A close up of a map

Description automatically generated

Figure 1: Representative depictions of the (a) triennial and (b) annual surveys. Black diamonds represent tow locations for one year. Grey lines depict the 50-meter and 200-meter isobaths.

Map

Description automatically generated

Figure 2: Bottom temperatures in degrees Celsius (a) before and (b) after 1992 on the continental shelf. Gray lines depict the temperature contours as predicted by a threshold GAM using bottom temperatures recorded by the NOAA triennial and annual survey data. 1992 was identified as the threshold year, at which point there was a general shift from profile (a) to (b).

Diagram, schematic

Description automatically generated

Figure 3: Final NMS ordination for both surveys. Green lines represent the depth gradient, and each species symbol indicates their PFMC management/taxonomic group. The habitat gradient is depicted on the right y axis and the diversity and richness gradients are represented by red arrows along which the variable increases.

Background pattern

Description automatically generated

Figure 4: Model output for TGAMs. The left and middle panels display model predicted probability of presence prior to and after the selected threshold year overlaid with survey tow locations (gray circles). The right panel depicts differences in probability of presence before and after the threshold year and is overlaid with areas of statistically significant decrease (open triangle) or increase (filled circle) in probability of presence following the threshold year.

Diagram

Description automatically generated

Figure 5: Effect of temperature on six species for which temperature was included as a covariate in each selected stationary GAM formulation for the annual survey.

Diagram

Description automatically generated

Figure 6: Effect of depth on eight species for each selected stationary GAM formulation for the annual survey.

