Bilaga 6: Statistikrapporter och skattad medelrespons

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Bilaga till Nyström Sandman m. fl. 2024. Mänsklig påverkan och effekter på bentisk miljö. Metoder för bedömning av havsbottnens integritet i svenska hav. Naturvårdsverket.

1 Innehåll

6.1 VIF, Variance inflation factor

VIF mäter korrelationen mellan variabler (James et al., 2013).

- VIF = 1: Variablerna är inte korrelerade.
- VIF är ungefär mellan 1 och 5: Variablerna är måttligt korrelerade.
- VIF > 5: Variablerna är starkt korrelerade.
- Vid VIF ≈ 10 och över är korrelationen signifikant och behöver hanteras.

Både för vegetation och sjöpennor har variablerna antal och korrelation reducerats genom principalkomponentanalys, PCA. Slutgiltig VIF redovisas nedan.

Grund vegetation, Sörmland/Östergötland

	Variables	VIF
1	SWM	1.886
2	dist_runoff	1.302
3	pav_zon_25	1.204
4	depth	1.171
5	rock	1.173
6	block	1.216
7	stone	1.106
8	gravel	1.221
10	soft_sand_1	1.095

Epibentisk fauna, sjöpennor, Kattegatt

	Variables	VIF
1	m30_adjusted	1.792
2	djup	3.380
3	swm_d	2.839
4	Nephrops_norvegicus_fs5	2.803
5	temp_1	3.473
6	salt_1	4.362
7	curr_1	1.869
8	curr_2	1.941
9	soft_coarse_1	2.465
10	hard_sand_1	2.620
11	hard_sand_2	1.733

Som framgår av tabellerna ovan har VIF reducerats till fullt acceptabla nivåer genom genomförda PCA-analyser, både för fallstudiet i grunda områden och för trålning i djupa områden.

6.2 Vegetationsmodeller

Nedan följer omfattande rapporter från statistiska analyser per art och grupp/index.

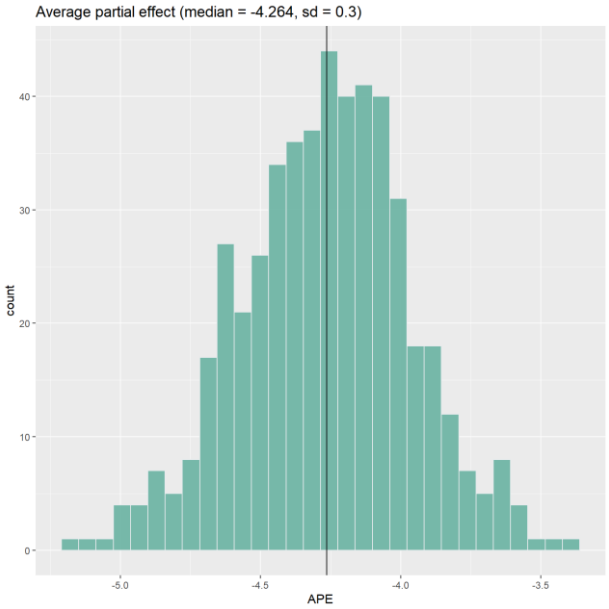
- Statistiskt relevanta resultat är satta i **fetstil**.
- Ej statistiskt relevanta (vid 95% konfidensnivå) är rödmarkerade.
- Direkt felaktiga resultat, subjektivt bedömda, är markerade i lila.

EQR100

WeightIt/svyglm

```
MODEL INFO:
 Observations: 13386
 Dependent Variable: EQR100
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.10
 Adj. R² = 0.10

 Standard errors: Robust
 ------------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p    VIF
 ----------------- ------- ------- ------- -------- ------ ------
 (Intercept)         56.97   56.15   57.80   135.43   0.00
 pav_zon_25          -5.42   -6.66   -4.17    -8.51   0.00   1.47
 SWM                 -4.05   -4.77   -3.34   -11.10   0.00   2.82
 dist_runoff          4.12    3.25    5.00     9.23   0.00   2.01
 depth                3.10    2.33    3.86     7.94   0.00   1.67
 rock                 2.69    2.13    3.25     9.39   0.00   1.33
 block                1.97    1.41    2.54     6.85   0.00   1.22
 stone                1.65    1.06    2.24     5.46   0.00   1.12
 gravel               1.35    0.80    1.91     4.76   0.00   1.22
 soft_sand_1          6.98    6.17    7.80    16.80   0.00   1.14
 ------------------------------------------------------------------

Margins
-------
      factor     AME     SE        z      p   lower   upper
       block  1.9729 0.2882   6.8463 0.0000  1.4081  2.5377
       depth  3.0992 0.3902   7.9423 0.0000  2.3344  3.8640
 dist_runoff  4.1208 0.4463   9.2332 0.0000  3.2460  4.9955
      gravel  1.3547 0.2848   4.7575 0.0000  0.7966  1.9128
  pav_zon_25 -5.4154 0.6361  -8.5132 0.0000 -6.6622 -4.1687
        rock  2.6910 0.2864   9.3949 0.0000  2.1296  3.2524
 soft_sand_1  6.9812 0.4156  16.7981 0.0000  6.1667  7.7958
       stone  1.6470 0.3019   5.4562 0.0000  1.0554  2.2387
         SWM -4.0510 0.3649 -11.1003 0.0000 -4.7663 -3.3357

Adjusted predictions at the mean
--------------------------------
# Predicted values of EQR100

pav_zon_25 | Predicted |       95% CI
-------------------------------------
         0 |     56.58 | 55.74, 57.42
         1 |     51.16 | 50.17, 52.16
         2 |     45.75 | 43.65, 47.84
         3 |     40.33 | 37.03, 43.63
         4 |     34.92 | 30.39, 39.45
         5 |     29.50 | 23.74, 35.27
```

Bayesian Causal Exposure Model




```
Covariate inclusion, exposure model
-----------------------------------
  SWM dist_runoff depth rock block stone gravel soft_sand_1 prob.
1   0           1     1    1     1     1      0           1     1

Covariate inclusion frequency, effect model
-------------------------------------------
    covariate frequency
1         SWM      1.00
2 dist_runoff      1.00
3       depth      1.00
4        rock      1.00
5       block      1.00
6       stone      0.99
7      gravel      0.89
8 soft_sand_1      1.00
```

Median of estimated effect: -4.264
Std of estimated effect: 0.3

twangContinuous by treatment only

```
MODEL INFO:
 Observations: 13386
 Dependent Variable: EQR100
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.06
 Adj. R² = 0.06

 Standard errors: Robust
 ------------------------------------------------------------
                       Est.    2.5%   97.5%   t val.      p
 ----------------- -------- ------- ------- -------- ------
 (Intercept)          56.72   55.78   57.65   118.88   0.00
 pav_zon_25           -5.09   -6.51   -3.66    -7.01   0.00
 ------------------------------------------------------------
```

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of EQR100

pav_zon_25 | Predicted |       95% CI
-------------------------------------
         0 |     56.72 | 55.78, 57.65
         1 |     51.63 | 50.53, 52.73
         2 |     46.54 | 44.18, 48.91
         3 |     41.46 | 37.71, 45.20
         4 |     36.37 | 31.22, 41.52
         5 |     31.28 | 24.72, 37.84
```

---

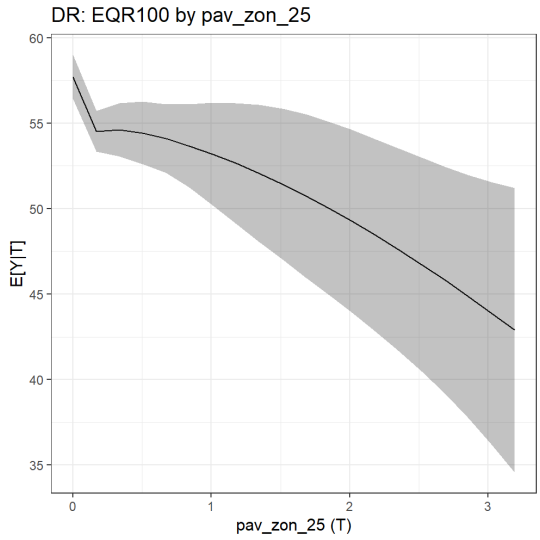
twangContinuous by all covariates

```
MODEL INFO:
 Observations: 13386
 Dependent Variable: EQR100
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.12
 Adj. R² = 0.12

 Standard errors: Robust
 ------------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p    VIF
 ----------------- ------- ------- ------- -------- ------ ------
 (Intercept)         56.69   55.82   57.56   127.46   0.00
 pav_zon_25          -3.48   -5.18   -1.78    -4.01   0.00   2.67
 SWM                 -3.32   -4.29   -2.35    -6.72   0.00   4.03
 dist_runoff          3.64    2.50    4.79     6.23   0.00   2.25
 depth                3.71    2.68    4.74     7.07   0.00   1.91
 rock                 2.71    2.12    3.29     9.05   0.00   1.37
 block                2.00    1.33    2.67     5.82   0.00   1.37
 stone                1.34    0.53    2.15     3.23   0.00   1.29
 gravel               1.46    0.89    2.03     5.01   0.00   1.24
 soft_sand_1          7.09    5.59    8.59     9.27   0.00   1.56
 wts                 -0.16   -0.45    0.12    -1.12   0.26   2.12
 ------------------------------------------------------------------

Adjusted predictions at the mean
--------------------------------
# Predicted values of EQR100

pav_zon_25 | Predicted |       95% CI
-------------------------------------
         0 |     54.68 | 52.28, 57.09
         1 |     51.21 | 49.79, 52.62
         2 |     47.73 | 45.72, 49.73
         3 |     44.25 | 40.81, 47.68
         4 |     40.77 | 35.72, 45.81
         5 |     37.29 | 30.59, 43.98
```

Causal Forest

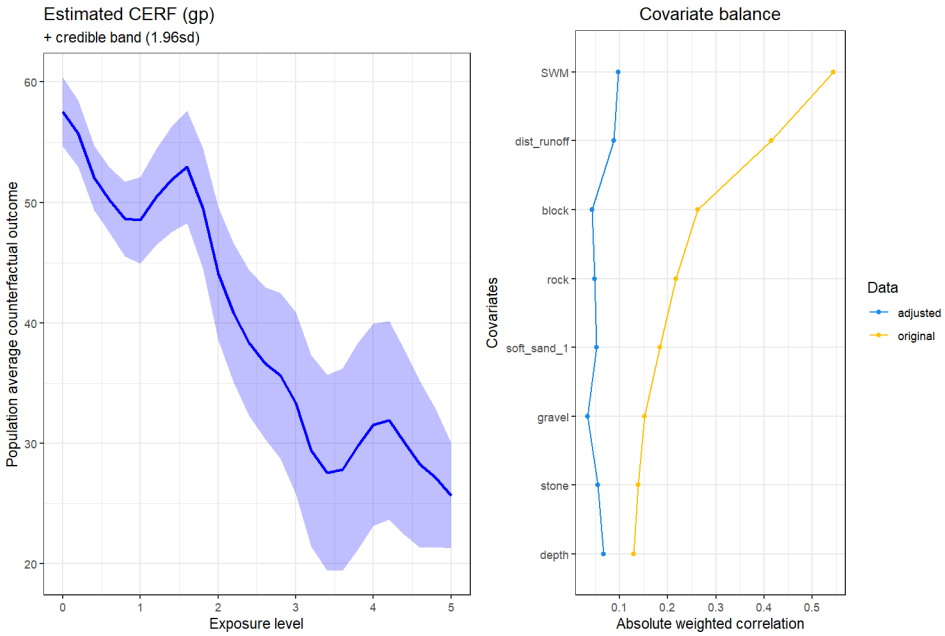
```
Best linear fit using forest predictions (on held-out data)
as well as the mean forest prediction as regressors, along
with one-sided heteroskedasticity-robust (HC3) SEs:

                               Estimate Std. Error t value             Pr(>t)
mean.forest.prediction           1.0575     0.0969    10.9 <0.0000000000000002 ***
differential.forest.prediction   1.6618     0.0890    18.7 <0.0000000000000002 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Agerage partial effect:
estimate  std.err
  -2.449    1.662
```

Continuous spline



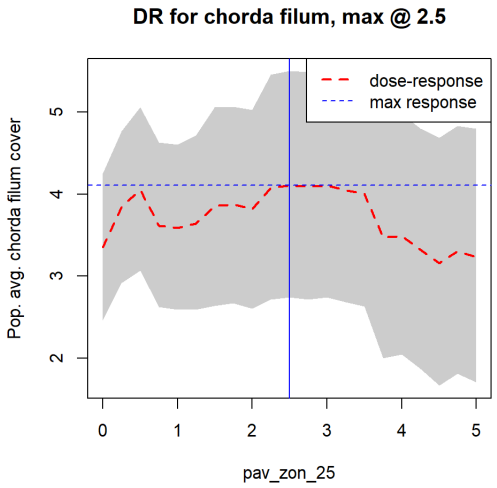

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of EQR100

pav_zon_25 | Predicted |       95% CI
--------------------------------------
      0.00 |     57.70 | 56.41, 58.99
      0.03 |     56.23 | 55.23, 57.23
      0.10 |     54.82 | 53.43, 56.21
      0.20 |     54.56 | 53.40, 55.71
      0.35 |     54.59 | 53.00, 56.19
      0.57 |     54.30 | 52.43, 56.17
      0.90 |     53.49 | 50.83, 56.14
      5.00 |     31.05 | 11.04, 51.06
```

Conditional dose-response function, GPCERF



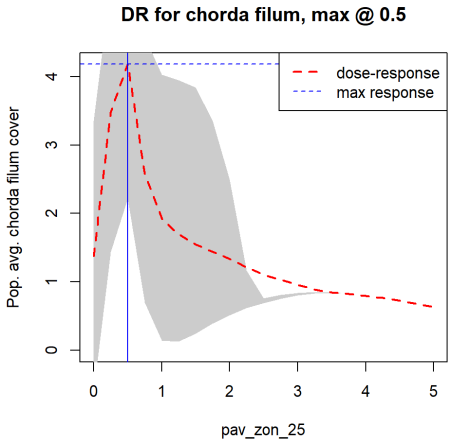

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,24) = 212.431, p = 0.000
R² = 0.898
Adj. R² = 0.894

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.    t val.       p
----------------- -------- ------- --------- -------
(Intercept)         56.272   1.316    42.770   0.000
exposure            -6.577   0.451   -14.575   0.000

Max of response: 56.272 at exposure 0
Min of response: 23.385 at exposure 5

Raw GPCERF max/min:
-------------------
Max of response: 57.508 at exposure 0
Min of response: 25.657 at exposure 5

Adjusted predictions at the mean
--------------------------------
# Predicted values of EQR100

exposure | Predicted |       95% CI
-----------------------------------
    0.00 |     56.27 | 53.56, 58.99
    0.50 |     52.98 | 50.66, 55.31
    1.50 |     46.41 | 44.73, 48.09
    2.00 |     43.12 | 41.64, 44.59
    2.50 |     39.83 | 38.43, 41.23
    3.00 |     36.54 | 35.07, 38.01
    3.50 |     33.25 | 31.57, 34.93
    5.00 |     23.39 | 20.67, 26.10
```

Continuous dose-response model, BART

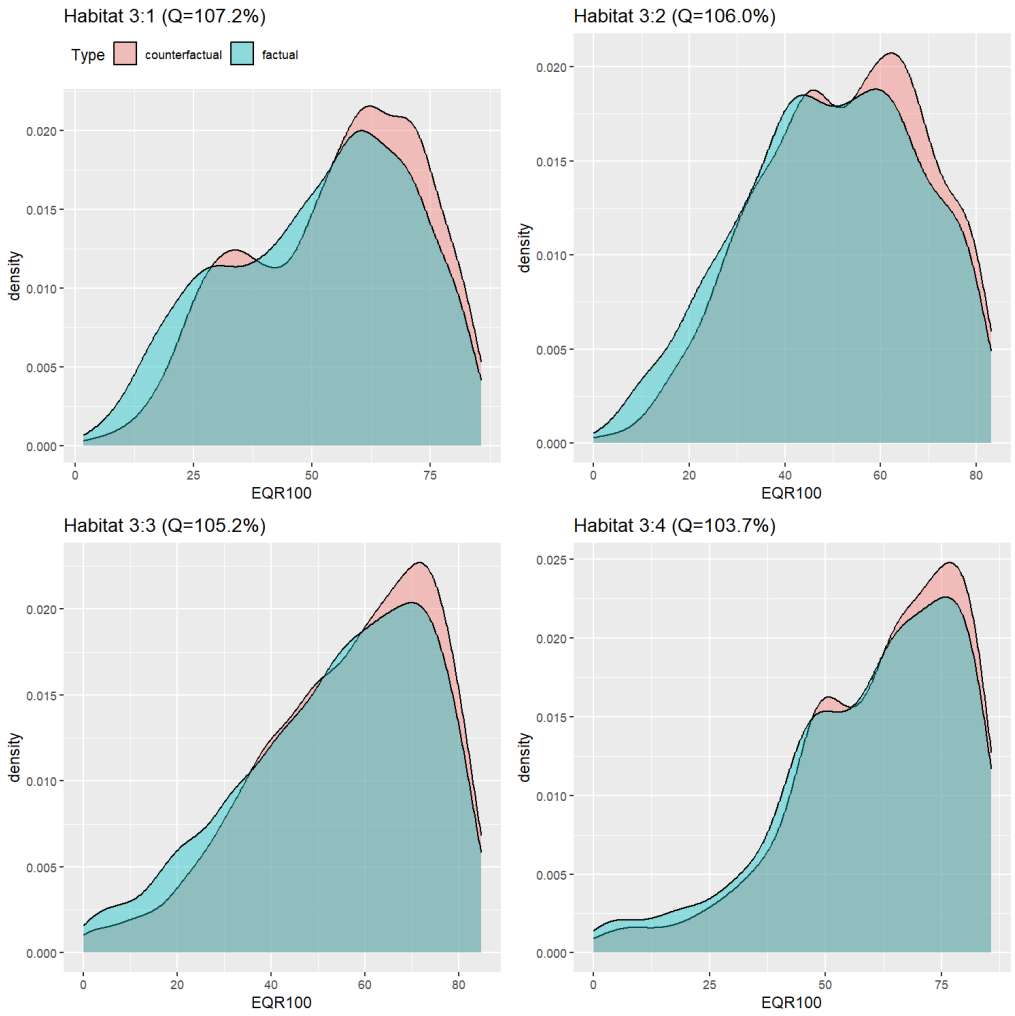


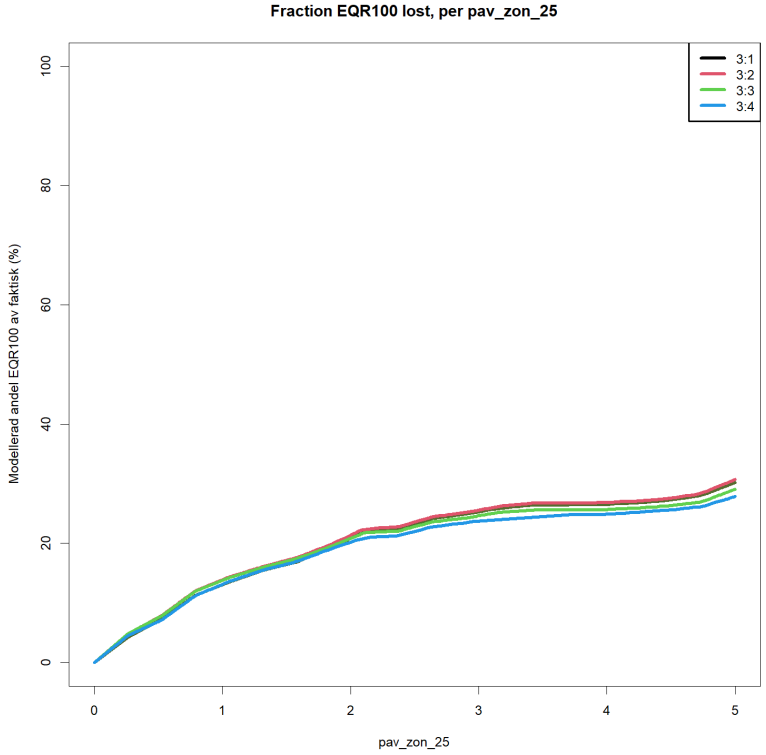

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 0.431, p = 0.519
R² = 0.022
Adj. R² = -0.029

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)         52.529   0.558   94.127   0.000
exposure            -0.125   0.191   -0.657   0.519
--------------------------------------------------

Max of response: 52.529 at exposure 0
Min of response: 51.902 at exposure 5

Raw bart max/min:
-----------------
Max of response: 55.859 at exposure 0.25
Min of response: 50.637 at exposure 2

Adjusted predictions at the mean
--------------------------------
# Predicted values of EQR100

exposure | Predicted |       95% CI
-----------------------------------
    0.00 |     52.53 | 51.36, 53.70
    0.50 |     52.47 | 51.46, 53.47
    1.50 |     52.34 | 51.62, 53.07
    2.00 |     52.28 | 51.64, 52.92
    2.50 |     52.22 | 51.61, 52.82
    3.00 |     52.15 | 51.52, 52.79
    3.50 |     52.09 | 51.37, 52.82
    5.00 |     51.90 | 50.73, 53.07
```

Continuous dose-response model, GAM




```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 23.627, p = 0.000
R² = 0.554
Adj. R² = 0.531

Standard errors: OLS
-----------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)         41.462   3.021   13.727   0.000
exposure            -5.024   1.034   -4.861   0.000
-----------------------------------------------------

Max of response: 41.462 at exposure 0
Min of response: 16.344 at exposure 5

Raw gam max/min:
-----------------
Max of response: 51.385 at exposure 0
Min of response: 18.47 at exposure 3

Adjusted predictions at the mean
--------------------------------
# Predicted values of EQR100

exposure | Predicted |       95% CI
-------------------------------------
    0.00 |     41.46 | 35.14, 47.78
    0.50 |     38.95 | 33.52, 44.38
    1.50 |     33.93 | 30.00, 37.85
    2.00 |     31.42 | 27.97, 34.86
    2.50 |     28.90 | 25.63, 32.18
    3.00 |     26.39 | 22.94, 29.84
    3.50 |     23.88 | 19.95, 27.80
    5.00 |     16.34 | 10.02, 22.67
```


Habitat 3:1 (Q=107.2%)
Type
counterfactual
factual
density
EQR100
Habitat 3:2 (Q=106.0%)
Habitat 3:3 (Q=105.2%)
Habitat 3:4 (Q=103.7%)

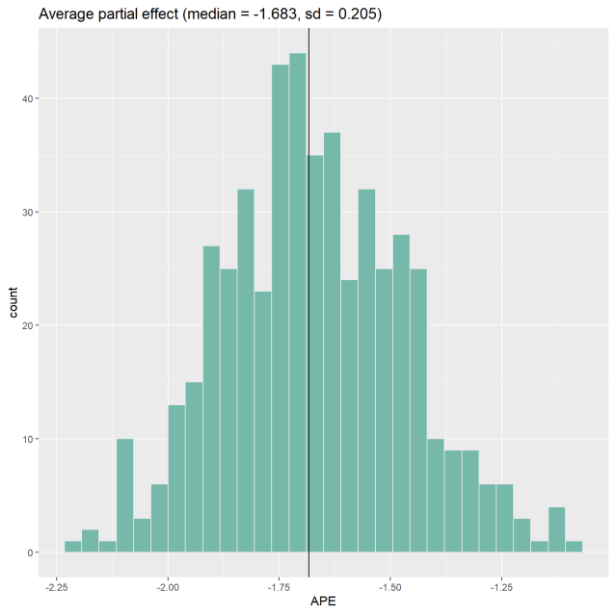

Fraction EQR100 lost, per pav_zon_25
3:1
3:2
3:3
3:4
Modellerad andel EQR100 av faktisk (%)
pav_zon_25

Tracheophyta

WeightIt/svyglm

```
MODEL INFO:
 Observations: 13065
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.20
 Adj. R² = 0.20

 Standard errors: Robust
 ------------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p    VIF
 ----------------- ------- ------- ------- -------- ------ ------
 (Intercept)         22.43   21.88   22.98    79.93   0.00
 pav_zon_25          -1.25   -2.11   -0.38    -2.84   0.00   1.73
 SWM                  2.09    1.65    2.52     9.36   0.00   2.34
 dist_runoff          3.11    2.52    3.71    10.31   0.00   2.16
 depth               -8.94   -9.43   -8.44   -35.44   0.00   1.44
 rock                -7.26   -7.55   -6.97   -48.83   0.00   1.57
 block               -3.31   -3.57   -3.05   -24.72   0.00   1.40
 stone               -2.68   -2.99   -2.37   -16.90   0.00   1.24
 gravel              -2.05   -2.37   -1.74   -12.71   0.00   1.26
 soft_sand_1          1.34    0.75    1.93     4.42   0.00   1.27
 ------------------------------------------------------------------

Margins
-------
      factor     AME     SE        z      p   lower   upper
       block -3.3075 0.1338 -24.7219 0.0000 -3.5698 -3.0453
       depth -8.9393 0.2523 -35.4358 0.0000 -9.4338 -8.4449
 dist_runoff  3.1135 0.3019  10.3143 0.0000  2.5219  3.7051
      gravel -2.0514 0.1614 -12.7084 0.0000 -2.3678 -1.7350
  pav_zon_25 -1.2473 0.4399  -2.8352 0.0046 -2.1096 -0.3851
        rock -7.2629 0.1487 -48.8324 0.0000 -7.5545 -6.9714
 soft_sand_1  1.3396 0.3031   4.4199 0.0000  0.7456  1.9336
       stone -2.6757 0.1583 -16.9024 0.0000 -2.9860 -2.3654
         SWM  2.0863 0.2230   9.3575 0.0000  1.6493  2.5233

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |       95% CI
-------------------------------------
         0 |     22.93 | 22.36, 23.50
         1 |     21.68 | 21.01, 22.35
         2 |     20.44 | 19.00, 21.87
         3 |     19.19 | 16.91, 21.46
         4 |     17.94 | 14.82, 21.06
         5 |     16.69 | 12.71, 20.67
```

Bayesian Causal Exposure Model




```
Covariate inclusion, exposure model
-----------------------------------
  SWM dist_runoff depth rock block stone gravel soft_sand_1 prob.
1   1           1     1    1     1     1      0           1     1

Covariate inclusion frequency, effect model
-------------------------------------------
    covariate frequency
1         SWM         1
2 dist_runoff         1
3       depth         1
4        rock         1
5       block         1
6       stone         1
7      gravel         1
8 soft_sand_1         1
```

Median of estimated effect: -1.683
Std of estimated effect: 0.205

---

twangContinuous by treatment only

```
MODEL INFO:
 Observations: 13065
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.00
 Adj. R² = 0.00

 Standard errors: Robust
 ------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p
 ---------------- ------- ------- ------- -------- ------
 (Intercept)         22.21   21.60   22.83    70.73   0.00
 pav_zon_25          -0.66   -1.61    0.28    -1.37   0.17
 ------------------------------------------------------------
```

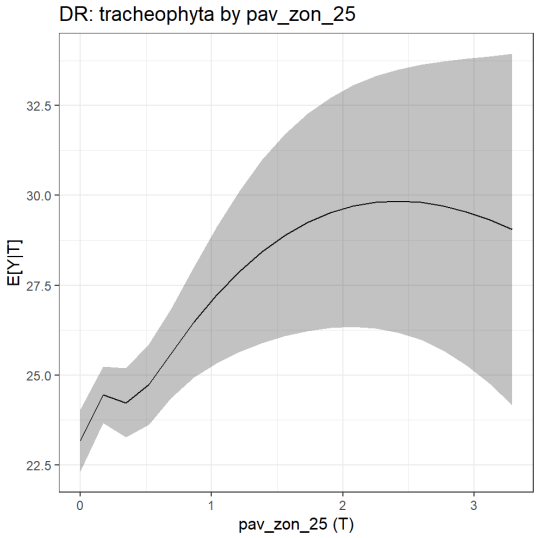
```
Margins
-------
     factor     AME     SE       z      p   lower  upper
 pav_zon_25 -0.6624 0.4822 -1.3737 0.1695 -1.6075 0.2827


Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |       95% CI
-------------------------------------
         0 |     22.21 | 21.60, 22.83
         1 |     21.55 | 20.84, 22.27
         2 |     20.89 | 19.33, 22.45
         3 |     20.23 | 17.75, 22.70
         4 |     19.57 | 16.16, 22.97
         5 |     18.90 | 14.56, 23.25
```

---

twangContinuous by all covariates

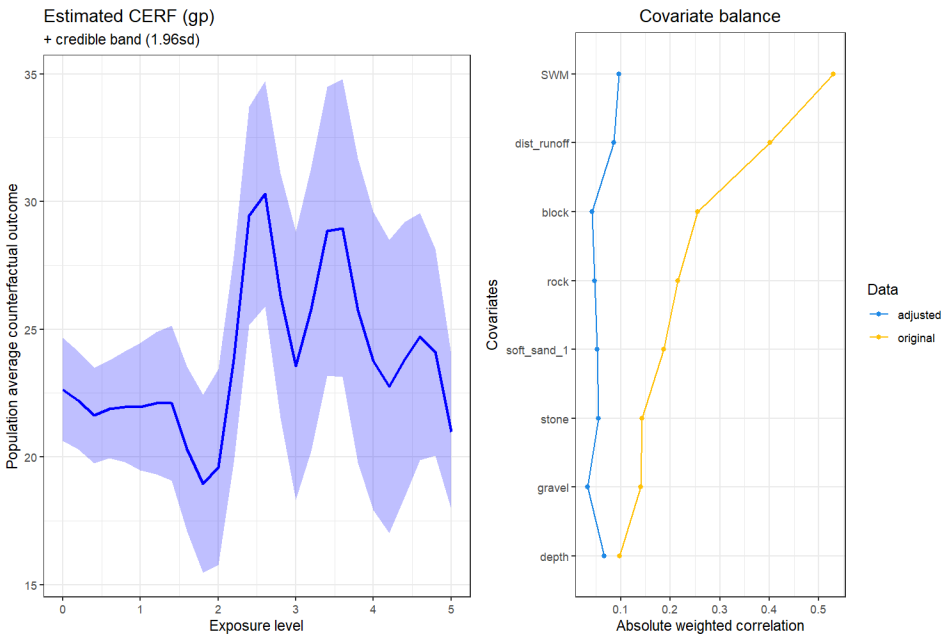
```
MODEL INFO:
 Observations: 13065
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.21
 Adj. R² = 0.21

 Standard errors: Robust
 ------------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p    VIF
 ----------------- ------- ------- ------- -------- ------ ------
 (Intercept)         22.15   21.61   22.69    80.59   0.00
 pav_zon_25          -0.41   -1.23    0.41    -0.98   0.33   2.37
 SWM                  2.25    1.73    2.77     8.47   0.00   3.22
 dist_runoff          3.61    2.77    4.45     8.45   0.00   3.57
 depth               -9.23   -9.90   -8.55   -26.79   0.00   2.24
 rock                -7.45   -7.74   -7.16   -50.72   0.00   1.54
 block               -3.39   -3.67   -3.11   -24.02   0.00   1.40
 stone               -2.79   -3.15   -2.43   -15.17   0.00   1.36
 gravel              -2.10   -2.42   -1.78   -12.83   0.00   1.25
 soft_sand_1          0.88    0.22    1.54     2.60   0.01   1.32
 wts                 -0.17   -0.34    0.00    -1.93   0.05   1.75
 ------------------------------------------------------------------

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |       95% CI
-------------------------------------
         0 |     21.93 | 21.07, 22.80
         1 |     21.52 | 20.88, 22.16
         2 |     21.11 | 19.92, 22.31
         3 |     20.70 | 18.76, 22.65
         4 |     20.29 | 17.55, 23.03
         5 |     19.88 | 16.34, 23.43
```

