2	0	yes	2	100000	100,000	3	27.5	5
Trichechus inunguis	Amazonian Manatee	2	0	yes	2	8,000-30,000	14,000	4	25	5

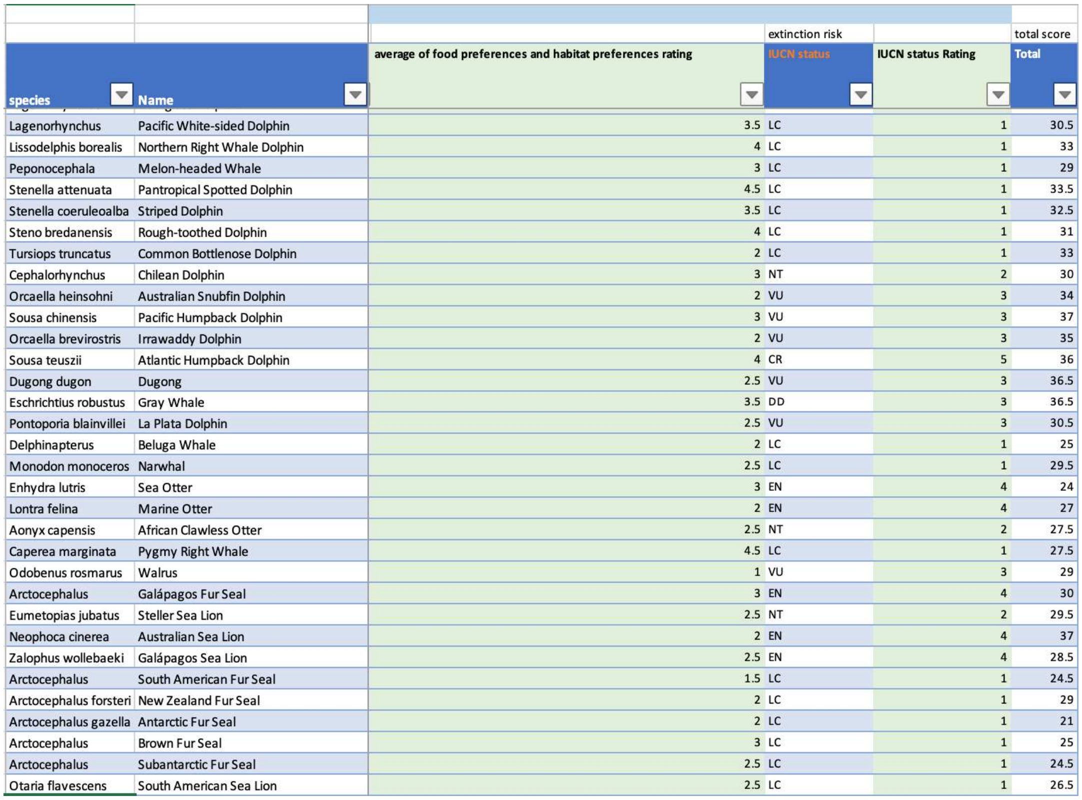


							prey preferences			
species	Name	prey type (fish)	prey type (cephalopods)	prey type (krill/plankton)	prey type (other invertebrates)	prey type (vegetation)	prey type (mammals)	prey type (other)	cephalopods/vegetation	fish
Zalophus	California Sea Lion	yes	yes	no	no	no	no	no	yes	yes
Arctocephalus	Juan Fernández Fur Seal	yes	yes	no	no	no	no	no	yes	yes
Arctocephalus	Guadalupe Fur Seal	yes	yes	no	no	no	no	no	yes	yes
Callorhinus ursinus	Northern Fur Seal	yes	yes	no	no	no	no	no	yes	yes
Phocarctos hookeri	New Zealand Sea Lion	yes	no	no	yes	no	no	yes (birds)	no	yes
Monachus monachus	Mediterranean Monk Seal	yes	yes	no	no	no	no	no	yes	yes
Monachus	Hawaiian Monk Seal	yes	yes	no	yes	no	no	no	yes	yes
Histriophoca fasciata	Ribbon Seal	yes	yes	no	yes	no	no	no	yes	yes
Phoca largha	Spotted Seal	yes	yes	no	yes	no	no	no	yes	yes
Erignathus barbatus	Bearded Seal	yes	yes	no	yes	no	no	no	yes	yes
Halichoerus grypus	Grey Seal	yes	no	no	no	no	no	no	no	yes
Hydrurga leptonyx	Leopard Seal	yes	yes	yes	no	no	yes	yes (penguins and other	yes	yes
Leptonychotes	Weddell Seal	yes	yes	no	no	no	no	no	yes	yes
Lobodon	Crabeater Seal	yes	yes	yes	no	no	no	no	yes	yes
Mirounga	Northern Elephant Seal	yes	yes	no	yes	no	no	no	yes	yes
Mirounga leonina	Southern Elephant Seal	yes	yes	no	no	no	no	no	yes	yes
Ommatophoca rossii	Ross Seal	yes	yes	yes	no	no	no	no	yes	yes
Pagophilus	Harp Seal	yes	yes	no	yes	no	no	no	yes	yes
Phoca vitulina	Harbor Seal	yes	yes	no	yes	no	no	no	yes	yes
Pusa hispida	Ringed Seal	yes	no	no	yes	no	no	no	no	yes
Cystophora cristata	Hooded Seal	yes	yes	yes	yes	no	no	no	yes	yes
Phocoena sinus	Vaquita	yes	yes	no	yes	no	no	no	yes	yes
Phocoena dioptrica	Spectacled Porpoise	yes	no	yes	no	no	no	no	no	yes
Phocoena spinipinnis	Burmeister's Porpoise	yes	yes	no	yes	no	no	no	yes	yes
Phocoena phocoena	Harbour Porpoise	yes	yes	no	no	no	no	no	yes	yes
Phocoenoides dalli	Dall's Porpoise	yes	yes	no	no	no	no	no	yes	yes
Neophocaena	Indo-Pacific Finless Porpoise	yes	yes	no	yes	no	no	no	yes	yes
Kogia breviceps	Pygmy Sperm Whale	yes	yes	no	yes	no	no	no	yes	yes
Kogia sima	Dwarf Sperm Whale	yes	yes	no	yes	no	no	no	yes	yes
Physeter	Sperm Whale	no	yes	no	no	no	no	no	yes	no
Trichechus inunguis	Amazonian Manatee	no	no	no	no	yes	no	no	yes	no

