# Supplementary material: ICES Journal of Marine Science, 75

# The utility of spatial model-based estimators of unobserved bycatch

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**Table S1.** Annual bycatch (tonnes) and bycatch rate (percent of hauls) for species selected from the US West Coast Groundfish Observer Program (WCGOP) dataset. All selected species are exclusively discarded. The summarized data are 35 440 post-IFQ hauls (4007 trips) observed in 2011–2015 in the area north of Cape Falcon, Oregon (45.77°N).

| | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Catch (t)** | **% Hauls** | **Catch (t)** | **% Hauls** | **Catch (t)** | **% Hauls** | **Catch (t)** | **% Hauls** | **Catch (t)** | **% Hauls** |
| Big skate | 25.2 | 10.2 | 33.9 | 10.8 | 24.1 | 9.1 | 68.2 | 17.9 | 34.0 | 18.5 |
| Black skate | 18.5 | 17.3 | 15.3 | 14.4 | 14.0 | 15.2 | 13.7 | 15.3 | 10.5 | 13.3 |
| Brown catshark | 19.3 | 45.6 | 21.5 | 43.5 | 24.3 | 45.4 | 25.4 | 45.4 | 22.9 | 45.8 |
| California slickhead | 9.3 | 12.3 | 6.3 | 8.1 | 6.4 | 9.0 | 5.3 | 9.3 | 4.7 | 6.7 |
| Dungeness crab | 120.1 | 27.6 | 137.8 | 32.7 | 98.2 | 25.3 | 105.0 | 31.9 | 86.8 | 30.7 |
| Grenadier | 116.8 | 34.0 | 121.9 | 29.8 | 108.1 | 29.8 | 64.0 | 26.0 | 42.0 | 22.5 |
| Octopus | 3.7 | 15.9 | 2.8 | 13.2 | 4.7 | 15.4 | 3.4 | 13.2 | 2.4 | 10.9 |
| Pacific hake | 147.6 | 55.1 | 165.8 | 58.2 | 148.0 | 54.2 | 122.7 | 56.2 | 143.8 | 60.7 |
| Pacific halibut | 61.0 | 29.3 | 62.3 | 30.3 | 63.7 | 27.1 | 53.8 | 33.9 | 65.9 | 36.2 |
| Rosethorn rockfish | 0.7 | 3.3 | 0.7 | 4.5 | 0.9 | 5.9 | 0.8 | 4.2 | 0.1 | 2.5 |
| Sandpaper skate | 25.9 | 44.9 | 33.0 | 48.4 | 35.0 | 51.8 | 33.9 | 53.9 | 34.3 | 55.4 |
| Slender sole | 18.7 | 20.7 | 35.2 | 23.6 | 46.7 | 26.9 | 31.7 | 31.3 | 28.2 | 31.2 |
| Spiny dogfish shark | 268.7 | 42.5 | 261.4 | 46.5 | 258.0 | 39.2 | 262.9 | 46.9 | 165.5 | 42.2 |
| Spotted ratfish | 50.7 | 37.5 | 58.7 | 42.3 | 69.0 | 41.9 | 57.3 | 44.4 | 59.4 | 48.8 |
| Tanner crab | 136.3 | 46.3 | 85.1 | 38.6 | 104.2 | 39.7 | 84.3 | 39.4 | 84.9 | 34.4 |

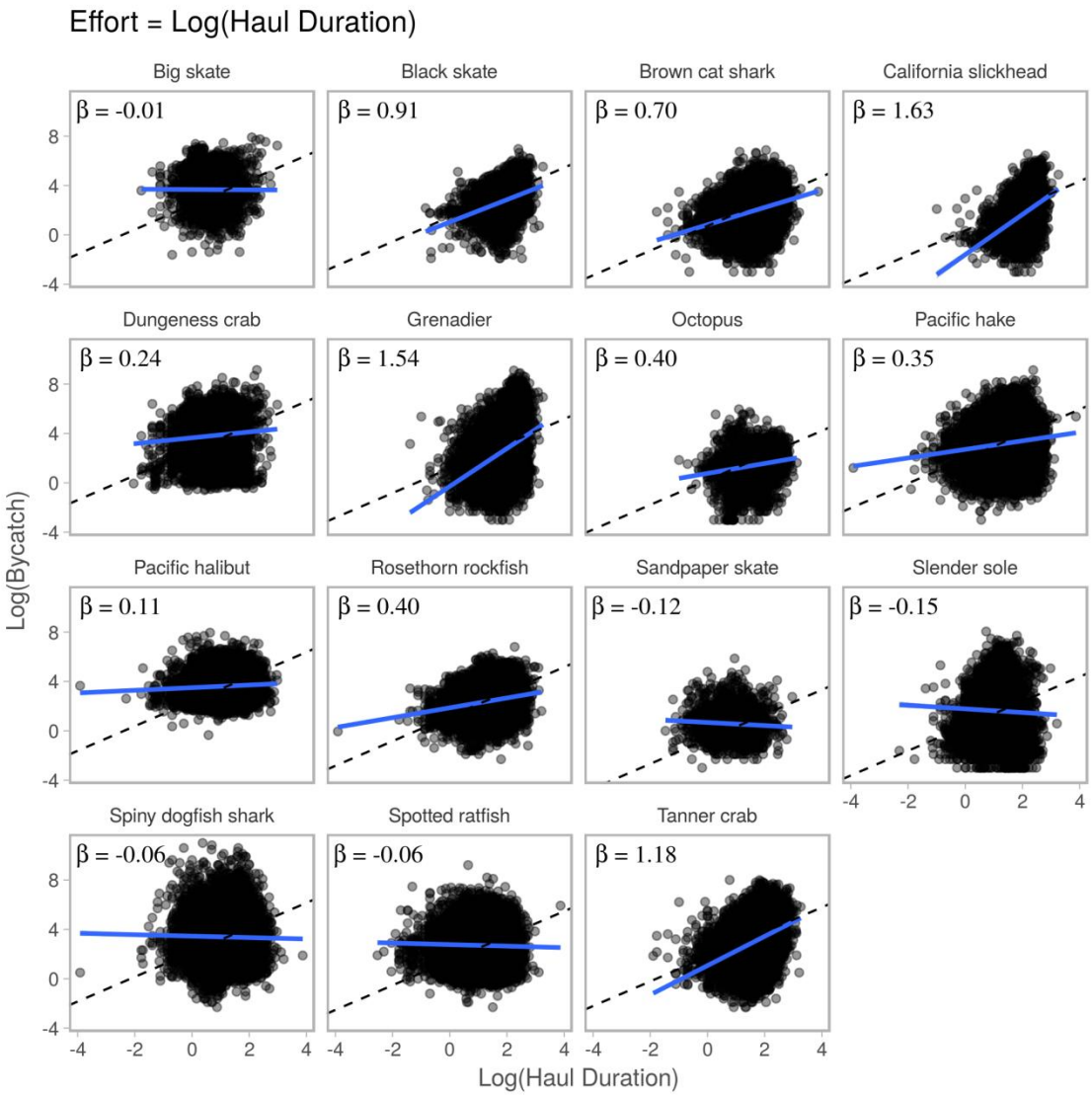



**Figure S1.** Estimated relationships between fishing effort (haul duration in hours) and bycatch (kg) for 15 species analyzed in the west coast groundfish trawl fishery. The slope terms $\beta$ of log-log linear models are exponents of an assumed power law fit to each species, $\text{Bycatch} = \alpha\text{Effort}^{\beta}$. Most $\beta$ are much less than 1, indicating the relationship between bycatch and effort is either weak or not linear. Data ($n = 35\,440$) consist of observed hauls from the West Coast Groundfish Observer Program recorded in 2011–2015 in the area north of Cape Falcon, Oregon (45.77°N).

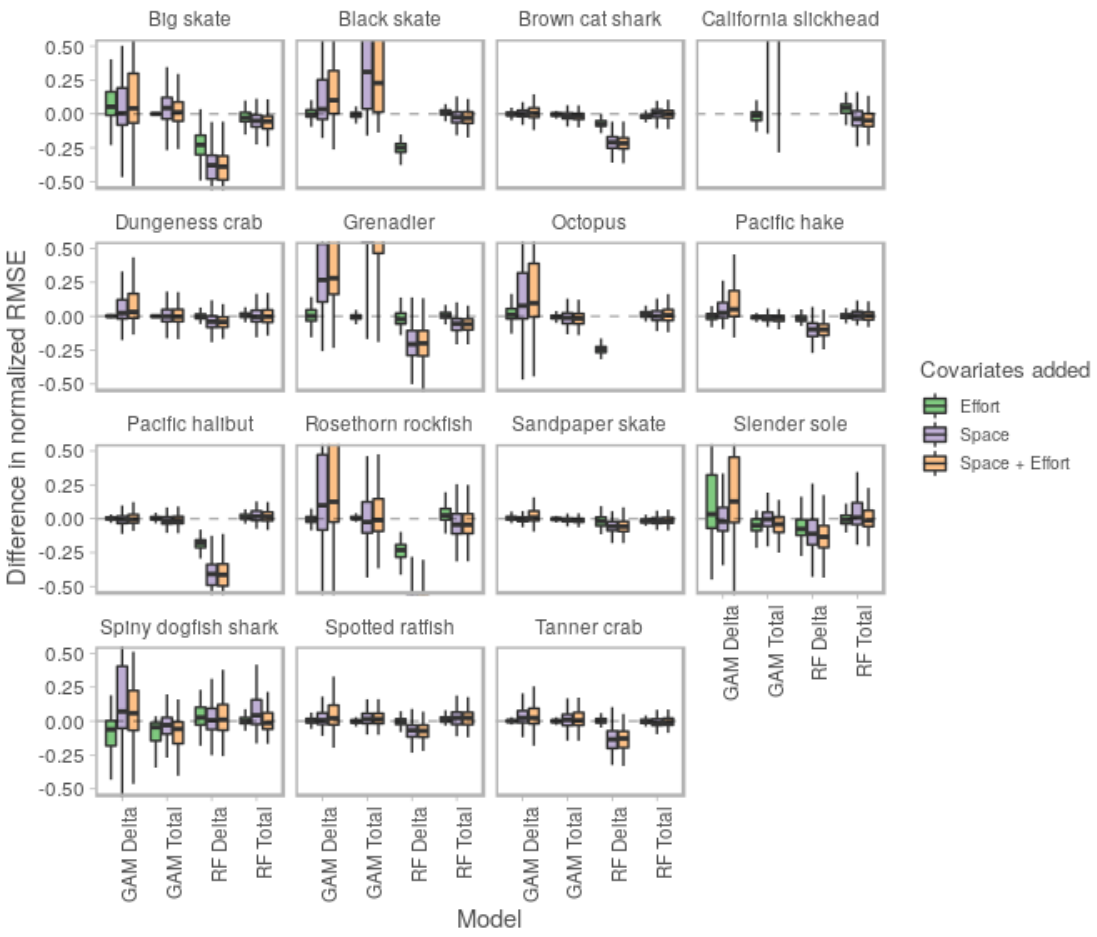



**Figure S2.** Change in predictive performance (normalized RMSE) when adding fishing effort and spatial location as covariates in each model. For many species, adding space to the GAM-Delta and GAM-Total models led to worse predictions (positive change in RMSE, above dashed line). On the other hand, adding space to the RF-Delta model consistently improved predictions (negative change in RMSE, below dashed line). For RF-Total, including space had either slightly improved predictions or had no effect. Adding effort had little effect for nearly all species and models and never had a larger effect than adding space.

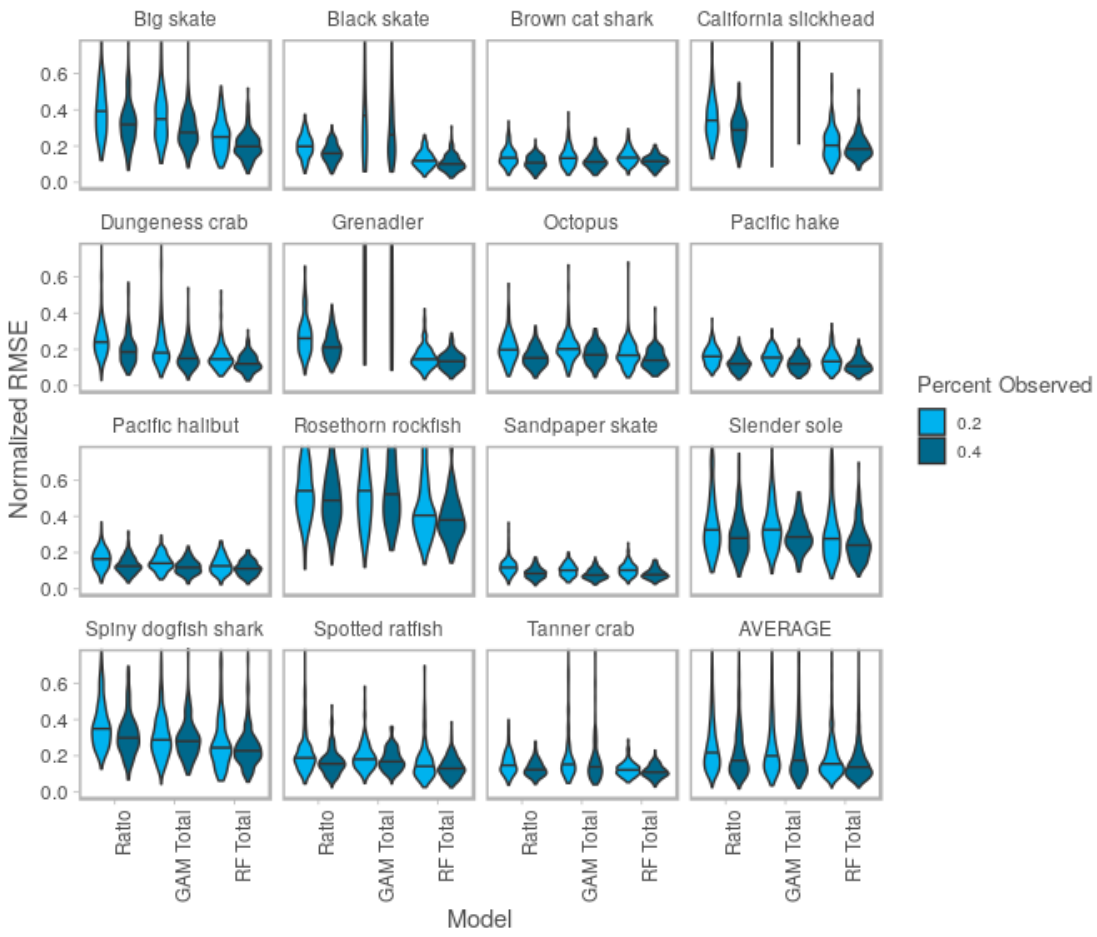



**Figure S3.** Predictive performance (normalized RMSE) for different levels of simulated observer coverage. Averaged across species, RF-Total had lower median RMSE than the ratio estimator, even at half the observer coverage (RF-Total at 20%: 0.155, Ratio at 40%: 0.180). GAM-Total failed to converge for 3/15 species.

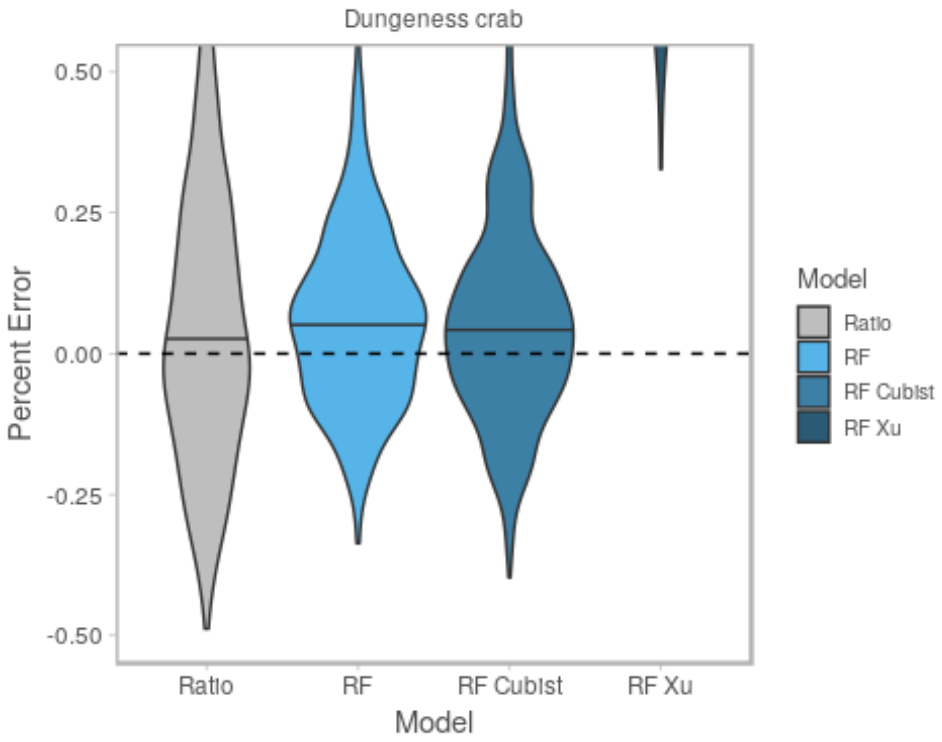



**Figure S4.** Performance of RF bias correction methods applied to Dungeness crab bycatch (percent error, PE, averaged across years 2011–2015). The ratio estimator is unbiased (median PE = 0.002). RF is positively biased (median PE = 0.055) and Cubist is less positively biased (median PE = 0.043). Cubist reduces bias by fitting a linear model in regression tree terminal nodes instead of using the data mean (Quinlan, 1992, 1993). The second method (Xu, 2013) fits a second RF model to the residuals of the original RF, but this method performed poorly (median PE = 1.107, off chart).

## Random forest and GAM models

For each (of 15) species, we fit the models described below. **fac(x)** is shorthand for treating covariate *x* as a factor. All random forest models were fit with **ntree=500** and default **mtry**. All GAMs were fit with **family=Tweedie(p=tweedie_p[i])**, **method="REML".** All data are at the haul-level.

