Pinniped Strandings

**Abstract**

**Introduction**

**Methods**  
*Data Sources*  
Data for this analysis were drawn from the NOAA National Marine Fisheries Service national stranding database (accessed October 2015), including records for all pinnipeds stranded along Oregon and Washington from 1985 to 2015 (n = 8066). In Oregon and Washington, there are numerous stranding networks responsible for retrieving and documenting stranded marine mammals and contributing their data to the national stranding database.

*Data Characteriziation*  
The total number of pinnipeds stranded along the coasts of Oregon and Washington were characterized according to several variables including sex, age class, species which were summed by month, year, and stranding location. In addition to examining total stranding cases (both live and dead) across these variables, the number of human interaction cases were also examined. Human interaction cases are determined by veterinarians and recorded on the Level A stranding intake form, and include "Yes" or "No" designations for whether there is evidence for fisheries interactions, gunshot wounds, boat collisions, or "other`` human interactions. Records for dead or decomposed animals can be missing certain fields, resulting in "Unknown" or "Unidentified" fields, and are therefore only included in analyses where possible.

*Statistical Analysis*  
Age class, sex, and species-level summaries - Mean annual and monthly stranding cases were compared across age classes and sex were compared using one-way ANOVA tests and post-hoc Tukey HSD tests for multiple comparisons, using age class, sex, and species as independent variables and mean monthly stranding cases as the dependent variable.

Temporal patterns - To determine whether strandings and human interaction cases have changed over the study period, we used linear regressions of annual stranding cases against year and repeated this analysis for each species and for proportions of sex and age classes. The presence of monthly or seasonal patterns were tested using one-way ANOVA and post-hoc Tukey HSD tests with month as the independent variable and mean monthly stranding cases as the dependent variable, as above.

Spatial patterns - To determine possible spatial patterns in overall strandings and human interaction cases, we used mixed-effects GLM using county as the fixed effect predictor, year and month as random effects, and mean monthly fisheries interaction cases as the dependent variable (sex and age class and species?). For this analysis, we assume stranding location can be used as a relative approximation for where human interaction events occurred.

**Results**  
From 2006 to 2015, local stranding response networks identified and recovered a total of 8066 stranded pinnipeds along the coast of Oregon and Washington. The majority of these strandings were harbor seals (61%) and California sea lions (23%), followed by a smaller number of Steller sea lions (10%), northern elephant seals (3%), Guadalupe fur seals (2%), and northern fur seals (1%) (Table 9), and 22% were alive at the time of recovery.

Stranding causes noted in the stranding records include malnutrition, injury, sickness, out of habitat, abandonment, and human interaction. Findings of human interaction comprised 14% of all stranding cases, including fisheries interactions (n = 221, comprising 19% of all human interactions cases), gunshot wounds (n = 375, comprising 33%), boat collision injuries (n = 62, comprising 5%), and "other`` (n = 513, comprising 45%).

*Species*  
As would be expected, the average annual strandings is significantly different across species over the study period (F = 101.7, p < 0.001), ranging from 8.1 for northern fur seals to 493.6 for harbor seals (Figure 1). As mentioned above, harbor seals comprise the majority of all strandings cases, but comprise a slightly smaller proportion of human interactions cases (Table species.prop.HI.table). The different types of human interaction cases vary considerably across species. For example, gunshot wounds make up 56% of human interaction cases for California sea lions, but comprise only 15% and 34% for harbor seals and northern elephant seals, respecively (Table 10, also Figure species.year.shot.figure).

*Sex and Age Class*  
The sex and age class of strandings remained relatively consistent across the study period. From 2006 to 2015, 42% of all stranding cases were male, 20% female, and 38% unidentified (Table). Across all strandings, the majority were pups (40%) and adults (34%), followed by yearlings (10%) and subadults (10%) (Table 11). However, the sex composition varies depending on age class (Table 12), with the proportion of female strandings ranging from 12% for subadults to 26% for pups and the proportion of males ranging from 28% of pups to 62% of adults. The age class composition of stranded animals varies seasonally, ranging from 10-20% pups when strandings are low in the winter to 60% when strandings are higher during July and August (Figure 2).

Similar to all combined stranding cases, the sex composition of human interaction cases is % male and % female (Table Sex.composition.table), and 10 - 60% pup depending on the month. The sex composition is similar across different types of human interaction cases except that gunshot wounds are more prominent for males compared with females (Table Sex.composition.table). Human interaction cases for each age class shows that fisheries entanglements are most prominent for pups and yearlings while gunshot wounds are more common in subadults and adults, with boat collision injuries being uncommon for all age classes (Table Age.composition.table).

*Temporal Patterns*  
All stranding cases - To examine temporal patterns in the stranding data such as whether strandings or human interaction cases have increased or decreased in recent years, or whether there are seasonal differences in the number of cases, we conducted linear regression and anova tests on the average number of cases within months and years of the study period. These analyses were then conducted at the species level as well.