Continuous spline




```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |       95% CI
-------------------------------------
      0.00 |     23.18 | 22.32, 24.05
      0.03 |     23.94 | 23.28, 24.59
      0.10 |     24.53 | 23.62, 25.44
      0.20 |     24.36 | 23.61, 25.10
      0.35 |     24.24 | 23.27, 25.21
      0.58 |     25.02 | 23.87, 26.17
      0.92 |     26.72 | 25.06, 28.37
      5.00 |     24.63 | 13.92, 35.34
```

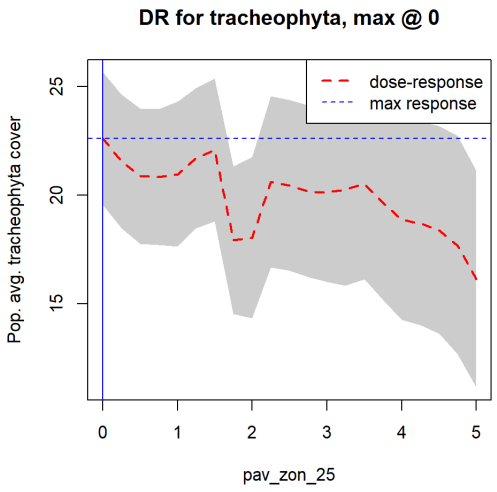
Conditional dose-response function, GPCERF




```
Linear trend analysis
---------------------
```

```
MODEL FIT:
F(1,24) = 3.636, p = 0.069
R² = 0.132
Adj. R² = 0.095

Standard errors: OLS
--------------------------------------------------
                      Est.     S.E.    t val.       p
---------------- -------- ------- -------- -------
(Intercept)         21.991   1.095   20.082   0.000
exposure             0.716   0.376    1.907   0.069
--------------------------------------------------

Max of response: 25.571 at exposure 5
Min of response: 21.991 at exposure 0

Raw GPCERF max/min:
-------------------
Max of response: 30.298 at exposure 2.6
Min of response: 18.953 at exposure 1.8

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |       95% CI
-----------------------------------
    0.00 |     21.99 | 19.73, 24.25
    0.50 |     22.35 | 20.41, 24.29
    1.50 |     23.06 | 21.67, 24.46
    2.00 |     23.42 | 22.20, 24.65
    2.50 |     23.78 | 22.62, 24.94
    3.00 |     24.14 | 22.91, 25.36
    3.50 |     24.50 | 23.10, 25.89
    5.00 |     25.57 | 23.31, 27.83
```

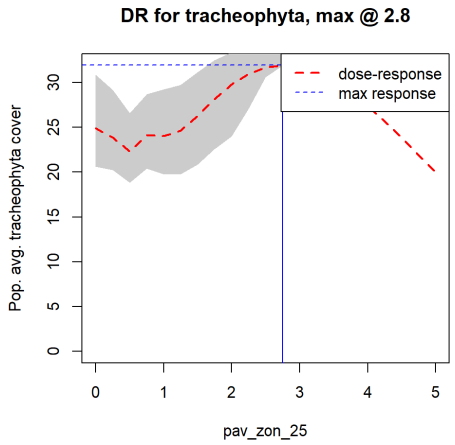
Continuous dose-response model, BART




```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 24.629, p = 0.000
R² = 0.565
Adj. R² = 0.542
```

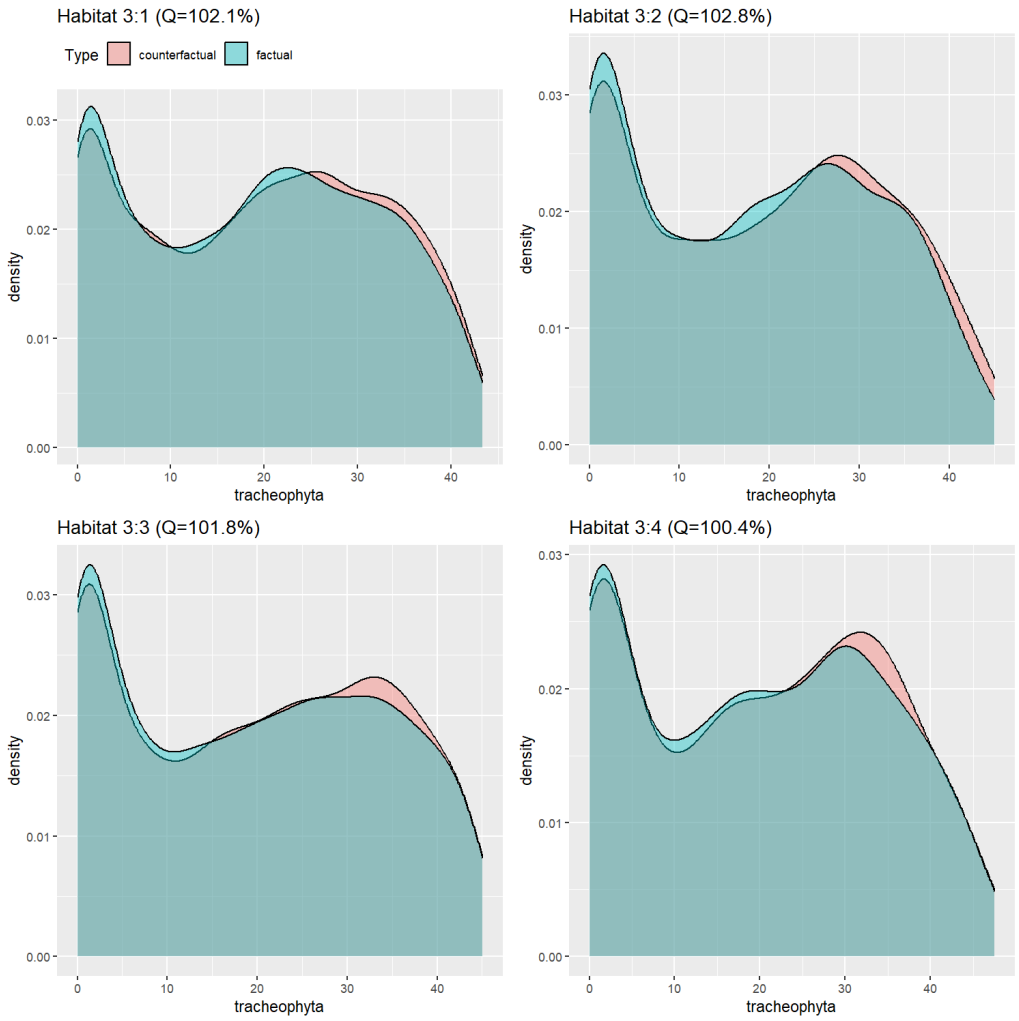
```
Standard errors: OLS
--------------------------------------------------
                     Est.    S.E.   t val.       p
---------------- -------- ------- -------- -------
(Intercept)        21.903   0.468   46.841   0.000
exposure           -0.794   0.160   -4.963   0.000
--------------------------------------------------

Max of response: 21.903 at exposure 0
Min of response: 17.932 at exposure 5

Raw bart max/min:
-----------------
Max of response: 22.615 at exposure 0
Min of response: 16.139 at exposure 5

Adjusted predictions at the mean
---------------------------------
# Predicted values of cover

exposure | Predicted |       95% CI
-----------------------------------
    0.00 |     21.90 | 20.92, 22.88
    0.50 |     21.51 | 20.67, 22.35
    1.50 |     20.71 | 20.10, 21.32
    2.00 |     20.31 | 19.78, 20.85
    2.50 |     19.92 | 19.41, 20.42
    3.00 |     19.52 | 18.99, 20.05
    3.50 |     19.12 | 18.52, 19.73
    5.00 |     17.93 | 16.95, 18.91
```

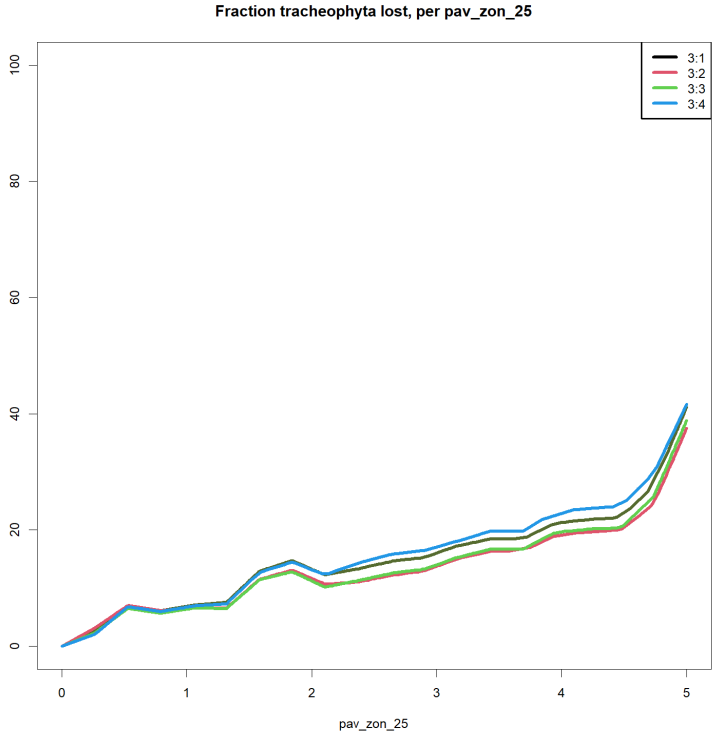
Continuous dose-response model, GAM




```
MODEL FIT:
F(1,19) = 0.061, p = 0.807
R² = 0.003
Adj. R² = -0.049

Standard errors: OLS
--------------------------------------------------
                     Est.    S.E.   t val.       p
---------------- -------- ------- -------- -------
(Intercept)        26.481   1.580   16.756   0.000
exposure            0.134   0.541    0.248   0.807
--------------------------------------------------
```

```
Max of response: 27.151 at exposure 5
Min of response: 26.481 at exposure 0

Raw gam max/min:
-----------------
Max of response: 31.936 at exposure 2.75
Min of response: 19.996 at exposure 5

Adjusted predictions at the mean
---------------------------------
# Predicted values of cover

exposure | Predicted |       95% CI
-----------------------------------
    0.00 |     26.48 | 23.17, 29.79
    0.50 |     26.55 | 23.71, 29.39
    1.50 |     26.68 | 24.63, 28.74
    2.00 |     26.75 | 24.94, 28.55
    2.50 |     26.82 | 25.10, 28.53
    3.00 |     26.88 | 25.08, 28.69
    3.50 |     26.95 | 24.90, 29.00
    5.00 |     27.15 | 23.84, 30.46
```


Habitat 3:1 (Q=102.1%)
Type
counterfactual
factual
Habitat 3:2 (Q=102.8%)
Habitat 3:3 (Q=101.8%)
Habitat 3:4 (Q=100.4%)
density
tracheophyta

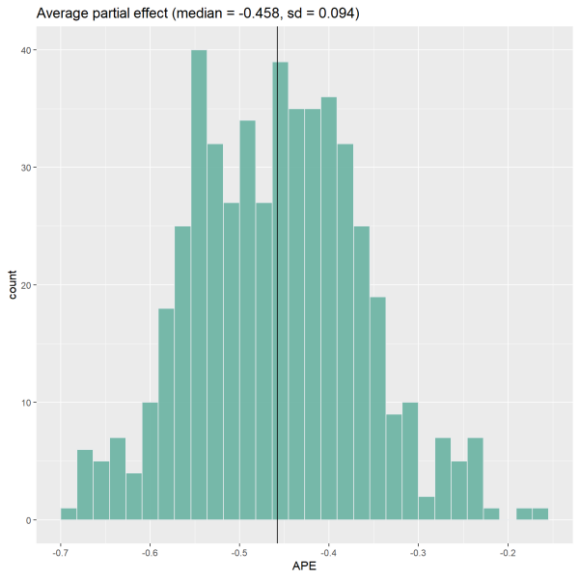

Fraction tracheophyta lost, per pav_zon_25
3:1
3:2
3:3
3:4
pav_zon_25

Zostera marina

WeightIt/svyglm

```
MODEL INFO:
Observations: 11484
Dependent Variable: cover
Type: Survey-weighted linear regression

MODEL FIT:
R² = 0.07
Adj. R² = 0.07

Standard errors: Robust
------------------------------------------------------------------
                     Est.    2.5%   97.5%   t val.      p    VIF
----------------- ------- ------- ------- -------- ------ ------
(Intercept)          3.70    3.49    3.91    34.04   0.00
pav_zon_25          -0.99   -1.11   -0.88   -16.94   0.00   1.52
SWM                  0.31    0.08    0.55     2.58   0.01   3.24
dist_runoff          1.24    1.07    1.41    14.51   0.00   1.51
depth                0.93    0.78    1.08    12.37   0.00   1.24
rock                -1.05   -1.19   -0.91   -15.03   0.00   2.03
block               -0.87   -1.00   -0.74   -13.01   0.00   1.96
stone               -0.49   -0.65   -0.33    -5.98   0.00   1.39
gravel              -0.38   -0.58   -0.19    -3.83   0.00   1.26
soft_sand_1          1.44    1.26    1.62    15.44   0.00   1.22
------------------------------------------------------------------

Margins
-------
      factor     AME     SE        z      p   lower   upper
       block -0.8683 0.0667 -13.0113 0.0000 -0.9991 -0.7375
       depth  0.9289 0.0751  12.3668 0.0000  0.7816  1.0761
 dist_runoff  1.2390 0.0854  14.5092 0.0000  1.0716  1.4063
      gravel -0.3841 0.1003  -3.8307 0.0001 -0.5807 -0.1876
  pav_zon_25 -0.9947 0.0587 -16.9386 0.0000 -1.1098 -0.8796
        rock -1.0488 0.0698 -15.0325 0.0000 -1.1856 -0.9121
 soft_sand_1  1.4380 0.0931  15.4394 0.0000  1.2555  1.6206
       stone -0.4888 0.0818  -5.9771 0.0000 -0.6491 -0.3285
         SWM  0.3119 0.1208   2.5825 0.0098  0.0752  0.5486

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |       95% CI
-------------------------------------
         0 |      3.71 |  3.49,  3.92
         1 |      2.71 |  2.55,  2.88
         2 |      1.72 |  1.53,  1.90
         3 |      0.72 |  0.46,  0.99
         4 |     -0.27 | -0.63,  0.09
         5 |     -1.26 | -1.73, -0.80
```

Bayesian Causal Exposure Model




```
Covariate inclusion, exposure model
-----------------------------------

  SWM dist_runoff depth rock block stone gravel soft_sand_1 prob.
1   1           1     1    1     1     1      0           1     1

Covariate inclusion frequency, effect model
-------------------------------------------

    covariate frequency
1         SWM     1.000
2 dist_runoff     1.000
3       depth     1.000
4        rock     1.000
5       block     1.000
6       stone     1.000
7      gravel     0.994
8 soft_sand_1     1.000
```

Median of estimated effect: -0.458
Std of estimated effect: 0.094

---

twangContinuous by treatment only

```
MODEL INFO:
 Observations: 13065
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.03
 Adj. R² = 0.03

 Standard errors: Robust
 ------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p
 ----------------- ------- ------- ------- -------- ------
 (Intercept)          3.59    3.37    3.80    33.43   0.00
 pav_zon_25          -0.75   -0.80   -0.71   -30.85   0.00
```

```
 ------------------------------------------------------

Margins
-------
     factor     AME     SE       z      p   lower  upper
 pav_zon_25 -0.7542 0.0244 -30.8542 0.0000 -0.8022 -0.7063

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |       95% CI
---------------------------------------
         0 |      3.59 |  3.37,  3.80
         1 |      2.83 |  2.66,  3.00
         2 |      2.08 |  1.95,  2.20
         3 |      1.32 |  1.23,  1.41
         4 |      0.57 |  0.49,  0.64
         5 |     -0.19 | -0.27, -0.10
```

twangContinuous by all covariates

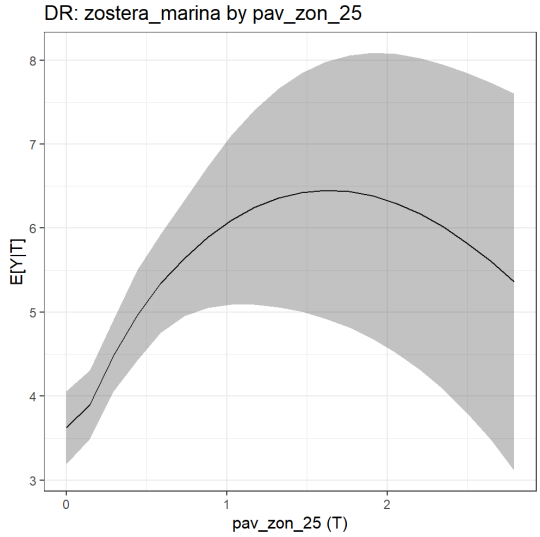
```
MODEL INFO:
 Observations: 13065
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.08
 Adj. R² = 0.08

 Standard errors: Robust
 ------------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p    VIF
 ----------------- ------- ------- ------- -------- ------ ------
 (Intercept)          3.57    3.37    3.78    34.23   0.00
 pav_zon_25          -0.63   -0.74   -0.52   -11.44   0.00   3.12
 SWM                  0.51    0.26    0.76     3.95   0.00   3.94
 dist_runoff          1.14    0.98    1.30    13.88   0.00   1.75
 depth                0.87    0.72    1.01    12.05   0.00   1.22
 rock                -1.11   -1.22   -1.00   -19.85   0.00   2.56
 block               -0.83   -1.00   -0.67   -10.17   0.00   2.32
 stone               -0.40   -0.58   -0.23    -4.61   0.00   1.37
 gravel              -0.33   -0.56   -0.09    -2.74   0.01   1.48
 soft_sand_1          1.22    1.05    1.38    14.47   0.00   1.28
 wts                 -0.01   -0.03   -0.00    -2.42   0.02   2.58
 ------------------------------------------------------------------

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |       95% CI
---------------------------------------
         0 |      3.40 |  3.16, 3.64
         1 |      2.77 |  2.59, 2.94
         2 |      2.14 |  1.98, 2.30
         3 |      1.51 |  1.30, 1.71
         4 |      0.88 |  0.59, 1.17
         5 |      0.25 | -0.14, 0.63
```

Causal Forest

```
Best linear fit using forest predictions (on held-out data)
as well as the mean forest prediction as regressors, along
with one-sided heteroskedasticity-robust (HC3) SEs:

                              Estimate Std. Error t value Pr(>t)
mean.forest.prediction          -3.280      1.799   -1.82            0.97
differential.forest.prediction   1.651      0.238    6.95 0.0000000000019 ***

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

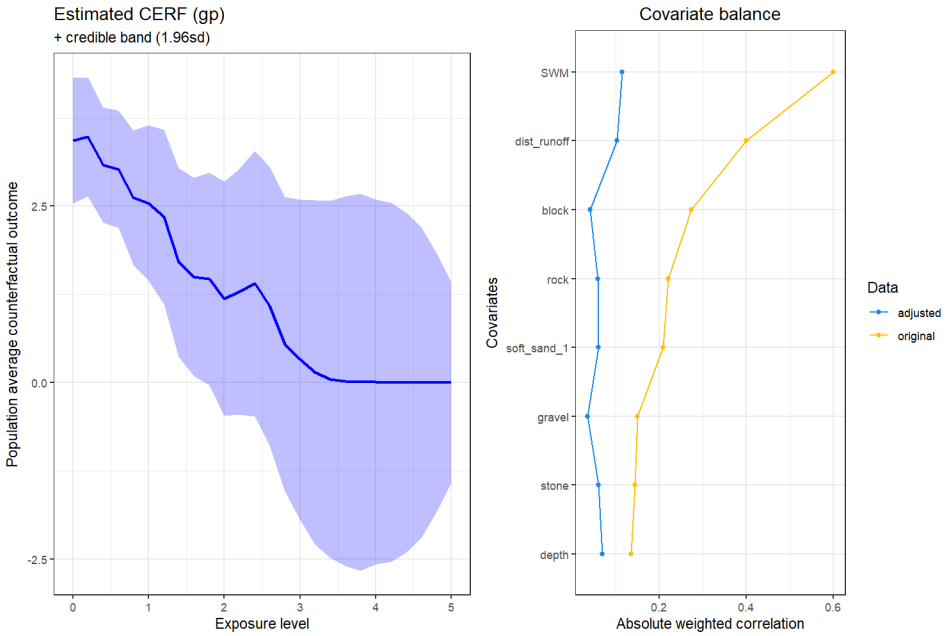
```
Conditional average treatment effects: 0

Agerage partial effect
----------------------
estimate  std.err
    0.64     0.58
```

Continuous spline



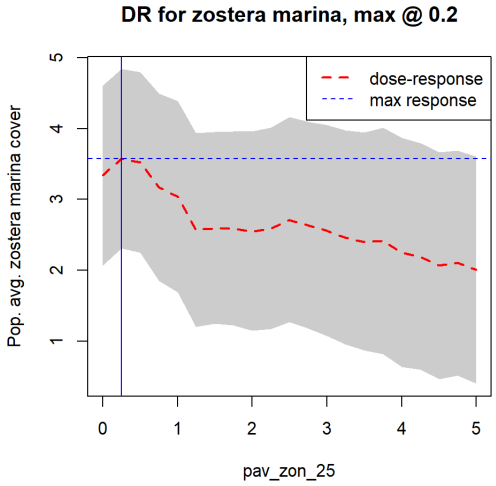

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |       95% CI
--------------------------------------
      0.00 |      3.62 |  3.19, 4.06
      0.03 |      3.61 |  3.29, 3.93
      0.10 |      3.73 |  3.29, 4.16
      0.20 |      4.10 |  3.74, 4.47
      0.35 |      4.67 |  4.19, 5.14
      0.57 |      5.29 |  4.71, 5.87
      0.88 |      5.88 |  5.05, 6.72
      5.00 |     -0.49 | -6.84, 5.86
```

Conditional dose-response function, GPCERF



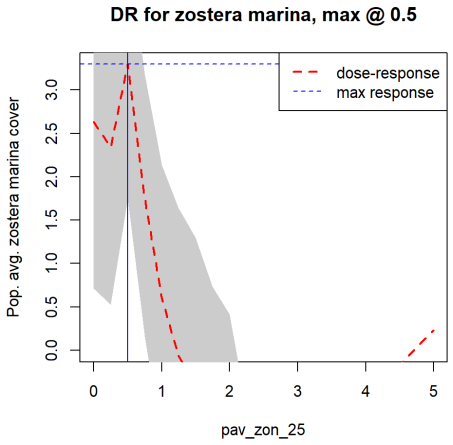

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,24) = 248.215, p = 0.000
R² = 0.912
Adj. R² = 0.908

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.    t val.       p
----------------- -------- ------- --------- -------
(Intercept)          3.120   0.142    21.978   0.000
exposure            -0.767   0.049   -15.755   0.000
--------------------------------------------------
Max of response: 3.12 at exposure 0
Min of response: -0.716 at exposure 5

Raw GPCERF max/min:
-------------------

Max of response: 3.481 at exposure 0.2
Min of response: 0 at exposure 5

Adjusted predictions at the mean
--------------------------------

# Predicted values of cover

exposure | Predicted |       95% CI
-----------------------------------
    0.00 |      3.12 |  2.83,  3.41
    0.50 |      2.74 |  2.49,  2.99
    1.50 |      1.97 |  1.79,  2.15
    2.00 |      1.59 |  1.43,  1.74
    2.50 |      1.20 |  1.05,  1.35
    3.00 |      0.82 |  0.66,  0.98
    3.50 |      0.43 |  0.25,  0.62
    5.00 |     -0.72 | -1.01, -0.42
```

Continuous dose-response model, BART

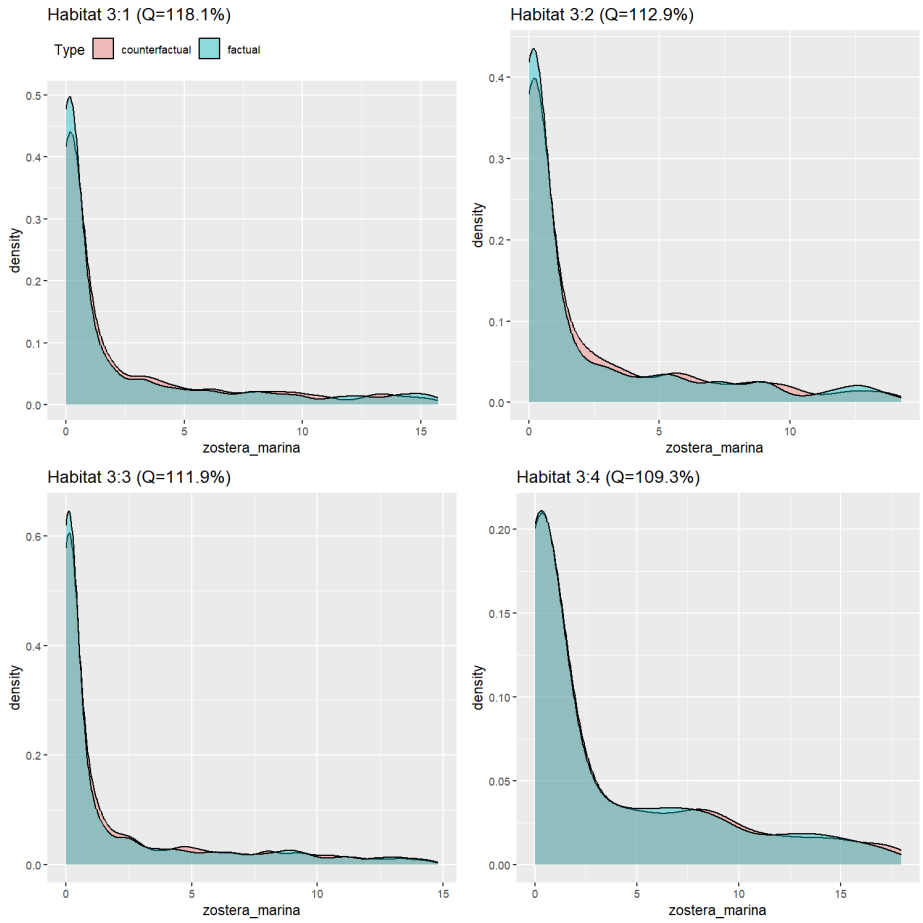


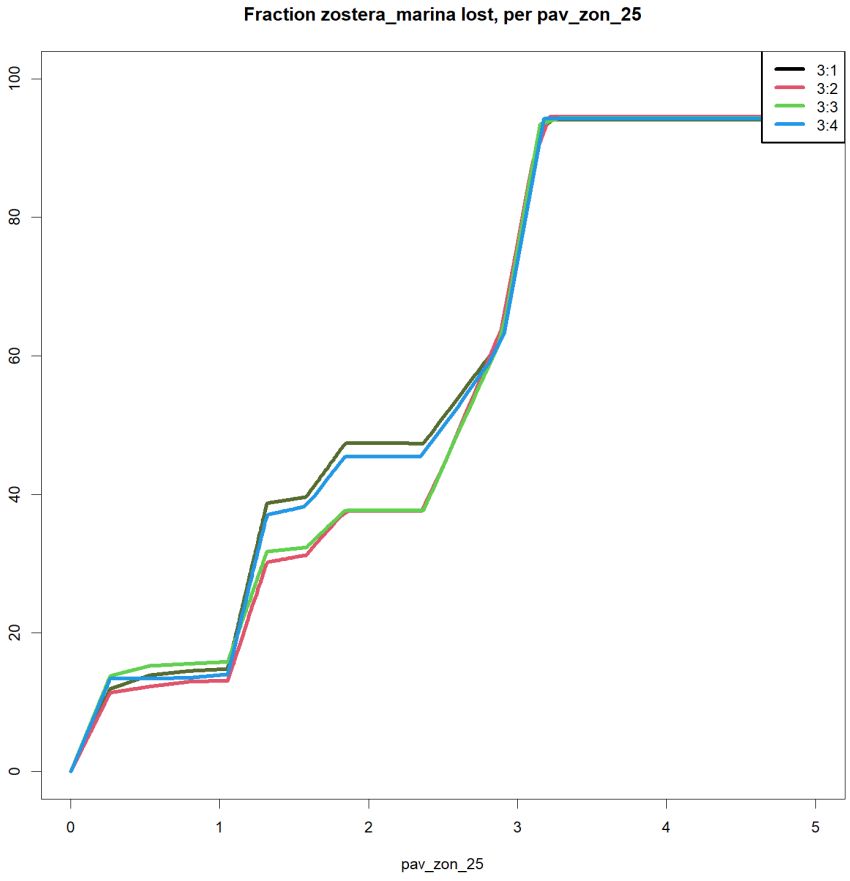