- *Y*: response, bycatch/discards (in kg)
- *year*: year (5 levels: 2011–2015)
- *depth_ interval*: depth of haul (3 levels: < 125, 126–250, > 250 fathoms)
- *season*: season (2 levels: summer, winter)
- *bimonth*: bimonthly period (6 levels: Jan–Feb, Mar–Apr, . . . , Nov–Dec)
- *logret*: log(retained target species catch in kg)
- *lat*: degrees latitude
- *long*: degrees longitude

For random forest models, we report the percent variance explained **[pseudo-$R2 = 1 - \frac{mse}{Var(y)}$]**. Random forest covariate effect plots were created using the **forestFloor R** package and custom code.

For GAM models, we report the output of **mgcv::summary.gam**, including percent deviance explained. GAM covariate effect plots were created using the **visreg R** package.

**RF-Total**
Designed to *mimic the stratified ratio estimator* by treating **year**, **season**, and **depth_interval** as factors. **bimonth** is included as linear and quadratic terms to avoid confounding with f**ac(season)**:

randomForest[*Y* ~ fac(year) + fac(season) + fac(depth_interval) + bimonth + I(bimonthˆ2) + logret + lat + long + I(latˆ2) + I(longˆ2)]

**GAM-Total**
Designed to *mimic the stratified ratio estimator* by treating **year**, **season**, and **depth_interval** as factors. **bimonth** is included as linear and quadratic terms to avoid confounding with **fac(season)**:

gam[*Y* ~ fac(year) + fac(season) + fac(depth_interval) + bimonth + I(bimonthˆ2) + logret + s(lat, long, k=50)]

**RF-Nonlinear**
Allow random forest to fit covariates with *full non-linear flexibility* (not as factors):

randomForest(*Y* ~ year + julian_day + time + depth + gear + logret + lat + long)

New covariates introduced:

- *julian_day*: Julian day of year
- *time*: time of day in hours
- *depth*: depth of haul in fathoms

- *gear*: gear type (3 levels: groundfish trawl w/ footrope < 8 inches, groundfish trawl w/ footrope > 8 inches, pineapple trawl)

**GAM-Nonlinear**

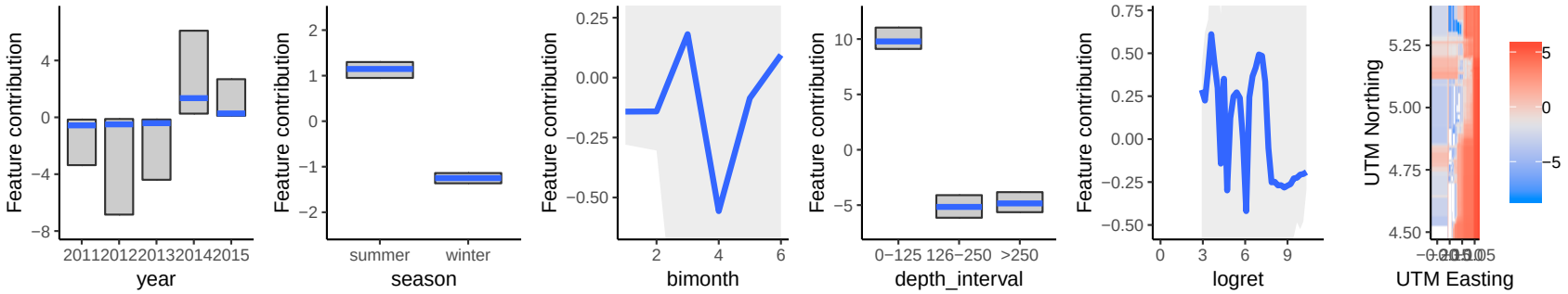
Allow GAM to fit covariates with *full non-linear flexibility* (not as factors):

gam[$Y$ ~ s(year,k=5) + s(julian_day,k=5) + s(time,k=5) + s(depth,k=5) + gear + logret + s(lat, long, k=50)]

## Species 1: Big Skate

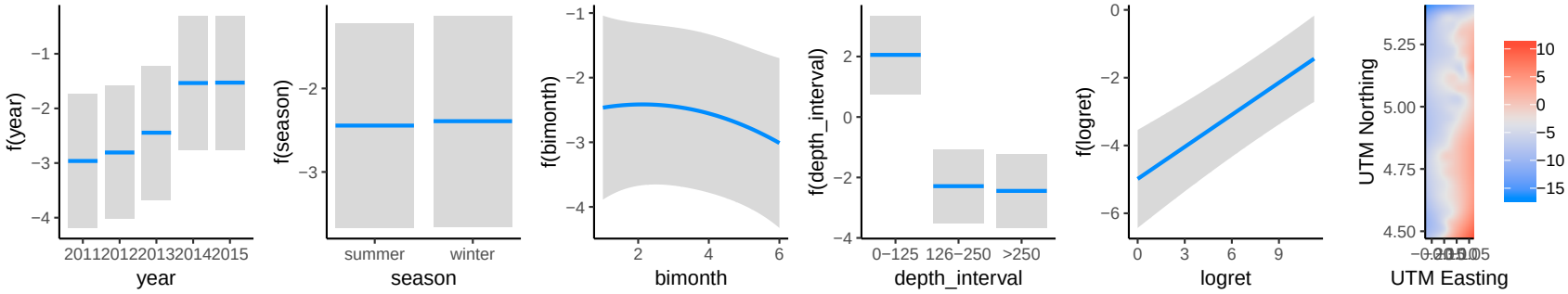
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 1989.101
          % Var explained: 47.8
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.233 Deviance explained = 65.8% -REML = 32567 Scale est. = 102.63 n = 35440

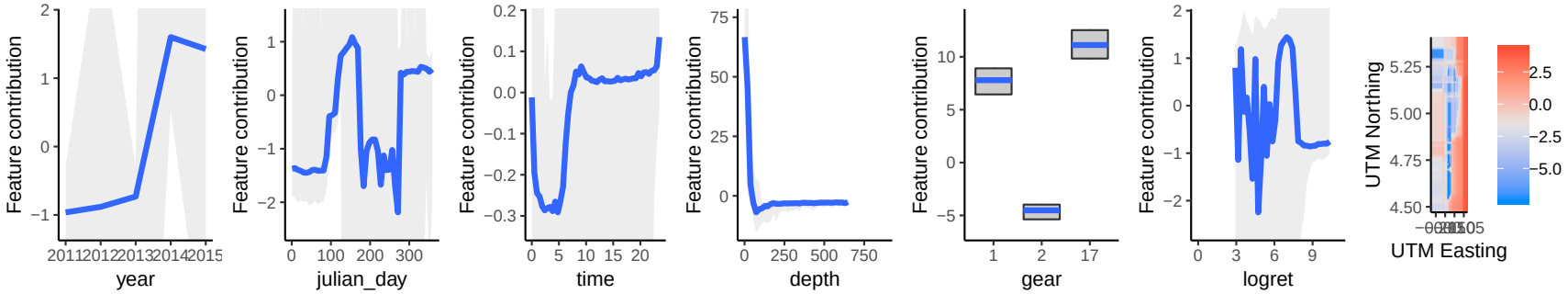



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 46.2 | 48.5 | 15.1 | 8.66e-121 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -6.02 | 0.806 | -7.47 | 8.29e-14 | *** |
| seasonwinter | 0.0525 | 0.248 | 0.212 | 0.832 | |
| bimonth | 0.169 | 0.37 | 0.457 | 0.648 | |
| I(bimonth^2) | -0.0398 | 0.0486 | -0.819 | 0.413 | |
| year2012 | 0.156 | 0.158 | 0.987 | 0.324 | |
| year2013 | 0.518 | 0.164 | 3.15 | 0.00163 | ** |
| year2014 | 1.43 | 0.156 | 9.17 | 4.96e-20 | *** |
| year2015 | 1.43 | 0.16 | 8.97 | 3.2e-19 | *** |
| depth_interval0-125 | 4.5 | 0.348 | 12.9 | 3.13e-38 | *** |
| depth_interval126-250 | 0.157 | 0.262 | 0.598 | 0.55 | |
| logret | 0.315 | 0.05 | 6.32 | 2.73e-10 | *** |

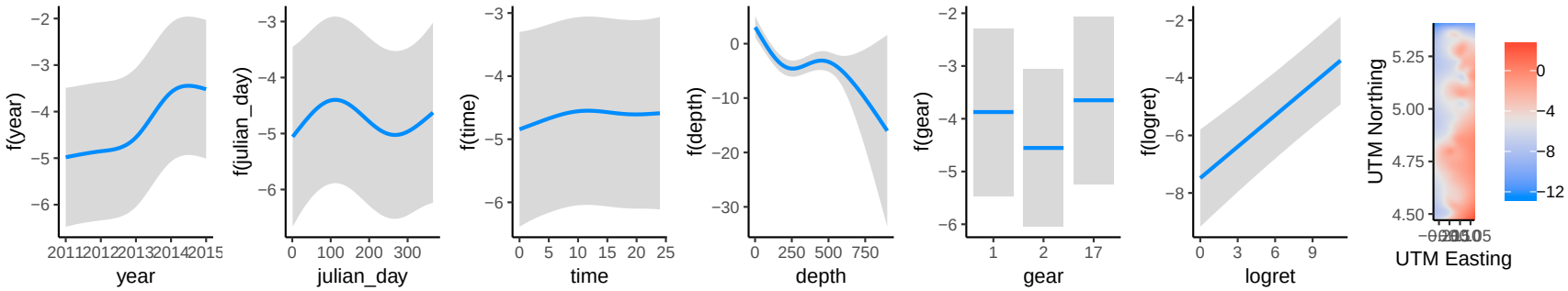
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 1784.603
          % Var explained: 53.17
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = 0.26 Deviance explained = 67.6% -REML = 32318 Scale est. = 95.592 n = 35440



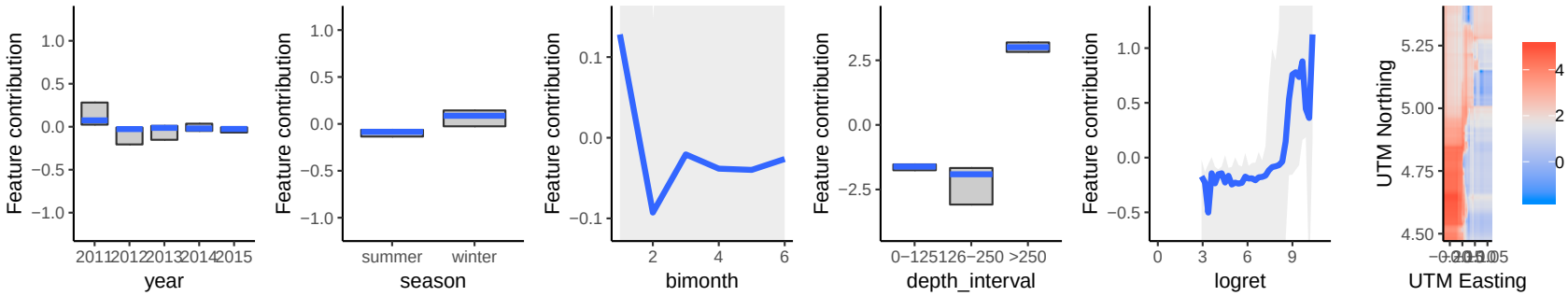

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 45.6 | 48.4 | 9.01 | 5.26e-63 | *** |
| s(year) | 3.91 | 3.99 | 41.7 | 7.89e-35 | *** |
| s(depth) | 3.89 | 3.99 | 31.5 | 3.1e-26 | *** |
| s(julian_day) | 3.75 | 3.96 | 5.17 | 0.000357 | *** |
| s(time) | 2.63 | 3.17 | 0.455 | 0.708 | |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -3.88 | 0.458 | -8.49 | 2.23e-17 | *** |
| gear2 | -0.681 | 0.289 | -2.35 | 0.0186 | * |
| gear17 | 0.224 | 0.109 | 2.06 | 0.0399 | * |
| logret | 0.364 | 0.0502 | 7.25 | 4.38e-13 | *** |

## Species 2: Black Skate

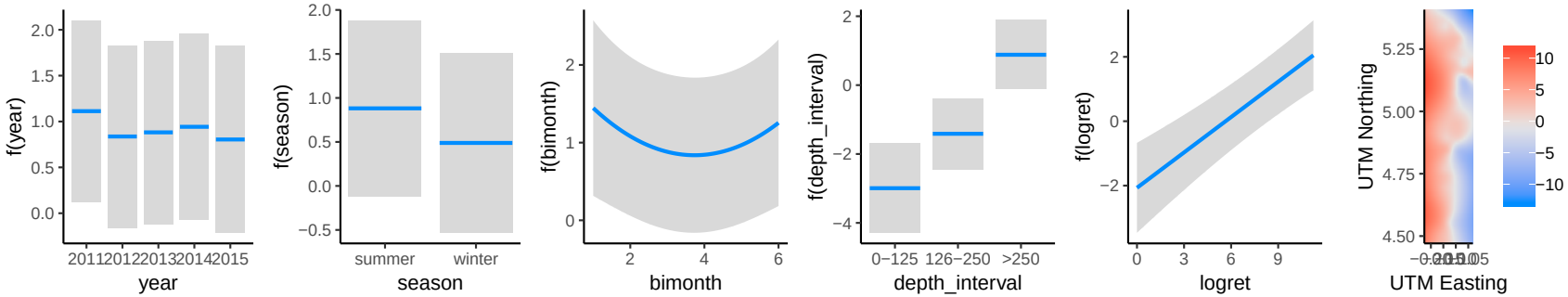
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 253.1007
          % Var explained: 48.13
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = -1.54 Deviance explained = 56% -REML = 33123 Scale est. = 139.75 n = 35440

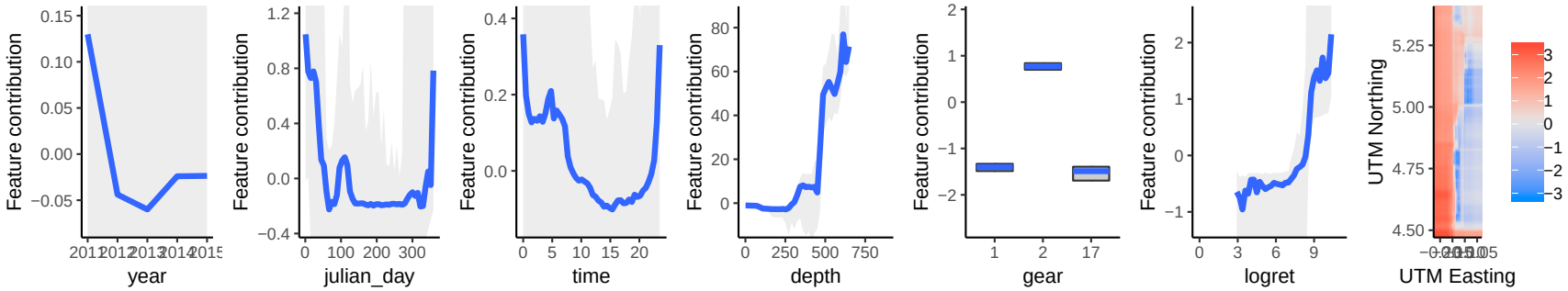



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 47 | 48.7 | 8.53 | 7.16e-59 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -0.848 | 0.71 | -1.19 | 0.232 | |
| seasonwinter | -0.393 | 0.203 | -1.94 | 0.0529 | . |
| bimonth | -0.606 | 0.272 | -2.23 | 0.0257 | * |
| I(bimonth^2) | 0.0812 | 0.0368 | 2.21 | 0.0274 | * |
| year2012 | -0.276 | 0.172 | -1.61 | 0.108 | |
| year2013 | -0.231 | 0.169 | -1.37 | 0.171 | |
| year2014 | -0.171 | 0.18 | -0.947 | 0.344 | |
| year2015 | -0.309 | 0.191 | -1.61 | 0.107 | |
| depth_interval0-125 | -3.87 | 0.461 | -8.4 | 4.8e-17 | *** |
| depth_interval126-250 | -2.29 | 0.193 | -11.9 | 2.2e-32 | *** |
| logret | 0.366 | 0.0634 | 5.77 | 7.85e-09 | *** |

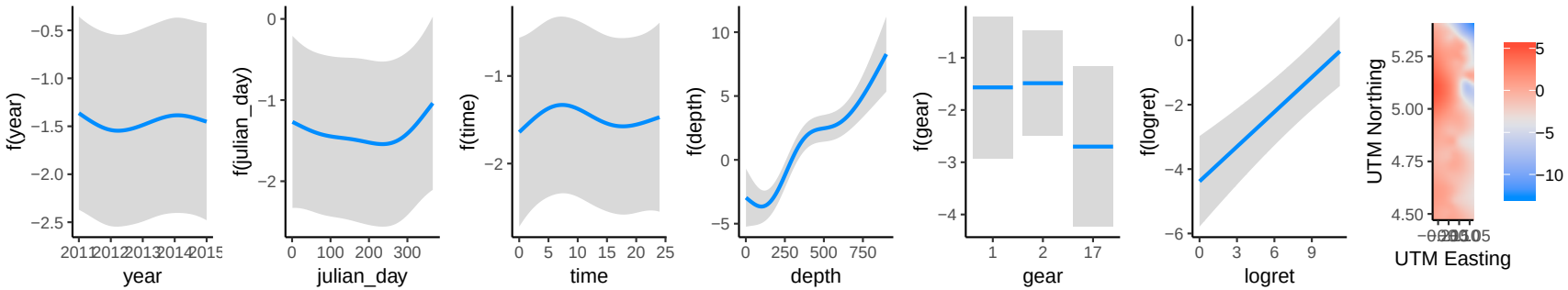
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 226.5094
          % Var explained: 53.58
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = -0.416 Deviance explained = 62.3% -REML = 32187 Scale est. = 122.09 n = 35440