On average, approximately 806.6 pinnipeds have stranded per year since 2006, which has not changed significantly over time (p = 0.39). A seasonal peak in strandings is evident, with significantly more strandings (amounting to 4-7 per month) occuring June through October (p < 0.001), consistently across years (Figures monthly.years.figure or barchart).

Examining these same data at the species level reveals changing number of cases over time, and unique seasonal stranding patterns. After taking into account the differences between species, annual strandings are significantly changing over the study for individual species, increasing for harbor seals and decreasing for all others (HELP with multiple regression output) (p < 0.001) (Figure). The seasonal peak in strandings is only evident in harbor seals (monthly.species.figure).

Human interaction cases - Even though the total number of strandings has not changed over the study period, the overall number of human interaction cases has increased significantly from 2006-2015 (T = 2.47, p < 0.05) (Figure Species.HI.figure). This is also evident in examining the proportion of total stranding cases comprised by human interaction cases over time, with human interaction cases increasing from 9% to 20% of overall strandings in 2006 to 2015, respectively (Table year.prop.HI).

On a seasonal basis, the summer peak in human interactions cases is most evident in pups (Figure monthly.HI.age.figure). Ttotal human interaction cases range from 11% to 23% depending on the month. The proportion of fisheries interaction cases is higher in June and August than other months, while boat injuries and gunshots do not change significantly throughout the months of the year (monthly.HI.figure.stacked). In examining individual years, it seems that there is often a one-month peak in stranding cases occurring during the summer, though the timing of the peak varies (Figure monthly.HI.year.figure).

Again examining individual species, harbor seals comprise the majority (55%) of overall human interactions cases followed by California sea lions (27%) (Table species.prop.HI). Gunshot wounds comprised 72% of human interaction cases for Steller sea lions, 56% of human interaction cases for California sea lions, but only 15% for harbor seals. In contrast, fisheries interactions comprised just under 20% of human interactions for all of those same three species. Boat collision cases are relatively low compared with the other types of human interaction cases, but was most prevalent for northern elephant seals, amounting to 14% of HI cases (Table species.prop.HI).

*Spatial Patterns*  
Over the study period slightly more strandings occurred in Washington, with 29% to 49% of all stranding cases occurring in Oregon, averaging 36.8% for the whole study period. Similarly, 34% of human interactions cases occurred in Oregon and the remaining in Washington. However, each specific type of human interaction are differently distributed between the two states compared with overall strandings and combined human interactions cases, with approximately 43% of fisheries interactions and 50% of gunshot wounds occurring in Oregon.

Individual species strandings are also not equally distributed between the two states. Guadalupe fur seal, northern elephant seal, and northern fur seal strandings are distributed approximately 60% in Oregon and 40% in Washington while California sea lion and Steller sea lion strandings are approximately 70% in Oregon and 30% in Washington. In contrast, harbor seal strandings are approximately 15% in Oregon and 85% in Washington (Figure state.species.figure or Table state.species.prop).

At the county level, strandings were not evenly distributed along the coast in either Oregon or Washington. In Washington, the majority of strandings occurred in Pierce and San Juan counties (Figure ). Similarly, the majority of human interaction cases occurred in Pierce county, with a disproportionately higher number of cases in Pacific county, the majority of which were gunshot wounds (Table bigtable.WA.HI.table). Certain "hotspots" for fisheries interactions and gunshot wounds were X, Y, and Z counties (Figure maps).

In Oregon, the majority of strandings occurred in Clatsop, Coos, and Lincoln counties (Table bigtable.OR.HI.table). These counties were also where the majority of human interaction cases occurred, though a disproportionately higher number of human interactions cases occurred in Clatsop, the majority of which where gunshot wounds (Table bigtable.OR.HI.table).

**Discussion**

**Figures and Tables**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Age | Female (N) | Female (%) | Male (N) | Male (%) | Unidentified |
| Pup | 823 | 26 | 898 | 28 | 1486 |
| Yearling | 155 | 19 | 270 | 32 | 412 |
| Subadult | 93 | 12 | 445 | 57 | 239 |
| Adult | 530 | 19 | 1704 | 62 | 508 |
| Unid | 35 | 7 | 64 | 13 | 404 |

## [1] "Table 1: Number and percentage of male, female, and unidentified strandings at each age class."

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Age.Class | All.prop | HI.prop | Prop.fish | Prop.shot | Prop.boat | Prop.other |
| Adult | 36 | 46 | 16 | 57 | 5 | 22 |
| Pup | 42 | 35 | 17 | 4 | 7 | 73 |
| Subadult | 10 | 12 | 21 | 50 | 6 | 23 |
| Yearling | 11 | 7 | 39 | 19 | 6 | 36 |

## [1] "Table 2: Age composition of all strandings (n = 8066) and all human interaction cases (n = 1101), and the percent composition of human interaction type for each age class."