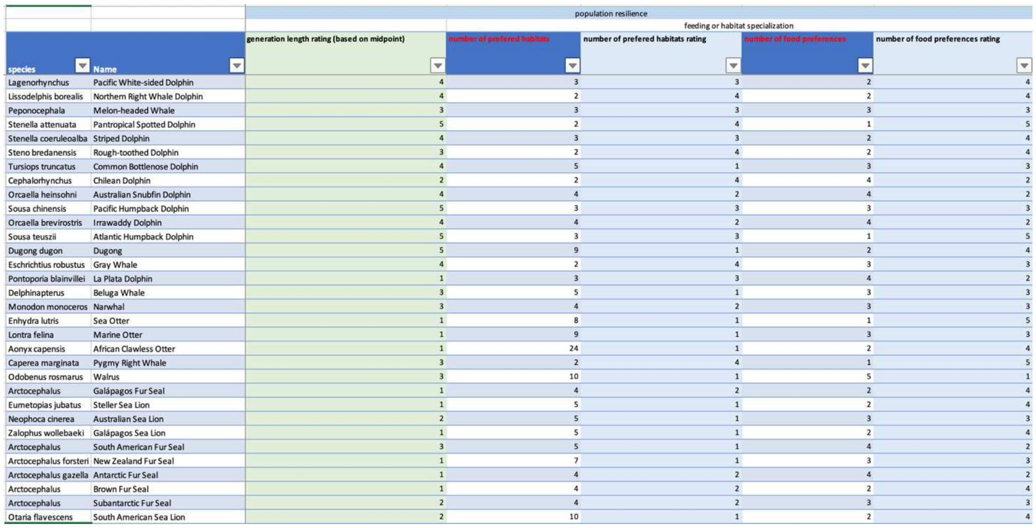
		body morphology					feeding mechaniam/foraging behavior	
species	Name	dorsal fin (yes/no)	dorsal fin rating	body size (mass-kg)	body size (mass-kg) midpoint	mass rating	feeding mechaniam/foraging behavior	feeding mechaniam/foraging behavior rating
Zalophus	California Sea Lion	no	0	78-289	183.5	3	swallower	3
Arctocephalus	Juan Fernández Fur Seal	no	0	50-140	95	4	swallower	3
Arctocephalus	Guadalupe Fur Seal	no	0	50-165	107.5	4	swallower	3
Callorhinus ursinus	Northern Fur Seal	no	0	40-220	130	4	swallower	3
Phocarctos hookeri	New Zealand Sea Lion	no	0	230-400	315	3	swallower	3
Monachus monachus	Mediterranean Monk Seal	no	0	240-300	270	3	swallower	3
Monachus	Hawaiian Monk Seal	no	0	170-240	205	3	swallower	3
Histriophoca fasciata	Ribbon Seal	no	0	77-88	82.5	5	swallower	3
Phoca largha	Spotted Seal	no	0	65-115	90	5	swallower	3
Erignathus barbatus	Bearded Seal	no	0	229-275	252	3	swallower	3
Halichoerus grypus	Grey Seal	no	0	174-298	236	3	swallower	3
Hydrurga leptonyx	Leopard Seal	no	0	300-500	400	3	swallower	3
Leptonychotes	Weddell Seal	no	0	340-447	393.5	3	swallower	3
Lobodon	Crabeater Seal	no	0	221-224	222.5	3	swallower	3
Mirounga	Northern Elephant Seal	no	0	504-1,704	1,104	2	swallower	3
Mirounga leonina	Southern Elephant Seal	no	0	390-3,250	1,820	2	swallower	3
Ommatophoca rossii	Ross Seal	no	0	129-216	172.5	3	swallower	3
Pagophilus	Harp Seal	no	0	109-135	122	4	swallower	3
Phoca vitulina	Harbor Seal	no	0	65-142	103.5	4	swallower	3
Pusa hispida	Ringed Seal	no	0	50-68	59	5	swallower	3
Cystophora cristata	Hooded Seal	no	0	160-300	230	3	swallower	3
Phocoena sinus	Vaquita	yes	1	42-44	43	5	biting	2
Phocoena dioptrica	Spectacled Porpoise	yes	1	55-80	67.5	5	biting	2
Phocoena spinipinnis	Burmeister's Porpoise	yes	1	72-79	75.5	5	biting	2
Phocoena phocoena	Harbour Porpoise	yes	1	50-65	57.5	5	biting	2
Phocoenoides dalli	Dall's Porpoise	yes	1	170	170	4	biting	2
Neophocaena	Indo-Pacific Finless Porpoise	no	0	32.5	32.5	5	biting	2
Kogia breviceps	Pygmy Sperm Whale	yes	1	424.6	424.6	3	biting	2
Kogia sima	Dwarf Sperm Whale	yes	1	202.5	202.5	3	biting	2
Physeter	Sperm Whale	yes	1	28500	28500	1	biting	2
Trichechus inunguis	Amazonian Manatee	no	0	480	480	2	grazer	4
Trichechus manatus	West Indian Manatee	no	0	500-685	592.5	2	grazer	4



		likelihood of exposure						
		distribution		water column position		longevity		
species	Name	overlap with plastic accumulation	overlap with plastic accumulation rating	bethic vs. pelagic vs. surface	bethic vs. pelagic vs. surface rating	lifespan (years)	lifespan midpoint (years)	lifespan rating
Zalophus	California Sea Lion	2.538115789	4	Benthic	5	19-25	22	2
Arctocephalus	Juan Fernández Fur Seal	2.493875867	3	Pelagic	1	13-23	18	1
Arctocephalus	Guadalupe Fur Seal	2.59641312	4	Pelagic	1	13-23	18	1
Callorhinus ursinus	Northern Fur Seal	2.258200184	2	Pelagic	1	23	23	2
Phocarctos hookeri	New Zealand Sea Lion	1.365786729	1	Benthic	5	23-26	24.5	2
Monachus monachus	Mediterranean Monk Seal	2.923731902	5	Benthic	5	30	30	3
Monachus	Hawaiian Monk Seal	3.167429997	5	Benthic	5	25-30	27.5	3
Histriophoca fasciata	Ribbon Seal	1.692752872	1	Pelagic	1	20-30	25	3
Phoca largha	Spotted Seal	2.009339996	2	Pelagic	1	35	35	3
Erignathus barbatus	Bearded Seal	1.933493056	2	Benthic	5	20-25	22.5	2
Halichoerus grypus	Grey Seal	2.62719865	4	Pelagic	1	15-25	20	2
Hydrurga leptonyx	Leopard Seal	0.707146829	1	Pelagic	1	26	26	3
Leptonychotes	Weddell Seal	0.707146829	1	Pelagic	1	25	25	3
Lobodon	Crabeater Seal	0.708232893	1	Pelagic	1	39	39	4
Mirounga	Northern Elephant Seal	2.500149342	3	Pelagic	1	14-21	17.5	1
Mirounga leonina	Southern Elephant Seal	1.41036262	1	Pelagic	1	23	23	2
Ommatophoca rossii	Ross Seal	0.708232893	1	Pelagic	1	20	20	2
Pagophilus	Harp Seal	2.269388119	2	Pelagic	1	30	30	3
Phoca vitulina	Harbor Seal	2.436457705	3	Benthic, Pelagic, Surface	5	40	40	4
Pusa hispida	Ringed Seal	1.964934006	2	Pelagic	1	50	50	4
Cystophora cristata	Hooded Seal	2.362927615	3	Pelagic	1	25-30	27.5	3
Phocoena sinus	Vaquita	2.440322263	3	Benthic, Pelagic	5	20	20	2
Phocoena dioptrica	Spectacled Porpoise	1.365140109	1	Pelagic	1	8-10	9	1
Phocoena spinipinnis	Burmeister's Porpoise	2.029849583	2	Pelagic	1	8-10	9	1
Phocoena phocoena	Harbour Porpoise	2.330231086	2	Pelagic	1	13	13	1
Phocoenoides dalli	Dall's Porpoise	2.472008636	3	Pelagic	1	15-20	17.5	1
Neophocaena	Indo-Pacific Finless Porpoise	3.371217738	5	Pelagic	1	33	33	3
Kogia breviceps	Pygmy Sperm Whale	2.666750668	4	Pelagic	1	17	17	1
Kogia sima	Dwarf Sperm Whale	2.67376848	5	Pelagic	1	22	22	2
Physeter	Sperm Whale	2.472056775	3	Pelagic	1	77	77	5
Trichechus inunguis	Amazonian Manatee	3.762121386	5	Benthic	5	30	30	3

