Impact of mussel seed fishery on subtidal macrozoobenthos in the western Wadden Sea

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Report number C003/13 PR 7

IMARES Wageningen UR

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Client:	Ministerie van Economische Zaken en Producten Organisatie van de Nederlandse Mosselcultuur
Publication date:	15 april 2013

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Summary

Within the framework of PRODUS, the effect of mussel fishery on the macrofauna species sampled with a box-corer was investigated following a so-called split-plot design. Within areas where mussel seed fishery was allowed, 40 plots/locations were chosen within which one part was open for commercial fisheries and one part was closed of fisheries. Box-corers were taken in 21 of these locations, sampled one to several times.

The present study confirms the existence of small scale differences in macrofauna species composition: even within a subtidal mussel bed, within a few hundreds of meters. The present study confirms large temporal variation in species composition, independently of any human impact.

The study shows short-term effects of fishery activities: a change in total density and in species composition (e.g. associated species). The study also shows mid-term effects on species diversity (number of species and Shannon-Wiener index). The effect is different depending on the fishery season. Overall, any fishery effects seem to be less important in determining species composition than external factors controlling mortality and recruitment.

Introduction

The research project on sustainable shellfish culture (PRODUS) is being implemented on behalf of the Ministry of Agriculture, Nature and Food Quality (LNV) and the shellfish sector. This assignment resulted from the new shellfish policy and the innovation agenda of the shellfish sector.

The 'PRODUS' research project is focussed on factors that determine the efficient exploitation of mussels in bottom culture, and on the impact of mussel culture, including mussel seed fishery, on the ecosystem. The standing stock dynamics and the yield of bottom culture of mussels is being studied in relation to environmental conditions, the role of predation, and the culture strategies of the farmers. A comparison is made of species composition and abundance of wild mussel seed beds, culture plots and other habitats.

It also investigates the effects of mussel seed fishing on mussel stocks and the nature values in sublitoral areas. For more information on the research questions and the research approach, we refer to Smaal et al (2013). In this report the effect of mussel seed fishery on the benthic fauna (as sampled by a box-corer) is analysed.

1. Materials and Methods

a. Experimental design

The experimental set up of the project is a so-called split-plot design (Ens et al., 2007). Within areas where mussel seed fishery is allowed (so-called whole plots), subplots of 400*200m are chosen within which one part was open for commercial fisheries (further referred as open or Impact part) and one part was closed to fisheries further referred as closed or Control part). Plots are further referred to as locations.

At the start of the study, it was decided that 40 of these experimental plots were needed in order to have sufficient power (set at 80%, with a probability of 5% to reject the null hypothesis of no changes when it fact there are) to detect differences of 10% (of the range of observed values at the start of the experiment) (Ens et al., 2007). The locations were not defined a-priori to avoid the high risk of no spat fall during the study period (Ens et al., 2007). At the start of the study (2006), there was a very poor spat fall. It was therefore decided, to define ten locations on beds of year class 2005 in autumn 2006. Most of these had already been fished before the start of the study. Two of them were already abandoned in 2007 because of fisheries in the closed part of the location (Van Stralen et al., 2013)The other 32 locations could be defined in not disturbed mussel seed beds in the subsequent years (up to 2009). All fishing boats are equipped with a black box which permanently monitors the location of the boats. Based on these data the effective area fished and the fishery intensity was estimated (Van Stralen et al., 2013)

The macrobenthic infauna (as sampled with box-corer; see next chapter) was eventually studied in 21 locations (Figure 1). Some of them were sampled once, others several times (Table 1). Six of them were situated on mussel beds of year class 2005 (Afsluitdijk west, Breesem, Molenrak west, Stompe, Vlieter, ZuidWest). At some locations new spat fall events occurred in the years following the time the locations were marked out. In some, therefore, commercial fisheries took place more than once: three were fished twice (Breesem, Zuidwest, Stompe) and one was fished five times (Visjagersgaatje) (Van Stralen et al., 2013)..

b. Benthic Sampling

In 2006, 12 samples were taken within the closed (Control) and open (Impact) parts of each location, in 2007 20 cores and in later years again 12 samples, resulting in a total of 1896 samples. All samples were taken within the central 1 ha of both the open and closed parts of each location. The number of replicate samples per location was adapted after a power analysis in 2008 on the basis of the PRODUS data available so far (Meesters and Fey-Hofstede, 2009). They showed that sufficient power for the biodiversity parameters could be achieved by 12 replicates per plot.

Samples were taken with a box-corer. From each box-corer, two cylindrical subsamples were taken (total area: 0.1664 m^2). Both subsamples were sieved together over a 1 mm sieve and samples were fixed in 10 % formalin. In the laboratory the organisms were sorted, identified to species level if possible and counted. The latter has been done by different laboratories. Therefore, identifications were checked for differences as different laboratories used different identification keys – moreover, some keys were updated during the study period - or have different opinions on the taxonomy of some species, and not everyone differentiated all species (some laboratories identified taxa as e.g. sea anemones to the species level while others did not). Therefore, some species were lumped to genus or a higher taxonomic level. The original list of 243 taxa was, thus, reduced to 185 taxa.

Table 1. Sampling locations and times of sampling. Only locations where samples were taken with box-corers are shown. Locations excluded from the analyses because of fishing disturbance are not shown.

location	T_0	T_1	T_2	T_3	T_4	T_5
Afsluitdijk West	25-sep-06	2-jul-07	19-jun-09	20-sep-10		
Breesem	25-sep-06	25-nov-06	14-jan-09	21-sep-09	24-nov-09	
Molenrak Oost	25-sep-06					
Molenrak West	25-sep-06	2-jul-07	19-jun-09	29-sep-10		
Omdraai	25-sep-06					
Txstroom-west	25-sep-06	25-nov-06				
Visjagersgaatje	25-sep-06	2-jul-07	19-jun-09	21-sep-09	24-nov-09	27-sep-10
Vlieter	25-sep-06	25-nov-06	14-jan-09	21-sep-10		
ZuidWest / Lutjewaard	25-sep-06	25-nov-06	14-jan-09	27-sep-10		
Stompe	17-apr-07	2-jul-07	19-jun-09	21-sep-10		
Gat van Stompe	27-aug-07	17-dec-07	24-nov-09	21-sep-10		
Stompe zuid	27-aug-07	17-dec-07	21-sep-09	24-nov-09	22-sep-10	
Afsluitdijk - AD10	14-apr-09	19-jun-09	20-sep-10			
Breezanddijk	14-apr-09	19-jun-09	22-sep-10			
Doovebalg DB23	14-apr-09	19-jun-09	23-sep-10			
Kornwerd / Boontjes	14-apr-09	19-jun-09	30-sep-10			
Zuidoostrak	14-apr-09	19-jun-09	30-sep-10			
Breesem W	21-sep-09	24-nov-09	24-sep-10			
Breesem Z	21-sep-09	24-nov-09	23-sep-10			
Griend / Blauwe Slenk noord	21-sep-09	24-nov-09	29-sep-10			
Inschot	21-sep-09	24-nov-09	30-sep-10			
Pollendam / Blauwe Slenk	21-sep-09	24-nov-09	29-sep-10			
Westkom	21-sep-09	24-nov-09	28-sep-10			
WestMeep	21-sep-09	24-nov-09	28-sep-10			

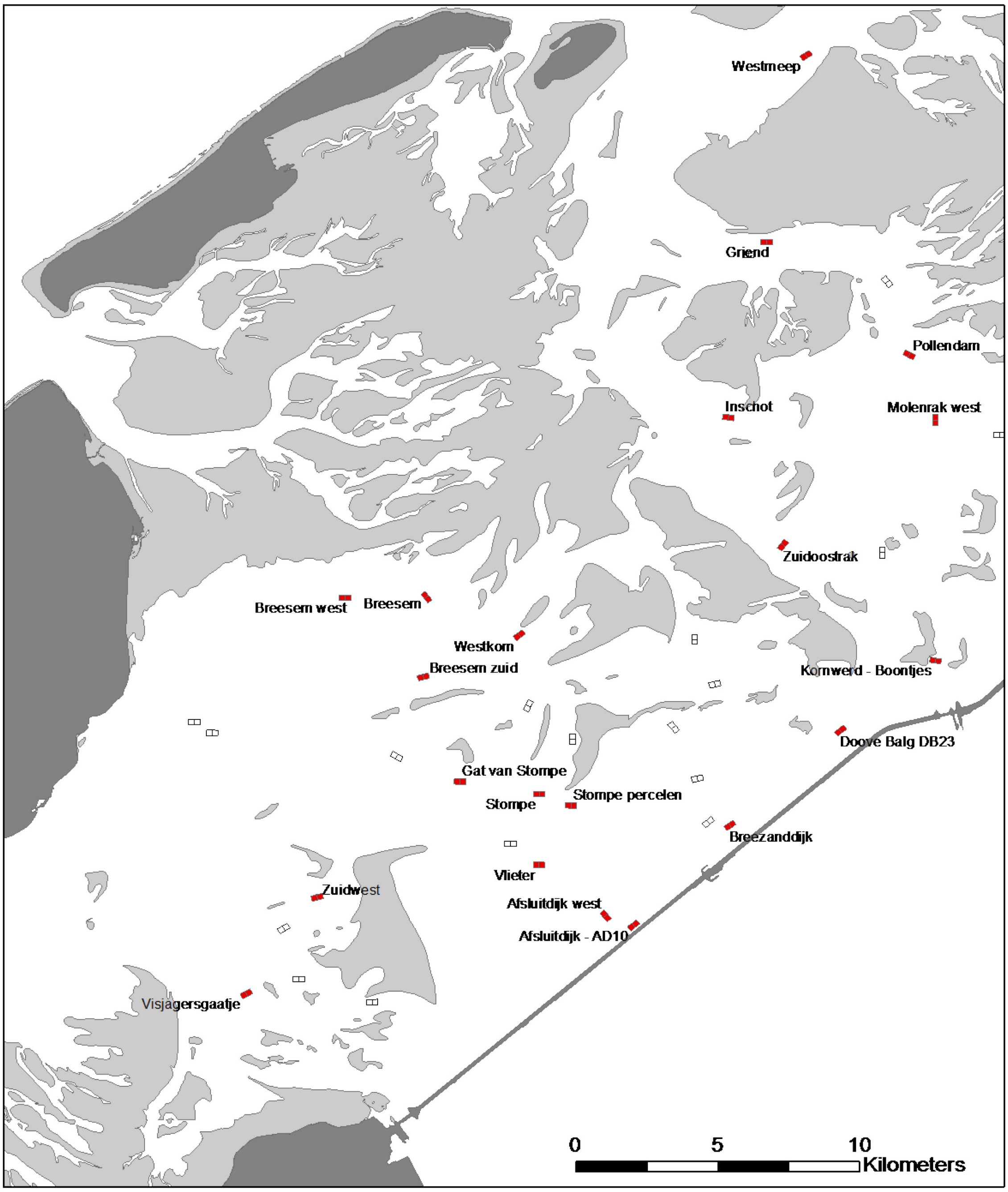


Figure 1. Map of the western Dutch Wadden Sea with locations used in the study of this project. The locations involved in this report (Table 1) are coloured red, and the location name is indicated. The other locations, not sampled by box-corer, are white coloured.

c. Data analyses

Univariate indices

In studies on temporal changes of the benthic community, a huge variety of indices is used (see e.g. Quintino et al., 2006). In this study, the following univariate indices were chosen: total density, number of species (S), Shannon-Wiener (H’, $\log_e$) and Pielou’s evenness (J = H’/ log(S)). Diversity indices S and H’ were calculated using the library *vegan* (Oksanen et al., 2011) of R (R Development Core Team, 2011). Because mussels have been fished in the open site, an effect on the total density and on the relative abundance of all species will be seen, even if no other species then mussels are impacted by fishery activities. Therefore, all calculations were done excluding mussels. To analyse the effects of fisheries on these community indices, linear mixed effect models were used (Pinheiro, 2008). Box-plots of data for each location, histograms of the data and QQ-plots were used to check the normality assumption. If necessary, a data transformation was used that achieved the best normalization for the data analysed. If necessary different variance structures were used to achieve heterogeneity within groups.

The analyses on the univariate indices were done for short-term effects of fisheries, i.e. shortly after mussel seed fisheries (6 times spring fishery, 15 times autumn fishery), and mid-term effects, i.e. 1 to 1.5 years after fisheries (5 times spring fishery, 6 times autumn fishery). T0 – sampling was always in the same season as T1, except for Molenrak West, Afsluitdijk West and Visjagersgaatje (Table 1). Analysis of long-term effects on these indices were not done because of the low number of locations sampled for a longer period.

The full data model included tree main effects, a three way interaction and three two way interactions. Main effects were time (before and after fishing activities), season (spring or autumn) and treatment (closed/Control or open/Impact). Since we were not so much interested in each specific location, but in the overall picture of fishing, sampling location was modelled as a random factor. Different variance structures were tested and applied if significantly improving the model fit. Nested models were compared using the Aikake Information Criteria (AIC) and tested using the F-test on the likelihood ratio which was calculated using restricted log likelihood (REML) for models with a different variance structure and maximum log likelihood (ML) for models with different fixed effects (see e.g. protocols in Zuur et al., 2009).

Model validation was done using validation graphs: residuals versus fitted values to check homogeneity, and box-plots of the residuals versus each explanatory variable to check independence.

All calculations were performed using R (R Development Core Team, 2011) and the package *nlme* (Pinheiro et al., 2011).

Species composition

Similarity

The Bray-Curtis dissimilarity index was used to quantify the distance between the species composition of Control and Impact parts of each location. As for the univariate indices, calculations were done on species density averages per treatment per location. Density data were fourth root transformed.

The effect was tested in two ways. First, a similars model was used as for the above mentioned univariate indices. However, because dissilimilarity between open and closed areas is calculated, treatment could not be an explanatory variable and, thus the interaction term treatment*time could not be tested. A model was set up with time and season as explanatory variables and the same procedure was followed for final model selection.

Secondly, a model was set up with only time as the main effect and location as random factor. Differences in similarity between control and impact part of each location before and after fisheries were tested using simulation by informal Bayesian inference (Gelman and Hill, 2007). A linear mixed model with similarity as response variable, time as explanatory variable and location as random factor was constructed and Monte Carlo Markov Chain simulation run (10000 simulations) to estimate model parameters and confidence intervals (McKechnie et al., 2009). The null model is: the difference in similarity between Control and Impact area is not different before and after fishing.

Changes in species composition were visualised using non-metric dimensional scaling (nMDS), an ordination method often used by ecologists. It may be preferred when the user wants to represent as much as possible of the distance relationships among objects in a few dimensions (Legendre and Birks, 2012). We used Bray-Curtis as dissimilarity index and set the number of dimensions to two.

All calculations were performed using R (R Development Core Team, 2011) and the packages *lme4* (Bates et al., 2011), *nlme* (Pinheiro et al., 2011), *arm* (Gelman et al., 2012) and *vegan* (Oksanen et al., 2011).

Principal Response Curves

Principal response curves (PRC) were used to analyse the time and treatment-dependent multivariate response of the benthic infauna. PRC are a special case of RDA (partial Redundancy Analysis for multivariate responses in repeated observation design (a single factor for *treatment* and a single factor for *time* points in repeated observations). RDA is the canonical form of principal components analysis (PCA), and is based on a linear response model between species and explanatory variables (as e.g. expected in short segments of ecological gradients) (see e.g. Jongman et al., 1987; Legendre and Birks, 2012; ter Braak and Prentice, 1988). The advantage of PRC over other multivariate methods is that it is able to focus on the part of the variance explained by a treatment. Instead of presenting data in diagrams that are often too cluttered to allow easy interpretation of the changes in treatment effects over time, the principal components of the treatment effects are plotted against time, expressed as deviations from the control treatment. Thus, PRC diagrams are much easier to interpret and visualise much clearer than standard constrained ordination diagrams how treatment effects develop over a longer period. The vertical axis of a PRC diagram contrasts each treatment with the control, expressed as a canonical regression coefficient. Associated with each PRC is a set of species weights, shown on the right side of the PRC diagram. Species' weights denote the relative contributions to the PRC, i.e. the strength of the response of each species. Thus, PRC allows a direct interpretation down to the species level: species with high positive weights follow the same pattern as the PRC and are highly affected by the treatment, whereas taxa with negative values behave contrarily to the PRC. Statistical significance of each principal component can be assessed by Monte Carlo permutation testing (den Besten and van den Brink, 2005; Lepš and Šmilauer, 2003; van den Brink and Ter Braak, 1998; Van den Brink and Ter Braak, 1999).

The PRC method was specially designed for the analysis of time series obtained from microcosms and mesocosms experiments (Moser et al., 2007; Pernin et al., 2006; Van den Brink and Ter Braak, 1999) but proved to be very successful in demonstrating treatment effects in field experiments (Cébron et al., 2011; den Besten and van den Brink, 2005; Devotto et al., 2008; Dively, 2005; Marriott et al., 2009; Tschöpe et al., 2011). PRC can also be used for the study of data that were not obtained experimentally but are the result of a biomonitoring programme. In that case an internal reference can be defined to display changes in time, or different sampling sited can be compared (den Besten and van den Brink, 2005; van den Brink et al., 2009). Only a few studies have used PRC to analyse such monitoring data, where it proved valuable (Bollmohr and Schulz, 2009; Bollmohr et al., 2011; Leonard et al., 2000; Neher et al., 2005; Okullo and Moe, 2011).

PRC is most useful to highlight site differences in time if the initial differences between sites are not very large, as could be expected in our case where the Control and Impact part of each site are situated side by side. Van den Brink et al (2009) do not recommend PRC for large-scale studies with large initial differences among sites. We therefore analysed the data for each location separately. The gradient in terms of the main effect of time is not restricted by linearity and can be of any complexity. Resulting species weights might identify species that may be tolerant or sensitive to disturbance (brought about by fisheries, in our case), thus could be interpreted as the affinity of the taxon with the PRCs. We checked for communality in the species involved and compared the percentage of the total variance that can be attributed to time with that attributable to the treatment regime.

The principal response curves method can be used to show trends over time with an internal reference or an external reference. Here we used the t0-situation as internal reference to show seperately the temporal changes in the Impact and the Control part of each site. Secondly, again for each site separately, the data of the Control box were used as external reference for an analysis of the changes in the Impact box.

The analysis was carried out using the R package *vegan* (Oksanen et al 2011; R Development Core Team 2011). The species density data were square root transformed. The significance of the first canonical axis (first PRC diagram) was tested by a Monte Carlo permutation of the treatments. The significance of each time-point is indicated by the p values generated from unrestricted Monte Carlo permutations of the first axis of separate RDA analyses for each time point.

Power analysis

The design of the study was set up to be able to find 10% differences (= effect size) with a power of 80% (type II error $\beta = 0.20$) and a significance level set to 5% (type I error $\alpha = 0.05$). A priori estimates were done for 3 biodiversity indices: number of species, Simpson's index and the score on the first DCA axis (Ens et al., 2007).

We checked the realized effect size for total density, number of species, evenness and Shannon-Wiener index for the same type I and II errors ($\alpha = 0.05$, $\beta = 0.20$), given the realized standard deviations. The standard deviation of these community indices was calculated using the location averaged species abundances at T0. Separate calculations were done for short-term and mid-term effects as the number of locations differs (21 for short-term, 11 for mid-term; see further) .

2. Results

a. Univariate indices

The boxplots in *Figure 2* show that there is a temporal variation in the chosen univariate community indices. In many cases temporal patterns were similarfor Control and Impact areas. Total density, for instance, decreases in the first year after spat fall between spring and autumn, irrespective of the treatment (Closed/Open) or the season of fisheries (spring/autumn). There are differences as well. Evenness and Shannon-Wiener e.g., increases in the first year after spat fall between spring and autumn in the closed area after spring fisheries only. Differences at the end of the time series are likely due to the low number of locations.

Short-term effects

For the analysis of short-term effects, data collected before (T_0) and after fishery (spring/01 or autumn/00) were selected. Data of 2006 (fishery on half grown mussels) were not excluded. Three-way interactions, indicating an effect of fishing, were never significant.
Total density is influenced by sampling time (Before/After) and treatment (Control/Impact) but the effect is not the same (*Table 2*). There is a significant interaction between both terms: the difference between control and impact sites is different before and after fishing, indicating an effect of fishing. The interactions plots indeed show that after spring fishery, densities have increased more in the closed than in the open parts of the locations. In autumn, densities decreased more in open than in closed areas (*Figure 3*). The interaction is stronger in spring (a disordinal interaction as lines cross) than in autumn (ordinal interaction as lines do not cross). There is also a significant interaction between season and time indicating that the densities before and after fishing depend on the season.
The evenness is only influenced by season and treatment (*Table 3*). No interaction terms are significant. Nevertheless, the interaction plots suggest that on average, the number of species increased less in open than in closed areas after spring fishery, and decreased more in open than in closed areas after autumn fisheries (*Figure 3*).
There is no significant interaction between time and treatment on the number of species (*Table 4*) and the Shannon-Wiener index (Table 4, 5). But the values before and after fishing depend on the season. The interaction plots (*Figure 3*) suggest that the decrease of both indices is the same in open and closed areas after autumn fishery but they develop different after spring fishery.
Model validation graphs are given in *Figure 4*. There was no sign for overdispersion of the models (dispersion values always around 1).

*Table 2. Short-term effects: model coefficients for total density. Final model: lme((tot_density+1)^.15~season+time+treatment+season:time+time:treatment, random=~1|location, weights=varIdent(form=~1|time*season)*

```
                                Value  Std.Error   DF   t-value p-value
(Intercept)                  3.819819 0.17658359 1126 21.631791  0.0000
Season (autumn)             -0.217369 0.13452277 1126 -1.615852  0.1064
Time (After)                 0.478977 0.13984980 1126  3.424940  0.0006
Treatment(Open)              0.026300 0.05308107 1126  0.495464  0.6204
Season (autumn):Time (After) -0.632638 0.14113681 1126 -4.482446  0.0000
Time (After):Treatment(Open) -0.200646 0.07443952 1126 -2.695421  0.0071
```

*Table 3. Short-term effects: model coefficients for evenness (J). Final model: lme(exp(J)~season+treatment, random=~1|location, weights= varIdent(form=~1|time*season))*

```
                        Value  Std.Error   DF   t-value p-value
(Intercept)         1.7124468 0.05934829 1092 28.854188  0.0000
Season (autumn)     0.3188247 0.05280578 1092  6.037687  0.0000
Treatment (Closed) -0.0625565 0.02029236 1092 -3.082762  0.0021
```

Table 4. Short-term effects: model coefficients for number of species (S). Final model: lme(sqrt(S)~season+time+season:time, random=~1|location)

```
                                 Value Std.Error   DF   t-value p-value
(Intercept)                  2.4705754 0.1751029 1128 14.109278  0.0000
Season (autumn)              0.7886706 0.1334253 1128  5.910951  0.0000
Time (After)                 0.3244655 0.1013994 1128  3.199876  0.0014
Season (autumn):Time (After) -0.7449155 0.1151034 1128 -6.471707  0.0000
```

Table 5. Short-term effects: model coefficients for Shannon-Wiener (H’). Final model: lme(H’~season+time+treatment+season:time,random=~1|location,weights=varIdent(form=~1|season))

```
                                 Value  Std.Error   DF   t-value p-value
(Intercept)                  1.1141786 0.13988814 1127  7.964783  0.0000
Season (autumn)              1.0497926 0.11712161 1127  8.963270  0.0000
Time (After)                 0.2143926 0.08448724 1127  2.537573  0.0113
Treatment (Open)             0.0855698 0.04043957 1127  2.115991  0.0346
Season (autumn):Time (After) -0.5766195 0.09872180 1127 -5.840853  0.0000
```

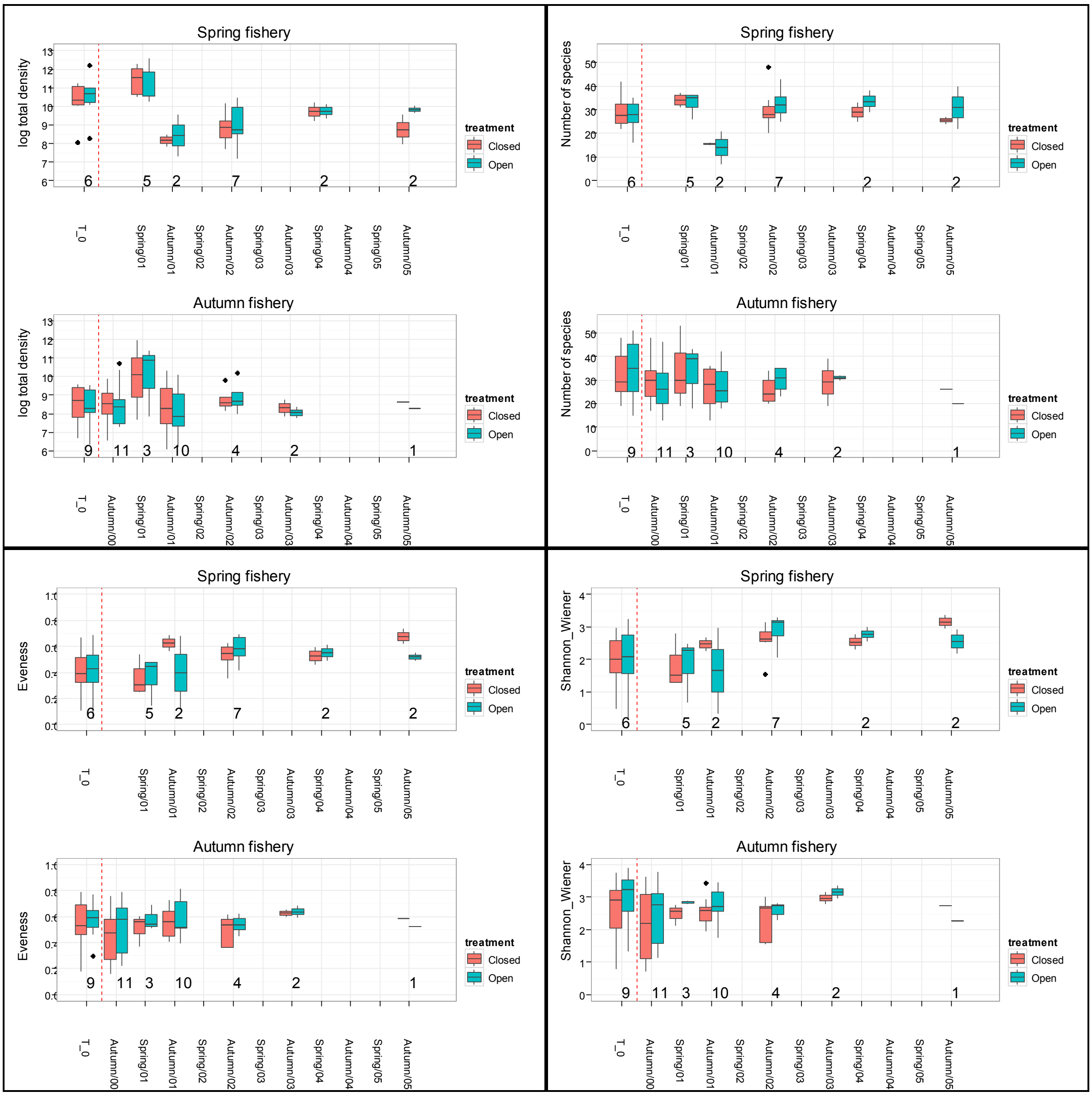


Figure 2. Boxplots of (location average) total density, number of species, evenness and Shannon-Wiener conditional on time, for locations where mussel seed fisheries took place the first time in spring or autumn, in areas open and closed for fisheries. T_0 is the situation prior to the fishing activities (excluding samples taken in 2006 and 2007 on beds settled in 2005; see text for further explanation). The time axis is rescaled to the year of spat fall prior to the sampling date (e.g. spring/02 is referring to data in spring of the second year after the spat fall). The numbers below the boxes denote the number of locations sampled.

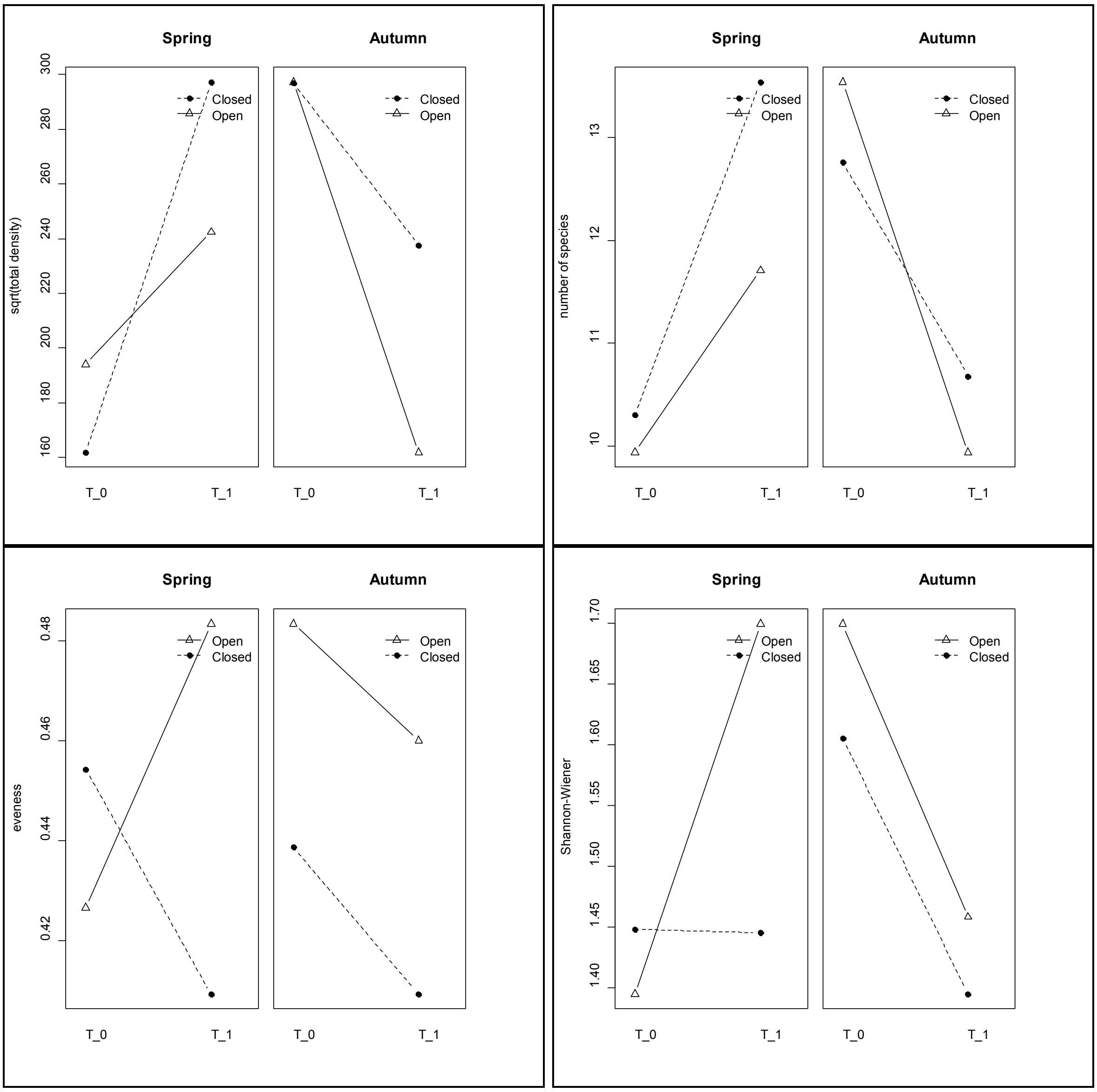


Figure 3. Interaction plot for short-term effects showing (on the y-axis) the mean of square root transformed total density (upper left), number of species (upper right), evenness (lower left) and Shannon-Wiener index (lower right) in spring and autumn. The x-axis gives the sampling time (t0, T1) and the lines the treatment type.

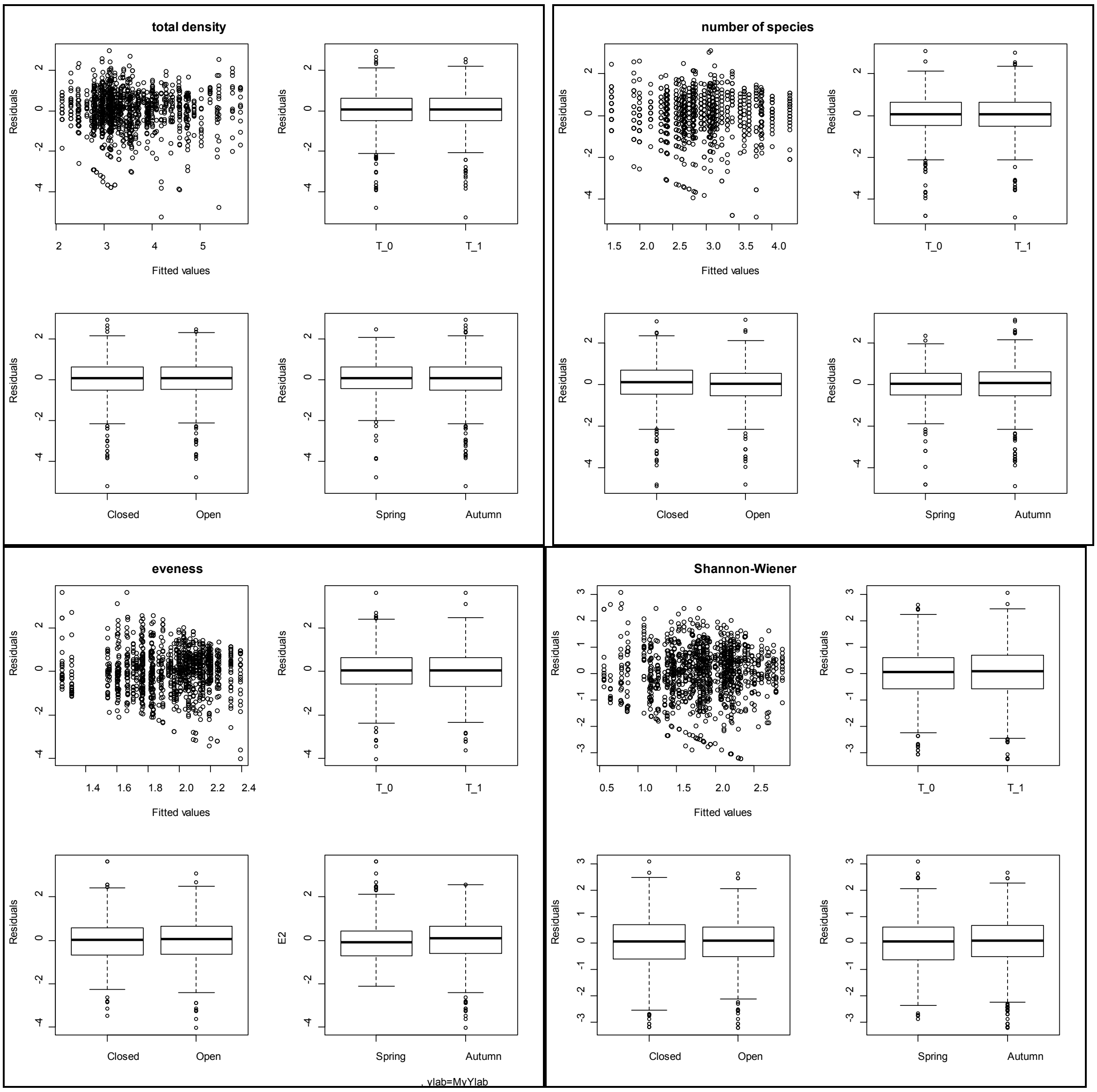


Figure 4. Model validation graphs for models on short-term effects in total density (upper left), number of species (upper right), evenness (lower left) and Shannon-Wiener index (lower right). Residuals are plotted versus the fitted values, sampling time, season, and treatment.

Mid-term effects

At mid-term there is no significant interaction between time and treatment, thus no indication of fishery effects on total density (*Table 6*). The interaction plots indeed show the same trends in open and closed parts, both when fisheries took place in spring or autumn (*Figure 5*). For evenness too, there is no significant interaction between time and treatment (*Table 7*). The interaction plot suggest different trends after autumn (*Figure 5*). For the number of species and the Shannon-Wiener index, the three-way interaction (time: treatment:season) is significant (*Table 8* and *Table 9*). Both in spring and autumn, the interaction between treatment and time (indicating possible fishery effects) are strong (disordinal) but depend on the season fishing took place. The interaction plots (*Figure 5*) show opposite trends in spring and autumn. The number of species, for instance, after spring fisheries increased in the open sites but decreased in the closed parts. After autumn fisheries, the number of species decreased both in the open and closed parts, but more in the open parts. Shannon-Wiener index showed the same trends in open and closed parts, after spring (increase) and autumn (decrease) fisheries, but the changes were stronger in the open parts.

Model validation graphs are given in *Figure 6*. There was no sign for overdispersion of the models (dispersion values always around 1).

*Table 6. Mid-term effects: model coefficients for total density. Final model: lme(tot_density^0.25 ~ time + treatment + season + time:season + treatment:season, random=~1|location, weights=varIdent(form=~1|season*Time)).*

```
                                   Value Std.Error  DF   t-value p-value
(Intercept)                     7.730013 0.8959457 536  8.627769  0.0000
Time (Before)                   1.123072 0.2984812 536  3.762621  0.0002
Treatment (Open)               -0.383939 0.2746875 536 -1.397729  0.1628
Season (spring)                 2.737416 1.3948135  10  1.962568  0.0781
Time (Before):Season (spring)   1.290995 0.6389239 536  2.020577  0.0438
Treatment (Open): Season (spring)  2.124881 0.5496475 536  3.865898  0.0001
```

Table 7. Mid-term effects: model coefficients for evenness (J). Final model: lme(exp(J) ~ Time + season + time:season , random=~1|location,weights=varIdent(form=~1|time)).

```
                                Value  Std.Error  DF   t-value p-value
(Intercept)                 1.5419500 0.08134407 523 18.955899  0.0000
Time (After)                0.2412979 0.04643726 523  5.196212  0.0000
Season (autumn)             0.3952492 0.10657521  10  3.708641  0.0041
Time (After): Season (autumn) -0.1849276 0.06351386 523 -2.911610  0.0037
```

*Table 8. Mid-term effects: model coefficients for number of species (S). Final model: lme((S + 0.1)^0.75 ~ time * treatment * season, random=~1|location, weights= varIdent(form=~1|season)).*

```
                                                Value Std.Error  DF   t-value p-value
(Intercept)                                  6.268876 0.7850769 534  7.985047  0.0000
Time (After)                                -1.208268 0.3201871 534 -3.773631  0.0002
Treatment (Open)                            -0.256489 0.3201871 534 -0.801060  0.4235
Season (autumn)                             -0.105912 1.0349662  10 -0.102333  0.9205
Time (After):Treatment (Open)                1.452890 0.4528130 534  3.208588  0.0014
Time (After):Season (autumn)                 0.579458 0.4662753 534  1.242738  0.2145
Treatment (Open):Season (autumn)             0.443509 0.4526288 534  0.979851  0.3276
Time (After):treatment(Open):Season (autumn) -1.946924 0.6533027 534 -2.980125  0.0030
```

*Table 9. Mid-term effects: model coefficients for Shannon-Wiener (H'). Final model: lme(H' ~ time * treatment * season , random=~1|location, weights= varIdent(form=~1|time)).*

```
                                                   Value Std.Error  DF   t-value p-value
(Intercept)                                    1.3872354 0.2808303 534  4.939763  0.0000
Time (After)                                   0.5017701 0.1311295 534  3.826522  0.0001
Treatment (Closed)                             0.1161598 0.1205374 534  0.963683  0.3356
Season (autumn)                                0.8099831 0.3676932  10  2.202878  0.0522
Time (After):Treatment (Closed)               -0.4155712 0.1854452 534 -2.240938  0.0254
Time (After):Season (autumn)                  -0.8084444 0.1762691 534 -4.586422  0.0000
Treatment (Closed):Season (autumn)            -0.2648875 0.1578205 534 -1.678411  0.0939
Time (After):Treatment(Closed):Season (autumn)  0.7337067 0.2476257 534  2.962967  0.0032
```

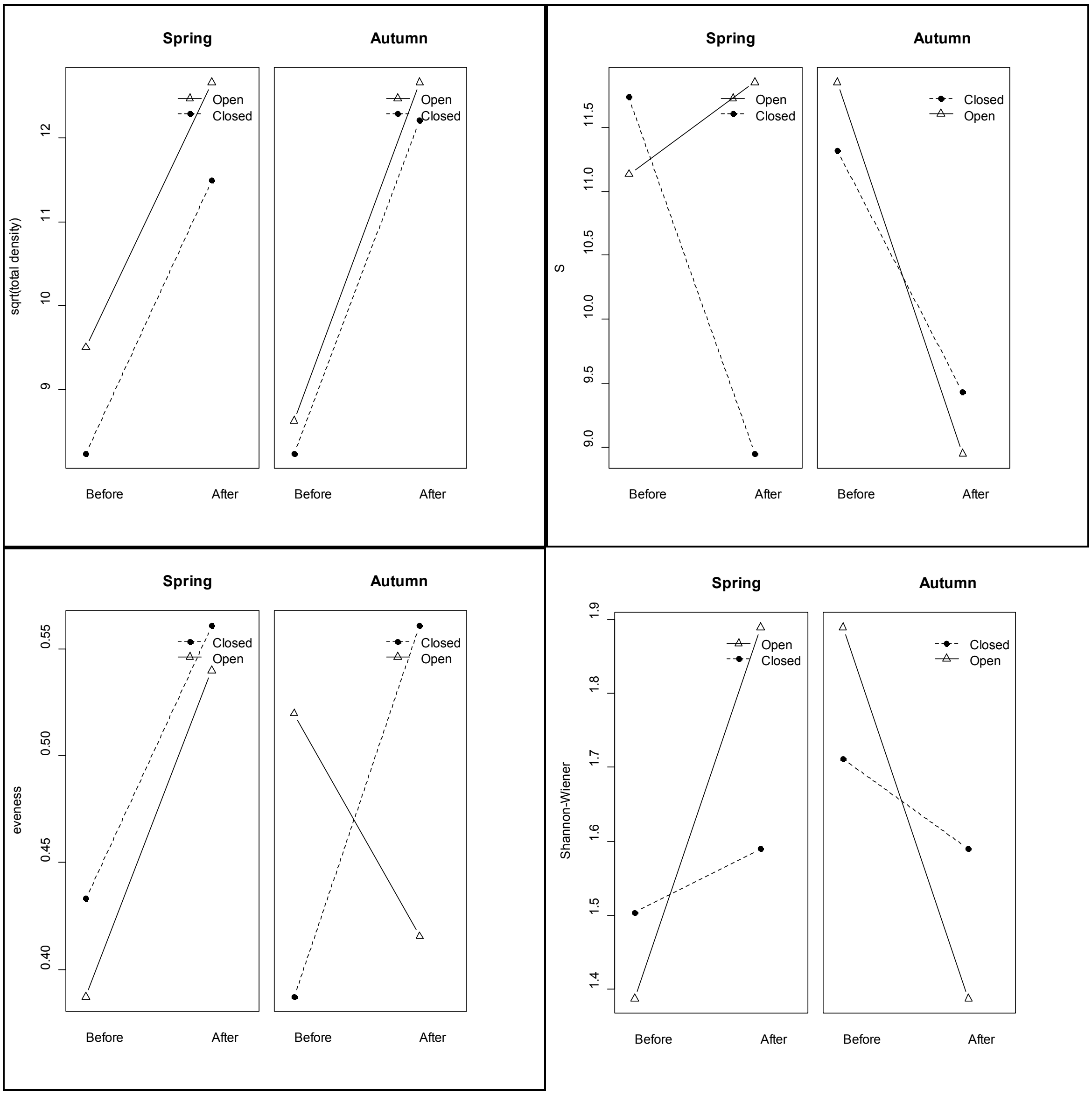


Figure 5. Interaction plot for mid-term effects showing (on the y-axis) the mean of square root transformed total density (upper left), number of species (S; upper right), evenness (lower left) and Shannon-Wiener index (lower right) in spring and autumn. The x-axis gives the sampling time (before and 1-1.5 year after fishing activities) and the lines the treatment type.

