**Model Evaluation**

The selected model (model D in table 1) used depth\_bin, season, our diel feature, nitrate, salinity, and mixed layer thickness as features. Starting from the null model, each of the features leading up to model D added progressively more information. Judging off loss over decisions in the validation set we see a significant jump in performance going from a null model (equal likelihood given to each depth bin) to a model aware of the depth bin (1.740 to 1.457). This is expected as the distribution of fish across depth bins was highly skewed toward shallower depths (table 2).

Next, we see another substantial improvement in our loss by adding our season features (1.457 to 1.368). This is also expected as there are strong changes in depth occupancy of fish through the seasons (figure 1). In general, across both sets the pattern is the same – fish tend to move deeper in the winter months with a peak in the depth <=25m bin in the months of May and June.

We see another improvement in loss upon the inclusion of our diel features (1.368 to 1.352). Overall, there is a large amount of variability even between the training and validation actuals, especially from August to October, but, across months, our model replicates the general pattern of occupancy throughout the day (figure 2). In most months we see occupancy <=25m peak during the day with especially strong diurnal variation in the months of August through October. In contrast to this, from March to May we see the opposite pattern, with fish more likely to be at depth at night.

Our final drop in loss comes with the addition of three environmental covariates – nitrate, salinity, and mixed layer thickness (1.352 to 1.339). These features were chosen from the slew of options as they were the only ones that individually added value to the model in the validation set when combined with the features in model C. For each of these the match between model and observed proportions is less clear in large part due to a high degree of variation in observed proportions between the validation and training sets themselves (figures 3-5). In general, for nitrate there seems to be an overall positive relationship between nitrate concentration and occupancy at depths below 25m however this relationship disappears during the spring and summer months. Salinity allows tends to follow a positive relationship for the winter months but seems to reverse in late summer. Finally mixed layer thickness seems to exhibit a positive relationship between itself and depth occupancy below 25m in early winter but reverses in spring. All in all, given the variation between training and validation actuals the model does a reasonable job at capturing these patterns.

**Assessing Likelihood of Occupancy Near the Seafloor**

Minimum risk in the months of February and August changes depending on where in the GOA you are (figure 6). In February there is an overall pattern of risk rising as you move out along the shelf and then dropping precipitously as you reach the shelf’s edge. Within this general pattern there are, however, a series of hotspots where the minimum likelihood is unusually high. In August risk is in general much lower with several strong hotspots remaining.

Zooming in on a specific H3 cell near Chignik (figure 7) we see that both depth occupancy and diurnal variation vary quite dramatically over the course of the year. First it should be observed that while average depth occupancy is shallowest in the spring, this seems to be due to an overall lack of variability during that time period. Technically speaking the shallowest instantaneous occupancy occurs during the summer months, but due to the extraordinary degree of variability in depth occupancy in this season the average across the day is lower than that in the spring. Following this the late fall and early winter see the fish spread far more evenly across all depth bins before they diel variability tapers off into late winter and the fish are at their overall deepest. Spring then sees a sharp rise with little change in variability before summer comes again withs its extraordinary variability.

Not only does the variability across the day change but the cycle flips in some places as well. In August we see that across the GOA risk is minimized at night (figure 8). However during the winter (February) we see that the time of day that minimizes risk is extraordinarily varied. In general nighttime is no longer when risk is minimized with either daytime or dawn or dusk between the appropriate time.

Finally, looking at how minimal likelihood of occupancy near seafloor is influenced by our environmental features we see in general that during February they exhibit a strong positive correlation – that is as our environmental features increase the likelihood of fish at depth increases as well (figure 9) . This pattern is all but neutralized in August.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model | Features | LC Train | LC Val | LD Train | LD Val |
| Null |  |  |  | 1.835 | 1.740 |
| A | depth\_bin | 0.470 | 0.526 | 1.412 | 1.457 |
| B | A + season | 0.438 | 0.487 | 1.330 | 1.368 |
| C | B + diel | 0.429 | 0.480 | 1.313 | 1.352 |
| D | C + nitrate, salinity, mlt | 0.426 | 0.474 | 1.308 | 1.339 |

**Table 1: Performance with Each Additional Feature.** LC and LD indicate loss (categorical cross entropy) over the contrasts and decisions respectively. From top to bottom each model incorporates a new set of features until we arrive at our selected model D. The Null model assumes each depth bin is as likely as all of the others.

|  |  |
| --- | --- |
| Depth Bin | Proportion of Samples |
| [0, 25] | 46.4% |
| (25, 50] | 16.6% |
| (50, 75] | 13.4% |
| (75, 100] | 10.7% |
| (100, 150] | 13.0% |
| (150, 200] | 4.9% |
| (200, 250] | 1.3% |
| (250, 300] | 0.6% |
| (300, 400] | 0.2% |
| (400, 500] | <0.1% |

**Table 2: Depth Skew.** Observed proportion of samples per depth bin.

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**Figure 1:** Actual and predicted proportion of fish in each depth bin by month over the validation dataset using our selected model.

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**Figure 2: Diel Variation** x-axis is the passage of the day in radians (starting at night (negative radians), sunrise at 0 radians, and then moving through the day (positive radians). y-axis is the actual and then expected probability of occupancy in the depth bins >=25m. Note the variation between the training set and the validation set in the actual proportions.

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**Figure 3:** **Proportions by Nitrate Bin** Observed vs predicted proportions of fish below 25m as a function of nitrate concentrations. Note the variation between training and validation sets.

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**Figure 4:** **Proportions by Salinity Bin** Observed vs predicted proportions of fish below 25m as a function of salinity. Note the variation between training and validation sets.

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**Figure 5:** **Proportions by Mixed Layer Thickness Bin** Observed vs predicted proportions of fish below 25m as a function of mixed layer thickness.

A map of the united states

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**Figure 6:** **Spatial Distribution of Minimum Risk** Minimum predicted risk in the lowest depth bin available to each H3 cell in February and August.

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**Figure 7: Full Year of Likelihoods**

A map of the world with dots

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**Figure 8: Time of Day Minimization** plotted is the portion of the day where risk is minimized for February 15 and August 15. Negative values (blue) indicate nighttime whereas positive values (red) indicate day.

A graph showing the same number of numbers

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**Figure 9: Likelihood of Bottom Occupancy vs Environmental Features**