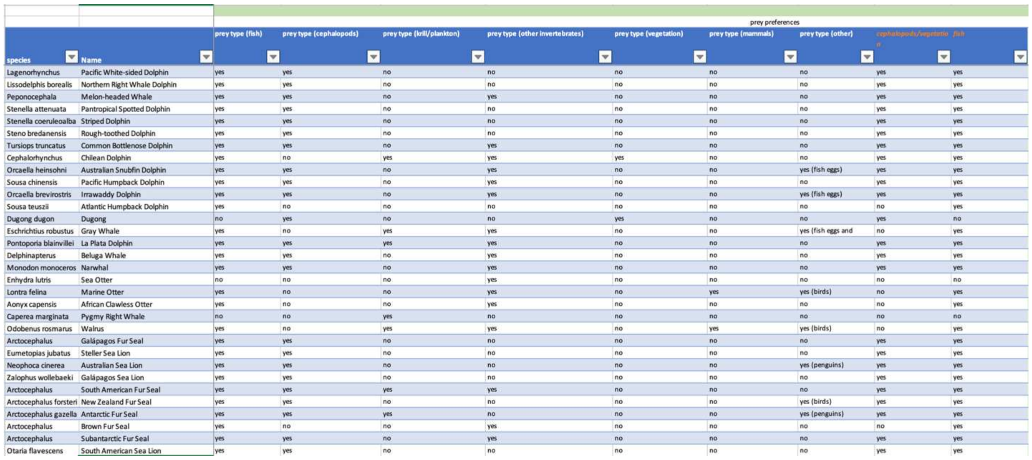


			extinction risk		total score
species	**Name**	**average of food preferences and habitat preferences rating**	**IUCN status**	**IUCN status Rating**	**Total**
Lagenorhynchus	Pacific White-sided Dolphin	3.5	LC	1	30.5
Lissodelphis borealis	Northern Right Whale Dolphin	4	LC	1	33
Peponocephala	Melon-headed Whale	3	LC	1	29
Stenella attenuata	Pantropical Spotted Dolphin	4.5	LC	1	33.5
Stenella coeruleoalba	Striped Dolphin	3.5	LC	1	32.5
Steno bredanensis	Rough-toothed Dolphin	4	LC	1	31
Tursiops truncatus	Common Bottlenose Dolphin	2	LC	1	33
Cephalorhynchus	Chilean Dolphin	3	NT	2	30
Orcaella heinsohni	Australian Snubfin Dolphin	2	VU	3	34
Sousa chinensis	Pacific Humpback Dolphin	3	VU	3	37
Orcaella brevirostris	Irrawaddy Dolphin	2	VU	3	35
Sousa teuszii	Atlantic Humpback Dolphin	4	CR	5	36
Dugong dugon	Dugong	2.5	VU	3	36.5
Eschrichtius robustus	Gray Whale	3.5	DD	3	36.5
Pontoporia blainvillei	La Plata Dolphin	2.5	VU	3	30.5
Delphinapterus	Beluga Whale	2	LC	1	25
Monodon monoceros	Narwhal	2.5	LC	1	29.5
Enhydra lutris	Sea Otter	3	EN	4	24
Lontra felina	Marine Otter	2	EN	4	27
Aonyx capensis	African Clawless Otter	2.5	NT	2	27.5
Caperea marginata	Pygmy Right Whale	4.5	LC	1	27.5
Odobenus rosmarus	Walrus	1	VU	3	29
Arctocephalus	Galápagos Fur Seal	3	EN	4	30
Eumetopias jubatus	Steller Sea Lion	2.5	NT	2	29.5
Neophoca cinerea	Australian Sea Lion	2	EN	4	37
Zalophus wollebaeki	Galápagos Sea Lion	2.5	EN	4	28.5
Arctocephalus	South American Fur Seal	1.5	LC	1	24.5
Arctocephalus forsteri	New Zealand Fur Seal	2	LC	1	29
Arctocephalus gazella	Antarctic Fur Seal	2	LC	1	21
Arctocephalus	Brown Fur Seal	3	LC	1	25
Arctocephalus	Subantarctic Fur Seal	2.5	LC	1	24.5
Otaria flavescens	South American Sea Lion	2.5	LC	1	26.5



		population resilience				
			feeding or habitat specialization			
species	Name	generation length rating (based on midpoint)	number of prefered habitats	number of prefered habitats rating	number of food preferences	number of food preferences rating
Lagenorhynchus	Pacific White-sided Dolphin	4	3	3	2	4
Lissodelphis borealis	Northern Right Whale Dolphin	4	2	4	2	4
Peponocephala	Melon-headed Whale	3	3	3	3	3
Stenella attenuata	Pantropical Spotted Dolphin	5	2	4	1	5
Stenella coeruleoalba	Striped Dolphin	4	3	3	2	4
Steno bredanensis	Rough-toothed Dolphin	3	2	4	2	4
Tursiops truncatus	Common Bottlenose Dolphin	4	5	1	3	3
Cephalorhynchus	Chilean Dolphin	2	2	4	4	2
Orcaella heinsohni	Australian Snubfin Dolphin	4	4	2	4	2
Sousa chinensis	Pacific Humpback Dolphin	5	3	3	3	3
Orcaella brevirostris	Irrawaddy Dolphin	4	4	2	4	2
Sousa teuszii	Atlantic Humpback Dolphin	5	3	3	1	5
Dugong dugon	Dugong	5	9	1	2	4
Eschrichtius robustus	Gray Whale	4	2	4	3	3
Pontoporia blainvillei	La Plata Dolphin	1	3	3	4	2
Delphinapterus	Beluga Whale	3	5	1	3	3
Monodon monoceros	Narwhal	3	4	2	3	3
Enhydra lutris	Sea Otter	1	8	1	1	5
Lontra felina	Marine Otter	1	9	1	3	3
Aonyx capensis	African Clawless Otter	1	24	1	2	4
Caperea marginata	Pygmy Right Whale	3	2	4	1	5
Odobenus rosmarus	Walrus	3	10	1	5	1
Arctocephalus	Galápagos Fur Seal	1	4	2	2	4
Eumetopias jubatus	Steller Sea Lion	1	5	1	2	4
Neophoca cinerea	Australian Sea Lion	2	5	1	3	3
Zalophus wollebaeki	Galápagos Sea Lion	1	5	1	2	4
Arctocephalus	South American Fur Seal	3	5	1	4	2
Arctocephalus forsteri	New Zealand Fur Seal	1	7	1	3	3
Arctocephalus gazella	Antarctic Fur Seal	1	4	2	4	2
Arctocephalus	Brown Fur Seal	1	4	2	2	4
Arctocephalus	Subantarctic Fur Seal	2	4	2	3	3
Otaria flavescens	South American Sea Lion	2	10	1	2	4