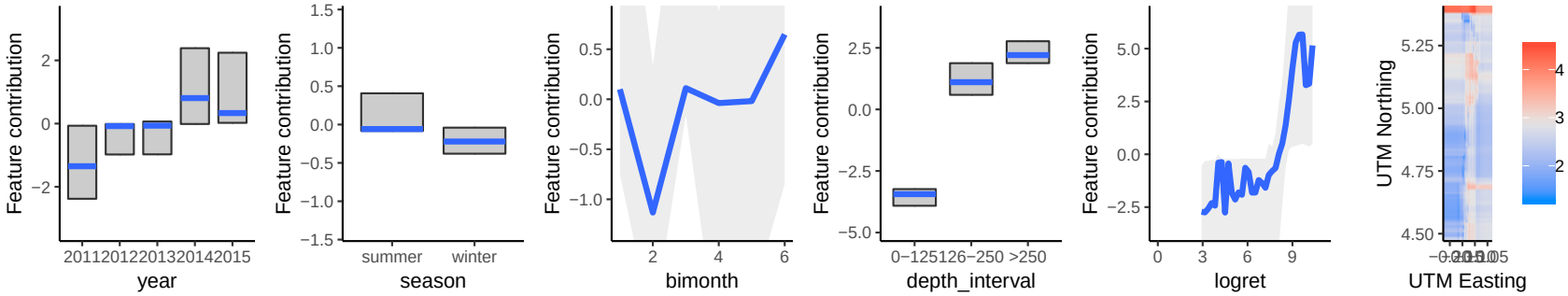

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 46.2 | 48.5 | 3.19 | 6.26e-13 | *** |
| s(year) | 3.32 | 3.75 | 0.453 | 0.764 | |
| s(depth) | 3.99 | 4 | 92.9 | 1.66e-78 | *** |
| s(julian_day) | 3.45 | 3.83 | 0.877 | 0.486 | |
| s(time) | 3.5 | 3.86 | 0.702 | 0.569 | |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -4.02 | 0.614 | -6.55 | 5.71e-11 | *** |
| gear2 | 0.0803 | 0.474 | 0.17 | 0.865 | |
| gear17 | -1.13 | 0.496 | -2.28 | 0.0223 | * |
| logret | 0.359 | 0.0623 | 5.77 | 8.02e-09 | *** |

## Species 3: Brown Cat Shark

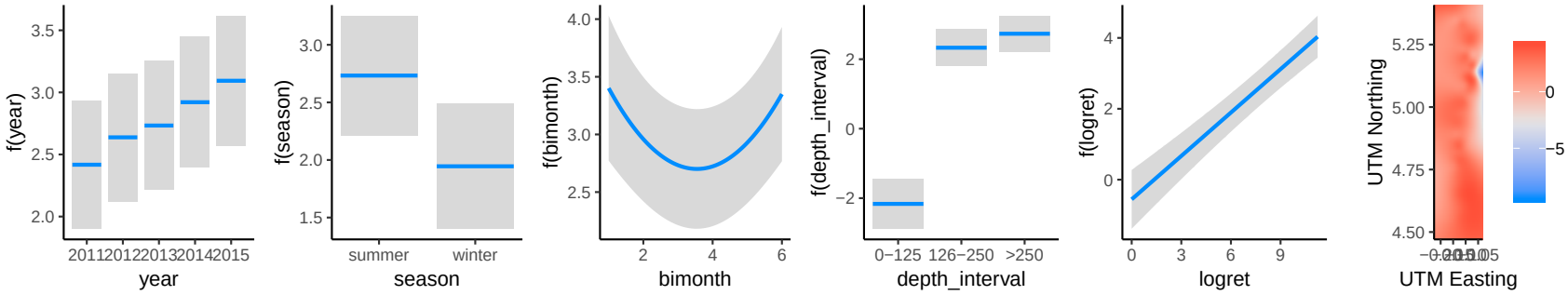
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 356.8372
          % Var explained: 20.8
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.121 Deviance explained = 45.4% -REML = 74672 Scale est. = 88.94 n = 35440

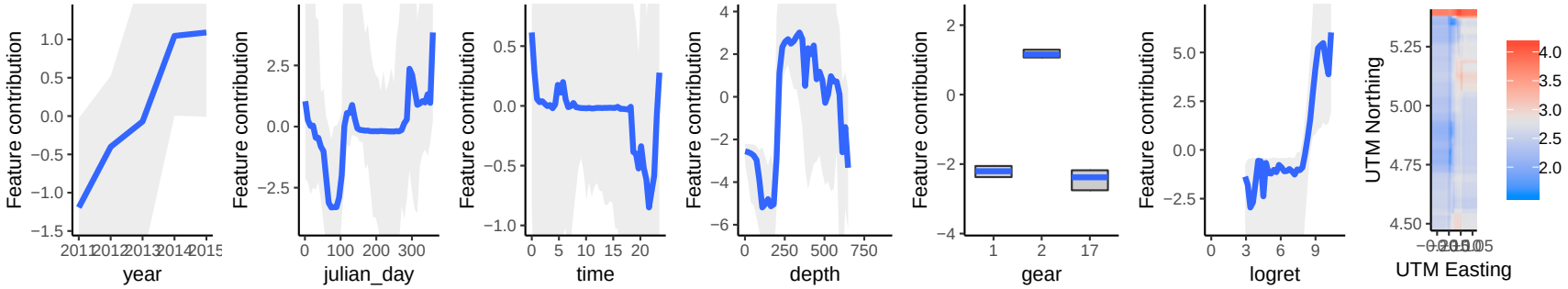



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 48.3 | 49 | 3.7 | 6.32e-17 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -0.18 | 0.479 | -0.376 | 0.707 | |
| seasonwinter | -0.788 | 0.135 | -5.82 | 5.99e-09 | *** |
| bimonth | -0.766 | 0.184 | -4.16 | 3.13e-05 | *** |
| I(bimonth^2) | 0.108 | 0.0249 | 4.34 | 1.46e-05 | *** |
| year2012 | 0.221 | 0.119 | 1.86 | 0.0631 | . |
| year2013 | 0.316 | 0.115 | 2.75 | 0.00591 | ** |
| year2014 | 0.503 | 0.121 | 4.14 | 3.44e-05 | *** |
| year2015 | 0.676 | 0.122 | 5.55 | 2.9e-08 | *** |
| depth_interval0-125 | -4.9 | 0.271 | -18.1 | 1.6e-72 | *** |
| depth_interval126-250 | -0.402 | 0.0936 | -4.3 | 1.73e-05 | *** |
| logret | 0.408 | 0.0423 | 9.65 | 5.37e-22 | *** |

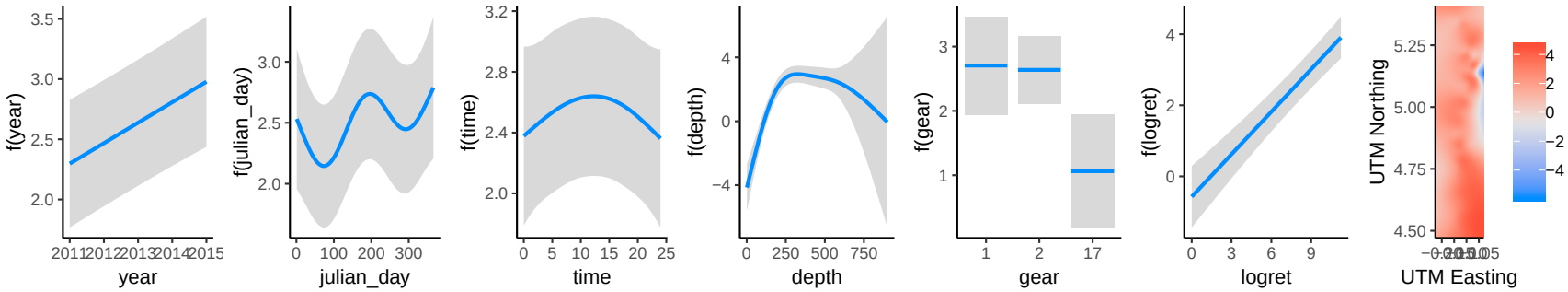
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 344.8937
          % Var explained: 23.45
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = 0.132 Deviance explained = 46.7% -REML = 74340 Scale est. = 91.971 n = 35440



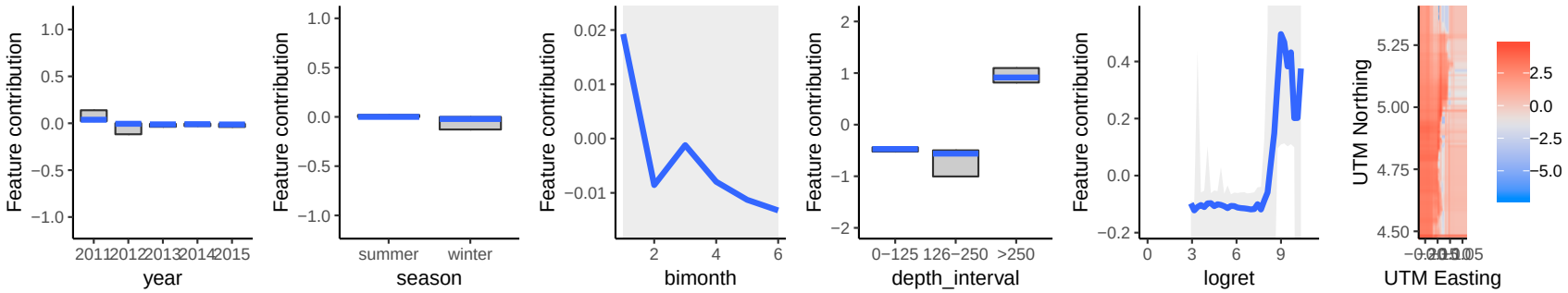

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 48 | 48.9 | 3.06 | 4.15e-12 | *** |
| s(year) | 1 | 1.01 | 35.4 | 2.48e-09 | *** |
| s(depth) | 3.98 | 4 | 35.1 | 2.62e-29 | *** |
| s(julian_day) | 3.98 | 4 | 5.69 | 0.00014 | *** |
| s(time) | 3.32 | 3.75 | 1.27 | 0.279 | |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -2.69 | 0.412 | -6.52 | 7.02e-11 | *** |
| gear2 | -0.0681 | 0.286 | -0.238 | 0.812 | |
| gear17 | -1.64 | 0.329 | -4.99 | 6.13e-07 | *** |
| logret | 0.399 | 0.0432 | 9.22 | 3.04e-20 | *** |

## Species 4: California Slickhead

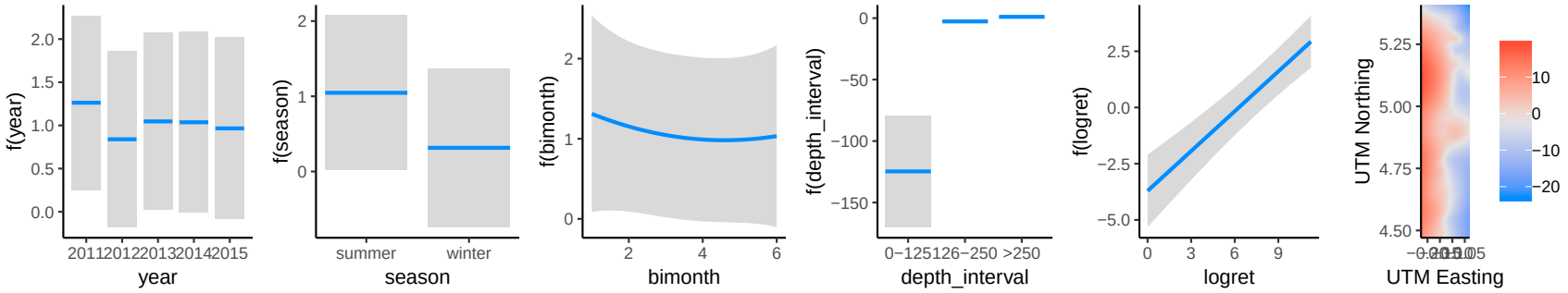
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 145.0971
          % Var explained: 42.62
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = -9.19e+03 Deviance explained = 65.7% -REML = 18895 Scale est. = 97.632 n = 35440

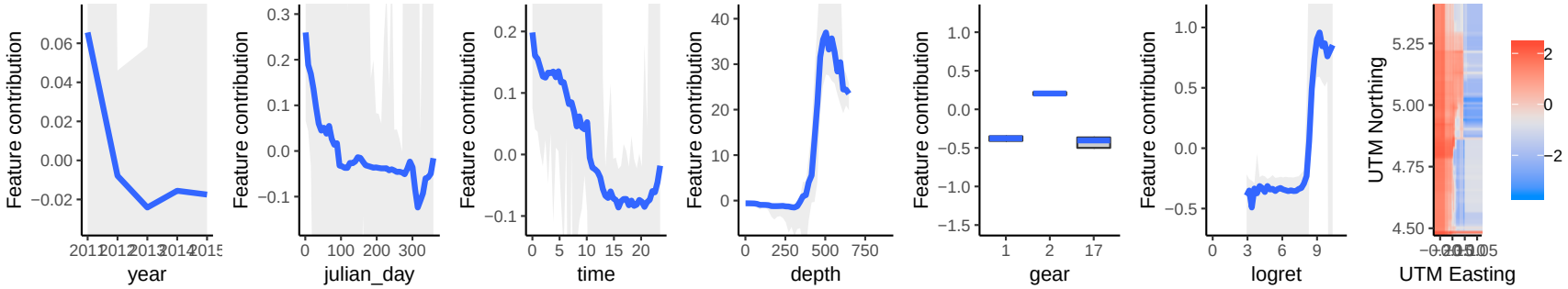



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 43.7 | 46.4 | 19.1 | 1.78e-153 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -5.31 | 0.979 | -5.42 | 5.87e-08 | *** |
| seasonwinter | -0.731 | 0.252 | -2.9 | 0.00375 | ** |
| bimonth | -0.235 | 0.343 | -0.686 | 0.492 | |
| I(bimonth^2) | 0.0256 | 0.0463 | 0.553 | 0.58 | |
| year2012 | -0.423 | 0.214 | -1.98 | 0.048 | * |
| year2013 | -0.216 | 0.211 | -1.03 | 0.304 | |
| year2014 | -0.227 | 0.23 | -0.986 | 0.324 | |
| year2015 | -0.297 | 0.242 | -1.23 | 0.219 | |
| depth_interval0-125 | -126 | 23.1 | -5.43 | 5.6e-08 | *** |
| depth_interval126-250 | -3.74 | 0.251 | -14.9 | 2.68e-50 | *** |
| logret | 0.59 | 0.0808 | 7.31 | 2.83e-13 | *** |

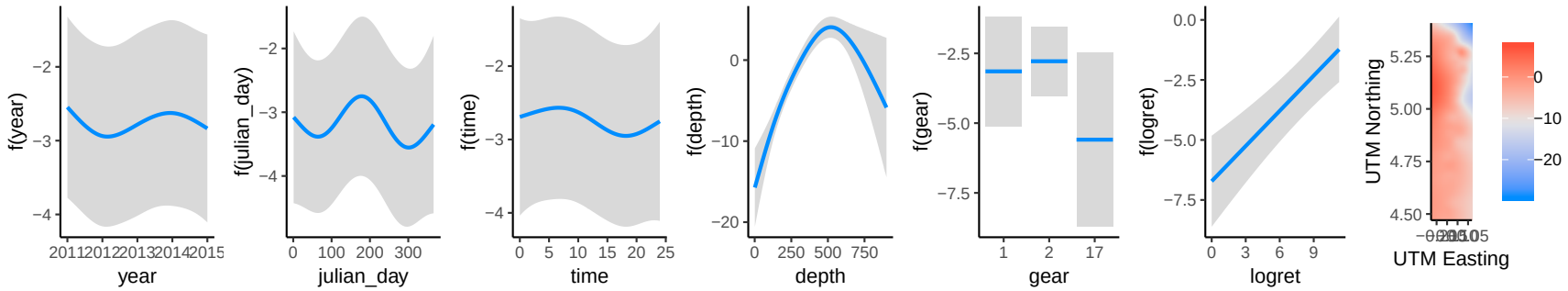
**RF$_{\text{Nonlinear}}$**

```
Mean of squared residuals: 127.1781
          % Var explained: 49.7
```




**GAM$_{\text{Nonlinear}}$**

R-sq.(adj) = -14.3 Deviance explained = 76.2% -REML = 17595 Scale est. = 103.48 n = 35440



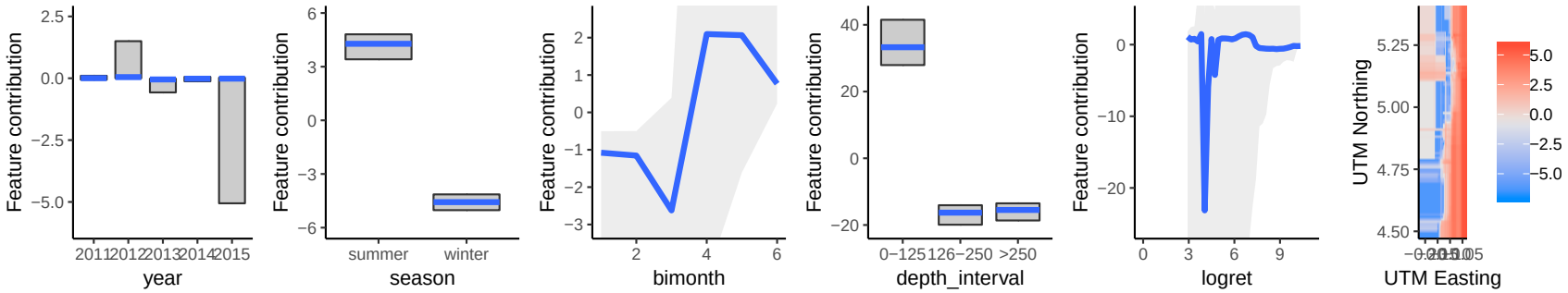

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 43 | 46.3 | 3.73 | 2e-16 | *** |
| s(year) | 3.56 | 3.89 | 0.853 | 0.476 | |
| s(depth) | 3.94 | 4 | 120 | 4.75e-102 | *** |
| s(julian_day) | 3.9 | 3.99 | 1.84 | 0.13 | |
| s(time) | 3.27 | 3.71 | 0.864 | 0.508 | |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -11.5 | 1.07 | -10.7 | 8.35e-27 | *** |
| gear2 | 0.362 | 0.792 | 0.457 | 0.647 | |
| gear17 | -2.45 | 1.53 | -1.6 | 0.109 | |
| logret | 0.489 | 0.0915 | 5.34 | 9.4e-08 | *** |