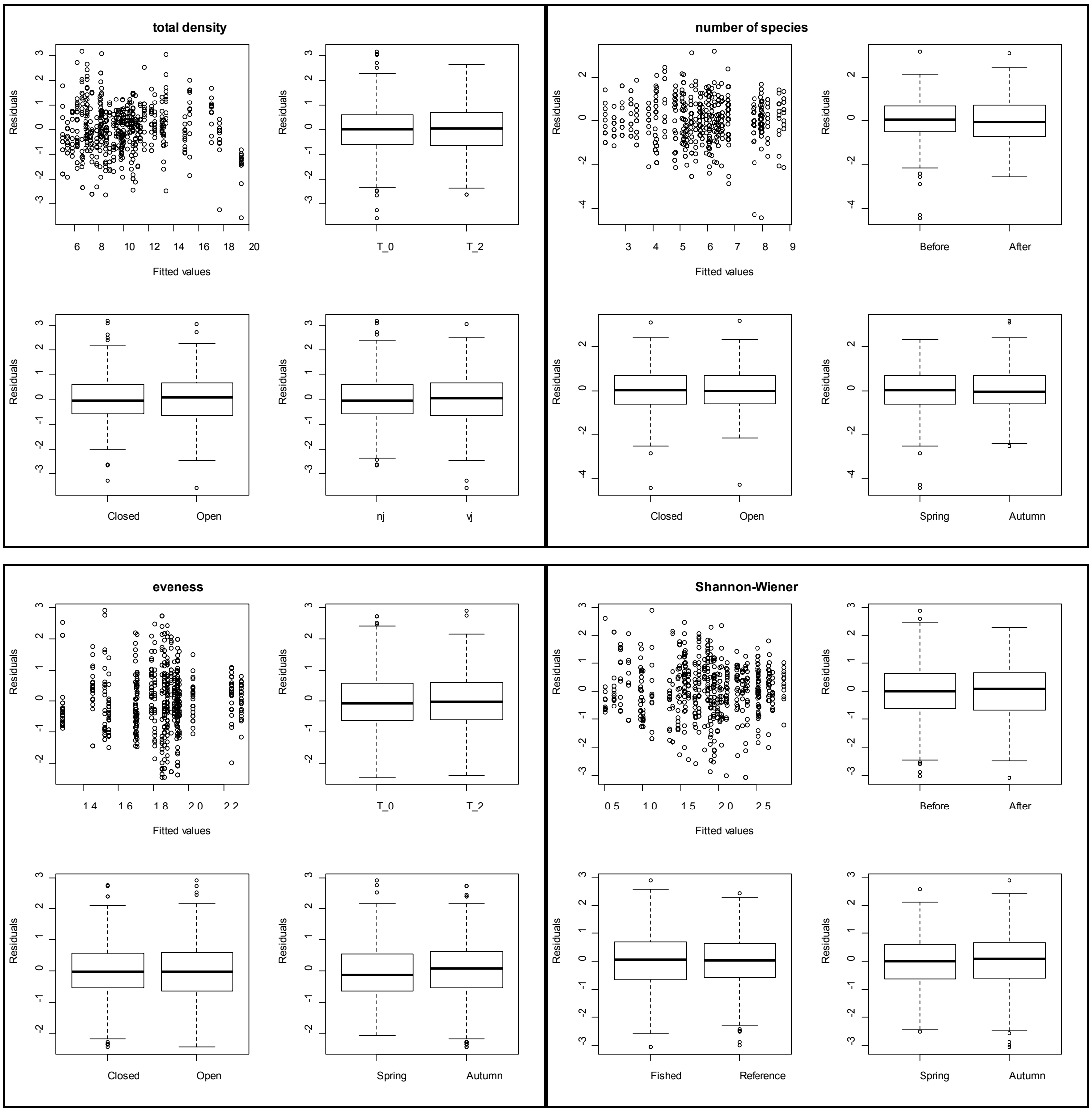


Figure 6. Model validation graphs for models on mid-term effects in total density (upper left), number of species (upper right), evenness (lower left) and Shannon-Wiener index (lower right). Residuals are plotted versus the fitted values, sampling time, season, and treatment.

b. Similarity

Short-terms effects

Model validation of a linear regression model did not point to heterogeneity. The final model did only include time as an explanatory variable (*Table 10*) and indicated significantly less similarity (increased dissimilarity) between open and closed part of the locations after mussel seed fisheries. Hierarchical modelling with locations as random factor reveals the same results. The 95% confidence limits do not contain zero (*Table 11*) and the actual p-value is estimated as 0.0001. In the MDS plot the centroids of the samples taken in open and closed parts are, overall, further apart at T1 than at T0 (*Figure 7*), although that seems not to be the case for all locations (*Figure 8*).

Table 10. Short-term effects: model coefficients for linear model for dissimilarity. Final model: lm(sqrt(dissimilarity)~time).

```
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)      0.52178    0.01556  33.523   <2e-16 ***
Time (T1)        0.04681    0.02201   2.127   0.0397 *
```

Table 11. Short-term effects on dissimilarity. Model coefficients for hierarchical model using locations as random factor: lmer(sqrt(dissimilarity) ~ time +(1|location). T1 is given relative to T0. Confidence limits are based on 10000 simulations.

```
   Estimate Std. Error   value        95%CL
T0   0.52178    0.01556   33.52   0.49  0.55
T1   0.04681    0.01310    3.57   0.02  0.07
```

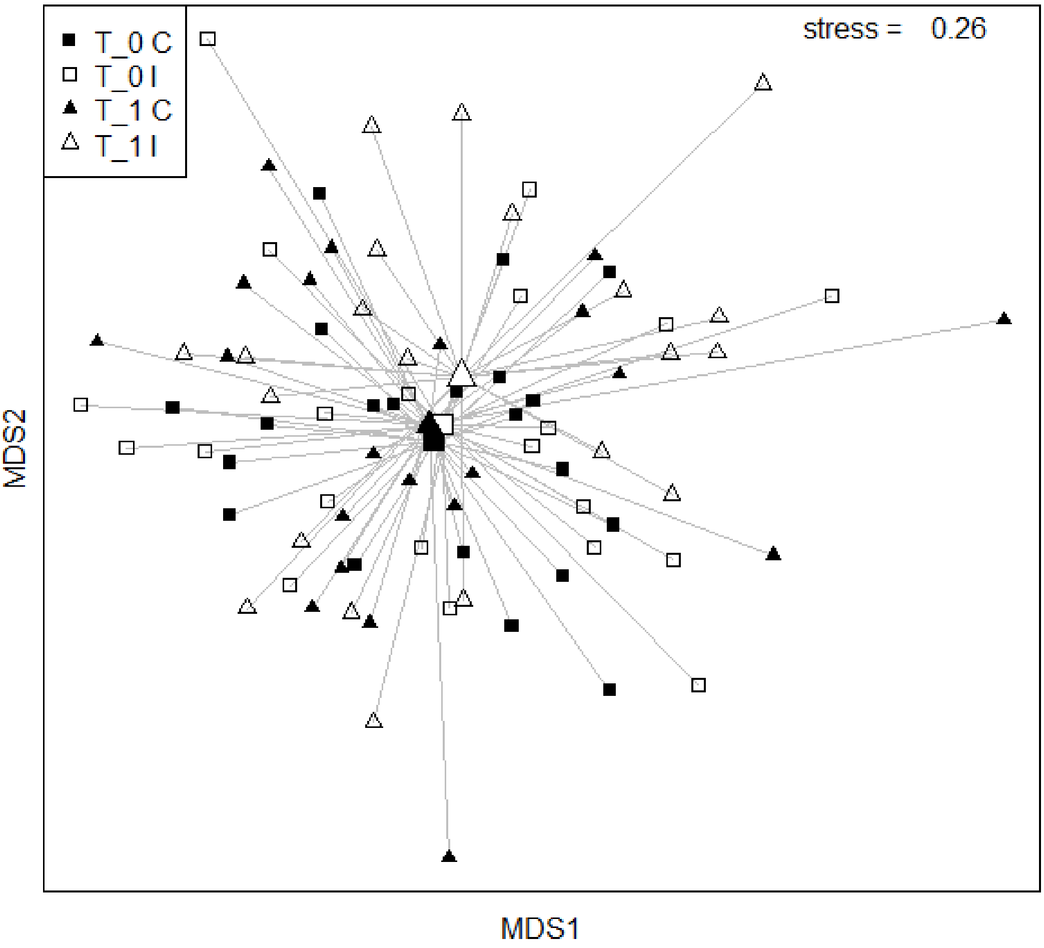


Figure 7. MDS graph of plots showing the ordination of the locations in relation to treatment (C = closed/Control, I = Impact/open) and time (T0, T1). Centroids for the four groups are shown and each location is connected to its group centroid by a grey line.

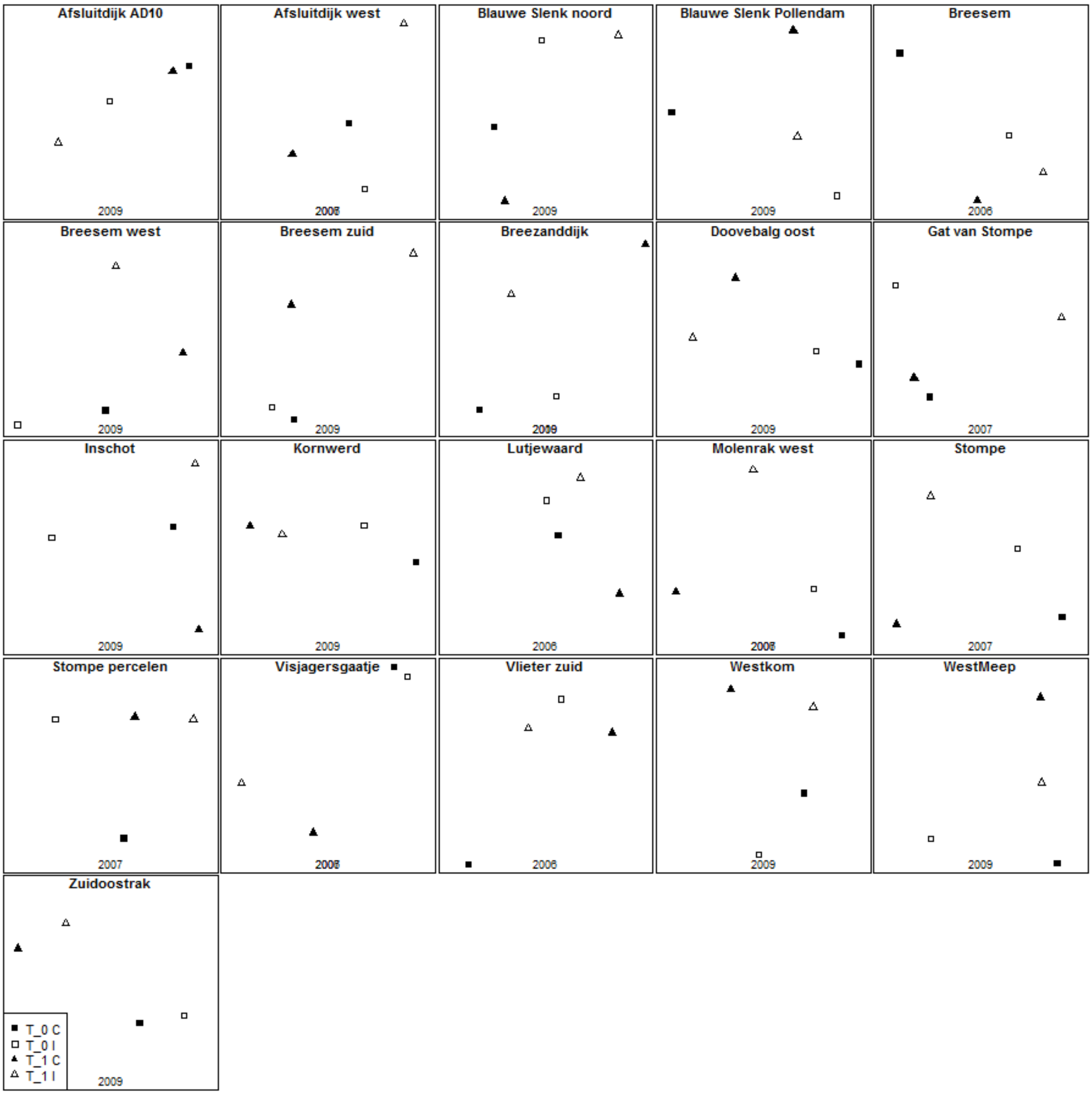


Figure 8. MDS graphs for each location separately.

Mid-term effects

There is no significant difference in similarity between the open and closed part of the locations 1-1.5 years after mussel seed fisheries. Neither time nor season or their interaction were significant in the linear regression model. Hierarchical modelling with locations as random factor revealed the same results. The 95% confidence limits contain zero (*Table 12*) and the actual p-value is estimated as 0.3111. In the MDS plot the centroids of the samples taken in open and closed parts are, overall, almost equally close to each other in T0 and Tmid (*Figure 9*), although for some locations the distance is larger (*Figure 10*).

Table 12. Mid-term effects on dissimilarity: model coefficients for hierarchical model using locations as random factor. Tmid is given relative to T0. Confidence limits are based on 10000 simulations.

```
        Estimate Std. Error   value        95%CL
T-0      0.26594    0.03121   8.521   0.21  0.33
T_mid    0.01996    0.04035   0.495  -0.06  0.10
```

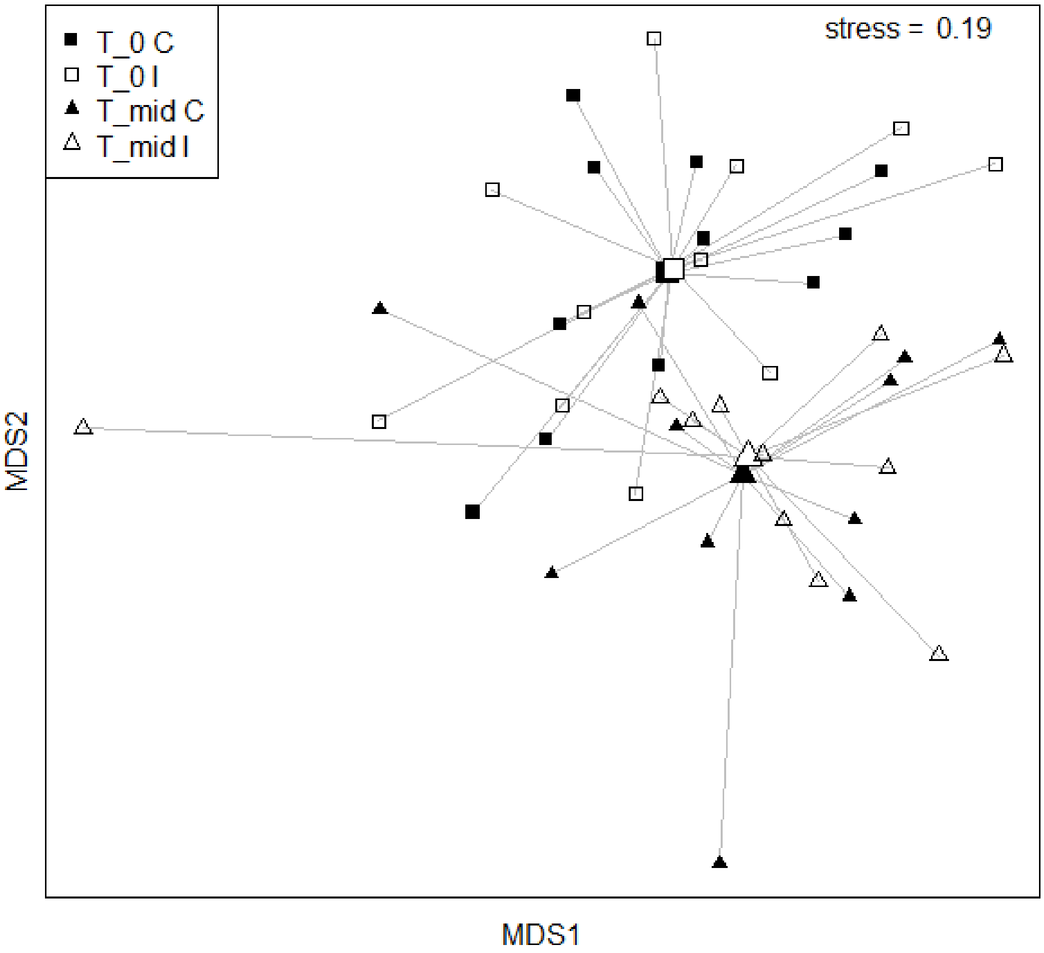


Figure 9. MDS graph of samples showing the ordination of the locations in relation to treatment (C = openclosed/Control, I = closedImpact/open) and time (T0, Tmid). Centroids for the four groups are shown.

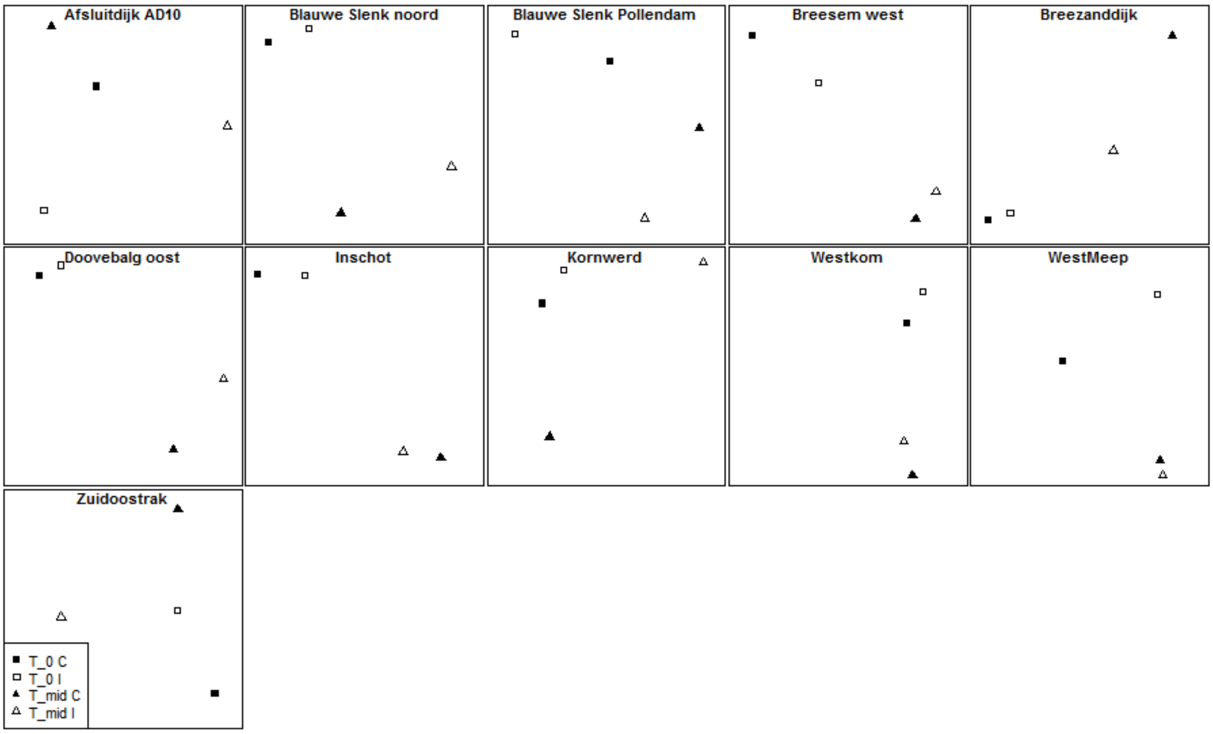


Figure 10. MDS graphs for each location separately.

c. Principal Response Curves

A detailed example: Molenrak west

In order to better understand the results of the PRC method, we compared the results of one location (Molenrak west, MR-w) with that of an RDA analysis. The RDA analysis (*Figure 11*) clearly shows the changes in species composition in time, both in the open and closed parts. In the RDA diagram samples with similar species composition lie close together, samples with very different species composition lie far apart. The relative abundance of species in samples can be derived by projecting the sample points onto an imaginary line drawn through a species point and the origin of the plot.

Not surprisingly, mussels are one of the species abundant in samples taken at T0. At T2, the community is characterized by a larger abundance of species such as *Marenzelleria* sp., *Scoloplos armiger, Streblospio benedicti* and *Pygospio elegans*, both in the open and closed area. At the last sampling point (T3) the community composition has changed again. The species composition in the open part, however, has become more different from that in the closed part: the samples taken in each part (and their centroid) are lying far apart in the ordination diagram. The species composition in the open part seems to be very similar to that at the start of the study (T0).

The interpretation in terms of how the changes in species composition in open and closed parts differ, is difficult to derive from this diagram. The PRC method represents the time trajectory as a horizontal line, enabling an easier interpretation.

Figure 12 shows the first component of the PRC diagram using the species composition at T0 as reference point for the samples taken at later dates, separately for the parts of this location open and closed to mussel fishery. The diagram displays differences in species composition between the time series and the reference point. The reference points get a zero value at all other dates. At both parts the changes are significant (p=0.005). The differences are largest at T2. At all sampling dates, differences with T0 are significant, except for T1 in the closed area, i.e. short after fisheries. In the RDA diagram T1 is almost overlapping with T0 (and, therefore, not visible in the diagram). The species axes on the right shows the affinity of the species with the response shown in the diagram. We choose for two axes, to make a distinction between the most numerically dominant species and the species with the largest weight. It is clear that both in the open as closed area, the polychaete *Pygospio elegans* e.g. has increased in time. This is also clear from the RDA diagram. At T2 (June 2009), both the control as the open part have the highest score on the second RDA axis, as is *P. elegans*. Thus, major changes in species composition are not restricted to the fished part of the location. In both parts the species composition tend to return to its original state: in the PRC diagram the canonical coefficients at T3 has decreased compared to the T2 situation.

The treatment effects, i.e. the deviations of treatment from the control and the species involved, are more clear in the PRC diagram using the development in the closed part as reference time series (*Figure 13*) than in the RDA diagram (*Figure 11*). Species such as *Alitta succinea*, Oligochaeta, *Polydora cornuta*, *Lanice conchilega* and *Heteromastus filiformis* are, in general, more abundant in the open part, *Hydrobia ulvae* and *Cerastoderma edule* in the closed part. On the basis of the Monte Carlo permutation tests per sampling date, the species composition in the control and open part differ significantly at all sampling dates except T2, i.e. when the population of *P. elegans* is at top, the species composition in the control and open part differ. At that time, there is no significant difference in species composition between the open and the closed part. The difference is largest at the end of the study period. This is also evident from the RDA diagram: the largest distance between control and open is at T3.

At Molenrak west 24% of the total variance can be attributed to time, whereas only 14% can be attributed to the treatment (including interaction with time). Sixty-two percent of the latter is explained by the first constrained axis, shown in the first PRC diagram. Thus, the changes in species composition do differ in the open and the closed parts of this location, which might be due to fisheries. Apparently, differences are largest at the end of the study period. However, open and closed part already differ at the start of the study, and common changes are much more important than explained by the treatment regime.

Overview

The PRC curves for the analyses of all locations are given in Appendix B, along with RDA diagrams per sampling date and some boxplots for selected species.

At almost all locations the benthic community composition changes significantly over time, irrespective of treatment (Table 14). At following 3 locations only, there was no overall significance change in one part of the location: Afsluitdijk-AD10 (closed part), Pollendam (open part) and Zuidoostrak (open part).

At 7 of the 21 locations, changes in species composition in the open part were not significantly different from those in the closed part of the location (see p-values in Table 15). This does not mean that the species composition was not different at all. Indeed, it was at most of the sampling dates (see Appendix A). At the other sites, the species composition was significantly different in the open and the closed part, indicating a possible effect of fisheries.

At all but 3 stations, the percentage variance explained by time is, however, larger than that by the treatment regime (*Table 15*). At Vlieter-zuid and WestMeep the percentage is about the same. At Pollendam, the treatment regime could explain much more of the variation than time: 17% versus 10%. At this location, *Mytilus edulis* and *Nereis virens* are more abundant in the open part, Oligochaeta and *Nereis succinea*, among others, more in the closed part. The density of mussels based on the box-corer samples was at T1, i.e. after fisheries, higher in the open part than in the closed part (see Appendix A).The data collected with the dredge show the same distribution van Stralen et al, 2013; Glorius et al, 2013).

The percentage variance explained by time and treatment regime (almost always much smaller than that by time) is not related to the moment of fisheries, or the length of the time series.

d. Power

The realized detectable effect size for the short-term analyses with a power of 80% is a bit larger than anticipated: 12 – 16% (*Table 13*). For the mid-term analyses (11 locations), the effect sizes are larger: 17-23%.

Table 13. Effect size that can be detected (α = 0.05, β = 0.20)

	Effect size T0-T1	Effect size T0-Tmid
Total density	11.76	16.98
Number of species	15.84	22.82
Evenness	15.63	21.83
Shannon-Wiener	15.89	22.42

Table 14. Significance of the first Principal Response Curve of differences in species composition of the benthic fauna in open and closed parts of a location, using T0 as internal reference point. Significant p-values point to significant changes in species composition over time.

location	Closed	Open
Afsluitdijk - AD10	0.220	0.017
Afsluitdijk West	0.005	0.005
Breesem	0.005	0.005
Breesem W	0.005	0.005
Breesem Z	0.005	0.010
Breezanddijk	0.005	0.005
Doovebalg DB23	0.005	0.005
Gat van Stompe	0.005	0.005
Griend	0.005	0.005
Inschot	0.005	0.005
Kornwerd (Boontjes)	0.005	0.005
Molenrak West	0.005	0.005
Pollendam	0.005	0.130
Stompe	0.005	0.005
Stompe percelen	0.005	0.005
Visjagersgaatje	0.010	0.015
Vlieter (zuid)	0.017	0.005
Westkom	0.005	0.005
WestMeep	0.041	0.010
Zuidoostrak	0.005	0.060
ZuidWest (Lutjewaard)	0.005	0.005

Table 15. Percentages of the total variance that can be attributed to time and treatment regime (including interaction with time) of analyses using the closed part of the locations as reference time series, and p-values of the first PRC of these analyses, indicating different temporal changes in species composition in the open and the closed part of the location.

	% variance accounted for by		p-value
location	Time	Treatment regime	First PRC
Afsluitdijk - AD10	14.5	11.0	0.010
Afsluitdijk West	27.2	6.0	0.140
Breesem	26.2	7.8	0.005
Breesem W	37.3	7.7	0.005
Breesem Z	14.3	23.6	0.005
Breezanddijk	32.2	18.6	0.005
Doovebalg DB23	23.7	6.9	0.059
Gat van Stompe	22.5	7.4	0.010
Griend	21.8	4.3	0.180
Inschot	25.7	4.0	0.140
Kornwerd (Boontjes)	34.4	14.1	0.005
Molenrak West	27.4	15.9	0.005
Pollendam	9.8	17.0	0.005
Stompe	43.5	11.6	0.005
Stompe percelen	16.8	4.9	0.005
Visjagersgaatje	49.4	6.0	0.010
Vlieter (zuid)	20.1	17.1	0.005
Westkom	17.2	4.0	0.200
WestMeep	10.1	11.0	0.005
Zuidoostrak	26.3	7.7	0.086
ZuidWest (Lutjewaard)	27.6	4.4	0.051

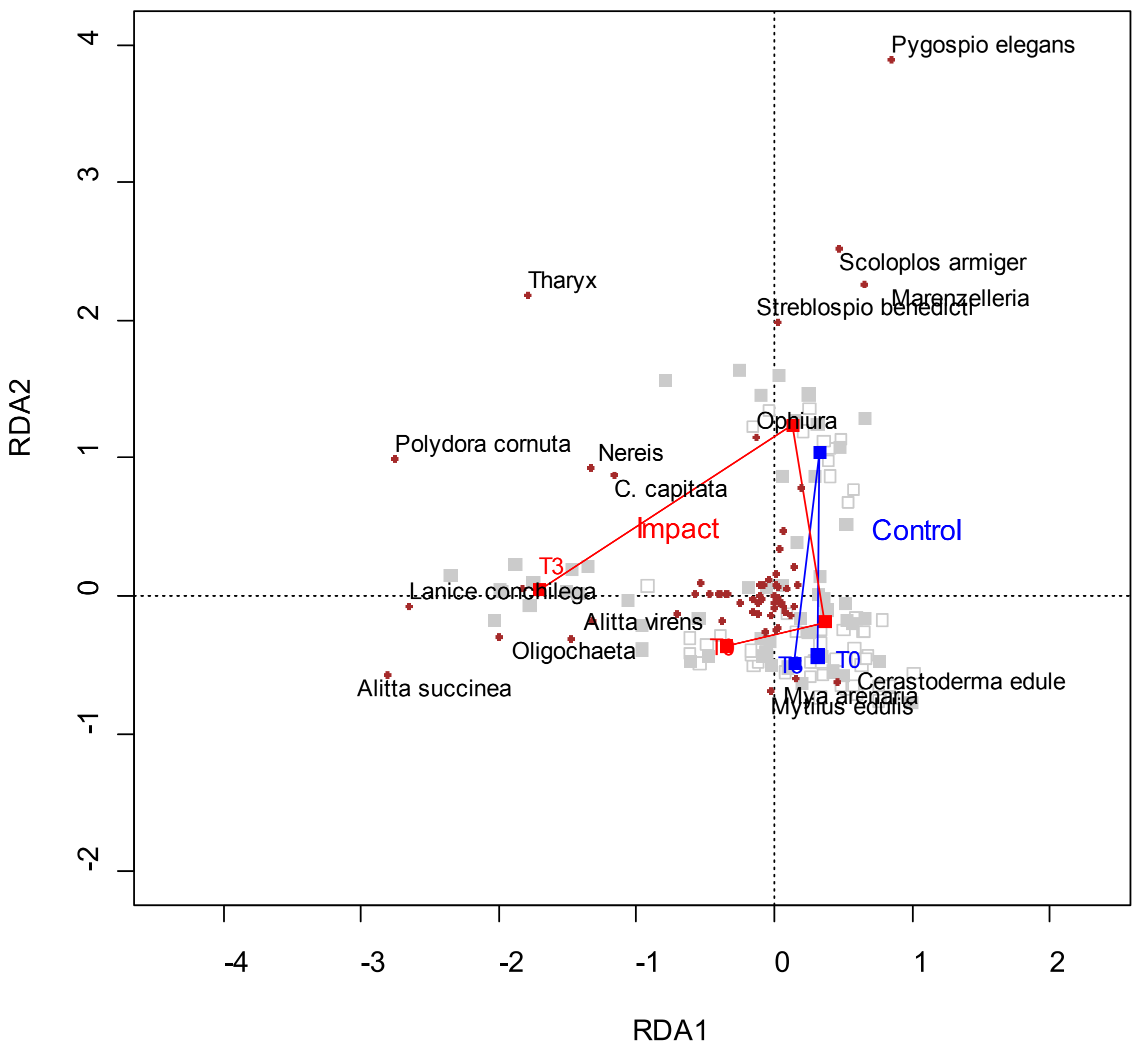


Figure 11. Ordination diagram (RDA) of square root transformed data at Molenrak west. Number of years after T0 and treatment level (Control, Impact), as well as their interactions, were taken as explanatory variables. Individual samples are given in grey (open/Impact part) or white (closed/Control part). The centroids of each sampling data (T0, …T3) are given in red (open/Impact) and bleu (closed/Control). The lines represent the course of the (centroid of the) treatment levels in the ordination diagram Of all variance, 43% can be attributed to the explanatory variables, Of this explained variance, 35% is explained in the diagram. Only those taxa are shown that are most discriminating in the diagram.

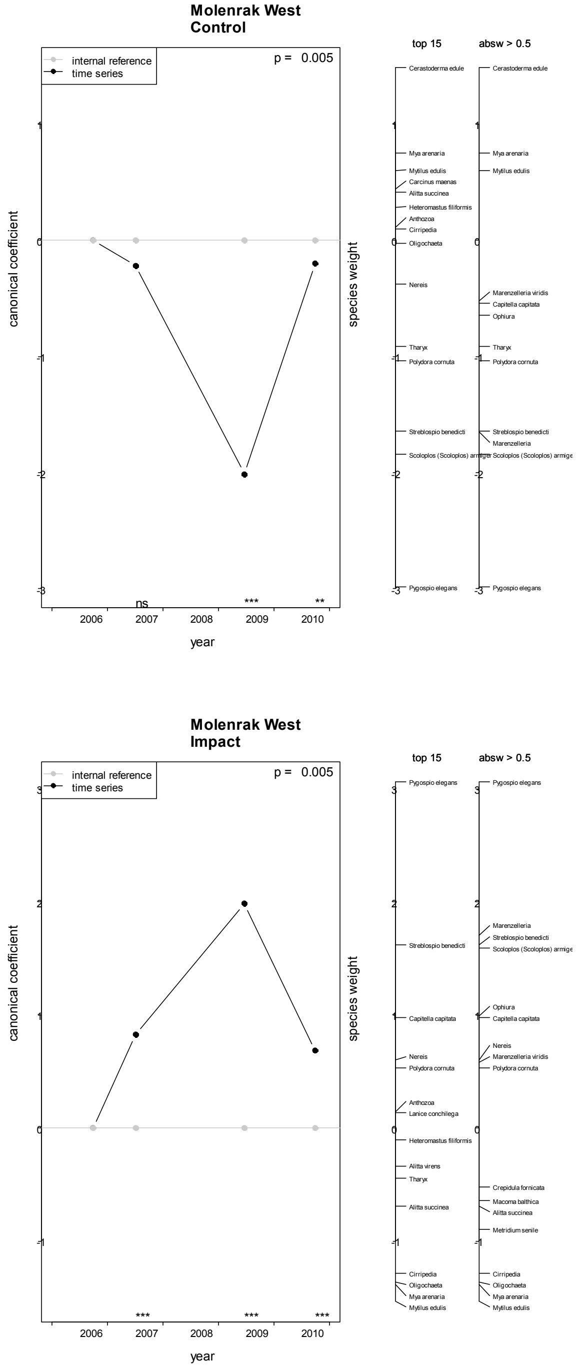


Figure 12. Diagrams for the first component of the PRC of differences in species composition resulting from separate analysis of the benthic fauna in the open and closed part of location Molenrak West, using T0 as an internal reference. The species weights in the right part of the diagrams represent the affinity of species with the response shown in the diagram. The 15 numerically dominant species (top 15), and species with a species weight larger than 0.5 or smaller then -0.5 (absw> 0.5) are shown. The significance of differences between Control and Impact parts at each time point is indicted by the asterisks generated from unrestricted Monte Carlo permutation (p<0.05, ** p<0.01, *** p<0.001)*

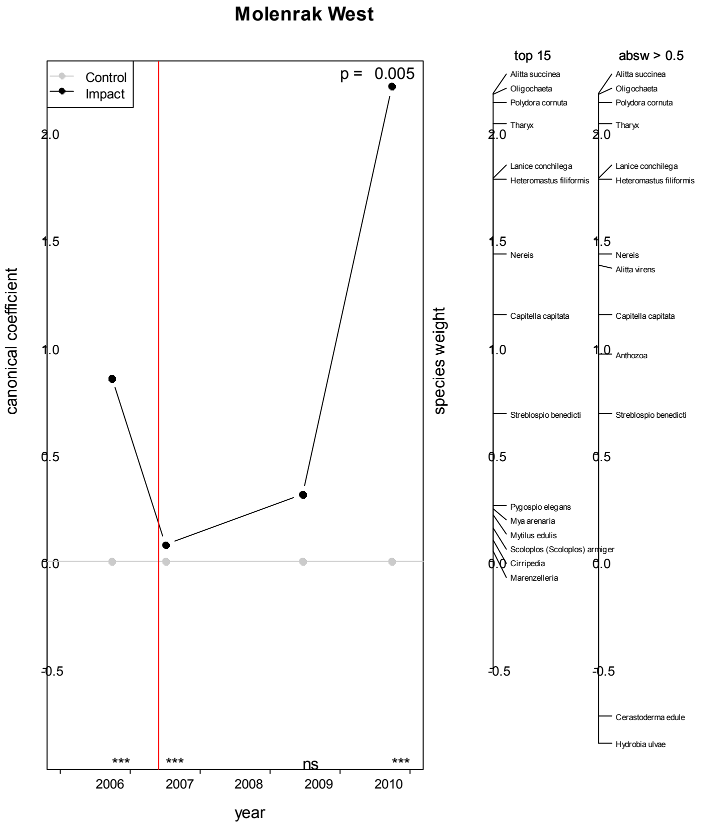


Figure 13. Diagram for the first component of the PRC of differences in species composition of the benthic fauna between the open (Impact) and closed (Control) part of location Molenrak West, using the closed part as reference. The species weights in the right part of the diagrams represent the affinity of species with the response shown in the diagram. The 15 numerically dominant species (top 15), and species with a species weight larger than 0.5 or smaller then -0.5 (absw> 0.5) are shown. The red line indicates the moment of mussel seed fisheries. The significance of differences at each time point is indicted by the asterisks generated from unrestricted Monte Carlo permutation (p<0.05, ** p<0.01, *** p<0.001). The differences between open and closed part explained 14% of all variation, of which 62% is displayed on the y-axis of the first PRC. Therefore, not all differences are well represented in the first response diagram, as e.g. the differences at T1.*

3. Discussion

Benthic species composition is well-known to show spatial differences. At larger scales this is generated by differences in physical processes, at smaller scales biologically generated patterns are important (Herman et al., 1996; Legendre et al., 1997; McArdle et al., 1997; Thrush et al., 1997). Mussel beds too show spatial patterns, at different scales including small-scale variation (Lawrie and McQuaid, 2001; van de Koppel et al., 2005). There is also a spatial variation within locations in the silt content, and differences between open and closed parts of the locations (van Bemmelen et al, 2013). Such patterns will have consequences for patterns in community attributes such as species richness and species composition. This is confirmed by the present study. At many locations, the species composition of the open and closed part was significantly different already at T0.

Macrobenthic communities are also characterized by large temporal fluctuations, resulting from differences in recruitment success, recruitment patterns and mortality rates (see e.g. Kröncke et al., 2011; Van Hoey et al., 2007). And opportunistic species, with short reproductive and recruitment cycles, are periodically very abundant. Almost all study areas of this study indeed show significant changes in species composition, irrespective of fishing activities (principal response curves with T0 as internal reference, fig 12). Some of these changes were large-scale and could be seen at many locations. High densities of *Pygospio elegans*, for instance, are recorded in 2009 and contribute to the significant temporal changes. *P. elegans* appears to have high species weights in PRC analyses comparing the open and closed parts at 11 of the locations studied.

Mussel beds offer, because they form a three dimensional hard substrate structure, offers habitat for hard substrate epibenthic species, and shelter for mobile epibenthic species. Mussels change the sediment characteristics, favouring endobenthic species with a high tolerance for organic enriched sediments. Thus, mussel bed do influence biodiversity by facilitation and inhibition of species, but the result is a higher species richness than the surrounding soft sediment habitat (Drent et al, 2013a; (Dolmer et al., 2001; Ens et al., 2007; Koivisto and Westerbom, 2012; Koivisto and Westerbom, 2010; Markert et al., 2010; Norling and Kautsky, 2008; Saier et al., 2002; Ysebaert et al., 2009).
It is, therefore, reasonable to expect at least a temporarily effect of mussel seed fisheries. For instance, a decrease in densities of associated species, a decrease of the total density, or a decrease in species richness. And, as the species composition is changed due to the mussels, we also expect the species composition in fished areas to be more identical to that on sand banks than in mussel beds.

The present study showed a significant impact of fishing on the total density (excluding mussels) in the short term: after fishing densities were higher in the closed plots than in the open plots. This is in accordance with Dolmer et al (2001) who found 40 days after dredging lower density in the trawled area, particularly of polychaetes.
The differences in species composition in fished areas compared to closed areas were larger after mussel seed fisheries. In the diagrams of the RDA analysis at T1 (see appendix A) differences between open en closed parts were, irrespective of the fishery season, often due to higher densities in the closed parts of mussels - of course –, associated hard substrate species (barnacles) and species such as *Alitta virens*, *Lanice conchilega*, *Harmothoe imbricata*, *Polydora cornuta* and *Capitella capitata*. These species were associated with sublitoral mussels (Drent et al, 2013b)(Dolmer et al., 2001; Markert et al., 2010; Ysebaert et al., 2009).

After 1 to 1.5 years, the difference in the similarity in species composition in open and closed parts compared to differences before fishing activities is no longer significant. The interaction between time and treatment (open vs. closed) for total density was not significant, indicating no lasting effect of fisheries. The analyses point, however, to significant different changes over this period in the number of species and the Shannon-Wiener index. The response differs according to the period of fishing activities, in spring or in autumn. The number of species, for instance, increased after spring fishery in the open part and declined in the closed part, while after autumn fishery it decreased in both parts, but faster in the open part. The interaction terms at short term were not significant, although the interaction plots suggest different trends. Effects on number of species, thus, seem to last for at least 1-1.5 years. Dolmer et al (2001) studied the infauna in dredged and control areas up to 40 days after the dredged sites were dredged, and reported lower number of species in the dredged area at the end of the study period.

Long-term effects (3-4 years) on the univariate and multivariate indices could not be analysed. From the PRC's there does no common pattern in changes in species composition show up. This might be partly due to different developments of the mussel population at the different locations. In some of these locations more than one spat fall and fishery event occurred. At Breesem, e.g., the last sampling date is short after the last fishery event, and the closed area is then still characterized by mussels and associated species as *Lanice conchil*ega and *Carcinus maenas*, thus only reflecting short-term effects. But also at other locations that were not fished for a long period, as e.g. Afsluitdijk west, species such as *Allita succinea* and *Polydora cornuta* were more abundant in the closed than in the open part at the end of the study period. This could be related to the higher densities of mussels in the open part of this location than in the closed part, at least as sampled by the box-corer. Even small patches of mussels have a large impact on the associated fauna, and the number of species present (Norling and Kautsky, 2008)Differences in species composition between open and closed parts are, however, at almost all locations much smaller than common temporal changes. And, thus, any fishery effects seem to be less important in determining species composition than external factors controlling mortality and recruitment. This is in agreement with Hoffmann & Dolmer (2000). In the Limfjord (Denmark) the closed area appeared to have no significant influence on the epibenthic fauna, suggesting that other factors than mussel dredging determine the observed spatial and temporal variability of the ecosystem.

4. Conclusion

- The present study confirms the existence of small scale differences in macrofauna species composition: even within a subtidal mussel bed, within a few hundreds of meters. The present study confirms large temporal variation in species composition, independently of any human impact
- The study shows short-term effects: a change in total density and in species composition (e.g. associated species)
- The study shows mid-term effects on species diversity (number of species and Shannon-Wiener index). The effect is different depending on the fishery season.

5. References

Bates, D., Maechler, M., Bolker, B., 2011. lme4: Linear mixed-effects models using S4 classes. R package version 0.999375-42. http://CRAN.R-project.org/package=lme4.

Bollmohr, S., Schulz, R., 2009. Seasonal Changes of Macroinvertebrate Communities in a Western Cape River, South Africa, Receiving Nonpoint-Source Insecticide Pollution. Environmental Toxicology and Chemistry 28, 809-817.

Bollmohr, S., van den Brink, P.J., Wade, P.W., Day, J.A., Schulz, R., 2011. Environmental variables, pesticide pollution and meiofaunal community structure in two contrasting temporarily open/closed False Bay estuaries. Water Sa 37, 391-400.

Cébron, A., Cortet, J., Criquet, S., Biaz, A., Calvert, V., Caupert, C., Pernin, C., Leyval, C., 2011. Biological functioning of PAH-polluted and thermal desorption-treated soils assessed by fauna and microbial bioindicators. Research in Microbiology doi:10.1016/j.resmic.2011.02.01.1.

den Besten, P.J., van den Brink, P.J., 2005. Bioassay responses and effects on benthos after pilot remediations in the delta of the rivers Rhine and Meuse. Environmental Pollution 136, 197-208.

Devotto, L., Cisternas, E., Carrillo, R., Gerding, M., 2008. NON-TARGET EFFECTS OF Dalaca pallens BLANCHARD CONTROL EXAMINED THROUGH PRINCIPAL RESPONSE CURVES: A GUILD APPROACH IN SOUTHERN CHILE. Chilean Journal of Agricultural Research 68, 228-237.

Dively, G.P., 2005. Impact of Transgenic VIP3A x Cry1Ab Lepidopteran-resistant Field Corn on the Nontarget Arthropod Community. Environmental Entomology 34, 1267-1291.

Dolmer, P., Kristensen, T., Christiansen, M.L., Petersen, M.I., Kristensen, P.S., Hoffmann, E., 2001. Short-term impact of blue mussel dredging (*Mytilus edulis* L.) on a benthic community. Hydrobiologia 465, 115-127.

Ens, B.J., Craeymeersch, J.A., Fey, F.E., Heessen, H.J.L., Smaal, A.C., Brinkman, A.G., Dekker, R., van der Meer , J., van Stralen, M.R., 2007. Sublitorale natuurwaarden in de Waddenzee. Een overzicht van bestaande kennis en een beschrijving van een onderzoekopzet voor een studie naar het effect van mosselzaadvisserij en mosselkweek op sublitorale natuurwaarden. Wageningen IMARES, Rapportnummer C077/07. 117 pp.

Gelman, A., Hill, J., 2007. Data Analysis Using Regression and Multilevel/Hierarchical Models. Cambridge University Press, New York

Gelman, A., Su , Y.-S., Yajima, M., Hill, J., Pittau, M., Kerman, J., Zheng, T., 2012. arm: Data Analysis Using Regression and Multilevel/Hierarchical Models. R package version 1.5-02. http://CRAN.R-project.org/package=arm.

Herman, P., de Vries, M., Thoolen, P., Vonk, M., Baart, A., Boon, J., 1996. Micro-macro. Een onderzoek naar de relatie tussen hydrodynamische factoren en kleinschalige verspreiding van macrobenthos. In Wintermans, G. et al (1996) Habitat mapping and description of the Dutch coastal waters. BEON Rapport, 96(5), part 4.

Hoffmann, E., Dolmer, P., 2000. Effect of closed areas on distribution of fish and epibenthos. Ices Journal of Marine Science 57, 1310-1314.

Jongman, R.H.G., ter Braak, C.J.F., van Tongeren, O.F.R., 1987. Data analysis in community and landscape ecology. Pudoc, Wageningen.

Koivisto, M., Westerbom, M., 2012. Invertebrate communities associated with blue mussel beds in a patchy environment: a landscape ecology approach. Mar Ecol Prog Ser 471, 101-110.

Koivisto, M.E., Westerbom, M., 2010. Habitat structure and complexity as determinants of biodiversity in blue mussel beds on sublittoral rocky shores. Mar Biol 157, 1463-1474.

Kröncke, I., Reiss, H., Eggleton, J.D., Berman, M.J.N., Cochrane, S., Craeymeersch, J.A., Degraer, S., Desroy, N., Dewarumez, J.M., Duineveld, G., Essink, K., Hillewaert, H., Laveleye, M., Moll, A., Nehring, S., Newell, J., Pohlmann, T., Rachor, E., Reed, H.L., Robertson, M., Rumohr, H., Schratzberger, M., Smith, R., Vanden Berghe, E., van Dalfsen, J., Van Hoey, G., Vincx, M., 2011. Changes in North Sea macrofauna communities and species distribution between 1986 and 2000. Estuarine and Coastal Shelf Science 94, 1-15.