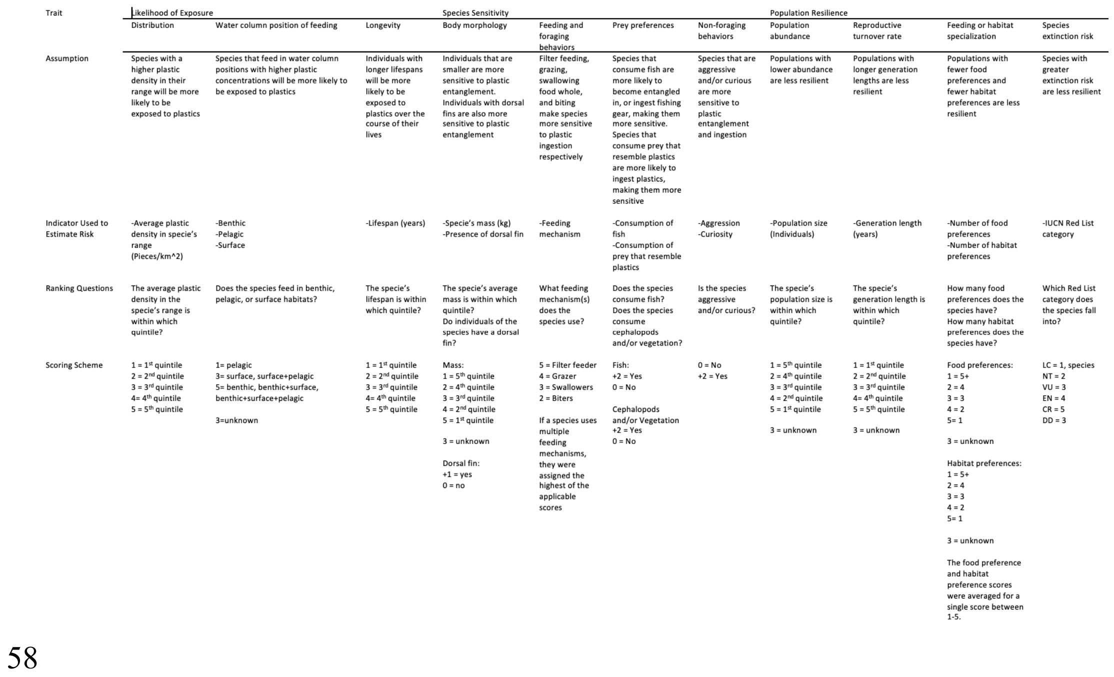
				non-foraging behaviors		abundance			
species	Name	prey type resemblence (rating)	prey type causing interaction with plastic rating	curios/aggressive	curiosity rating	population size	population size midpoint	population size rating	generation length
Lagenorhynchus	Pacific White-sided Dolphin	2	2	yes	2	over 1,000,000	1,000,000	1	21.8
Lissodelphis borealis	Northern Right Whale Dolphin	2	2	yes	2	Hundreds of	200,000	2	19.8
Peponocephala	Melon-headed Whale	2	2	yes	2	180000	180,000	2	unknown
Stenella attenuata	Pantropical Spotted Dolphin	2	2	yes	2	over 2,300,000	2,300,000	1	23
Stenella coeruleoalba	Striped Dolphin	2	2	yes	2	2000000	2,000,000	1	21.8
Steno bredanensis	Rough-toothed Dolphin	2	2	yes	2	221186	221,186	2	unknown
Tursiops truncatus	Common Bottlenose Dolphin	2	2	yes	2	750000	750,000	1	20.6
Cephalorhynchus	Chilean Dolphin	2	2	yes	2	low thousands	2,000	5	14
Orcaella heinsohni	Australian Snubfin Dolphin	2	2	yes	2	9,000-10,000	9,500	5	20
Sousa chinensis	Pacific Humpback Dolphin	2	2	yes	2	13000	13,000	4	25
Orcaella brevirostris	Irrawaddy Dolphin	2	2	yes	2	92	92	5	20
Sousa teuszii	Atlantic Humpback Dolphin	0	2	yes	2	1500	1,500	5	25
Dugong dugon	Dugong	2	0	no	0	30000	30,000	4	23.5
Eschrichtius robustus	Gray Whale	0	2	yes	2	26960	26,960	4	19.3
Pontoporia blainvillei	La Plata Dolphin	2	2	yes	2	40000	40,000	3	9.3
Delphinapterus	Beluga Whale	2	2	yes	2	136000	136,000	2	14.9
Monodon monoceros	Narwhal	2	2	yes	2	123000	123,000	2	17.59
Enhydra lutris	Sea Otter	0	0	no	0	128902	128,902	2	7
Lontra felina	Marine Otter	0	2	yes	2	800-2,000	1,000	5	10
Aonyx capensis	African Clawless Otter	0	2	yes	2	over 21,500	21,500	4	4.4
Caperea marginata	Pygmy Right Whale	0	0	yes	2	unknown	unknown	3	unknown
Odobenus rosmarus	Walrus	0	2	yes	2	112500	112,500	3	15
Arctocephalus	Galápagos Fur Seal	2	2	no	0	15000	15,000	4	10
Eumetopias jubatus	Steller Sea Lion	2	2	yes	2	81327	81,327	3	10
Neophoca cinerea	Australian Sea Lion	2	2	yes	2	6500	6,500	5	12.6
Zalophus wollebaeki	Galápagos Sea Lion	2	2	yes	2	40000	40,000	3	10
Arctocephalus	South American Fur Seal	2	2	yes	2	238000	238,000	2	17
Arctocephalus forsteri	New Zealand Fur Seal	2	2	yes	2	100000	100,000	3	9.9
Arctocephalus gazella	Antarctic Fur Seal	2	2	yes	2	700,000-1,000,000	850,000	1	9.1
Arctocephalus	Brown Fur Seal	0	2	yes	2	1060000	1,060,000	1	9.1
Arctocephalus	Subantarctic Fur Seal	2	2	yes	2	200000	200,000	2	10.7
Otaria flavescens	South American Sea Lion	2	2	yes	2	425000	425,000	1	12