```
Linear trend analysis
---------------------

MODEL FIT:
F(1,19) = 100.019, p = 0.000
R² = 0.840
Adj. R² = 0.832

Standard errors: OLS
-----------------------------------------------------
                      Est.    S.E.    t val.       p
----------------- -------- ------- --------- -------
(Intercept)          3.305   0.078    42.192   0.000
exposure            -0.268   0.027   -10.001   0.000
-----------------------------------------------------
Max of response: 3.305 at exposure 0
Min of response: 1.965 at exposure 5

Raw bart max/min:
-----------------

Max of response: 3.574 at exposure 0.25
Min of response: 2.006 at exposure 5

Adjusted predictions at the mean
--------------------------------

# Predicted values of cover

exposure | Predicted |     95% CI
---------------------------------
    0.00 |      3.30 | 3.14, 3.47
    0.50 |      3.17 | 3.03, 3.31
    1.50 |      2.90 | 2.80, 3.00
    2.00 |      2.77 | 2.68, 2.86
    2.50 |      2.63 | 2.55, 2.72
    3.00 |      2.50 | 2.41, 2.59
    3.50 |      2.37 | 2.26, 2.47
    5.00 |      1.96 | 1.80, 2.13
```

Continuous dose-response model, GAM




```
MODEL FIT:
F(1,19) = 11.318, p = 0.003
R² = 0.373
Adj. R² = 0.340

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          1.354   0.456    2.968   0.008
exposure            -0.525   0.156   -3.364   0.003
--------------------------------------------------
Max of response: 1.354 at exposure 0
Min of response: -1.272 at exposure 5

Raw gam max/min:
-----------------
Max of response: 3.297 at exposure 0.5
Min of response: -1.134 at exposure 2.75

Adjusted predictions at the mean
---------------------------------
# Predicted values of cover

exposure | Predicted |       95% CI
-----------------------------------
    0.00 |      1.35 |  0.40,  2.31
    0.50 |      1.09 |  0.27,  1.91
    1.50 |      0.57 | -0.03,  1.16
    2.00 |      0.30 | -0.22,  0.82
    2.50 |      0.04 | -0.45,  0.54
    3.00 |     -0.22 | -0.74,  0.30
    3.50 |     -0.48 | -1.08,  0.11
    5.00 |     -1.27 | -2.23, -0.32
```


Habitat 3:1 (Q=118.1%)
Type
counterfactual
factual
density
zostera_marina
Habitat 3:2 (Q=112.9%)
density
zostera_marina
Habitat 3:3 (Q=111.9%)
density
zostera_marina
Habitat 3:4 (Q=109.3%)
density
zostera_marina

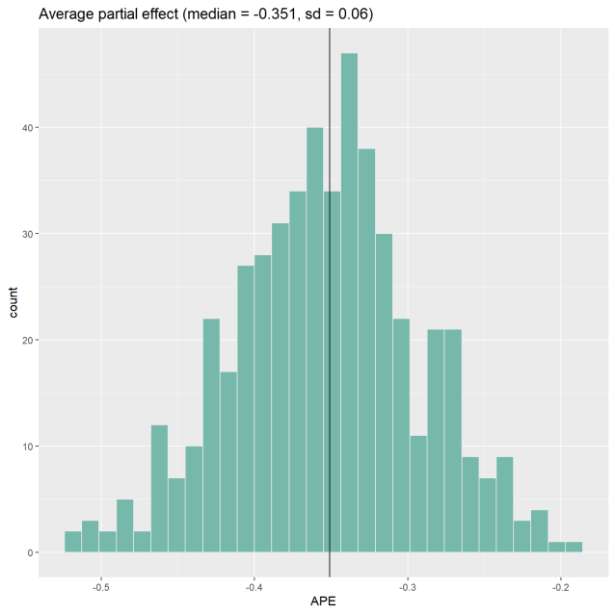

Fraction zostera_marina lost, per pav_zon_25
3:1
3:2
3:3
3:4
pav_zon_25

Chorda filum

WeightIt/svyglm

```
MODEL INFO:
 Observations: 13190
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.08
 Adj. R² = 0.08

 Standard errors: Robust
 ------------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p    VIF
 ---------------- ------- ------- ------- -------- ------ ------
 (Intercept)          3.67    3.54    3.80    54.59   0.00
 pav_zon_25          -0.62   -0.72   -0.52   -12.19   0.00   1.13
 SWM                 -0.95   -1.08   -0.82   -13.85   0.00   2.77
 dist_runoff          0.24    0.13    0.35     4.31   0.00   1.27
 depth               -0.01   -0.11    0.08    -0.28   0.78   1.20
 rock                -0.29   -0.39   -0.18    -5.25   0.00   1.41
 block               -0.12   -0.21   -0.02    -2.32   0.02   1.57
 stone                0.19    0.05    0.34     2.60   0.01   1.31
 gravel              -0.16   -0.26   -0.07    -3.43   0.00   1.34
 soft_sand_1          1.64    1.52    1.77    25.31   0.00   1.40
 ------------------------------------------------------------------

Margins
-------
      factor     AME     SE        z      p   lower   upper
       block -0.1154 0.0497  -2.3214 0.0203 -0.2128 -0.0180
       depth -0.0138 0.0483  -0.2850 0.7757 -0.1084  0.0808
 dist_runoff  0.2423 0.0562   4.3119 0.0000  0.1322  0.3525
      gravel -0.1630 0.0475  -3.4290 0.0006 -0.2562 -0.0698
  pav_zon_25 -0.6160 0.0505 -12.1887 0.0000 -0.7150 -0.5169
        rock -0.2867 0.0546  -5.2465 0.0000 -0.3938 -0.1796
 soft_sand_1  1.6437 0.0649  25.3111 0.0000  1.5164  1.7710
       stone  0.1921 0.0740   2.5971 0.0094  0.0471  0.3371
         SWM -0.9498 0.0686 -13.8519 0.0000 -1.0842 -0.8154

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |     95% CI
-----------------------------------
         0 |      3.67 | 3.54, 3.81
         1 |      3.06 | 2.94, 3.17
         2 |      2.44 | 2.27, 2.61
         3 |      1.82 | 1.57, 2.08
         4 |      1.21 | 0.86, 1.55
         5 |      0.59 | 0.15, 1.03
```

Bayesian Causal Exposure Model




```
Covariate inclusion, exposure model
-----------------------------------
  SWM dist_runoff depth rock block stone gravel soft_sand_1  prob.
1   1           1     1    1     1     1      0           1 0.6868
2   0           1     1    1     1     1      0           1 0.3132

Covariate inclusion frequency, effect model
-------------------------------------------
    covariate frequency
1         SWM     1.000
2 dist_runoff     1.000
3       depth     0.594
4        rock     1.000
5       block     0.652
6       stone     0.844
7      gravel     0.162
8 soft_sand_1     1.000
```

Median of estimated effect: -0.351
Std of estimated effect: 0.06

---

twangContinuous by treatment only

```
MODEL INFO:
 Observations: 13190
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.02
 Adj. R² = 0.02

 Standard errors: Robust
 ------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p
 ----------------- ------- ------- ------- -------- ------
 (Intercept)          3.67    3.53    3.80    53.52   0.00
 pav_zon_25          -0.56   -0.62   -0.50   -19.61   0.00
 ------------------------------------------------------------
```

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |     95% CI
-----------------------------------
         0 |      3.67 | 3.53, 3.80
         1 |      3.11 | 3.00, 3.22
         2 |      2.55 | 2.43, 2.66
         3 |      1.99 | 1.85, 2.13
         4 |      1.43 | 1.25, 1.61
         5 |      0.87 | 0.64, 1.09
```

---

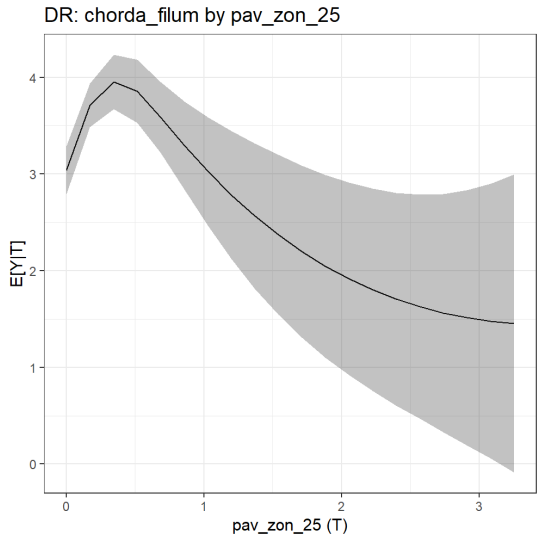
twangContinuous by all covariates

```
MODEL INFO:
 Observations: 13190
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.09
 Adj. R² = 0.09

 Standard errors: Robust
 ------------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p    VIF
 ----------------- ------- ------- ------- -------- ------ ------
 (Intercept)          3.66    3.53    3.79    55.19   0.00
 pav_zon_25          -0.39   -0.49   -0.29    -7.78   0.00   2.25
 SWM                 -0.90   -1.03   -0.76   -12.94   0.00   2.69
 dist_runoff          0.30    0.20    0.41     5.64   0.00   1.24
 depth                0.02   -0.07    0.12     0.46   0.64   1.22
 rock                -0.32   -0.41   -0.22    -6.40   0.00   1.42
 block               -0.13   -0.23   -0.03    -2.62   0.01   1.61
 stone                0.18    0.03    0.32     2.41   0.02   1.33
 gravel              -0.18   -0.28   -0.09    -3.87   0.00   1.32
 soft_sand_1          1.51    1.38    1.64    22.37   0.00   1.66
 wts                 -0.06   -0.08   -0.04    -5.00   0.00   2.50
 ------------------------------------------------------------------

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |     95% CI
-----------------------------------
         0 |      3.47 | 3.30, 3.65
         1 |      3.08 | 2.97, 3.20
         2 |      2.69 | 2.56, 2.82
         3 |      2.30 | 2.10, 2.50
         4 |      1.90 | 1.62, 2.19
         5 |      1.51 | 1.13, 1.89
```

Causal Forest

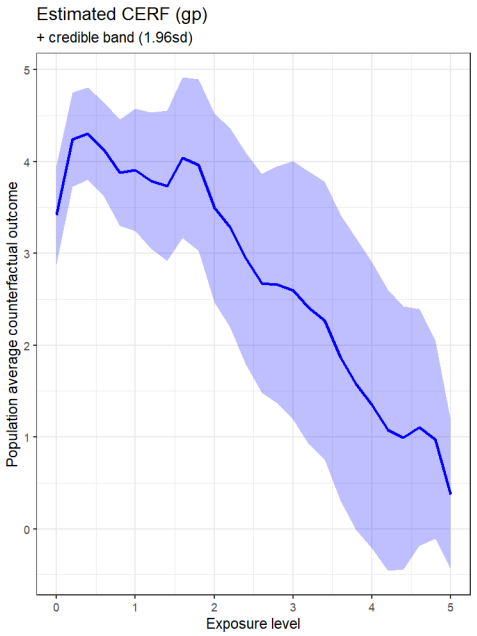
```
Best linear fit using forest predictions (on held-out data)
as well as the mean forest prediction as regressors, along
with one-sided heteroskedasticity-robust (HC3) SEs:

                               Estimate Std. Error t value             Pr(>t)
mean.forest.prediction           1.0130     0.0818    12.4 <0.0000000000000002 ***
differential.forest.prediction   1.4920     0.0978    15.2 <0.0000000000000002 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Conditional average treatment effects: -0.8

Agerage partial effect
----------------------
estimate  std.err
 -0.3229   0.2546
```

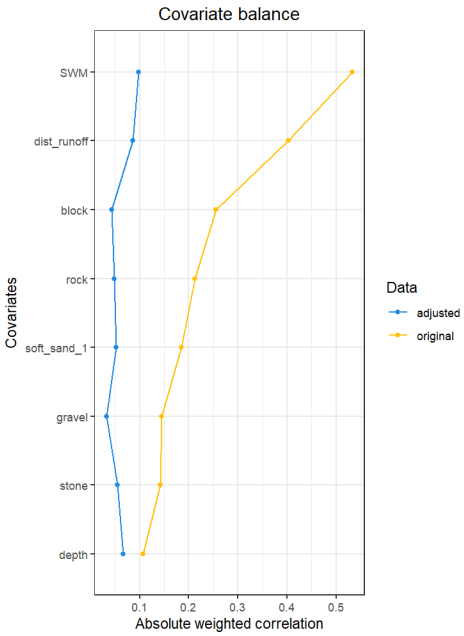
Continuous spline




```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
-------------------------------------
      0.00 |      3.04 |  2.79, 3.29
      0.03 |      3.20 |  3.02, 3.39
      0.10 |      3.47 |  3.21, 3.74
      0.20 |      3.78 |  3.56, 3.99
      0.35 |      3.95 |  3.67, 4.24
      0.58 |      3.77 |  3.43, 4.11
      0.91 |      3.21 |  2.72, 3.70
      5.00 |      1.66 | -1.88, 5.19
```

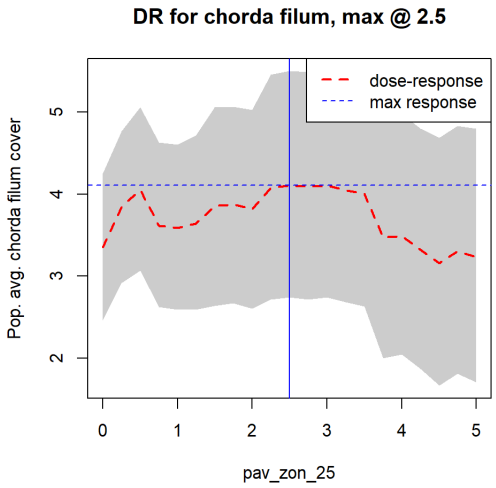
Conditional dose-response function, GPCERF





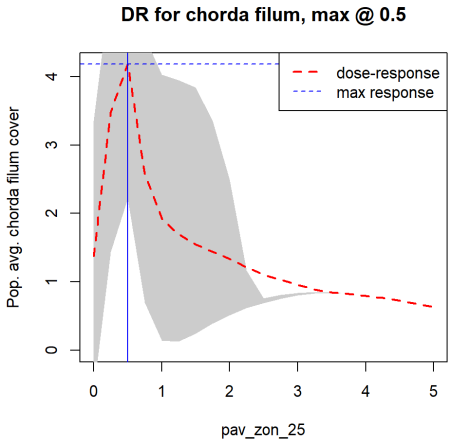

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,24) = 239.285, p = 0.000
R² = 0.909
Adj. R² = 0.905

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.    t val.       p
----------------- -------- ------- --------- -------
(Intercept)          4.642   0.144    32.236   0.000
exposure            -0.764   0.049   -15.469   0.000
--------------------------------------------------

Max of response: 4.642 at exposure 0
Min of response: 0.822 at exposure 5

Raw GPCERF max/min:
-------------------
Max of response: 4.302 at exposure 0.4
Min of response: 0.371 at exposure 5

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |     95% CI
---------------------------------
    0.00 |      4.64 | 4.35, 4.94
    0.50 |      4.26 | 4.01, 4.52
    1.50 |      3.50 | 3.31, 3.68
    2.00 |      3.11 | 2.95, 3.28
    2.50 |      2.73 | 2.58, 2.89
    3.00 |      2.35 | 2.19, 2.51
    3.50 |      1.97 | 1.78, 2.15
    5.00 |      0.82 | 0.52, 1.12
```

Continuous dose-response model, BART

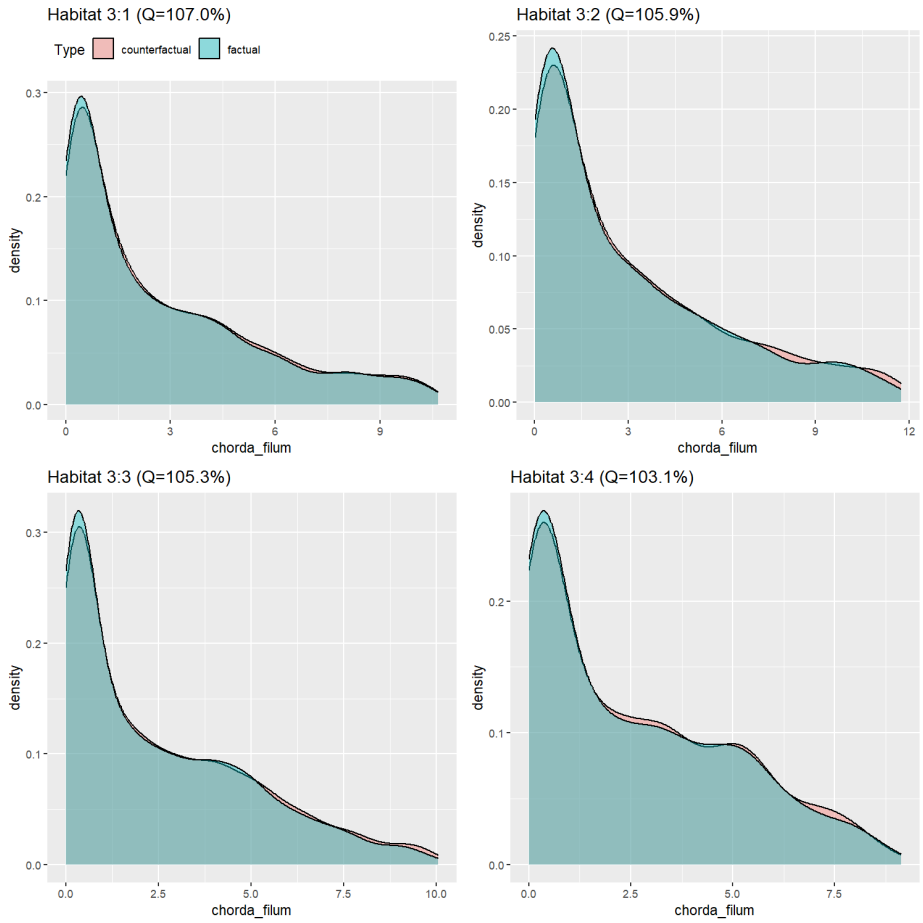


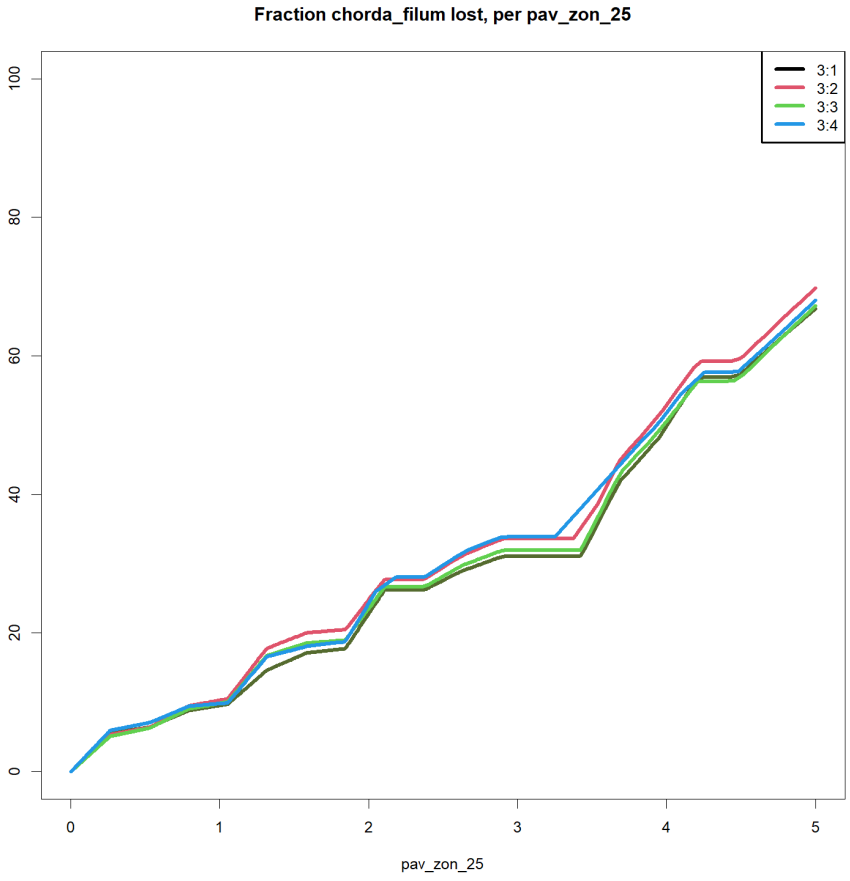

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 3.069, p = 0.096
R² = 0.139
Adj. R² = 0.094

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          3.911   0.130   30.131   0.000
exposure            -0.078   0.044   -1.752   0.096
--------------------------------------------------

Max of response: 3.911 at exposure 0
Min of response: 3.522 at exposure 5

Raw bart max/min:
-----------------
Max of response: 4.111 at exposure 2.5
Min of response: 3.16 at exposure 4.5

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |     95% CI
--------------------------------
    0.00 |      3.91 | 3.64, 4.18
    0.50 |      3.87 | 3.64, 4.11
    1.50 |      3.79 | 3.63, 3.96
    2.00 |      3.76 | 3.61, 3.90
    2.50 |      3.72 | 3.58, 3.86
    3.00 |      3.68 | 3.53, 3.83
    3.50 |      3.64 | 3.47, 3.81
    5.00 |      3.52 | 3.25, 3.79
```

Continuous dose-response model, GAM




```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 27.941, p = 0.000
R² = 0.595
Adj. R² = 0.574

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          2.592   0.257   10.078   0.000
exposure            -0.465   0.088   -5.286   0.000
--------------------------------------------------

Max of response: 2.592 at exposure 0
Min of response: 0.266 at exposure 5

Raw gam max/min:
-----------------
Max of response: 4.18 at exposure 0.5
Min of response: 0.63 at exposure 5

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |      95% CI
-----------------------------------
    0.00 |      2.59 |  2.05, 3.13
    0.50 |      2.36 |  1.90, 2.82
    1.50 |      1.89 |  1.56, 2.23
    2.00 |      1.66 |  1.37, 1.96
    2.50 |      1.43 |  1.15, 1.71
    3.00 |      1.20 |  0.90, 1.49
    3.50 |      0.96 |  0.63, 1.30
    5.00 |      0.27 | -0.27, 0.80
```


Habitat 3:1 (Q=107.0%)
Type
counterfactual
factual
density
chorda_filum
Habitat 3:2 (Q=105.9%)
density
chorda_filum
Habitat 3:3 (Q=105.3%)
density
chorda_filum
Habitat 3:4 (Q=103.1%)
density
chorda_filum

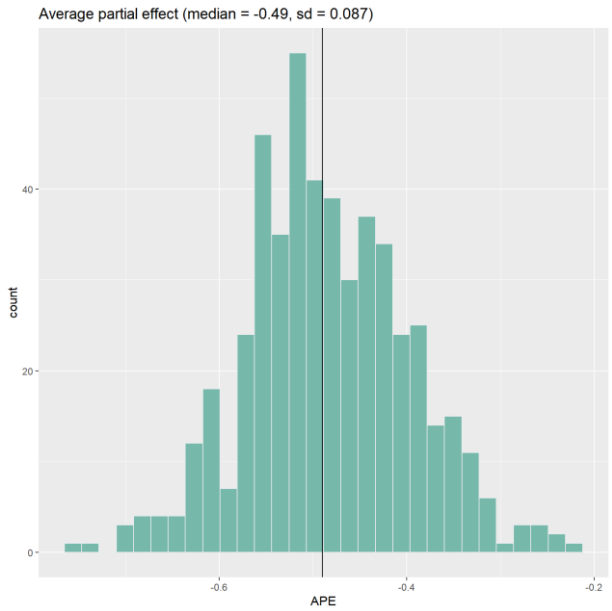

Fraction chorda_filum lost, per pav_zon_25
3:1
3:2
3:3
3:4
pav_zon_25

Charales spp.

WeightIt/svyglm

```
MODEL INFO:
 Observations: 11444
 Dependent Variable: response_data_causal
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.06
 Adj. R² = 0.06

Standard errors: Robust
-------------------------------------------------------------
                     Est.    2.5%   97.5%   t val.      p    VIF
----------------- ------- ------- ------- -------- ------ ------
 (Intercept)          2.40    2.09    2.72    14.78   0.00
 pav_zon_25          -0.40   -0.54   -0.27    -5.89   0.00   1.83
 SWM                  0.36    0.21    0.51     4.73   0.00   3.01
 dist_runoff         -0.82   -1.19   -0.44    -4.26   0.00   4.03
 depth               -2.24   -2.64   -1.85   -11.02   0.00   7.51
 rock                -0.50   -0.59   -0.42   -11.69   0.00   2.42
 block               -0.20   -0.26   -0.13    -6.27   0.00   1.33
 stone               -0.43   -0.54   -0.32    -7.48   0.00   1.70
 gravel              -0.07   -0.16    0.03    -1.42   0.15   1.10
 soft_sand_1         -1.08   -1.33   -0.84    -8.73   0.00   3.71
-------------------------------------------------------------

Margins
-------
      factor     AME     SE        z      p   lower   upper
       block -0.1962 0.0313  -6.2711 0.0000 -0.2575 -0.1349
       depth -2.2440 0.2035 -11.0246 0.0000 -2.6430 -1.8451
 dist_runoff -0.8164 0.1918  -4.2561 0.0000 -1.1923 -0.4404
      gravel -0.0671 0.0472  -1.4224 0.1549 -0.1596  0.0254
  pav_zon_25 -0.4045 0.0687  -5.8910 0.0000 -0.5391 -0.2699
        rock -0.5014 0.0429 -11.6898 0.0000 -0.5855 -0.4174
 soft_sand_1 -1.0836 0.1241  -8.7322 0.0000 -1.3268 -0.8404
       stone -0.4292 0.0574  -7.4770 0.0000 -0.5417 -0.3167
         SWM  0.3600 0.0762   4.7259 0.0000  0.2107  0.5092

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |     95% CI
-----------------------------------
         0 |      2.55 | 2.20, 2.89
         1 |      2.14 | 1.88, 2.40
         2 |      1.74 | 1.51, 1.97
         3 |      1.33 | 1.06, 1.61
         4 |      0.93 | 0.56, 1.29
         5 |      0.52 | 0.05, 1.00
```

Bayesian Causal Exposure Model




```
Covariate inclusion, exposure model
-----------------------------------
  SWM dist_runoff depth rock block stone gravel soft_sand_1 prob.
1   1           1     1    1     0     1      0           1     1

Covariate inclusion frequency, effect model
-------------------------------------------
    covariate frequency
1         SWM     1.000
2 dist_runoff     1.000
3       depth     1.000
4        rock     1.000
5       block     0.070
6       stone     0.998
7      gravel     0.010
8 soft_sand_1     1.000
```

Median of estimated effect: -0.49
Std of estimated effect: 0.087

---

twangContinuous by treatment only

```
MODEL INFO:
 Observations: 11444
 Dependent Variable: charales
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.00
 Adj. R² = 0.00

 Standard errors: Robust
 ------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p
 ---------------- ------- ------- ------- -------- ------
 (Intercept)          2.42    2.09    2.75    14.40   0.00
 pav_zon_25          -0.35   -0.46   -0.24    -6.11   0.00
 ------------------------------------------------------------
```

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |     95% CI
-----------------------------------
         0 |      2.42 | 2.09, 2.75
         1 |      2.07 | 1.82, 2.32
         2 |      1.72 | 1.52, 1.93
         3 |      1.38 | 1.16, 1.59
         4 |      1.03 | 0.76, 1.30
         5 |      0.68 | 0.32, 1.04
```

---

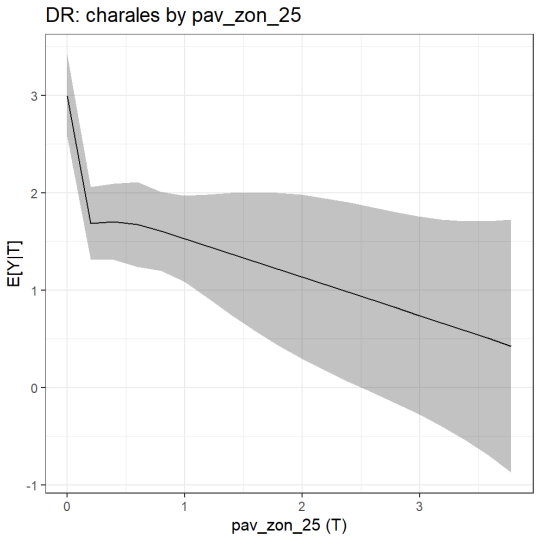
twangContinuous by all covariates

```
MODEL INFO:
 Observations: 11444
 Dependent Variable: charales
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.06
 Adj. R² = 0.06

 Standard errors: Robust
 ------------------------------------------------------------------
                       Est.    2.5%   97.5%   t val.      p     VIF
 ----------------- ------- ------- ------- -------- ------ -------
 (Intercept)          2.37    2.06    2.68    15.03   0.00
 pav_zon_25          -0.57   -0.84   -0.30    -4.13   0.00   10.88
 SWM                  0.31    0.18    0.44     4.58   0.00    2.63
 dist_runoff         -0.76   -1.10   -0.41    -4.34   0.00    3.65
 depth               -2.01   -2.37   -1.66   -11.20   0.00    7.09
 rock                -0.49   -0.57   -0.41   -12.35   0.00    2.44
 block               -0.19   -0.25   -0.13    -6.47   0.00    1.34
 stone               -0.41   -0.52   -0.30    -7.12   0.00    1.75
 gravel              -0.07   -0.16    0.02    -1.55   0.12    1.11
 soft_sand_1         -1.15   -1.39   -0.91    -9.40   0.00    3.81
 wts                  0.05   -0.01    0.11     1.53   0.13    7.91
 ------------------------------------------------------------------