Lawrie, S.M., McQuaid, C.D., 2001. Scales of mussel bed complexity: structure, associated biota and recruitment. J Exp Mar Biol Ecol 257, 135-161.

Legendre, P., Birks, H., 2012. From classical to canonical ordination, in: Birks, H.J.B., Lotter, A.F., Juggins, S., Smol, J.P. (Eds.), Tracking Environmental Change Using Lake Sediments. Springer.

Legendre, P., Thrush, S.F., Cummings, V.J., Dayton, P.K., Grant, J., Hewitt, J.E., Hines, A.H., McArdle, B.H., Pridmore, R.D., Schneider, D.C., Turner, S.J., Whitlatch, R.B., Wilkinson, M.R., 1997. Spatial structure of bivalves in a sandflat: scale and generating processes. J Exp Mar Biol Ecol 216, 99-128.

Leonard, A.W., Hyne, R.V., Lim, R.P., Pablo, F., Van den Brink, P.J., 2000. Riverine endosulfan concentrations in the Namoi River, Australia: Link to cotton field runoff and macroinvertebrate population densities. Environmental Toxicology and Chemistry 19, 1540-1551.

Lepš, J., Šmilauer, P., 2003. Multivariate analysis of ecological data using CANOCO. Cambridge University Press, New York. 283 pp.

Markert, A., Wehrmann, A., Kroncke, I., 2010. Recently established Crassostrea-reefs versus native Mytilus-beds: differences in ecosystem engineering affects the macrofaunal communities (Wadden Sea of Lower Saxony, southern German Bight). Biol Invasions 12, 15-32.

Marriott, C.A., Hood, K., Fisher, J.M., Pakeman, R.J., 2009. Long-term impacts of extensive grazing and abandonment on the species composition, richness, diversity and productivity of agricultural grassland. Agriculture Ecosystems & Environment 134, 190-200.

McArdle, B.H., Hewitt, J.E., Thrush, S.F., 1997. Pattern from process: it is not as easy as it looks. J Exp Mar Biol Ecol 216, 229-242.

McKechnie, S., Bragg, C., Newman, J., Scott, D., Fletcher, D., Moller, H., 2009. Assessing the monitoring of sooty shearwater (Puffinus griseus) abundance in southern New Zealand. Wildlife Res 36, 541-552.

Meesters, H.W.G., Fey-Hofstede, F.E., 2009. PRODUS deelproject 3 sublitorale natuurwaarden: Invloed van aantal monsters per locatie en totaal aantal locaties op de 'power' om het verschil in het aantal unieke soorten te vinden. Wageningen IMARES Rapport 09.001. 25 pp.

Moser, T., Rombke, J., Schallnass, H.J., Van Gestel, C.A.M., 2007. The use of the multivariate Principal Response Curve (PRC) for community level analysis: a case study on the effects of carbendazim on enchytraeids in Terrestrial Model Ecosystems (TME). Ecotoxicology 16, 573-583.

Neher, D.A., Wu, J., Barbercheck, M.E., Anas, O., 2005. Ecosystem type affects interpretation of soil nematode community measures. Applied Soil Ecology 30, 47-64.

Norling, P., Kautsky, N., 2008. Patches of the mussel Mytilus sp are islands of high biodiversity in subtidal sediment habitats in the Baltic Sea. Aquat Biol 4, 75-87.

Oksanen, J., Blanchet, F., Kindt, R., Legendre, P., Minchin, P., O'Hara, R., Simpson, G., Solymos, P., Stevens, M., Wagner, H., 2011. Vegan: Community Ecology Package. R package version 2.0-0. http://CRAN.R-project.org/package=vegan.

Okullo, P., Moe, S., 2011. Termite activity, not grazing, is the main determinant of spatial variation in savanna herbaceous vegetation. Journal of Ecology doi:10.1111/j.1365-2745.2011.01889.x.

Pernin, C., Ambrosi, J.P., Cortet, J., Joffre, R., Le Petit, J., Tabone, E., Torre, F., Krogh, P.H., 2006. Effects of sewage sludge and copper enrichment on both soil mesofauna community and decomposition of oak leaves (Quercus suber) in a mesocosm. Biology and Fertility of Soils 43, 39-50.

Pinheiro, J., 2008. R - manual: The nlme Package. Version 3.1-89. June 9, 2008. Linear and Nonlinear Mixed Effects Models. 339 pp.

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., the R Development Core Team, 2011. nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-100.

Quintino, V., Elliott, M., Rodrigues, A.M., 2006. The derivation, performance and role of univariate and multivariate indicators of benthic change: Case studies at differing spatial scales. J Exp Mar Biol Ecol 330, 368-382.

R Development Core Team, 2011. R: A language and environment for statistical computing, reference index version 2.13.9. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org. .

Saier, B., Buschbaum, C., Reise, K., 2002. Subtidal mussel beds in the Wadden Sea: threatened oases of biodiversity. Wadden Sea Newsletter 1, 12-14.

Smaal, A., Craeymeersch, J.A., Drent, J., Jansen, J., Glorius, S., van Stralen, M., 2013. Effecten van mosselzaadvisserij op sublitorale natuurwaarden : samenvattend eindrapport. IMARES Rapport C006/13. .

ter Braak, C.J.F., Prentice, I.C., 1988. A theory of gradient analysis. Advances in Ecological Research 18, 272-318.

Thrush, S.F., Cummings, V.J., Dayton, P.K., Ford, R., Grant, J., Hewitt, J.E., Hines, A.H., Lawrie, S.M., Pridmore, R.D., Legendre, P., McArdle, B.H., Schneider, D.C., Turner, S.J., Whitlatch, R.B., Wilkinson, M.R.,

1997. Matching the outcome of small-scale density manipulation experiments with larger scale patterns: an example of bivalve adult/juvenile interactions. J Exp Mar Biol Ecol 216, 153-169.
Tschöpe, O., Wallschlager, D., Burkart, M., Tielborger, K., 2011. Managing open habitats by wild ungulate browsing and grazing: A case-study in North-Eastern Germany. Applied Vegetation Science 14, 200-209.
van de Koppel, J., Rietkerk, M., Dankers, N., Herman, P.M.J., 2005. Scale-dependent feedback and regular spatial patterns in young mussel beds. The American Naturalist 165, E66-E77.
van den Brink, P.J., den Besten, P.J., bij de Vaate, A., ter Braak, C.J.F., 2009. Principal response curves technique for the analysis of multivariate biomonitoring time series. Environmental Monitoring and Assessment 152, 271-281.
van den Brink, P.J., Ter Braak, C.J.F., 1998. Multivariate analysis of stress in experimental ecosystems by Principal Response Curves and similarity analysis. Aquatic Ecology 32, 163-178.
Van den Brink, P.J., Ter Braak, C.J.F., 1999. Principal response curves: analysis of time-dependent multivariate responses of biological community to stress. Environmental Toxicology and Chemistry 18, 138-148.
Van Hoey, G., Vincx, M., Degraer, S., 2007. Temporal variability in the Abra alba community determined by global and local events. J Sea Res 58, 144-155.
Van Stralen, M., Jansen, J.M.J., Smaal, A., 2013. Het mosselbestand op de PRODUS-vakken en de effecten van de visserij daarop. MarinX/IMARES rapport. .
Ysebaert, T., Hart, M., Herman, P.M.J., 2009. Impacts of bottom and suspended cultures of mussels Mytilus spp. on the surrounding sedimentary environment and macrobenthic biodiversity. Helgoland Marine Research 63, 59-74.
Zuur, A.F., Ieno, E.N., Walker, N., Saveliev, A.A., Smith, G.M., 2009. Mixed effects models and extensions in ecology with R. Springer-Verlag New York, New York, NY.

Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

Justification

Report number : C003/13
Project Number : 4308501015

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Dr. I. Tulp

Signature: Ingrid Tulp

Datum: 7 January 2013

Approved: Dr. B.D. Dauwe
Head of department Delta

Signature:

Date: 7 January 2013

Appendix **A. Rapport van de Audit commissie en reactie van de Produs auteurs**

Audit van het Project Onderzoek DUurzame Schelpdiercultuur (PRODUS)

4. Specifieke commentaren

4.2. PR7: Impact of mussel seed fishery on subtidal macrozoobenthos in the western Wadden Sea

Het rapport is over het algemeen duidelijk, al laat de typografische kwaliteit van de grafieken veel te wensen over (te kleine letters, vreemde lijnen, onduidelijke symbolen). Het rapport heeft geen inleiding waarin de vragen worden gespecifieerd en de hypotheses uitgewerkt die zullen worden getoetst. Er is een groot scala aan responsvariabelen gemeten, de statistiek is goed uitgewerkt en de conclusies zijn helder. De belangrijkste conclusie is dat er significante korte en middellange termijn effecten van mosselvisserij op de geassocieerde gemeenschap zijn, zoals bemonsterd met de boxcorer. Op de lange termijn zijn er geen effecten aantoonbaar.

In de inleiding wordt nu verwezen naar Smaal et al (2013; Samenvattend eindrapport) voor nadere informatie over vraagsteling en opzet van het onderzoek.

De samenhang met rapport PR6 is beperkt. Dit rapport is geschreven in het Engels, maar het is niet duidelijk waarom. Er is meer geïnvesteerd in de analyse en interpretatie van de data, maar minder in de afwerking van de tekst. Er zijn veel univariate en multivariate variabelen gebruikt en geanalyseerd met mixed models om de effecten van visserij te onderzoeken.

In feite is maar een beperkt aantal univariate variabelen gebruikt: totale dichtheid, aantal soorten, Shannon-Wiener index, eveness and Bray-Curtis similariteit. Multivariaat is eindelijk maar een type univariate analyse uitgevoerd: PRC, ondersteund door RDA per tijdspunt. Verder is in discussie is nu wel aandacht besteed aan gepubliceerd onderzoek.

Figuur 2 geeft een globale vergelijking van univariate variabelen tussen bevist en onbevist. Gezien de grote variatie tussen locaties en het gepaarde karakter van de proef geeft dit slechts een deel van de resultaten weer. Verdere details worden gegeven in zeer technische en gedetailleerde interactieplotjes, en in multivariate ordinatieplots. Het zou informatief kunnen zijn om als tussenvorm een plot te maken zoals figuur 2, maar met het gemiddelde relatieve verschil tussen bevist en onbevist. Ook hier zouden deze relatieve verschillen tussen paren gerelateerd kunnen worden aan omgevingsfactoren om te onderzoeken in welke mate het visserijeffect afhankelijk is van de lokale omstandigheden.

Ook de audit-cie geeft aan dat de resultaten weergegeven (moeten) worden met behulp van interactieplots. Analyses met linear mixed effects model komen praktisch op hetzelfde neer als de klassieke standaardanalyse (variantieanalyse) en kunnen zelfs als een verbetering gezien worden. In de modellen zouden ook omgevingsvariabelen meegenomen kunnen worden. In eerste instantie *valt te deken aan sedimentkarakteristieken. Omdat vaak geen sedimentanalyses uitgevoerd zijn, is dit niet verder meegenomen bij de analyses.*

Op basis van informatie die elders wordt gegeven (bijvoorbeeld in het overzichtsrapport PR1) kan men aannemen dat de fauna zeer verschillend is in boxcores met en zonder mossels. Men vraagt zich af of dat hier ook het geval is. Indien het zo is, dan zou correctie voor het al dan niet voorkomen van mosselen in de boxcores een groot gedeelte van de variatie in de fauna kunnen verklaren. Dit zou toelaten te onderzoeken of visserij alleen effect heeft via het verwijderen van mosselen en hun geassocieerde fauna, of ook indirect via bijvoorbeeld bodemverstoring of beschadiging van grote organismen.

In het rapport was al kort aangegeven dat verschillen zeker voor een deel aan geassocieerde fauna te wijten waren. Dat is nu iets explicieter opgenomen, met referenties naar rapport van Drent (2013).

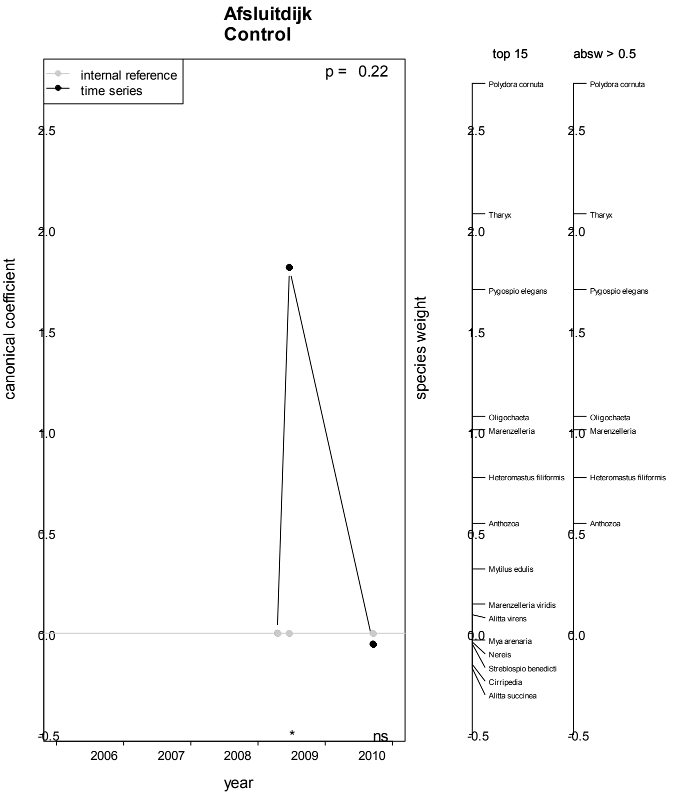
De commissie ondersteunt de eerste drie conclusies van het rapport (grote lokale verschillen, significante korte en middellange termijn effecten), maar niet de laatste. Hier wordt gesteld dat: “Fishery effects on the long-term, if any, seem to be less important in determining macrofauna species composition than external factors controlling mortality and recruitment”. Gezien de beperkingen in de proefopzet kan dit niet geconcludeerd worden. Vooraf was, op basis van power analyses gesteld dat er 40 proeflocaties nodig waren om een visserijeffect van 10% te kunnen aantonen. Analyse achteraf laat zien dat de ‘statistische slagkracht’ zelfs op de korte termijn al iets kleiner was dan vooraf voorzien. Door het verlies van locaties over de tijd, nam de mogelijkheid om verschillen aan te tonen verder af (tabel 13 in het rapport). Ondanks een lagere analysekracht, worden er tóch significante verschillen aangetoond voor de korte en middellange termijn. Op de lange termijn zijn effecten niet meer aantoonbaar, maar het valt moeilijk uit te sluiten dat dit te wijten is aan de verder verkleinde power van de testen.

*De conclusies mbt de lange termijn, zijn enkel gebaseerd op de PRC-analyses. Daaruit blijkt dat andere factoren dan visserij een belangrijkere rol lijken te spelen bij de veranderingen in soortensamenstelling. Dat is in overeenstemming met bevindingen in Denemarken (*Hoffmann & Dolmer 2000). Omdat de resultaten niet even hard zijn als deze op de korte en middenlange termijn, is een conclusie over lange-termijnseffecten geschrapt.

Appendix B

Figures and diagrams as result from the PRC analyses per location:

- diagrams first PRC of separate analyses of open and closed parts, using T0 as reference point
- diagrams for first PRC, using closed area as reference point
- RDA diagrams per sampling data (constrained axis = y-axis), with boxplots of scores along the constrained axis and weight of species
- Boxplots for selected species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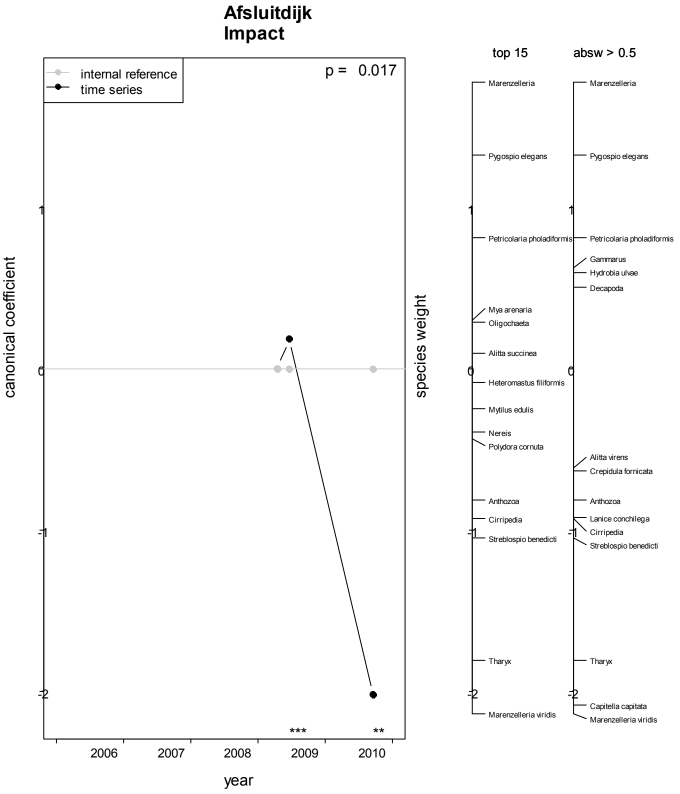
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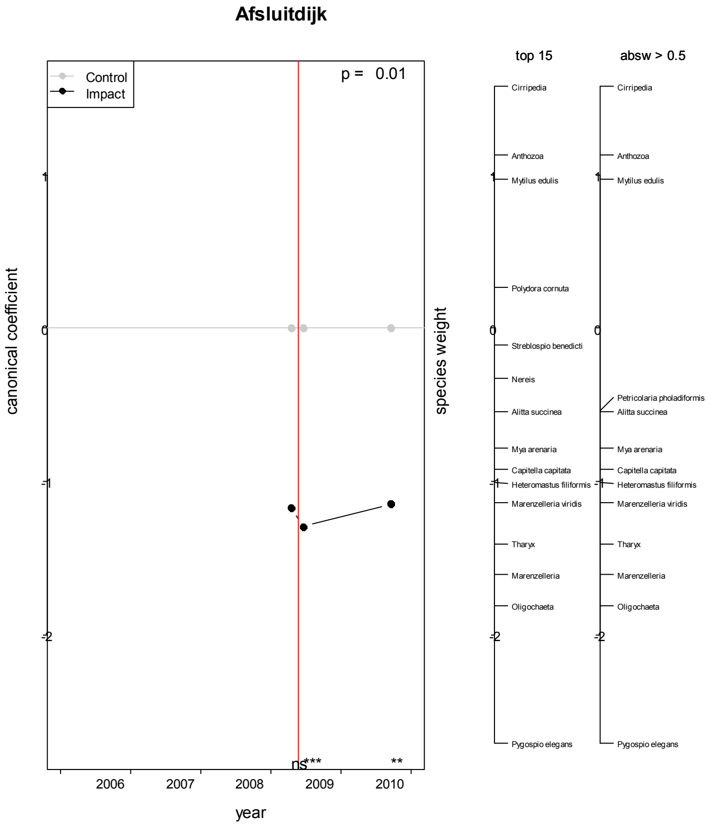
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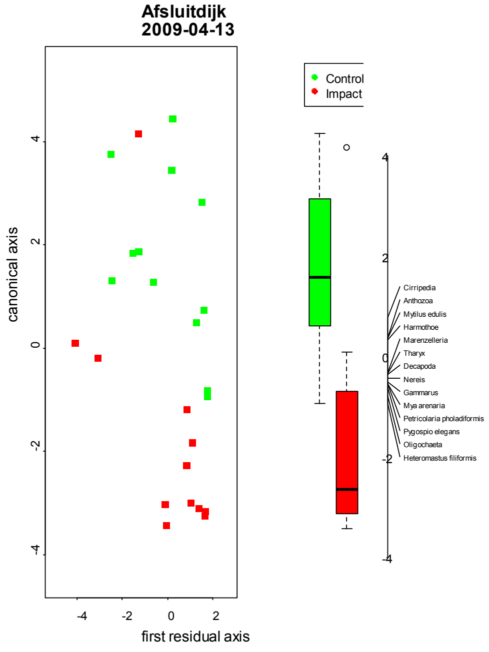
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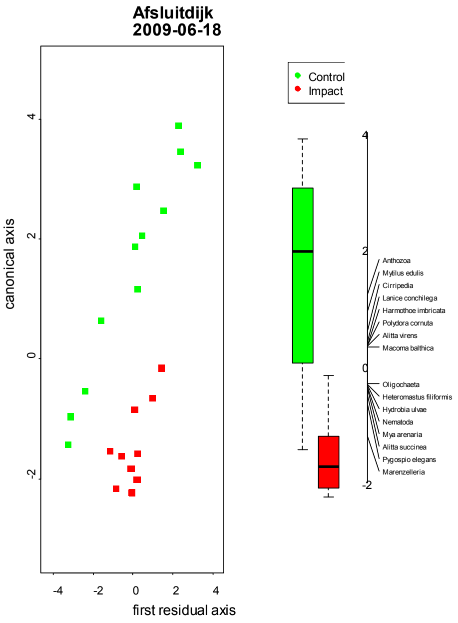
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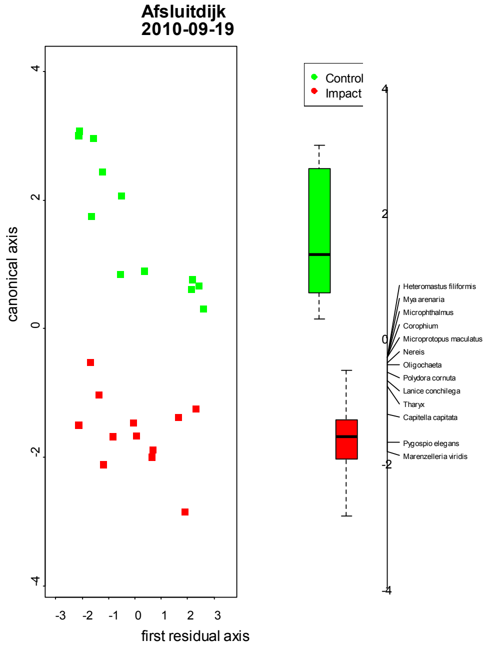
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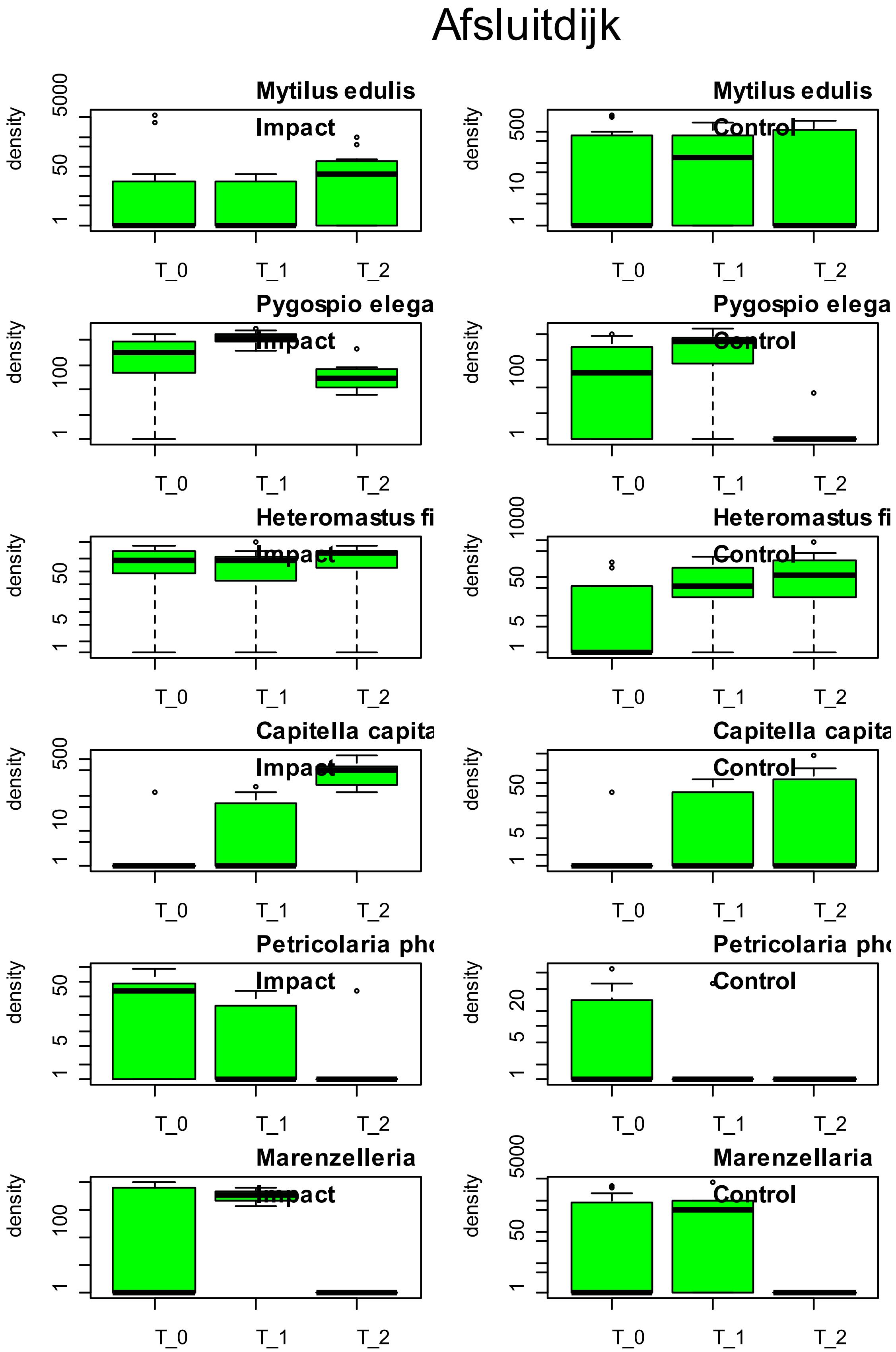
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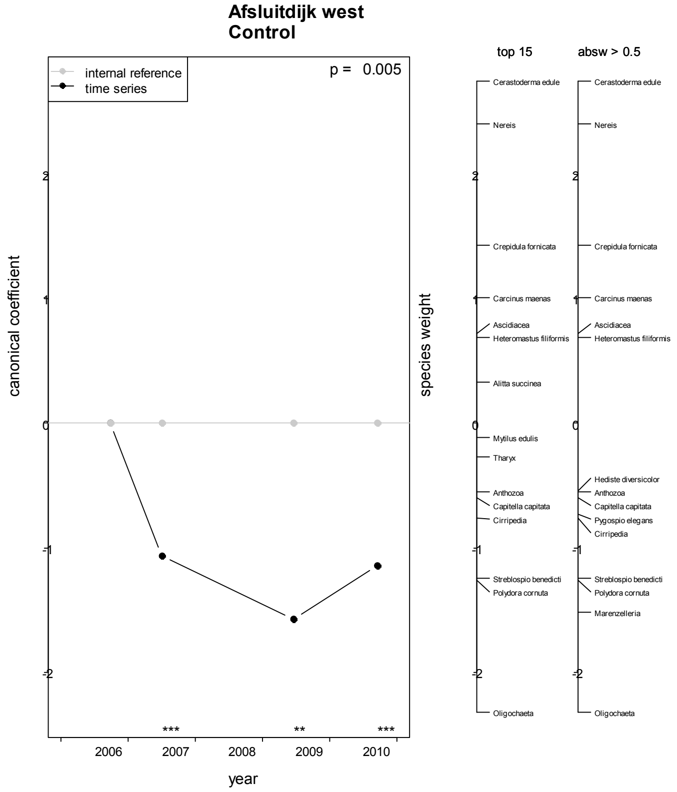
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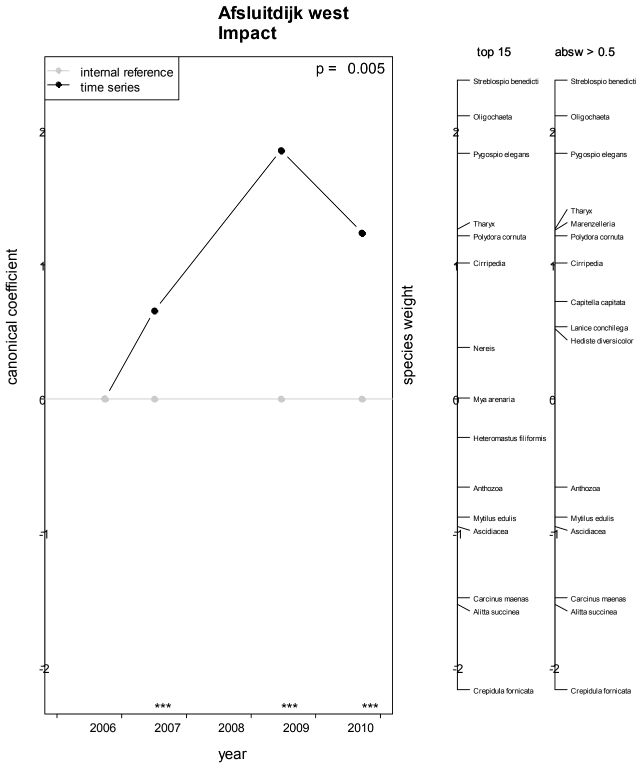
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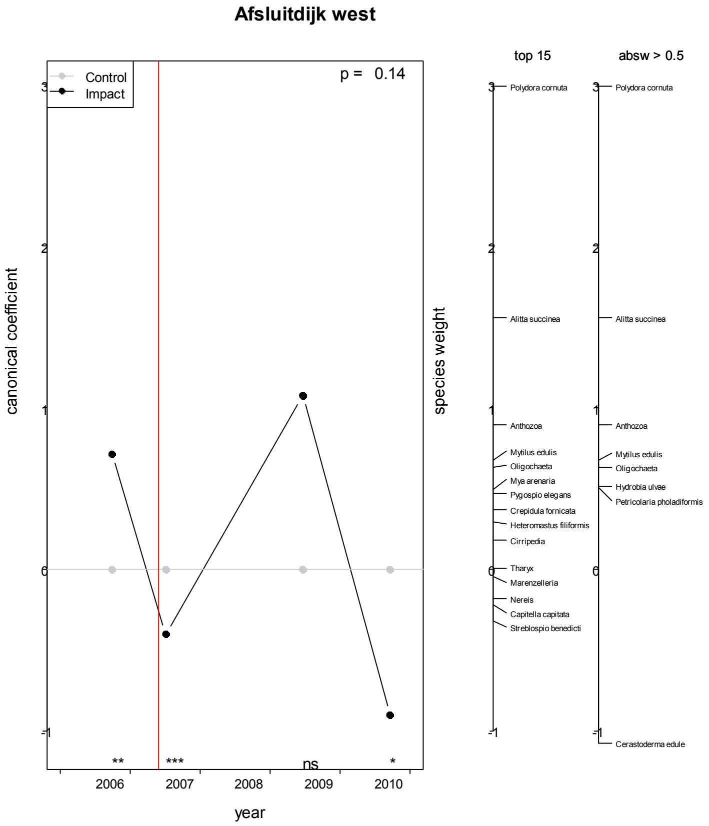
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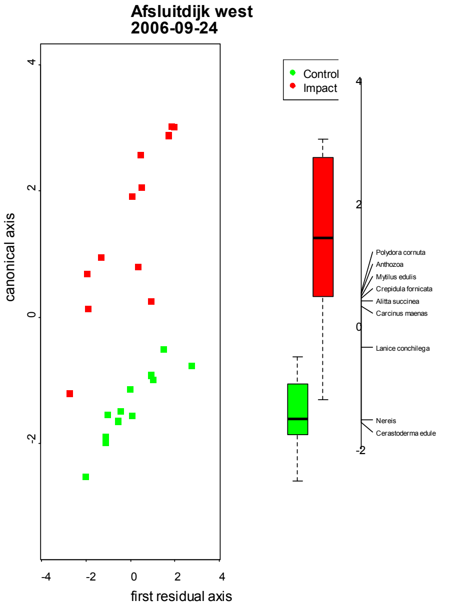
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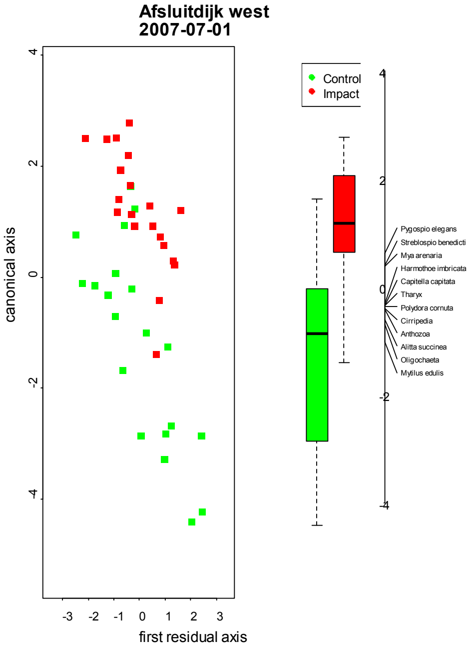
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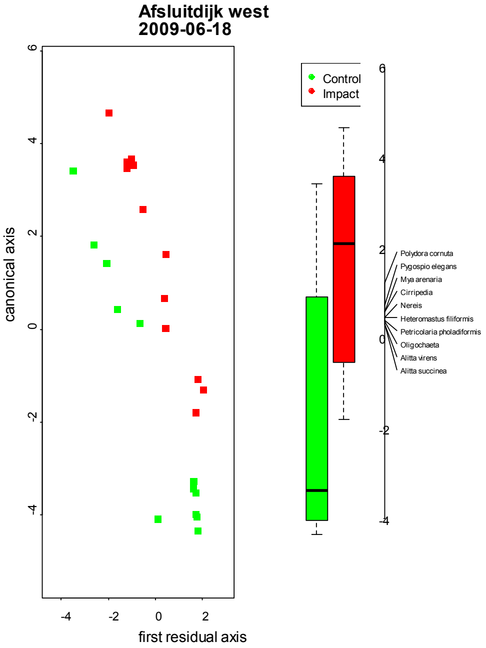
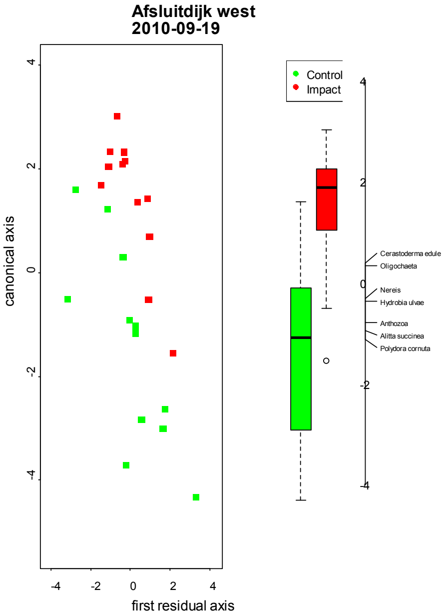
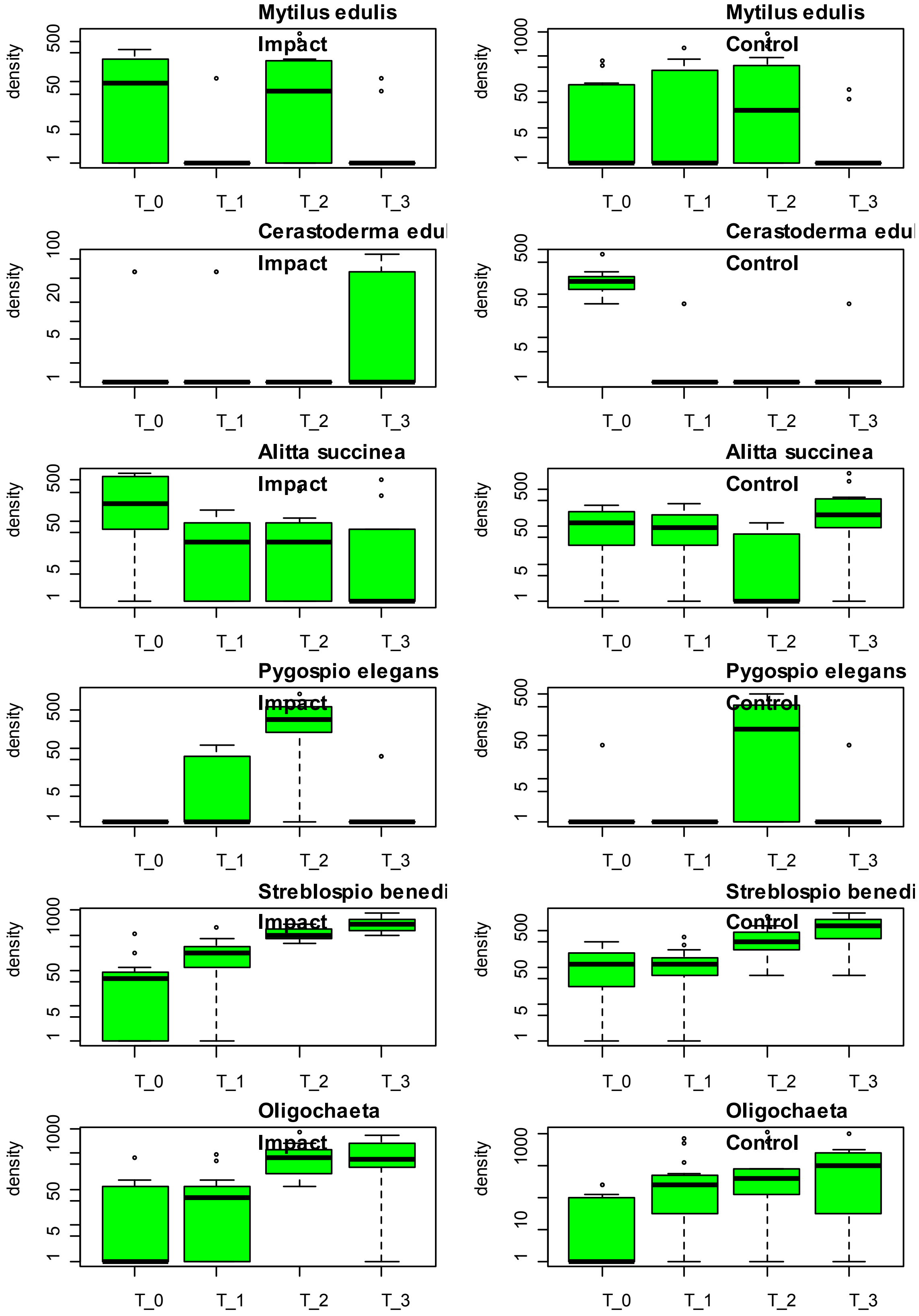
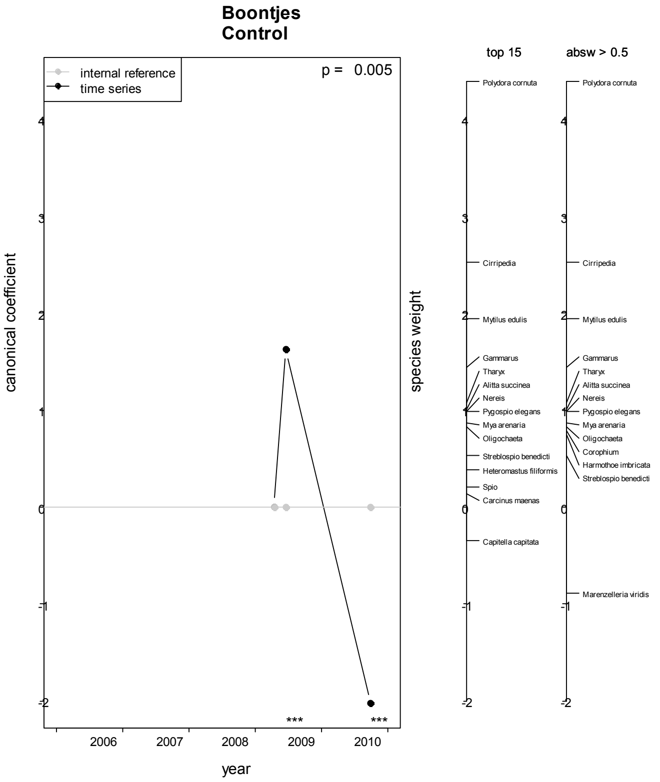
Impact
Pygospio elegans
Streblospio benedicti
Mya arenaria
Harmothoe imbricata
Capitella capitata
Tharyx
Polydora cornuta
Cirripedia
Anthozoa
Alitta succinea
Oligochaeta
Mytilus edulis

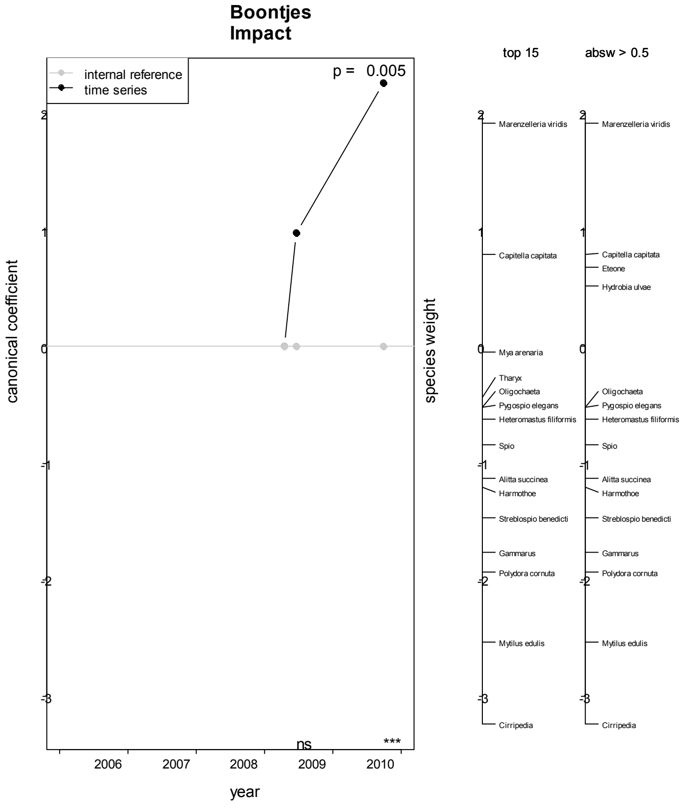

Afsluitdijk west
2009-06-18
canonical axis
first residual axis
-4
-2
0
2
4
6
Control
Impact
Polydora cornuta
Pygospio elegans
Mya arenaria
Cirripedia
Nereis
Heteromastus filiformis
Petricolaria pholadiformis
Oligochaeta
Alitta virens
Alitta succinea

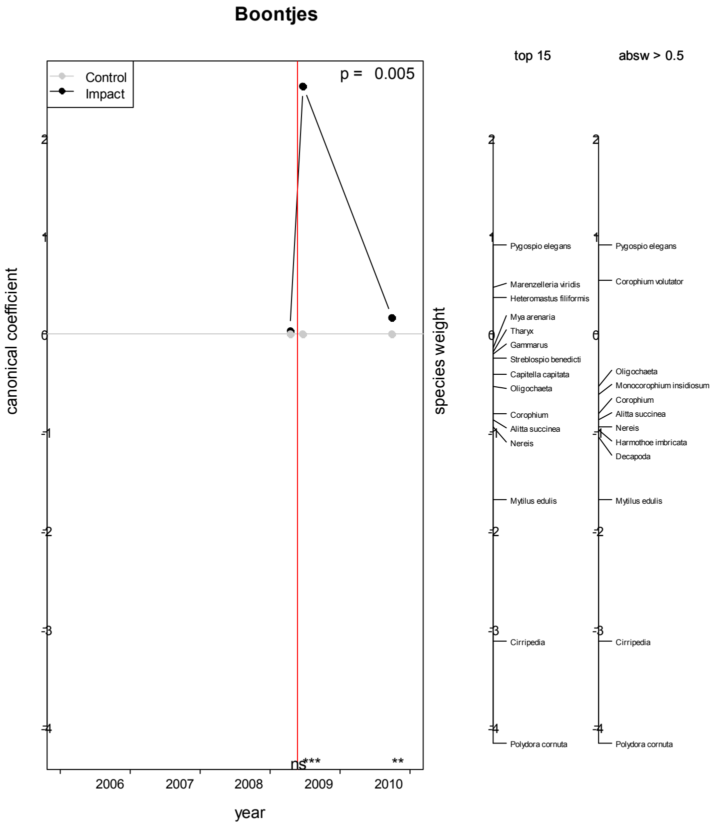

Afsluitdijk west
2010-09-19
canonical axis
first residual axis
-4
-2
0
2
4
Control
Impact
Cerastoderma edule
Oligochaeta
Nereis
Hydrobia ulvae
Anthozoa
Alitta succinea
Polydora cornuta