		prey preferences								
species	Name	prey type (fish)	prey type (cephalopods)	prey type (krill/plankton)	prey type (other invertebrates)	prey type (vegetation)	prey type (mammals)	prey type (other)	cephalopods/vegetatio n	fish
Lagenorhynchus	Pacific White-sided Dolphin	yes	yes	no	no	no	no	no	yes	yes
Lissodelphis borealis	Northern Right Whale Dolphin	yes	yes	no	no	no	no	no	yes	yes
Peponocephala	Melon-headed Whale	yes	yes	no	yes	no	no	no	yes	yes
Stenella attenuata	Pantropical Spotted Dolphin	yes	yes	no	no	no	no	no	yes	yes
Stenella coeruleoalba	Striped Dolphin	yes	yes	no	no	no	no	no	yes	yes
Steno bredanensis	Rough-toothed Dolphin	yes	yes	no	no	no	no	no	yes	yes
Tursiops truncatus	Common Bottlenose Dolphin	yes	yes	no	yes	no	no	no	yes	yes
Cephalorhynchus	Chilean Dolphin	yes	no	yes	yes	yes	no	no	yes	yes
Orcaella heinsohni	Australian Snubfin Dolphin	yes	yes	no	yes	no	no	yes (fish eggs)	yes	yes
Sousa chinensis	Pacific Humpback Dolphin	yes	yes	no	yes	no	no	no	yes	yes
Orcaella brevirostris	Irrawaddy Dolphin	yes	yes	no	yes	no	no	yes (fish eggs)	yes	yes
Sousa teuszii	Atlantic Humpback Dolphin	yes	no	no	no	no	no	no	no	yes
Dugong dugon	Dugong	no	yes	no	no	yes	no	no	yes	no
Eschrichtius robustus	Gray Whale	yes	no	yes	yes	no	no	yes (fish eggs and	no	yes
Pontoporia blainvillei	La Plata Dolphin	yes	yes	yes	yes	no	no	no	yes	yes
Delphinapterus	Beluga Whale	yes	yes	no	yes	no	no	no	yes	yes
Monodon monoceros	Narwhal	yes	yes	no	yes	no	no	no	yes	yes
Enhydra lutris	Sea Otter	no	no	no	yes	no	no	no	no	no
Lontra felina	Marine Otter	yes	no	no	yes	no	yes	yes (birds)	no	yes
Aonyx capensis	African Clawless Otter	yes	no	no	yes	no	no	no	no	yes
Caperea marginata	Pygmy Right Whale	no	no	yes	no	no	no	no	no	no
Odobenus rosmarus	Walrus	yes	no	yes	yes	no	yes	yes (birds)	no	yes
Arctocephalus	Galápagos Fur Seal	yes	yes	no	no	no	no	no	yes	yes
Eumetopias jubatus	Steller Sea Lion	yes	yes	no	no	no	no	no	yes	yes
Neophoca cinerea	Australian Sea Lion	yes	yes	no	no	no	no	yes (penguins)	yes	yes
Zalophus wollebaeki	Galápagos Sea Lion	yes	yes	no	no	no	no	no	yes	yes
Arctocephalus	South American Fur Seal	yes	yes	yes	yes	no	no	no	yes	yes
Arctocephalus forsteri	New Zealand Fur Seal	yes	yes	no	no	no	no	yes (birds)	yes	yes
Arctocephalus gazella	Antarctic Fur Seal	yes	yes	yes	no	no	no	yes (penguins)	yes	yes
Arctocephalus	Brown Fur Seal	yes	no	no	yes	no	no	no	no	yes
Arctocephalus	Subantarctic Fur Seal	yes	yes	no	yes	no	no	no	yes	yes
Otaria flavescens	South American Sea Lion	yes	yes	no	no	no	no	no	yes	yes

Table 2

Table 2 shows plastic ingestion and entanglement ranking framework for marine mammals.



Trait	Likelihood of Exposure			Species Sensitivity				Population Resilience			
	Distribution	Water column position of feeding	Longevity	Body morphology	Feeding and foraging behaviors	Prey preferences	Non-foraging behaviors	Population abundance	Reproductive turnover rate	Feeding or habitat specialization	Species extinction risk
Assumption	Species with a higher plastic density in their range will be more likely to be exposed to plastics	Species that feed in water column positions with higher plastic concentrations will be more likely to be exposed to plastics	Individuals with longer lifespans will be more likely to be exposed to plastics over the course of their lives	Individuals that are smaller are more sensitive to plastic entanglement. Individuals with dorsal fins are also more sensitive to plastic entanglement	Filter feeding, grazing, swallowing food whole, and biting make species more sensitive to plastic ingestion respectively	Species that consume fish are more likely to become entangled in, or ingest fishing gear, making them more sensitive. Species that consume prey that resemble plastics are more likely to ingest plastics, making them more sensitive	Species that are aggressive and/or curious are more sensitive to plastic entanglement and ingestion	Populations with lower abundance are less resilient	Populations with longer generation lengths are less resilient	Populations with fewer food preferences and fewer habitat preferences are less resilient	Species with greater extinction risk are less resilient
Indicator Used to Estimate Risk	-Average plastic density in specie's range (Pieces/km^2)	-Benthic -Pelagic -Surface	-Lifespan (years)	-Specie's mass (kg) -Presence of dorsal fin	-Feeding mechanism	-Consumption of fish -Consumption of prey that resemble plastics	-Aggression -Curiosity	-Population size (Individuals)	-Generation length (years)	-Number of food preferences -Number of habitat preferences	-IUCN Red List category
Ranking Questions	The average plastic density in the specie's range is within which quintile?	Does the species feed in benthic, pelagic, or surface habitats?	The specie's lifespan is within which quintile?	The specie's average mass is within which quintile? Do individuals of the species have a dorsal fin?	What feeding mechanism(s) does the species use?	Does the species consume fish? Does the species consume cephalopods and/or vegetation?	Is the species aggressive and/or curious?	The specie's population size is within which quintile?	The specie's generation length is within which quintile?	How many food preferences does the species have? How many habitat preferences does the species have?	Which Red List category does the species fall into?
Scoring Scheme	1 = 1st quintile 2 = 2nd quintile 3 = 3rd quintile 4= 4th quintile 5 = 5th quintile	1= pelagic 3= surface, surface+pelagic 5= benthic, benthic+surface, benthic+surface+pelagic 3=unknown	1 = 1st quintile 2 = 2nd quintile 3 = 3rd quintile 4= 4th quintile 5 = 5th quintile	Mass: 1 = 5th quintile 2 = 4th quintile 3 = 3rd quintile 4 = 2nd quintile 5 = 1st quintile 3 = unknown Dorsal fin: +1 = yes 0 = no	5 = Filter feeder 4 = Grazer 3 = Swallowers 2 = Biters If a species uses multiple feeding mechanisms, they were assigned the highest of the applicable scores	Fish: +2 = Yes 0 = No Cephalopods and/or Vegetation +2 = Yes 0 = No	0 = No +2 = Yes	1 = 5th quintile 2 = 4th quintile 3 = 3rd quintile 4 = 2nd quintile 5 = 1st quintile 3 = unknown	1 = 1st quintile 2 = 2nd quintile 3 = 3rd quintile 4= 4th quintile 5 = 5th quintile 3 = unknown	Food preferences: 1 = 5+ 2 = 4 3 = 3 4 = 2 5= 1 3 = unknown Habitat preferences: 1 = 5+ 2 = 4 3 = 3 4 = 2 5= 1 3 = unknown The food preference and habitat preference scores were averaged for a single score between 1-5.	LC = 1, species NT = 2 VU = 3 EN = 4 CR = 5 DD = 3