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Age Class | All Strandings (%) | Human Interactions (%) | Fisheries Interactions (%) | Gunshots (%) | Boat Injuries (%) | Other (%) |
| Female | 20 | 28 | 18 | 29 | 6 | 47 |
| Male | 42 | 56 | 16 | 43 | 6 | 36 |
| Unid | 38 | 16 | 34 | 9 | 3 | 55 |

## [1] "Table 3: Sex composition of all strandings (n = 8066) and all human interaction cases (n = 1101), and the percent composition of human interaction type for each sex."

|  |  |  |
| --- | --- | --- |
| Species | Number | Percent |
| California sea lion | 1884 | 23 |
| Guadalupe fur seal | 138 | 2 |
| Harbor seal | 4936 | 61 |
| Northern elephant seal | 215 | 3 |
| Northern fur seal | 81 | 1 |
| Steller sea lion | 812 | 10 |

## [1] "Table 4: Sum total and percentage of all stranding cases per species (n = 8066)."

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Species | All Strandings (%) | Human Interactions (%) | Fisheries (%) | Gunshot (%) | Boat (%) | Other (%) |
| California sea lion | 23 | 27 | 18 | 56 | 4 | 22 |
| Guadalupe fur seal | 2 | 2 | 0 | 0 | 0 | 0 |
| Harbor seal | 61 | 55 | 18 | 15 | 7 | 61 |
| Northern elephant seal | 3 | 3 | 10 | 34 | 14 | 41 |
| Northern fur seal | 1 | 2 | 0 | 0 | 0 | 0 |
| Steller sea lion | 10 | 12 | 18 | 72 | 1 | 9 |

## [1] "Table 5: Species composition of all strandings and all human interaction cases and the percent composition of human interaction type for each species."

|  |  |  |
| --- | --- | --- |
| Species | Oregon (%) | Washington (%) |
| California sea lion | 75 | 25 |
| Guadalupe fur seal | 59 | 41 |
| Harbor seal | 16 | 84 |
| Northern elephant seal | 61 | 39 |
| Northern fur seal | 59 | 41 |
| Steller sea lion | 68 | 32 |

## [1] "Table 6: The percentage of strandings occurring in each state per species shows significantly higher proportion of harbor seals occurring in Washington."

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| County | All Strandings (%) | Human Interactions (%) | Fisheries (%) | Gunshot (%) | Boat (%) | Other (%) |
| Clallam | 6 | 6 | 12 | 26 | 7 | 56 |
| Clark | 0 | 1 | 0 | 100 | 0 | 0 |
| Cowlitz | 0 | 1 | 0 | 100 | 0 | 0 |
| Grays Harbor | 10 | 8 | 10 | 21 | 0 | 69 |
| Island | 7 | 4 | 11 | 33 | 30 | 26 |
| Jefferson | 4 | 4 | 27 | 3 | 6 | 64 |
| King | 7 | 7 | 29 | 25 | 0 | 46 |
| Kitsap | 6 | 7 | 24 | 10 | 0 | 66 |
| Mason | 2 | 2 | 27 | 13 | 0 | 60 |
| Pacific | 7 | 16 | 20 | 64 | 0 | 16 |
| Pierce | 19 | 19 | 9 | 10 | 4 | 77 |
| San Juan | 18 | 6 | 20 | 11 | 20 | 48 |
| Skagit | 1 | 2 | 18 | 6 | 6 | 71 |
| Skamania | 0 | 0 | 0 | 0 | 0 | 100 |
| Snohomish | 2 | 2 | 25 | 6 | 0 | 69 |
| Thurston | 4 | 5 | 22 | 18 | 8 | 52 |
| Whatcom | 6 | 10 | 5 | 17 | 15 | 63 |

## [1] "Table 7: Proportion of all strandings, human interaction cases (%) and the composition of human interaction cases for each county in Washington."

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| County | All Strandings (%) | Human Interactions (%) | Fisheries (%) | Gunshot (%) | Boat (%) | Other (%) |
| Clackamas | 0 | 1 | 0 | 100 | 0 | 0 |
| Clatsop | 19 | 56 | 14 | 71 | 7 | 9 |
| Columbia | 0 | 1 | 67 | 33 | 0 | 0 |
| Coos | 17 | 8 | 48 | 11 | 0 | 41 |
| Curry | 10 | 2 | 33 | 50 | 0 | 17 |
| Douglas | 3 | 1 | 0 | 50 | 0 | 50 |
| Lane | 8 | 4 | 62 | 31 | 0 | 8 |
| Lincoln | 33 | 20 | 40 | 18 | 7 | 35 |
| Multnomah | 0 | 2 | 17 | 83 | 0 | 0 |
| Tillamook | 9 | 7 | 39 | 43 | 0 | 17 |

## [1] "Table 8: Proportion of all strandings (%), human interaction cases (%) and the composition of human interaction cases for each county in Oregon."