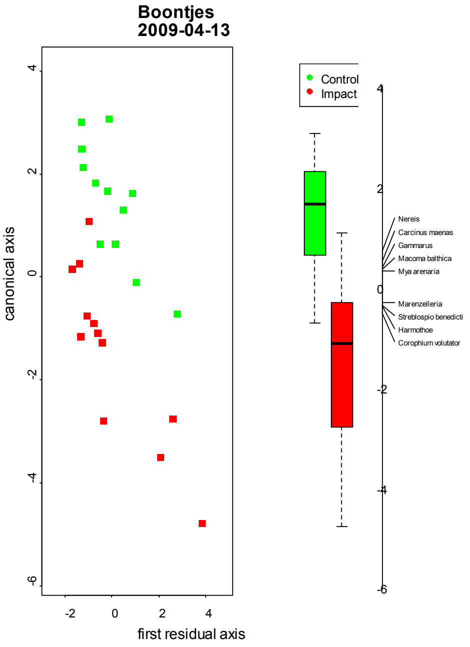
Afsluitdijk west

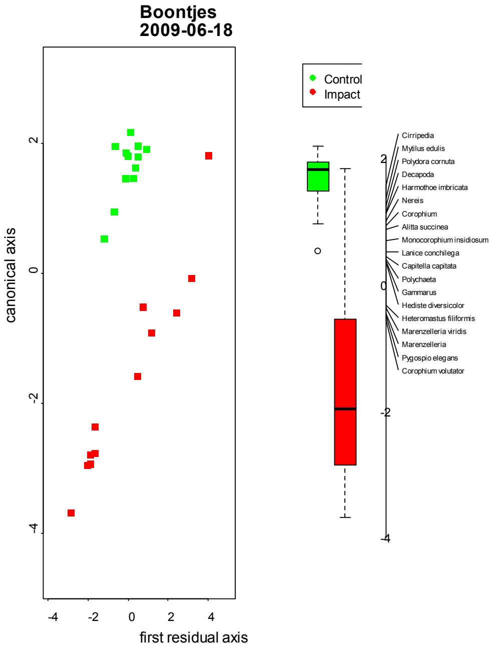


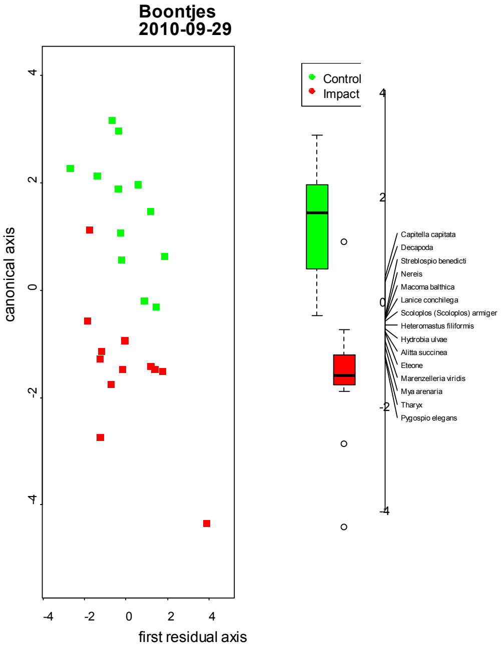

Boontjes
Control
internal reference
time series
p = 0.005
canonical coefficient
4
3
2
1
0
-1
-2
***
***
2006
2007
2008
2009
2010
year
top 15
absw > 0.5
species weight
Polydora cornuta
Cirripedia
Mytilus edulis
Gammarus
Tharyx
Alitta succinea
Nereis
Pygospio elegans
Mya arenaria
Oligochaeta
Streblospio benedicti
Heteromastus filiformis
Spio
Carcinus maenas
Capitella capitata
Polydora cornuta
Cirripedia
Mytilus edulis
Gammarus
Tharyx
Alitta succinea
Nereis
Pygospio elegans
Mya arenaria
Oligochaeta
Corophium
Harmothoe imbricata
Streblospio benedicti
Marenzelleria viridis


Boontjes
Impact
internal reference
time series
p = 0.005
canonical coefficient
2
1
0
-1
-2
-3
ns
***
2006
2007
2008
2009
2010
year
top 15
absw > 0.5
species weight
Marenzelleria viridis
Capitella capitata
Mya arenaria
Tharyx
Oligochaeta
Pygospio elegans
Heteromastus filiformis
Spio
Alitta succinea
Harmothoe
Streblospio benedicti
Gammarus
Polydora cornuta
Mytilus edulis
Cirripedia
Marenzelleria viridis
Capitella capitata
Eteone
Hydrobia ulvae
Oligochaeta
Pygospio elegans
Heteromastus filiformis
Spio
Alitta succinea
Harmothoe
Streblospio benedicti
Gammarus
Polydora cornuta
Mytilus edulis
Cirripedia

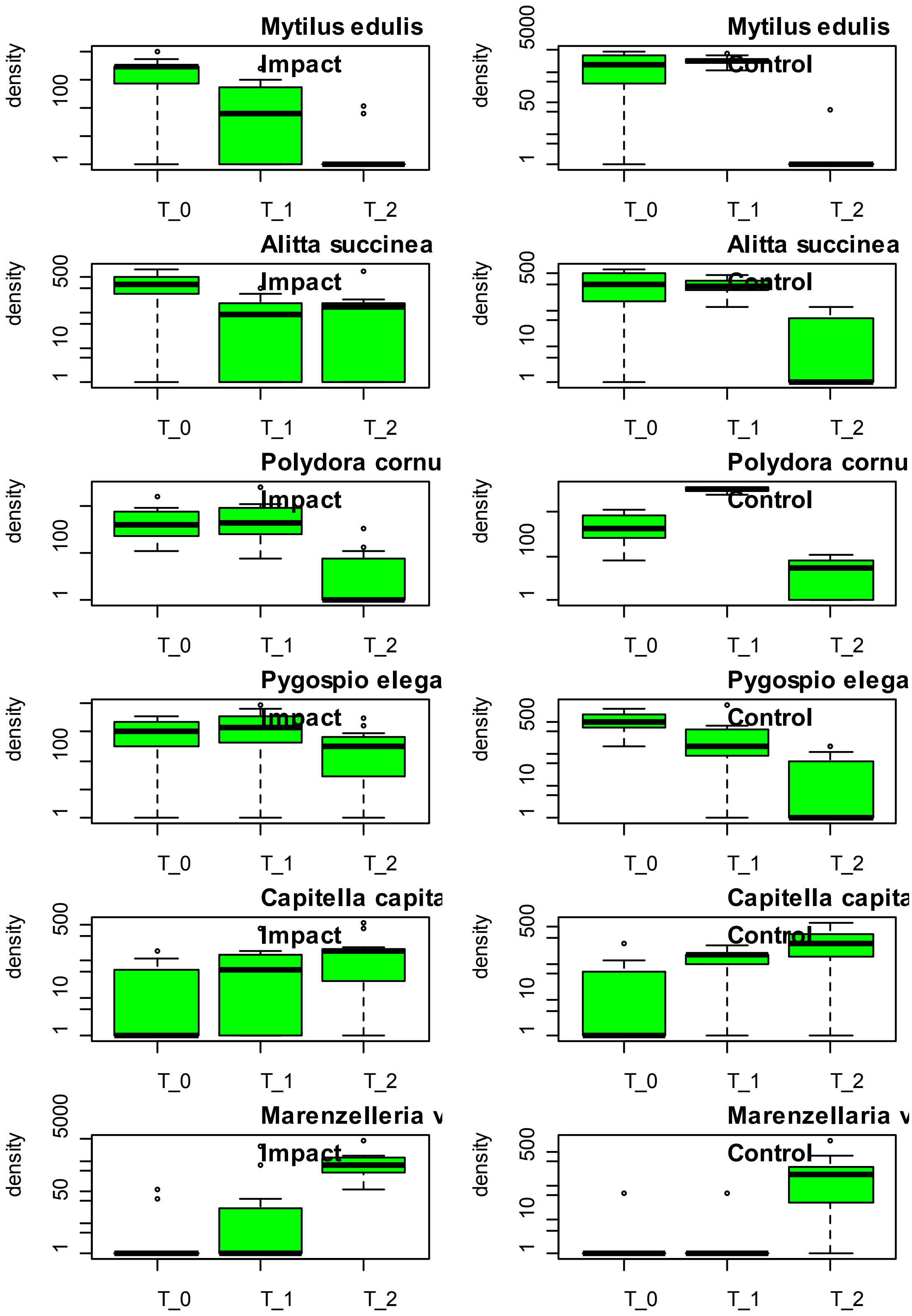

Boontjes
Control
Impact
p = 0.005
canonical coefficient
2
1
0
-1
-2
-3
-4
ns
***
**
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Pygospio elegans
Marenzelleria viridis
Heteromastus filiformis
Mya arenaria
Tharyx
Gammarus
Streblospio benedicti
Capitella capitata
Oligochaeta
Corophium
Alitta succinea
Nereis
Mytilus edulis
Cirripedia
Polydora cornuta
Pygospio elegans
Corophium volutator
Oligochaeta
Monocorophium insidiosum
Corophium
Alitta succinea
Nereis
Harmothoe imbricata
Decapoda
Mytilus edulis
Cirripedia
Polydora cornuta

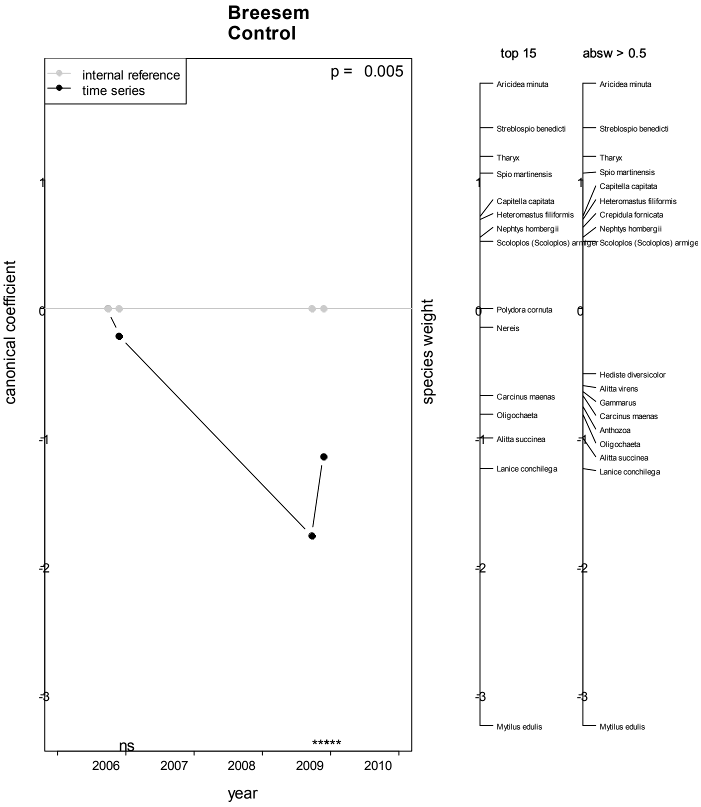

Boontjes
2009-04-13
canonical axis
first residual axis
4
2
0
-2
-4
-6
-2
0
2
4
Control
Impact
Nereis
Carcinus maenas
Gammarus
Macoma balthica
Mya arenaria
Marenzelleria
Streblospio benedicti
Harmothoe
Corophium volutator

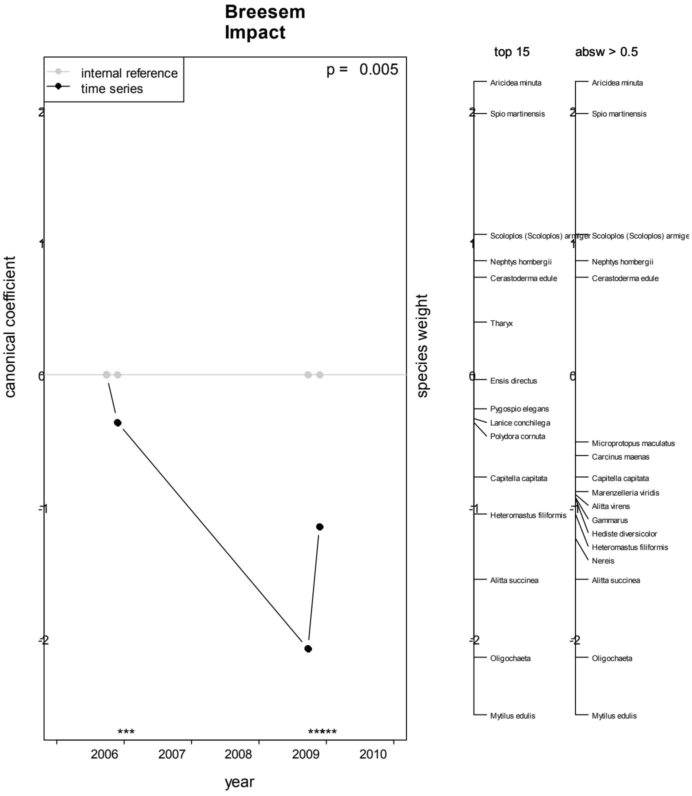

Boontjes
2009-06-18
canonical axis
first residual axis
2
0
-2
-4
-4
-2
0
2
4
Control
Impact
Cirripedia
Mytilus edulis
Polydora cornuta
Decapoda
Harmothoe imbricata
Nereis
Corophium
Alitta succinea
Monocorophium insidiosum
Lanice conchilega
Capitella capitata
Polychaeta
Gammarus
Hediste diversicolor
Heteromastus filiformis
Marenzelleria viridis
Marenzelleria
Pygospio elegans
Corophium volutator

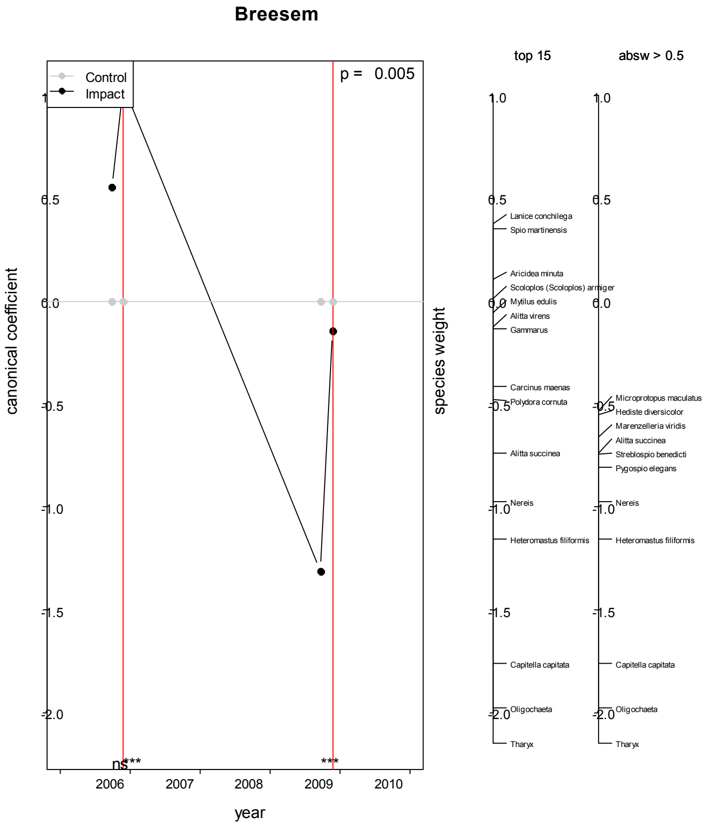

Boontjes
2010-09-29
canonical axis
first residual axis
4
2
0
-2
-4
-4
-2
0
2
4
Control
Impact
Capitella capitata
Decapoda
Streblospio benedicti
Nereis
Macoma balthica
Lanice conchilega
Scoloplos (Scoloplos) armiger
Heteromastus filiformis
Hydrobia ulvae
Alitta succinea
Eteone
Marenzelleria viridis
Mya arenaria
Tharyx
Pygospio elegans

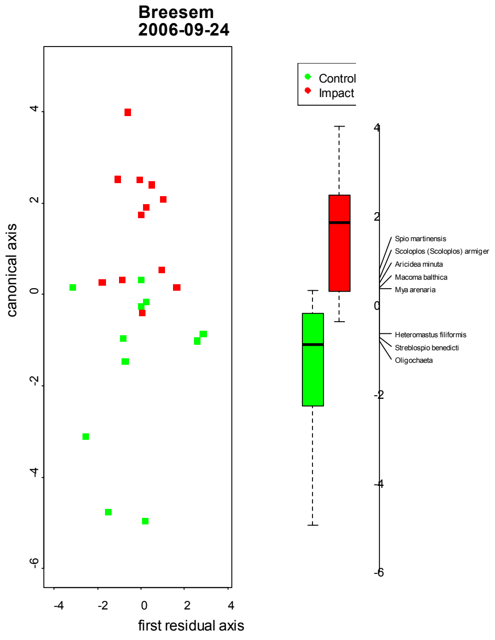
Boontjes

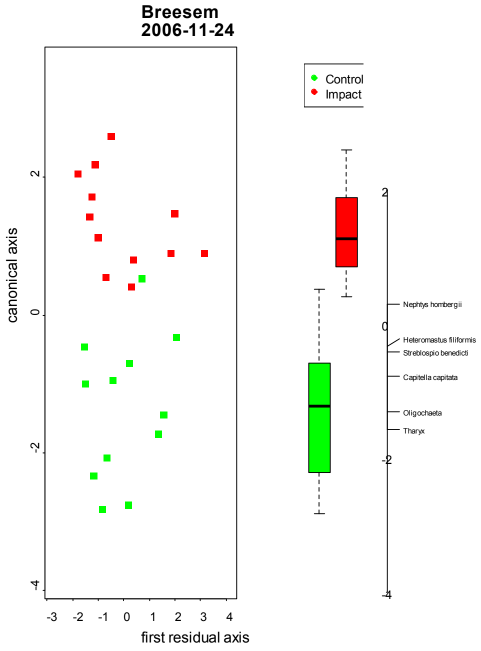

Mytilus edulis
Impact
Mytilus edulis
Control
Alitta succinea
Impact
Alitta succinea
Control
Polydora cornu
Impact
Polydora cornu
Control
Pygospio elega
Impact
Pygospio elega
Control
Capitella capita
Impact
Capitella capita
Control
Marenzelleria v
Impact
Marenzellaria v
Control
density
1
10
50
100
500
5000
T_0
T_1
T_2

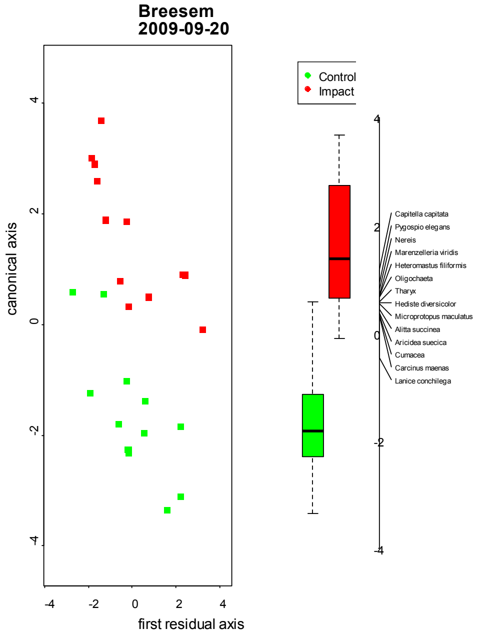

Breesem
Control
internal reference
time series
p = 0.005
canonical coefficient
1
0
-1
-2
-3
ns
*****
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Aricidea minuta
Streblospio benedicti
Tharyx
Spio martinensis
Capitella capitata
Heteromastus filiformis
Nephtys hombergii
Scoloplos (Scoloplos) armiger
Polydora cornuta
Nereis
Carcinus maenas
Oligochaeta
Alitta succinea
Lanice conchilega
Mytilus edulis
Aricidea minuta
Streblospio benedicti
Tharyx
Spio martinensis
Capitella capitata
Heteromastus filiformis
Crepidula fornicata
Nephtys hombergii
Scoloplos (Scoloplos) armiger
Hediste diversicolor
Alitta virens
Gammarus
Carcinus maenas
Anthozoa
Oligochaeta
Alitta succinea
Lanice conchilega
Mytilus edulis

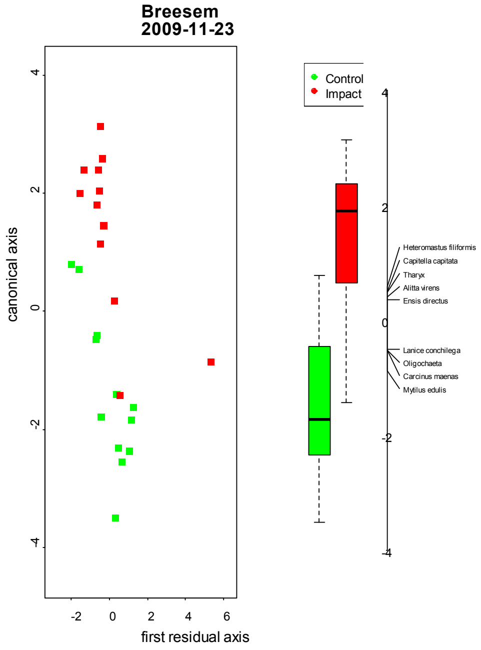

Breesem
Impact
internal reference
time series
p = 0.005
canonical coefficient
2
1
0
-1
-2
***
*****
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Aricidea minuta
Spio martinensis
Scoloplos (Scoloplos) armiger
Nephtys hombergii
Cerastoderma edule
Tharyx
Ensis directus
Pygospio elegans
Lanice conchilega
Polydora cornuta
Capitella capitata
Heteromastus filiformis
Alitta succinea
Oligochaeta
Mytilus edulis
Aricidea minuta
Spio martinensis
Scoloplos (Scoloplos) armiger
Nephtys hombergii
Cerastoderma edule
Micropotopus maculatus
Carcinus maenas
Capitella capitata
Marenzelleria viridis
Alitta virens
Gammarus
Hediste diversicolor
Heteromastus filiformis
Nereis
Alitta succinea
Oligochaeta
Mytilus edulis


Breesem
Control
Impact
p = 0.005
canonical coefficient
1
0.5
0.0
-0.5
-1.0
-1.5
-2.0
ns***
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
Lanice conchilega
Spio martinensis
Aricidea minuta
Scoloplos (Scoloplos) armiger
Mytilus edulis
Alitta virens
Gammarus
Carcinus maenas
Polydora cornuta
Alitta succinea
Nereis
Heteromastus filiformis
Capitella capitata
Oligochaeta
Tharyx
Microprotopus maculatus
Hediste diversicolor
Marenzelleria viridis
Alitta succinea
Streblospio benedicti
Pygospio elegans
Nereis
Heteromastus filiformis
Capitella capitata
Oligochaeta
Tharyx

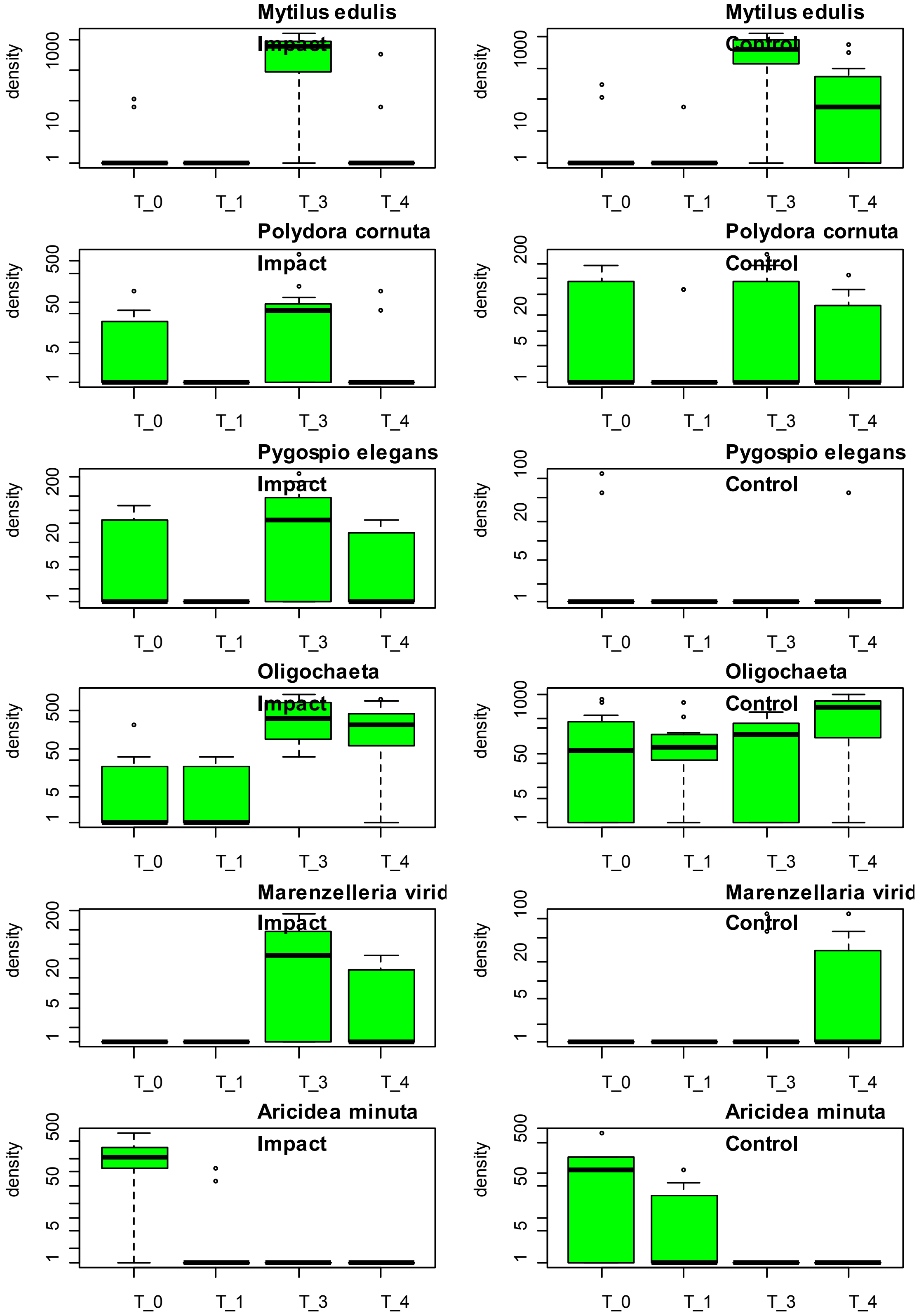

Breesem
2006-09-24
canonical axis
4
2
0
-2
-4
-6
-4
-2
0
2
4
first residual axis
🟩 Control
🟥 Impact
4
2
0
-2
-4
-6
Spio martinensis
Scoloplos (Scoloplos) armiger
Aricidea minuta
Macoma balthica
Mya arenaria
Heteromastus filiformis
Streblospio benedicti
Oligochaeta

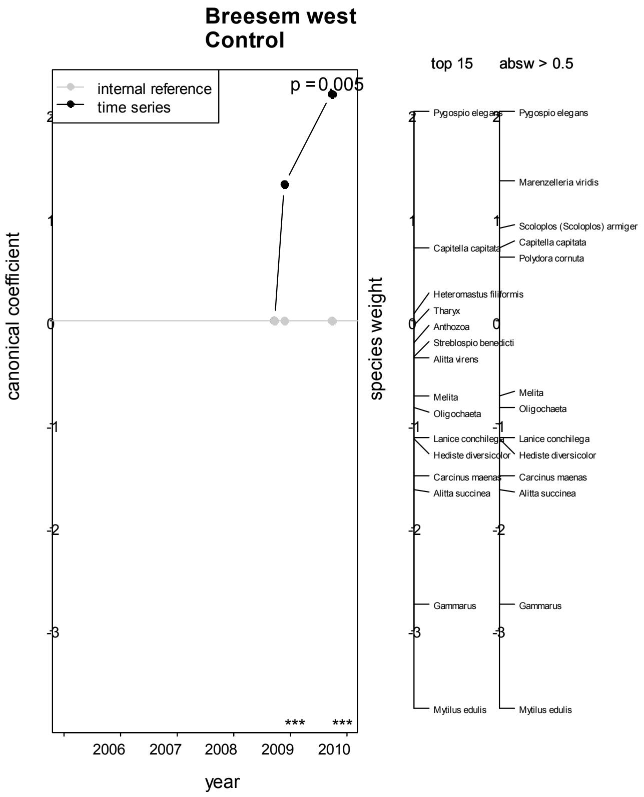

Breesem
2006-11-24
canonical axis
2
0
-2
-4
-3
-2
-1
0
1
2
3
4
first residual axis
🟩 Control
🟥 Impact
2
0
-2
-4
Nephtys hombergii
Heteromastus filiformis
Streblospio benedicti
Capitella capitata
Oligochaeta
Tharyx

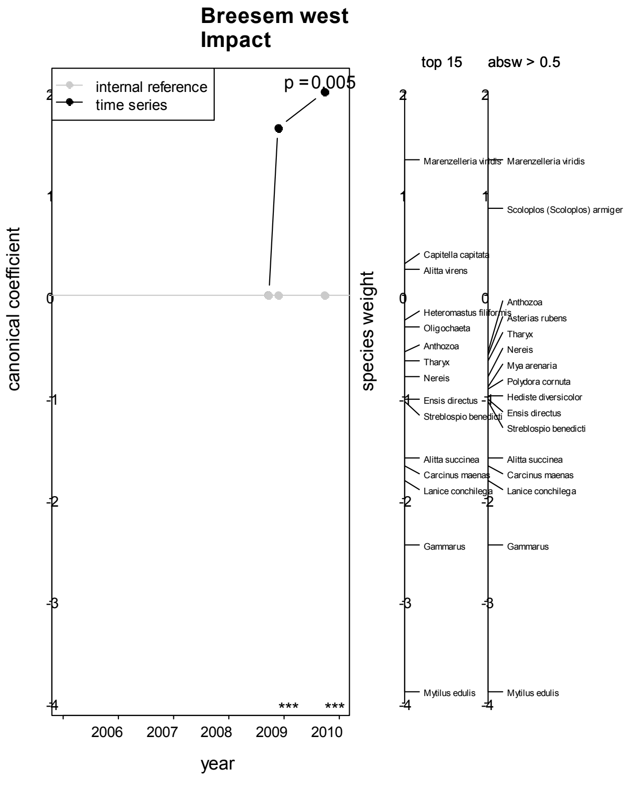

Breesem
2009-09-20
canonical axis
4
2
0
-2
-4
-4
-2
0
2
4
first residual axis
🟩 Control
🟥 Impact
4
2
0
-2
-4
Capitella capitata
Pygospio elegans
Nereis
Marenzelleria viridis
Heteromastus filiformis
Oligochaeta
Tharyx
Hediste diversicolor
Microprotopus maculatus
Alitta succinea
Aricidea suecica
Cumacea
Carcinus maenas
Lanice conchilega

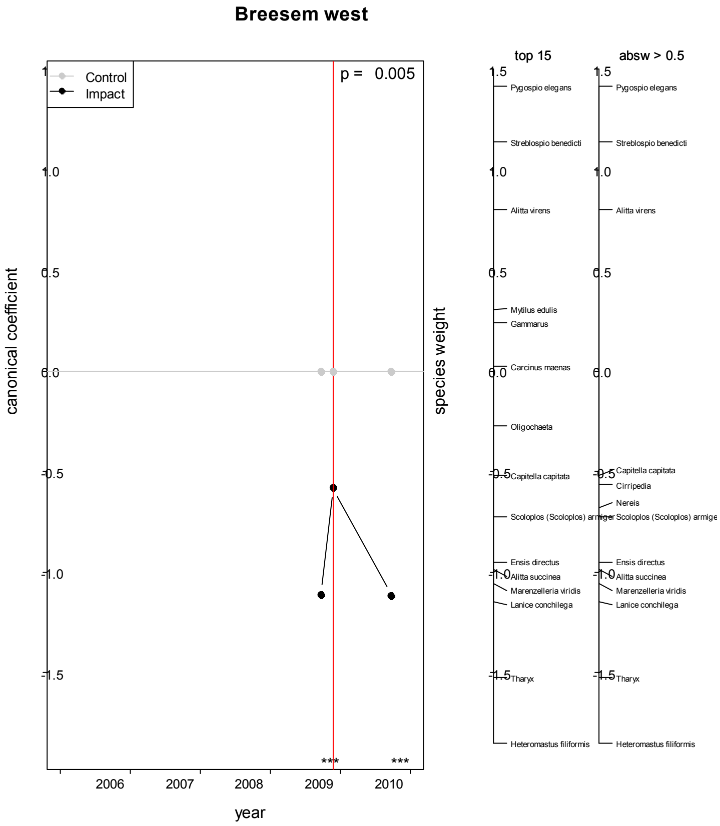

Breesem
2009-11-23
canonical axis
4
2
0
-2
-4
-2
0
2
4
6
first residual axis
🟩 Control
🟥 Impact
4
2
0
-2
-4
Heteromastus filiformis
Capitella capitata
Tharyx
Alitta virens
Ensis directus
Lanice conchilega
Oligochaeta
Carcinus maenas
Mytilus edulis

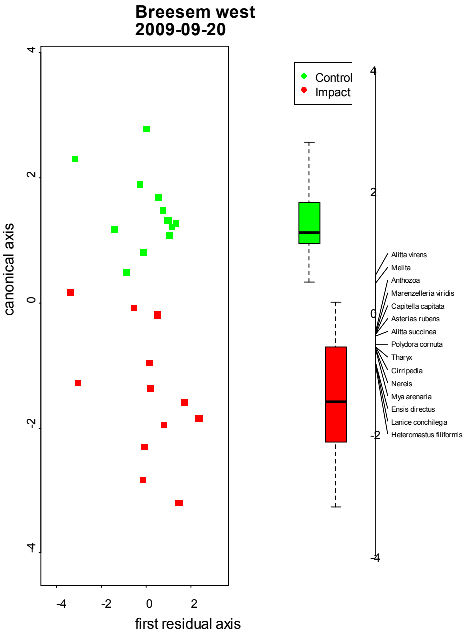
Breesem

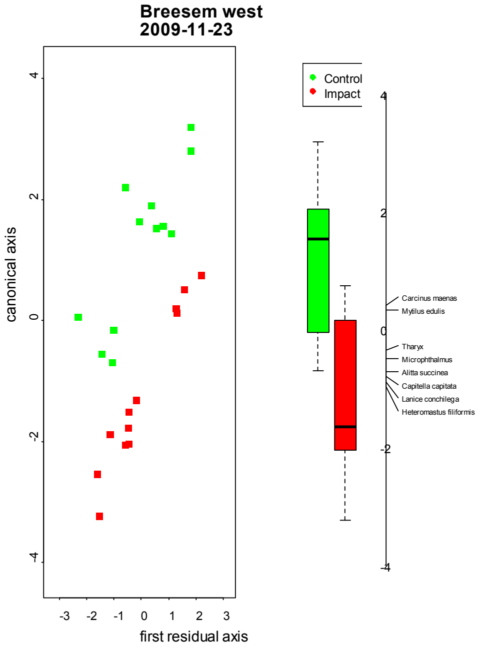

Mytilus edulis
Impact
density
1
10
100
1000
Mytilus edulis
Control
Polydora cornuta
Impact
1
5
50
500
Polydora cornuta
Control
1
5
20
200
Pygospio elegans
Impact
1
5
20
200
Pygospio elegans
Control
1
5
20
100
Oligochaeta
Impact
1
5
50
500
Oligochaeta
Control
1
5
50
1000
Marenzelleria virid
Impact
1
5
20
200
Marenzellaria virid
Control
1
5
20
100
Aricidea minuta
Impact
1
5
50
500
Aricidea minuta
Control
T_0
T_1
T_3
T_4

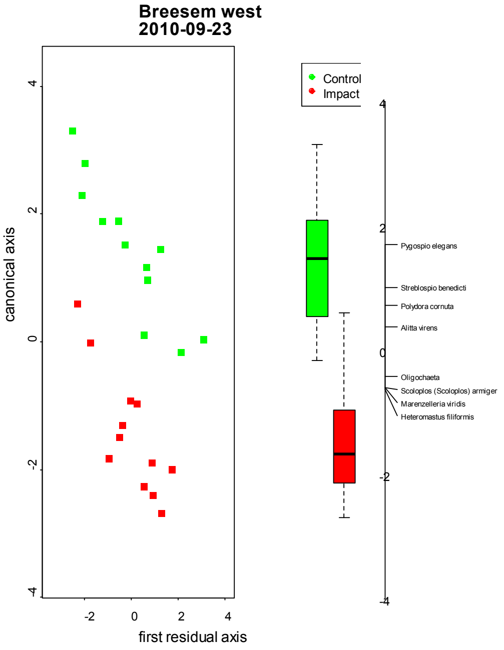

Breesem west
Control
internal reference
time series
p = 0.005
canonical coefficient
year
2006
2007
2008
2009
2010
***
***
top 15
absw > 0.5
species weight
Pygospio elegans
Marenzelleria viridis
Scoloplos (Scoloplos) armiger
Capitella capitata
Polydora cornuta
Heteromastus filiformis
Tharyx
Anthozoa
Streblospio benedicti
Alitta virens
Melita
Oligochaeta
Lanice conchilega
Hediste diversicolor
Carcinus maenas
Alitta succinea
Gammarus
Mytilus edulis

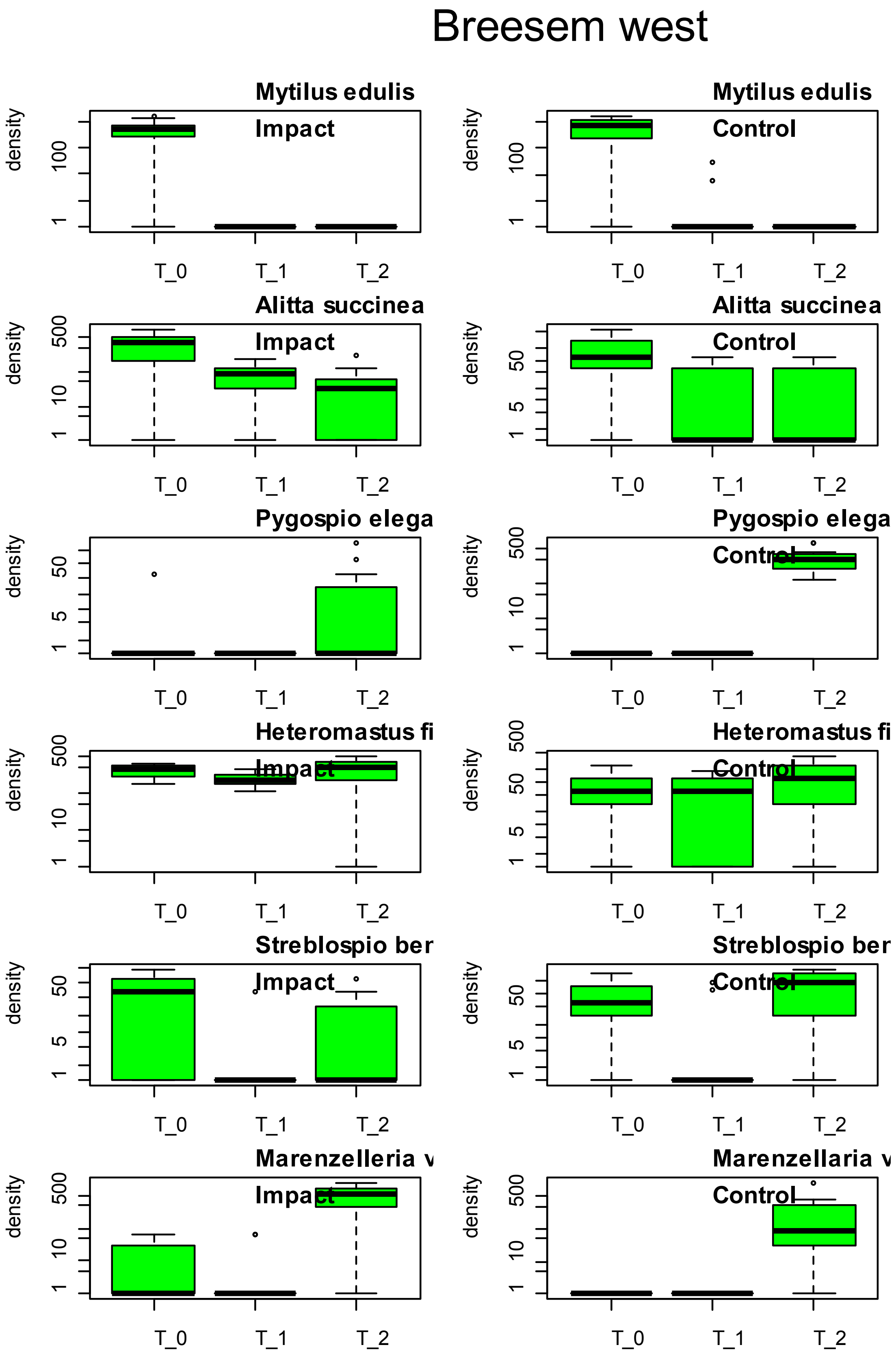

Breesem west
Impact
internal reference
time series
p = 0.005
canonical coefficient
year
2006
2007
2008
2009
2010
***
***
top 15
absw > 0.5
species weight
Marenzelleria viridis
Scoloplos (Scoloplos) armiger
Capitella capitata
Alitta virens
Heteromastus filiformis
Oligochaeta
Anthozoa
Asterias rubens
Tharyx
Nereis
Mya arenaria
Polydora cornuta
Hediste diversicolor
Ensis directus
Streblospio benedicti
Alitta succinea
Carcinus maenas
Lanice conchilega
Gammarus
Mytilus edulis

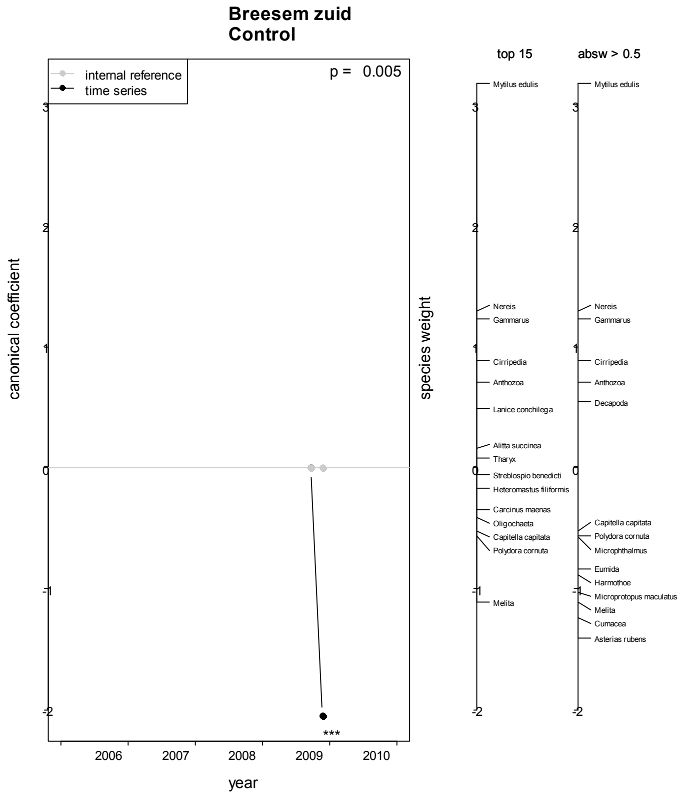

Breesem west
Control
Impact
p = 0.005
canonical coefficient
1.0
0.5
0.0
-0.5
-1.0
-1.5
year
2006
2007
2008
2009
2010
***
***
species weight
top 15
absw > 0.5
1.5
Pygospio elegans
Streblospio benedicti
Alitta virens
Mytilus edulis
Gammarus
Carcinus maenas
Oligochaeta
Capitella capitata
Cirripedia
Nereis
Scoloplos (Scoloplos) armiger
Ensis directus
Alitta succinea
Marenzelleria viridis
Lanice conchilega
Tharyx
Heteromastus filiformis

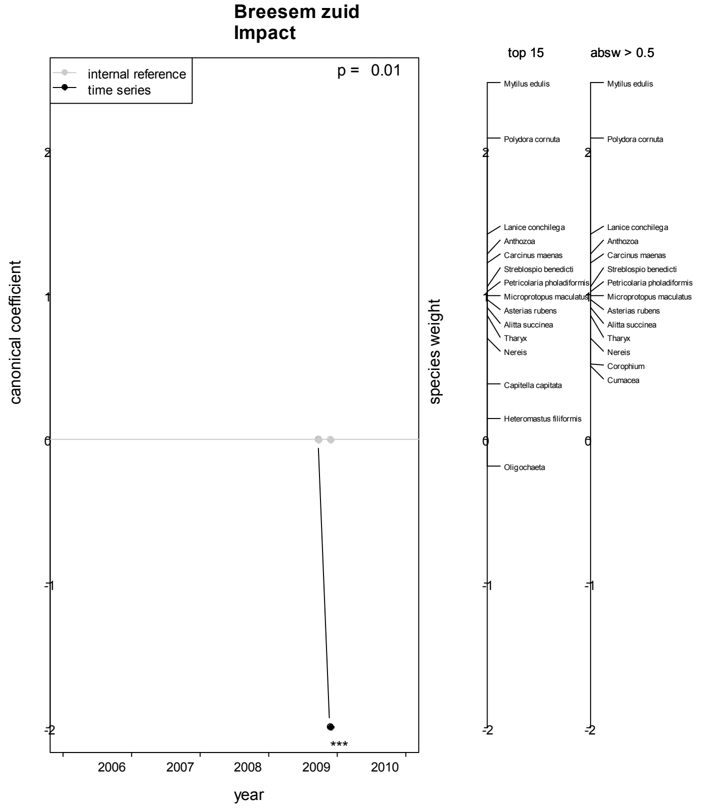

Breesem west
2009-09-20
canonical axis
first residual axis
4
2
0
-2
-4
-4
-2
0
2
Control
Impact
4
2
0
-2
-4
Alitta virens
Melita
Anthozoa
Marenzelleria viridis
Capitella capitata
Asterias rubens
Alitta succinea
Polydora cornuta
Tharyx
Cirripedia
Nereis
Mya arenaria
Ensis directus
Lanice conchilega
Heteromastus filiformis


Breesem west
2009-11-23
canonical axis
first residual axis
4
2
0
-2
-4
-3
-2
-1
0
1
2
3
Control
Impact
4
2
0
-2
-4
Carcinus maenas
Mytilus edulis
Tharyx
Microphthalmus
Alitta succinea
Capitella capitata
Lanice conchilega
Heteromastus filiformis