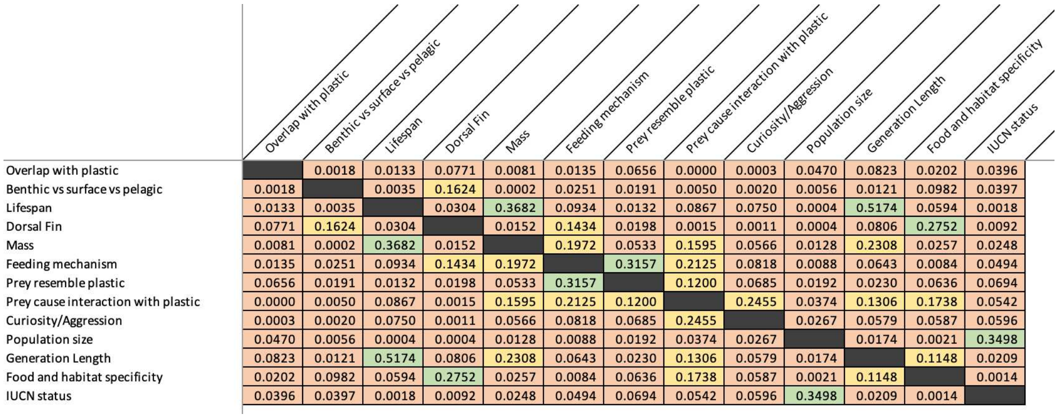
Table 3

Table 3 shows score breakdown of the top 11 ranked species

Scientific Name	**Common Name**	**Taxa**	**Likelihood of Exposure Score**	**Species Sensitivity Score**	**Population Resilience Score**	**Final Score**
Monachus schauinslandi	Hawaiian Monk Seal	Pinniped	13	12	14.5	39.5
Trichechus senegalensis	African Manatee	Sirenian	13	12	14	39
Phocoena sinus	Vaquita	Cetacean	10	14	14.5	38.5
Monachus monachus	Mediterranean Monk Seal	Pinniped	13	12	13.5	38.5
Eubalaena glacialis	North Atlantic Right Whale	Cetacean	13	6	19	38
Trichechus inunguis	Amazonian Manatee	Sirenian	13	10	15	38
Trichechus manatus	West Indian Manatee	Sirenian	13	10	15	38
Balaenoptera borealis	Sei Whale	Cetacean	9	13	15.5	37.5
Cephalorhynchus hectori	Hector's Dolphin	Cetacean	8	14	15.5	37.5
Sousa chinensis	Pacific Humpback Dolphin	Cetacean	10	12	15	37
Neophoca cinerea	Australian Sea Lion	Pinniped	12	12	13	37

Table 4

Table 4 shows correlation coefficients between all trait scores.



	Overlap with plastic	Benthic vs surface vs pelagic	Lifespan	Dorsal Fin	Mass	Feeding mechanism	Prey resemble plastic	Prey cause interaction with plastic	Curiosity/Aggression	Population size	Generation Length	Food and habitat specificity	IUCN status
Overlap with plastic	■	0.0018	0.0133	0.0771	0.0081	0.0135	0.0656	0.0000	0.0003	0.0470	0.0823	0.0202	0.0396
Benthic vs surface vs pelagic	0.0018	■	0.0035	0.1624	0.0002	0.0251	0.0191	0.0050	0.0020	0.0056	0.0121	0.0982	0.0397
Lifespan	0.0133	0.0035	■	0.0304	0.3682	0.0934	0.0132	0.0867	0.0750	0.0004	0.5174	0.0594	0.0018
Dorsal Fin	0.0771	0.1624	0.0304	■	0.0152	0.1434	0.0198	0.0015	0.0011	0.0004	0.0806	0.2752	0.0092
Mass	0.0081	0.0002	0.3682	0.0152	■	0.1972	0.0533	0.1595	0.0566	0.0128	0.2308	0.0257	0.0248
Feeding mechanism	0.0135	0.0251	0.0934	0.1434	0.1972	■	0.3157	0.2125	0.0818	0.0088	0.0643	0.0084	0.0494
Prey resemble plastic	0.0656	0.0191	0.0132	0.0198	0.0533	0.3157	■	0.1200	0.0685	0.0192	0.0230	0.0636	0.0694
Prey cause interaction with plastic	0.0000	0.0050	0.0867	0.0015	0.1595	0.2125	0.1200	■	0.2455	0.0374	0.1306	0.1738	0.0542
Curiosity/Aggression	0.0003	0.0020	0.0750	0.0011	0.0566	0.0818	0.0685	0.2455	■	0.0267	0.0579	0.0587	0.0596
Population size	0.0470	0.0056	0.0004	0.0004	0.0128	0.0088	0.0192	0.0374	0.0267	■	0.0174	0.0021	0.3498
Generation Length	0.0823	0.0121	0.5174	0.0806	0.2308	0.0643	0.0230	0.1306	0.0579	0.0174	■	0.1148	0.0209
Food and habitat specificity	0.0202	0.0982	0.0594	0.2752	0.0257	0.0084	0.0636	0.1738	0.0587	0.0021	0.1148	■	0.0014
IUCN status	0.0396	0.0397	0.0018	0.0092	0.0248	0.0494	0.0694	0.0542	0.0596	0.3498	0.0209	0.0014	■