## Species 5: Dungeness Crab

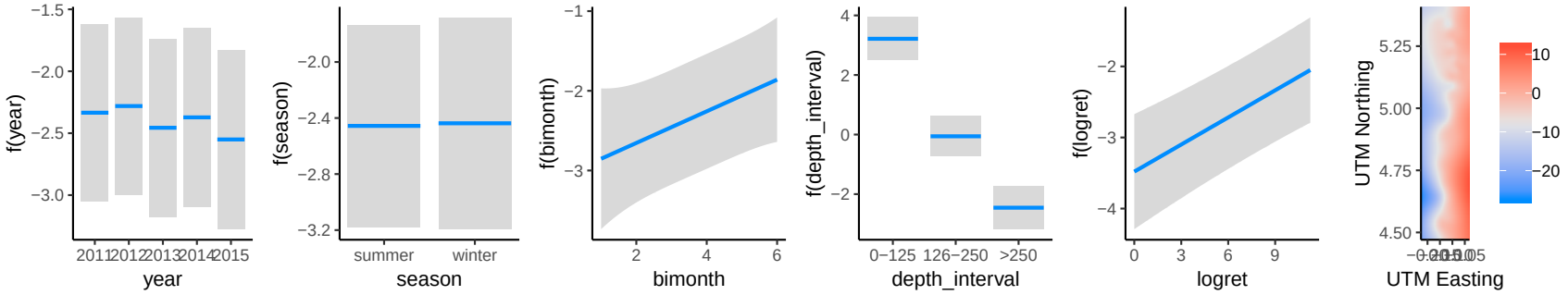
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 11727.1
          % Var explained: 28.81
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.213 Deviance explained = 75.9% -REML = 65965 Scale est. = 55.075 n = 35440

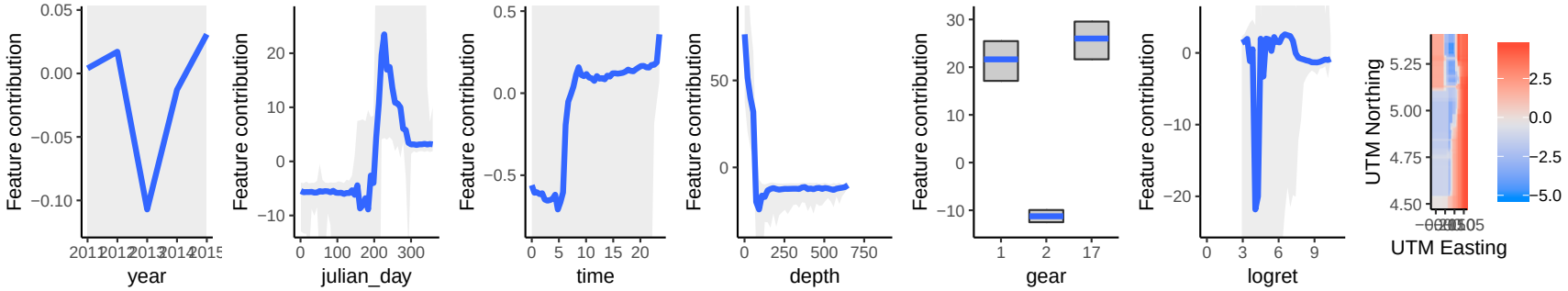



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 47.9 | 48.9 | 19.5 | 9.75e-166 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -5.35 | 0.542 | -9.87 | 6.04e-23 | *** |
| seasonwinter | 0.0186 | 0.162 | 0.115 | 0.909 | |
| bimonth | 0.198 | 0.26 | 0.763 | 0.445 | |
| I(bimonth^2) | 6.62e-05 | 0.0336 | 0.00197 | 0.998 | |
| year2012 | 0.0538 | 0.0808 | 0.666 | 0.506 | |
| year2013 | -0.122 | 0.0853 | -1.42 | 0.154 | |
| year2014 | -0.0376 | 0.0877 | -0.429 | 0.668 | |
| year2015 | -0.216 | 0.0901 | -2.4 | 0.0165 | * |
| depth_interval0-125 | 5.67 | 0.234 | 24.3 | 3.16e-129 | *** |
| depth_interval126-250 | 2.4 | 0.195 | 12.3 | 1.03e-34 | *** |
| logret | 0.127 | 0.0246 | 5.16 | 2.5e-07 | *** |

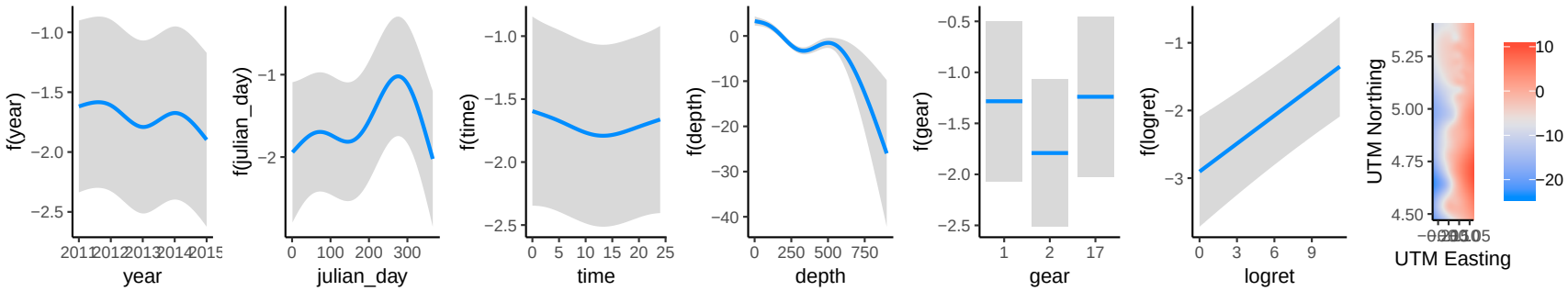
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 10642.64
          % Var explained: 35.39
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = 0.231 Deviance explained = 77.3% -REML = 65494 Scale est. = 50.523 n = 35440



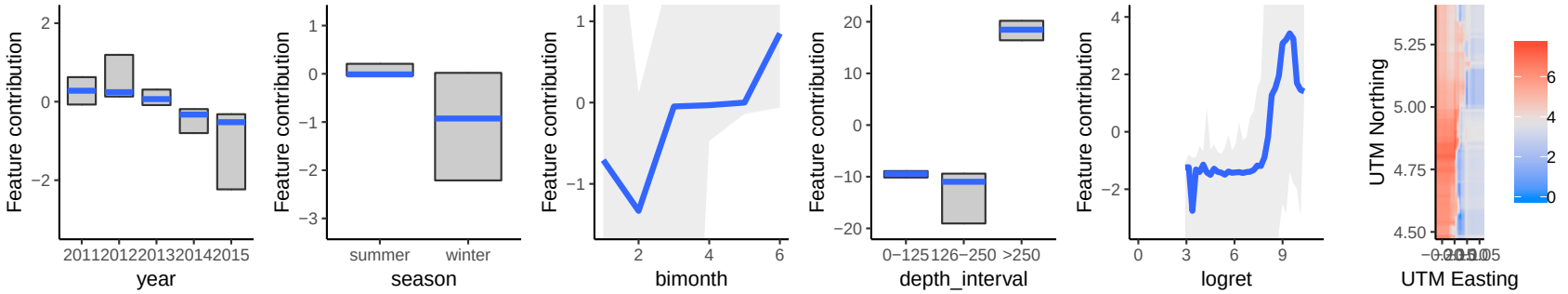

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 47.8 | 48.9 | 13.9 | 6.66e-111 | *** |
| s(year) | 3.89 | 3.99 | 4.3 | 0.00226 | ** |
| s(depth) | 3.97 | 4 | 104 | 1.55e-88 | *** |
| s(julian_day) | 3.97 | 4 | 29.3 | 2.62e-24 | *** |
| s(time) | 2.87 | 3.39 | 1.01 | 0.395 | |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -2.05 | 0.238 | -8.63 | 6.21e-18 | *** |
| gear2 | -0.508 | 0.16 | -3.18 | 0.00148 | ** |
| gear17 | 0.0437 | 0.0594 | 0.735 | 0.462 | |
| logret | 0.138 | 0.0241 | 5.73 | 1.02e-08 | *** |

## Species 6: Grenadier

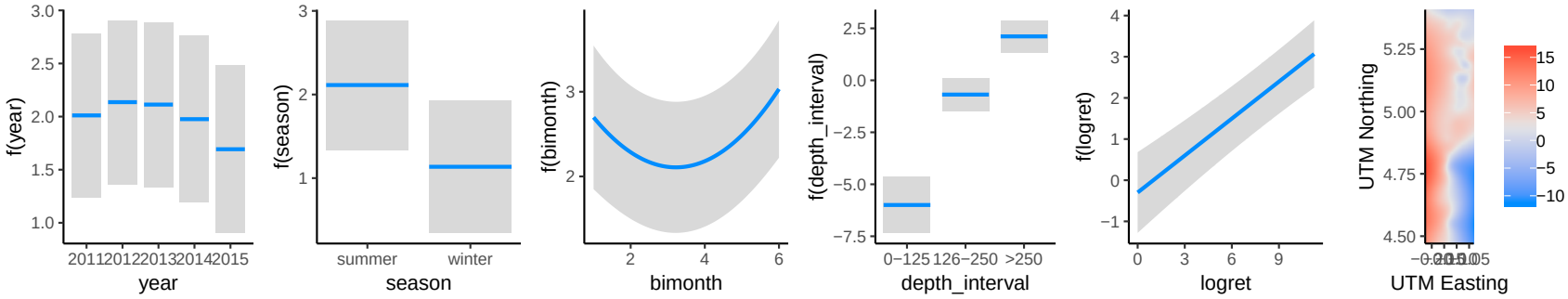
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 18071.56
          % Var explained: 49.32
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = -241 Deviance explained = 66.8% -REML = 63079 Scale est. = 133.84 n = 35440

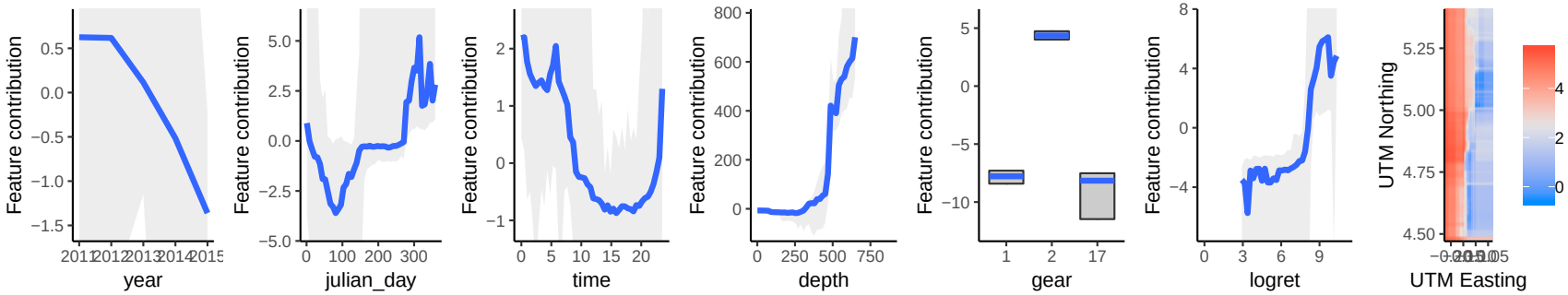



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 48 | 48.9 | 34.4 | 8.71000001824745e-316 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | 1.6 | 0.462 | 3.47 | 0.000516 | *** |
| seasonwinter | -0.977 | 0.131 | -7.48 | 7.64e-14 | *** |
| bimonth | -0.771 | 0.181 | -4.27 | 1.95e-05 | *** |
| I(bimonth^2) | 0.12 | 0.0244 | 4.91 | 9.18e-07 | *** |
| year2012 | 0.125 | 0.105 | 1.19 | 0.235 | |
| year2013 | 0.102 | 0.106 | 0.964 | 0.335 | |
| year2014 | -0.0354 | 0.118 | -0.299 | 0.765 | |
| year2015 | -0.318 | 0.13 | -2.46 | 0.014 | * |
| depth_interval0-125 | -8.11 | 0.58 | -14 | 2.96e-44 | *** |
| depth_interval126-250 | -2.8 | 0.137 | -20.5 | 7.95e-93 | *** |
| logret | 0.299 | 0.0394 | 7.6 | 2.95e-14 | *** |

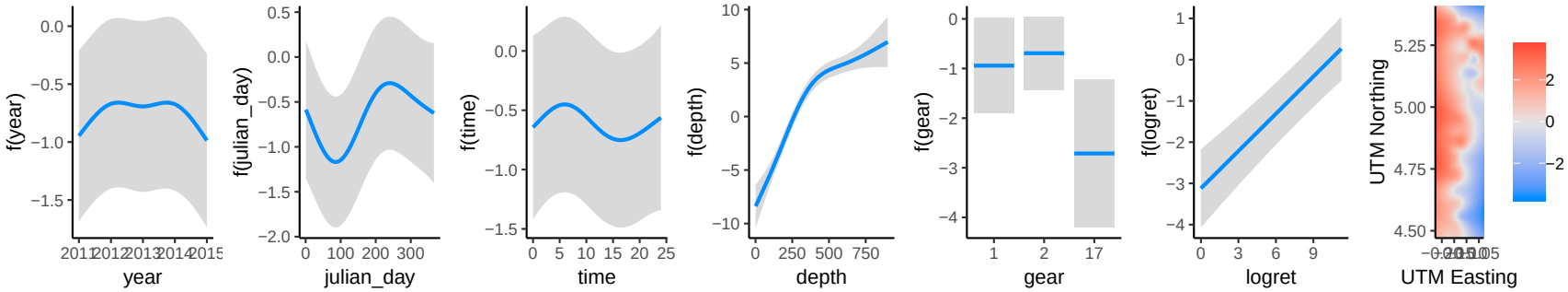
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 15794.11
          % Var explained: 55.71
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = 0.397 Deviance explained = 78% -REML = 58132 Scale est. = 102.36 n = 35440



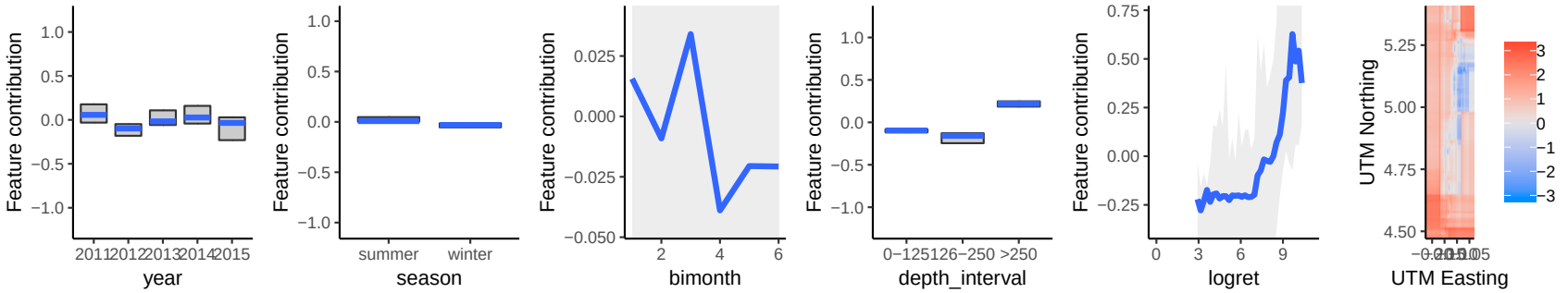

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 45.7 | 48.1 | 11.6 | 3.84e-87 | *** |
| s(year) | 3.85 | 3.99 | 3.98 | 0.00323 | ** |
| s(depth) | 3.97 | 4 | 371 | 2.52000000822904e-316 | *** |
| s(julian_day) | 3.97 | 4 | 18.2 | 5.15e-15 | *** |
| s(time) | 3.79 | 3.97 | 2.32 | 0.0554 | . |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -3.54 | 0.435 | -8.14 | 3.97e-16 | *** |
| gear2 | 0.25 | 0.322 | 0.776 | 0.438 | |
| gear17 | -1.77 | 0.685 | -2.58 | 0.00975 | ** |
| logret | 0.301 | 0.0382 | 7.89 | 3.01e-15 | *** |

## Species 7: Octopus Unid

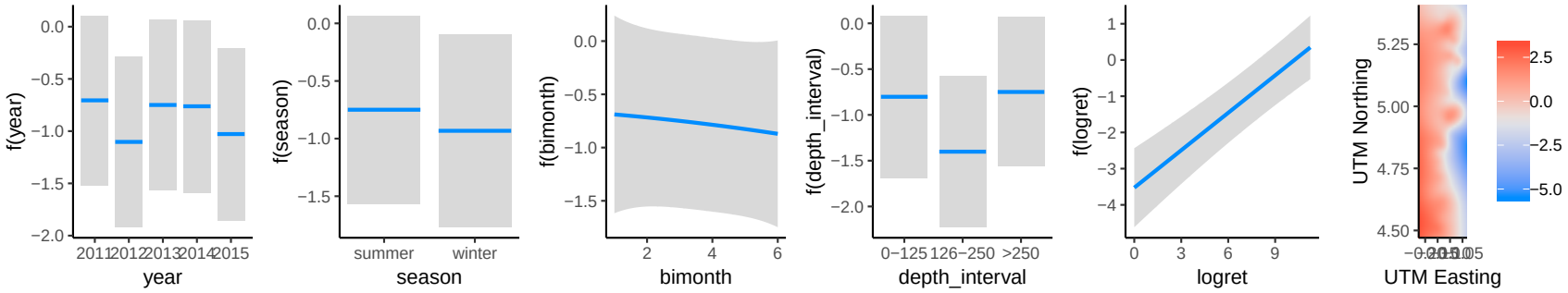
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 36.92363
          % Var explained: 2.19
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.0433 Deviance explained = 20.2% -REML = 27714 Scale est. = 56.927 n = 35440