Breesem west
2010-09-23
canonical axis
first residual axis
4
2
0
-2
-4
-2
0
2
4
Control
Impact
4
2
0
-2
-4
Pygospio elegans
Streblospio benedicti
Polydora cornuta
Alitta virens
Oligochaeta
Scoloplos (Scoloplos) armiger
Marenzelleria viridis
Heteromastus filiformis


Breesem west
Mytilus edulis
Impact
density
100
1
T_0
T_1
T_2
Mytilus edulis
Control
density
100
1
T_0
T_1
T_2
Alitta succinea
Impact
density
500
10
1
T_0
T_1
T_2
Alitta succinea
Control
density
50
5
1
T_0
T_1
T_2
Pygospio elega
density
50
5
1
T_0
T_1
T_2
Pygospio elega
Control
density
500
10
1
T_0
T_1
T_2
Heteromastus fi
Impact
density
500
10
1
T_0
T_1
T_2
Heteromastus fi
Control
density
500
50
5
1
T_0
T_1
T_2
Streblospio ber
Impact
density
50
5
1
T_0
T_1
T_2
Streblospio ber
Control
density
50
5
1
T_0
T_1
T_2
Marenzelleria v
Impact
density
500
10
1
T_0
T_1
T_2
Marenzellaria v
Control
density
500
10
1
T_0
T_1
T_2


Breesem zuid
Control
internal reference
time series
p = 0.005
canonical coefficient
3
2
1
0
-1
-2
***
2006
2007
2008
2009
2010
year
species weight
top 15
Mytilus edulis
3
2
Nereis
Gammarus
1
Cirripedia
Anthozoa
Lanice conchilega
Alitta succinea
Tharyx
0
Streblospio benedicti
Heteromastus filiformis
Carcinus maenas
Oligochaeta
Capitella capitata
Polydora cornuta
-1
Melita
-2
absw > 0.5
Mytilus edulis
3
2
Nereis
Gammarus
1
Cirripedia
Anthozoa
Decapoda
0
Capitella capitata
Polydora cornuta
Microphthalmus
Eumida
Harmothoe
-1
Microprotopus maculatus
Melita
Cumacea
Asterias rubens
-2


Breesem zuid
Impact
internal reference
time series
p = 0.01
canonical coefficient
2
1
0
-1
-2
***
2006
2007
2008
2009
2010
year
species weight
top 15
Mytilus edulis
Polydora cornuta
2
Lanice conchilega
Anthozoa
Carcinus maenas
Streblospio benedicti
Petricolaria pholadiformis
1
Microprotopus maculatus
Asterias rubens
Alitta succinea
Tharyx
Nereis
Capitella capitata
Heteromastus filiformis
0
Oligochaeta
-1
-2
absw > 0.5
Mytilus edulis
Polydora cornuta
2
Lanice conchilega
Anthozoa
Carcinus maenas
Streblospio benedicti
Petricolaria pholadiformis
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Microprotopus maculatus
Asterias rubens
Alitta succinea
Tharyx
Nereis
Corophium
Cumacea
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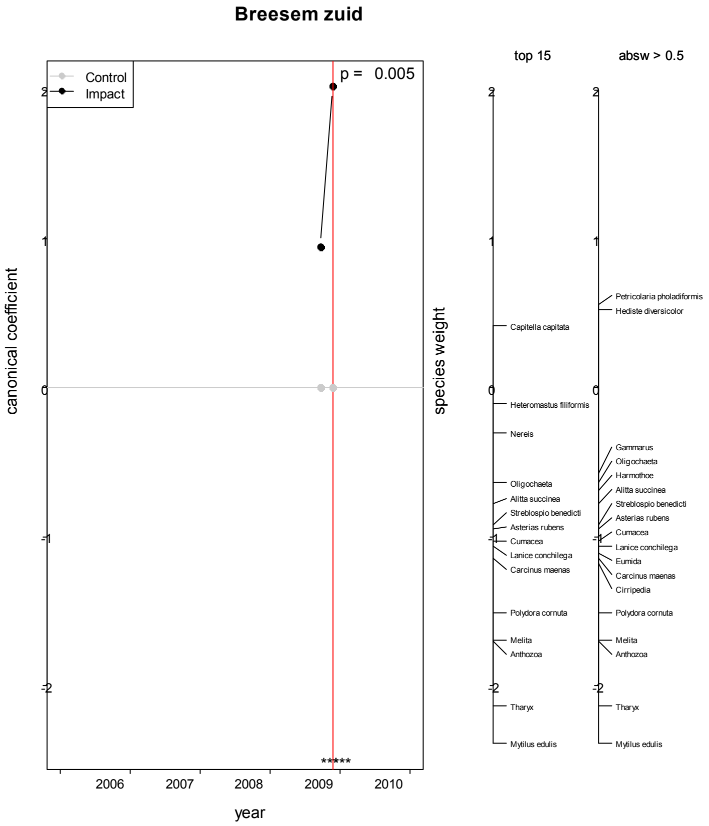
-1
-2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Control
Impact
p = 0.005
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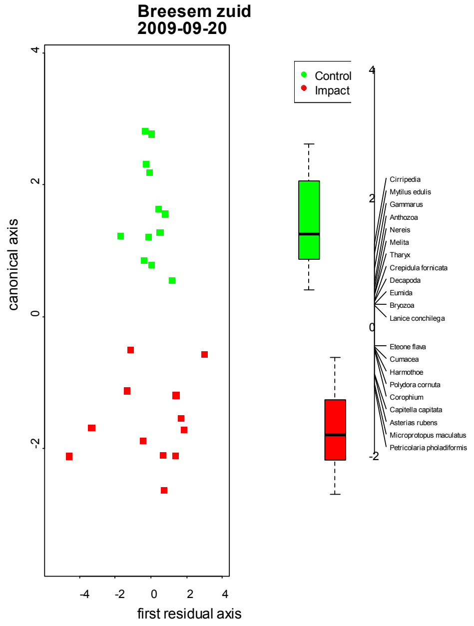
2006
2007
2008
2009
2010
year
top 15
absw > 0.5
species weight
Capitella capitata
Heteromastus filiformis
Nereis
Oligochaeta
Alitta succinea
Streblospio benedicti
Asterias rubens
Cumacea
Lanice conchilega
Carcinus maenas
Polydora cornuta
Melita
Anthozoa
Tharyx
Mytilus edulis
Petricolaria pholadiformis
Hediste diversicolor
Gammarus
Oligochaeta
Harmothoe
Alitta succinea
Streblospio benedicti
Asterias rubens
Cumacea
Lanice conchilega
Eumida
Carcinus maenas
Cirripedia
Polydora cornuta
Melita
Anthozoa
Tharyx
Mytilus edulis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2009-09-20
canonical axis
4
2
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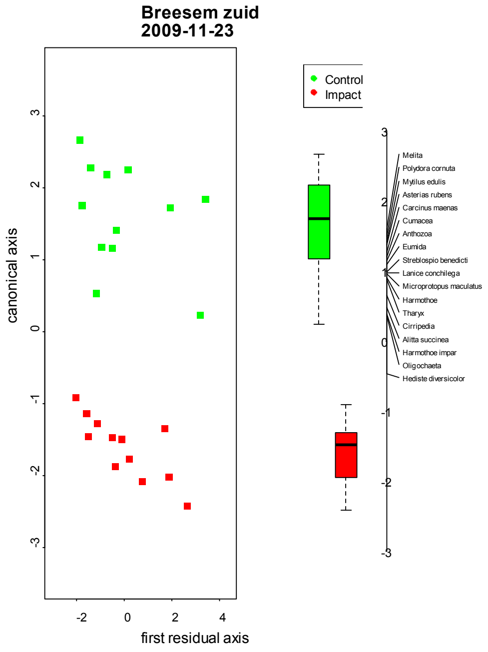
-2
-4
-2
0
2
4
first residual axis
Control
Impact
Cirripedia
Mytilus edulis
Gammarus
Anthozoa
Nereis
Melita
Tharyx
Crepidula fornicata
Decapoda
Eumida
Bryozoa
Lanice conchilega
Eteone flava
Cumacea
Harmothoe
Polydora cornuta
Corophium
Capitella capitata
Asterias rubens
Microprotopus maculatus
Petricolaria pholadiformis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2009-11-23
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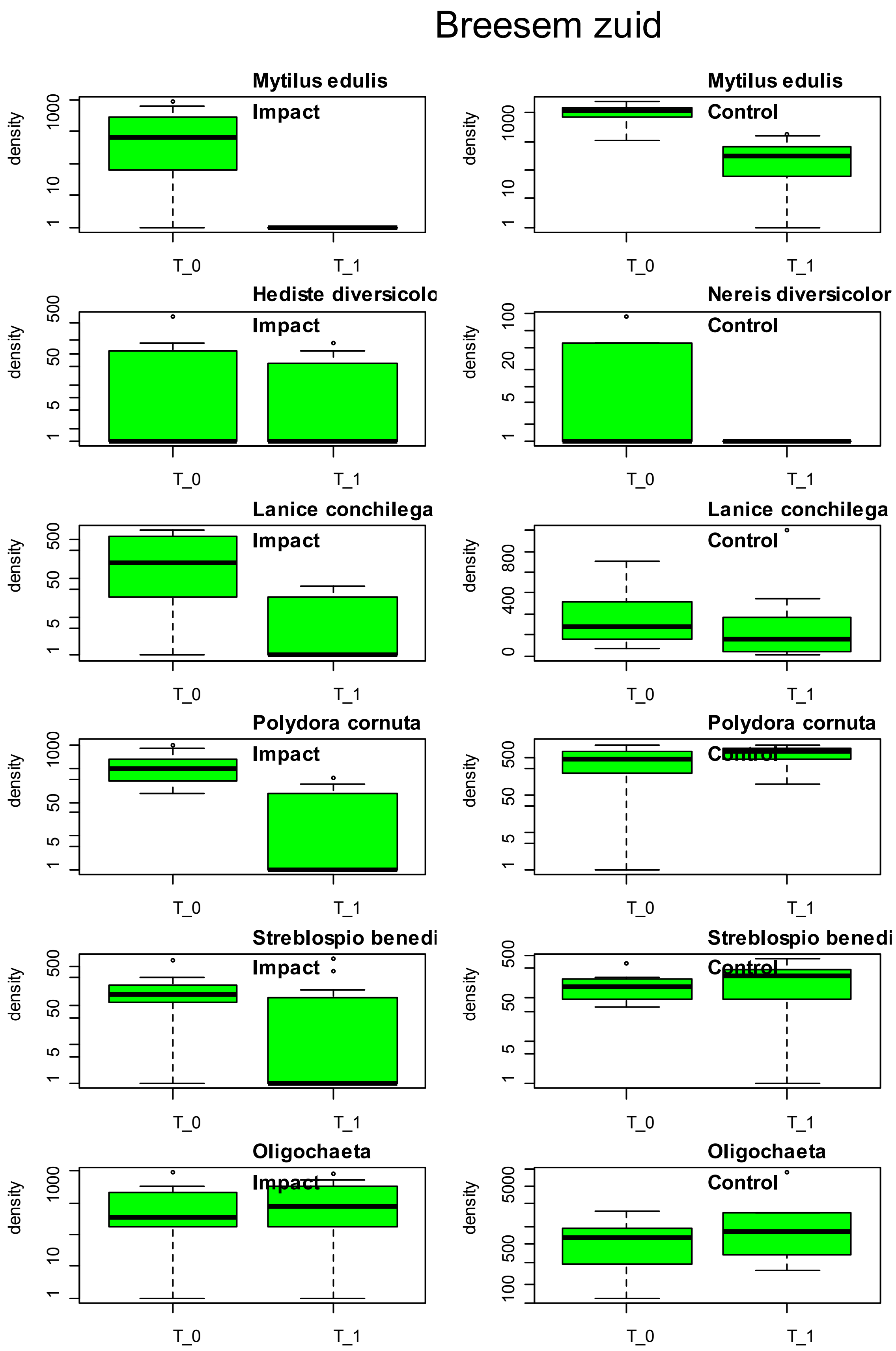
-1
-2
-3
-2
0
2
4
first residual axis
Control
Impact
Melita
Polydora cornuta
Mytilus edulis
Asterias rubens
Carcinus maenas
Cumacea
Anthozoa
Eumida
Streblospio benedicti
Lanice conchilega
Microprotopus maculatus
Harmothoe
Tharyx
Cirripedia
Alitta succinea
Harmothoe impar
Oligochaeta
Hediste diversicolor


Breesem zuid
Mytilus edulis
Impact
density
1
10
100
1000
T_0
T_1
Mytilus edulis
Control
density
1
10
100
1000
T_0
T_1
Hediste diversicolo
Impact
density
1
5
50
500
T_0
T_1
Nereis diversicolor
Control
density
1
5
20
100
T_0
T_1
Lanice conchilega
Impact
density
1
5
50
500
T_0
T_1
Lanice conchilega
Control
density
0
400
800
T_0
T_1
Polydora cornuta
Impact
density
1
5
50
1000
T_0
T_1
Polydora cornuta
Control
density
1
5
50
500
T_0
T_1
Streblospio benedi
Impact
density
1
5
50
500
T_0
T_1
Streblospio benedi
Control
density
1
5
50
500
T_0
T_1
Oligochaeta
Impact
density
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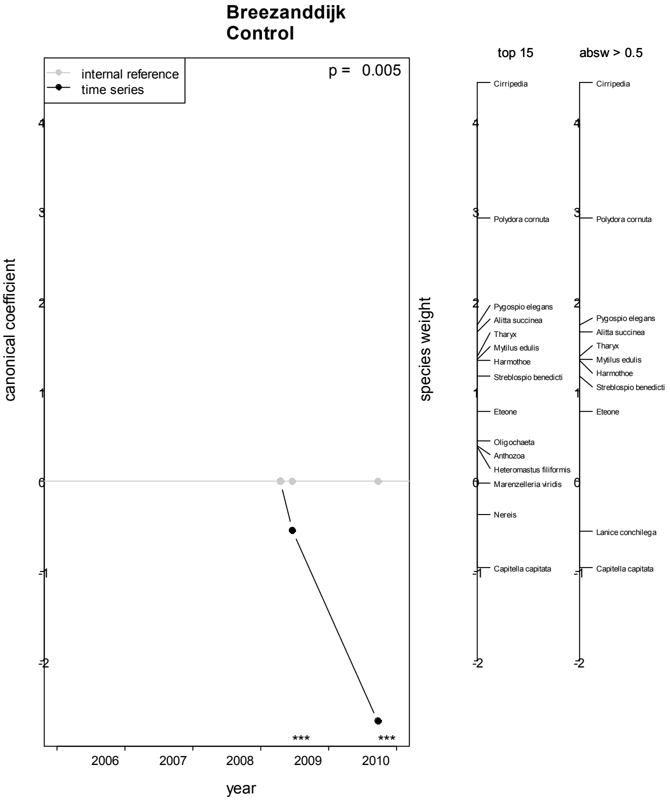
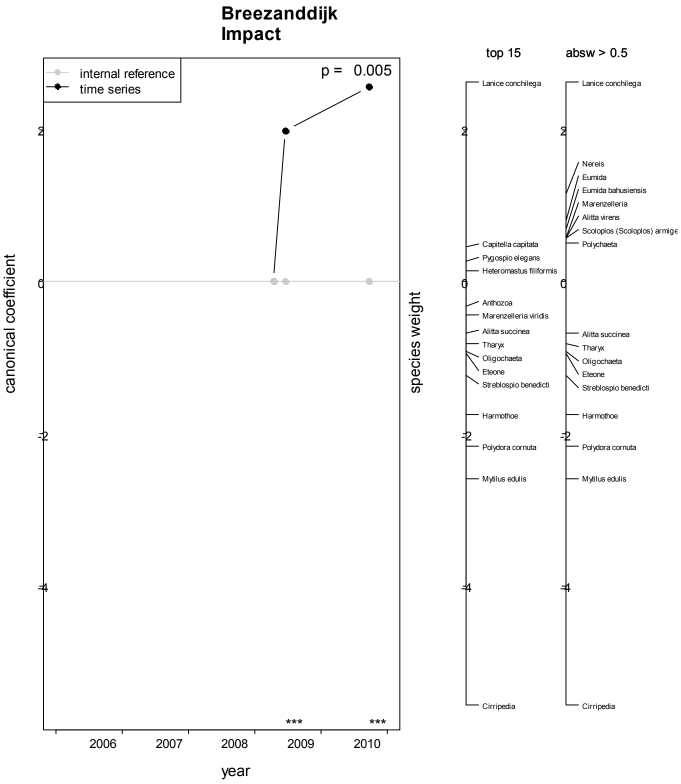
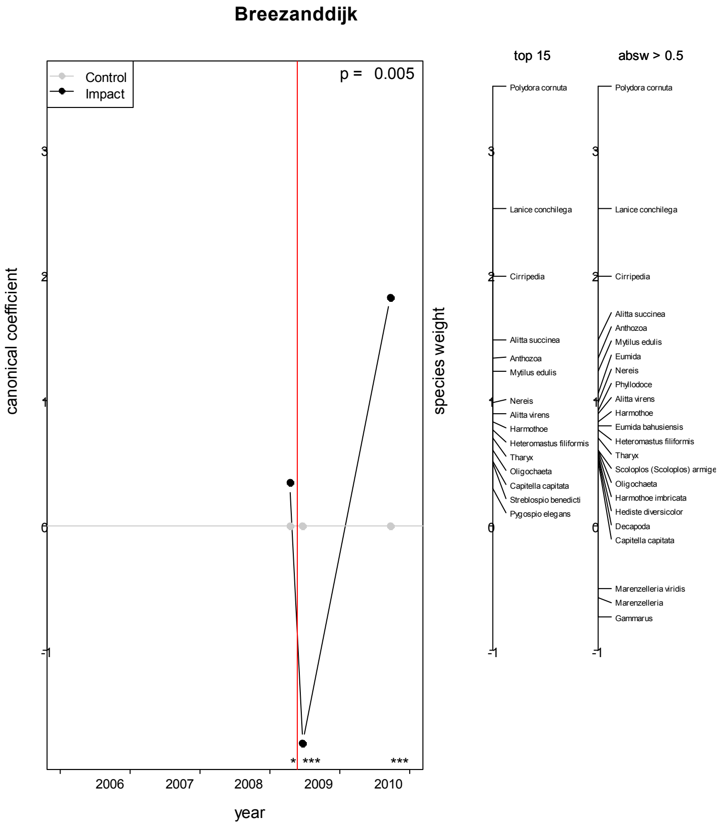
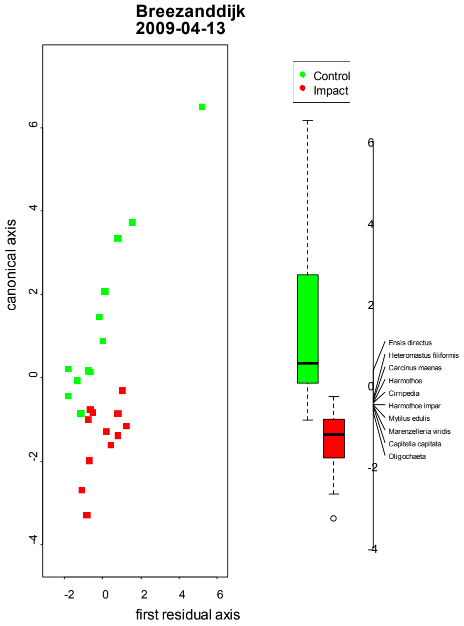
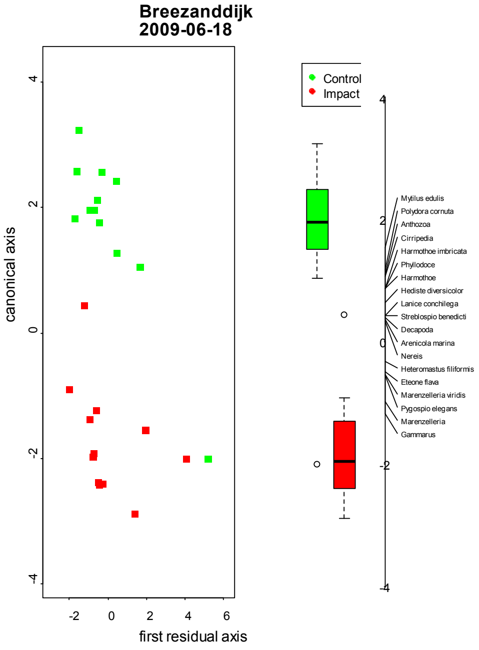
1000
T_0
T_1
Oligochaeta
Control
density
100
500
5000
T_0
T_1

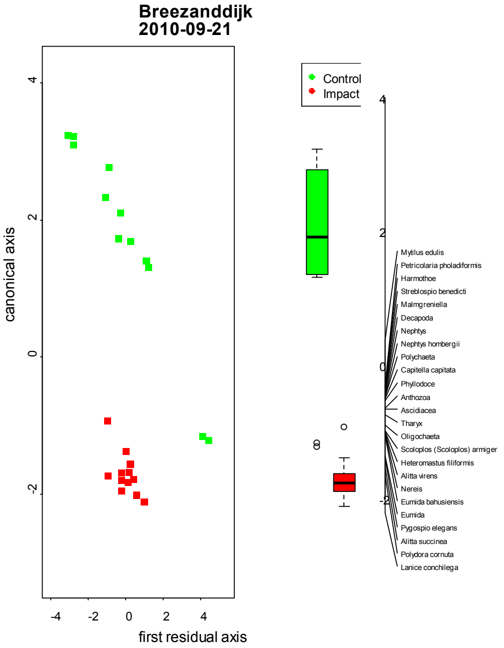

Breezanddijk
Control
internal reference
time series
p = 0.005
canonical coefficient
4
3
2
1
0
-1
-2
***
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Cirripedia
Polydora cornuta
Pygospio elegans
Alitta succinea
Tharyx
Mytilus edulis
Harmothoe
Streblospio benedicti
Eteone
Oligochaeta
Anthozoa
Heteromastus filiformis
Marenzelleria viridis
Nereis
Capitella capitata
Lanice conchilega


Breezanddijk
Impact
internal reference
time series
p = 0.005
canonical coefficient
2
0
-2
-4
***
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Lanice conchilega
Capitella capitata
Pygospio elegans
Heteromastus filiformis
Anthozoa
Marenzelleria viridis
Alitta succinea
Tharyx
Oligochaeta
Eteone
Streblospio benedicti
Harmothoe
Polydora cornuta
Mytilus edulis
Cirripedia
Nereis
Eumida
Eumida bahusiensis
Marenzelleria
Alitta virens
Scoloplos (Scoloplos) armige
Polychaeta

Breezanddijk
Control
Impact
p = 0.005
canonical coefficient
3
2
1
0
-1
* ***
***
2006
2007
2008
2009
2010
year
species weight
top 15
Polydora cornuta
Lanice conchilega
Cirripedia
Alitta succinea
Anthozoa
Mytilus edulis
Nereis
Alitta virens
Harmothoe
Heteromastus filiformis
Tharyx
Oligochaeta
Capitella capitata
Streblospio benedicti
Pygospio elegans
absw > 0.5
Polydora cornuta
Lanice conchilega
Cirripedia
Alitta succinea
Anthozoa
Mytilus edulis
Eumida
Nereis
Phyllodoce
Alitta virens
Harmothoe
Eumida bahusiensis
Heteromastus filiformis
Tharyx
Scoloplos (Scoloplos) armige
Oligochaeta
Harmothoe imbricata
Hediste diversicolor
Decapoda
Capitella capitata
Marenzelleria viridis
Marenzelleria
Gammarus


Breezanddijk
2009-04-13
canonical axis
first residual axis
-2
0
2
4
6
-4
-2
0
2
4
6
Control
Impact
Ensis directus
Heteromastus filiformis
Carcinus maenas
Harmothoe
Cirripedia
Harmothoe impar
Mytilus edulis
Marenzelleria viridis
Capitella capitata
Oligochaeta


Breezanddijk
2009-06-18
canonical axis
first residual axis
-2
0
2
4
6
-4
-2
0
2
4
Control
Impact
Mytilus edulis
Polydora cornuta
Anthozoa
Cirripedia
Harmothoe imbricata
Phyllodoce
Harmothoe
Hediste diversicolor
Lanice conchilega
Streblospio benedicti
Decapoda
Arenicola marina
Nereis
Heteromastus filiformis
Eteone flava
Marenzelleria viridis
Pygospio elegans
Marenzelleria
Gammarus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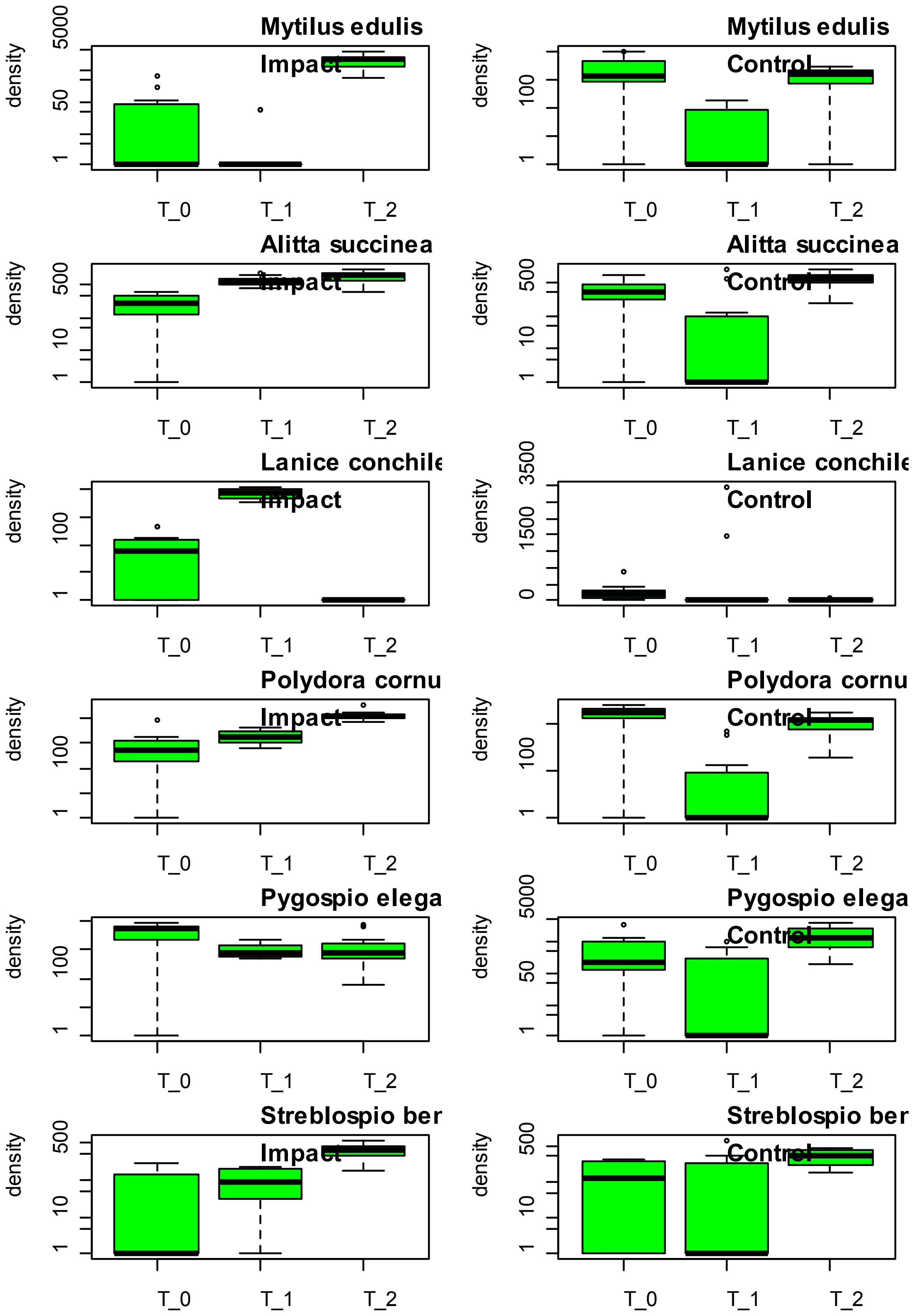
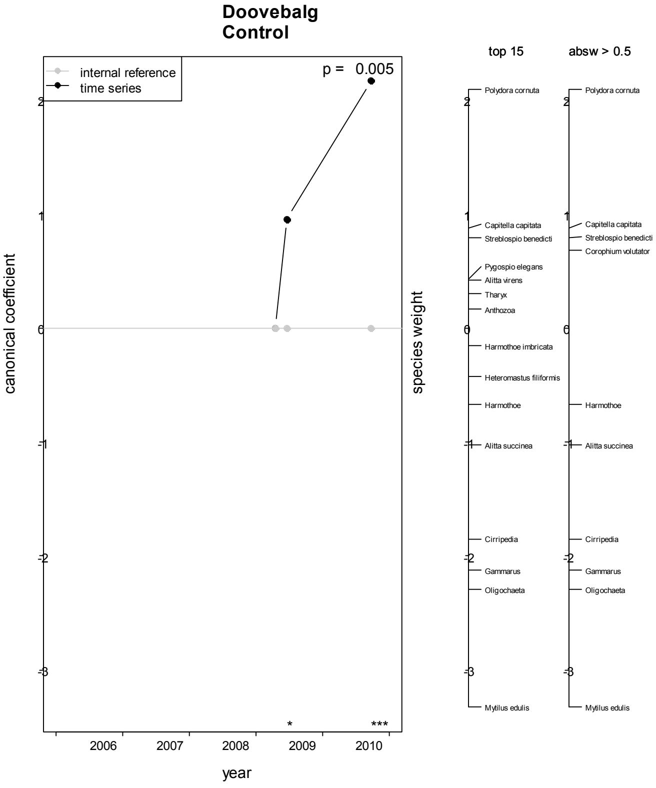
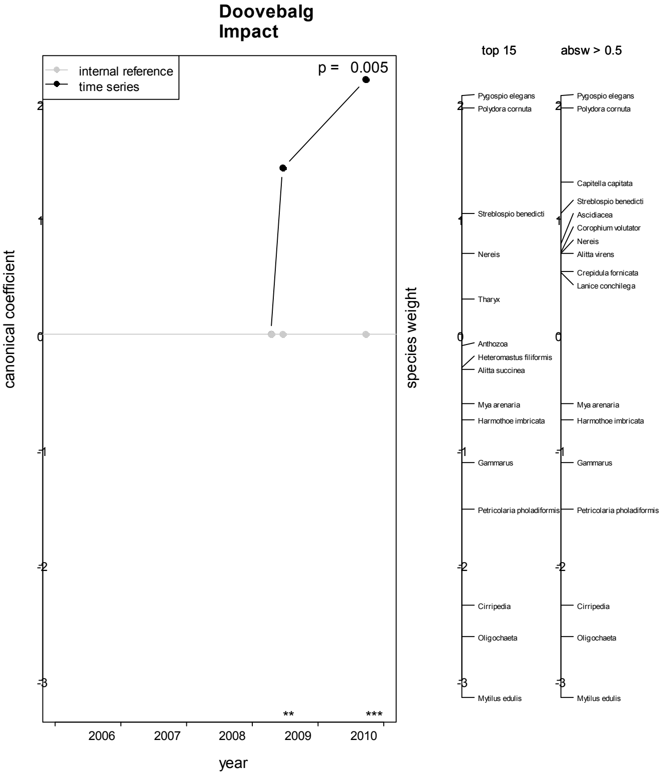
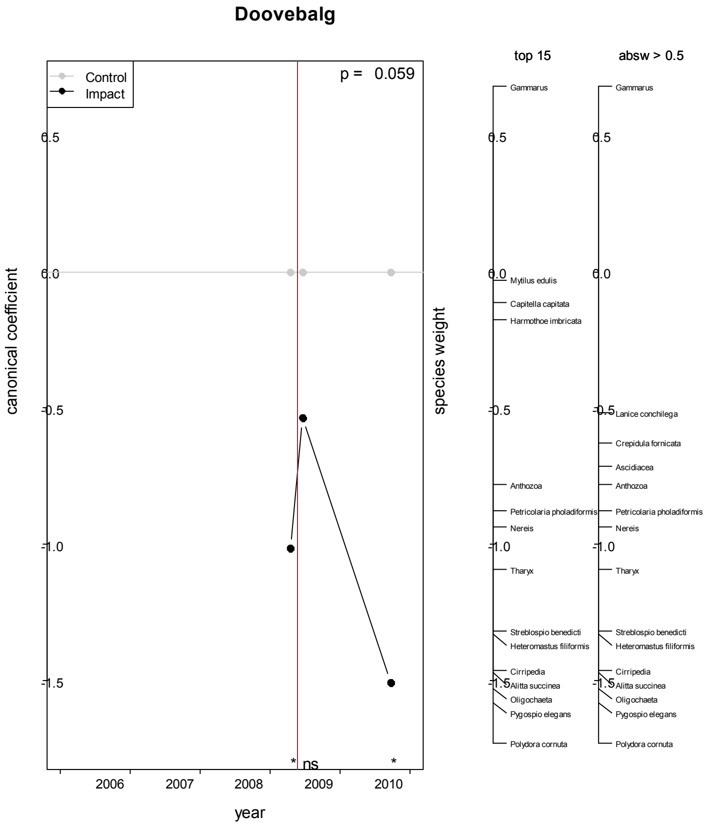
2010-09-21
canonical axis
first residual axis
-4
-2
0
2
4
-2
0
2
4
Control
Impact
Mytilus edulis
Petricolaria pholadiformis
Harmothoe
Streblospio benedicti
Malmgreniella
Decapoda
Nephtys
Nephtys hombergii
Polychaeta
Capitella capitata
Phyllodoce
Anthozoa
Ascidiacea
Tharyx
Oligochaeta
Scoloplos (Scoloplos) armiger
Heteromastus filiformis
Alitta virens
Nereis
Eumida bahusiensis
Eumida
Pygospio elegans
Alitta succinea
Polydora cornuta
Lanice conchilega

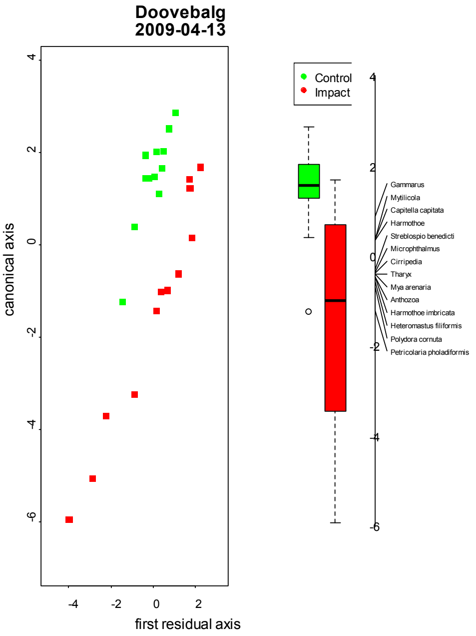
Breezanddijk

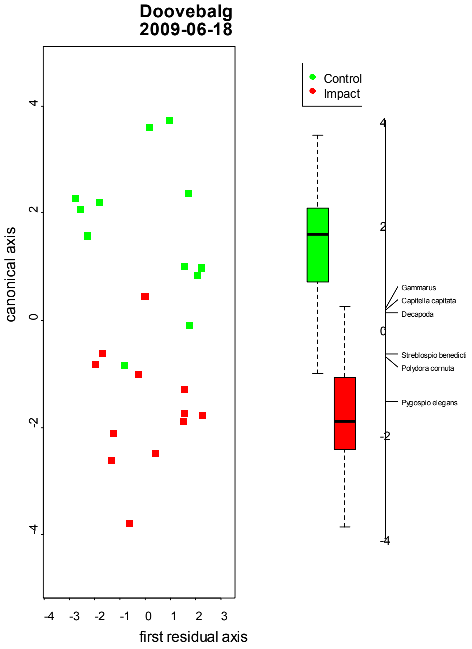



Doovebalg
Control
internal reference
time series
p = 0.005
canonical coefficient
2
1
0
-1
-2
-3
*
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Polydora cornuta
Capitella capitata
Streblospio benedicti
Pygospio elegans
Alitta virens
Tharyx
Anthozoa
Harmothoe imbricata
Heteromastus filiformis
Harmothoe
Alitta succinea
Cirripedia
Gammarus
Oligochaeta
Mytilus edulis
Corophium volutator


Doovebalg
Impact
internal reference
time series
p = 0.005
canonical coefficient
2
1
0
-1
-2
-3
**
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Pygospio elegans
Polydora cornuta
Streblospio benedicti
Nereis
Tharyx
Anthozoa
Heteromastus filiformis
Alitta succinea
Mya arenaria
Harmothoe imbricata
Gammarus
Petricolaria pholadiformis
Cirripedia
Oligochaeta
Mytilus edulis
Capitella capitata
Ascidiacea
Corophium volutator
Alitta virens
Crepidula fornicata
Lanice conchilega


Doovebalg
Control
Impact
p = 0.059
canonical coefficient
0.5
0.0
-0.5
-1.0
-1.5
* ns
*
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Gammarus
Mytilus edulis
Capitella capitata
Harmothoe imbricata
Lanice conchilega
Crepidula fornicata
Ascidiacea
Anthozoa
Petricolaria pholadiformis
Nereis
Tharyx
Streblospio benedicti
Heteromastus filiformis
Cirripedia
Alitta succinea
Oligochaeta
Pygospio elegans
Polydora cornuta


Doovebalg
2009-04-13
canonical axis
4
2
0
-2
-4
-6
-4
-2
0
2
first residual axis
Control
Impact
4
2
0
-2
-4
-6
Gammarus
Mytilicola
Capitella capitata
Harmothoe
Streblospio benedicti
Microphthalmus
Cirripedia
Tharyx
Mya arenaria
Anthozoa
Harmothoe imbricata
Heteromastus filiformis
Polydora cornuta
Petricolaria pholadiformis


Doovebalg
2009-06-18
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2
0
-2
-4
-4
-3
-2
-1
0
1
2
3
first residual axis
Control
Impact
4
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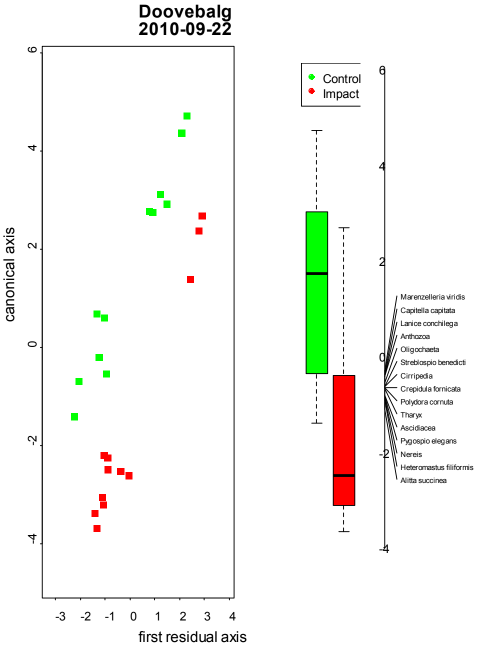
0
-2
-4
Gammarus
Capitella capitata
Decapoda
Streblospio benedicti
Polydora cornuta
Pygospio elegans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2010-09-22
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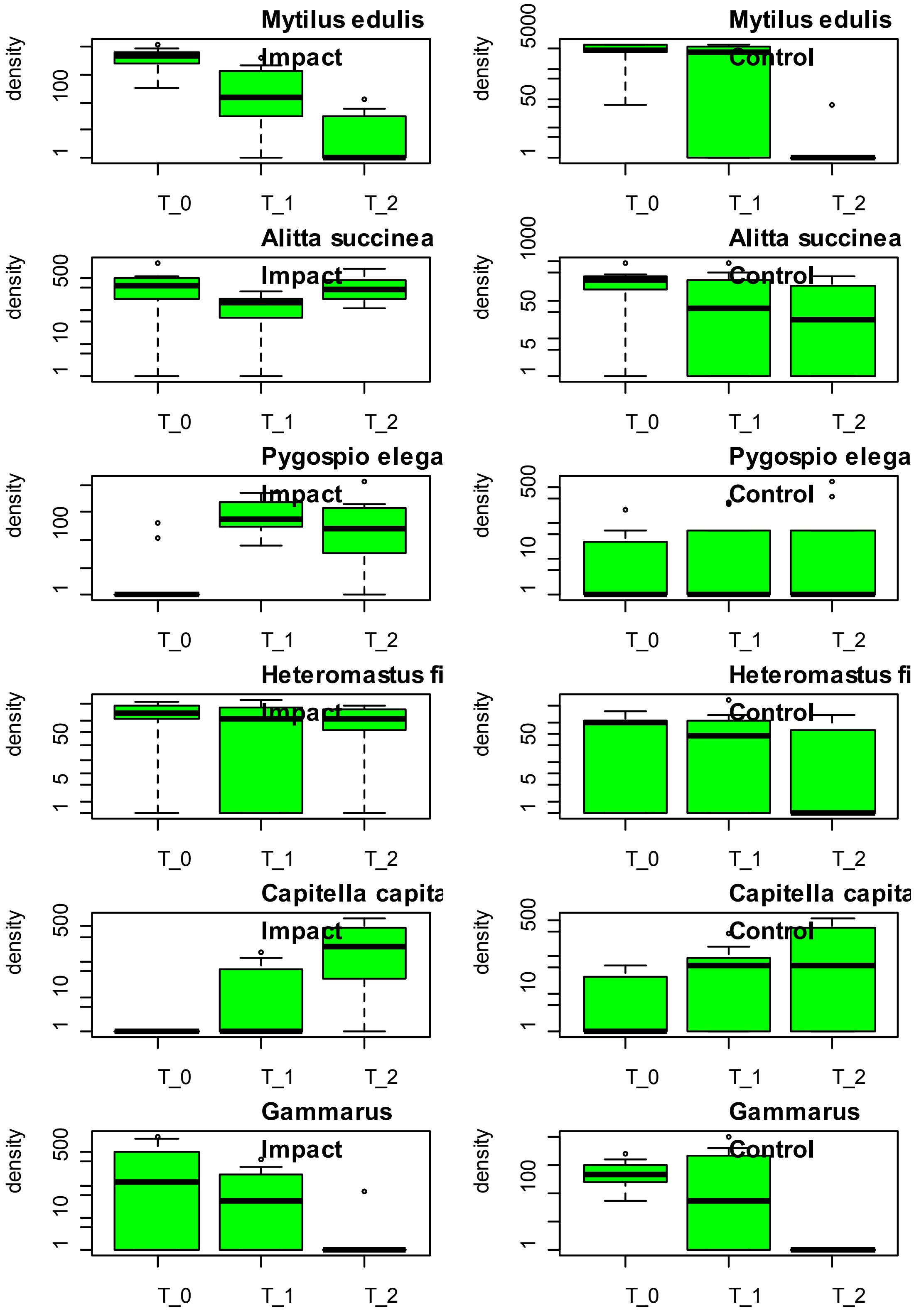
6
4
2
0
-2
-4
-3
-2
-1
0
1
2
3
4
first residual axis
Control
Impact
6
4
2
0
-2
-4
Marenzelleria viridis
Capitella capitata
Lanice conchilega
Anthozoa
Oligochaeta
Streblospio benedicti
Cirripedia
Crepidula fornicata
Polydora cornuta
Tharyx
Ascidiacea
Pygospio elegans
Nereis
Heteromastus filiformis
Alitta succinea