APPENDIX B

FIGURES CREATED FOR THIS THESIS

FIGURES

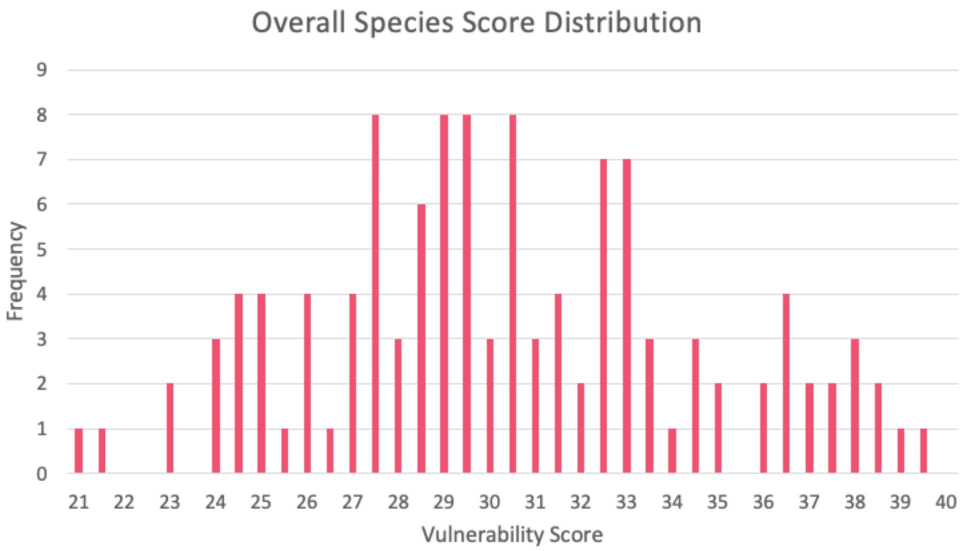


Figure 1. Distribution of cumulative score of all species

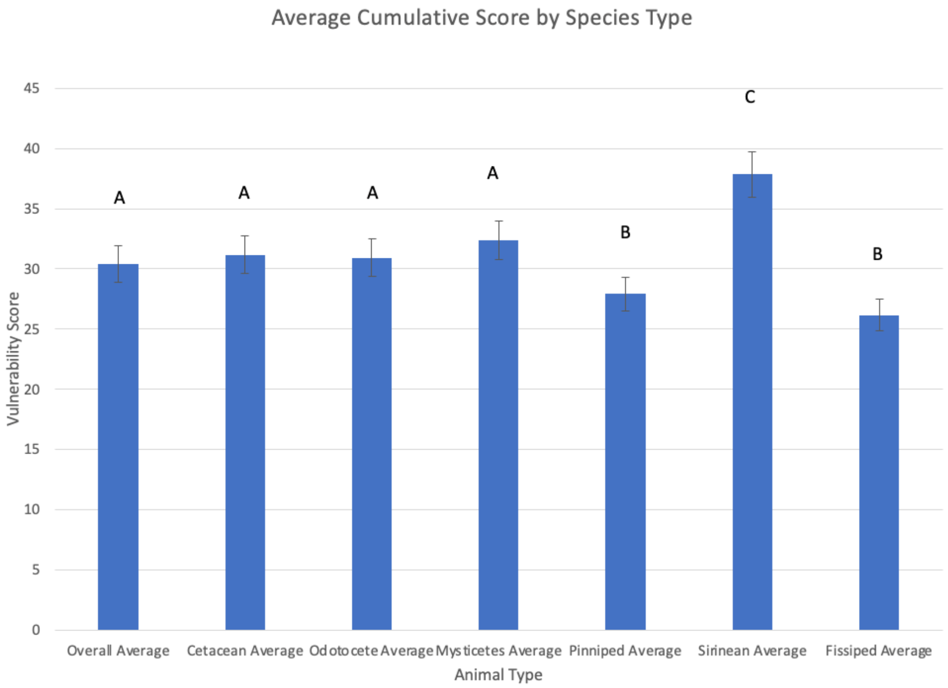


Figure 2. Average cumulative plastic risk score of different animal groups. All groups labeled 'A' are not significantly different from one another but are different from all animal groups labeled differently. All groups labeled 'B' are not significantly different from one another but are different from all animal groups labeled differently. The group labeled C is significantly different than all groups labeled differently. All statistical analysis was conducted with an alpha value of 0.05.

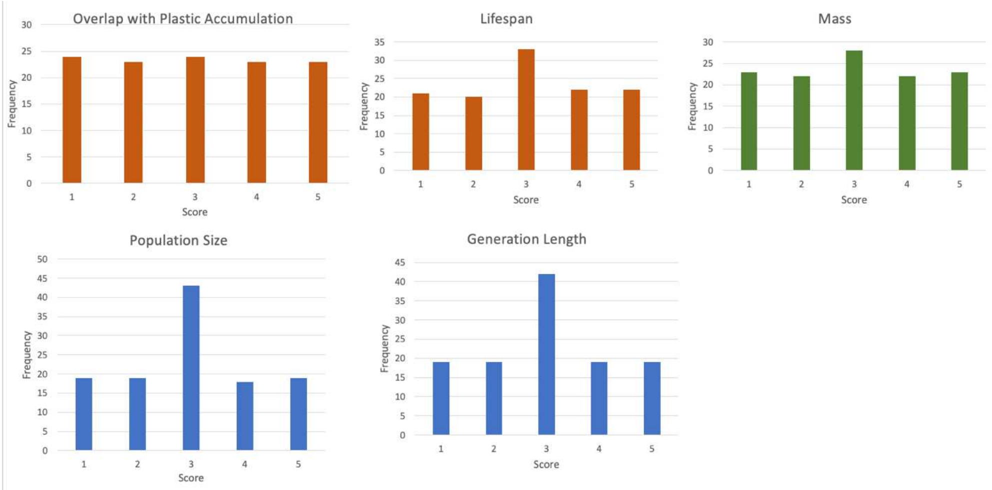


Figure 3a. Distribution of individual trait scores for quantitative traits scored by quintile. Likelihood of exposure traits are shown in orange, species sensitivity traits are shown in green, and population resilience traits are shown in blue.