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
-----------------------------------
         0 |      2.67 |  2.20, 3.13
         1 |      2.09 |  1.84, 2.35
         2 |      1.52 |  1.28, 1.76
         3 |      0.95 |  0.50, 1.39
         4 |      0.38 | -0.32, 1.08
         5 |     -0.19 | -1.16, 0.77
```

Causal Forest

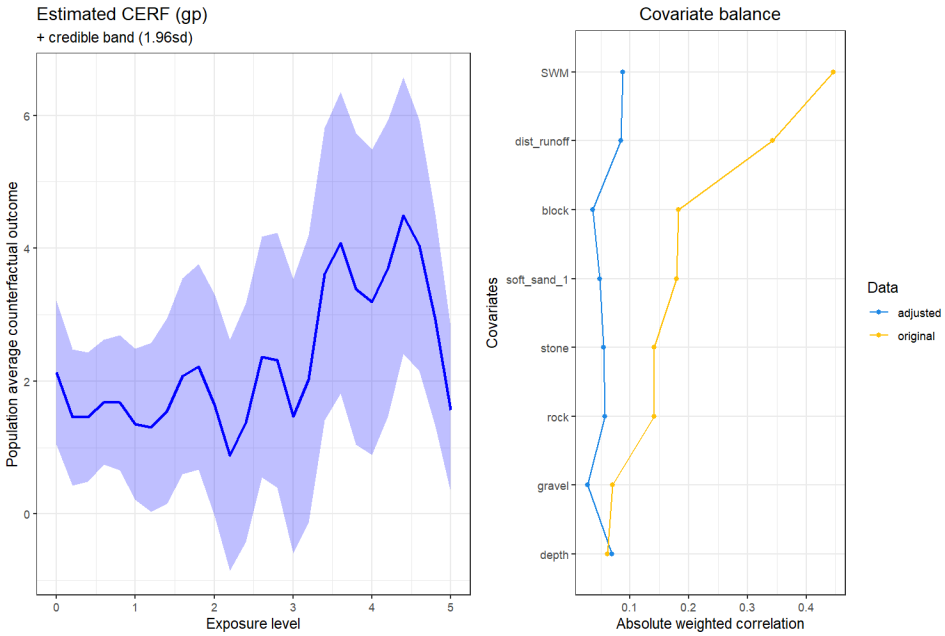
```
Best linear fit using forest predictions (on held-out data)
as well as the mean forest prediction as regressors, along
with one-sided heteroskedasticity-robust (HC3) SEs:

                               Estimate Std. Error t value              Pr(>t)
mean.forest.prediction           -0.236      0.681   -0.35                0.64
differential.forest.prediction    1.673      0.190    8.80 <0.0000000000000002 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Conditional average treatment effects: 0.1

Agerage partial effect
----------------------
estimate  std.err
 -0.2066   0.1798
```

Continuous spline



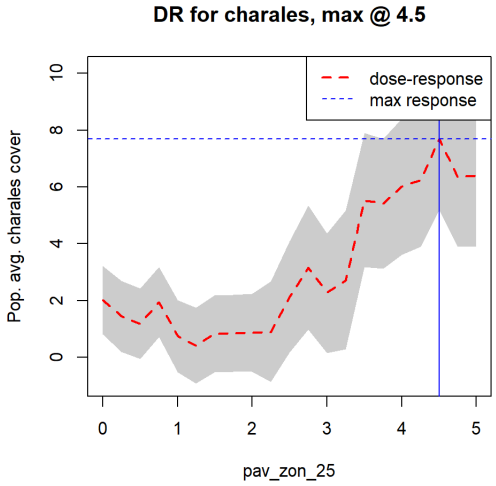

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
-------------------------------------
      0.00 |      3.00 |  2.58, 3.42
      0.04 |      2.45 |  2.14, 2.75
      0.12 |      1.88 |  1.48, 2.29
      0.23 |      1.68 |  1.34, 2.02
      0.39 |      1.70 |  1.32, 2.09
      0.62 |      1.67 |  1.23, 2.10
      0.98 |      1.54 |  1.10, 1.97
      5.00 |     -0.06 | -2.29, 2.16
```

Conditional dose-response function, GPCERF



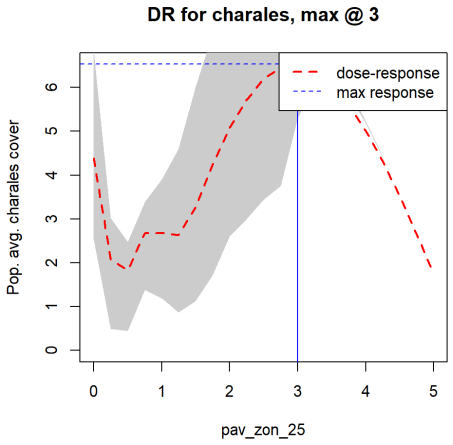

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,24) = 18.998, p = 0.000
R² = 0.442
Adj. R² = 0.419

Standard errors: OLS
--------------------------------------------------
                     Est.    S.E.   t val.       p
---------------- ------- ------- -------- -------
(Intercept)         1.192   0.299    3.993   0.001
exposure            0.446   0.102    4.359   0.000
--------------------------------------------------
Max of response: 3.423 at exposure 5
Min of response: 1.192 at exposure 0

Raw GPCERF max/min:
-------------------

Max of response: 4.491 at exposure 4.4
Min of response: 0.885 at exposure 2.2
Adjusted predictions at the mean
--------------------------------

# Predicted values of cover

exposure | Predicted |     95% CI
---------------------------------
    0.00 |      1.19 | 0.58, 1.81
    0.50 |      1.42 | 0.89, 1.94
    1.50 |      1.86 | 1.48, 2.24
    2.00 |      2.08 | 1.75, 2.42
    2.50 |      2.31 | 1.99, 2.62
    3.00 |      2.53 | 2.20, 2.86
    3.50 |      2.75 | 2.37, 3.13
    5.00 |      3.42 | 2.81, 4.04
```

Continuous dose-response model, BART

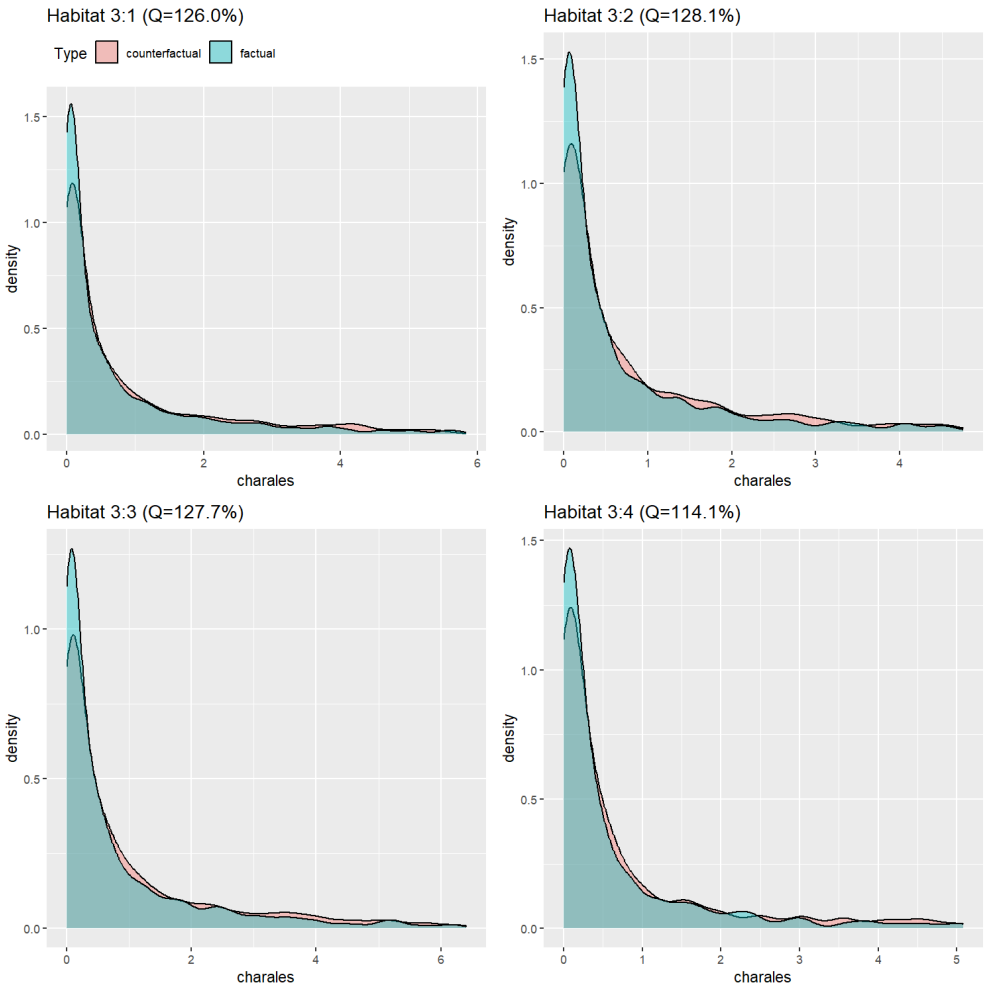


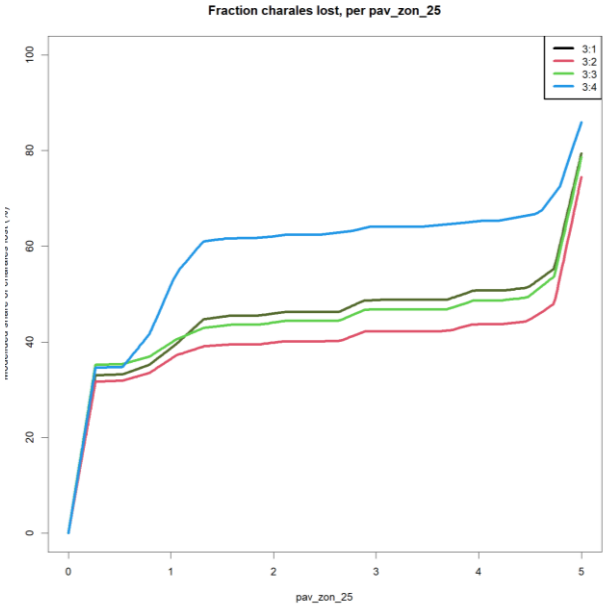

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 53.456, p = 0.000
R² = 0.738
Adj. R² = 0.724

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)         -0.227   0.532   -0.426   0.675
exposure             1.332   0.182    7.311   0.000
--------------------------------------------------

Max of response: 6.431 at exposure 5
Min of response: -0.227 at exposure 0

Raw bart max/min:
-----------------
Max of response: 7.696 at exposure 4.5
Min of response: 0.418 at exposure 1.25

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |      95% CI
---------------------------------
    0.00 |     -0.23 | -1.34, 0.89
    0.50 |      0.44 | -0.52, 1.40
    1.50 |      1.77 |  1.08, 2.46
    2.00 |      2.44 |  1.83, 3.04
    2.50 |      3.10 |  2.52, 3.68
    3.00 |      3.77 |  3.16, 4.38
    3.50 |      4.43 |  3.74, 5.13
    5.00 |      6.43 |  5.32, 7.54
```

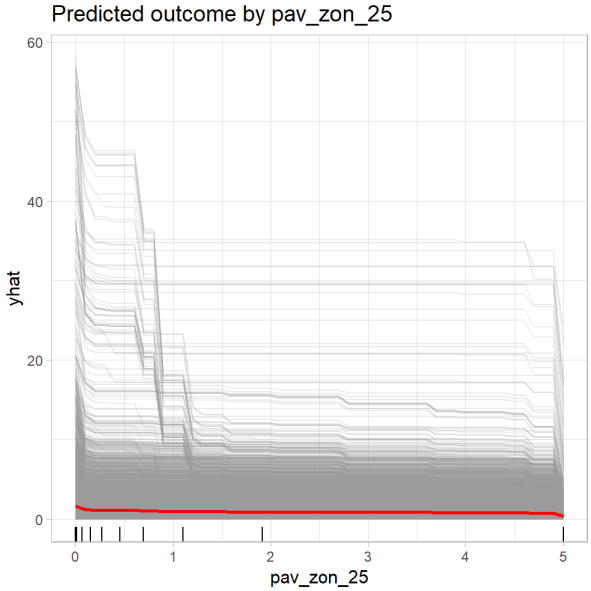
Continuous dose-response model, GAM




```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 1.387, p = 0.253
R² = 0.068
Adj. R² = 0.019

Standard errors: OLS
--------------------------------------------------
                     Est.    S.E.   t val.       p
---------------- ------- ------- -------- -------
(Intercept)         3.540   0.697    5.081   0.000
exposure            0.281   0.238    1.178   0.253
--------------------------------------------------

Max of response: 4.944 at exposure 5
Min of response: 3.54 at exposure 0

Raw gam max/min:
----------------
Max of response: 6.532 at exposure 3
Min of response: 1.749 at exposure 5

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |     95% CI
--------------------------------
    0.00 |      3.54 | 2.08, 5.00
    0.50 |      3.68 | 2.43, 4.93
    1.50 |      3.96 | 3.06, 4.87
    2.00 |      4.10 | 3.31, 4.90
    2.50 |      4.24 | 3.49, 5.00
    3.00 |      4.38 | 3.59, 5.18
    3.50 |      4.52 | 3.62, 5.43
    5.00 |      4.94 | 3.49, 6.40
```


Habitat 3:1 (Q=126.0%)
Type
counterfactual
factual
density
charales
Habitat 3:2 (Q=128.1%)
density
charales
Habitat 3:3 (Q=127.7%)
density
charales
Habitat 3:4 (Q=114.1%)
density
charales


Fraction charales lost, per pav_zon_25
3:1
3:2
3:3
3:4
pav_zon_25

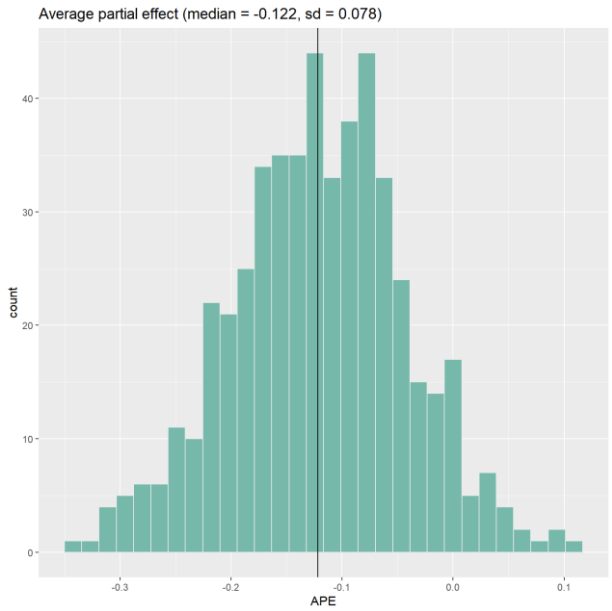

Predicted outcome by pav_zon_25
yhat
pav_zon_25

Monostoma balticum

WeightIt/svyglm

```
MODEL INFO:
 Observations: 11480
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.02
 Adj. R² = 0.02

 Standard errors: Robust
------------------------------------------------------------------
                     Est.    2.5%   97.5%   t val.      p    VIF
----------------- ------- ------- ------- -------- ------ ------
 (Intercept)          1.56    1.39    1.73    18.17   0.00
 pav_zon_25          -0.33   -0.40   -0.26    -9.33   0.00   1.36
 SWM                 -0.95   -1.13   -0.77   -10.44   0.00   4.94
 dist_runoff          0.14    0.04    0.25     2.61   0.01   1.52
 depth                0.61    0.47    0.76     8.23   0.00   1.90
 rock                 0.01   -0.12    0.14     0.14   0.89   1.32
 block               -0.06   -0.13    0.02    -1.42   0.16   1.41
 stone               -0.16   -0.27   -0.05    -2.93   0.00   1.49
 gravel              -0.05   -0.15    0.05    -1.04   0.30   1.20
 soft_sand_1          0.99    0.80    1.17    10.27   0.00   3.04
------------------------------------------------------------------

Margins
-------
      factor     AME     SE        z      p   lower   upper
       block -0.0565 0.0399  -1.4162 0.1567 -0.1346  0.0217
       depth  0.6114 0.0743   8.2307 0.0000  0.4658  0.7570
 dist_runoff  0.1436 0.0549   2.6131 0.0090  0.0359  0.2512
      gravel -0.0517 0.0499  -1.0366 0.2999 -0.1495  0.0461
  pav_zon_25 -0.3337 0.0357  -9.3344 0.0000 -0.4037 -0.2636
        rock  0.0097 0.0674   0.1434 0.8860 -0.1224  0.1418
 soft_sand_1  0.9864 0.0960  10.2698 0.0000  0.7981  1.1746
       stone -0.1631 0.0556  -2.9328 0.0034 -0.2722 -0.0541
         SWM -0.9483 0.0909 -10.4364 0.0000 -1.1264 -0.7702

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
-----------------------------------
         0 |      1.59 |  1.42, 1.76
         1 |      1.25 |  1.11, 1.40
         2 |      0.92 |  0.78, 1.06
         3 |      0.59 |  0.41, 0.76
         4 |      0.25 |  0.03, 0.48
         5 |     -0.08 | -0.36, 0.20
```

Bayesian Causal Exposure Model




```
Covariate inclusion, exposure model
-----------------------------------
  SWM dist_runoff depth rock block stone gravel soft_sand_1  prob.
1   1           1     1    1     0     1      0           1 0.7985
2   1           1     1    1     1     1      0           1 0.2015

Covariate inclusion frequency, effect model
-------------------------------------------
    covariate frequency
1         SWM     1.000
2 dist_runoff     1.000
3       depth     1.000
4        rock     0.166
5       block     0.012
6       stone     0.612
7      gravel     0.002
8 soft_sand_1     1.000

Median of estimated effect: -0.122
Std of estimated effect: 0.078
```

---

twangContinuous by treatment only

```
MODEL INFO:
 Observations: 11480
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.01
 Adj. R² = 0.01

 Standard errors: Robust
 ------------------------------------------------------------
                       Est.    2.5%   97.5%   t val.      p
 ----------------- ------- ------- ------- -------- ------
 (Intercept)           1.49    1.33    1.66    17.84   0.00
 pav_zon_25           -0.28   -0.31   -0.25   -16.60   0.00
 ------------------------------------------------------------
```

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |     95% CI
-----------------------------------
         0 |      1.49 | 1.33, 1.66
         1 |      1.21 | 1.08, 1.35
         2 |      0.93 | 0.83, 1.04
         3 |      0.65 | 0.57, 0.73
         4 |      0.38 | 0.31, 0.44
         5 |      0.10 | 0.04, 0.16
```

---

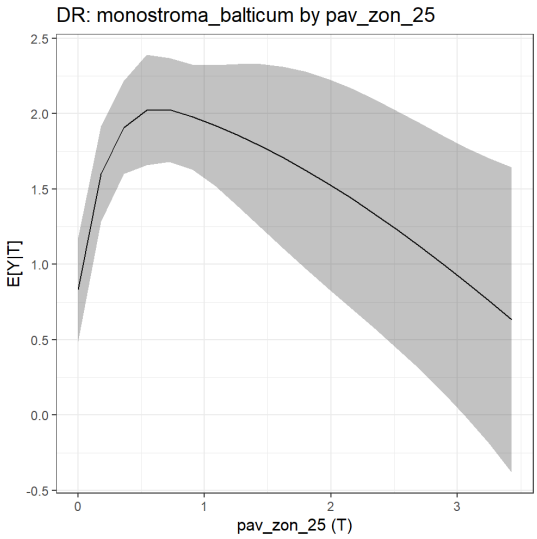
twangContinuous by all covariates

```
MODEL INFO:
 Observations: 11480
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.03
 Adj. R² = 0.03

 Standard errors: Robust
 ------------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p    VIF
 ----------------- ------- ------- ------- -------- ------ ------
 (Intercept)          1.57    1.40    1.74    18.04   0.00
 pav_zon_25          -0.35   -0.40   -0.29   -11.47   0.00   2.37
 SWM                 -0.91   -1.09   -0.74   -10.18   0.00   4.75
 dist_runoff          0.16    0.07    0.26     3.40   0.00   1.36
 depth                0.63    0.49    0.78     8.59   0.00   1.98
 rock                 0.01   -0.12    0.13     0.11   0.91   1.33
 block               -0.07   -0.14    0.01    -1.80   0.07   1.40
 stone               -0.13   -0.24   -0.03    -2.54   0.01   1.36
 gravel              -0.03   -0.13    0.06    -0.73   0.46   1.17
 soft_sand_1          0.82    0.66    0.98    10.06   0.00   3.13
 wts                 -0.00   -0.00    0.00    -1.16   0.25   1.95
 ------------------------------------------------------------------

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
------------------------------------
         0 |      1.61 |  1.42, 1.80
         1 |      1.26 |  1.12, 1.41
         2 |      0.92 |  0.80, 1.03
         3 |      0.57 |  0.46, 0.68
         4 |      0.22 |  0.09, 0.36
         5 |     -0.12 | -0.30, 0.06
```

Causal Forest

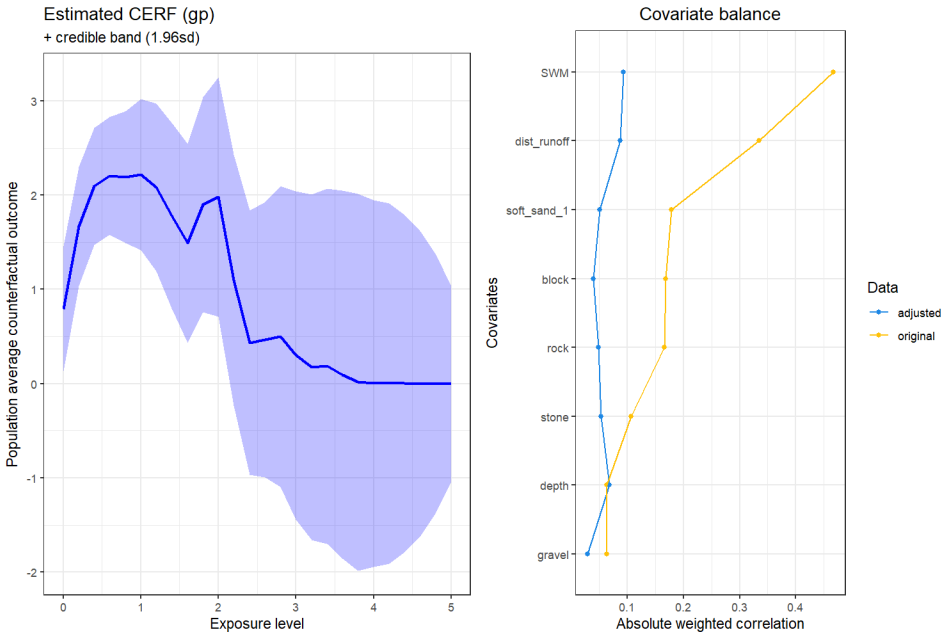
```
Best linear fit using forest predictions (on held-out data)
as well as the mean forest prediction as regressors, along
with one-sided heteroskedasticity-robust (HC3) SEs:

                               Estimate Std. Error t value     Pr(>t)
mean.forest.prediction           -0.046      0.612   -0.08       0.53
differential.forest.prediction    3.236      0.632    5.12 0.00000016 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Conditional average treatment effects: -0.1

Agerage partial effect
----------------------
estimate  std.err
  0.3535   0.1816
```

Continuous spline




```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
-------------------------------------
      0.00 |      0.83 |  0.49, 1.18
      0.04 |      1.08 |  0.83, 1.33
      0.11 |      1.39 |  1.06, 1.72
      0.22 |      1.69 |  1.41, 1.98
      0.38 |      1.93 |  1.61, 2.25
      0.61 |      2.03 |  1.67, 2.40
      0.96 |      1.96 |  1.60, 2.32
      5.00 |     -0.56 | -2.63, 1.51
```

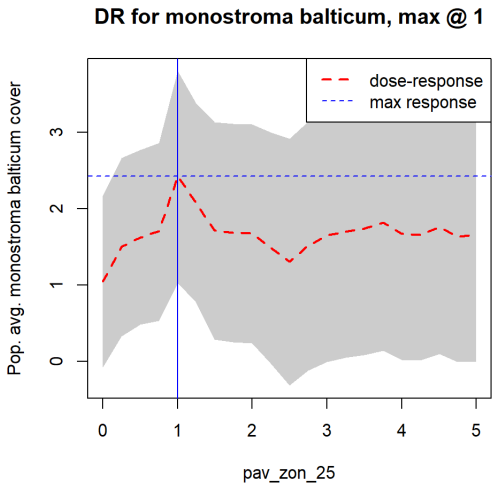
Conditional dose-response function, GPCERF




```
Linear trend analysis
---------------------

MODEL FIT:
F(1,24) = 66.422, p = 0.000
R² = 0.735
Adj. R² = 0.724

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          2.167   0.180   12.056   0.000
exposure            -0.502   0.062   -8.150   0.000
--------------------------------------------------
Max of response: 2.167 at exposure 0
Min of response: -0.345 at exposure 5

Raw GPCERF max/min:
-------------------

Max of response: 2.218 at exposure 1
Min of response: 0 at exposure 4.8

Adjusted predictions at the mean
--------------------------------

# Predicted values of cover

exposure | Predicted |      95% CI
---------------------------------
    0.00 |      2.17 |  1.80, 2.54
    0.50 |      1.92 |  1.60, 2.23
    1.50 |      1.41 |  1.18, 1.64
    2.00 |      1.16 |  0.96, 1.36
    2.50 |      0.91 |  0.72, 1.10
    3.00 |      0.66 |  0.46, 0.86
    3.50 |      0.41 |  0.18, 0.64
```

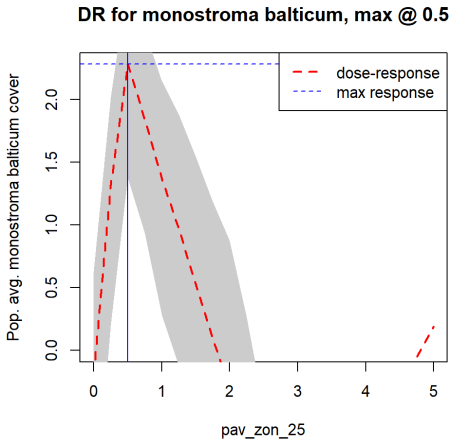
```
    5.00 |      -0.35 | -0.72, 0.0
```

Continuous dose-response model, BART

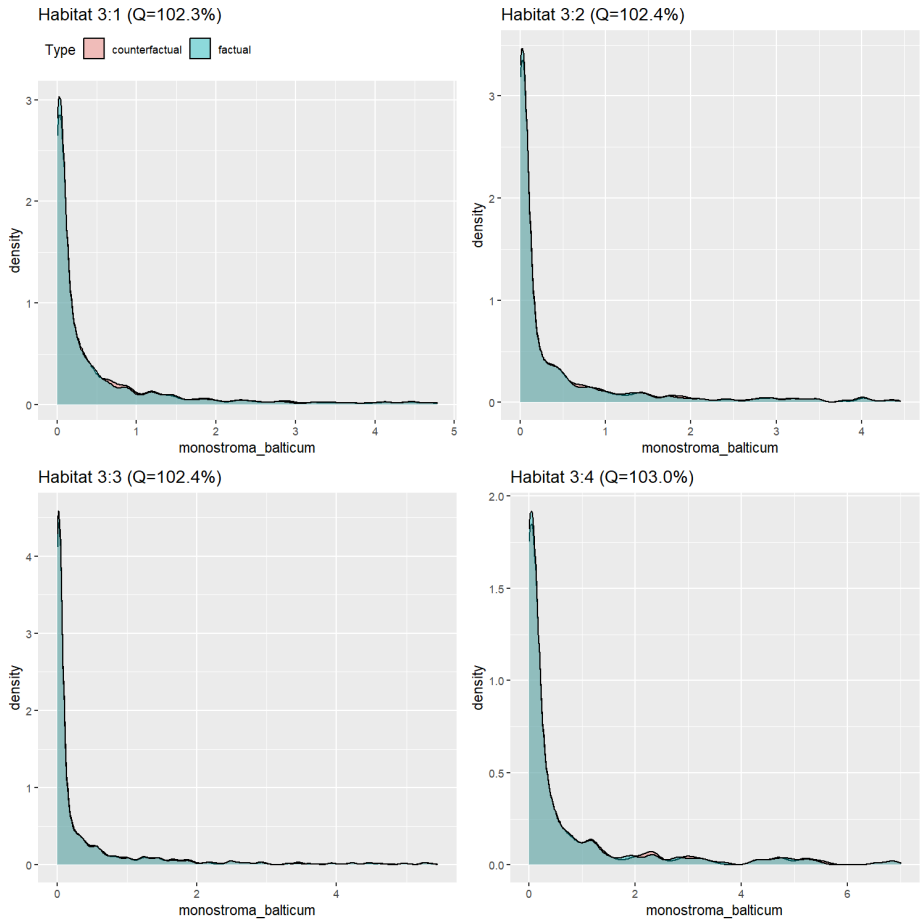


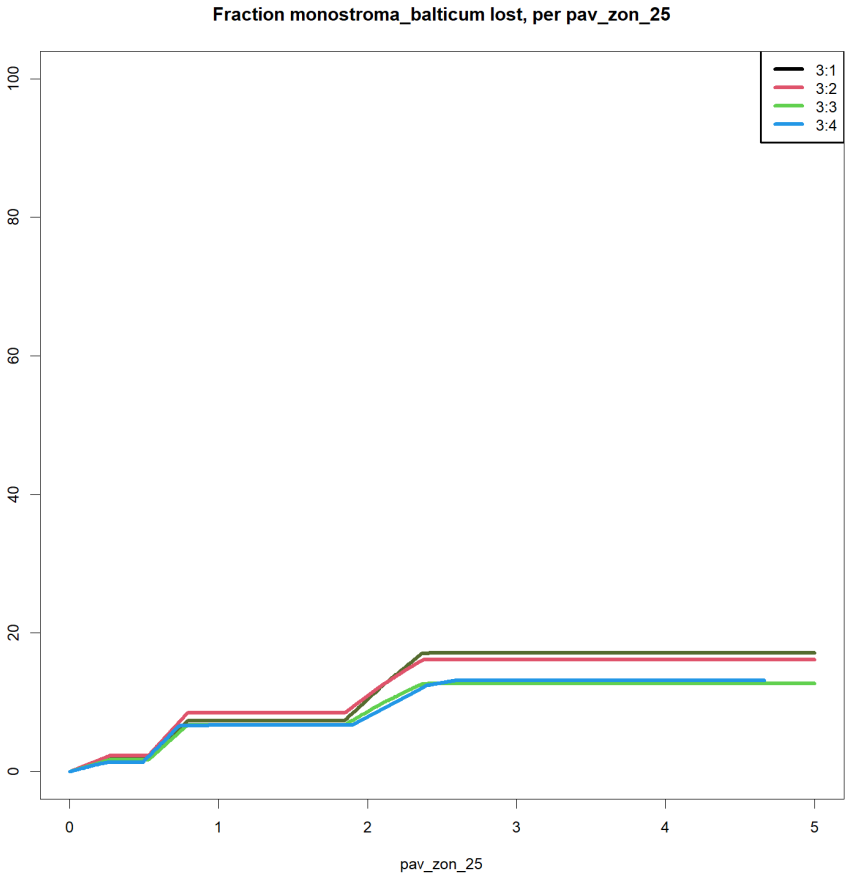