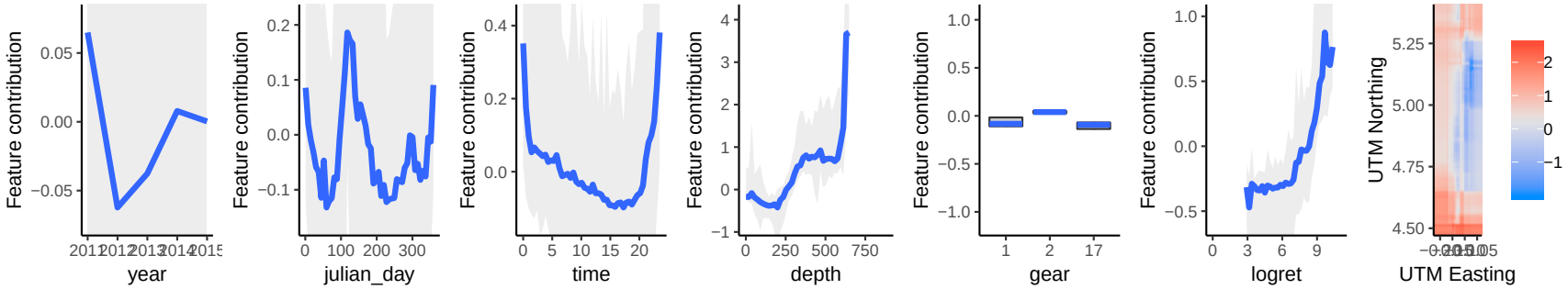



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 43.5 | 47.7 | 7.92 | 1.99e-52 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -2.76 | 0.559 | -4.95 | 7.61e-07 | *** |
| seasonwinter | -0.183 | 0.164 | -1.12 | 0.264 | |
| bimonth | -0.0225 | 0.226 | -0.0993 | 0.921 | |
| I(bimonth^2) | -0.002 | 0.0304 | -0.0658 | 0.948 | |
| year2012 | -0.398 | 0.137 | -2.91 | 0.00363 | ** |
| year2013 | -0.0443 | 0.126 | -0.35 | 0.726 | |
| year2014 | -0.0568 | 0.136 | -0.418 | 0.676 | |
| year2015 | -0.323 | 0.143 | -2.25 | 0.0242 | * |
| depth_interval0-125 | -0.0528 | 0.219 | -0.241 | 0.809 | |
| depth_interval126-250 | -0.652 | 0.125 | -5.24 | 1.65e-07 | *** |
| logret | 0.345 | 0.0474 | 7.27 | 3.76e-13 | *** |

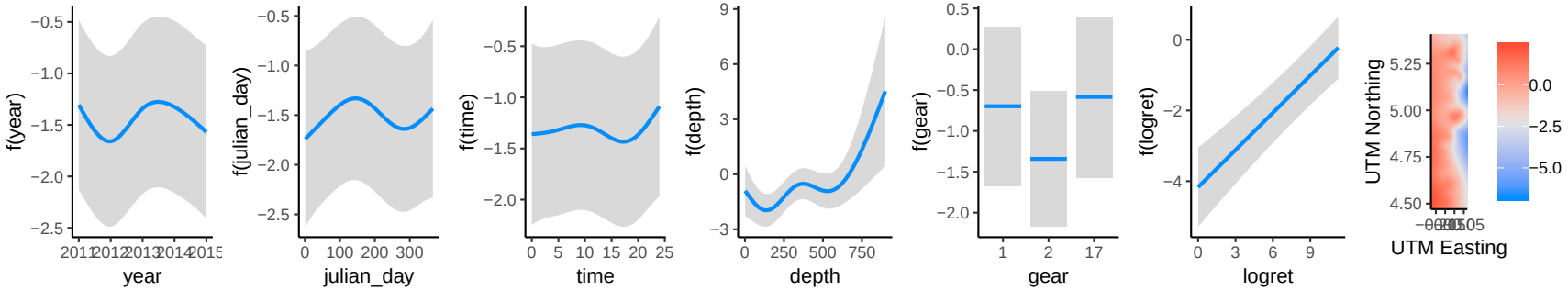
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 36.05839
          % Var explained: 4.48
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = 0.0407 Deviance explained = 21% -REML = 27672 Scale est. = 55.784 n = 35440



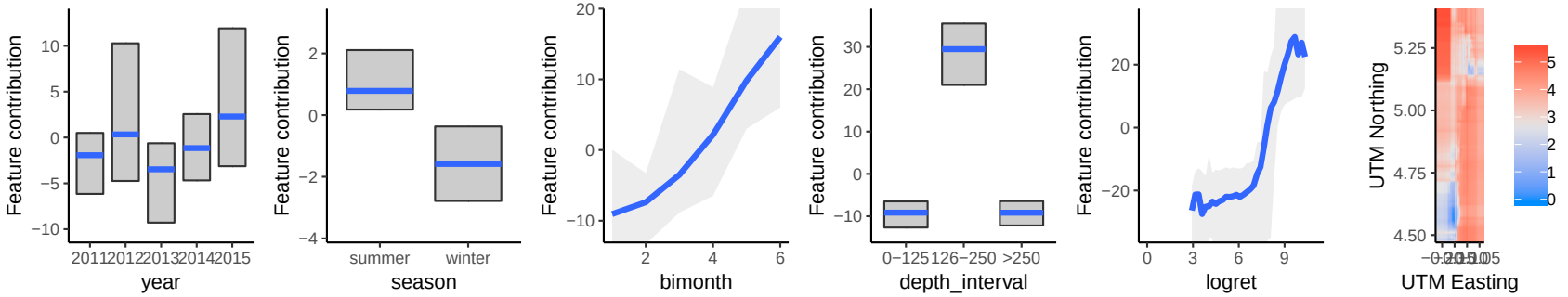

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 44.4 | 48 | 7.53 | 2.21e-49 | *** |
| s(year) | 3.84 | 3.98 | 2.7 | 0.022 | * |
| s(depth) | 3.96 | 4 | 12.4 | 7.68e-10 | *** |
| s(julian_day) | 3.6 | 3.91 | 1.61 | 0.134 | |
| s(time) | 3.52 | 3.87 | 0.981 | 0.513 | |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -2.96 | 0.427 | -6.95 | 3.71e-12 | *** |
| gear2 | -0.644 | 0.272 | -2.37 | 0.018 | * |
| gear17 | 0.115 | 0.183 | 0.628 | 0.53 | |
| logret | 0.351 | 0.0475 | 7.39 | 1.49e-13 | *** |

## Species 8: Pacific Hake

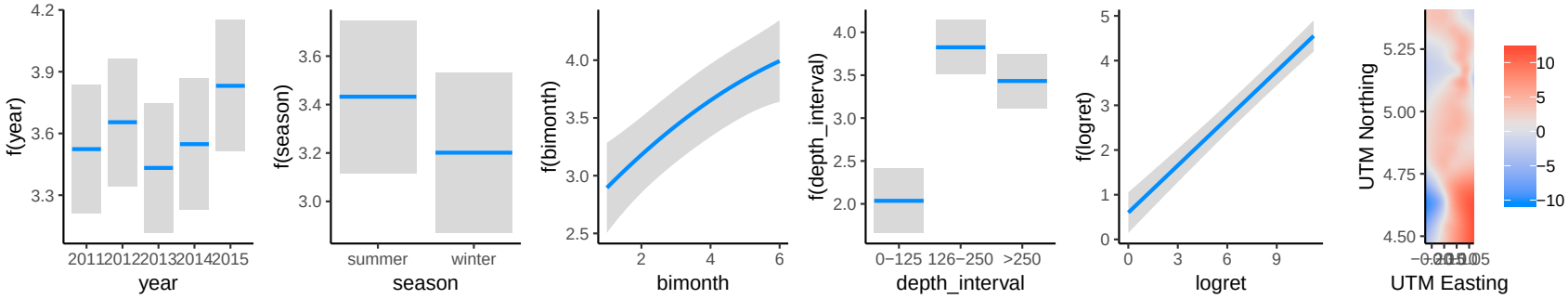
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 18788.2
          % Var explained: 20.61
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.0796 Deviance explained = 22.8% -REML = 1.2473e+05 Scale est. = 49.425 n = 35440

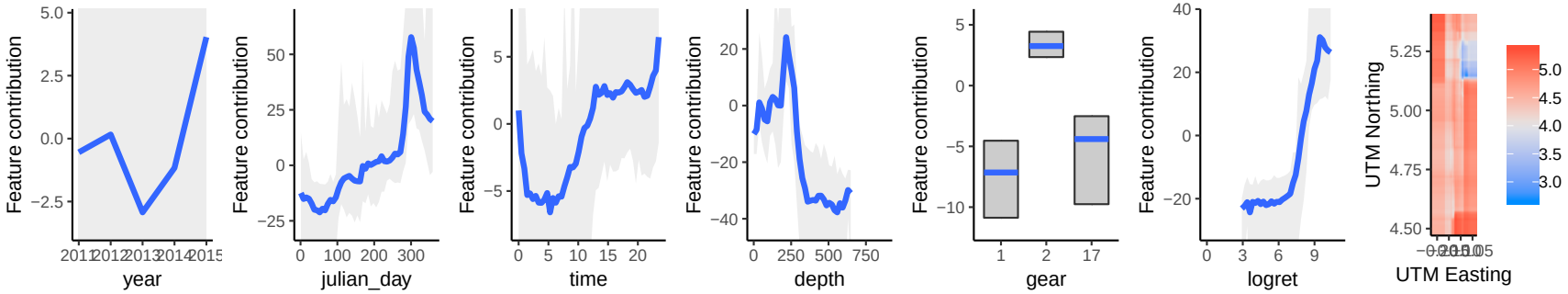



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 48.7 | 49 | 21.1 | 2.24e-182 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | 0.00278 | 0.277 | 0.01 | 0.992 | |
| seasonwinter | -0.231 | 0.0825 | -2.8 | 0.00511 | ** |
| bimonth | 0.334 | 0.119 | 2.81 | 0.00496 | ** |
| I(bimonth^2) | -0.0164 | 0.0159 | -1.03 | 0.301 | |
| year2012 | 0.131 | 0.0643 | 2.03 | 0.0419 | * |
| year2013 | -0.0913 | 0.0637 | -1.43 | 0.152 | |
| year2014 | 0.0242 | 0.0684 | 0.354 | 0.723 | |
| year2015 | 0.308 | 0.0679 | 4.54 | 5.78e-06 | *** |
| depth_interval0-125 | -1.4 | 0.117 | -12 | 5.58e-33 | *** |
| depth_interval126-250 | 0.393 | 0.0567 | 6.93 | 4.36e-12 | *** |
| logret | 0.352 | 0.0216 | 16.3 | 2.56e-59 | *** |

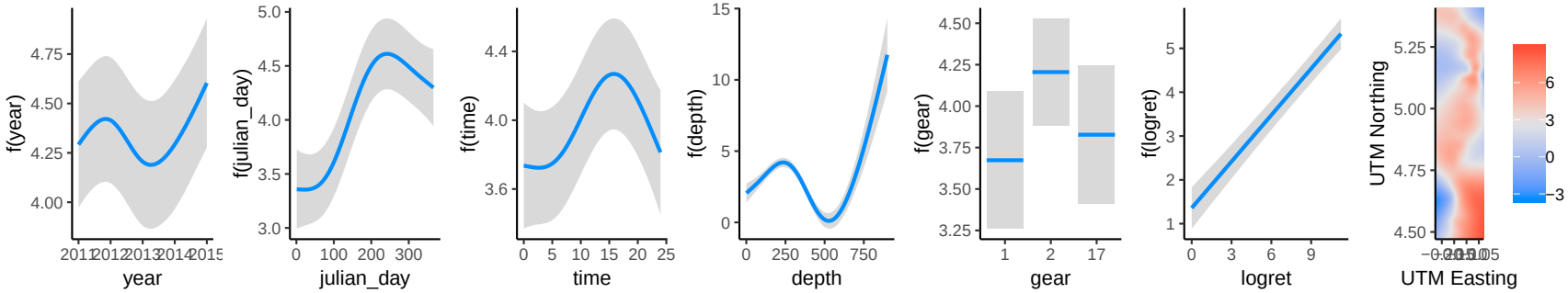
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 17934.13
          % Var explained: 24.22
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = -0.0354 Deviance explained = 27.4% -REML = 1.2361e+05 Scale est. = 48.638 n = 35440



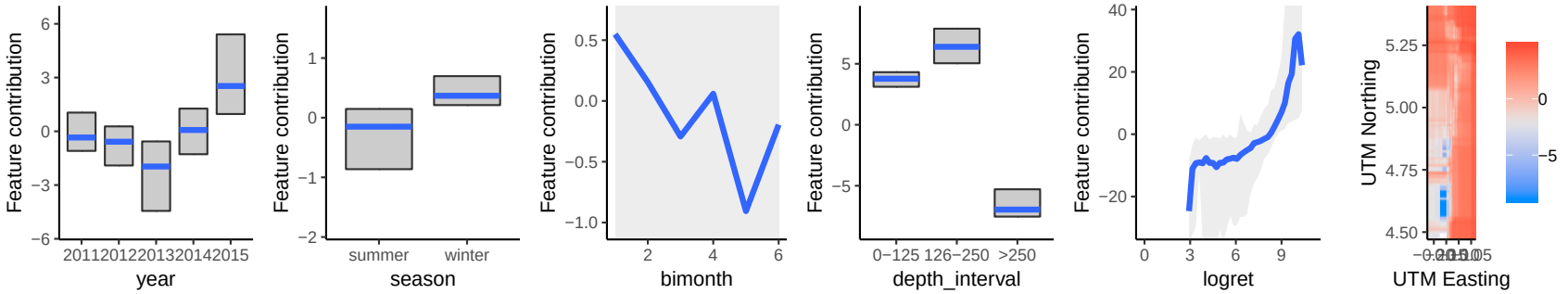

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 48.5 | 49 | 15.9 | 2.96e-130 | *** |
| s(year) | 3.89 | 3.99 | 10.5 | 1.19e-08 | *** |
| s(depth) | 3.99 | 4 | 138 | 3.94e-117 | *** |
| s(julian_day) | 3.95 | 4 | 92.4 | 2.8e-78 | *** |
| s(time) | 3.88 | 3.99 | 20.4 | 8.62e-17 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -0.0724 | 0.199 | -0.363 | 0.716 | |
| gear2 | 0.532 | 0.133 | 3.98 | 6.82e-05 | *** |
| gear17 | 0.154 | 0.0848 | 1.81 | 0.0697 | . |
| logret | 0.353 | 0.0218 | 16.2 | 8.02e-59 | *** |

## Species 9: Pacific Halibut

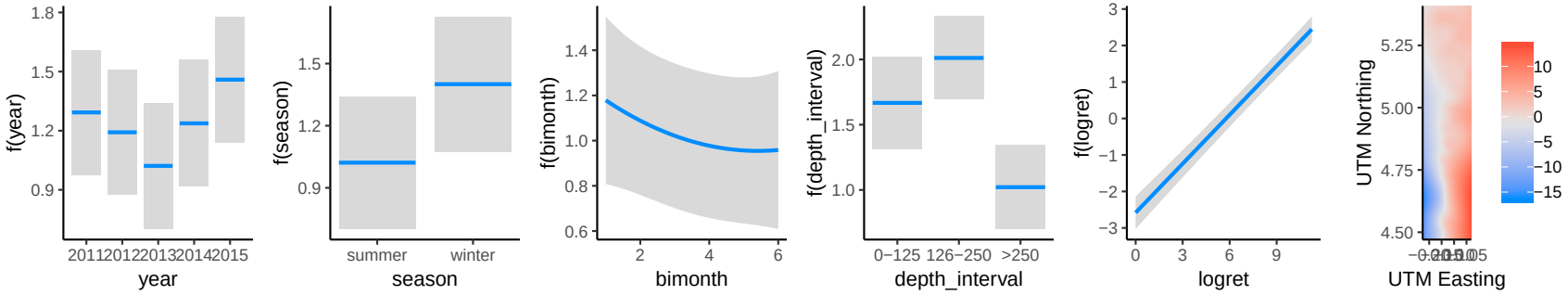
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 3041.369
          % Var explained: 18.98
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.103 Deviance explained = 27.3% -REML = 74265 Scale est. = 44.927 n = 35440