Table 1: Number of hauls containing each species were summed for the Northwest Fisheries Science Center annual survey (NWFSC) and the Alaska Fisheries Science Center triennial survey (AFSC) to determine occurrence. Only species that occurred in over 1% of hauls are listed below. Depth, in meters, and temperature ranges, in degrees Celsius, were calculated using both survey datasets. Bolded species were selected for individual analyses.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | No. of Hauls | | | % Occurrence | |  |  |
| Common Name | Scientific Name | NWFSC | AFSC | NWFSC | | AFSC | Depth (m) | Temp. (°C) |
| Rex sole | ***Glyptocephalus zachirus*** | **2327** | **1778** | **97%** | | **92%** | **78 - 438** | **5.8 - 8.1** |
| Dover sole | ***Microstomus pacificus*** | **2258** | **1687** | **94%** | | **87%** | **82 - 711** | **5.7 - 8.1** |
| Petrale sole | ***Eopsetta jordani*** | **2219** | **1206** | **92%** | | **62%** | **72 - 192** | **6.7 - 8.3** |
| Spotted ratfish | *Hydrolagus colliei* | 1963 | 853 | 82% | | 44% | 78 - 307 | 6.3 - 8.1 |
| English sole | ***Parophrys vetulus*** | **1902** | **1245** | **79%** | | **64%** | **70 - 201** | **6.7 - 8.3** |
| Arrowtooth flounder | ***Atheresthes stomas*** | **1883** | **1269** | **78%** | | **65%** | **90 - 406** | **5.9 - 8.1** |
| Longnose skate | *Raja rhina* | 1862 | 518 | 77% | | 27% | 91 - 459 | 5.7 - 8.1 |
| Lingcod | ***Ophiodon elongatus*** | **1596** | **892** | **66%** | | **46%** | **77 - 213** | **6.7 - 8.3** |
| Pacific sanddab | ***Citharichthys sordidus*** | **1536** | **1149** | **64%** | | **59%** | **68 - 137** | **7.0 - 8.5** |
| Greenstriped rockfish | *Sebastes elongatus* | 1296 | 910 | 54% | | 47% | 108 - 215 | 6.6 - 8.1 |
| Sablefish | ***Anoplopoma fimbria*** | **1236** | **1247** | **51%** | | **64%** | **107 - 957** | **5.5 - 8.0** |
| Big skate | *Beringraja binoculata* | 1086 | 174 | 45% | | 9% | 68 - 169 | 6.8 - 8.5 |
| Sandpaper skate | *Bathyraja kincaidii* | 1002 | 193 | 42% | | 10% | 108 - 447 | 5.6 - 7.7 |
| Spiny dogfish | *Squalus suckleyi* | 985 | 1087 | 41% | | 56% | 79 - 311 | 6.4 - 8.2 |
| Darkblotched rockfish | *Sebastes crameri* | 791 | 787 | 33% | | 41% | 120 - 357 | 6.1 - 7.9 |
| Flathead sole | *Hippoglossoides elassodon* | 693 | 493 | 29% | | 25% | 98 - 183 | 6.6 - 7.8 |
| Yellowtail rockfish | *Sebastes flavidus* | 549 | 629 | 23% | | 32% | 98 - 188 | 6.7 - 7.8 |
| Canary rockfish | *Sebastes pinniger* | 548 | 589 | 23% | | 30% | 79 - 195 | 6.7 - 8.2 |
| Stripetail rockfish | *Sebastes saxicola* | 504 | 246 | 21% | | 13% | 120 - 230 | 6.6 - 8.3 |
| Pacific cod | *Gadus macrocephalus* | 330 | 269 | 14% | | 14% | 74 -194 | 6.7 - 7.8 |
| Rosethorn rockfish | *Sebastes helvomaculatus* | 314 | 199 | 13% | | 10% | 65 - 107 | 6.0 - 7.8 |
| Curlfin sole | *Pleuronichthys decurrens* | 276 | 79 | 11% | | 4% | 62 - 94 | 7.1 - 8.6 |
| Splitnose rockfish | *Sebastes diploproa* | 270 | 211 | 11% | | 11% | 160 - 381 | 5.9 - 7.7 |
| Sharpchin rockfish | *Sebastes zacentrus* | 253 | 219 | 11% | | 11% | 144 - 299 | 6.3 - 7.9 |
| Rock sole | *Lepidopsetta bilineata* | 247 | 51 | 10% | | 3% | 64 - 112 | 7.0 - 8.1 |
| Shortspine thornyhead | *Sebastolobus alascanus* | 212 | 371 | 9% | | 19% | 196 - 1020 | 5.3 - 7.5 |
| Pacific Ocean perch | *Sebastes alutus* | 184 | 182 | 8% | | 9% | 160 - 402 | 5.8 - 7.6 |
| Butter sole | *Isopsetta isolepis* | 162 | 27 | 7% | | 1% | 61 - 83 | 7.1 - 8.7 |
| Redbanded rockfish | *Sebastes babcocki* | 166 | 122 | 7% | | 6% | 170 - 372 | 5.9 - 7.5 |
| Yelloweye rockfish | *Sebastes ruberrimus* | 159 | 109 | 7% | | 6% | 92 - 199 | 6.7 - 8.1 |
| Kelp greenling | *Hexagrammos decagrammus* | 145 | 46 | 6% | | 2% | 69 - 122 | 7.1 - 8.7 |
| Chilipepper | *Sebastes goodei* | 152 | 30 | 6% | | 2% | 120 - 235 | 6.7 - 8.8 |
| Blackspotted/Rougheye | *Sebastes aleutian. / melanost.* | 141 | 190 | 6% | | 10% | 139 - 425 | 5.6 - 7.5 |
| Sand sole | *Psettichthys melanostictus* | 113 | 64 | 5% | | 3% | 60 - 79 | 7.3 - 8.6 |
| Greenspotted rockfish | *Sebastes chlorostictus* | 121 | 28 | 5% | | 1% | 99 - 175 | 7.0 - 8.2 |
| Widow rockfish | *Sebastes entomelas* | 131 | 160 | 5% | | 8% | 131 - 312 | 6.2 - 7.9 |
| Shortbelly rockfish | *Sebastes jordani* | 109 | 124 | 5% | | 6% | 115 - 234 | 6.7 - 8.4 |
| Redstripe rockfish | *Sebastes proriger* | 126 | 156 | 5% | | 8% | 100 - 221 | 6.6 - 8.0 |
| California skate | *Raja inornata* | 73 | 2 | 3% | | - | 67 - 103 | 7.4 - 9.2 |
| Starry skate | *Raja stellulata* | 84 | 6 | 3% | | 30% | 70 - 157 | 6.9 - 8.6 |
| Pygmy rockfish | *Sebastes wilsoni* | 83 | 89 | 3% | | 5% | 97 - 180 | 6.8 - 8.1 |
| Starry flounder | *Platichthys stellatus* | 44 | 18 | 2% | | - | 62 - 78 | 7.2 - 8.6 |
| Silvergray rockfish | *Sebastes brevispinis* | 45 | 83 | 2% | | 4% | 95 - 255 | 6.3 - 7.7 |
| Quillback rockfish | *Sebastes maliger* | 45 | 18 | 2% | | - | 65 - 107 | 7.1 - 8.1 |
| Bocaccio | *Sebastes paucispinis* | 53 | 137 | 2% | | 7% | 103 - 229 | 6.8 - 8.5 |
| Black rockfish | *Sebastes melanops* | 6 | 27 | - | | 1% | 60 - 79 | 7.1 - 8.6 |