```
MODEL FIT:
F(1,19) = 0.094, p = 0.762
R² = 0.005
Adj. R² = -0.047

Standard errors: OLS
--------------------------------------------------
                     Est.    S.E.   t val.       p
----------------- ------- ------- -------- -------
(Intercept)         1.639   0.113   14.463   0.000
exposure            0.012   0.039    0.307   0.762
--------------------------------------------------

Max of response: 1.698 at exposure 5
Min of response: 1.639 at exposure 0

Raw bart max/min:
-----------------
Max of response: 2.424 at exposure 1
Min of response: 1.047 at exposure 0

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |     95% CI
--------------------------------
    0.00 |      1.64 | 1.40, 1.88
    0.50 |      1.64 | 1.44, 1.85
    1.50 |      1.66 | 1.51, 1.80
    2.00 |      1.66 | 1.53, 1.79
    2.50 |      1.67 | 1.55, 1.79
    3.00 |      1.67 | 1.55, 1.80
    3.50 |      1.68 | 1.53, 1.83
    5.00 |      1.70 | 1.46, 1.94
```

Continuous dose-response model, GAM




```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 12.298, p = 0.002
R² = 0.393
Adj. R² = 0.361

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          1.029   0.343    3.003   0.007
exposure            -0.411   0.117   -3.507   0.002
--------------------------------------------------

Max of response: 1.029 at exposure 0
Min of response: -1.027 at exposure 5

Raw gam max/min:
-----------------
Max of response: 2.281 at exposure 0.5
Min of response: -1.073 at exposure 3

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |       95% CI
-------------------------------------
    0.00 |      1.03 |  0.31,  1.75
    0.50 |      0.82 |  0.21,  1.44
    1.50 |      0.41 | -0.03,  0.86
    2.00 |      0.21 | -0.18,  0.60
    2.50 |      0.00 | -0.37,  0.37
    3.00 |     -0.20 | -0.60,  0.19
    3.50 |     -0.41 | -0.86,  0.04
    5.00 |     -1.03 | -1.74, -0.31
```


Habitat 3:1 (Q=102.3%)
Type
counterfactual
factual
density
monostroma_balticum
Habitat 3:2 (Q=102.4%)
density
monostroma_balticum
Habitat 3:3 (Q=102.4%)
density
monostroma_balticum
Habitat 3:4 (Q=103.0%)
density
monostroma_balticum

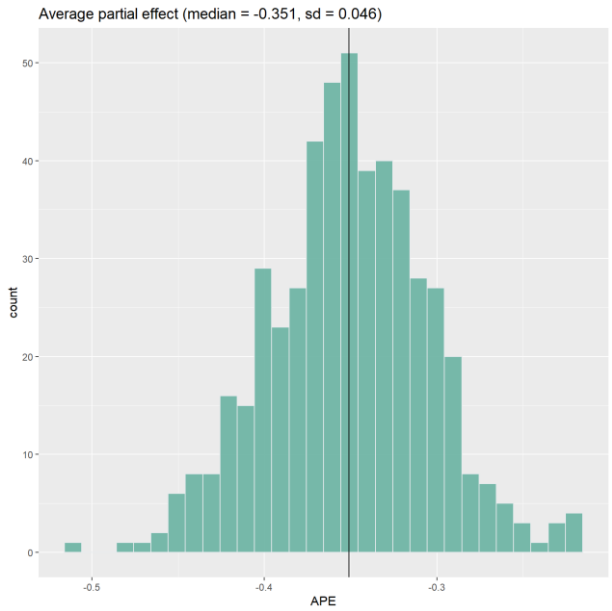

Fraction monostroma_balticum lost, per pav_zon_25
3:1
3:2
3:3
3:4
pav_zon_25

Ruppia (både R. cirrhosa och R. maritima)

WeightIt/svyglm

```
MODEL INFO:
 Observations: 12741
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.06
 Adj. R² = 0.06

 Standard errors: Robust
 ------------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p    VIF
 ----------------- ------- ------- ------- -------- ------ ------
 (Intercept)          1.38    1.26    1.50    22.54   0.00
 pav_zon_25          -0.26   -0.34   -0.19    -6.66   0.00   1.30
 SWM                 -0.15   -0.24   -0.06    -3.36   0.00   2.86
 dist_runoff          0.29    0.18    0.41     5.13   0.00   1.78
 depth               -1.14   -1.26   -1.01   -17.61   0.00   2.43
 rock                -0.45   -0.51   -0.40   -15.38   0.00   2.64
 block               -0.19   -0.24   -0.14    -7.61   0.00   1.70
 stone               -0.01   -0.12    0.09    -0.28   0.78   1.50
 gravel               0.23    0.09    0.38     3.16   0.00   1.58
 soft_sand_1          0.40    0.29    0.52     6.98   0.00   1.39
 ------------------------------------------------------------------

Margins
-------
      factor     AME     SE        z      p   lower   upper
       block -0.1938 0.0255  -7.6116 0.0000 -0.2437 -0.1439
       depth -1.1368 0.0646 -17.6058 0.0000 -1.2633 -1.0102
 dist_runoff  0.2937 0.0573   5.1265 0.0000  0.1814  0.4059
      gravel  0.2316 0.0733   3.1608 0.0016  0.0880  0.3753
  pav_zon_25 -0.2640 0.0397  -6.6562 0.0000 -0.3417 -0.1862
        rock -0.4535 0.0295 -15.3837 0.0000 -0.5112 -0.3957
 soft_sand_1  0.4034 0.0578   6.9800 0.0000  0.2901  0.5166
       stone -0.0147 0.0515  -0.2846 0.7760 -0.1157  0.0863
         SWM -0.1537 0.0457  -3.3601 0.0008 -0.2434 -0.0641

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
-------------------------------------
         0 |      1.42 |  1.29, 1.54
         1 |      1.15 |  1.06, 1.25
         2 |      0.89 |  0.77, 1.02
         3 |      0.63 |  0.44, 0.81
         4 |      0.36 |  0.11, 0.62
         5 |      0.10 | -0.23, 0.43
```

Bayesian Causal Exposure Model




```
Covariate inclusion, exposure model
-----------------------------------
  SWM dist_runoff depth rock block stone gravel soft_sand_1  prob.
1   1           1     1    1     1     1      0           1 0.7618
2   1           1     1    1     0     1      0           1 0.2382

Covariate inclusion frequency, effect model
-------------------------------------------
    covariate frequency
1         SWM     1.000
2 dist_runoff     1.000
3       depth     1.000
4        rock     1.000
5       block     0.980
6       stone     0.332
7      gravel     0.994
8 soft_sand_1     1.000
```

Median of estimated effect: -0.351
Std of estimated effect: 0.046

---

twangContinuous by treatment only

```
MODEL INFO:
 Observations: 12741
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.00
 Adj. R² = 0.00

 Standard errors: Robust
 ------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p
 ----------------- ------- ------- ------- -------- ------
 (Intercept)          1.38    1.26    1.50    22.78   0.00
 pav_zon_25          -0.19   -0.25   -0.14    -6.85   0.00
 ------------------------------------------------------------
```

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |     95% CI
-----------------------------------
         0 |      1.38 | 1.26, 1.50
         1 |      1.19 | 1.09, 1.28
         2 |      0.99 | 0.89, 1.10
         3 |      0.80 | 0.67, 0.93
         4 |      0.61 | 0.43, 0.78
         5 |      0.41 | 0.19, 0.64
```

---

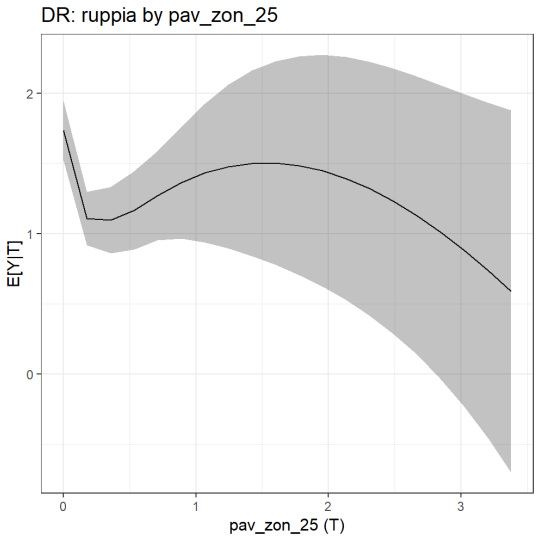
twangContinuous by all covariates

```
MODEL INFO:
 Observations: 12741
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.06
 Adj. R² = 0.06

 Standard errors: Robust
 ------------------------------------------------------------------
                       Est.    2.5%   97.5%   t val.      p    VIF
 ----------------- ------- ------- ------- -------- ------ ------
 (Intercept)           1.37    1.25    1.48    22.97   0.00
 pav_zon_25           -0.24   -0.35   -0.13    -4.44   0.00   3.51
 SWM                  -0.13   -0.22   -0.04    -2.97   0.00   2.68
 dist_runoff           0.25    0.14    0.36     4.58   0.00   1.71
 depth                -1.07   -1.19   -0.95   -17.43   0.00   2.56
 rock                 -0.46   -0.52   -0.41   -16.74   0.00   2.82
 block                -0.21   -0.26   -0.16    -7.91   0.00   1.62
 stone                 0.00   -0.10    0.11     0.02   0.98   1.51
 gravel                0.21    0.08    0.35     3.06   0.00   1.48
 soft_sand_1           0.34    0.23    0.45     6.18   0.00   1.40
 wts                   0.01   -0.01    0.03     0.64   0.52   3.02
 ------------------------------------------------------------------

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
-----------------------------------
         0 |      1.43 |  1.27, 1.59
         1 |      1.19 |  1.09, 1.29
         2 |      0.95 |  0.82, 1.08
         3 |      0.71 |  0.49, 0.92
         4 |      0.47 |  0.15, 0.78
         5 |      0.23 | -0.19, 0.64
```

Causal Forest

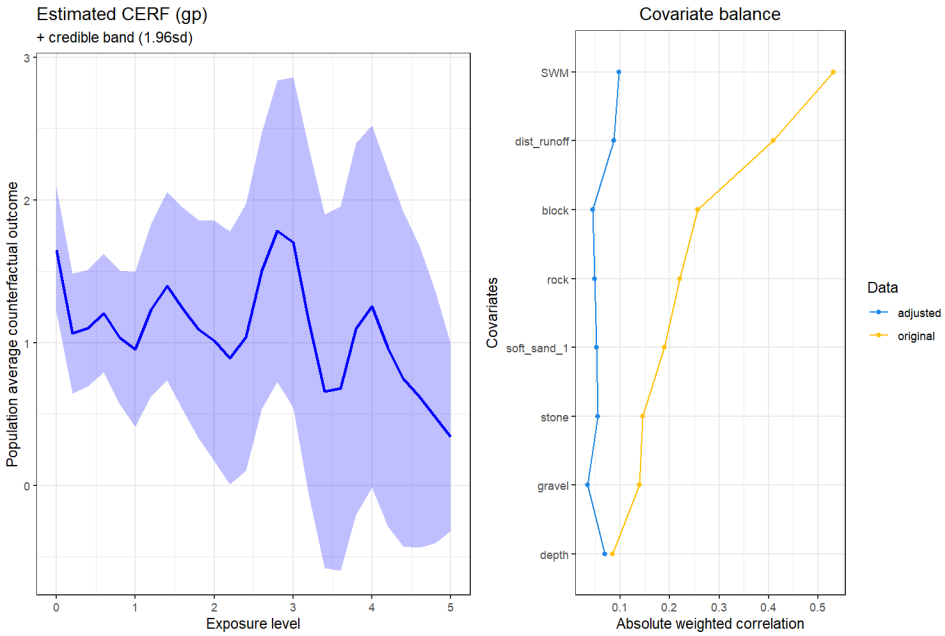
```
Best linear fit using forest predictions (on held-out data)
as well as the mean forest prediction as regressors, along
with one-sided heteroskedasticity-robust (HC3) SEs:

                               Estimate Std. Error t value              Pr(>t)
mean.forest.prediction            0.625      0.572    1.09                0.14
differential.forest.prediction    1.289      0.151    8.56 <0.0000000000000002 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Conditional average treatment effects: -0.1

Agerage partial effect
----------------------
estimate  std.err
-0.09177  0.17174
```

Continuous spline



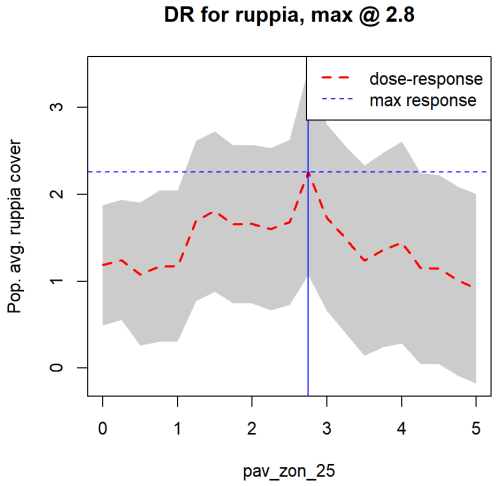

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
-------------------------------------
      0.00 |      3.04 |  2.79, 3.29
      0.03 |      3.20 |  3.02, 3.39
      0.10 |      3.47 |  3.21, 3.74
      0.20 |      3.78 |  3.56, 3.99
      0.35 |      3.95 |  3.67, 4.24
      0.58 |      3.77 |  3.43, 4.11
      0.91 |      3.21 |  2.72, 3.70
      5.00 |      1.66 | -1.88, 5.19
```

Conditional dose-response function, GPCERF



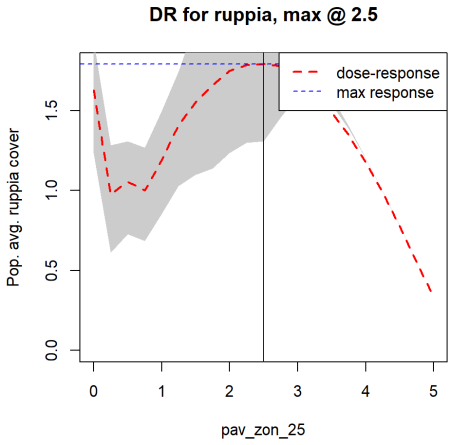

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,24) = 8.306, p = 0.008
R² = 0.257
Adj. R² = 0.226

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          1.372   0.121   11.381   0.000
exposure            -0.119   0.041   -2.882   0.008
--------------------------------------------------

Max of response: 1.372 at exposure 0
Min of response: 0.776 at exposure 5

Raw GPCERF max/min:
-------------------
Max of response: 1.782 at exposure 2.8
Min of response: 0.34 at exposure 5

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |     95% CI
---------------------------------
    0.00 |      1.37 | 1.12, 1.62
    0.50 |      1.31 | 1.10, 1.53
    1.50 |      1.19 | 1.04, 1.35
    2.00 |      1.13 | 1.00, 1.27
    2.50 |      1.07 | 0.95, 1.20
    3.00 |      1.01 | 0.88, 1.15
    3.50 |      0.95 | 0.80, 1.11
    5.00 |      0.78 | 0.53, 1.02
```

Continuous dose-response model, BART

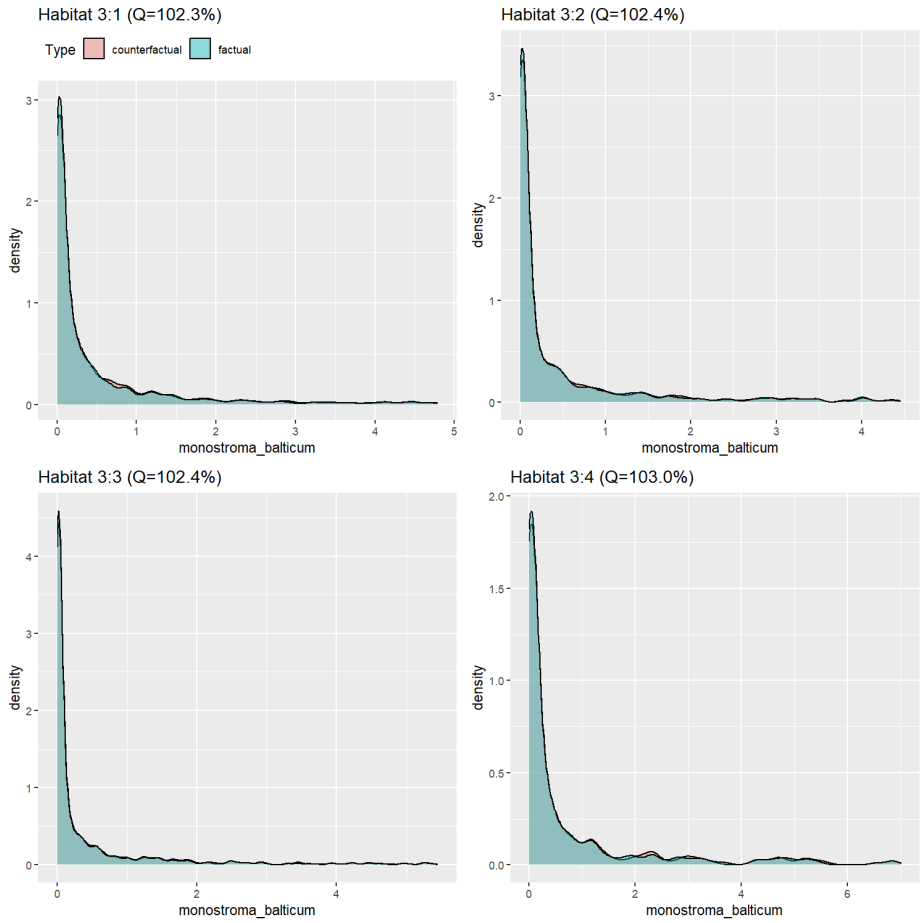


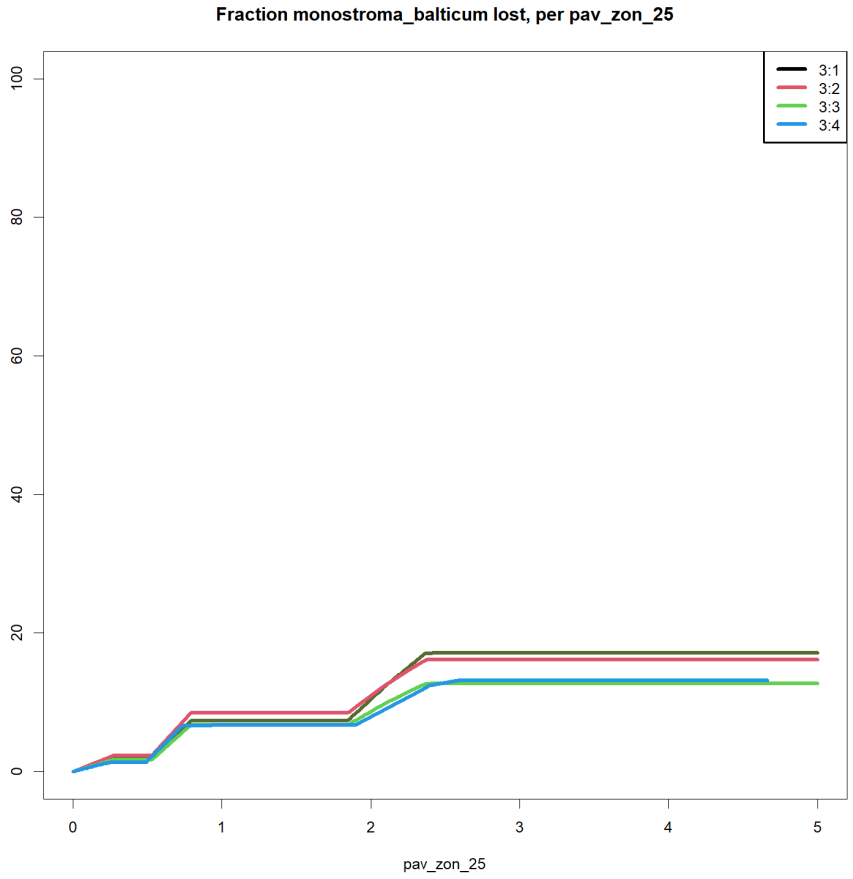

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 0.477, p = 0.498
R² = 0.025
Adj. R² = -0.027

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          1.497   0.140   10.655   0.000
exposure            -0.033   0.048   -0.691   0.498
--------------------------------------------------

Max of response: 1.497 at exposure 0
Min of response: 1.331 at exposure 5

Raw bart max/min:
-----------------
Max of response: 2.255 at exposure 2.75
Min of response: 0.921 at exposure 5
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |     95% CI
--------------------------------
    0.00 |      1.50 | 1.20, 1.79
    0.50 |      1.48 | 1.23, 1.73
    1.50 |      1.45 | 1.26, 1.63
    2.00 |      1.43 | 1.27, 1.59
    2.50 |      1.41 | 1.26, 1.57
    3.00 |      1.40 | 1.24, 1.56
    3.50 |      1.38 | 1.20, 1.56
    5.00 |      1.33 | 1.04, 1.62
```

Continuous dose-response model, GAM




```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 3.126, p = 0.093
R² = 0.141
Adj. R² = 0.096

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          1.571   0.172    9.141   0.000
exposure            -0.104   0.059   -1.768   0.093
--------------------------------------------------

Max of response: 1.571 at exposure 0
Min of response: 1.051 at exposure 5

Raw gam max/min:
-----------------
Max of response: 1.79 at exposure 2.5
Min of response: 0.33 at exposure 5
Adjusted predictions at the mean
---------------------------------
# Predicted values of cover

exposure | Predicted |     95% CI
---------------------------------
    0.00 |      1.57 | 1.21, 1.93
    0.50 |      1.52 | 1.21, 1.83
    1.50 |      1.42 | 1.19, 1.64
    2.00 |      1.36 | 1.17, 1.56
    2.50 |      1.31 | 1.13, 1.50
    3.00 |      1.26 | 1.06, 1.46
    3.50 |      1.21 | 0.98, 1.43
    5.00 |      1.05 | 0.69, 1.41
```


Habitat 3:1 (Q=102.3%)
Type
counterfactual
factual
density
monostroma_balticum
Habitat 3:2 (Q=102.4%)
density
monostroma_balticum
Habitat 3:3 (Q=102.4%)
density
monostroma_balticum
Habitat 3:4 (Q=103.0%)
density
monostroma_balticum

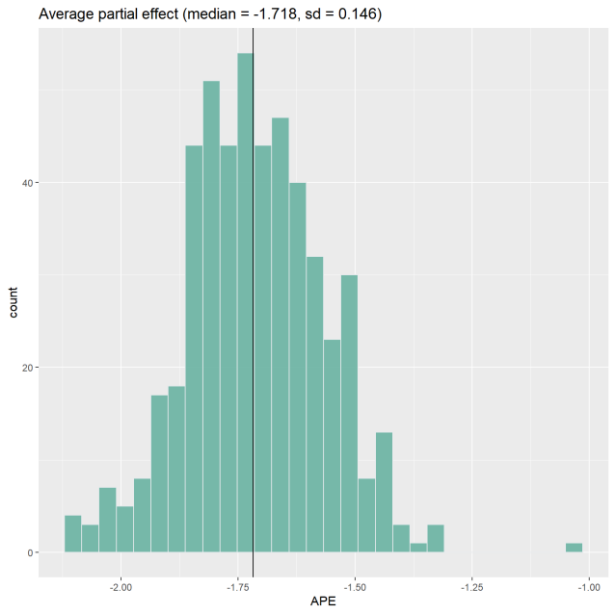

Fraction monostroma_balticum lost, per pav_zon_25
3:1
3:2
3:3
3:4
pav_zon_25

Stuckenia pectinata

WeightIt/svyglm

```
MODEL INFO:
 Observations: 12976
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.10
 Adj. R² = 0.10

 Standard errors: Robust

-------------------------------------------------------------------
                     Est.    2.5%   97.5%   t val.      p    VIF
----------------- ------- ------- ------- -------- ------ ------
 (Intercept)          9.65    9.24   10.06    46.16   0.00
 pav_zon_25          -0.76   -1.42   -0.10    -2.26   0.02   2.18
 SWM                  1.62    1.28    1.96     9.27   0.00   2.38
 dist_runoff          2.49    2.06    2.92    11.37   0.00   2.29
 depth               -4.72   -5.08   -4.36   -25.45   0.00   1.71
 rock                -3.22   -3.45   -3.00   -28.03   0.00   1.78
 block               -1.37   -1.58   -1.16   -12.74   0.00   1.53
 stone               -1.08   -1.32   -0.85    -8.97   0.00   1.36
 gravel              -1.38   -1.60   -1.15   -12.00   0.00   1.37
 soft_sand_1          0.77    0.32    1.23     3.33   0.00   1.60
-------------------------------------------------------------------

Estimated dispersion parameter = 286.1

Margins
-------
      factor     AME     SE        z      p   lower   upper
       block -1.3705 0.1076 -12.7401 0.0000 -1.5813 -1.1596
       depth -4.7200 0.1855 -25.4497 0.0000 -5.0835 -4.3565
 dist_runoff  2.4895 0.2189  11.3714 0.0000  2.0604  2.9186
      gravel -1.3758 0.1146 -11.9999 0.0000 -1.6005 -1.1511
  pav_zon_25 -0.7606 0.3373  -2.2552 0.0241 -1.4216 -0.0996
        rock -3.2209 0.1149 -28.0344 0.0000 -3.4461 -2.9958
 soft_sand_1  0.7722 0.2317   3.3324 0.0009  0.3180  1.2264
       stone -1.0848 0.1209  -8.9693 0.0000 -1.3218 -0.8477
         SWM  1.6179 0.1745   9.2698 0.0000  1.2758  1.9599

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
-----------------------------------
         0 |      9.81 | 9.39, 10.23
         1 |      9.05 | 8.55,  9.55
         2 |      8.29 | 7.19,  9.38
         3 |      7.53 | 5.79,  9.27
         4 |      6.77 | 4.38,  9.16
         5 |      6.01 | 2.96,  9.05
```

Bayesian Causal Exposure Model




```
Covariate inclusion, exposure model
-----------------------------------
  SWM dist_runoff depth rock block stone gravel soft_sand_1   prob.
1   1           1     1    1     1     1      0           1 0.93024
2   1           1     1    1     0     1      0           1 0.06976

Covariate inclusion frequency, effect model
-------------------------------------------
    covariate frequency
1         SWM     1.000
2 dist_runoff     1.000
3       depth     1.000
4        rock     1.000
5       block     1.000
6       stone     1.000
7      gravel     1.000
8 soft_sand_1     0.768
```

Median of estimated effect: -1.718
Std of estimated effect: 0.146

---

twangContinuous by treatment only

```
MODEL INFO:
 Observations: 12976
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.00
 Adj. R² = 0.00

 Standard errors: Robust
 ------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p
 ----------------- ------- ------- ------- -------- ------
 (Intercept)          9.58    9.17    9.99    45.81   0.00
 pav_zon_25          -0.49   -1.04    0.06    -1.73   0.08
 ------------------------------------------------------------
```

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |     95% CI
-----------------------------------
         0 |      9.58 | 9.17, 9.99
         1 |      9.09 | 8.65, 9.54
         2 |      8.60 | 7.68, 9.52
         3 |      8.11 | 6.66, 9.56
         4 |      7.62 | 5.63, 9.62
         5 |      7.13 | 4.59, 9.67
```

---

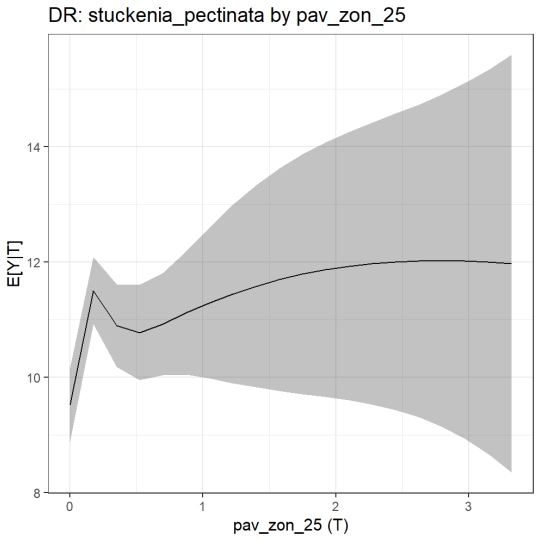
twangContinuous by all covariates

```
MODEL INFO:
 Observations: 12976
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.11
 Adj. R² = 0.11

 Standard errors: Robust
 ------------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p    VIF
 ----------------- ------- ------- ------- -------- ------ ------
 (Intercept)          9.53    9.14    9.91    48.29   0.00
 pav_zon_25          -0.53   -1.02   -0.04    -2.13   0.03   2.19
 SWM                  1.57    1.21    1.94     8.36   0.00   2.74
 dist_runoff          2.78    2.19    3.37     9.18   0.00   3.48
 depth               -4.86   -5.26   -4.46   -23.66   0.00   2.01
 rock                -3.32   -3.54   -3.10   -29.61   0.00   1.65
 block               -1.38   -1.60   -1.17   -12.66   0.00   1.51
 stone               -1.10   -1.37   -0.84    -8.10   0.00   1.42
 gravel              -1.37   -1.59   -1.15   -12.16   0.00   1.33
 soft_sand_1          0.53    0.05    1.02     2.14   0.03   1.66
 wts                  0.02   -0.09    0.13     0.34   0.73   1.67 ------------------
-----------------------------------------------

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
------------------------------------
         0 |      9.63 | 9.09, 10.16
         1 |      9.10 | 8.67,  9.52
         2 |      8.57 | 7.83,  9.31
         3 |      8.04 | 6.86,  9.22
         4 |      7.51 | 5.86,  9.15
         5 |      6.98 | 4.86,  9.10
```