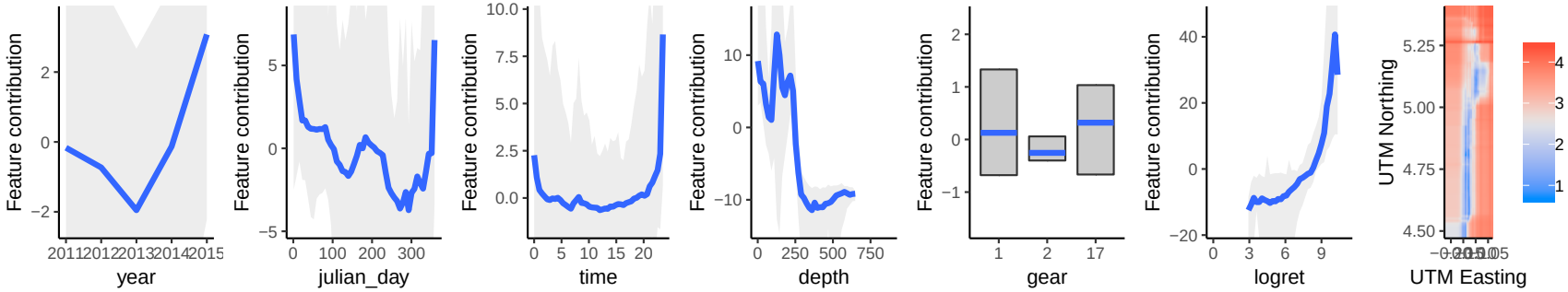



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 47.7 | 48.9 | 43.8 | 0 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -1.62 | 0.239 | -6.78 | 1.2e-11 | *** |
| seasonwinter | 0.379 | 0.0713 | 5.31 | 1.08e-07 | *** |
| bimonth | -0.124 | 0.0959 | -1.3 | 0.195 | |
| I(bimonth^2) | 0.0115 | 0.0129 | 0.891 | 0.373 | |
| year2012 | -0.101 | 0.0565 | -1.79 | 0.0742 | . |
| year2013 | -0.271 | 0.0563 | -4.82 | 1.47e-06 | *** |
| year2014 | -0.0556 | 0.0595 | -0.935 | 0.35 | |
| year2015 | 0.166 | 0.0576 | 2.89 | 0.00386 | ** |
| depth_interval0-125 | 0.646 | 0.0996 | 6.49 | 8.95e-11 | *** |
| depth_interval126-250 | 0.99 | 0.0524 | 18.9 | 3.35e-79 | *** |
| logret | 0.447 | 0.0203 | 22.1 | 3.85e-107 | *** |

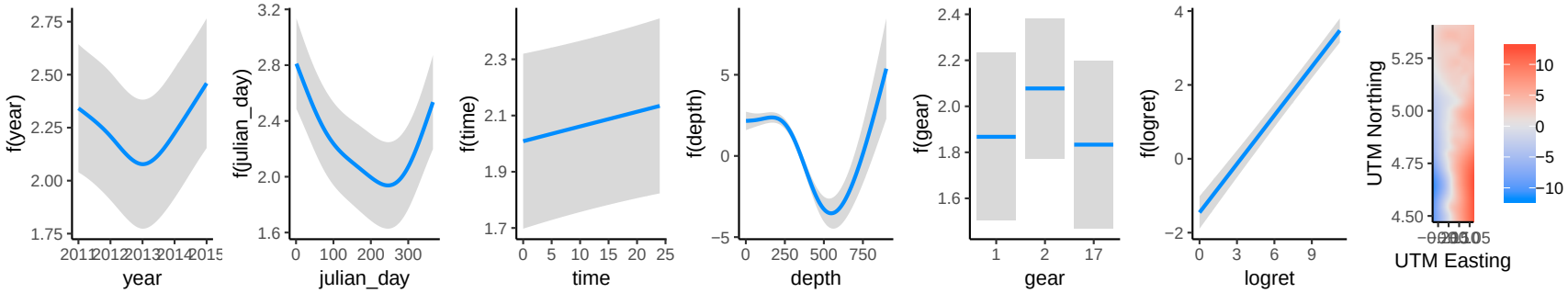
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 2970.634
          % Var explained: 20.86
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = 0.109 Deviance explained = 29.3% -REML = 73942 Scale est. = 41.378 n = 35440



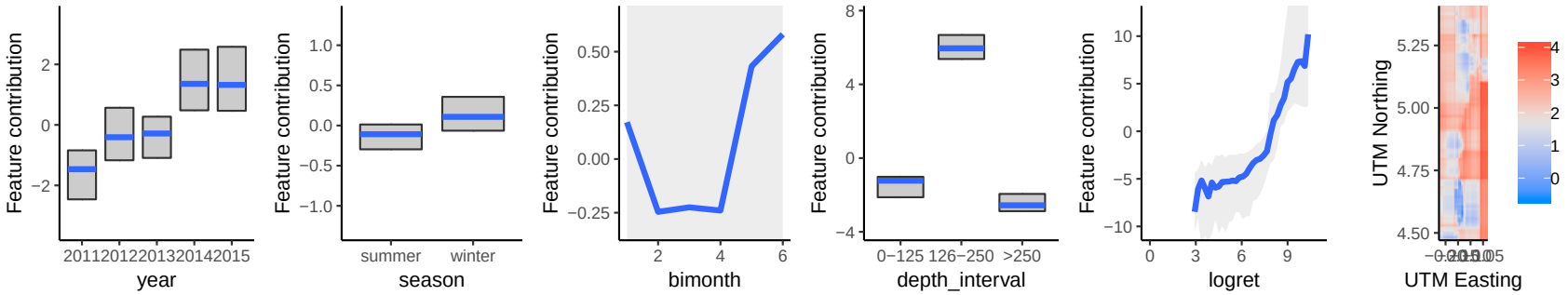

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 47.2 | 48.8 | 41.1 | 0 | *** |
| s(year) | 3.59 | 3.9 | 15.1 | 5.61e-12 | *** |
| s(depth) | 3.98 | 4 | 140 | 2.4e-119 | *** |
| s(julian_day) | 3.83 | 3.98 | 26.3 | 6.75e-22 | *** |
| s(time) | 1.01 | 1.02 | 3.54 | 0.0592 | . |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -1.55 | 0.178 | -8.73 | 2.76e-18 | *** |
| gear2 | 0.21 | 0.105 | 2 | 0.0453 | * |
| gear17 | -0.0341 | 0.0602 | -0.566 | 0.571 | |
| logret | 0.438 | 0.0196 | 22.4 | 3.17e-110 | *** |

## Species 10: Sandpaper Skate

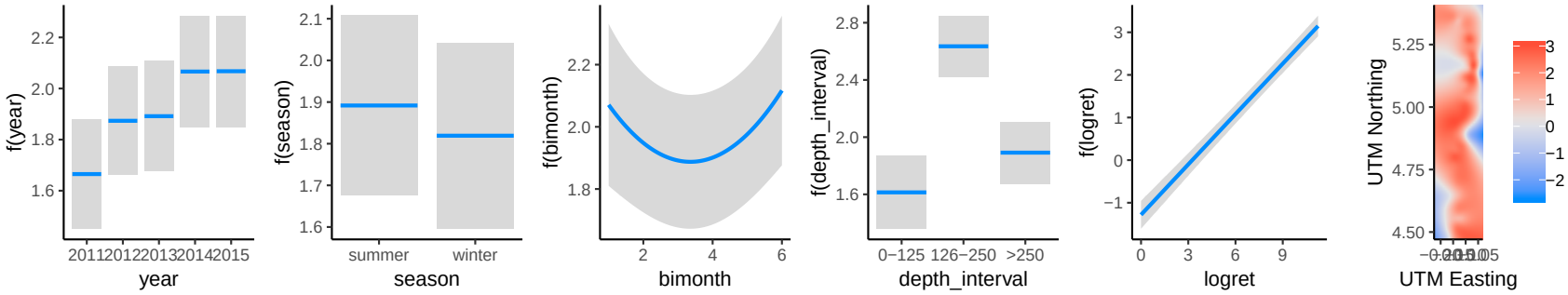
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 385.3107
          % Var explained: 22.37
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.125 Deviance explained = 20% -REML = 92531 Scale est. = 20.414 n = 35440

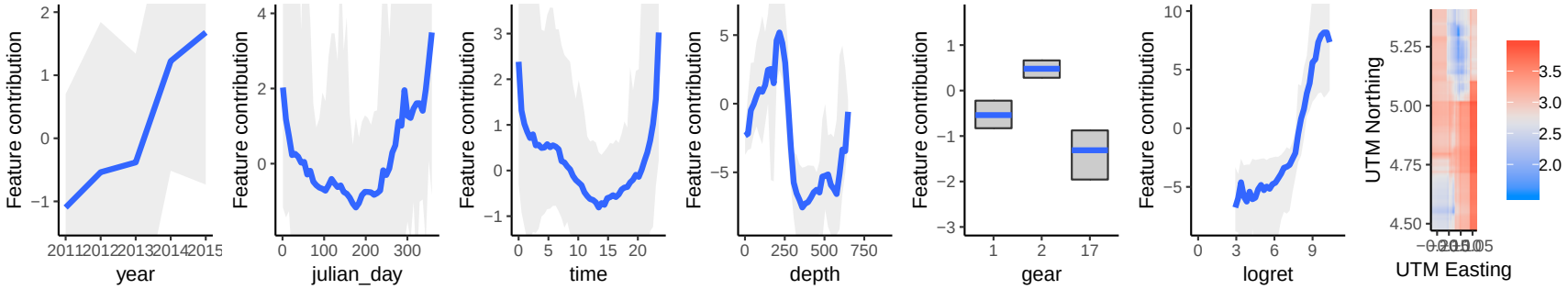



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 48.3 | 49 | 28.5 | 1.56e-256 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -1.17 | 0.19 | -6.13 | 8.83e-10 | *** |
| seasonwinter | -0.0725 | 0.0552 | -1.31 | 0.189 | |
| bimonth | -0.221 | 0.0756 | -2.92 | 0.00345 | ** |
| I(bimonth^2) | 0.0329 | 0.0102 | 3.24 | 0.00121 | ** |
| year2012 | 0.209 | 0.0462 | 4.52 | 6.3e-06 | *** |
| year2013 | 0.227 | 0.0449 | 5.05 | 4.55e-07 | *** |
| year2014 | 0.401 | 0.0471 | 8.52 | 1.64e-17 | *** |
| year2015 | 0.403 | 0.0476 | 8.47 | 2.65e-17 | *** |
| depth_interval0-125 | -0.278 | 0.0803 | -3.46 | 0.00054 | *** |
| depth_interval126-250 | 0.744 | 0.0387 | 19.2 | 8.38e-82 | *** |
| logret | 0.394 | 0.0162 | 24.3 | 2.52e-129 | *** |

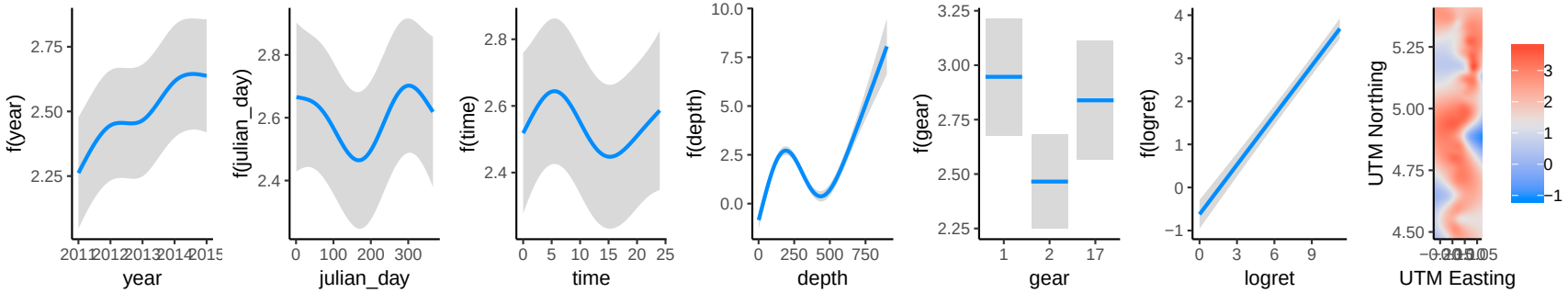
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 371.2104
          % Var explained: 25.21
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = 0.0892 Deviance explained = 23.4% -REML = 91802 Scale est. = 19.723 n = 35440



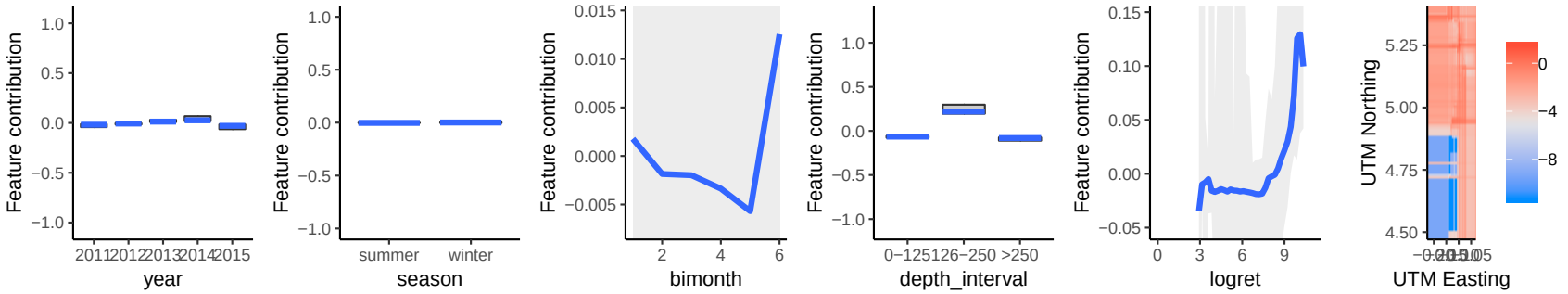

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 47.9 | 48.9 | 26.7 | 4.88e-238 | *** |
| s(year) | 3.76 | 3.97 | 20.7 | 6.69e-17 | *** |
| s(depth) | 4 | 4 | 277 | 8.25e-236 | *** |
| s(julian_day) | 3.83 | 3.98 | 6.43 | 2.58e-05 | *** |
| s(time) | 3.73 | 3.96 | 5.01 | 0.000366 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -0.803 | 0.142 | -5.67 | 1.41e-08 | *** |
| gear2 | -0.481 | 0.0834 | -5.77 | 8.02e-09 | *** |
| gear17 | -0.108 | 0.0563 | -1.92 | 0.0551 | . |
| logret | 0.383 | 0.016 | 23.9 | 1.8e-125 | *** |

## Species 11: Rosethorn Rockfish

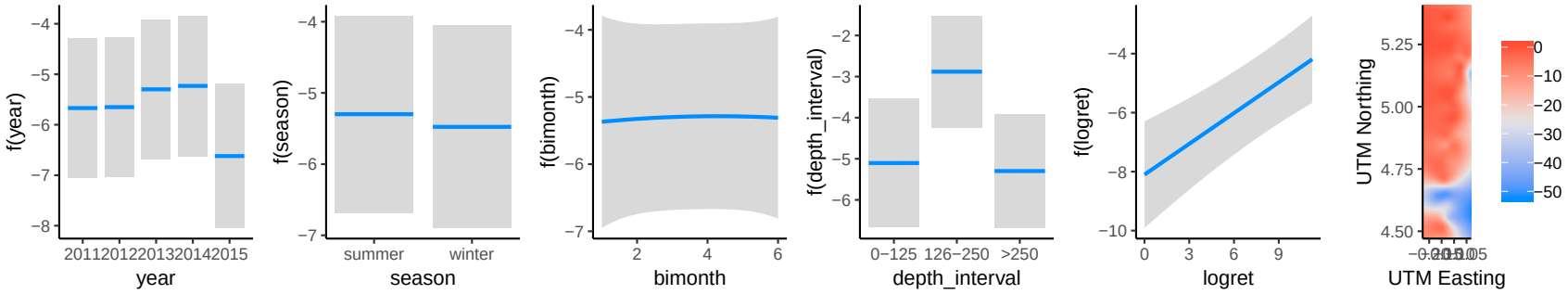
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 7.098818
          % Var explained: 17.73
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.00397 Deviance explained = 52.8% -REML = 8403.7 Scale est. = 63.336 n = 35440

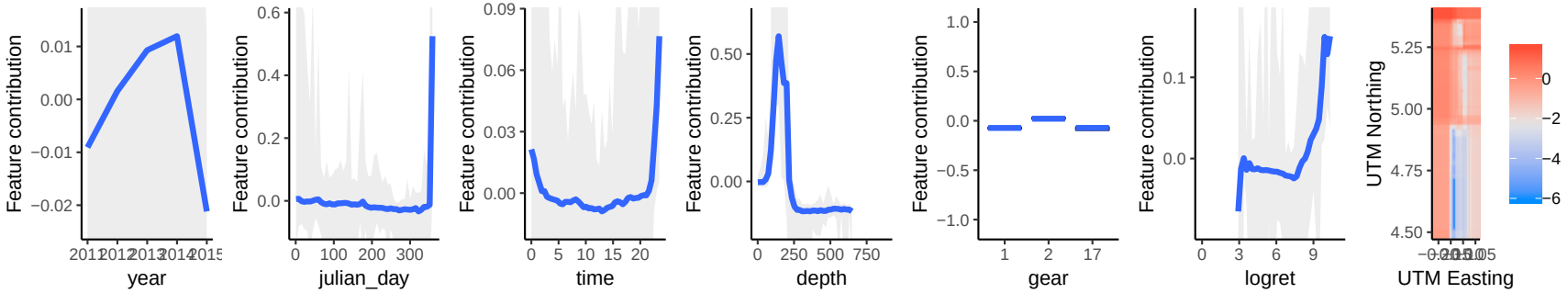



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 45.9 | 47.2 | 9.94 | 4.45e-69 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -11.1 | 1.46 | -7.61 | 2.86e-14 | *** |
| seasonwinter | -0.178 | 0.291 | -0.611 | 0.541 | |
| bimonth | 0.0664 | 0.394 | 0.168 | 0.866 | |
| I(bimonth^2) | -0.00776 | 0.0533 | -0.146 | 0.884 | |
| year2012 | 0.0185 | 0.253 | 0.0731 | 0.942 | |
| year2013 | 0.371 | 0.234 | 1.58 | 0.114 | |
| year2014 | 0.439 | 0.257 | 1.71 | 0.0873 | . |
| year2015 | -0.951 | 0.301 | -3.16 | 0.00157 | ** |
| depth_interval0-125 | 0.195 | 0.443 | 0.44 | 0.66 | |
| depth_interval126-250 | 2.42 | 0.211 | 11.4 | 2.85e-30 | *** |
| logret | 0.348 | 0.0767 | 4.54 | 5.74e-06 | *** |