Doovebalg


Mytilus edulis
Impact
Mytilus edulis
Control
Alitta succinea
Impact
Alitta succinea
Control
Pygospio elega
Impact
Pygospio elega
Control
Heteromastus fi
Impact
Heteromastus fi
Control
Capitella capita
Impact
Capitella capita
Control
Gammarus
Impact
Gammarus
Control
density
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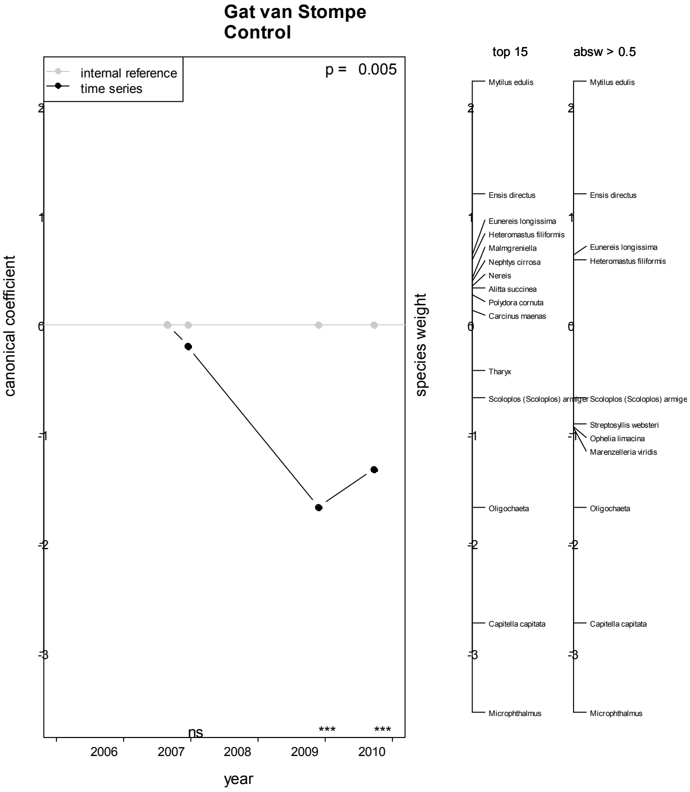
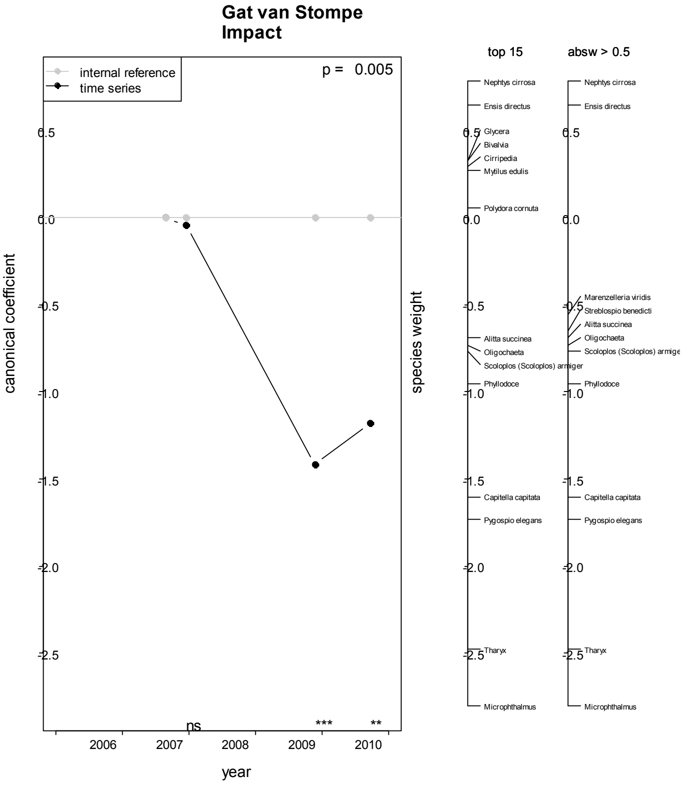
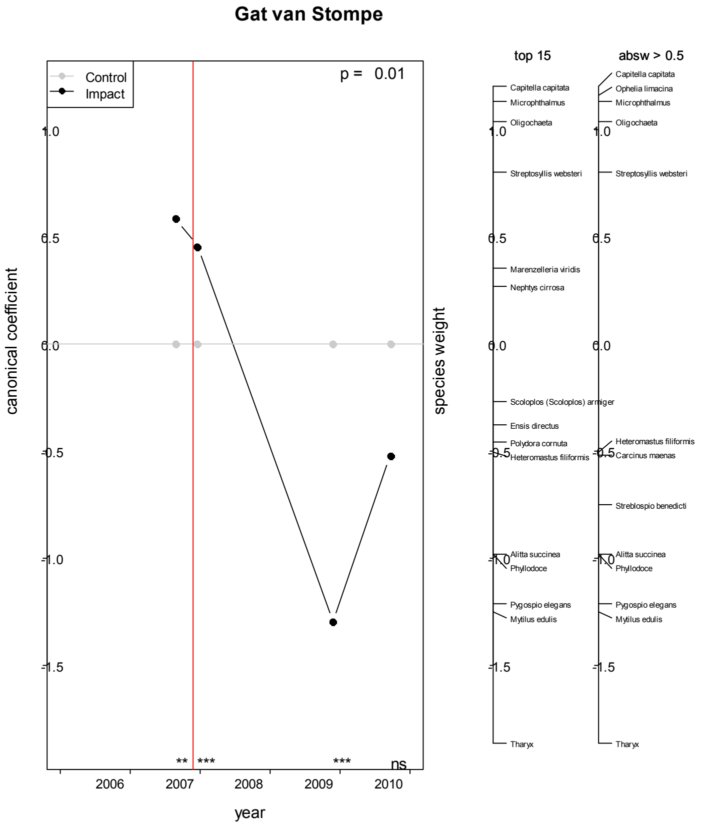
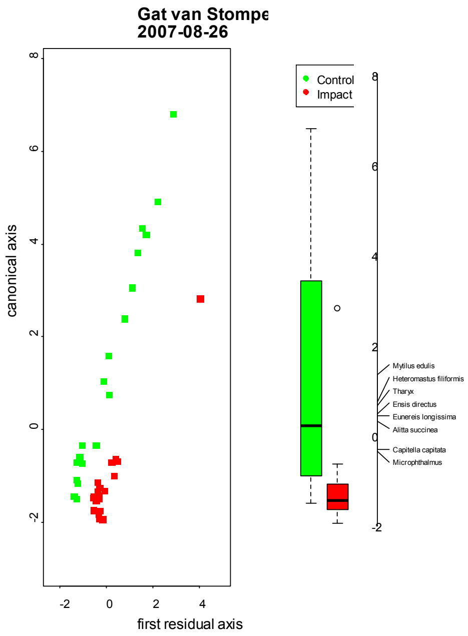
500
1000
5000
T_0
T_1
T_2

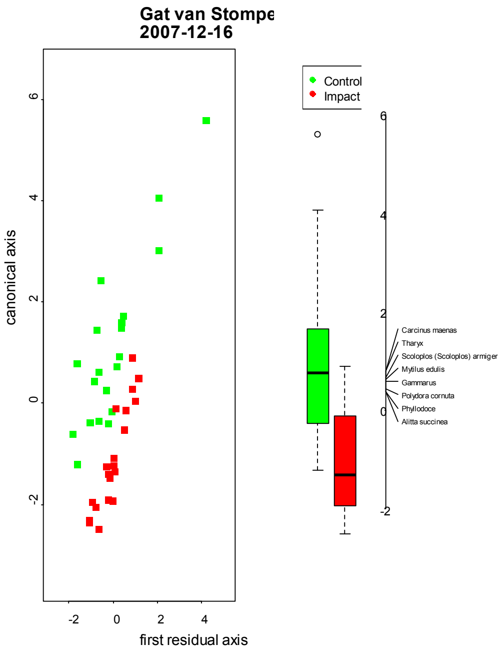

Gat van Stompe
Control
internal reference
time series
p = 0.005
canonical coefficient
2
1
0
-1
-2
-3
ns
***
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Mytilus edulis
Ensis directus
Eunereis longissima
Heteromastus filiformis
Malmgreniella
Nephtys cirrosa
Nereis
Alitta succinea
Polydora cornuta
Carcinus maenas
Tharyx
Scoloplos (Scoloplos) armiger
Streptosyllis websteri
Ophelia limacina
Marenzelleria viridis
Oligochaeta
Capitella capitata
Microphthalmus


Gat van Stompe
Impact
internal reference
time series
p = 0.005
canonical coefficient
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
ns
***
**
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Nephtys cirrosa
Ensis directus
Glycera
Bivalvia
Cirripedia
Mytilus edulis
Polydora cornuta
Marenzelleria viridis
Streblospio benedicti
Alitta succinea
Oligochaeta
Scoloplos (Scoloplos) armiger
Phyllodoce
Capitella capitata
Pygospio elegans
Tharyx
Microphthalmus

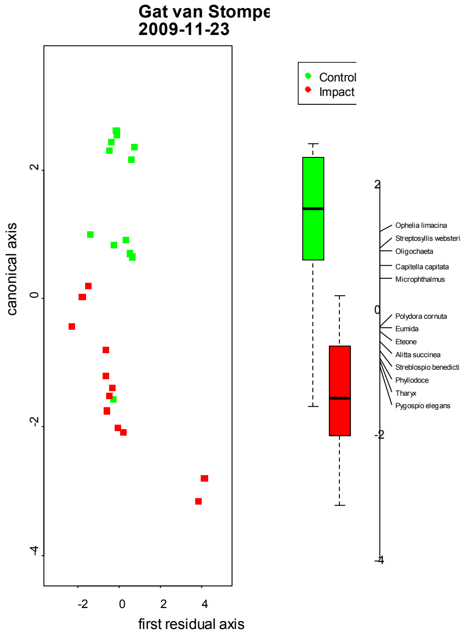

Gat van Stompe
Control
Impact
p = 0.01
canonical coefficient
1.0
0.5
0.0
-0.5
-1.0
-1.5
** *** *** ns
2006
2007
2008
2009
2010
year
species weight
top 15
Capitella capitata
Microphthalmus
Oligochaeta
Streptosyllis websteri
Marenzelleria viridis
Nephtys cirrosa
Scoloplos (Scoloplos) armiger
Ensis directus
Polydora cornuta
Heteromastus filiformis
Alitta succinea
Phyllodoce
Pygospio elegans
Mytilus edulis
Tharyx
absw > 0.5
Capitella capitata
Ophelia limacina
Microphthalmus
Oligochaeta
Streptosyllis websteri
Heteromastus filiformis
Carcinus maenas
Streblospio benedicti
Alitta succinea
Phyllodoce
Pygospio elegans
Mytilus edulis
Tharyx



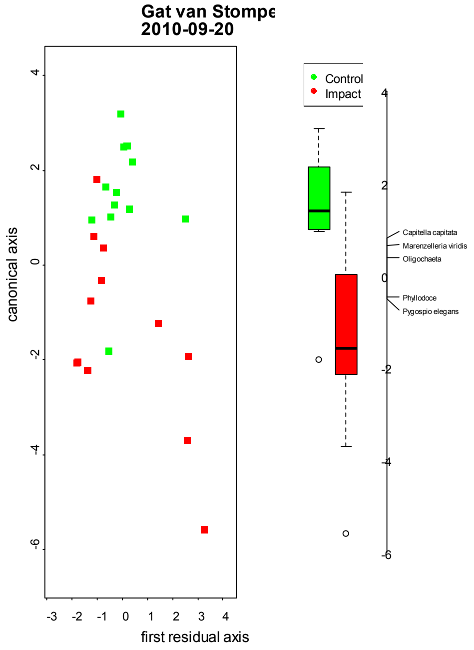
Gat van Stompe
2007-08-26



Gat van Stompe
2007-12-16

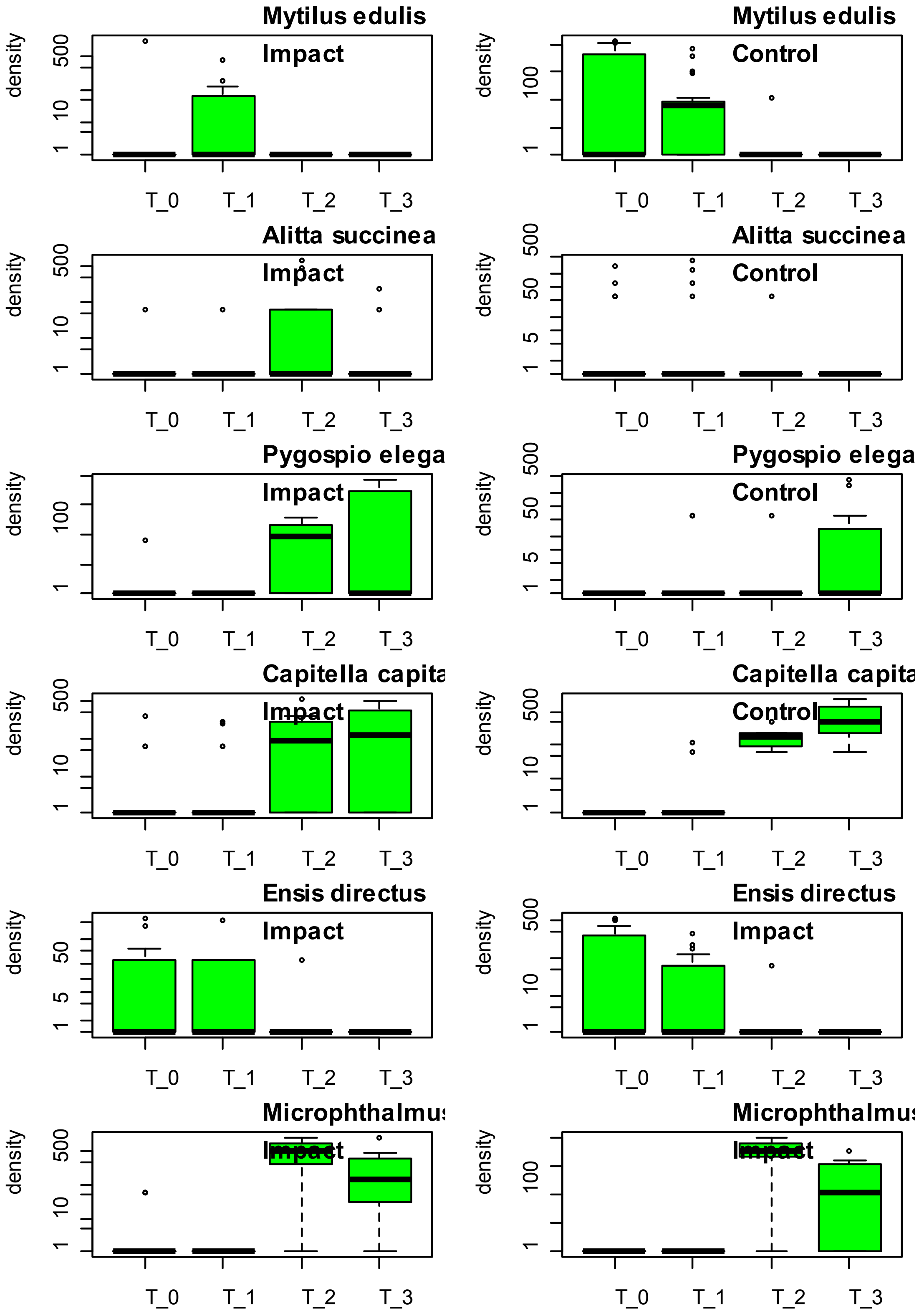


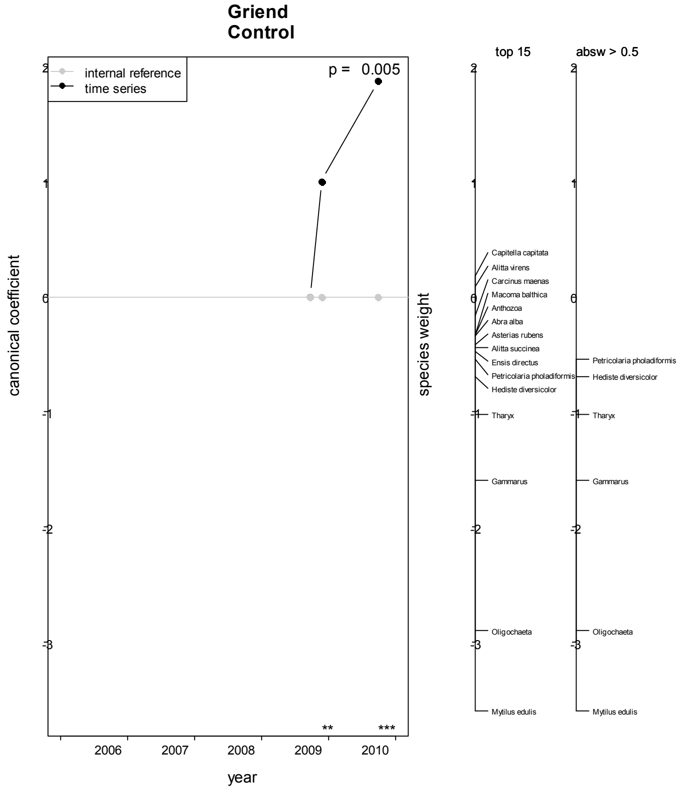
Gat van Stompe
2009-11-23

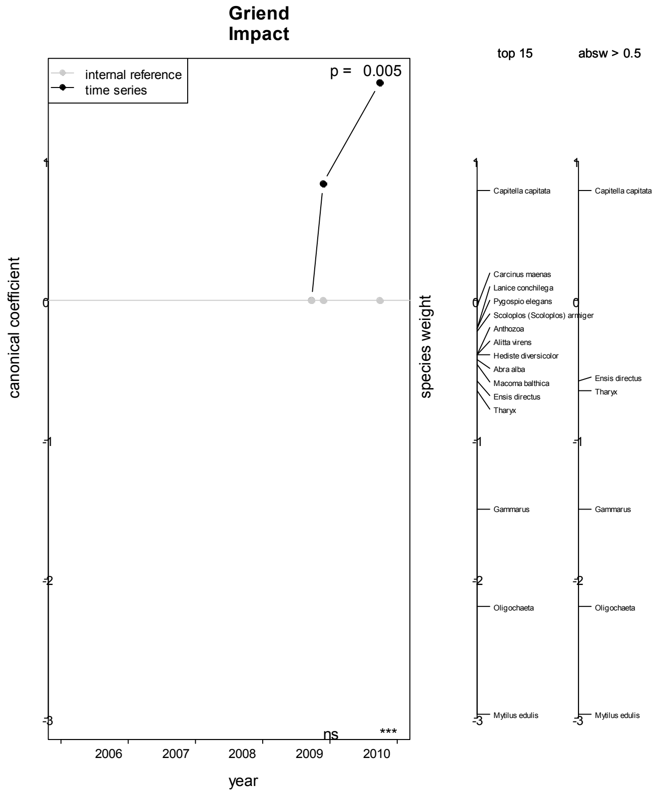


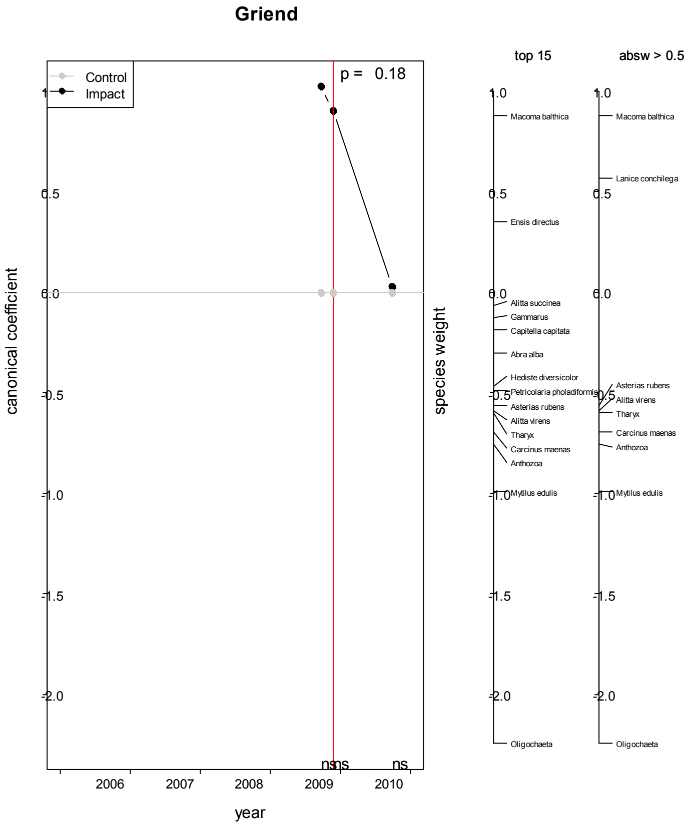
Gat van Stompe
2010-09-20

Gat van Stompe




Griend
Control
internal reference
time series
p = 0.005
canonical coefficient
2
1
0
-1
-2
-3
**
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Capitella capitata
Alitta virens
Carcinus maenas
Macoma balthica
Anthozoa
Abra alba
Asterias rubens
Alitta succinea
Ensis directus
Petricolaria pholadiformis
Hediste diversicolor
Tharyx
Gammarus
Oligochaeta
Mytilus edulis
Petricolaria pholadiformis
Hediste diversicolor
Tharyx
Gammarus
Oligochaeta
Mytilus edulis


Griend
Impact
internal reference
time series
p = 0.005
canonical coefficient
1
0
-1
-2
-3
ns
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Capitella capitata
Carcinus maenas
Lanice conchilega
Pygospio elegans
Scoloplos (Scoloplos) armiger
Anthozoa
Alitta virens
Hediste diversicolor
Abra alba
Macoma balthica
Ensis directus
Tharyx
Gammarus
Oligochaeta
Mytilus edulis
Capitella capitata
Ensis directus
Tharyx
Gammarus
Oligochaeta
Mytilus edulis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Control
Impact
p = 0.18
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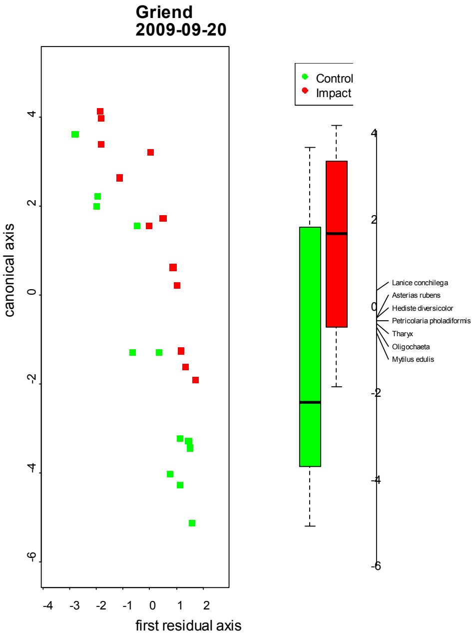
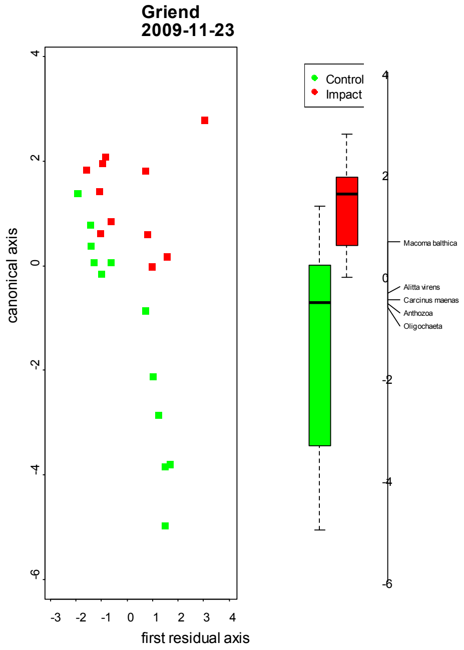
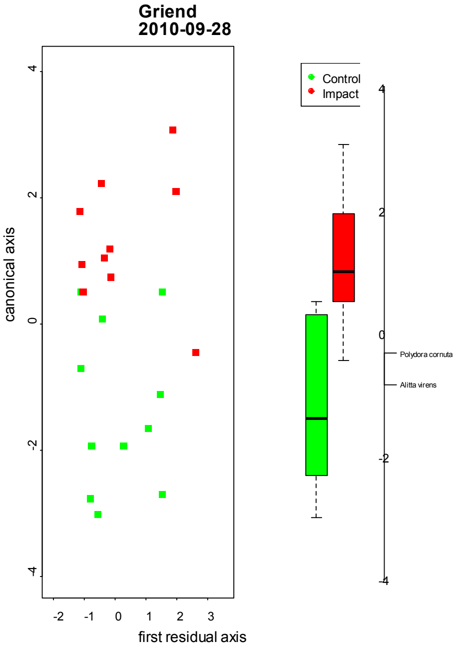
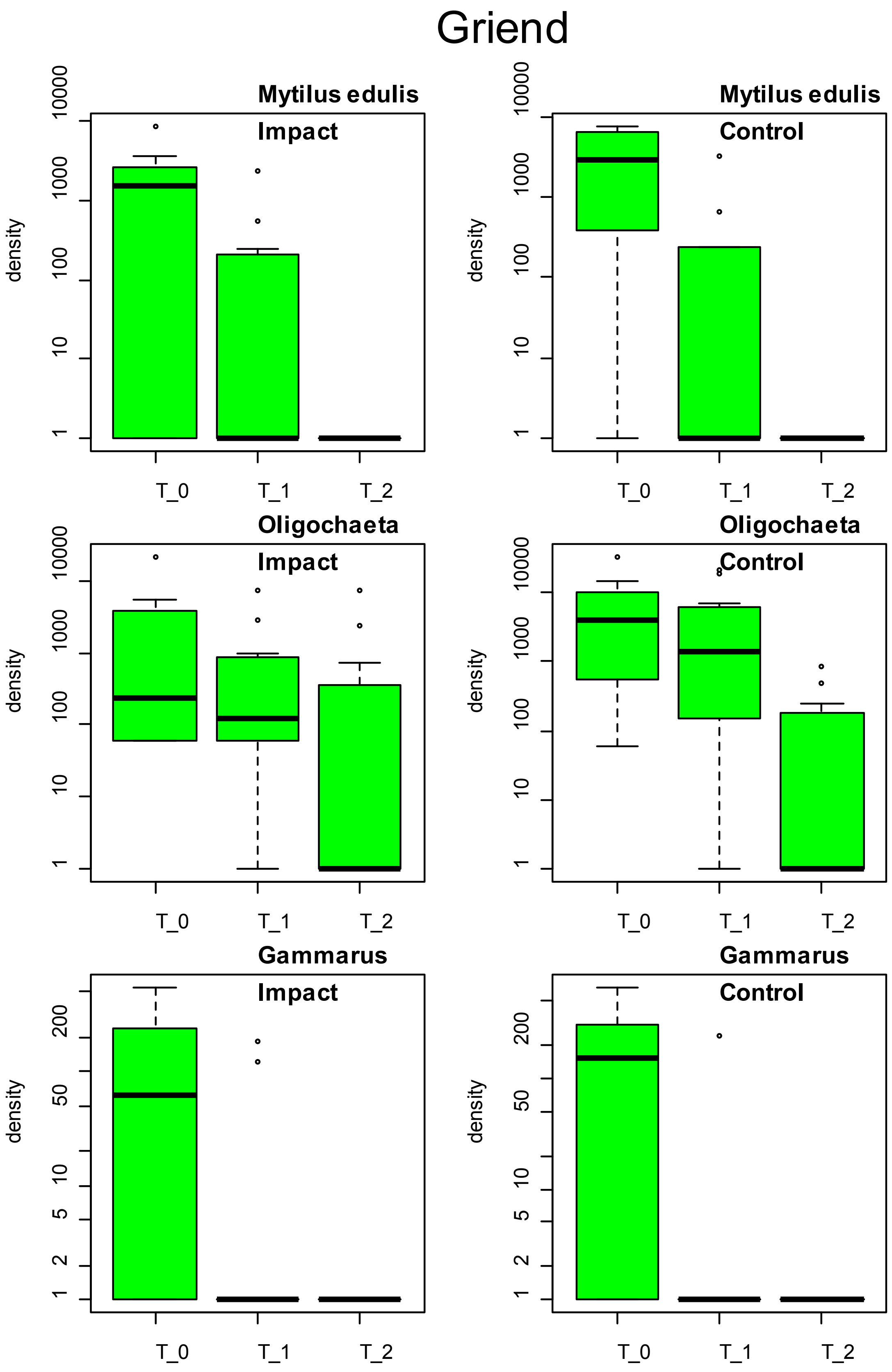
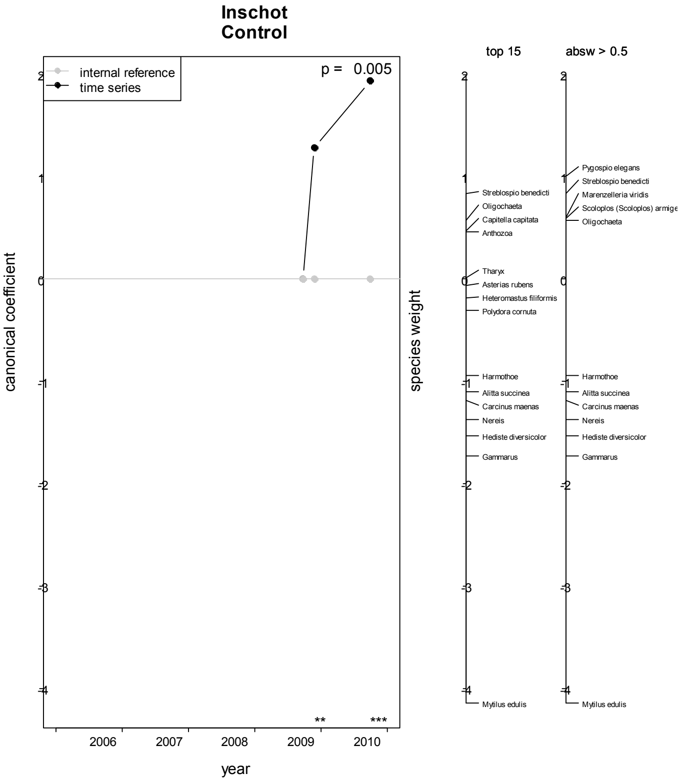
0.5
0.0
-0.5
-1.0
-1.5
-2.0
ns
ns
ns
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Macoma balthica
Ensis directus
Alitta succinea
Gammarus
Capitella capitata
Abra alba
Hediste diversicolor
Petricolaria pholadiformis
Asterias rubens
Alitta virens
Tharyx
Carcinus maenas
Anthozoa
Mytilus edulis
Oligochaeta
Macoma balthica
Lanice conchilega
Asterias rubens
Alitta virens
Tharyx
Carcinus maenas
Anthozoa
Mytilus edulis
Oligochaeta

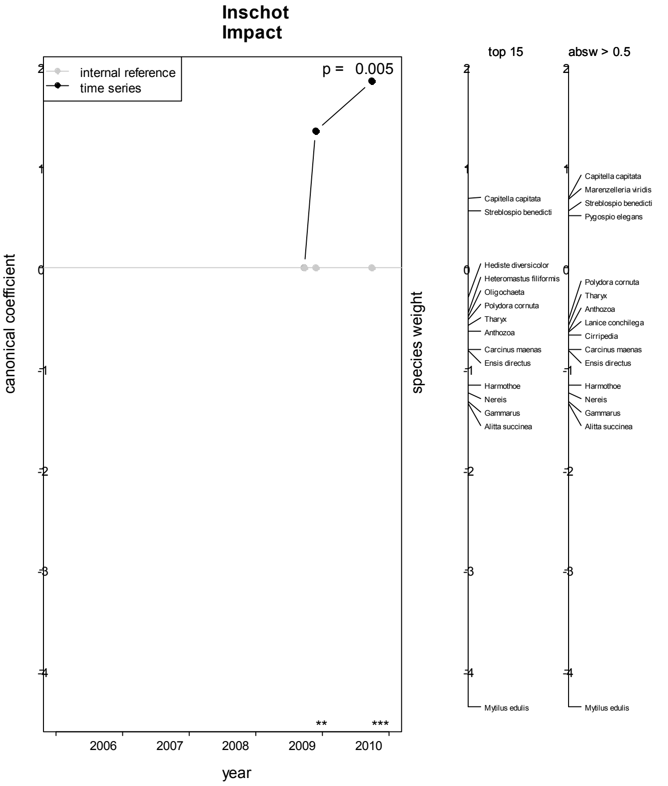

Griend
2009-09-20
canonical axis
first residual axis
-4
-3
-2
-1
0
1
2
4
2
0
-2
-4
-6
Control
Impact
Lanice conchilega
Asterias rubens
Hediste diversicolor
Petricolaria pholadiformis
Tharyx
Oligochaeta
Mytilus edulis

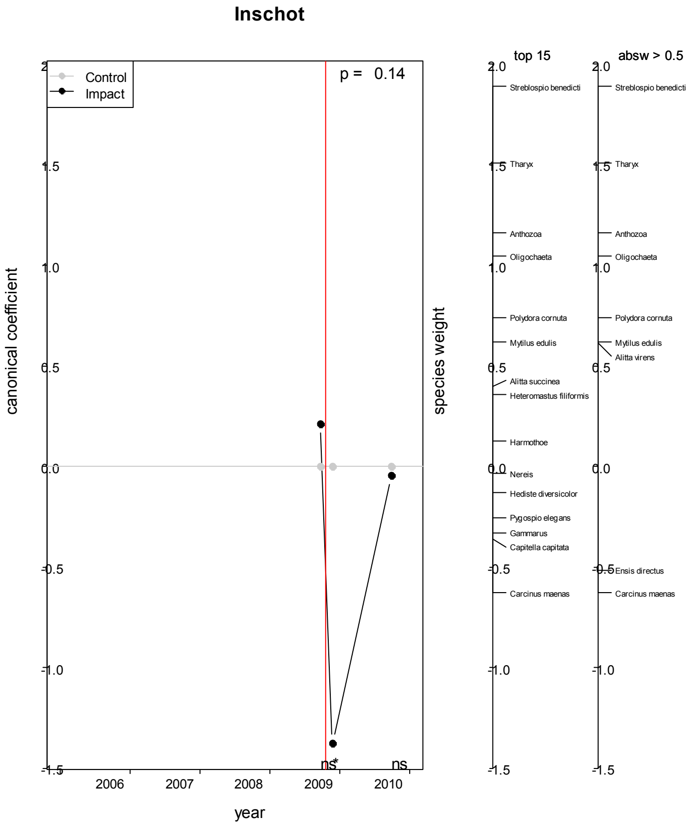

Griend
2009-11-23
canonical axis
first residual axis
-3
-2
-1
0
1
2
3
4
4
2
0
-2
-4
-6
Control
Impact
Macoma balthica
Alitta virens
Carcinus maenas
Anthozoa
Oligochaeta

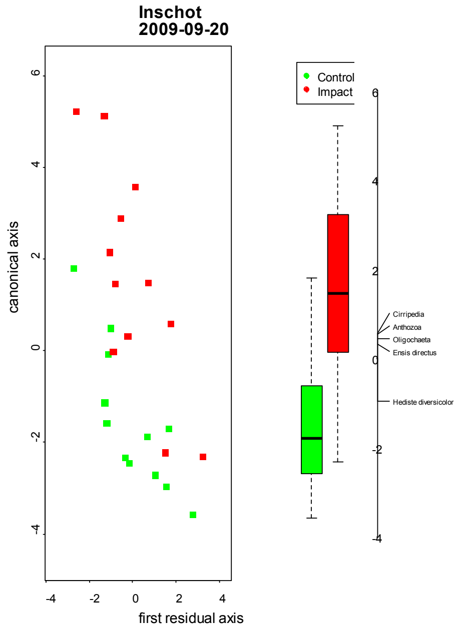

Griend
2010-09-28
canonical axis
first residual axis
-2
-1
0
1
2
3
4
2
0
-2
-4
Control
Impact
Polydora cornuta
Alitta virens

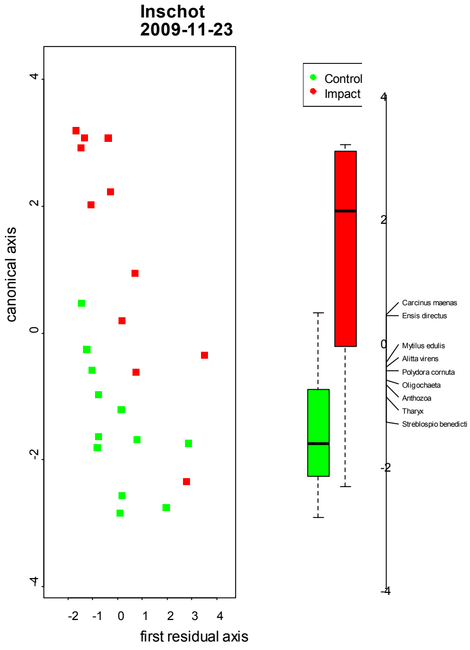

Griend
Mytilus edulis
Impact
Mytilus edulis
Control
Oligochaeta
Impact
Oligochaeta
Control
Gammarus
Impact
Gammarus
Control
density
1
10
100
1000
10000
2
5
50
200
T_0
T_1
T_2

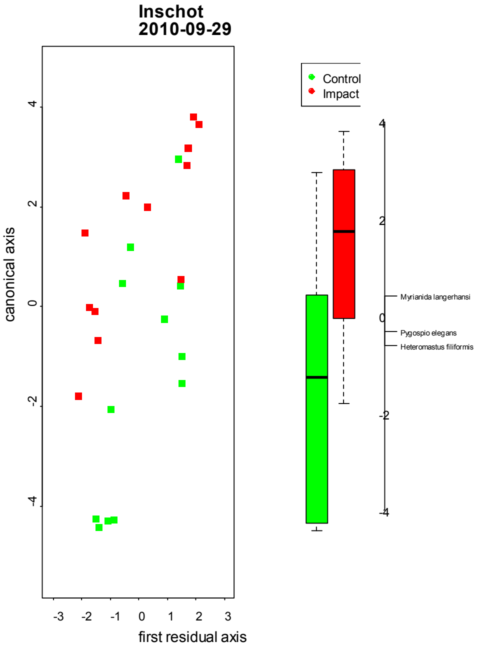

Inschot
Control
internal reference
time series
p = 0.005
canonical coefficient
2
1
0
-1
-2
-3
-4
**
***
2006
2007
2008
2009
2010
year
species weight
top 15
Streblospio benedicti
Oligochaeta
Capitella capitata
Anthozoa
Tharyx
Asterias rubens
Heteromastus filiformis
Polydora cornuta
Harmothoe
Alitta succinea
Carcinus maenas
Nereis
Hediste diversicolor
Gammarus
Mytilus edulis
absw > 0.5
Pygospio elegans
Streblospio benedicti
Marenzelleria viridis
Scoloplos (Scoloplos) armige
Oligochaeta
Harmothoe
Alitta succinea
Carcinus maenas
Nereis
Hediste diversicolor
Gammarus
Mytilus edulis


Inschot
Impact
internal reference
time series
p = 0.005
canonical coefficient
2
1
0
-1
-2
-3
-4
**
***
2006
2007
2008
2009
2010
year
species weight
top 15
Capitella capitata
Streblospio benedicti
Hediste diversicolor
Heteromastus filiformis
Oligochaeta
Polydora cornuta
Tharyx
Anthozoa
Carcinus maenas
Ensis directus
Harmothoe
Nereis
Gammarus
Alitta succinea
Mytilus edulis
absw > 0.5
Capitella capitata
Marenzelleria viridis
Streblospio benedicti
Pygospio elegans
Polydora cornuta
Tharyx
Anthozoa
Lanice conchilega
Cirripedia
Carcinus maenas
Ensis directus
Harmothoe
Nereis
Gammarus
Alitta succinea
Mytilus edulis

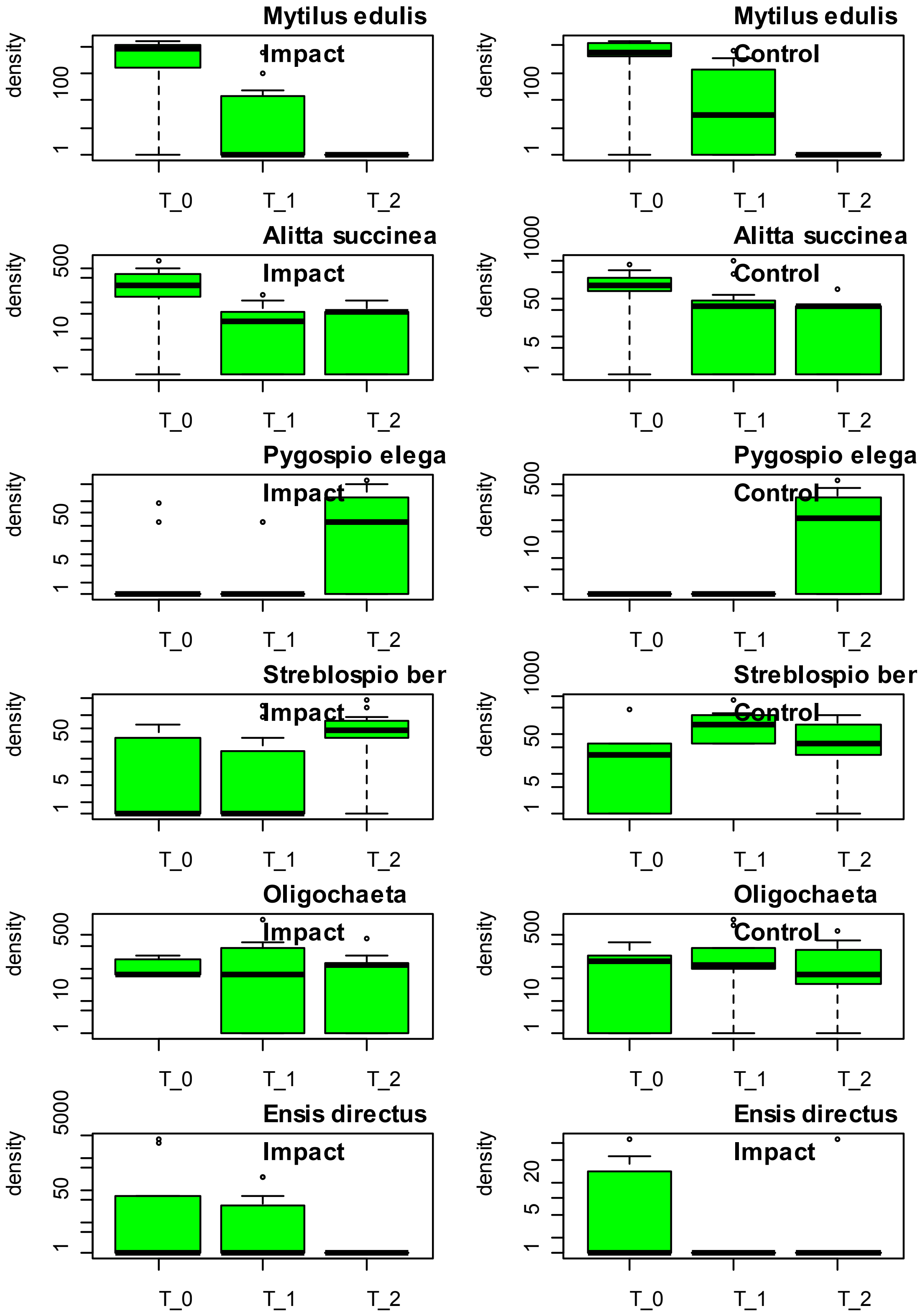

Inschot
Control
Impact
p = 0.14
canonical coefficient
year
2006
2007
2008
2009
2010
ns*
ns
2
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
species weight
top 15
absw > 0.5
Streblospio benedicti
Tharyx
Anthozoa
Oligochaeta
Polydora cornuta
Mytilus edulis
Alitta succinea
Heteromastus filiformis
Harmothoe
Nereis
Hediste diversicolor
Pygospio elegans
Gammarus
Capitella capitata
Carcinus maenas
Alitta virens
Ensis directus

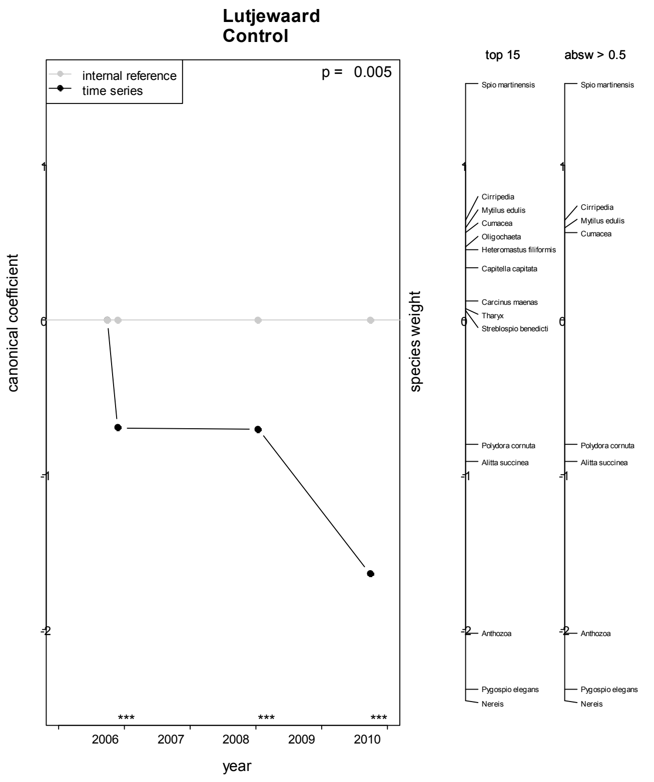

Inschot
2009-09-20

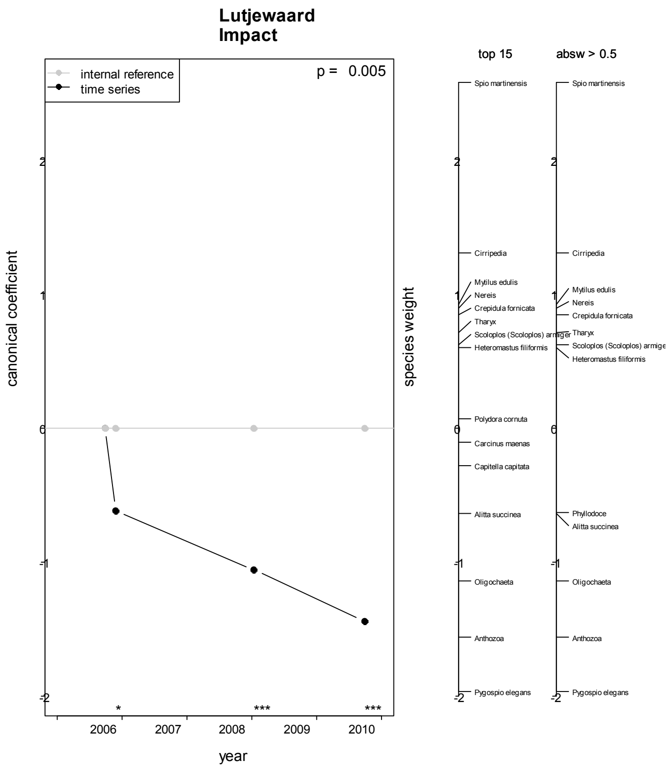

Inschot
2009-11-23

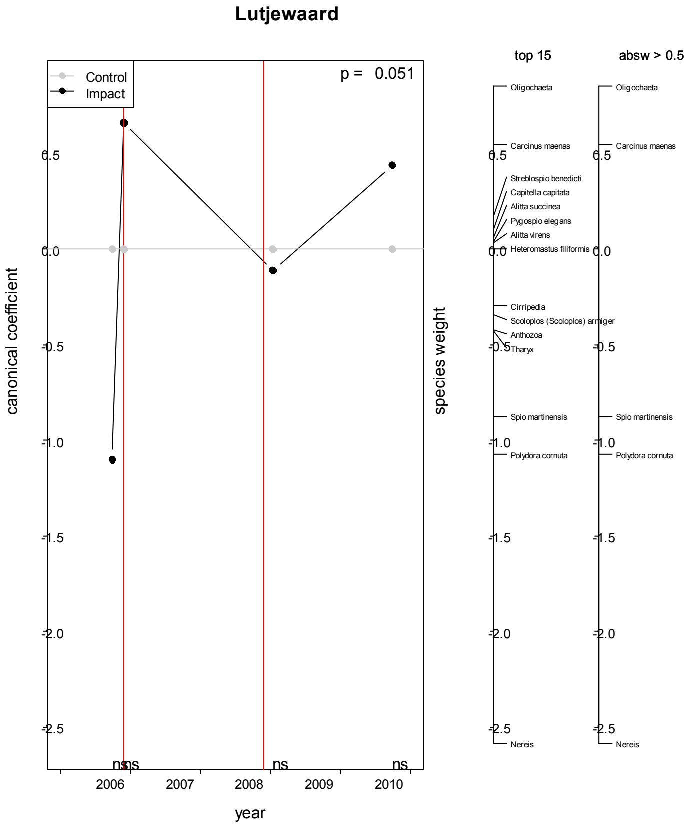

Inschot
2010-09-29

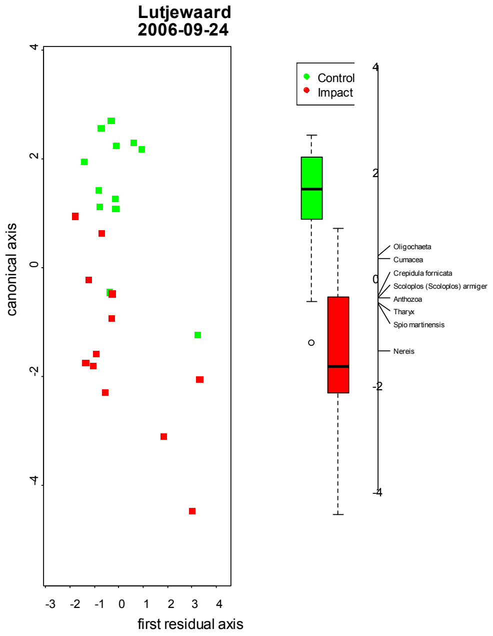
Inschot

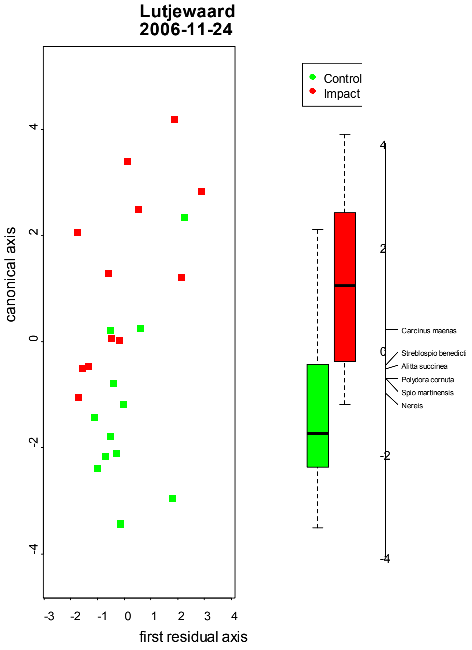

Mytilus edulis
Impact
density
1
100
T_0
T_1
T_2
Mytilus edulis
Control
density
1
100
T_0
T_1
T_2
Alitta succinea
Impact
density
1
10
500
T_0
T_1
T_2
Alitta succinea
Control
density
1
5
50
1000
T_0
T_1
T_2
Pygospio elega
Impact
density
1
5
50
T_0
T_1
T_2
Pygospio elega
Control
density
1
10
500
T_0
T_1
T_2
Streblospio ber
Impact
density
1
5
50
T_0
T_1
T_2
Streblospio ber
Control
density
1
5
50
1000
T_0
T_1
T_2
Oligochaeta
Impact
density
1
10
500
T_0
T_1
T_2
Oligochaeta
Control
density
1
10
500
T_0
T_1
T_2
Ensis directus
Impact
density
1
50
5000
T_0
T_1
T_2
Ensis directus
Impact
density
1
5
20
T_0
T_1
T_2