Causal Forest

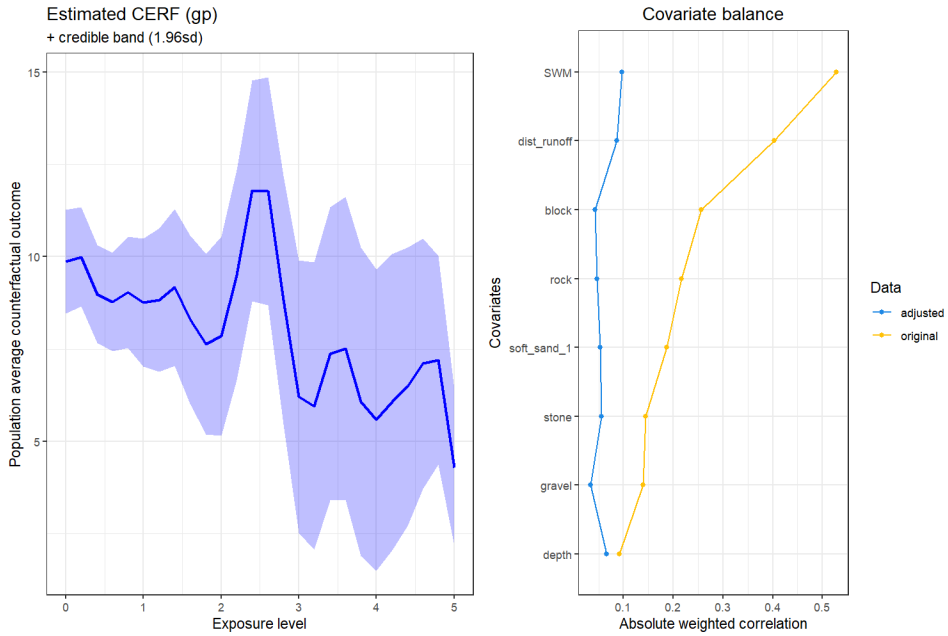
```
Best linear fit using forest predictions (on held-out data)
as well as the mean forest prediction as regressors, along
with one-sided heteroskedasticity-robust (HC3) SEs:

                               Estimate Std. Error t value             Pr(>t)
mean.forest.prediction           -4.690      6.754   -0.69               0.76
differential.forest.prediction    1.112      0.114    9.79 <0.0000000000000002 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Conditional average treatment effects: 0

Agerage partial effect
----------------------
estimate  std.err
  0.4602   0.6011
```

Continuous spline



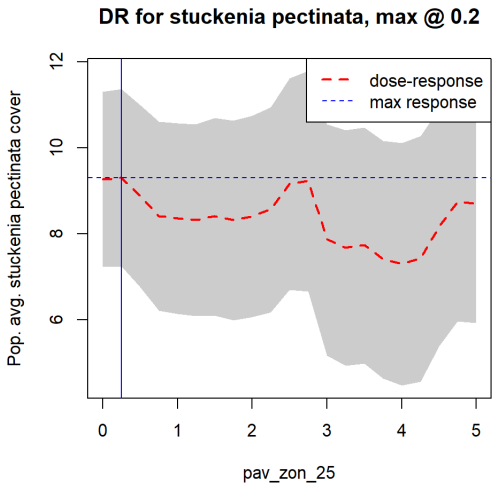

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |       95% CI
-------------------------------------
      0.00 |      9.51 |  8.87, 10.16
      0.03 |     10.61 | 10.12, 11.09
      0.10 |     11.54 | 10.87, 12.21
      0.20 |     11.37 | 10.82, 11.92
      0.36 |     10.88 | 10.16, 11.61
      0.58 |     10.81 |  9.97, 11.65
      0.93 |     11.17 | 10.03, 12.31
      5.00 |     11.38 |  3.34, 19.42
```

Conditional dose-response function, GPCERF



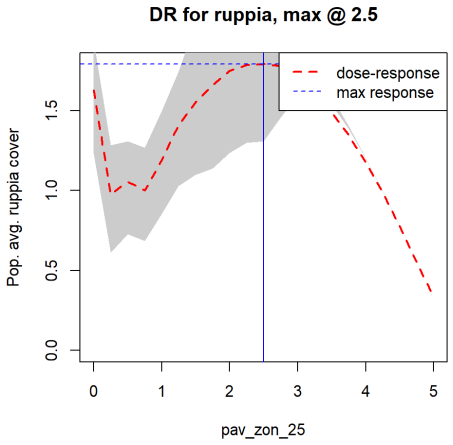

```
Linear trend analysis
---------------------

MODEL FIT:
F(1,24) = 19.829, p = 0.000
R² = 0.452
Adj. R² = 0.430

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)         10.043   0.526   19.094   0.000
exposure            -0.803   0.180   -4.453   0.000
--------------------------------------------------
Max of response: 10.043 at exposure 0
Min of response: 6.026 at exposure 5

Raw GPCERF max/min:
-------------------
Max of response: 11.789 at exposure 2.4
Min of response: 4.281 at exposure 5

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |      95% CI
-----------------------------------
    0.00 |     10.04 | 8.96, 11.13
    0.50 |      9.64 | 8.71, 10.57
    1.50 |      8.84 | 8.17,  9.51
    2.00 |      8.44 | 7.85,  9.02
    2.50 |      8.03 | 7.48,  8.59
    3.00 |      7.63 | 7.04,  8.22
    3.50 |      7.23 | 6.56,  7.90
    5.00 |      6.03 | 4.94,  7.11
```

Continuous dose-response model, BART

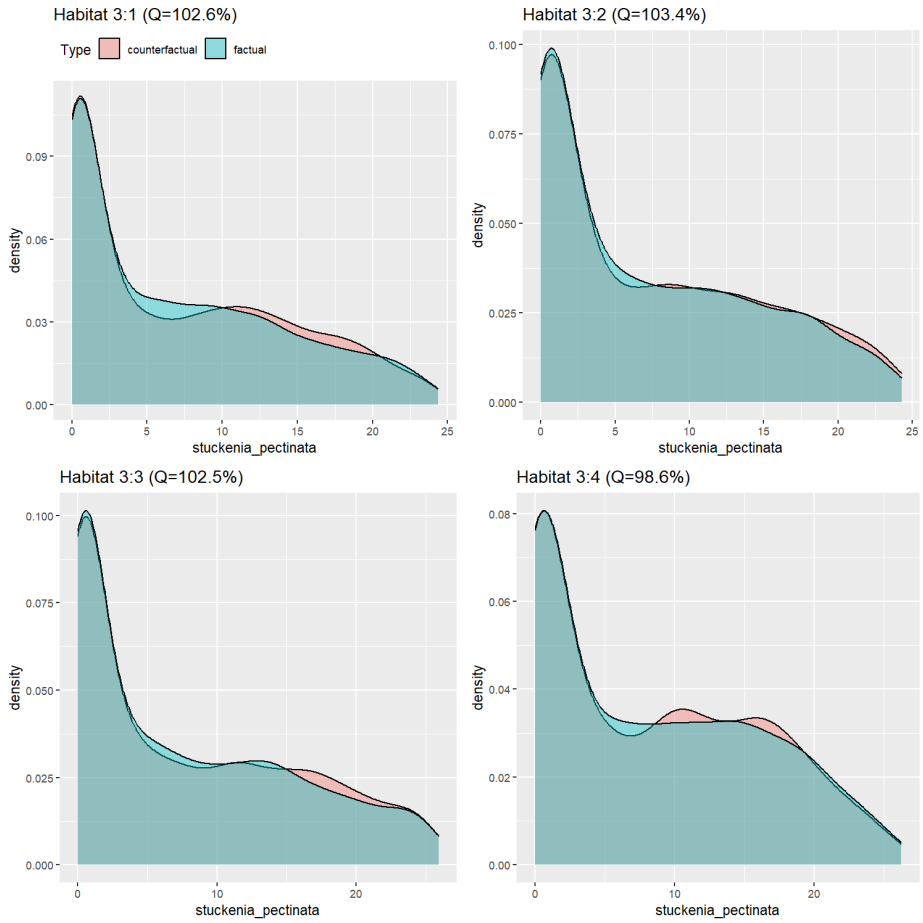


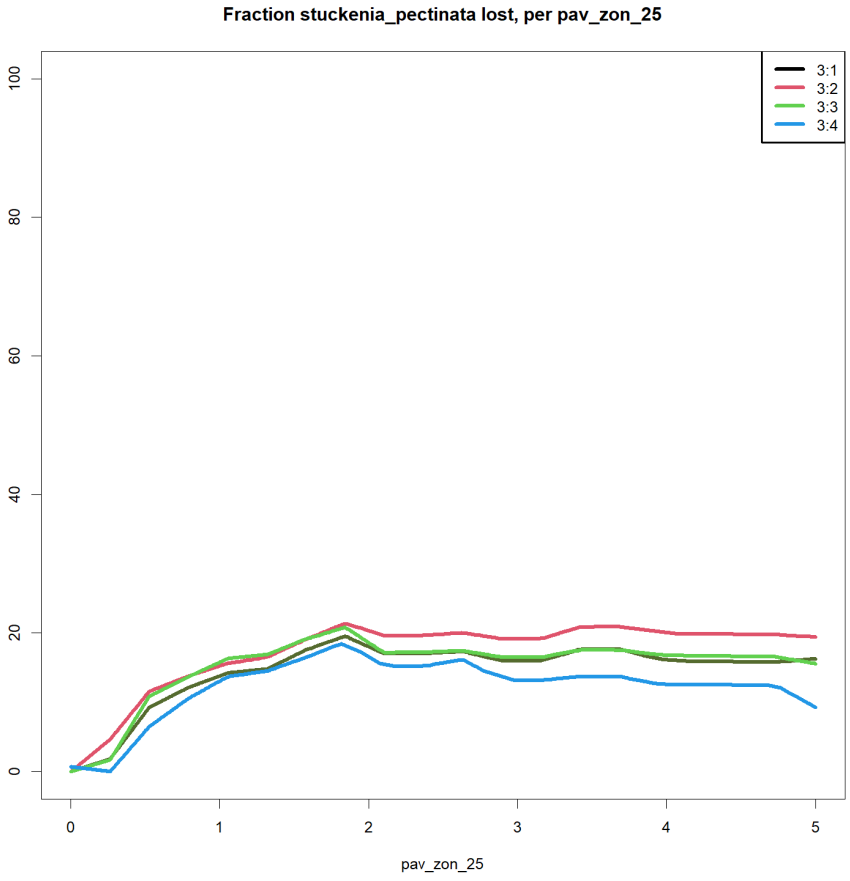

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 6.618, p = 0.019
R² = 0.258
Adj. R² = 0.219

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          8.876   0.232   38.309   0.000
exposure            -0.204   0.079   -2.573   0.019
--------------------------------------------------
Max of response: 8.876 at exposure 0
Min of response: 7.856 at exposure 5

Raw bart max/min:
-----------------
Max of response: 9.302 at exposure 0.25
Min of response: 7.298 at exposure 4

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |     95% CI
--------------------------------
    0.00 |      8.88 | 8.39, 9.36
    0.50 |      8.77 | 8.36, 9.19
    1.50 |      8.57 | 8.27, 8.87
    2.00 |      8.47 | 8.20, 8.73
    2.50 |      8.37 | 8.11, 8.62
    3.00 |      8.26 | 8.00, 8.53
    3.50 |      8.16 | 7.86, 8.46
    5.00 |      7.86 | 7.37, 8.34
```

Continuous dose-response model, GAM




```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 144.045, p = 0.000
R² = 0.883
Adj. R² = 0.877

Standard errors: OLS
-----------------------------------------------------
                      Est.    S.E.    t val.       p
----------------- -------- ------- --------- -------
(Intercept)         10.521   0.261    40.337   0.000
exposure            -1.071   0.089   -12.002   0.000
-----------------------------------------------------
Max of response: 10.521 at exposure 0
Min of response: 5.166 at exposure 5

Raw gam max/min:
-----------------
Max of response: 10.338 at exposure 0
Min of response: 4.212 at exposure 5

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |      95% CI
-----------------------------------
    0.00 |     10.52 | 9.98, 11.07
    0.50 |      9.99 | 9.52, 10.45
    1.50 |      8.91 | 8.58,  9.25
    2.00 |      8.38 | 8.08,  8.68
    2.50 |      7.84 | 7.56,  8.13
    3.00 |      7.31 | 7.01,  7.61
    3.50 |      6.77 | 6.43,  7.11
    5.00 |      5.17 | 4.62,  5.71
```


Habitat 3:1 (Q=102.6%)
Type
counterfactual
factual
density
stuckenia_pectinata
Habitat 3:2 (Q=103.4%)
density
stuckenia_pectinata
Habitat 3:3 (Q=102.5%)
density
stuckenia_pectinata
Habitat 3:4 (Q=98.6%)
density
stuckenia_pectinata

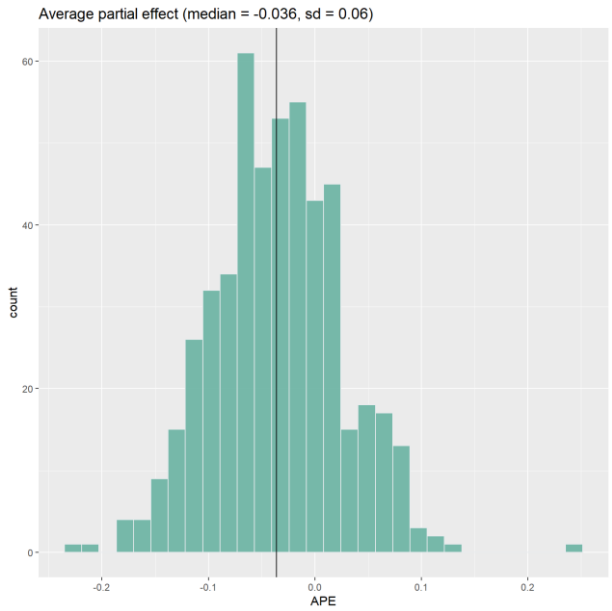

Fraction stuckenia_pectinata lost, per pav_zon_25
3:1
3:2
3:3
3:4
pav_zon_25

Zannichellia palustris

WeightIt/svyglm

```
MODEL INFO:
 Observations: 12891
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.01
 Adj. R² = 0.01

Standard errors: Robust
------------------------------------------------------------------
                     Est.    2.5%   97.5%   t val.      p    VIF
---------------- ------- ------- ------- -------- ------ ------
 (Intercept)         1.67    1.52    1.81    22.32   0.00
 pav_zon_25          0.11   -0.09    0.32     1.09   0.28   1.53
 SWM                 0.03   -0.08    0.15     0.59   0.56   2.44
 dist_runoff         0.54    0.39    0.68     7.16   0.00   2.24
 depth               0.01   -0.09    0.10     0.17   0.87   1.22
 rock               -0.35   -0.43   -0.26    -7.63   0.00   1.40
 block              -0.23   -0.31   -0.16    -6.06   0.00   1.42
 stone              -0.07   -0.17    0.02    -1.62   0.11   1.18
 gravel             -0.18   -0.28   -0.08    -3.43   0.00   1.22
 soft_sand_1         0.07   -0.09    0.22     0.84   0.40   1.20
------------------------------------------------------------------

Margins
-------
      factor     AME     SE       z      p   lower   upper
       block -0.2327 0.0384 -6.0552 0.0000 -0.3080 -0.1574
       depth  0.0082 0.0489  0.1669 0.8674 -0.0878  0.1041
 dist_runoff  0.5371 0.0751  7.1564 0.0000  0.3900  0.6842
      gravel -0.1754 0.0511 -3.4338 0.0006 -0.2755 -0.0753
  pav_zon_25  0.1130 0.1041  1.0851 0.2779 -0.0911  0.3171
        rock -0.3451 0.0452 -7.6317 0.0000 -0.4337 -0.2564
 soft_sand_1  0.0653 0.0774  0.8440 0.3986 -0.0863  0.2170
       stone -0.0749 0.0463 -1.6179 0.1057 -0.1656  0.0158
         SWM  0.0346 0.0590  0.5870 0.5572 -0.0810  0.1502

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |     95% CI
-----------------------------------
         0 |      1.67 | 1.53, 1.82
         1 |      1.79 | 1.62, 1.96
         2 |      1.90 | 1.56, 2.24
         3 |      2.01 | 1.47, 2.55
         4 |      2.13 | 1.39, 2.87
         5 |      2.24 | 1.30, 3.18
```

Bayesian Causal Exposure Model




```
Covariate inclusion, exposure model
-----------------------------------
  SWM dist_runoff depth rock block stone gravel soft_sand_1  prob.
1   1           1     1    1     1     1      0           1 0.7842
2   1           1     1    1     0     1      0           1 0.2158

Covariate inclusion frequency, effect model
-------------------------------------------
    covariate frequency
1         SWM     1.000
2 dist_runoff     1.000
3       depth     0.084
4        rock     1.000
5       block     0.962
6       stone     0.146
7      gravel     0.216
8 soft_sand_1     0.262
```

Median of estimated effect: -0.036
Std of estimated effect: 0.06

---

twangContinuous by treatment only

```
MODEL INFO:
 Observations: 12891
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.00
 Adj. R² = 0.00

 Standard errors: Robust
 ------------------------------------------------------------
                     Est.    2.5%   97.5%   t val.      p
 ----------------- ------ ------- ------- -------- ------
 (Intercept)         1.64    1.51    1.77    24.38   0.00
 pav_zon_25          0.05   -0.09    0.18     0.70   0.49
 ------------------------------------------------------------
```

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |     95% CI
-----------------------------------
         0 |      1.64 | 1.51, 1.77
         1 |      1.69 | 1.56, 1.82
         2 |      1.74 | 1.50, 1.97
         3 |      1.79 | 1.43, 2.15
         4 |      1.83 | 1.34, 2.32
         5 |      1.88 | 1.26, 2.51
```

---

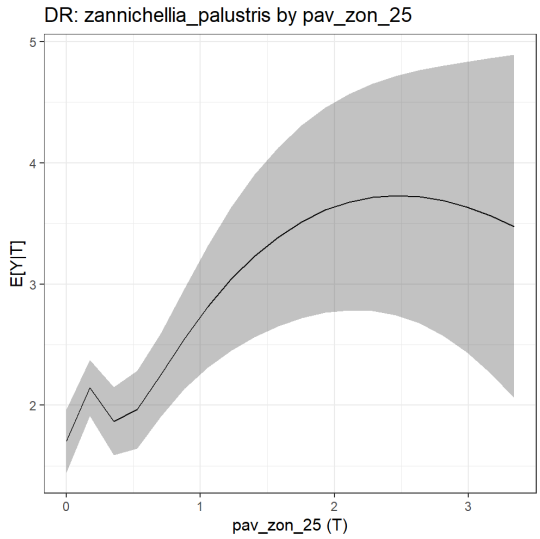
twangContinuous by all covariates

```
MODEL INFO:
 Observations: 12891
 Dependent Variable: cover
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.01
 Adj. R² = 0.01

 Standard errors: Robust
 ------------------------------------------------------------------
                      Est.    2.5%   97.5%   t val.      p    VIF
 ----------------- ------- ------- ------- -------- ------ ------
 (Intercept)          1.61    1.48    1.75    23.43   0.00
 pav_zon_25           0.33    0.09    0.57     2.66   0.01   4.58
 SWM                  0.05   -0.06    0.17     0.89   0.37   2.59
 dist_runoff          0.60    0.42    0.77     6.73   0.00   2.67
 depth                0.03   -0.08    0.13     0.50   0.61   1.27
 rock                -0.33   -0.41   -0.26    -8.70   0.00   1.48
 block               -0.24   -0.31   -0.17    -6.42   0.00   1.39
 stone               -0.07   -0.16    0.02    -1.47   0.14   1.21
 gravel              -0.17   -0.27   -0.08    -3.45   0.00   1.20
 soft_sand_1          0.04   -0.10    0.18     0.58   0.56   1.31
 wts                 -0.06   -0.10   -0.02    -2.92   0.00   3.52
 ------------------------------------------------------------------

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |     95% CI
-----------------------------------
         0 |      1.32 | 1.08, 1.57
         1 |      1.65 | 1.52, 1.78
         2 |      1.97 | 1.68, 2.27
         3 |      2.30 | 1.77, 2.83
         4 |      2.63 | 1.86, 3.39
         5 |      2.95 | 1.95, 3.95
```

Causal Forest

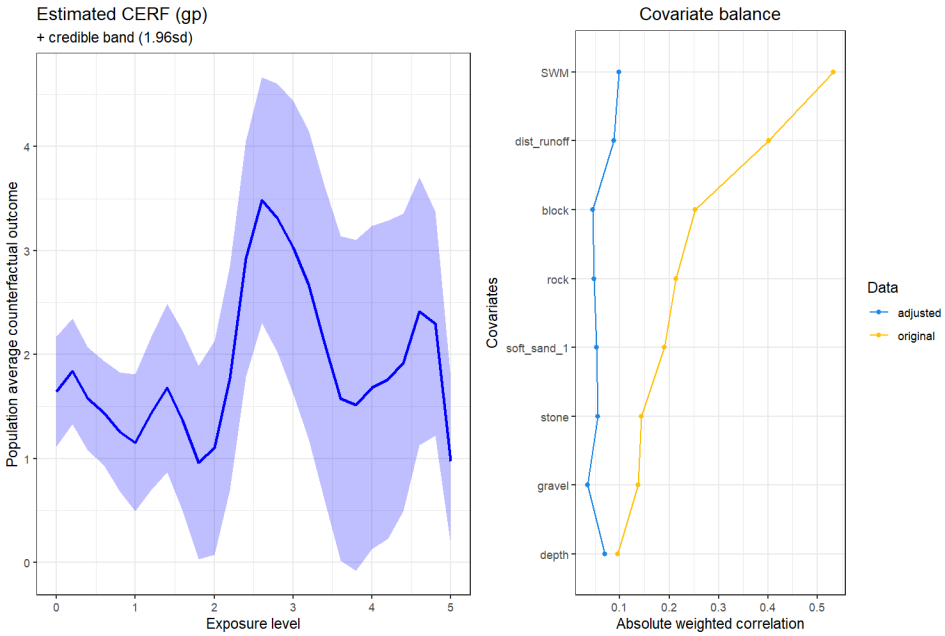
```
Best linear fit using forest predictions (on held-out data)
as well as the mean forest prediction as regressors, along
with one-sided heteroskedasticity-robust (HC3) SEs:

                               Estimate Std. Error t value       Pr(>t)
mean.forest.prediction            1.086      0.210    5.18 0.0000001147 ***
differential.forest.prediction    1.279      0.201    6.37 0.0000000001 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Conditional average treatment effects: 0.5

Agerage partial effect
----------------------
estimate  std.err
 -0.1361   0.2107
```

Continuous spline



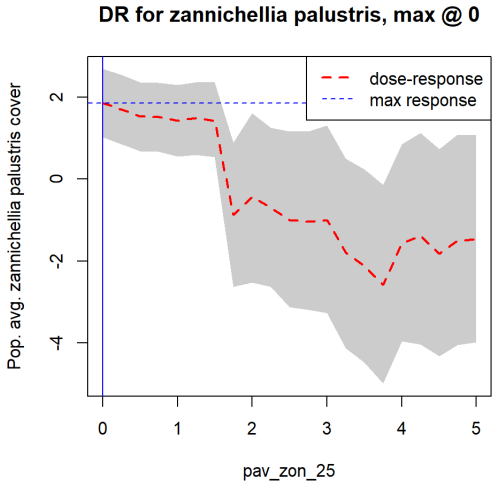

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

pav_zon_25 | Predicted |      95% CI
-------------------------------------
      0.00 |      1.71 |  1.45, 1.97
      0.03 |      2.03 |  1.84, 2.23
      0.10 |      2.26 |  1.99, 2.53
      0.20 |      2.08 |  1.86, 2.30
      0.35 |      1.87 |  1.59, 2.15
      0.58 |      2.04 |  1.72, 2.37
      0.92 |      2.62 |  2.18, 3.05
      5.00 |      2.10 | -1.03, 5.23
```

Conditional dose-response function, GPCERF



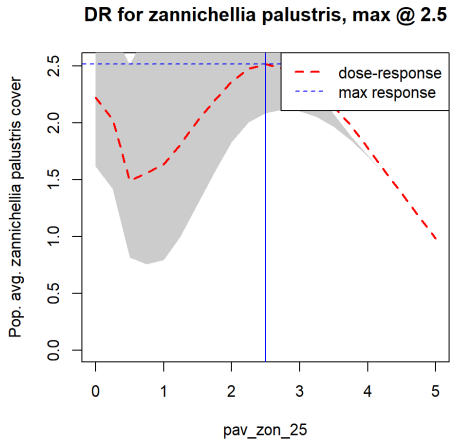

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,24) = 1.758, p = 0.197
R² = 0.068
Adj. R² = 0.029

Standard errors: OLS
--------------------------------------------------
                     Est.    S.E.    t val.       p
----------------- ------- ------- -------- -------
(Intercept)         1.579   0.266    5.945   0.000
exposure            0.121   0.091    1.326   0.197
--------------------------------------------------

Max of response: 2.183 at exposure 5
Min of response: 1.579 at exposure 0

Raw GPCERF max/min:
-------------------
Max of response: 3.484 at exposure 2.6
Min of response: 0.962 at exposure 1.8

Adjusted predictions at the mean
--------------------------------
# Predicted values of outcome

exposure | Predicted |     95% CI
---------------------------------
    0.00 |      1.58 | 1.03, 2.13
    0.50 |      1.64 | 1.17, 2.11
    1.50 |      1.76 | 1.42, 2.10
    2.00 |      1.82 | 1.52, 2.12
    2.50 |      1.88 | 1.60, 2.16
    3.00 |      1.94 | 1.64, 2.24
    3.50 |      2.00 | 1.66, 2.34
    5.00 |      2.18 | 1.63, 2.73
```

Continuous dose-response model, BART

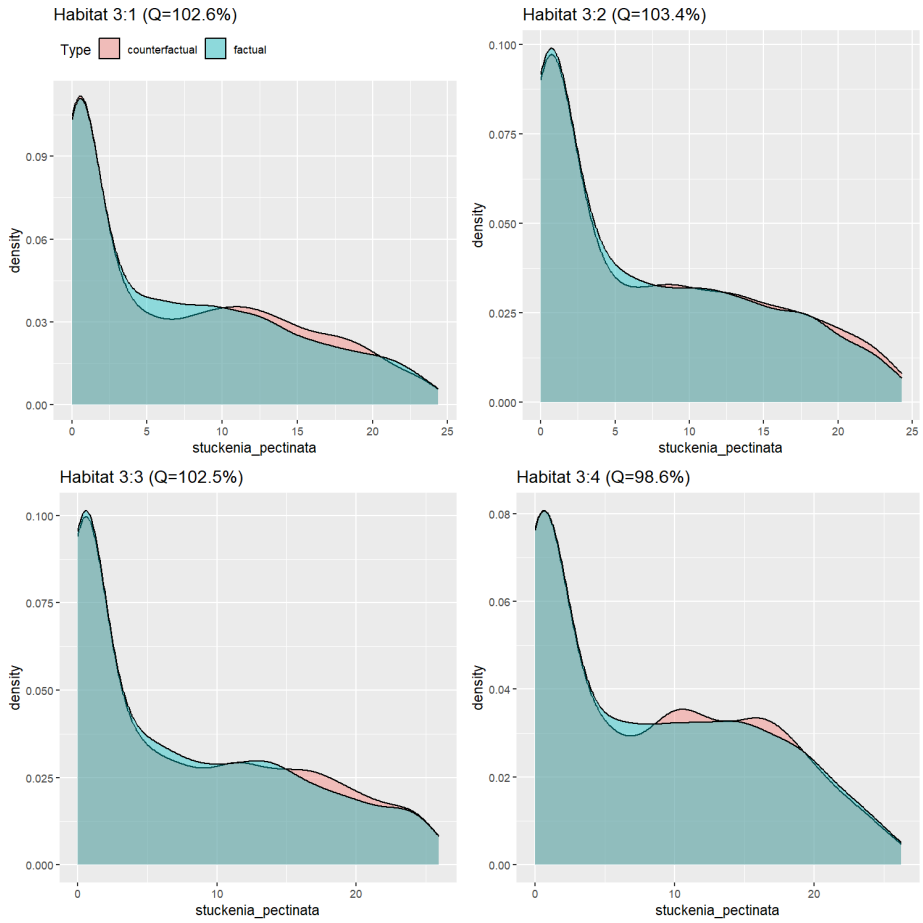


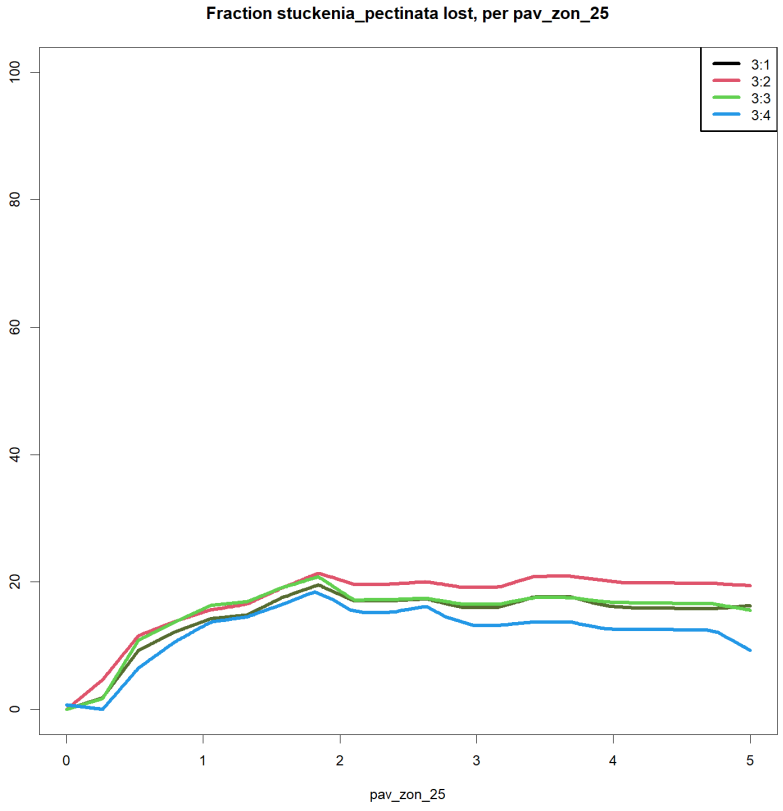

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 73.815, p = 0.000
R² = 0.795
Adj. R² = 0.785

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          1.752   0.293    5.984   0.000
exposure            -0.860   0.100   -8.592   0.000
--------------------------------------------------

Max of response: 1.752 at exposure 0
Min of response: -2.551 at exposure 5

Raw bart max/min:
-----------------
Max of response: 1.849 at exposure 0
Min of response: -2.579 at exposure 3.75

Adjusted predictions at the mean
--------------------------------
# Predicted values of cover

exposure | Predicted |       95% CI
-----------------------------------
    0.00 |      1.75 |  1.14,  2.36
    0.50 |      1.32 |  0.80,  1.85
    1.50 |      0.46 |  0.08,  0.84
    2.00 |      0.03 | -0.30,  0.36
    2.50 |     -0.40 | -0.72, -0.08
    3.00 |     -0.83 | -1.16, -0.50
    3.50 |     -1.26 | -1.64, -0.88
    5.00 |     -2.55 | -3.16, -1.94
```