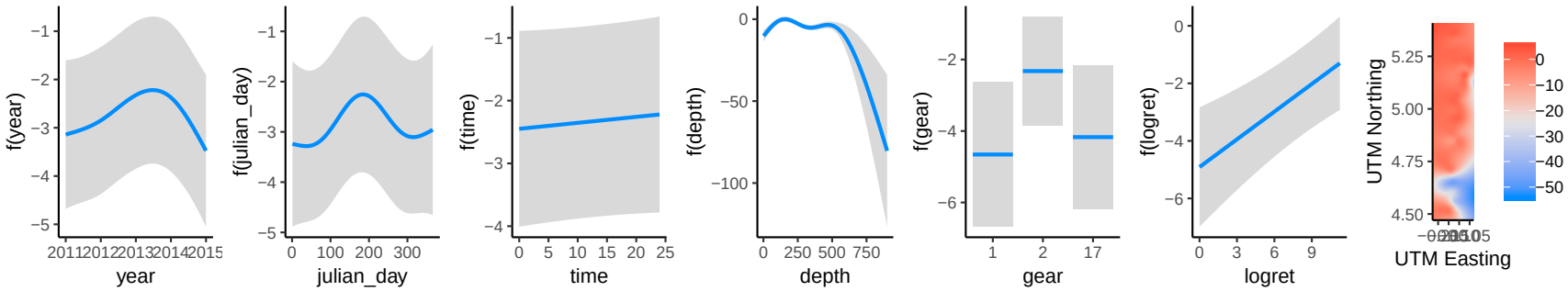
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 6.679766
          % Var explained: 22.59
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = 0.0729 Deviance explained = 59.5% -REML = 8114.9 Scale est. = 77.733 n = 35440



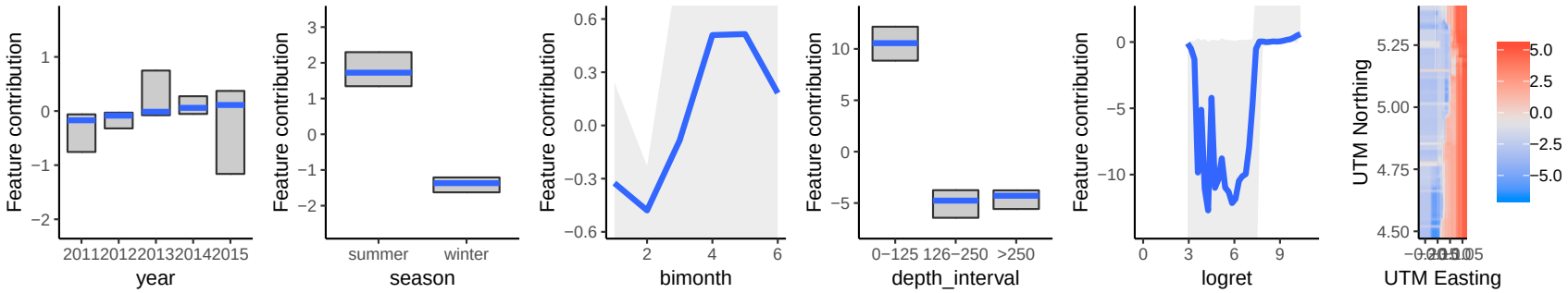

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 45.6 | 47.1 | 6.42 | 2.83e-38 | *** |
| s(year) | 3.68 | 3.94 | 5.16 | 0.000429 | *** |
| s(depth) | 3.97 | 4 | 44.7 | 1.72e-37 | *** |
| s(julian_day) | 3.77 | 3.97 | 2.44 | 0.0378 | * |
| s(time) | 1.01 | 1.01 | 0.461 | 0.499 | |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -12.6 | 1.58 | -7.99 | 1.44e-15 | *** |
| gear2 | 2.33 | 0.684 | 3.41 | 0.00064 | *** |
| gear17 | 0.487 | 0.487 | 0.999 | 0.318 | |
| logret | 0.321 | 0.0889 | 3.61 | 0.000306 | *** |

## Species 12: Slender Sole

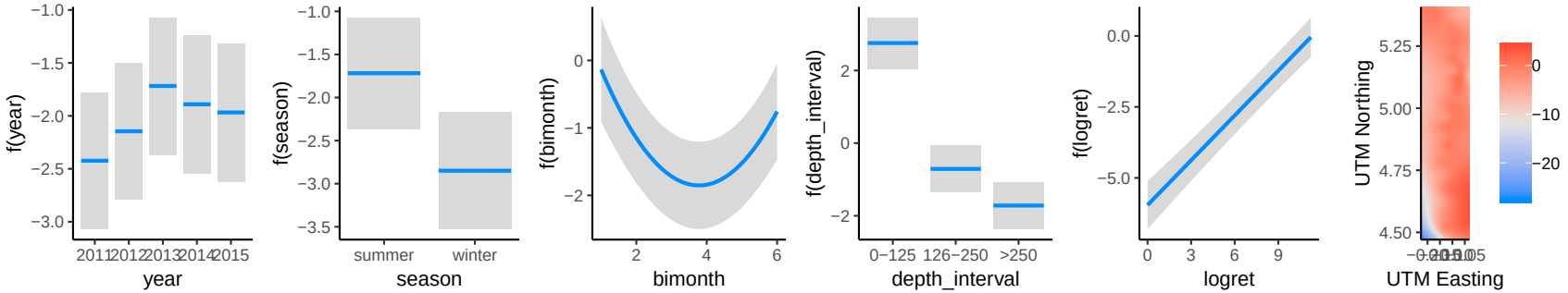
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 2193.15
          % Var explained: 28.43
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.129 Deviance explained = 47.3% -REML = 51504 Scale est. = 47.418 n = 35440

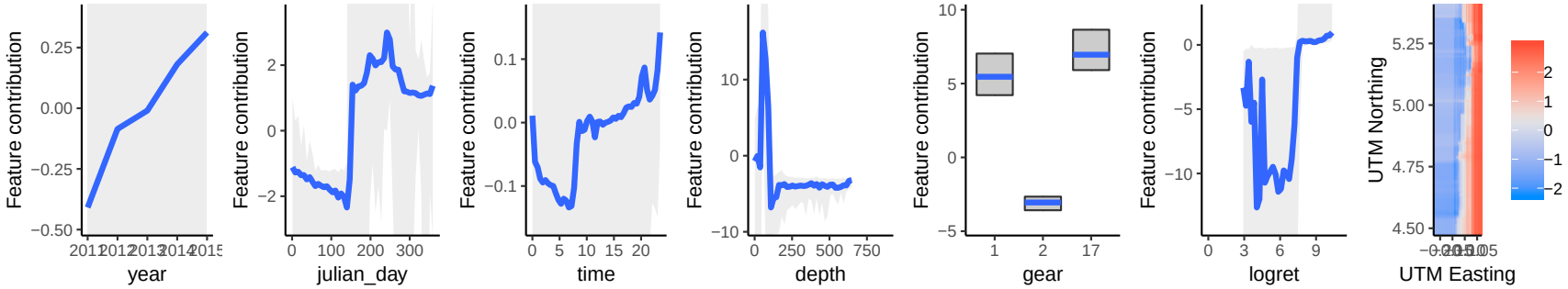



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 48 | 48.9 | 13.1 | 9.18e-104 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -3.53 | 0.495 | -7.12 | 1.08e-12 | *** |
| seasonwinter | -1.13 | 0.159 | -7.11 | 1.14e-12 | *** |
| bimonth | -1.68 | 0.218 | -7.69 | 1.47e-14 | *** |
| I(bimonth^2) | 0.222 | 0.0292 | 7.62 | 2.52e-14 | *** |
| year2012 | 0.278 | 0.114 | 2.44 | 0.0147 | * |
| year2013 | 0.705 | 0.11 | 6.44 | 1.23e-10 | *** |
| year2014 | 0.533 | 0.116 | 4.57 | 4.78e-06 | *** |
| year2015 | 0.456 | 0.117 | 3.88 | 0.000103 | *** |
| depth_interval0-125 | 4.47 | 0.199 | 22.5 | 4.96e-111 | *** |
| depth_interval126-250 | 1.01 | 0.122 | 8.28 | 1.31e-16 | *** |
| logret | 0.526 | 0.0359 | 14.7 | 1.51e-48 | *** |

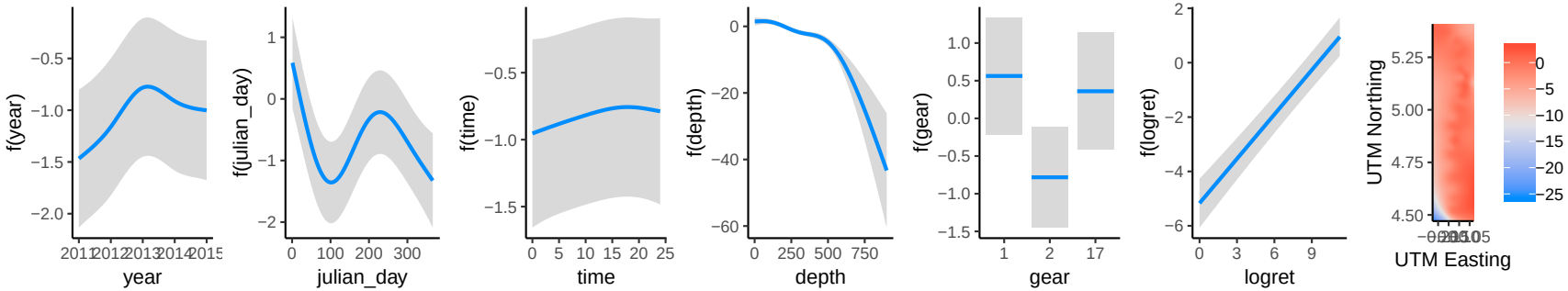
**RF$_{\text{Nonlinear}}$**

```
Mean of squared residuals: 2006.376
          % Var explained: 34.53
```




**GAM$_{\text{Nonlinear}}$**

R-sq.(adj) = 0.144 Deviance explained = 48.6% -REML = 51284 Scale est. = 51.074 n = 35440



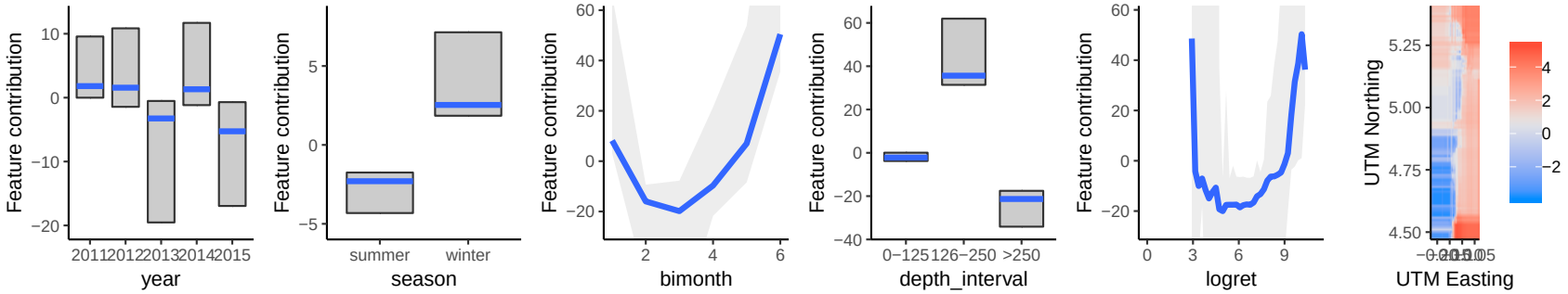

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 47.9 | 48.9 | 10.2 | 1.47e-75 | *** |
| s(year) | 3.73 | 3.96 | 10.1 | 4.15e-08 | *** |
| s(depth) | 3.95 | 4 | 59.9 | 2.91e-50 | *** |
| s(julian_day) | 3.98 | 4 | 29.4 | 1.56e-24 | *** |
| s(time) | 2.05 | 2.53 | 0.809 | 0.434 | |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -3.89 | 0.341 | -11.4 | 4.17e-30 | *** |
| gear2 | -1.34 | 0.211 | -6.37 | 1.93e-10 | *** |
| gear17 | -0.203 | 0.101 | -2 | 0.0452 | * |
| logret | 0.544 | 0.038 | 14.3 | 2.5e-46 | *** |

## Species 13: Spiny Dogfish Shark

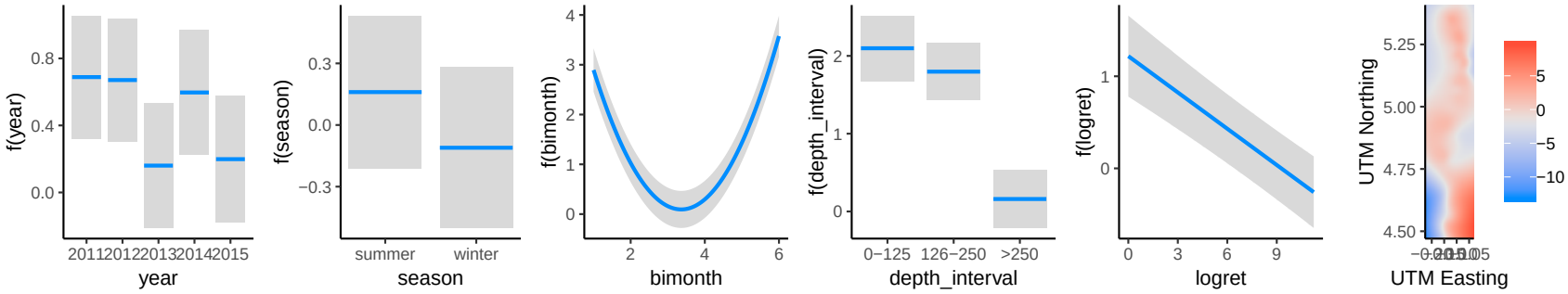
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 444124.3
          % Var explained: 25.06
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.0248 Deviance explained = 40.6% -REML = 1.0483e+05 Scale est. = 64.451 n = 35440

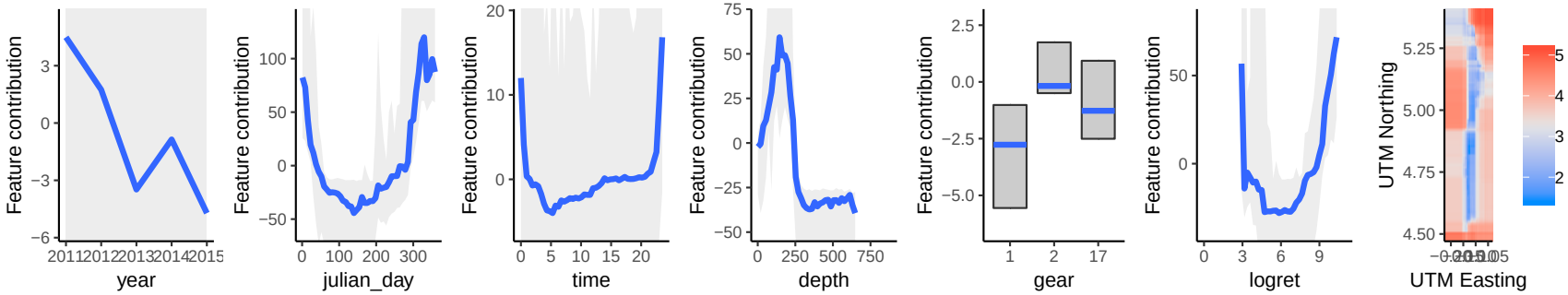



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 48.2 | 49 | 40.8 | 0 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | 7.67 | 0.255 | 30.1 | 2.23e-196 | *** |
| seasonwinter | -0.271 | 0.0944 | -2.87 | 0.00412 | ** |
| bimonth | -3.37 | 0.124 | -27.2 | 1.46e-161 | *** |
| I(bimonth^2) | 0.501 | 0.0169 | 29.7 | 5.82e-192 | *** |
| year2012 | -0.0176 | 0.0692 | -0.255 | 0.799 | |
| year2013 | -0.528 | 0.069 | -7.65 | 1.98e-14 | *** |
| year2014 | -0.0918 | 0.0724 | -1.27 | 0.204 | |
| year2015 | -0.49 | 0.0753 | -6.5 | 8.04e-11 | *** |
| depth_interval0-125 | 1.94 | 0.124 | 15.6 | 8.99e-55 | *** |
| depth_interval126-250 | 1.64 | 0.0654 | 25 | 6.35e-137 | *** |
| logret | -0.131 | 0.0158 | -8.31 | 9.88e-17 | *** |

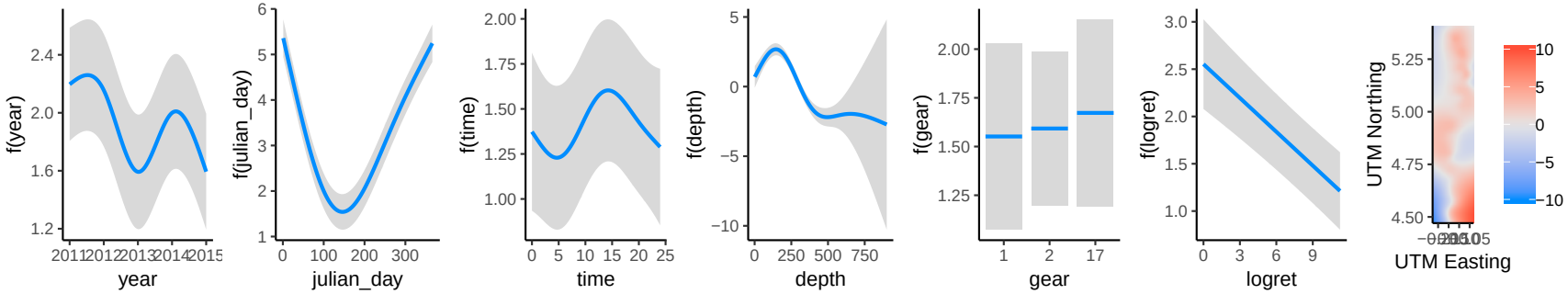
**RF$_{\text{Nonlinear}}$**

```
Mean of squared residuals: 468651
          % Var explained: 20.92
```