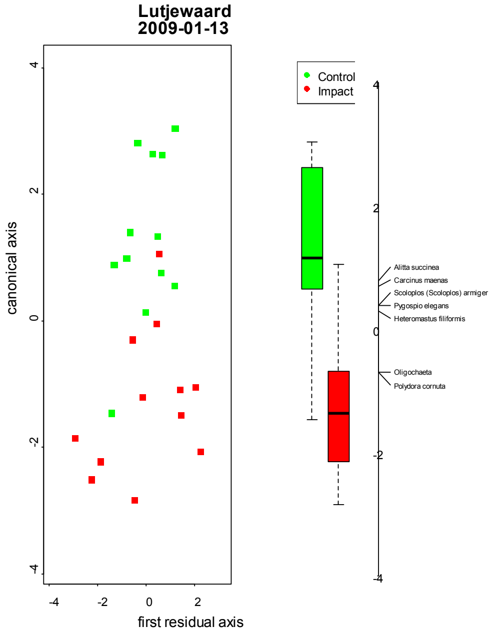

Lutjewaard
Control
internal reference
time series
p = 0.005
canonical coefficient
1
0
-1
-2
*** *** ***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Spio martinensis
Cirripedia
Mytilus edulis
Cumacea
Oligochaeta
Heteromastus filiformis
Capitella capitata
Carcinus maenas
Tharyx
Streblospio benedicti
Polydora cornuta
Alitta succinea
Anthozoa
Pygospio elegans
Nereis
Spio martinensis
Cirripedia
Mytilus edulis
Cumacea
Polydora cornuta
Alitta succinea
Anthozoa
Pygospio elegans
Nereis

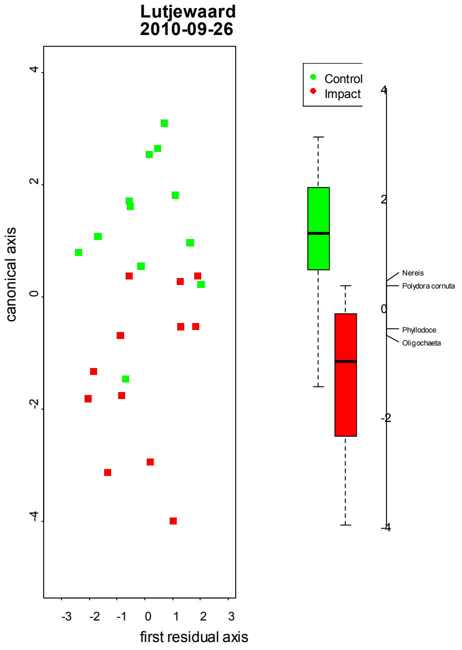

Lutjewaard
Impact
internal reference
time series
p = 0.005
canonical coefficient
2
1
0
-1
-2
* *** ***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Spio martinensis
Cirripedia
Mytilus edulis
Nereis
Crepidula fornicata
Tharyx
Scoloplos (Scoloplos) armiger
Heteromastus filiformis
Polydora cornuta
Carcinus maenas
Capitella capitata
Alitta succinea
Oligochaeta
Anthozoa
Pygospio elegans
Spio martinensis
Cirripedia
Mytilus edulis
Nereis
Crepidula fornicata
Tharyx
Scoloplos (Scoloplos) armige
Heteromastus filiformis
Phyllodoce
Alitta succinea
Oligochaeta
Anthozoa
Pygospio elegans


Lutjewaard
Control
Impact
p = 0.051
canonical coefficient
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
ns
ns
ns
ns
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Oligochaeta
Carcinus maenas
Streblospio benedicti
Capitella capitata
Alitta succinea
Pygospio elegans
Alitta virens
Heteromastus filiformis
Cirripedia
Scoloplos (Scoloplos) armiger
Anthozoa
Tharyx
Spio martinensis
Polydora cornuta
Nereis
Oligochaeta
Carcinus maenas
Spio martinensis
Polydora cornuta
Nereis

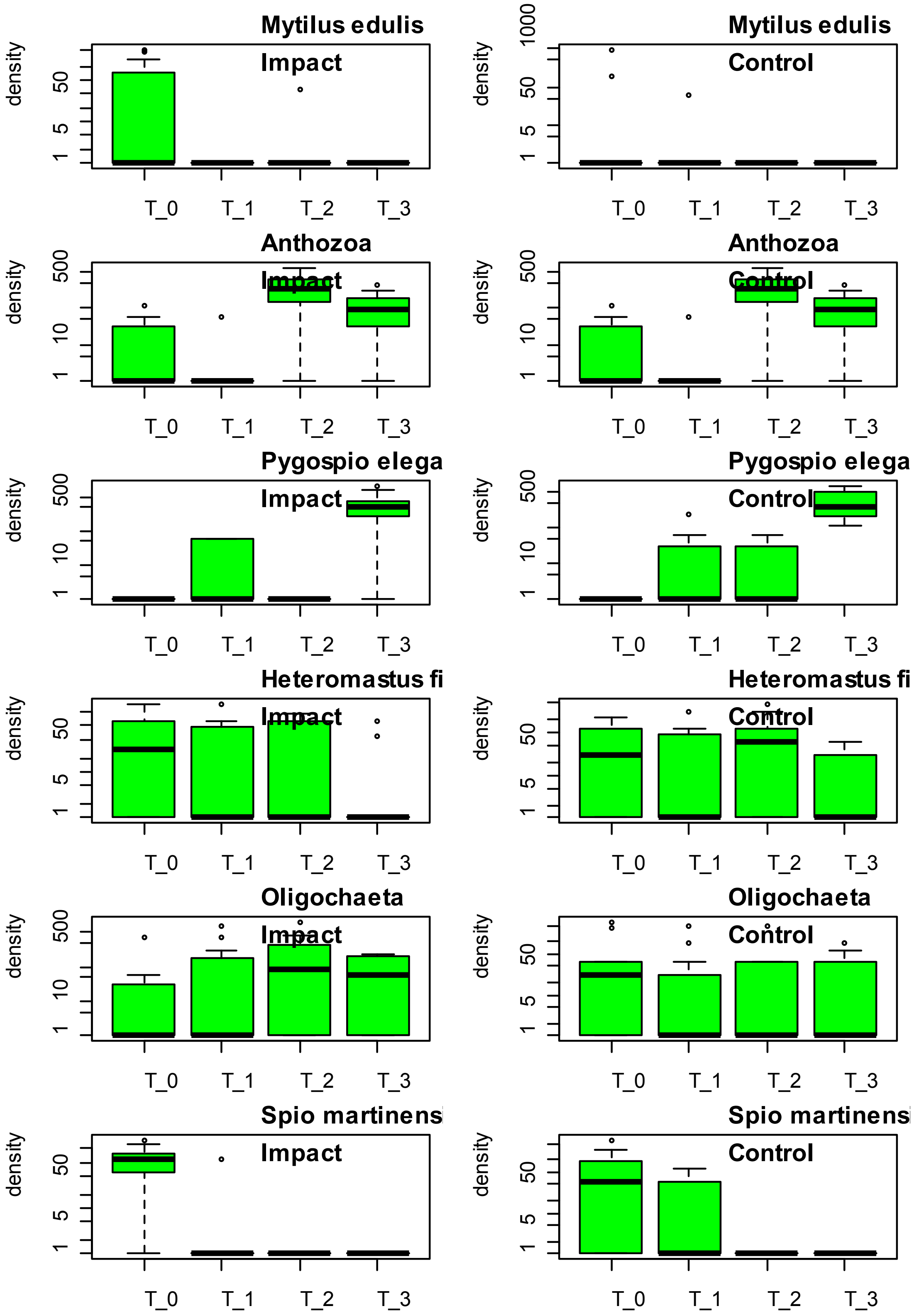

Lutjewaard
2006-09-24
canonical axis
4
2
0
-2
-4
-3 -2 -1 0 1 2 3 4
first residual axis
Control
Impact
4
2
0
-2
-4
Oligochaeta
Cumacea
Crepidula fornicata
Scoloplos (Scoloplos) armiger
Anthozoa
Tharyx
Spio martinensis
Nereis

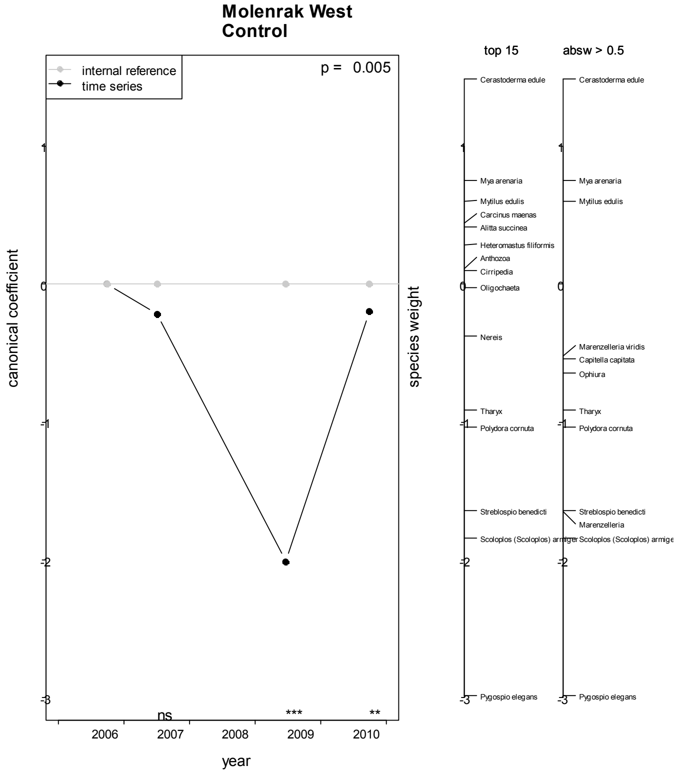

Lutjewaard
2006-11-24
canonical axis
4
2
0
-2
-4
-3 -2 -1 0 1 2 3 4
first residual axis
Control
Impact
4
2
0
-2
-4
Carcinus maenas
Streblospio benedicti
Alitta succinea
Polydora cornuta
Spio martinensis
Nereis

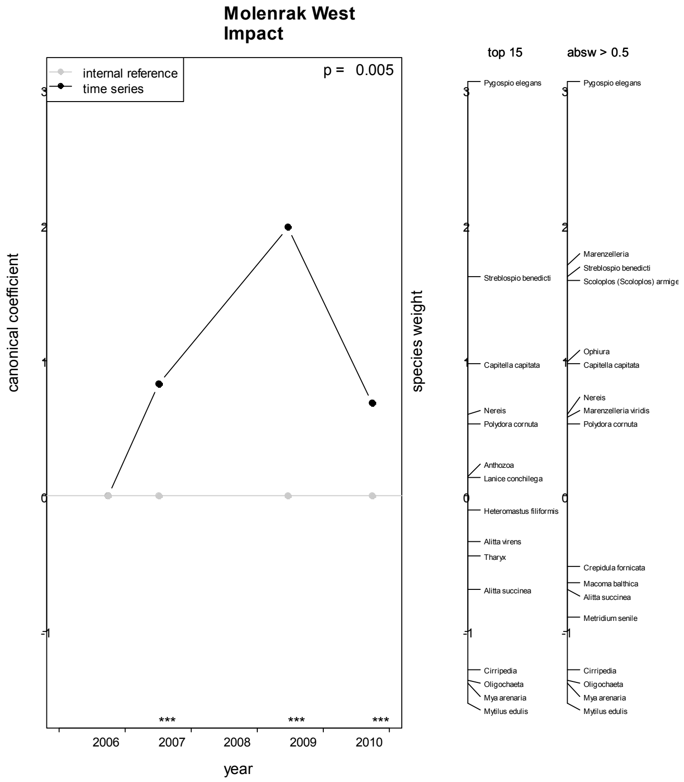

Lutjewaard
2009-01-13
canonical axis
4
2
0
-2
-4
-4 -2 0 2
first residual axis
Control
Impact
4
2
0
-2
-4
Alitta succinea
Carcinus maenas
Scoloplos (Scoloplos) armiger
Pygospio elegans
Heteromastus filiformis
Oligochaeta
Polydora cornuta

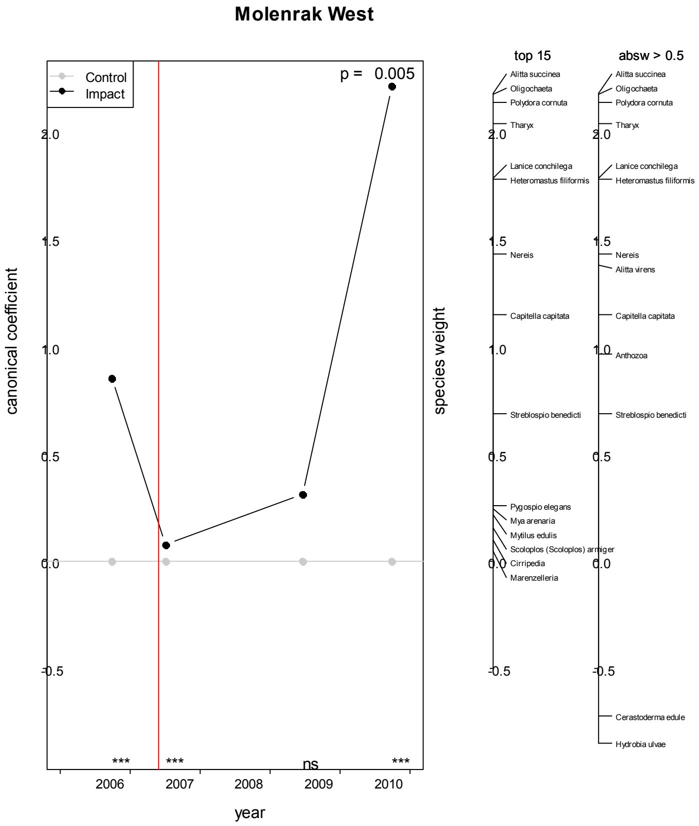

Lutjewaard
2010-09-26
canonical axis
4
2
0
-2
-4
-3 -2 -1 0 1 2 3
first residual axis
Control
Impact
4
2
0
-2
-4
Nereis
Polydora cornuta
Phyllodoce
Oligochaeta

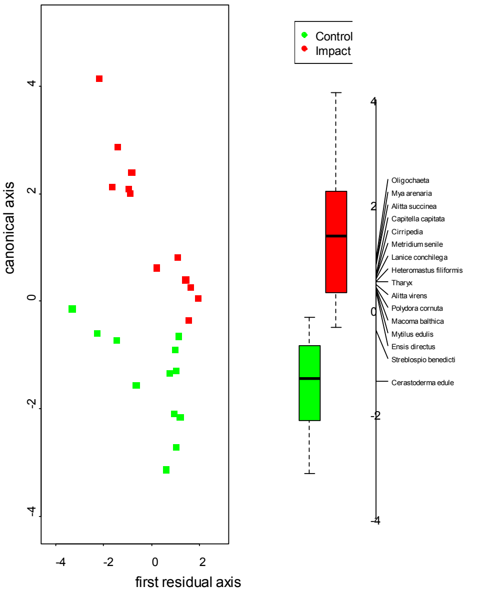
Lutjewaard


Mytilus edulis
Impact
Mytilus edulis
Control
Anthozoa
Impact
Anthozoa
Control
Pygospio elega
Impact
Pygospio elega
Control
Heteromastus fi
Impact
Heteromastus fi
Control
Oligochaeta
Impact
Oligochaeta
Control
Spio martinensi
Impact
Spio martinensi
Control
density
1
5
10
50
500
1000
T_0
T_1
T_2
T_3

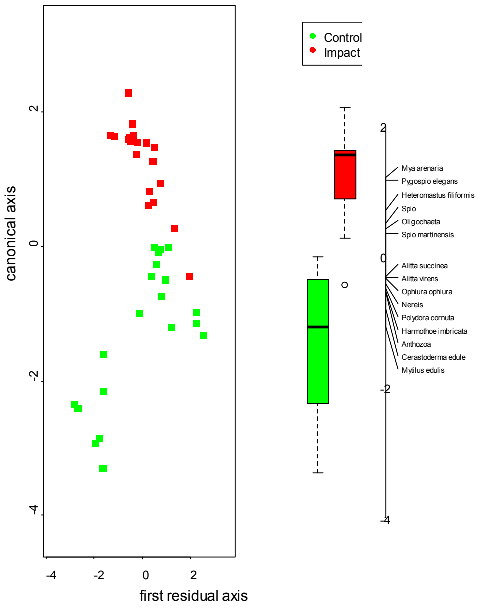

Molenrak West
Control
internal reference
time series
p = 0.005
canonical coefficient
1
0
-1
-2
-3
ns
***
**
2006
2007
2008
2009
2010
year
top 15
absw > 0.5
species weight
Cerastoderma edule
Mya arenaria
Mytilus edulis
Carcinus maenas
Alitta succinea
Heteromastus filiformis
Anthozoa
Cirripedia
Oligochaeta
Nereis
Tharyx
Polydora cornuta
Streblospio benedicti
Scoloplos (Scoloplos) armiger
Pygospio elegans
Cerastoderma edule
Mya arenaria
Mytilus edulis
Marenzelleria viridis
Capitella capitata
Ophiura
Tharyx
Polydora cornuta
Streblospio benedicti
Marenzelleria
Scoloplos (Scoloplos) armige
Pygospio elegans


Molenrak West
Impact
internal reference
time series
p = 0.005
canonical coefficient
3
2
1
0
-1
***
***
***
2006
2007
2008
2009
2010
year
top 15
absw > 0.5
species weight
Pygospio elegans
Streblospio benedicti
Capitella capitata
Nereis
Polydora cornuta
Anthozoa
Lanice conchilega
Heteromastus filiformis
Alitta virens
Tharyx
Alitta succinea
Cirripedia
Oligochaeta
Mya arenaria
Mytilus edulis
Pygospio elegans
Marenzelleria
Streblospio benedicti
Scoloplos (Scoloplos) armige
Ophiura
Capitella capitata
Nereis
Marenzelleria viridis
Polydora cornuta
Crepidula fornicata
Macoma balthica
Alitta succinea
Metridium senile
Cirripedia
Oligochaeta
Mya arenaria
Mytilus edulis

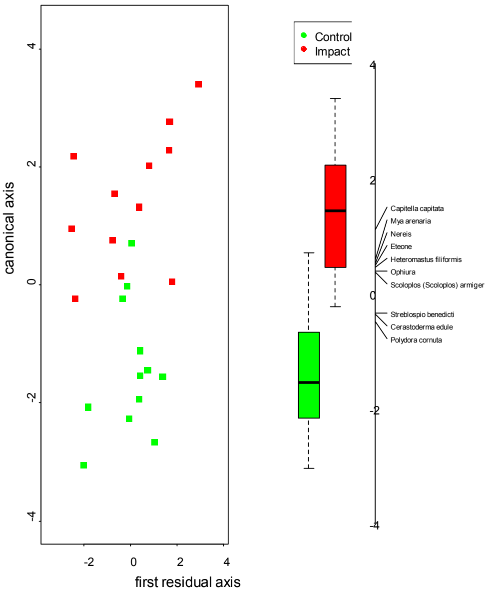

Molenrak West
Control
Impact
p = 0.005
canonical coefficient
2.0
1.5
1.0
0.5
0.0
-0.5
*** *** ns ***
2006 2007 2008 2009 2010
year
species weight
top 15
absw > 0.5
Alitta succinea
Oligochaeta
Polydora cornuta
Tharyx
Lanice conchilega
Heteromastus filiformis
Nereis
Alitta virens
Capitella capitata
Anthozoa
Streblospio benedicti
Pygospio elegans
Mya arenaria
Mytilus edulis
Scoloplos (Scoloplos) armiger
Cirripedia
Marenzelleria
Cerastoderma edule
Hydrobia ulvae



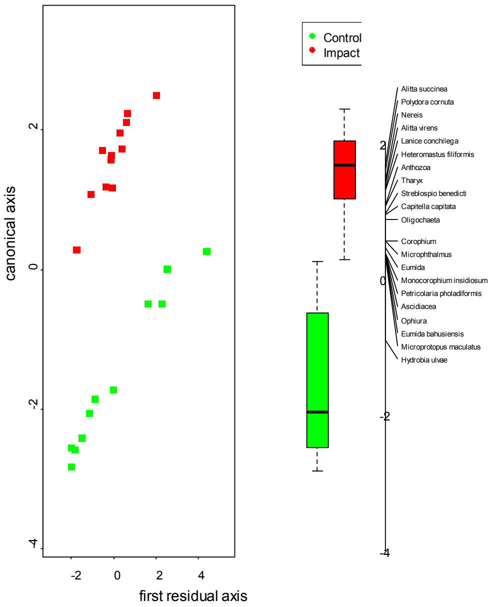
Molenrak West
2006-09-24



Molenrak West
2007-07-01

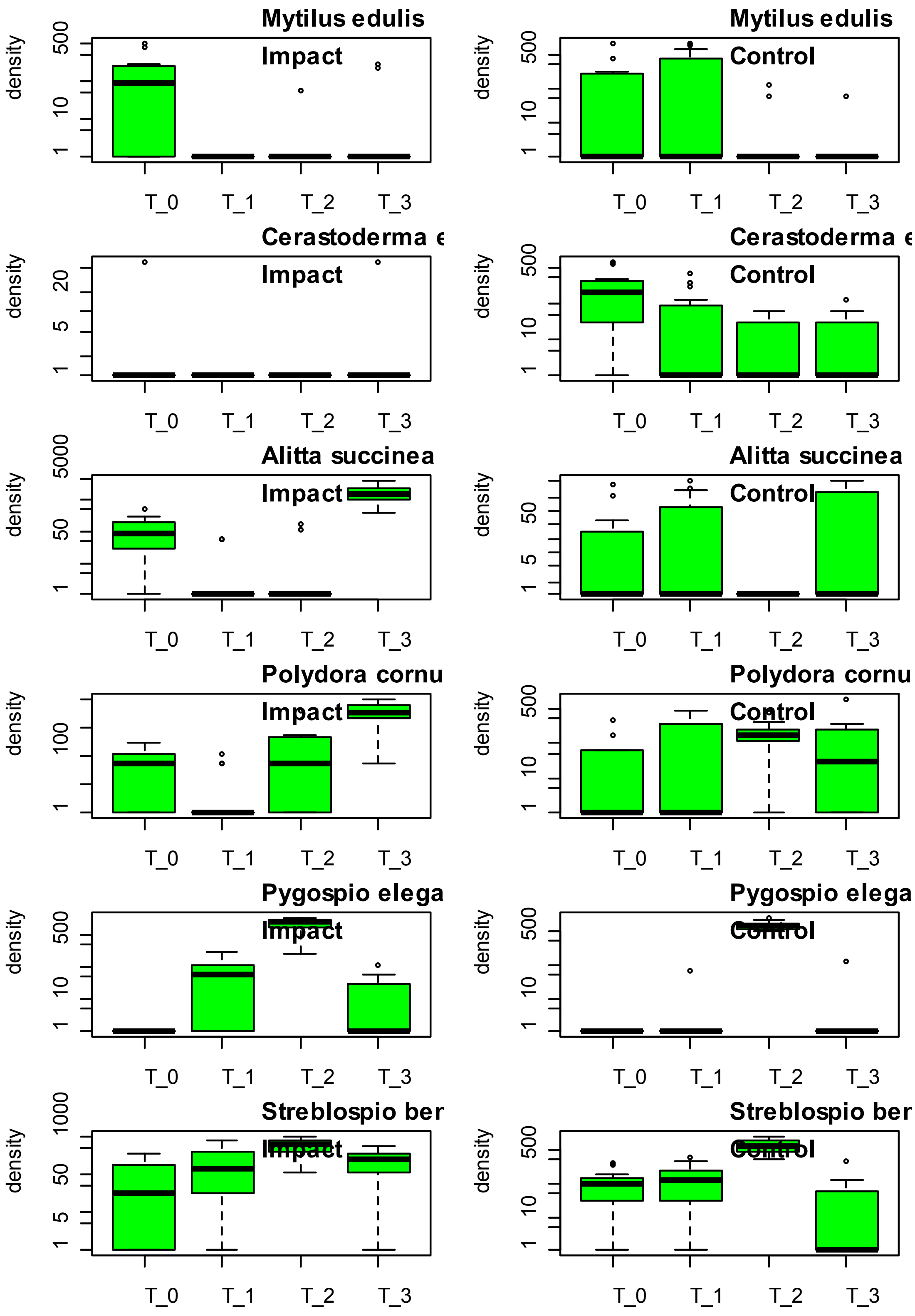


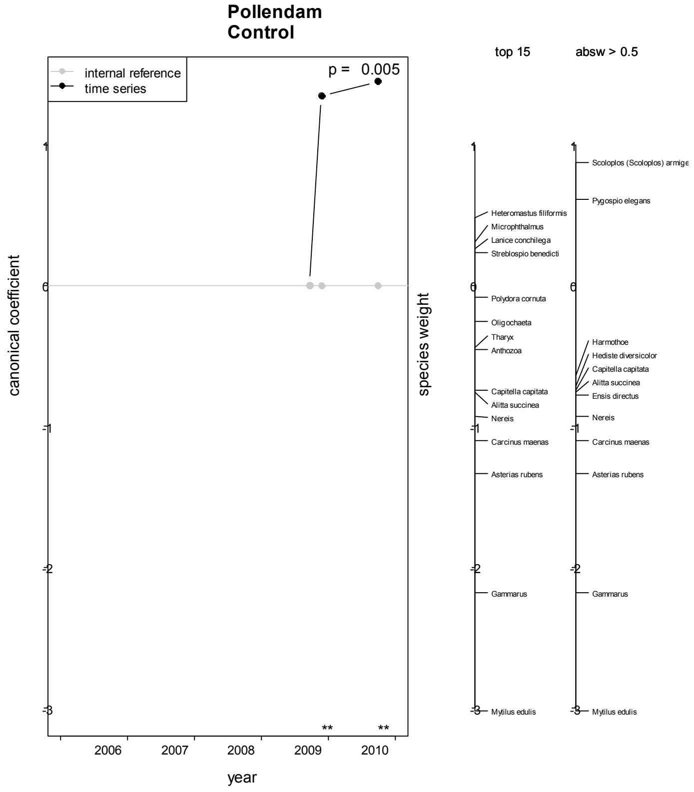
Molenrak West
2009-06-18



Molenrak West
2010-09-28

Molenrak West




Pollendam
Control
internal reference
time series
p = 0.005
canonical coefficient
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0
-1
-2
-3
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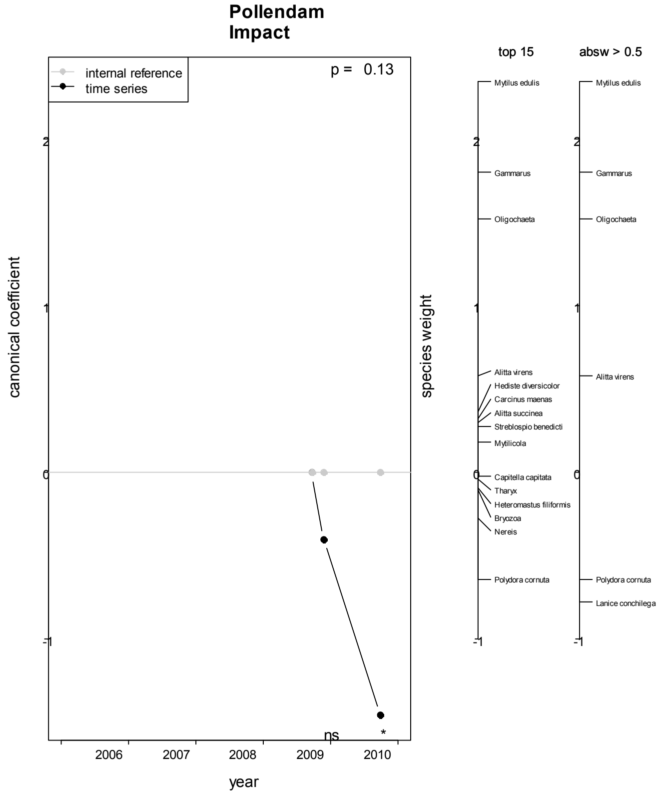
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Heteromastus filiformis
Microphthalmus
Lanice conchilega
Streblospio benedicti
Polydora cornuta
Oligochaeta
Tharyx
Anthozoa
Capitella capitata
Alitta succinea
Nereis
Carcinus maenas
Asterias rubens
Gammarus
Mytilus edulis
Scoloplos (Scoloplos) armige
Pygospio elegans
Harmothoe
Hediste diversicolor
Capitella capitata
Alitta succinea
Ensis directus
Nereis
Carcinus maenas
Asterias rubens
Gammarus
Mytilus edulis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Impact
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-1
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2006
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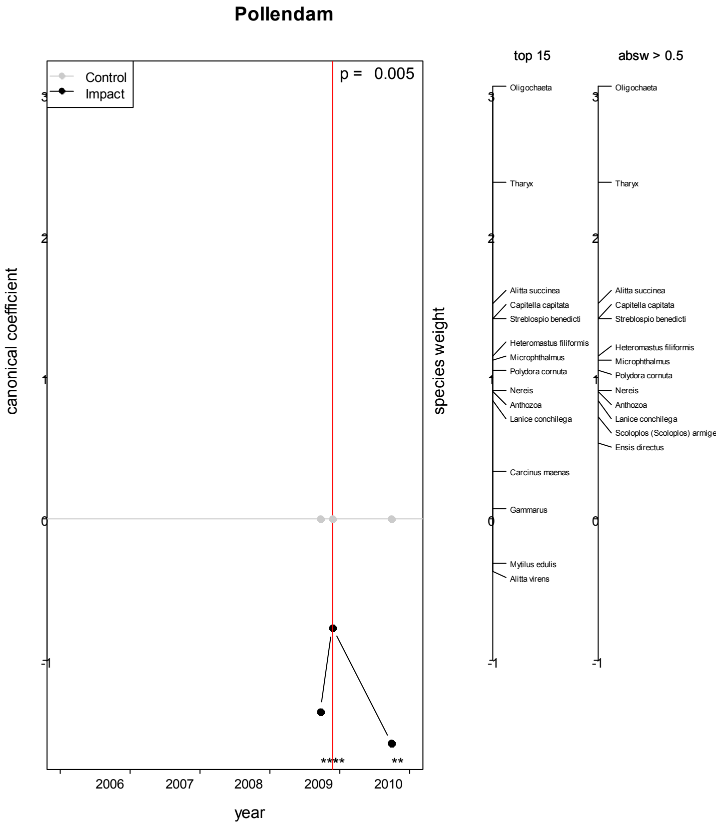
2008
2009
2010
year
species weight
top 15
absw > 0.5
Mytilus edulis
Gammarus
Oligochaeta
Alitta virens
Hediste diversicolor
Carcinus maenas
Alitta succinea
Streblospio benedicti
Mytilicola
Capitella capitata
Tharyx
Heteromastus filiformis
Bryozoa
Nereis
Polydora cornuta
Mytilus edulis
Gammarus
Oligochaeta
Alitta virens
Polydora cornuta
Lanice conchilega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Control
Impact
p = 0.005
canonical coefficient
3
2
1
0
-1
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**
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Oligochaeta
Tharyx
Alitta succinea
Capitella capitata
Streblospio benedicti
Heteromastus filiformis
Microphthalmus
Polydora cornuta
Nereis
Anthozoa
Lanice conchilega
Carcinus maenas
Gammarus
Mytilus edulis
Alitta virens
Oligochaeta
Tharyx
Alitta succinea
Capitella capitata
Streblospio benedicti
Heteromastus filiformis
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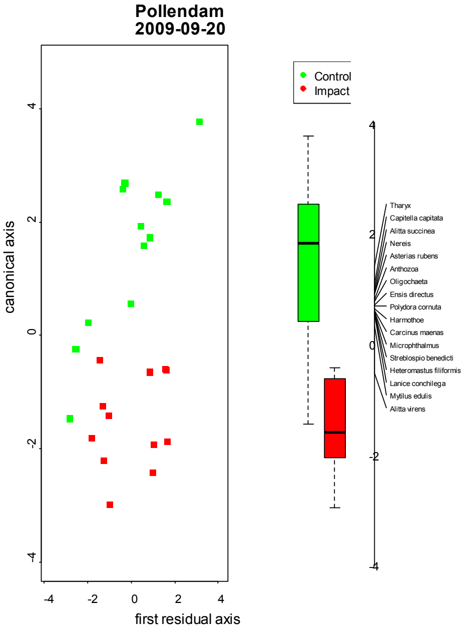
Nereis
Anthozoa
Lanice conchilega
Scoloplos (Scoloplos) armige
Ensis directus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2009-09-20
canonical axis
first residual axis
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4
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Impact
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Capitella capitata
Alitta succinea
Nereis
Asterias rubens
Anthozoa
Oligochaeta
Ensis directus
Polydora cornuta
Harmothoe
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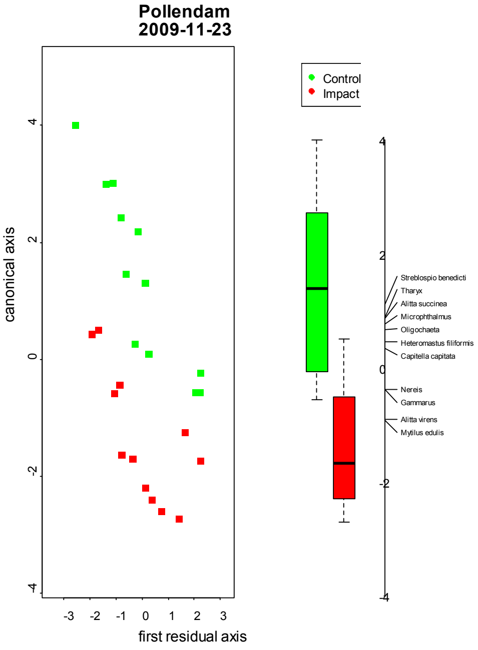
Streblospio benedicti
Heteromastus filiformis
Lanice conchilega
Mytilus edulis
Alitta virens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2009-11-23
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first residual axis
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-2
-1
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1
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3
-4
-2
0
2
4
Control
Impact
Streblospio benedicti
Tharyx
Alitta succinea
Microphthalmus
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Heteromastus filiformis
Capitella capitata
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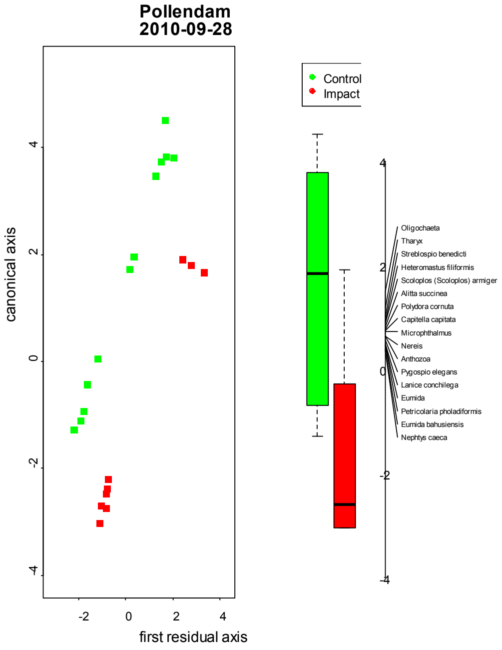
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Impact
Oligochaeta
Tharyx
Streblospio benedicti
Heteromastus filiformis
Scoloplos (Scoloplos) armiger
Alitta succinea
Polydora cornuta
Capitella capitata
Microphthalmus
Nereis
Anthozoa
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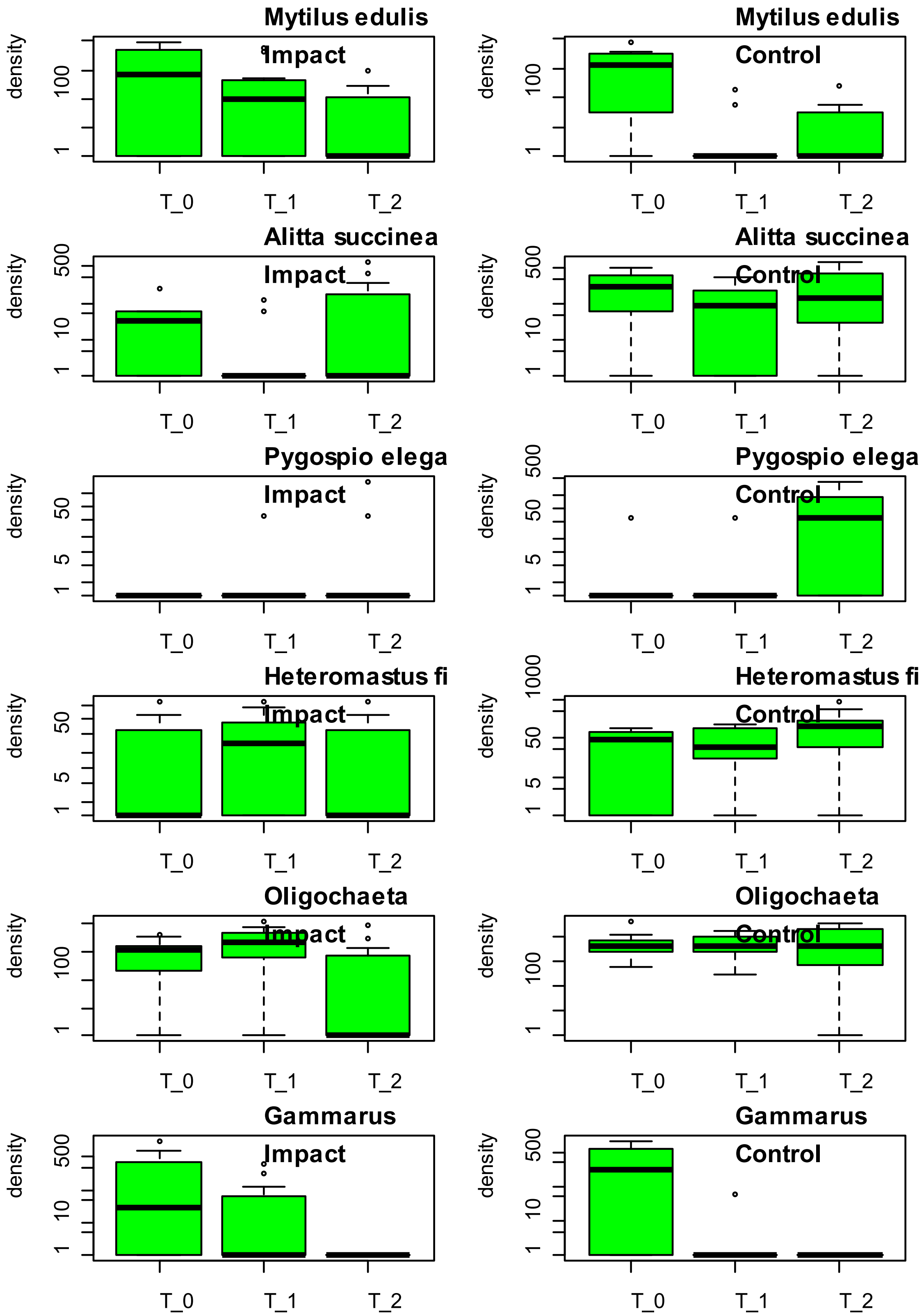
Lanice conchilega
Eumida
Petricolaria pholadiformis
Eumida bahusiensis
Nephtys caeca

Pollendam


Mytilus edulis
Impact
density
1
100
T_0
T_1
T_2
Mytilus edulis
Control
density
1
100
T_0
T_1
T_2
Alitta succinea
Impact
density
1
10
500
T_0
T_1
T_2
Alitta succinea
Control
density
1
10
500
T_0
T_1
T_2
Pygospio elega
Impact
density
1
5
50
T_0
T_1
T_2
Pygospio elega
Control
density
1
5
50
500
T_0
T_1
T_2
Heteromastus fi
Impact
density
1
5
50
T_0
T_1
T_2
Heteromastus fi
Control
density
1
5
50
1000
T_0
T_1
T_2
Oligochaeta
Impact
density
1
100
T_0
T_1
T_2
Oligochaeta
Control
density
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100
T_0
T_1
T_2
Gammarus
Impact
density
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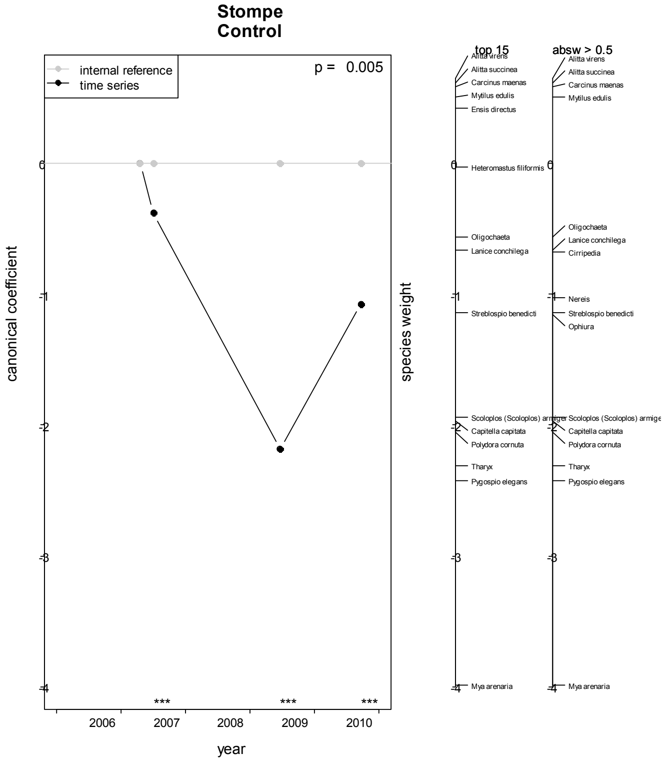
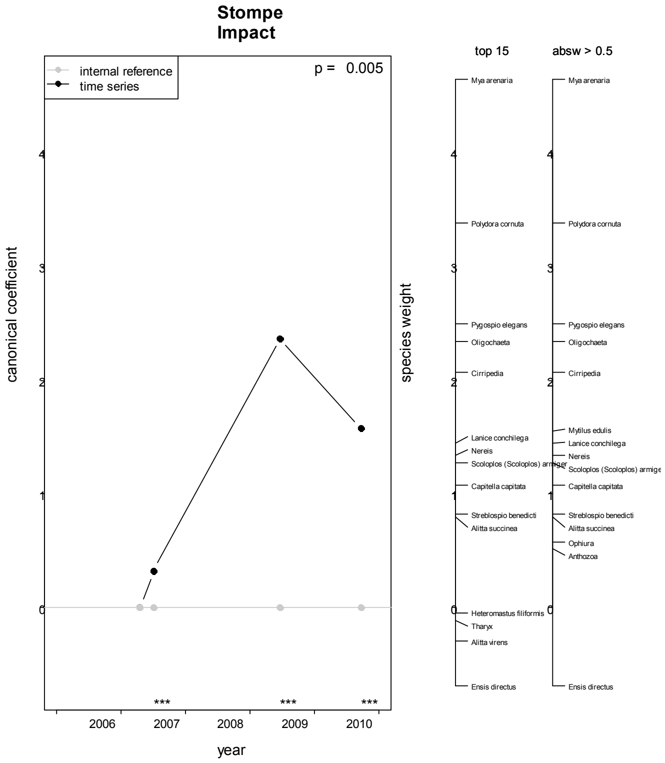
T_0
T_1
T_2
Gammarus
Control
density
1
10
500
T_0
T_1
T_2