Continuous dose-response model, GAM




```
Linear trend analysis
---------------------
MODEL FIT:
F(1,19) = 2.402, p = 0.138
R² = 0.112
Adj. R² = 0.066

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          2.167   0.182   11.926   0.000
exposure            -0.096   0.062   -1.550   0.138
--------------------------------------------------

Max of response: 2.167 at exposure 0
Min of response: 1.685 at exposure 5

Raw gam max/min:
-----------------
Max of response: 2.517 at exposure 2.5
Min of response: 0.985 at exposure 5

Adjusted predictions at the mean
---------------------------------
# Predicted values of cover

exposure | Predicted |     95% CI
---------------------------------
    0.00 |      2.17 | 1.79, 2.55
    0.50 |      2.12 | 1.79, 2.44
    1.50 |      2.02 | 1.79, 2.26
    2.00 |      1.97 | 1.77, 2.18
    2.50 |      1.93 | 1.73, 2.12
    3.00 |      1.88 | 1.67, 2.08
    3.50 |      1.83 | 1.59, 2.07
    5.00 |      1.68 | 1.30, 2.07
```


Habitat 3:1 (Q=102.6%)
Type
counterfactual
factual
density
stuckenia_pectinata
Habitat 3:2 (Q=103.4%)
Habitat 3:3 (Q=102.5%)
Habitat 3:4 (Q=98.6%)


Fraction stuckenia_pectinata lost, per pav_zon_25
3:1
3:2
3:3
3:4
pav_zon_25

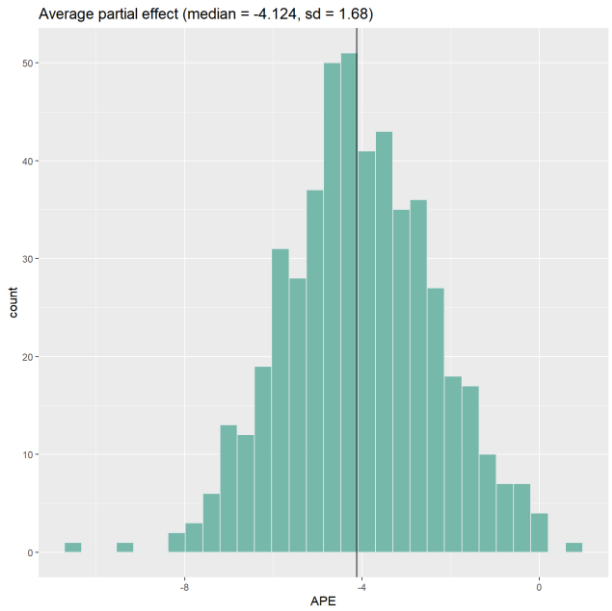
6.3 Sjöpennor

Vigrularia mirabilis

WeightIt/svyglm

```
MODEL INFO:
 Observations: 1200
 Dependent Variable: abundance
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.16
 Adj. R² = 0.16

 Standard errors: Robust
 ------------------------------------------------------------------------------
                                Est.     2.5%    97.5%   t val.      p      VIF
 ---------------------------- -------- -------- -------- -------- ------ -------
 (Intercept)                   24.64    19.98    29.31    10.37   0.00
 m30_adjusted                  -2.49    -4.03    -0.94    -3.16   0.00     2.59
 djup                          -5.11    -8.42    -1.79    -3.02   0.00     4.84
 swm_d                         14.64     8.62    20.65     4.77   0.00    15.64
 Nephrops_norvegicus_fs5       -1.19    -5.87     3.48    -0.50   0.62     6.60
 temp_1                       -15.82   -21.27   -10.38    -5.70   0.00    16.57
 salt_1                        -8.06   -12.58    -3.53    -3.49   0.00     6.05
 curr_1                         0.19    -2.55     2.93     0.14   0.89     3.65
 curr_2                         5.21     1.76     8.66     2.97   0.00     3.86
 soft_coarse_1                  4.03     0.73     7.33     2.39   0.02     6.10
 hard_sand_1                   -3.39    -6.90     0.12    -1.89   0.06     4.91
 hard_sand_2                   -0.53    -2.63     1.57    -0.49   0.62     2.22
 ------------------------------------------------------------------------------

Margins
-------
                  factor      AME     SE       z      p    lower    upper
                  curr_1   0.1905 1.3979  0.1363 0.8916  -2.5492   2.9303
                  curr_2   5.2102 1.7564  2.9664 0.0030   1.7677   8.6527
                    djup  -5.1092 1.6900 -3.0233 0.0025  -8.4214  -1.7969
             hard_sand_1  -3.3855 1.7889 -1.8926 0.0584  -6.8917   0.1206
             hard_sand_2  -0.5272 1.0710 -0.4923 0.6225  -2.6263   1.5718
            m30_adjusted  -2.4860 0.7867 -3.1600 0.0016  -4.0279  -0.9441
 Nephrops_norvegicus_fs5  -1.1936 2.3813 -0.5012 0.6162  -5.8609   3.4738
                  salt_1  -8.0553 2.3049 -3.4948 0.0005 -12.5728  -3.5378
           soft_coarse_1   4.0271 1.6827  2.3932 0.0167   0.7290   7.3252
                   swm_d  14.6355 3.0666  4.7726 0.0000   8.6251  20.6458
                  temp_1 -15.8219 2.7753 -5.7010 0.0000 -21.2613 -10.3824

Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

m30_adjusted | Predicted |       95% CI
---------------------------------------
           0 |     21.18 | 17.05, 25.31
           1 |     18.69 | 15.52, 21.87
           2 |     16.21 | 13.39, 19.02
           3 |     13.72 | 10.48, 16.96
           4 |     11.24 |  7.01, 15.46
           5 |      8.75 |  3.27, 14.23
           6 |      6.26 | -0.58, 13.11
```

Bayesian Causal Exposure Model




```
Covariate inclusion frequency, effect model
--------------------------------------------
                 covariate frequency
1                     djup     0.616
2                   swm_d      1.000
3  Nephrops_norvegicus_fs5     0.628
4                   temp_1     1.000
5                   salt_1     0.974
6                   curr_1     0.574
7                   curr_2     0.796
8            soft_coarse_1     0.058
9              hard_sand_1     0.872
10             hard_sand_2     0.104
```

Median of estimated effect: -4.124
Std of estimated effect: 1.68

---

twangContinuous by treatment only

```
MODEL INFO:
 Observations: 1200
 Dependent Variable: abundance
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.03
 Adj. R² = 0.03

 Standard errors: Robust
 ------------------------------------------------------------
                       Est.    2.5%   97.5%   t val.      p
 ------------------ ------- ------- ------- -------- ------
 (Intercept)          22.56   18.04   27.09     9.79   0.00
 m30_adjusted         -3.77   -5.08   -2.46    -5.66   0.00
 ------------------------------------------------------------
```

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

m30_adjusted | Predicted |       95% CI
---------------------------------------
           0 |     22.56 | 18.04, 27.09
           1 |     18.79 | 15.25, 22.34
           2 |     15.02 | 12.18, 17.86
           3 |     11.25 |  8.61, 13.90
           4 |      7.49 |  4.43, 10.54
           5 |      3.72 | -0.17,  7.61
           6 |     -0.05 | -4.98,  4.88
```

twangContinuous by all covariates

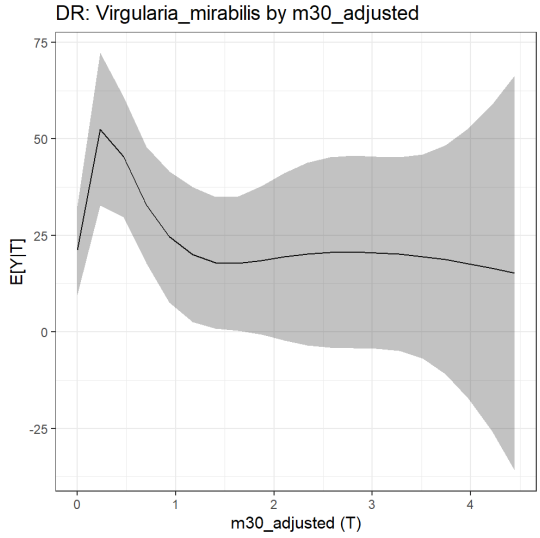
```
MODEL INFO:
 Observations: 1200
 Dependent Variable: abundance
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.15
 Adj. R² = 0.14

 Standard errors: Robust
 ------------------------------------------------------------------------------
                                 Est.     2.5%    97.5%   t val.      p     VIF
 ------------------------------ -------- -------- -------- -------- ------ -------
 (Intercept)                     22.62    18.23    27.02    10.09   0.00
 m30_adjusted                    -1.34    -3.19     0.51    -1.42   0.16    3.60
 djup                            -0.39    -4.40     3.63    -0.19   0.85    5.19
 swm_d                           16.02     9.31    22.72     4.69   0.00   15.43
 Nephrops_norvegicus_fs5         -0.35    -5.16     4.47    -0.14   0.89    7.32
 temp_1                         -15.96   -21.84   -10.07    -5.32   0.00   16.23
 salt_1                         -10.02   -15.16    -4.87    -3.82   0.00   10.14
 curr_1                          -3.02    -6.34     0.30    -1.78   0.07    3.22
 curr_2                           3.08    -1.08     7.23     1.45   0.15    3.92
 soft_coarse_1                    2.37    -2.79     7.52     0.90   0.37    7.24
 hard_sand_1                      0.67    -3.84     5.17     0.29   0.77    4.35
 hard_sand_2                      2.13    -0.22     4.47     1.78   0.08    2.21
 wts                             -0.05    -0.13     0.03    -1.24   0.22    2.50
 ------------------------------------------------------------------------------

Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

m30_adjusted | Predicted |       95% CI
---------------------------------------
           0 |     15.40 | 10.56, 20.24
           1 |     14.06 | 10.56, 17.56
           2 |     12.72 |  9.90, 15.54
           3 |     11.38 |  8.14, 14.63
           4 |     10.04 |  5.58, 14.51
           5 |      8.70 |  2.69, 14.72
           6 |      7.36 | -0.34, 15.07
```

Causal Forest

```
Best linear fit using forest predictions (on held-out data)
as well as the mean forest prediction as regressors, along
with one-sided heteroskedasticity-robust (HC3) SEs:
```

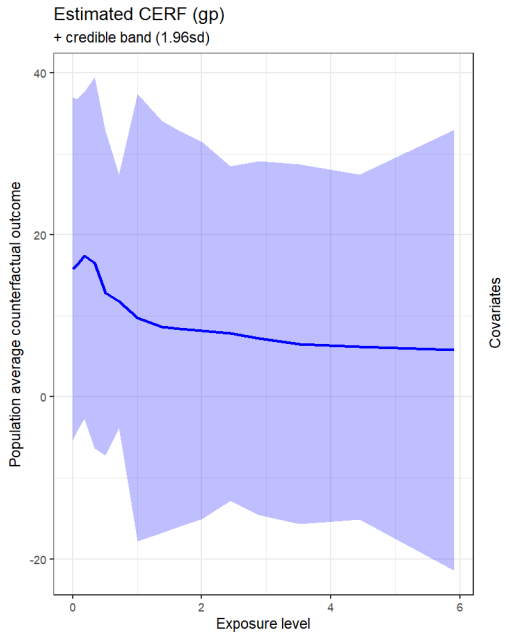
```
                                Estimate Std. Error t value Pr(>t)
mean.forest.prediction             1.305      0.512    2.55 0.0055 **
differential.forest.prediction     1.291      0.565    2.29 0.0112 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Agerage partial effect:
estimate  std.err
  -3.653    4.70
```

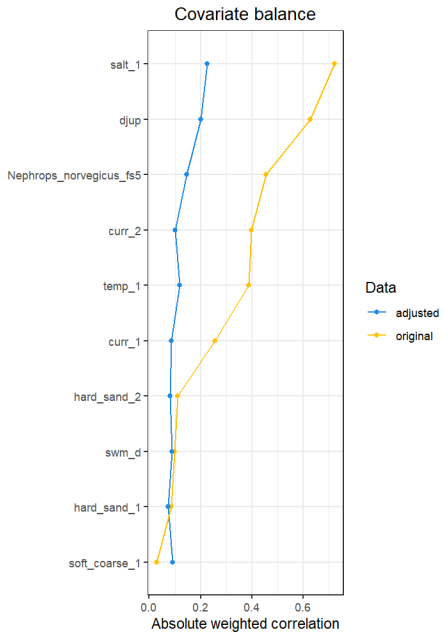
Continuous spline




```
Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

m30_adjusted | Predicted |          95% CI
-----------------------------------------
        0.00 |     21.11 |    9.59,  32.62
        0.27 |     53.01 |   33.11,  72.91
        0.53 |     41.36 |   26.72,  56.00
        0.96 |     24.12 |    7.00,  41.23
        1.48 |     17.71 |    0.68,  34.73
        2.03 |     19.21 |   -1.73,  40.16
        2.77 |     20.67 |   -4.30,  45.63
        5.91 |      5.11 | -121.73, 131.96
```

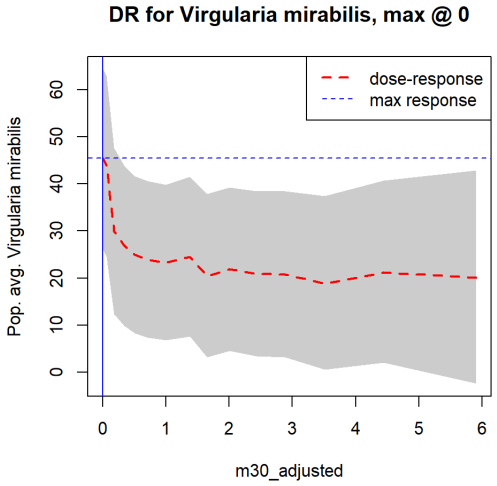
Conditional dose-response function, GPCERF





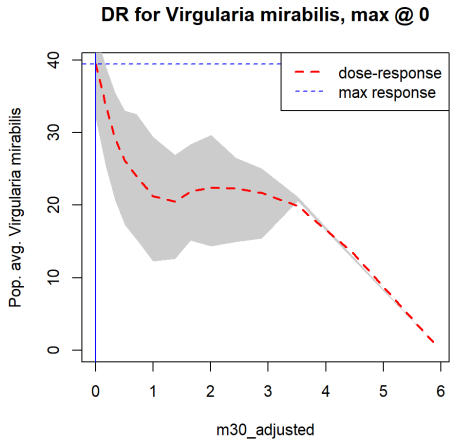

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,13) = 31.507, p = 0.000
R² = 0.708
Adj. R² = 0.685

Standard errors: OLS
--------------------------------------------------
                     Est.    S.E.   t val.       p
---------------- -------- ------- -------- -------
(Intercept)        14.203   0.876   16.208   0.000
exposure           -1.986   0.354   -5.613   0.000

Max of response: 14.203 at exposure 0
Min of response: 2.461 at exposure 5.91

Raw GPCERF max/min:
-------------------
Max of response: 17.448 at exposure 0.18
Min of response: 5.774 at exposure 5.91

Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

exposure | Predicted |       95% CI
-----------------------------------
    0.00 |     14.20 | 12.31, 16.10
    0.18 |     13.84 | 12.05, 15.64
    0.34 |     13.53 | 11.82, 15.25
    0.71 |     12.78 | 11.24, 14.33
    1.38 |     11.47 | 10.13, 12.80
    2.01 |     10.21 |  8.90, 11.52
    2.89 |      8.46 |  6.92, 10.00
    5.91 |      2.46 | -0.94,  5.86
```

Continuous dose-response model, BART



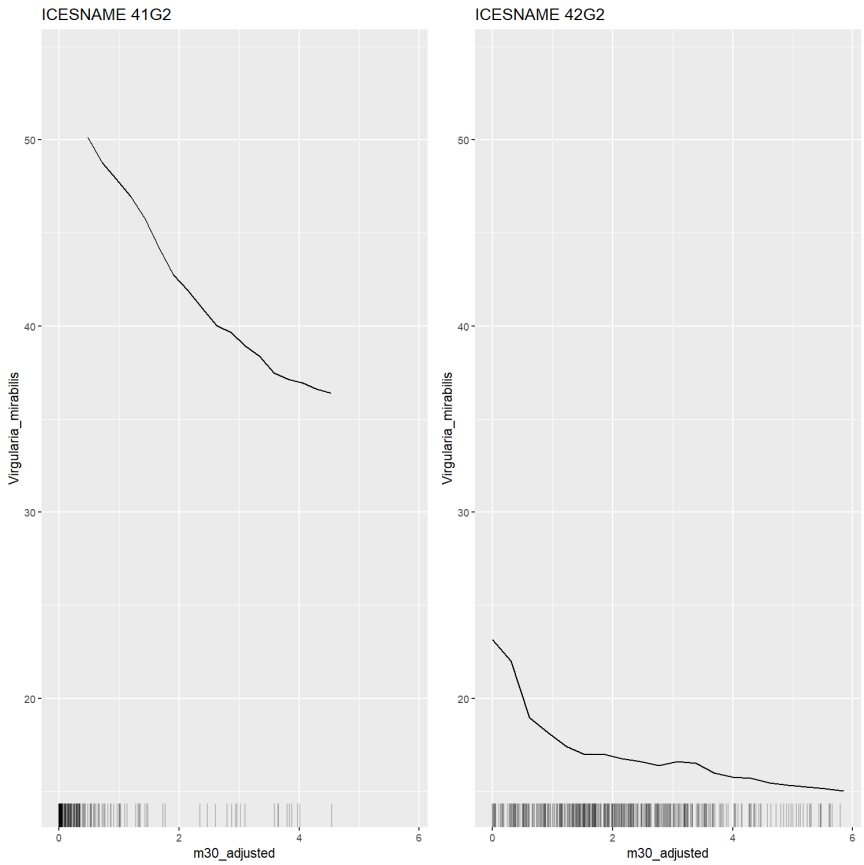

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,13) = 8.308, p = 0.013
R² = 0.390
Adj. R² = 0.343

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)         31.039   2.506   12.388   0.000
exposure            -2.916   1.012   -2.882   0.013
--------------------------------------------------

Max of response: 31.039 at exposure 0
Min of response: 13.8 at exposure 5.9

Raw bart max/min:
-----------------
Max of response: 45.477 at exposure 0
Min of response: 18.862 at exposure 3.5

Adjusted predictions at the mean
--------------------------------
# Predicted values of outcome

exposure | Predicted |       95% CI
-----------------------------------
    0.00 |     31.04 | 25.63, 36.45
    0.18 |     30.51 | 25.38, 35.64
    0.34 |     30.06 | 25.15, 34.96
    0.71 |     28.96 | 24.55, 33.37
    1.38 |     27.02 | 23.20, 30.85
    2.01 |     25.18 | 21.44, 28.92
    2.89 |     22.61 | 18.21, 27.02
    5.91 |     13.80 |  4.08, 23.52
```

Continuous dose-response model, GAM

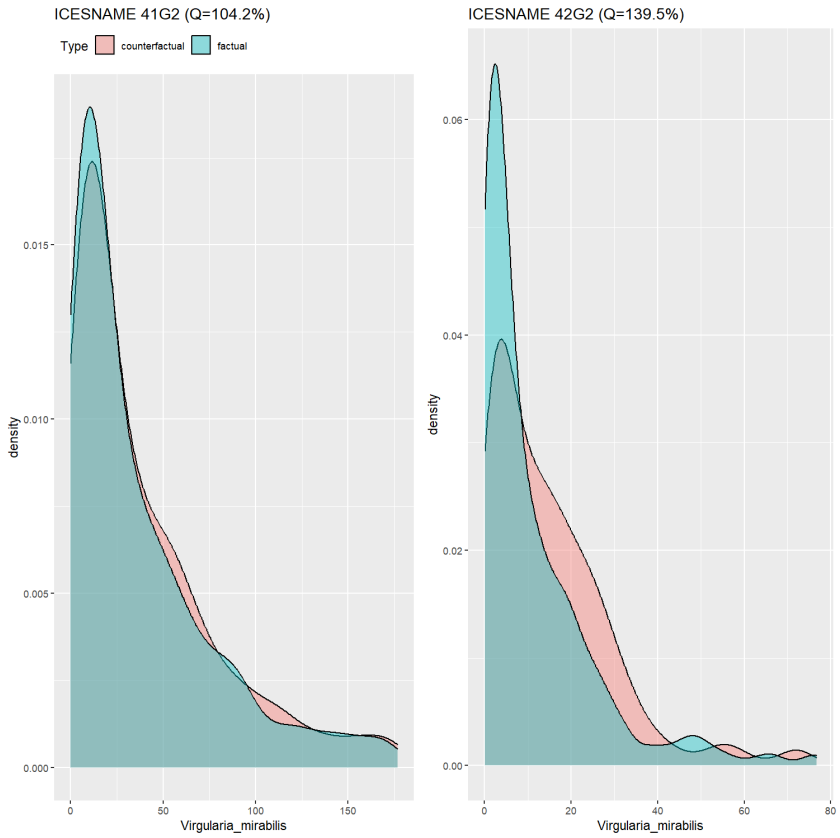



```
Linear trend analysis
---------------------
MODEL FIT:
F(1,13) = 51.565, p = 0.000
R² = 0.799
Adj. R² = 0.783

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)         32.284   1.656   19.492   0.000
exposure            -4.803   0.669   -7.181   0.000
--------------------------------------------------

Max of response: 32.284 at exposure 0
Min of response: 3.893 at exposure 5.91

Raw gam max/min:
-----------------
Max of response: 39.432 at exposure 0
Min of response: 0.722 at exposure 5.91

Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

exposure | Predicted |       95% CI
-------------------------------------
    0.00 |     32.28 | 28.71, 35.86
    0.18 |     31.41 | 28.02, 34.80
    0.34 |     30.67 | 27.42, 33.91
    0.71 |     28.86 | 25.94, 31.77
    1.38 |     25.67 | 23.14, 28.20
    2.01 |     22.63 | 20.16, 25.10
    2.89 |     18.41 | 15.50, 21.32
    5.91 |      3.89 | -2.53, 10.32
```

Conditional response



Conditional effects

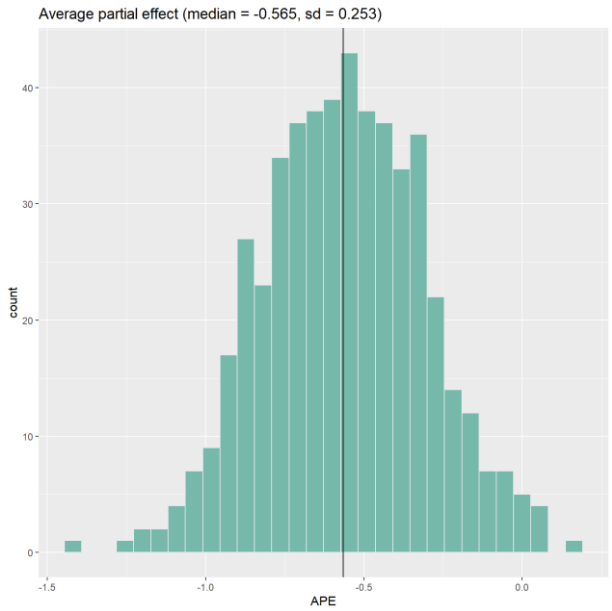


Pennatula phosphorea

WeightIt/svyglm

```
MODEL INFO:
 Observations: 1157
 Dependent Variable: abundance
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.07
 Adj. R² = 0.06

 Standard errors: Robust
 ------------------------------------------------------------------------------
                                 Est.    2.5%   97.5%   t val.      p      VIF
 ------------------------------ ------- ------- ------- -------- ------ -------
 (Intercept)                     4.07    3.40    4.74    11.87   0.00
 m30_adjusted                   -0.55   -0.85   -0.25    -3.57   0.00     2.02
 djup                           -2.26   -2.94   -1.58    -6.55   0.00     7.22
 swm_d                          -1.38   -2.27   -0.49    -3.04   0.00     5.93
 Nephrops_norvegicus_fs5         0.35   -0.71    1.42     0.65   0.52    12.11
 temp_1                          2.27    1.37    3.17     4.95   0.00     3.59
 salt_1                          1.97    0.96    2.98     3.84   0.00    14.95
 curr_1                         -0.24   -0.92    0.44    -0.69   0.49     2.66
 curr_2                          1.04    0.28    1.80     2.67   0.01     4.58
 soft_coarse_1                  -0.13   -0.68    0.42    -0.46   0.65     2.07
 hard_sand_1                    -0.31   -1.03    0.42    -0.83   0.41     5.33
 hard_sand_2                     0.91    0.28    1.54     2.85   0.00     2.56
 ------------------------------------------------------------------------------

Margins
-------
                  factor     AME     SE       z      p   lower   upper
                  curr_1 -0.2402 0.3468 -0.6925 0.4886 -0.9199  0.4396
                  curr_2  1.0403 0.3894  2.6714 0.0076  0.2770  1.8035
                    djup -2.2597 0.3450 -6.5492 0.0000 -2.9360 -1.5835
             hard_sand_1 -0.3067 0.3682 -0.8329 0.4049 -1.0283  0.4149
             hard_sand_2  0.9107 0.3196  2.8491 0.0044  0.2842  1.5372
            m30_adjusted -0.5485 0.1536 -3.5719 0.0004 -0.8495 -0.2475
 Nephrops_norvegicus_fs5  0.3517 0.5433  0.6472 0.5175 -0.7133  1.4166
                  salt_1  1.9701 0.5124  3.8449 0.0001  0.9658  2.9743
           soft_coarse_1 -0.1296 0.2822 -0.4593 0.6460 -0.6827  0.4235
                   swm_d -1.3807 0.4545 -3.0376 0.0024 -2.2716 -0.4898
                  temp_1  2.2707 0.4588  4.9494 0.0000  1.3715  3.1699

Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

m30_adjusted | Predicted |      95% CI
-------------------------------------
           0 |      4.10 |  3.40, 4.80
           1 |      3.55 |  3.04, 4.06
           2 |      3.00 |  2.53, 3.47
           3 |      2.45 |  1.85, 3.05
           4 |      1.90 |  1.08, 2.73
           5 |      1.36 |  0.27, 2.44
           6 |      0.81 | -0.56, 2.17
```

Bayesian Causal Exposure Model



Covariate inclusion frequency, effect model

	covariate	frequency
1	djup	0.838
2	swm_d	0.014
3	Nephrops_norvegicus_fs5	0.740
4	temp_1	0.120
5	salt_1	0.364
6	curr_1	0.716
7	curr_2	0.628
8	soft_coarse_1	0.030
9	hard_sand_1	0.634
10	hard_sand_2	1.000

Median of estimated effect: -0.565
Std of estimated effect: 0.253

---

twangContinuous by treatment only

```
MODEL INFO:
 Observations: 1157
 Dependent Variable: abundance
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.00
 Adj. R² = -0.00

 Standard errors: Robust
 ------------------------------------------------------------
                        Est.    2.5%   97.5%   t val.      p
 ------------------ ------- ------- ------- -------- ------
 (Intercept)            3.51    2.18    4.85     5.17   0.00
 m30_adjusted          -0.03   -1.03    0.96    -0.07   0.95
 ------------------------------------------------------------
```

```
Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

m30_adjusted | Predicted |      95% CI
-------------------------------------
           0 |      3.51 |  2.18, 4.85
           1 |      3.48 |  2.86, 4.10
           2 |      3.45 |  2.45, 4.44
           3 |      3.41 |  1.52, 5.30
           4 |      3.38 |  0.52, 6.23
           5 |      3.34 | -0.49, 7.18
           6 |      3.31 | -1.51, 8.13
```

---

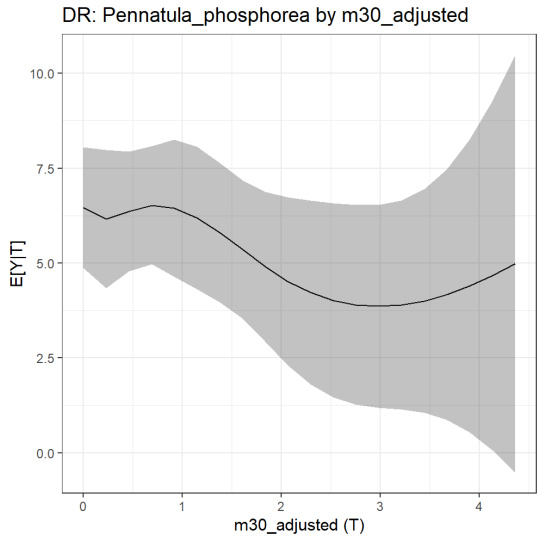
twangContinuous by all covariates

```
MODEL INFO:
 Observations: 1157
 Dependent Variable: abundance
 Type: Survey-weighted linear regression