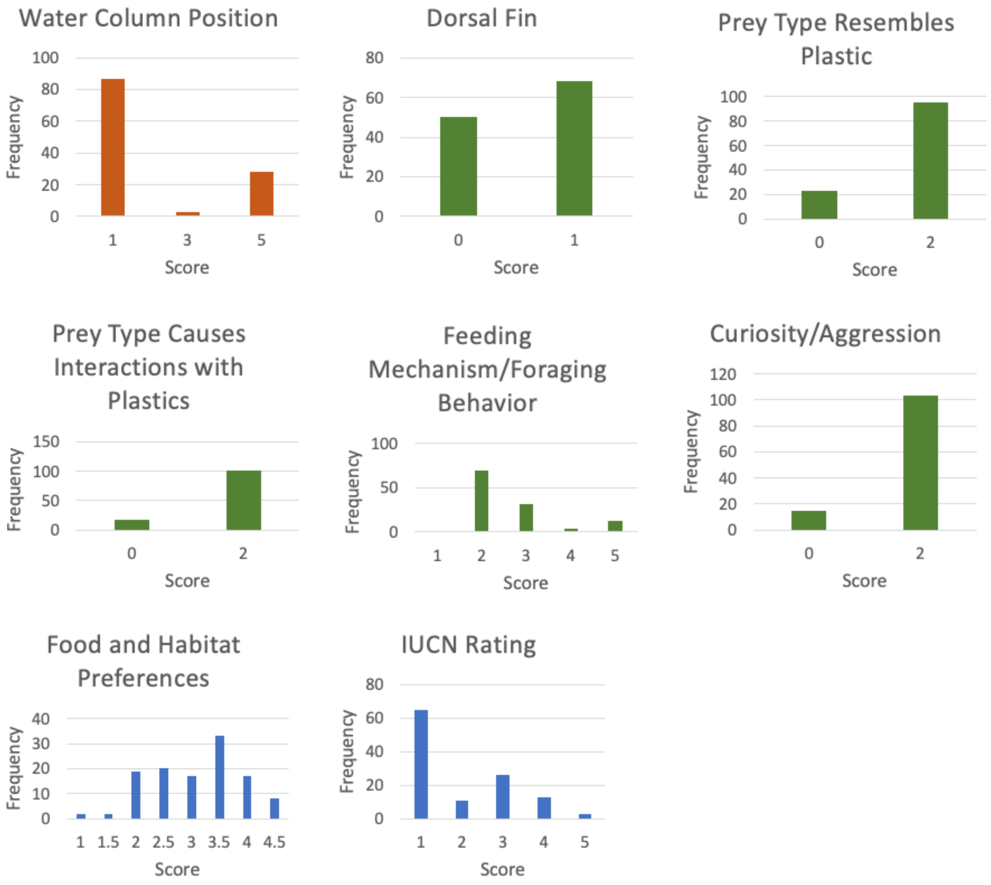


Figure 3b. Distribution of individual trait scores for qualitative traits scored by category. Likelihood of exposure traits are shown in orange, species sensitivity traits are shown in green, and population resilience traits are shown in blue.

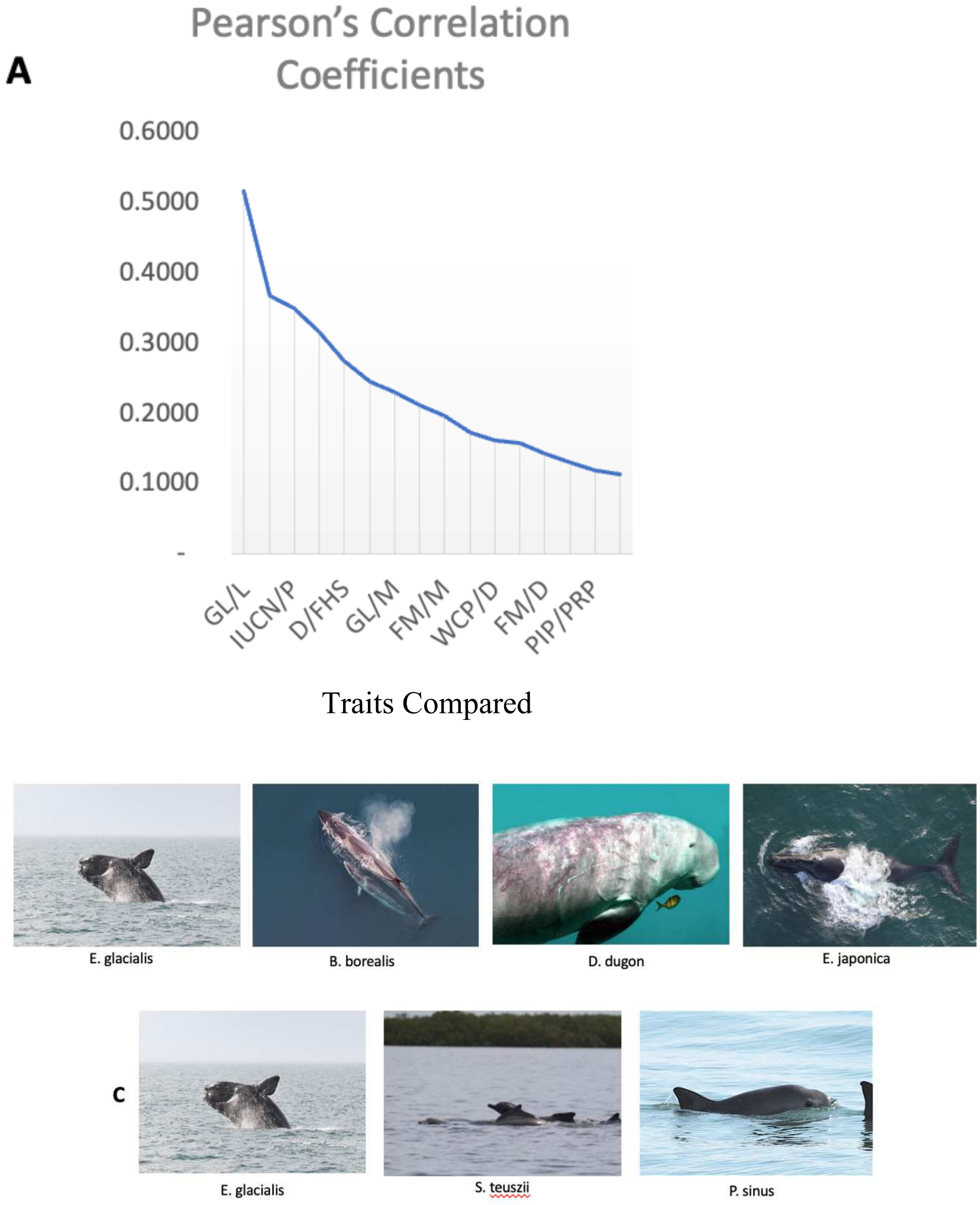


Figure 4. (A) Pearson correlation coefficients of scores for different traits (GL=Generation Length, L=Lifespan, M=Mass, IUCN=IUCN Status, PRP=Prey Resembles Plastics, FM=Feeding Mechanism, D=Dorsal Fin, FHS=Food and Habitat Specialization, CA=Curiosity and Aggression, PIP=Prey Causes Interactions with Plastic, WCP=Water Column Position). (B) The highest overall ranking species with scores of 5 in both GL and L, the most highly correlated traits (*Eubalaena glacialis, Balaenoptera borealis, Dugong dugon, Eubalaena japonica)* . (C) The species with scores of 5 in both

IUCN and P, the second most highly correlated traits (*Eubalaena glacialis, Sousa teuszii, Phocoena sinus*).