Table 2: MRPP results for the annual and triennial surveys. Categorical variables tested were year, PDO, and NPGO, all of which showed no relationship in visual assessment using the ordination plot. The A value indicates the amount of variance in each group, with A = 0 representing within-group randomization expected by chance and A = 1 representing within-group homogeneity. For community ecology an A > 0.3, for example, would mean there is substantially less randomization than expected by chance. The table shows there is little difference between positive and negative phase groupings for PDO and NPGO or between years.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Annual Survey | | Triennial Survey | |
| Variable | A value | p-value | A value | p-value |
| year | 0.017 | 0.001 | 0.055 | 0.001 |
| PDO | 0.0023 | 0.001 | 0.017 | 0.001 |
| NPGO | 0.0029 | 0.001 | 0.010 | 0.001 |

Table 3: TGAM results for eight groundfish species. Deviance explains the goodness of fit of the model. ΔAIC, change in Akaike's Information Criteria, indicates the difference in AIC between the reference model and the model containing the threshold.

|  |  |  |  |
| --- | --- | --- | --- |
| Species | Threshold Year | Deviance | ΔAIC |
| Petrale Sole | 2011 | 28.5% | 53.9 |
| Lingcod | 2009 | 11.3% | 46.4 |
| Arrowtooth Flounder | 2007 | 36.5% | 27.0 |
| Sablefish | 2003 | 24.5% | 11.3 |
| English Sole | 1995 | 35.0% | 64.0 |
| Dover Sole | 1995 | 23.1% | 154.8 |
| Pacific Sanddab | 1989 | 57.4% | 73.0 |
| Rex Sole | 1989 | 19.9% | 49.9 |

Table 4: GAM formulations for individual species using the annual survey data. Deviance explains the goodness of fit of the model. ΔAIC, change in Akaike's Information Criteria, indicates the difference in AIC between the reference model and the model containing the threshold.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Species | Best Model for Annual Survey | ΔAIC | | GCV | Deviance | | Adj. R2 | |
| Pacific Sanddab |  | 6.91 | 1.69 | | | 46.4% | | 0.45 | |
| English Sole |  | 1.48 | 1.45 | | | 31.2% | | 0.30 | |
| Lingcod |  | 0.51 | 0.64 | | | 15.0% | | 0.13 | |
| Petrale Sole |  | 1.96 | 0.84 | | | 22.9% | | 0.22 | |
| Arrowtooth Flounder |  | 7.38 | 0.80 | | | 43.6% | | 0.42 | |
| Dover Sole |  | 4.57 | 0.90 | | | 55.1% | | 0.54 | |
| Rex Sole |  | 3.25 | 1.04 | | | 34.3% | | 0.33 | |
| Sablefish |  | 0.58 | 0.82 | | | 15.4% | | 0.13 | |