**GAM$_{\text{Nonlinear}}$**

R-sq.(adj) = 0.0454 Deviance explained = 43.8% -REML = 1.0398e+05 Scale est. = 69.251 n = 35440



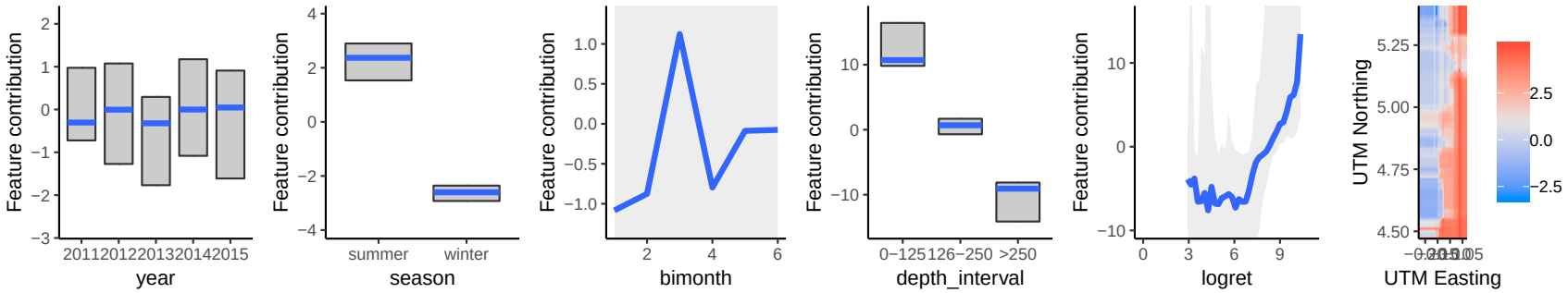

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 47.8 | 48.9 | 30.2 | 4.04e-273 | *** |
| s(year) | 3.98 | 4 | 30.3 | 3.05e-25 | *** |
| s(depth) | 3.96 | 4 | 218 | 2.39e-185 | *** |
| s(julian_day) | 3.99 | 4 | 514 | 0 | *** |
| s(time) | 3.84 | 3.98 | 6.37 | 3.26e-05 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | 3.65 | 0.168 | 21.8 | 2.35e-104 | *** |
| gear2 | 0.0409 | 0.142 | 0.288 | 0.773 | |
| gear17 | 0.121 | 0.0833 | 1.45 | 0.147 | |
| logret | -0.119 | 0.0167 | -7.15 | 8.76e-13 | *** |

## Species 14: Spotted Ratfish

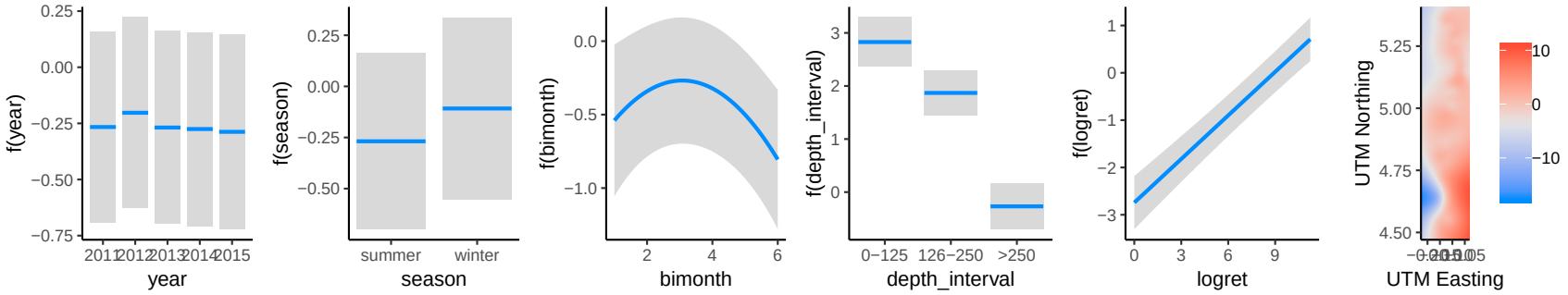
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 6941.341
          % Var explained: 7.86
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.0237 Deviance explained = 34.4% -REML = 88372 Scale est. = 46.446 n = 35440

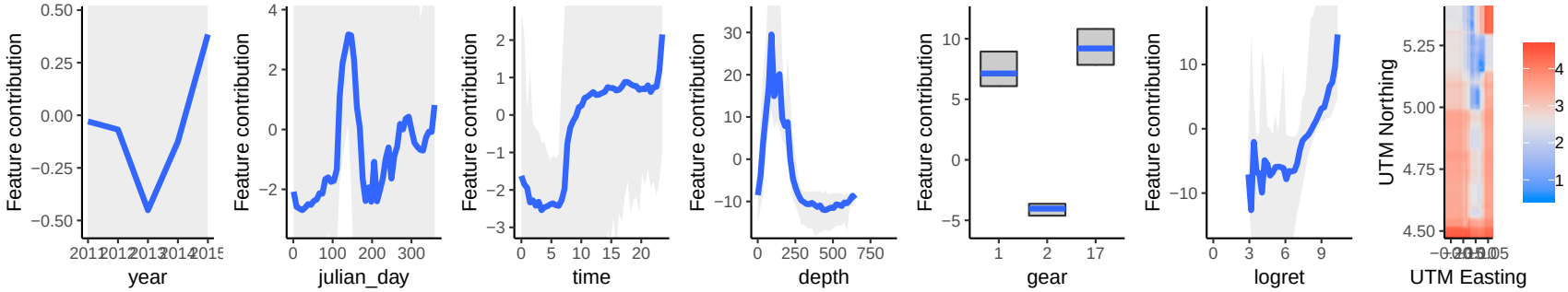



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 48.4 | 49 | 23.6 | 3.53e-205 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -2.69 | 0.332 | -8.09 | 5.94e-16 | *** |
| seasonwinter | 0.16 | 0.103 | 1.56 | 0.118 | |
| bimonth | 0.388 | 0.146 | 2.66 | 0.00777 | ** |
| I(bimonth^2) | -0.063 | 0.0194 | -3.25 | 0.00115 | ** |
| year2012 | 0.0635 | 0.0759 | 0.836 | 0.403 | |
| year2013 | -0.00229 | 0.0746 | -0.0306 | 0.976 | |
| year2014 | -0.00898 | 0.0789 | -0.114 | 0.909 | |
| year2015 | -0.0214 | 0.0793 | -0.27 | 0.787 | |
| depth_interval0-125 | 3.1 | 0.131 | 23.6 | 5.54e-122 | *** |
| depth_interval126-250 | 2.14 | 0.0778 | 27.5 | 2.39e-164 | *** |
| logret | 0.307 | 0.024 | 12.8 | 1.76e-37 | *** |

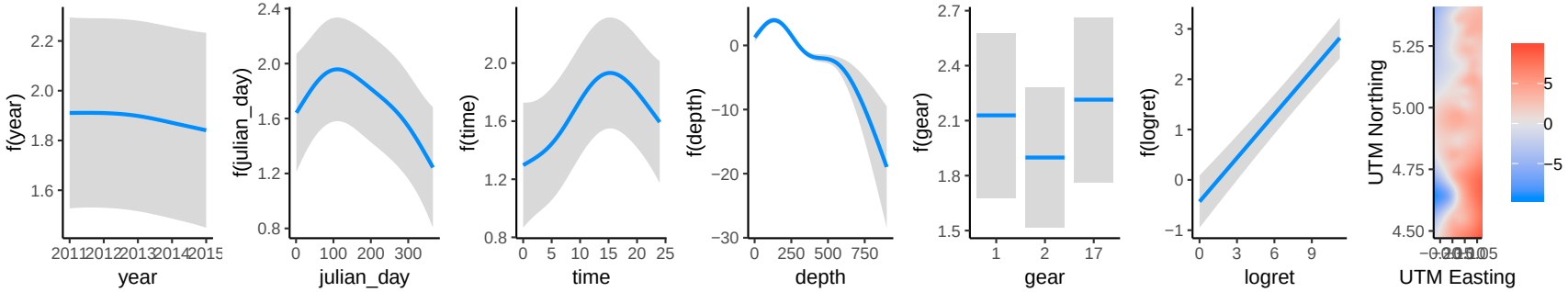
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 6596.819
          % Var explained: 12.44
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = 0.0547 Deviance explained = 39.8% -REML = 87121 Scale est. = 38.584 n = 35440



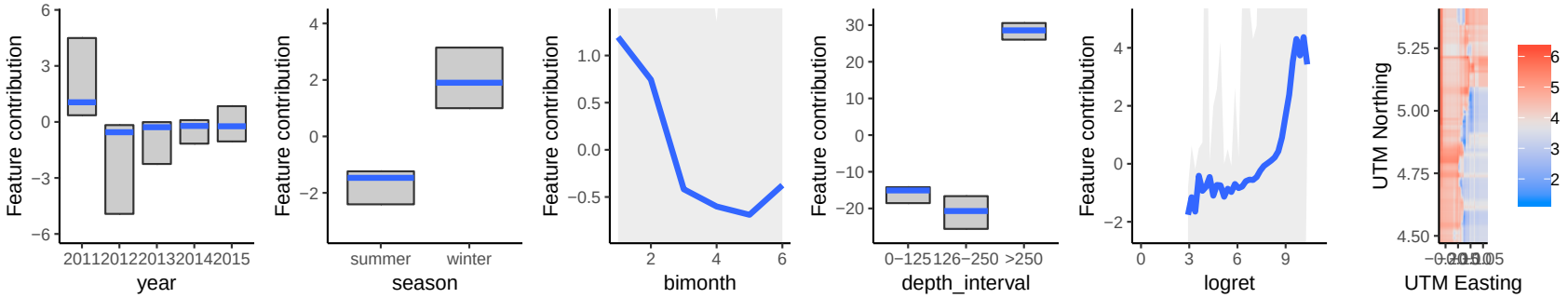

| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 48.1 | 49 | 22.1 | 7.34e-190 | *** |
| s(year) | 1.7 | 2.09 | 0.693 | 0.495 | |
| s(depth) | 3.98 | 4 | 375 | 5.5399580868179e-320 | *** |
| s(julian_day) | 3.65 | 3.93 | 12.4 | 5.92e-10 | *** |
| s(time) | 3.73 | 3.96 | 16.3 | 3.7e-13 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -0.557 | 0.198 | -2.81 | 0.00489 | ** |
| gear2 | -0.23 | 0.125 | -1.84 | 0.0657 | . |
| gear17 | 0.0856 | 0.0664 | 1.29 | 0.197 | |
| logret | 0.289 | 0.022 | 13.1 | 2.52e-39 | *** |

## Species 15: Tanneri Tanner Crab

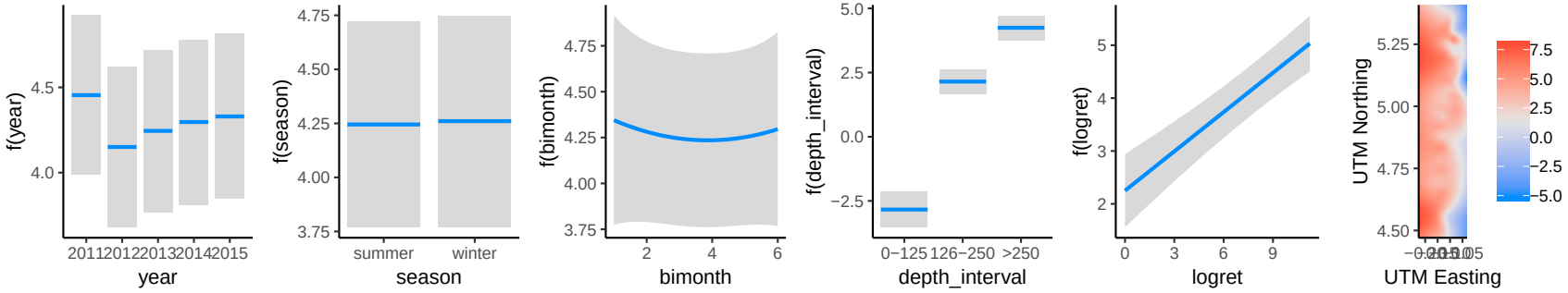
### $\mathbf{RF_{Total}}$

```
Mean of squared residuals: 7438.715
          % Var explained: 34.52
```




### $\mathbf{GAM_{Total}}$

R-sq.(adj) = 0.176 Deviance explained = 53.9% -REML = 85417 Scale est. = 85.96 n = 35440

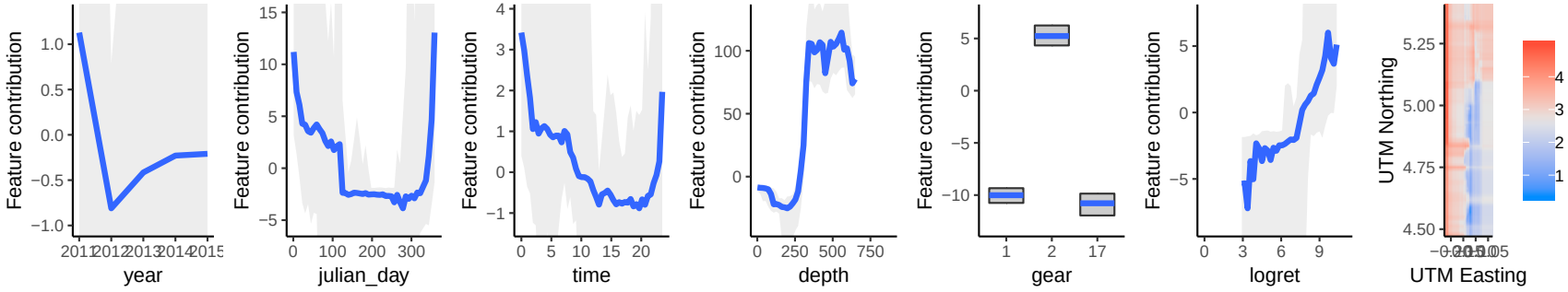



| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 48 | 48.9 | 8.84 | 2.42e-62 | *** |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | 1.73 | 0.398 | 4.35 | 1.38e-05 | *** |
| seasonwinter | 0.0155 | 0.121 | 0.128 | 0.898 | |
| bimonth | -0.103 | 0.162 | -0.637 | 0.524 | |
| I(bimonth^2) | 0.0134 | 0.022 | 0.609 | 0.543 | |
| year2012 | -0.304 | 0.105 | -2.9 | 0.00378 | ** |
| year2013 | -0.21 | 0.101 | -2.07 | 0.0386 | * |
| year2014 | -0.158 | 0.11 | -1.43 | 0.153 | |
| year2015 | -0.125 | 0.113 | -1.1 | 0.271 | |
| depth_interval0-125 | -7.08 | 0.273 | -26 | 1.97e-147 | *** |
| depth_interval126-250 | -2.1 | 0.0956 | -21.9 | 7.42e-106 | *** |
| logret | 0.248 | 0.0332 | 7.46 | 9.18e-14 | *** |

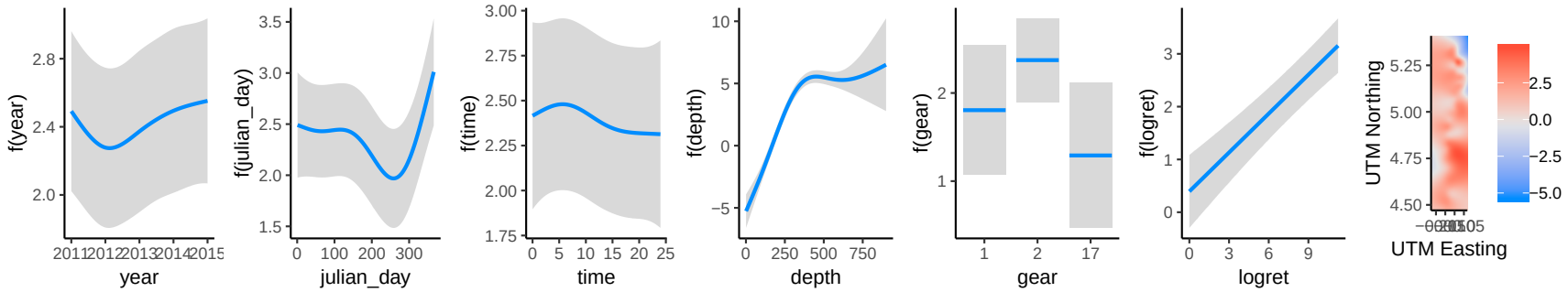
**$RF_{Nonlinear}$**

```
Mean of squared residuals: 6860.649
          % Var explained: 39.61
```




**$GAM_{Nonlinear}$**

R-sq.(adj) = 0.245 Deviance explained = 60.1% -REML = 83562 Scale est. = 75.678 n = 35440




| term | edf | ref.df | statistic | p.value | signif |
|---|---|---|---|---|---|
| s(avg_lat,avg_long) | 47.6 | 48.9 | 7.14 | 1.41e-46 | *** |
| s(year) | 3.65 | 3.93 | 2.09 | 0.0743 | . |
| s(depth) | 3.98 | 4 | 267 | 2.71e-227 | *** |
| s(julian_day) | 3.95 | 4 | 7.12 | 1.18e-05 | *** |
| s(time) | 3.07 | 3.56 | 0.968 | 0.389 | |

| term | estimate | std.error | statistic | p.value | signif |
|---|---|---|---|---|---|
| (Intercept) | -2.08 | 0.347 | -5.99 | 2.1e-09 | *** |
| gear2 | 0.568 | 0.291 | 1.95 | 0.0507 | . |
| gear17 | -0.514 | 0.33 | -1.56 | 0.12 | |
| logret | 0.246 | 0.0322 | 7.63 | 2.35e-14 | *** |