 MODEL FIT:
 R² = 0.09
 Adj. R² = 0.08

 Standard errors: Robust
 ------------------------------------------------------------------------------
                                Est.    2.5%   97.5%   t val.      p     VIF
 ------------------------------ ------- ------- ------- -------- ------ -------
 (Intercept)                     3.72    2.86    4.59     8.41   0.00
 m30_adjusted                   -0.46   -0.93    0.01    -1.92   0.06    3.30
 djup                           -1.27   -2.55    0.02    -1.93   0.05   12.39
 swm_d                          -2.32   -4.51   -0.13    -2.08   0.04   18.83
 Nephrops_norvegicus_fs5         0.46   -1.09    2.02     0.59   0.56   11.05
 temp_1                          3.01    1.77    4.24     4.78   0.00    4.97
 salt_1                          0.46   -1.94    2.86     0.37   0.71   35.38
 curr_1                         -0.33   -1.36    0.69    -0.64   0.52    3.48
 curr_2                          1.74    0.22    3.26     2.25   0.02    8.26
 soft_coarse_1                  -0.38   -1.32    0.57    -0.78   0.43    3.38
 hard_sand_1                     0.63   -0.73    1.99     0.91   0.36    6.68
 hard_sand_2                     0.83    0.16    1.50     2.42   0.02    1.56
 wts                             0.03   -0.06    0.12     0.73   0.46    5.77
 ------------------------------------------------------------------------------

Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

m30_adjusted | Predicted |     95% CI
-------------------------------------
           0 |      4.65 | 2.67, 6.63
           1 |      4.19 | 2.54, 5.84
           2 |      3.73 | 2.32, 5.13
           3 |      3.26 | 1.97, 4.56
           4 |      2.80 | 1.45, 4.15
           5 |      2.34 | 0.79, 3.90
           6 |      1.88 | 0.02, 3.74
```

Causal Forest

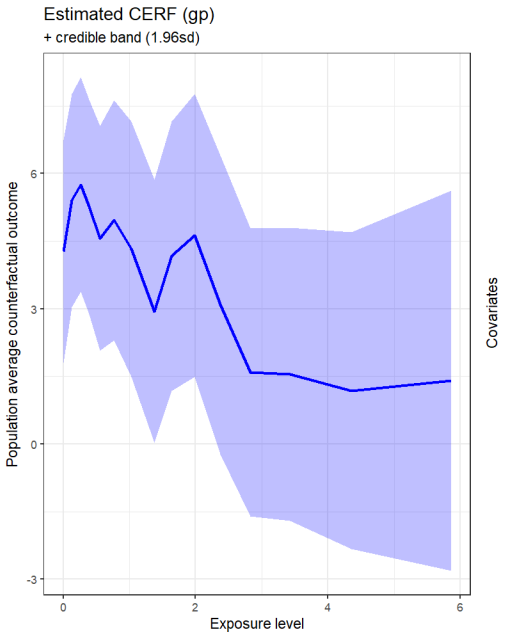
```
Best linear fit using forest predictions (on held-out data)
as well as the mean forest prediction as regressors, along
with one-sided heteroskedasticity-robust (HC3) SEs:

                               Estimate Std. Error t value   Pr(>t)
mean.forest.prediction            0.978      0.251    3.90 0.000051 ***
differential.forest.prediction    1.039      0.580    1.79    0.037 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Agerage partial effect:
estimate  std.err
 0.03565  0.24601
```

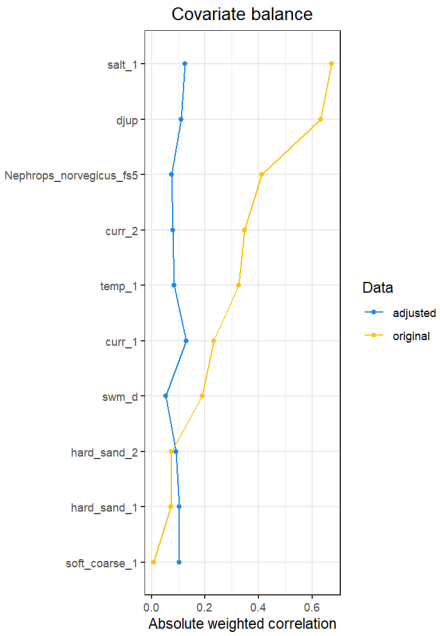
Continuous spline




```
Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

m30_adjusted | Predicted |          95% CI
-------------------------------------------
        0.00 |      6.52 |  4.87,  8.18
        0.24 |      6.05 |  4.16,  7.95
        0.49 |      6.35 |  4.78,  7.93
        0.84 |      6.61 |  4.84,  8.38
        1.39 |      5.95 |  4.08,  7.83
        1.91 |      4.91 |  2.84,  6.99
        2.60 |      4.09 |  1.46,  6.71
        5.86 |      8.18 | -5.06, 21.41
```

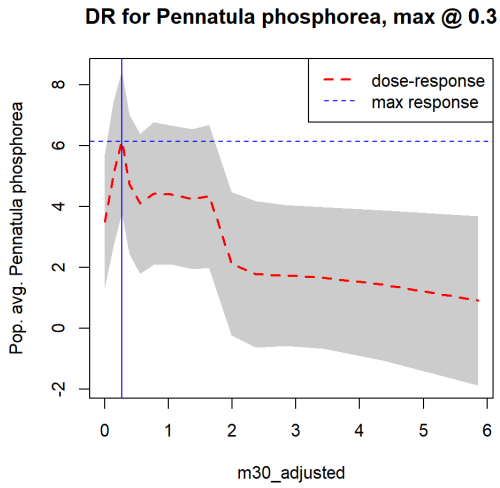
Conditional dose-response function, GPCERF





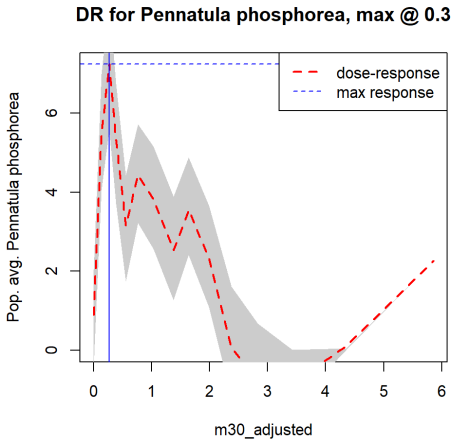

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,13) = 44.565, p = 0.000
R² = 0.774
Adj. R² = 0.757

Standard errors: OLS
--------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          5.147   0.299   17.193   0.000
exposure            -0.818   0.123   -6.676   0.000
--------------------------------------------------

Max of response: 5.147 at exposure 0
Min of response: 0.35 at exposure 5.9

Raw GPCERF max/min:
-------------------
Max of response: 5.756 at exposure 0.27
Min of response: 1.186 at exposure 4.36

Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance


exposure | Predicted |      95% CI
-----------------------------------
    0.00 |      5.15 |  4.50, 5.79
    0.27 |      4.93 |  4.33, 5.52
    0.39 |      4.83 |  4.25, 5.40
    0.77 |      4.52 |  4.00, 5.04
    1.38 |      4.02 |  3.57, 4.47
    1.99 |      3.52 |  3.08, 3.96
    2.83 |      2.83 |  2.32, 3.35
    5.86 |      0.35 | -0.81, 1.51
```

Continuous dose-response model, BART



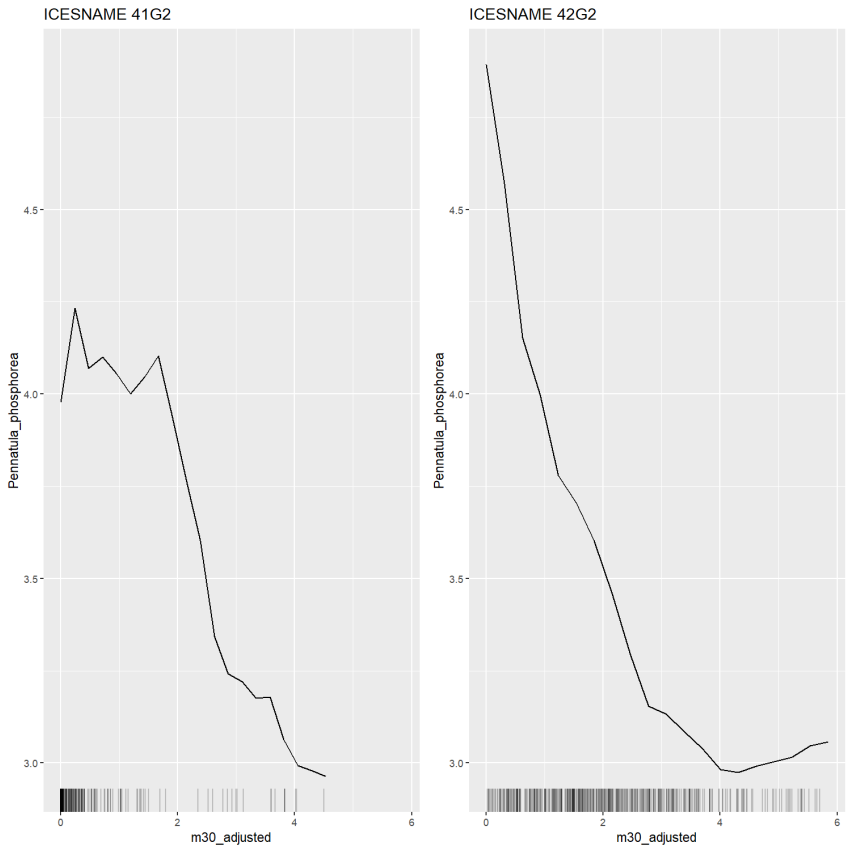

```
Linear trend analysis
---------------------
MODEL FIT:
F(1,13) = 36.762, p = 0.000
R² = 0.739
Adj. R² = 0.719

Standard errors: OLS
-----------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          4.833   0.326   14.836   0.000
exposure            -0.809   0.133   -6.063   0.000
-----------------------------------------------------

Max of response: 4.833 at exposure 0
Min of response: 0.092 at exposure 5.86

Raw bart max/min:
------------------
Max of response: 6.145 at exposure 0.27
Min of response: 0.914 at exposure 5.86

Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

exposure | Predicted |       95% CI
-------------------------------------
    0.00 |      4.83 |  4.13, 5.54
    0.27 |      4.62 |  3.97, 5.27
    0.39 |      4.52 |  3.89, 5.14
    0.77 |      4.21 |  3.65, 4.77
    1.38 |      3.72 |  3.23, 4.21
    1.99 |      3.22 |  2.74, 3.70
    2.83 |      2.55 |  1.99, 3.11
    5.86 |      0.09 | -1.17, 1.36
```

Continuous dose-response model, GAM

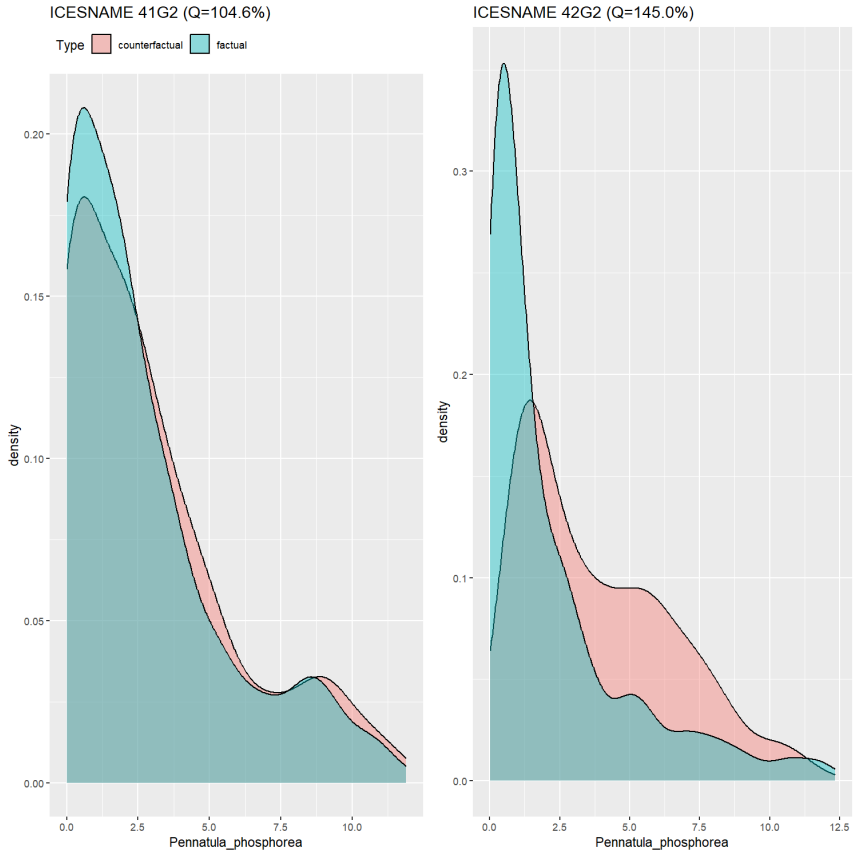



```
Linear trend analysis
---------------------
MODEL FIT:
F(1,13) = 7.216, p = 0.019
R² = 0.357
Adj. R² = 0.307

Standard errors: OLS
-----------------------------------------------------
                      Est.    S.E.   t val.       p
----------------- -------- ------- -------- -------
(Intercept)          4.166   0.771    5.401   0.000
exposure            -0.848   0.316   -2.686   0.019
-----------------------------------------------------

Max of response: 4.166 at exposure 0
Min of response: -0.807 at exposure 5.86

Raw gam max/min:
-----------------
Max of response: 7.239 at exposure 0.267
Min of response: -0.835 at exposure 3.42

Adjusted predictions at the mean
--------------------------------
# Predicted values of abundance

exposure | Predicted |       95% CI
-------------------------------------
    0.00 |      4.17 |  2.50, 5.83
    0.27 |      3.94 |  2.40, 5.48
    0.39 |      3.84 |  2.35, 5.32
    0.77 |      3.52 |  2.19, 4.84
    1.38 |      3.00 |  1.84, 4.16
    1.99 |      2.48 |  1.34, 3.61
    2.83 |      1.77 |  0.44, 3.09
    5.86 |     -0.81 | -3.80, 2.18
```

Conditional response



Conditional effects



6.4 Statistiskt meningsfulla resultat

Genom att sammanställa en matris över statistisk signifikans hos delresultaten, görs här en sammanvägd bedömning av om det är rimligt att hävda att association finns mellan exponering och utfall, och att denna association kan betraktas som kausal. Gröna prickar anger statistisk signifikant association mellan exponering och respons. Röd indikerar inga belägg för statistisk signifikans. Orange prick anger statistisk signifikant association men med omvänd verkan. Den slutliga signifikansen baseras på en subjektiv bedömning av om det sammantaget finns tillräckligt starka argument för att kunna hävda att exponeringen orsakar ett negativt utfall. Störst vikt har lagts vid de mest robusta metoderna, som är:

Metoder som endast ger medelrespons:

- WeightIt/svyglm
- Bayesian Causal Exposure Model
- twangContinuous by treatment only

Metod som ger kontinuerlig respons

- Conditional dose-response, GPCERF

Totalt sett bedöms X av 11 modellerade arter/grupper påverkas direkt och märkbart av fysisk påverkan.

Tabell 1. Sammanställning av statistisk signifikans hos delresultat, och sammanlagd bedömning. Gröna prickar anger statistisk signifikant association mellan eponering och respons. Röd indikerar inga belägg för statistisk signifikans. Orange prick anger statistisk signifinant association med med omvänd verkan.

Miljöparameter	WeightIt/svyglm	Bayesian Causal Exposure Model	twangContinuous by treatment only	twangContinuous by all covariates	Causal Forest	Continuous spline	Conditional dose-response, GPCERF	Continuous dose-response, BART	Continuous dose-response, GAM	Bedömd signifikans
EQR100	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢
Tracheophyta	🟢	🟢	🔴	🔴	🔴	🔴	🔴	🟢	🔴	🔴
Zostera marina	🟢	🟢	🟢	🟢	🔴	🔴	🟢	🟢	🟢	🟢
Chorda filum	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢
Charales spp.	🟢	🟢	🟢	🟢	🔴	🟢	🔴	🔴	🔴	🟢
Monostroma balticum	🟢	🔴	🟢	🟢	🔴	🟢	🟢	🔴	🟢	🟢
Ruppia maritima	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🔴	🔴	🟢
Stuckenia pectinata	🟢	🟢	🔴	🟢	🔴	🔴	🟢	🔴	🔴	🔴
Zanichellia palustris	🔴	🟢	🔴	🔴	🟢	🔴	🔴	🔴	🔴	🔴
Virgularia mirabilis	🟢	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🟢	🟢
Pennatula phosphorea	🟢	🟢	🔴	🔴	🟡	🟢	🟢	🟢	🟢	🟢

6.5 Att sammanställa medelrespons

Medelresponsen kan skattas direkt via AME/APE, men då förloras förmågan att se hur responsen varierar med intensiteten i exponeringen. För de kontinuerliga metoderna skulle man kunna bryta upp medelresponsen i olika intervall och medelvärdesbilda dessa. Detta skulle dock kräva att man hanterar modellernas olika kvalitet, tillförlitlighet och problem med outliers och kraftiga svängar (spline, GAM) och ”skakighet” (BART, GPCERF).

Som medelväg har av anledning med dessa problem, vars lösning ligger utanför detta projekt, har här istället medelresponsen för de kontinuerliga metoderna översatts till linjära ekvationer. De blir då jämförbara med metoderna som baseras på AME/APE.

Medelresponsen räknas lämpligtvis ut genom att antingen multiplicera AME/APE per exponeringsintervall, eller direkt konsultera de linjära omräkningarna för de kontinuerliga metoderna. Dessa omräkningar inkluderar ovan direkt prediktion per exponeringsintervall, som är liktydigt med predikterad förekomst minus predikterad respons.

Av modelleringstekniska skäl valdes dock att dela in modellerings- och prediktionsintervall i percentiler av exponering, med minst 5% av förekomsterna i varje percentil. Anledningen var att vissa intervall i exponering kan ha mycket få observationer och med få observationer blir modellerna dåliga. Av denna anledning är det lite knepigt att enkelt räkna om prediktionerna till procentuell förändring per intervall, men ett exempel görs ändå nedan, med utgångspunkt från *Pennatula phosphorea,* medelrespons AME/APE och kontinuerliga metoder, omräknad till linjär regression med sammanlagt medelvärde av -0,675.

Tabell 2. Exempel på förenklad omräkning av predikterad förekomst till andel förlust. Data från dos-responsmodellerna omräkad till linjär regression samt MAE/MPA från övriga metoder. Data avser Pennatula phosphorea och exponeringen är trålning (SAR).

EXPONERING	ABUNDANS	% FÖRLUST
0	5,15	0
0,5	4,8125	7%
1	4,475	13%
2	3,8	26%
3	3,125	39%
4	2,45	52%
6	1,1	79%
7	0,425	92%

I brist på mer robusta data och med tanke på modellernas olika utfall bör sifforna bedömas subjektivt när en generell sensitivitetsmatris skapas. Förutom medelvärdesberäkningar av AME/AME kan man även granska resultaten från maskininlärning;

- Responskurvor; ALE och PDP
- Kontrafaktiska respons, med resultat nedbrutet på miljötyp
- Kontrafaktiska effekter, med resultat (% förlust) på populationsnivå, ev. nedbrutet på miljö
- Kontrafaktisk modell, andel återstående vid olika exponeringsgrad

6.6 Förslag på medelrespons och sensitivitetsklass

Respons enligt statistik

Tabell 3. Ungefärlig progressiv förlust enligt de statistiska metoderna samt genom maskininlärning (andra värdet i kolumnen "% förlust per exp,").

Art/grupp	MAE	Intercept	% förlust per exp.	Exponeringstyp	Sensitivitet
Pennatula phosphorea	-0,72	5,15	-15%/-8%	SAR	4
Vigrularia mirabilis	-3,14	14,2	-11%/-4%	SAR	2
Zannichellia palustris*	-0,16	1,7	-9%	Påverkanszon	1
Stuckenia pectinata*	-1,09	10,0	-11%	Påverkanszon	2
Ruppia	-0,23	1,37	-17%**	Påverkanszon	3**
Monostoma balticum	-0,38	2,17	-18%/-6%	Påverkanszon	1
Charales spp.	-0,41	2,5	-17%	Påverkanszon	4
Chorda filum	-0,55	4,64	-12%	Påverkanszon	3
Zostera marina	-0,63	3,12	-20%	Påverkanszon	4
Tracheophyta*	-1,24	22,0	-6%	Påverkanszon	2
EQR100	-4,76	56,3	-8%	Påverkanszon	3

* Bedömd som ej statistiskt relevant
**Innehåller *både* den okänsliga *Ruppia maritima* och känsliga *Ruppia cirrhosa*

Siffrorna i tabellen ovan är framtagna med data från respektive område. Eftersom miljön för exempelvis *Zostera marina* ser helt annorlunda ut på Västkusten eller i Skåne kommer inte den uppskattade förlusten vara relevant där, eftersom den kumulativa belastningen från påverkan; indirekt, sekundär och tertiär, blir helt annorlunda. I synnerhet Sörmland har många vågskyddade områden med stort inslag av finare sediment i sandbottnarna och dessutom lägre salthalt och större belastning av näringsämnen än de mer öppna och välventilerade sandbottnarna i södra eller västra Sverige. Detta ger förstås effekter dels vad gäller direkt störning (exempelvis då vegetation slits loss), sekundärt, via uppvirvlande sediment, och i tredje hand, med efter störningen ökad näringsbelastning, påväxt osv.

Egentligen bör man ta fram liknande sensitivitetsmatriser för olika havsområden. En rimlig nivå på stratifiering är typvatten.

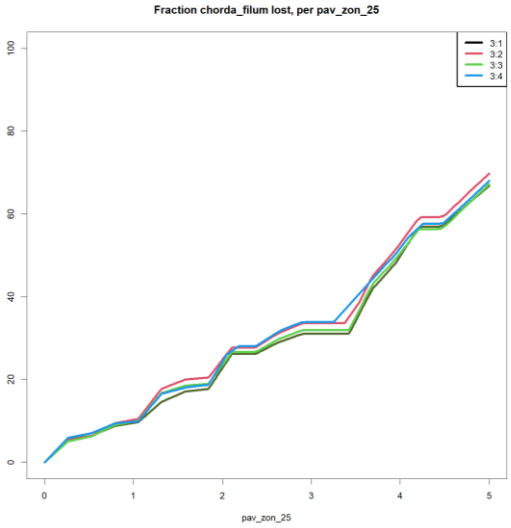
Respons enligt maskininlärning

Resultatet från maskininlärning, för vegetation redovisade i graferna som avser "Fraction xxx lost, per pav_zon_25" i avsnitt A.D2 att använda direkt för att skatta andel förlust. Denna andel förlust kan sedan jämföras med den statistiska bilden som redovisas ovan.

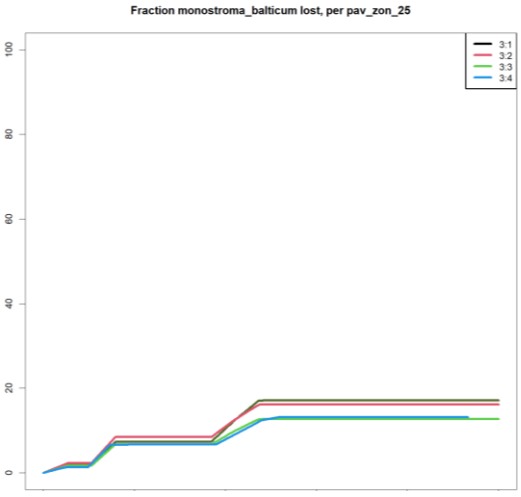
Nedan följer en jämförelse av fyra modeller. Först två som enligt Hansen (Hansen & Snickars, 2014) är känsliga respektive okänsliga, sedan det sammansatta EQR100 och slutligen gruppen kärlväxter, *tracheophyta*, aktuella för Vattenförvaltningen. Tolkningen av förändring med ökad fysisk störning biläggs respektive graf.

För tre av modellerna är överensstämmelsen mycket stor. De statistiska metoderna verkar dock övertolka effekterna på den okänsliga *Monostroma balticum*.

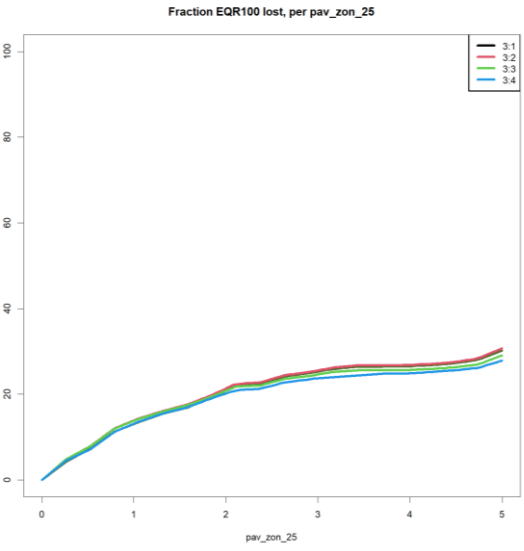
Analysen av kärlväxter visar att en så pass trubbig indikator inte fångar upp effekter när vissa arter går tillbaka och andra inom samma grupp istället ökar. Det som areellt och kvantitativt sett kan tyckas vara likvärdigt kan alltså, om en hel grupp slås samman och bildar ett index, dölja att hela artsammansättningen och biodiversiteten kan ha ändrat karaktär.



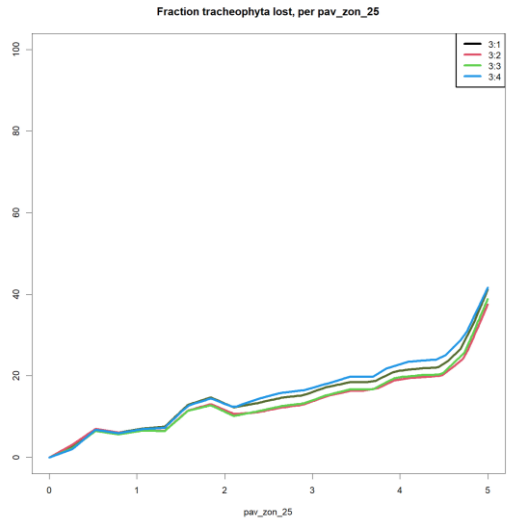
Chorda filum. Relativt linjär respons med max > 60 % förlorat vid påverkanszon 5. Detta ger genom maskininlärning ca -12 % per påverkanszon. Enligt de statistiska metoderna gav motsvarande analys också runt -12 %.



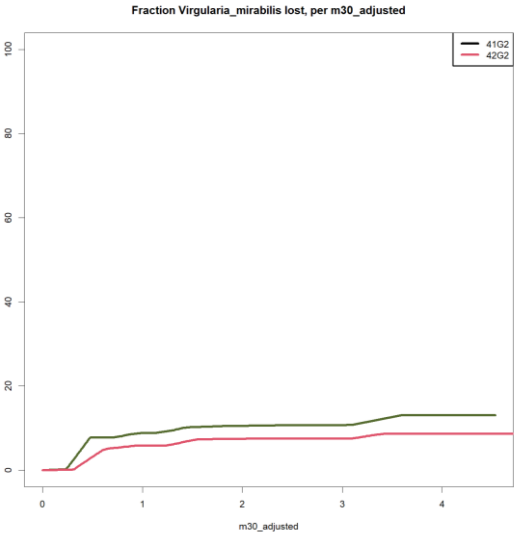
Monostroma balticum. Responsen planar ut efter zon 2,5 med max < 20 % förlorat vid påverkanszon 5, genom maskininlärning. Detta ger ca -4 % över intervallet eller -8,5 % räknat på zon 2,5. Medelvärdesbildat till -6 % per påverkanszon. Enligt de statistiska metoderna gav motsvarande analys: -18 % men eftersom arten anses tålig mot fysisk störning och eutrofiering verkar maskininlärning ha givit bättre resultat för denna art.



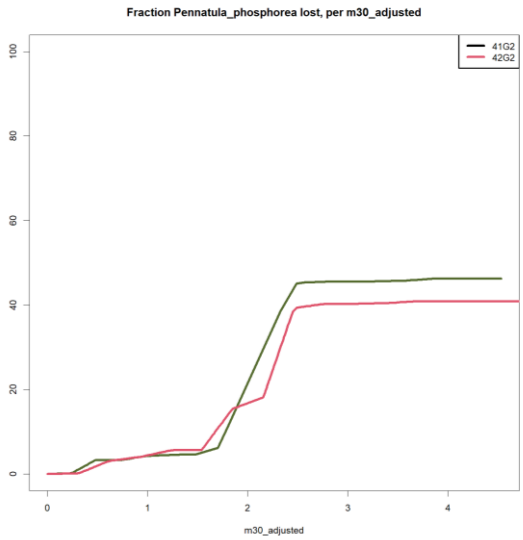
EQR100. Relativt linjär respons med max runt 30 % förlorat vid påverkanszon 5, genom maskininlärning. Detta ger ca -6 % per påverkanszon. Enligt de statistiska metoderna gav motsvarande analys i stort sett samma; ungefär -8 %.



Tracheophyta. Relativt linjär respons som pekar brantare uppåt vid maximal påverkanszon. Detta index består av både känsliga och okänsliga arter och därför påverkas det inte så mycket som man kanske kan förmoda, även om effekterna vid maximal påverkan säkert är ett utslag av att fler arter påverkas negativt vid denna belastning. Max ligger runt 40 % vid påverkanszon 5. Detta ger ca -8 % per påverkanszon. Enligt de statistiska metoderna gav motsvarande analys i stort sett samma; ungefär -6 %.



Virgularia mirabilis. Relativt linjär respons som pekar brantare uppåt vid maximal påverkanszon. Max ligger under 20 % vid SAR 5. Detta ger ca -4 % per SAR. Enligt de statistiska metoderna gav motsvarande analys en högre siffra, runt -11 %.



Pennatula phosphorea. Respons som stiger kraftigt kring SAR ≈ 2. Och planar ut vid maximal SAR. Max förlust ligger på lite drygt 40 % vid påverkanszon 5. Detta ger linjärt ca -8 % per påverkanszon. Enligt de statistiska metoderna gav motsvarande analys istället omkring - 15 %.

Referenser

Hansen, J. P., & Snickars, M. (2014). Applying macrophyte community indicators to assess anthropogenic pressures on shallow soft bottoms. *Hydrobiologia*, *738*(1), 171–189. https://urn.kb.se/resolve?urn=urn:nbn:se:su:diva-107411

James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). *An Introduction to Statistical Learning: With Applications in R*.