Stompe
Control
internal reference
time series
p = 0.005
canonical coefficient
0
-1
-2
-3
-4
***
***
***
2006
2007
2008
2009
2010
year
species weight
top 15
Alitta virens
Alitta succinea
Carcinus maenas
Mytilus edulis
Ensis directus
Heteromastus filiformis
Oligochaeta
Lanice conchilega
Streblospio benedicti
Scoloplos (Scoloplos) armiger
Capitella capitata
Polydora cornuta
Tharyx
Pygospio elegans
Mya arenaria
absw > 0.5
Alitta virens
Alitta succinea
Carcinus maenas
Mytilus edulis
Oligochaeta
Lanice conchilega
Cirripedia
Nereis
Streblospio benedicti
Ophiura
Scoloplos (Scoloplos) armige
Capitella capitata
Polydora cornuta
Tharyx
Pygospio elegans
Mya arenaria


Stompe
Impact
internal reference
time series
p = 0.005
canonical coefficient
4
3
2
1
0
***
***
***
2006
2007
2008
2009
2010
year
species weight
top 15
Mya arenaria
Polydora cornuta
Pygospio elegans
Oligochaeta
Cirripedia
Lanice conchilega
Nereis
Scoloplos (Scoloplos) armiger
Capitella capitata
Streblospio benedicti
Alitta succinea
Heteromastus filiformis
Tharyx
Alitta virens
Ensis directus
absw > 0.5
Mya arenaria
Polydora cornuta
Pygospio elegans
Oligochaeta
Cirripedia
Mytilus edulis
Lanice conchilega
Nereis
Scoloplos (Scoloplos) armige
Capitella capitata
Streblospio benedicti
Alitta succinea
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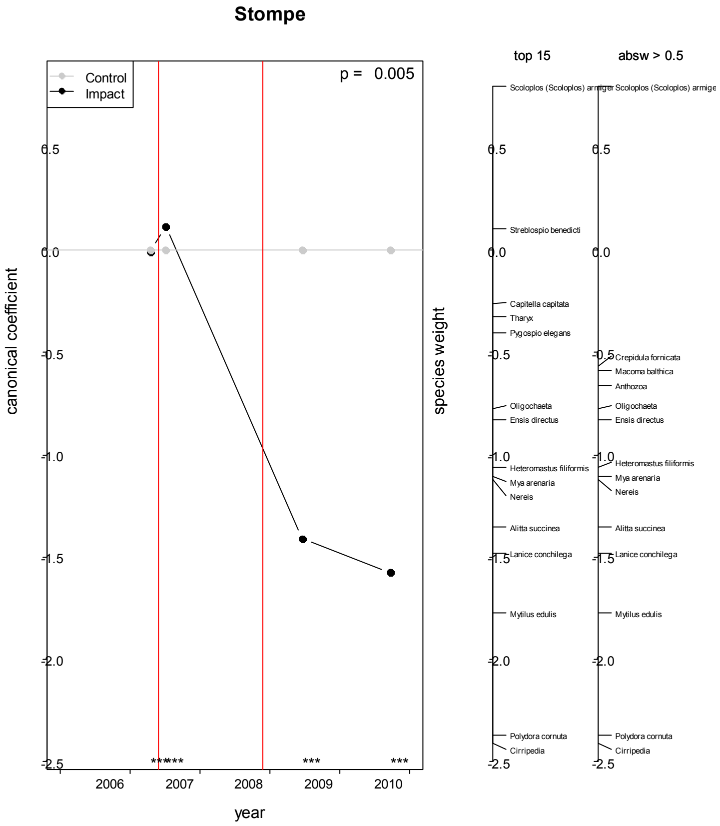
Anthozoa
Ensis directus


Stompe
Control
Impact
p = 0.005
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0.0
-0.5
-1.0
-1.5
-2.0
-2.5
canonical coefficient
2006
2007
2008
2009
2010
year
*** *** *** ***
top 15
absw > 0.5
species weight
Scoloplos (Scoloplos) armiger
Streblospio benedicti
Capitella capitata
Tharyx
Pygospio elegans
Oligochaeta
Ensis directus
Heteromastus filiformis
Mya arenaria
Nereis
Alitta succinea
Lanice conchilega
Mytilus edulis
Polydora cornuta
Cirripedia
Scoloplos (Scoloplos) armige
Crepidula fornicata
Macoma balthica
Anthozoa
Oligochaeta
Ensis directus
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Mya arenaria
Nereis
Alitta succinea
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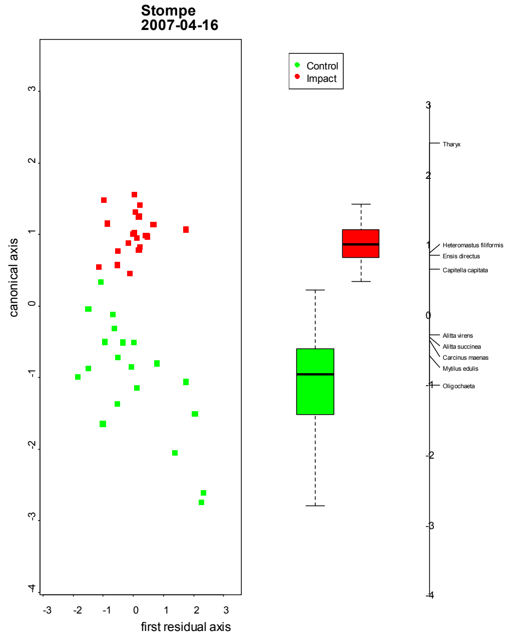
Polydora cornuta
Cirripedia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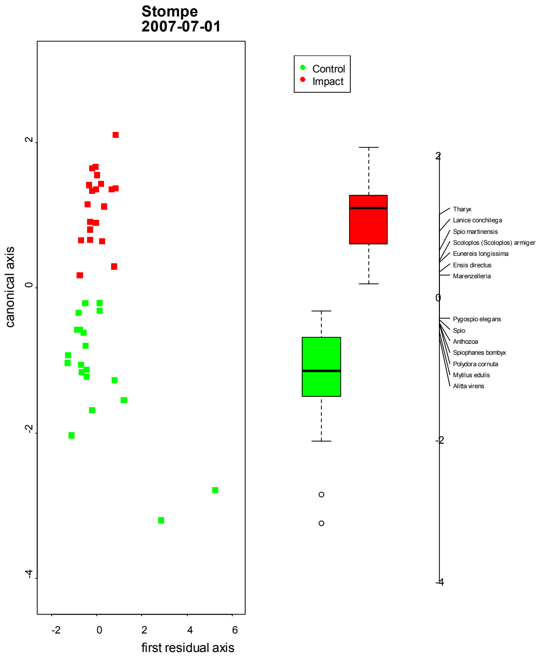
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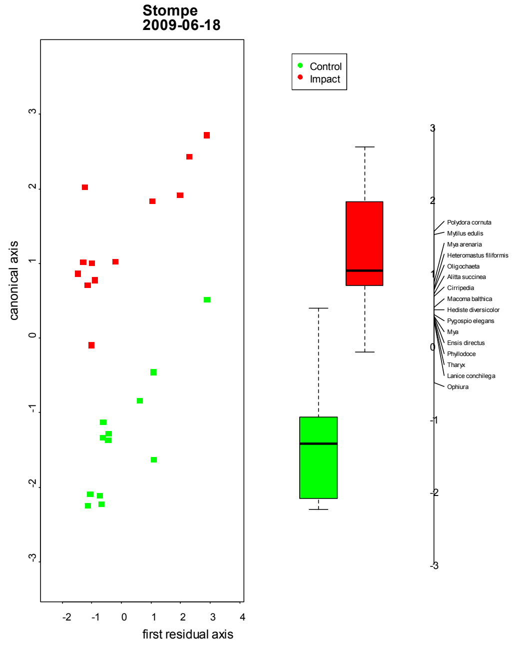
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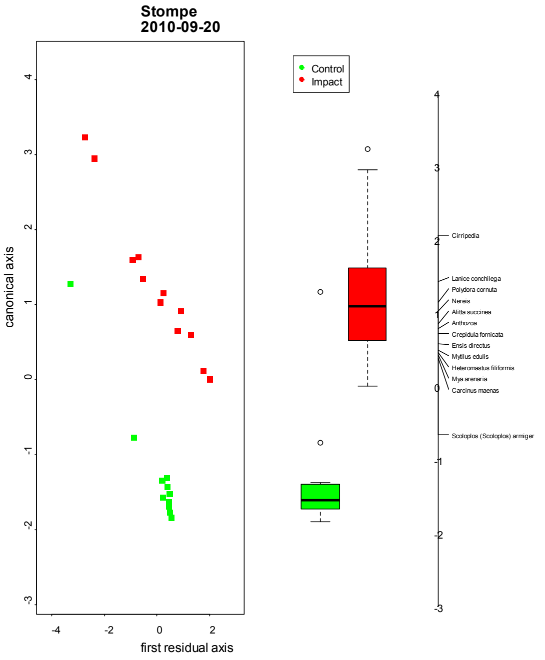
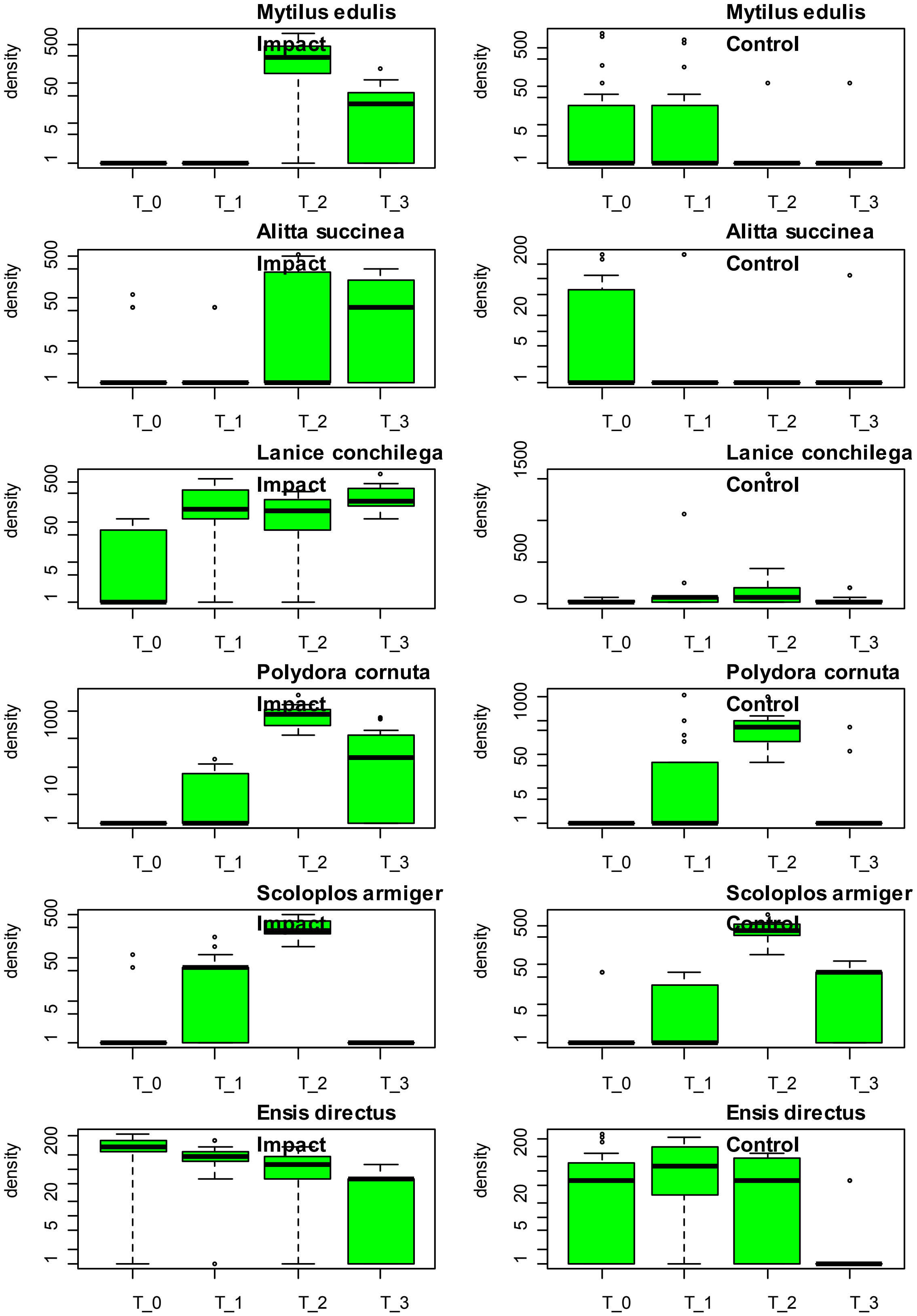

Stompe
2010-09-20

Stompe


Mytilus edulis
Impact
Control
Alitta succinea
Impact
Control
Lanice conchilega
Impact
Control
Polydora cornuta
Impact
Control
Scoloplos armiger
Impact
Control
Ensis directus
Impact
Control
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T_1
T_2
T_3
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10
20
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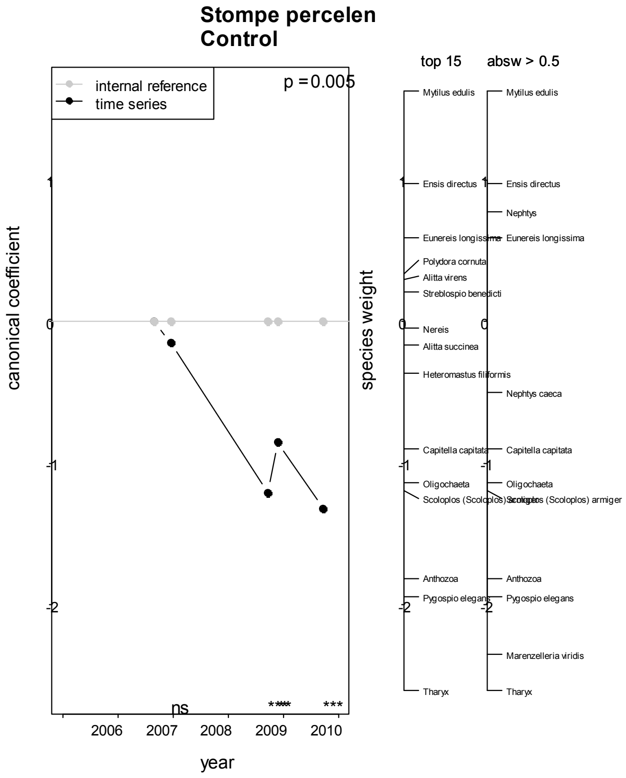
200
500
1000
1500
0


Stompe percelen
Control
internal reference
time series
p =0.005
canonical coefficient
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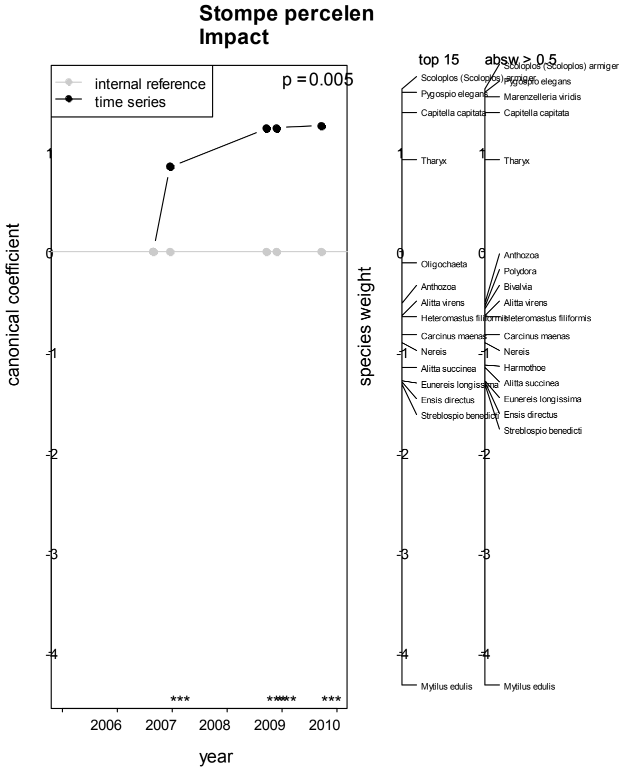
-1
-2
ns
***
***
***
2006
2007
2008
2009
2010
year
top 15
absw > 0.5
species weight
Mytilus edulis
Ensis directus
Eunereis longissima
Polydora cornuta
Alitta virens
Streblospio benedicti
Nereis
Alitta succinea
Heteromastus filiformis
Capitella capitata
Oligochaeta
Scoloplos (Scoloplos) armiger
Anthozoa
Pygospio elegans
Tharyx
Mytilus edulis
Ensis directus
Nephtys
Eunereis longissima
Nephtys caeca
Capitella capitata
Oligochaeta
Scoloplos (Scoloplos) armiger
Anthozoa
Pygospio elegans
Marenzelleria viridis
Tharyx


Stompe percelen
Impact
internal reference
time series
p =0.005
canonical coefficient
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-1
-2
-3
-4
***
***
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***
2006
2007
2008
2009
2010
year
top 15
absw > 0.5
species weight
Scoloplos (Scoloplos) armiger
Pygospio elegans
Capitella capitata
Tharyx
Oligochaeta
Anthozoa
Alitta virens
Heteromastus filiformis
Carcinus maenas
Nereis
Alitta succinea
Eunereis longissima
Ensis directus
Streblospio benedicti
Mytilus edulis
Scoloplos (Scoloplos) armiger
Pygospio elegans
Marenzelleria viridis
Capitella capitata
Tharyx
Anthozoa
Polydora
Bivalvia
Alitta virens
Heteromastus filiformis
Carcinus maenas
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Harmothoe
Alitta succinea
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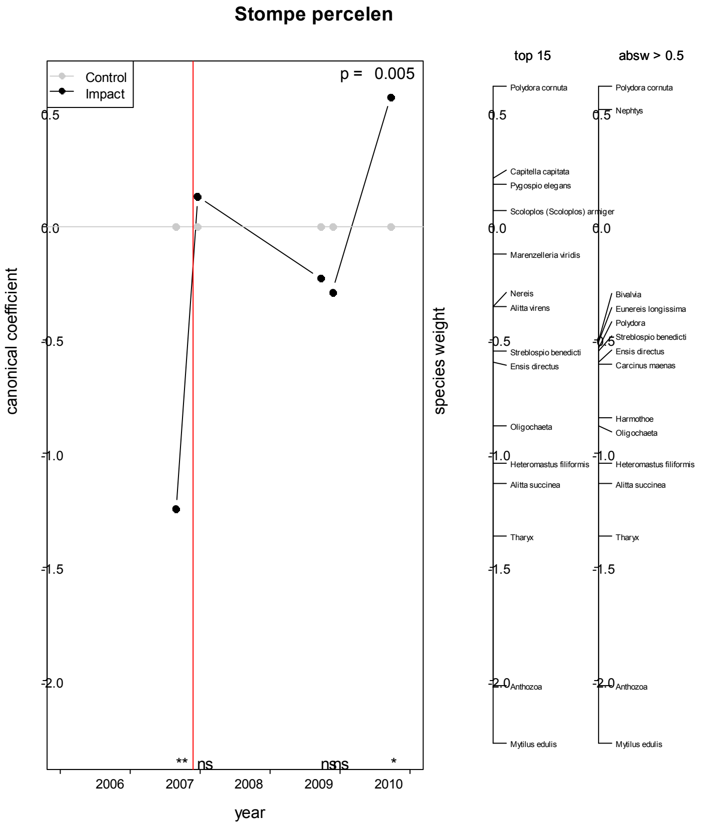
Ensis directus
Streblospio benedicti
Mytilus edulis


Stompe percelen
Control
Impact
p = 0.005
canonical coefficient
0.5
0.0
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-1.0
-1.5
-2.0
**
ns
ns
ns
*
2006
2007
2008
2009
2010
year
top 15
absw > 0.5
species weight
Polydora cornuta
Capitella capitata
Pygospio elegans
Scoloplos (Scoloplos) armiger
Marenzelleria viridis
Nereis
Alitta virens
Streblospio benedicti
Ensis directus
Oligochaeta
Heteromastus filiformis
Alitta succinea
Tharyx
Anthozoa
Mytilus edulis
Polydora cornuta
Nephtys
Bivalvia
Eunereis longissima
Polydora
Streblospio benedicti
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Alitta succinea
Tharyx
Anthozoa
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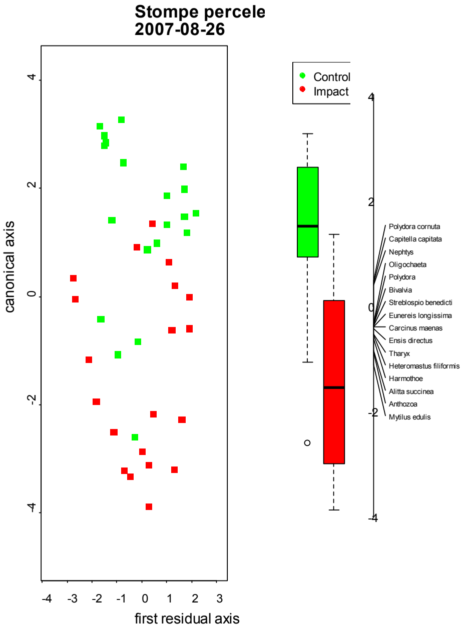
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first residual axis
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-2
-4
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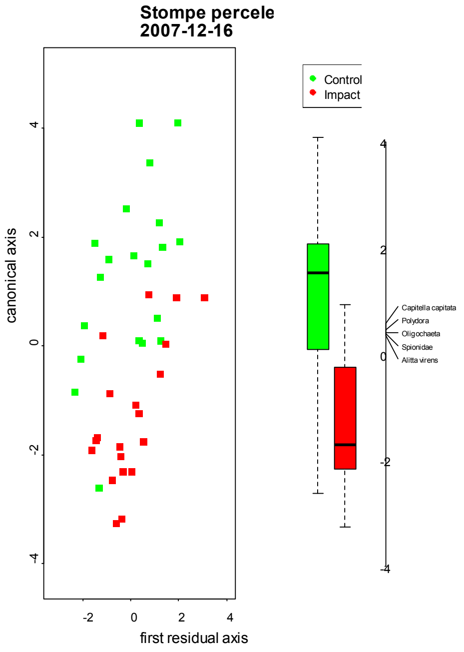
-2
-1
0
1
2
3
Control
Impact
4
2
0
-2
-4
Polydora cornuta
Capitella capitata
Nephtys
Oligochaeta
Polydora
Bivalvia
Streblospio benedicti
Eunereis longissima
Carcinus maenas
Ensis directus
Tharyx
Heteromastus filiformis
Harmothoe
Alitta succinea
Anthozoa
Mytilus edulis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2007-12-16
canonical axis
first residual axis
4
2
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-2
-4
-2
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2
4
Control
Impact
4
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-2
-4
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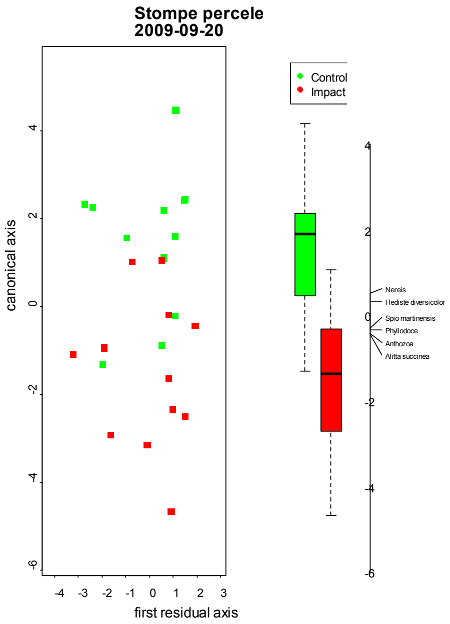
Polydora
Oligochaeta
Spionidae
Alitta virens


Stompe percele
2009-09-20
canonical axis
first residual axis
-4
-3
-2
-1
0
1
2
3
4
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-6
Control
Impact
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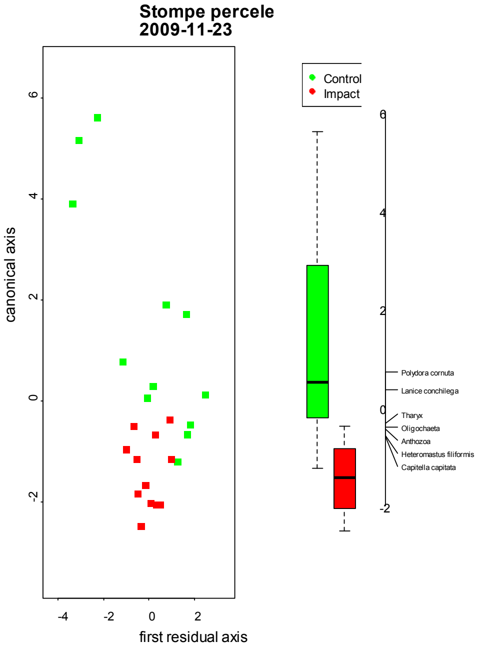
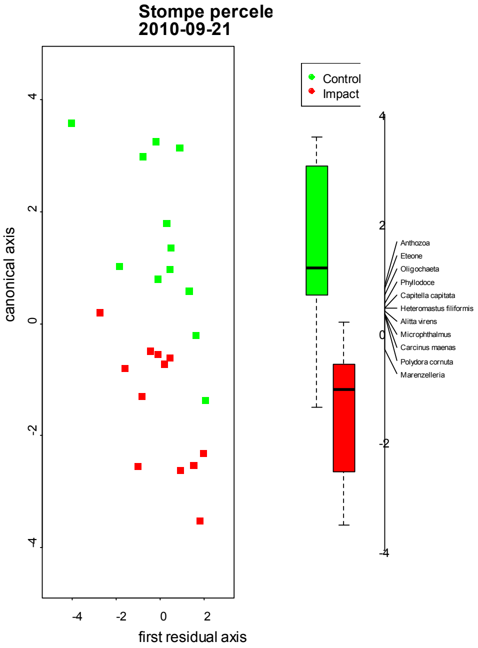
Hediste diversicolor
Spio martinensis
Phyllodoce
Anthozoa
Alitta succinea


Stompe percele
2009-11-23
canonical axis
first residual axis
-4
-2
0
2
6
4
2
0
-2
Control
Impact
Polydora cornuta
Lanice conchilega
Tharyx
Oligochaeta
Anthozoa
Heteromastus filiformis
Capitella capitata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2010-09-21
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first residual axis
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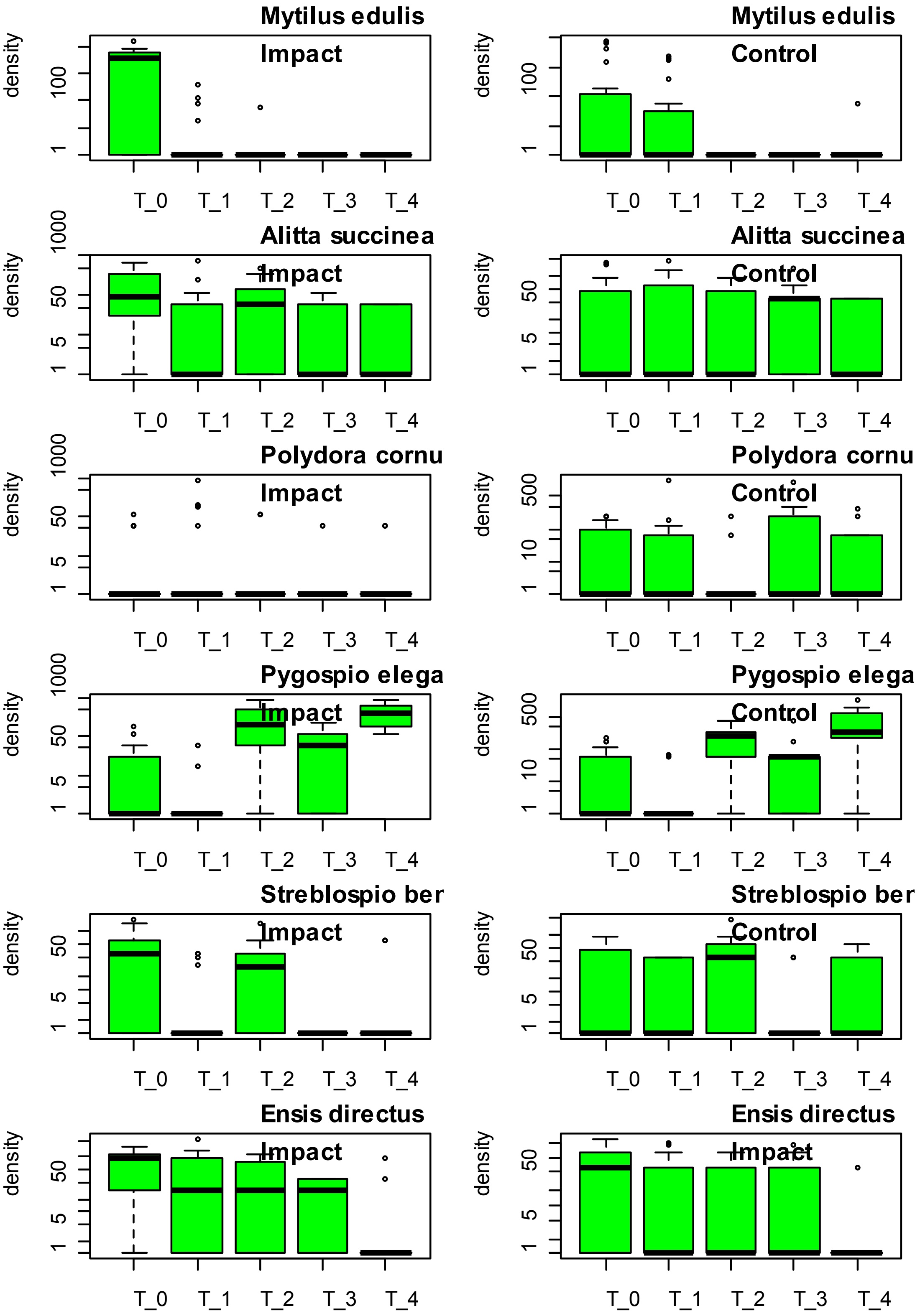
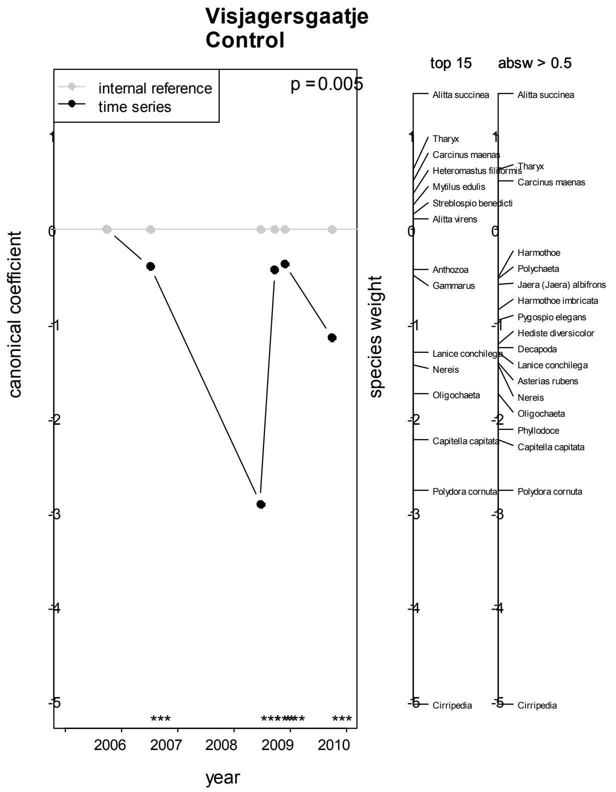
-2
0
2
4
2
0
-2
-4
Control
Impact
Anthozoa
Eteone
Oligochaeta
Phyllodoce
Capitella capitata
Heteromastus filiformis
Alitta virens
Microphthalmus
Carcinus maenas
Polydora cornuta
Marenzelleria

Stompe percelen




Visjagersgaatje
Control
internal reference
time series
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canonical coefficient
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-1
-2
-3
-4
-5
***
****
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Alitta succinea
Tharyx
Carcinus maenas
Heteromastus filiformis
Mytilus edulis
Streblospio benedicti
Alitta virens
Anthozoa
Gammarus
Lanice conchilega
Nereis
Oligochaeta
Capitella capitata
Polydora cornuta
Cirripedia
Alitta succinea
Tharyx
Carcinus maenas
Harmothoe
Polychaeta
Jaera (Jaera) albifrons
Harmothoe imbricata
Pygospio elegans
Hediste diversicolor
Decapoda
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Asterias rubens
Nereis
Oligochaeta
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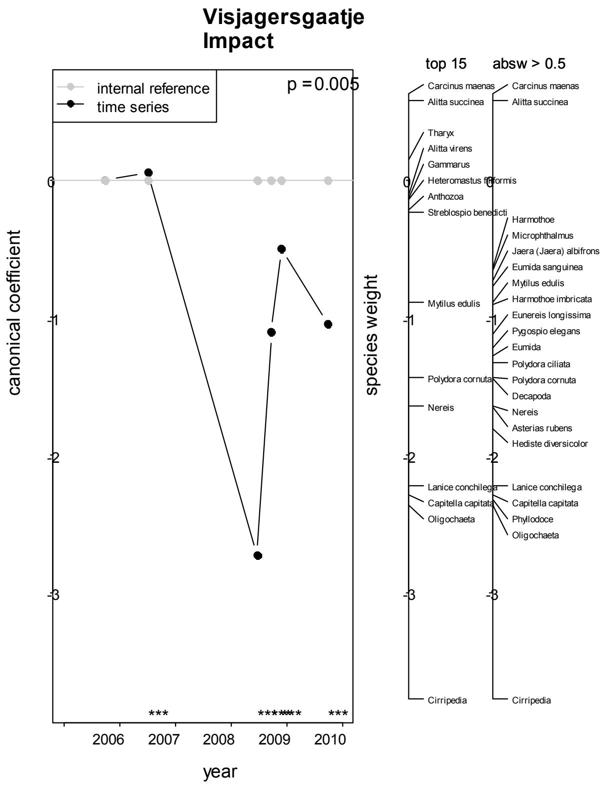
Cirripedia


Visjagersgaatje
Impact
internal reference
time series
p = 0.005
canonical coefficient
0
-1
-2
-3
***
****
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Carcinus maenas
Alitta succinea
Tharyx
Alitta virens
Gammarus
Heteromastus filiformis
Anthozoa
Streblospio benedicti
Mytilus edulis
Polydora cornuta
Nereis
Lanice conchilega
Capitella capitata
Oligochaeta
Cirripedia
Carcinus maenas
Alitta succinea
Harmothoe
Microphthalmus
Jaera (Jaera) albifrons
Eumida sanguinea
Mytilus edulis
Harmothoe imbricata
Eunereis longissima
Pygospio elegans
Eumida
Polydora ciliata
Polydora cornuta
Decapoda
Nereis
Asterias rubens
Hediste diversicolor
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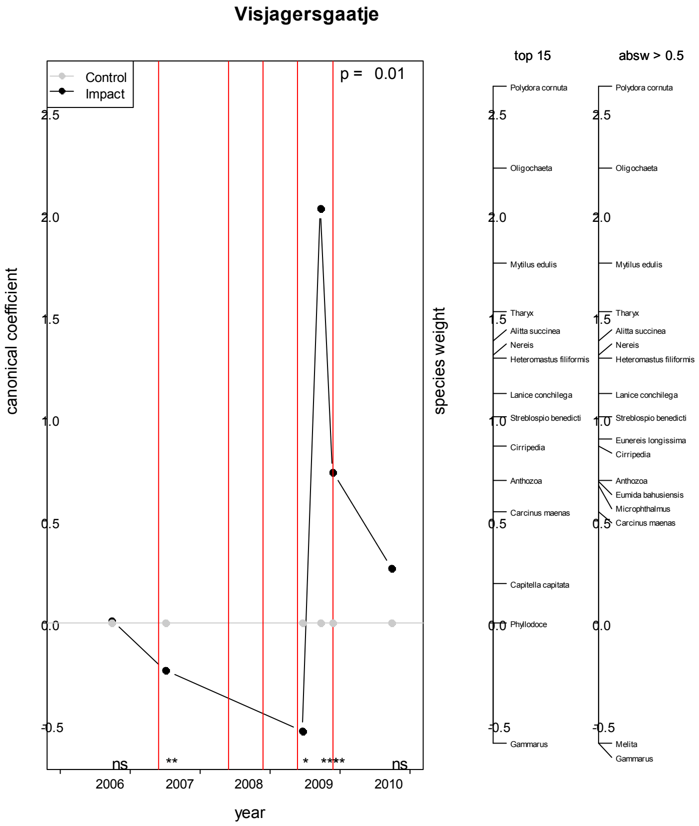
Oligochaeta
Cirripedia


Visjagersgaatje
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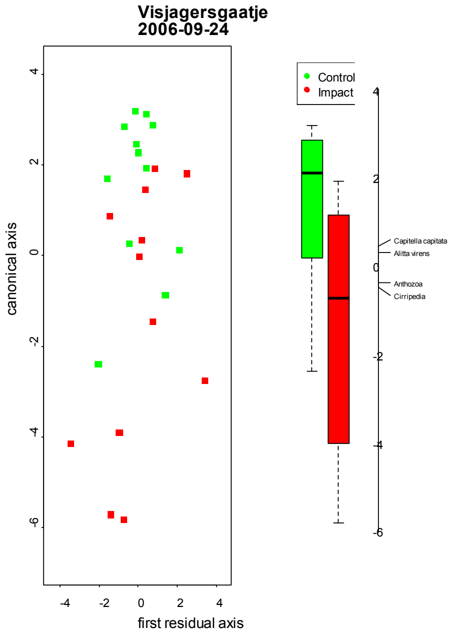
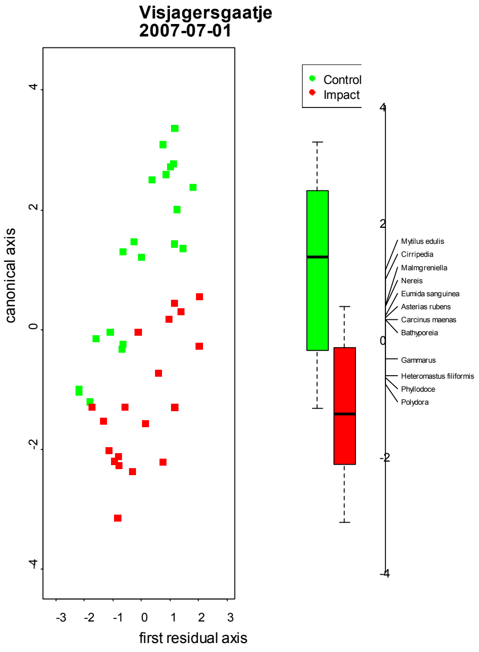
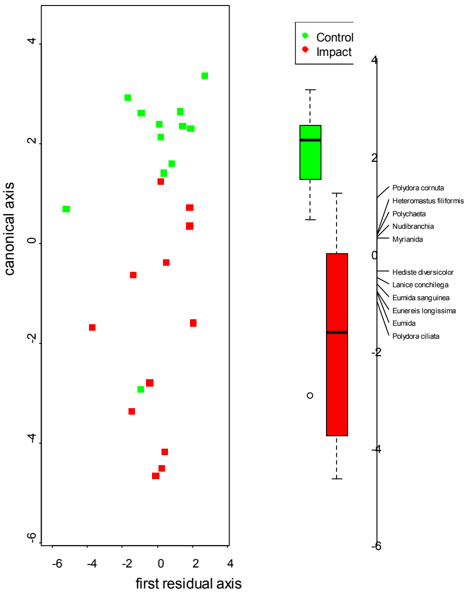
Impact
p = 0.01
canonical coefficient
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
ns
**
*
****
ns
2006
2007
2008
2009
2010
year
species weight
top 15
Polydora cornuta
Oligochaeta
Mytilus edulis
Tharyx
Alitta succinea
Nereis
Heteromastus filiformis
Lanice conchilega
Streblospio benedicti
Cirripedia
Anthozoa
Carcinus maenas
Capitella capitata
Phyllodoce
Gammarus
absw > 0.5
Polydora cornuta
Oligochaeta
Mytilus edulis
Tharyx
Alitta succinea
Nereis
Heteromastus filiformis
Lanice conchilega
Streblospio benedicti
Eunereis longissima
Cirripedia
Anthozoa
Eumida bahusiensis
Microphthalmus
Carcinus maenas
Melita
Gammarus

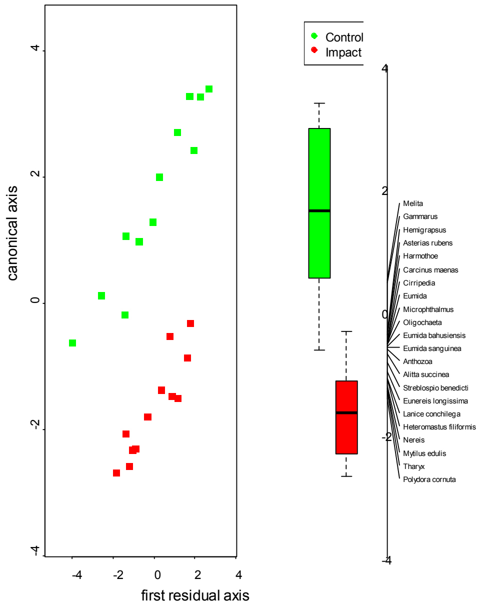

Visjagersgaatje
2006-09-24
canonical axis
4
2
0
-2
-4
-6
-4
-2
0
2
4
first residual axis
Control
Impact
4
2
0
-2
-4
-6
Capitella capitata
Alitta virens
Anthozoa
Cirripedia


Visjagersgaatje
2007-07-01
canonical axis
4
2
0
-2
-4
-3
-2
-1
0
1
2
3
first residual axis
Control
Impact
4
2
0
-2
-4
Mytilus edulis
Cirripedia
Malmgreniella
Nereis
Eumida sanguinea
Asterias rubens
Carcinus maenas
Bathyporeia
Gammarus
Heteromastus filiformis
Phyllodoce
Polydora

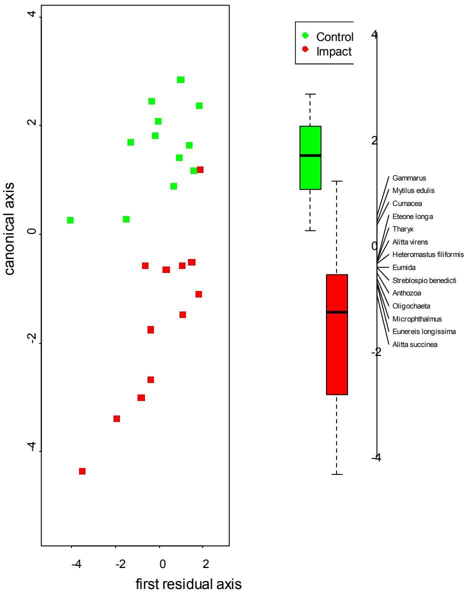
**Visjagersgaatje
2009-06-18**



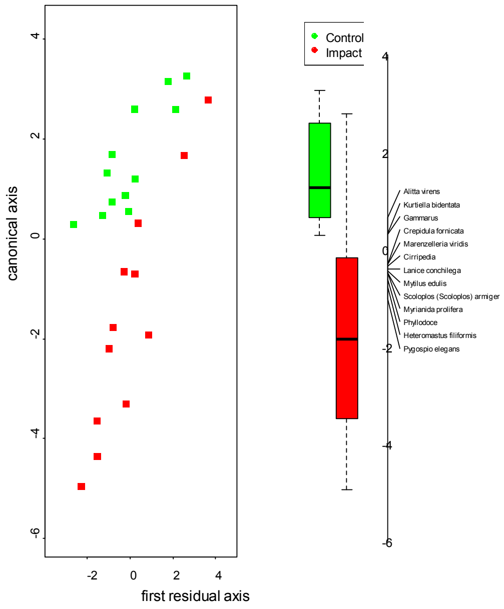
**Visjagersgaatje
2009-09-20**



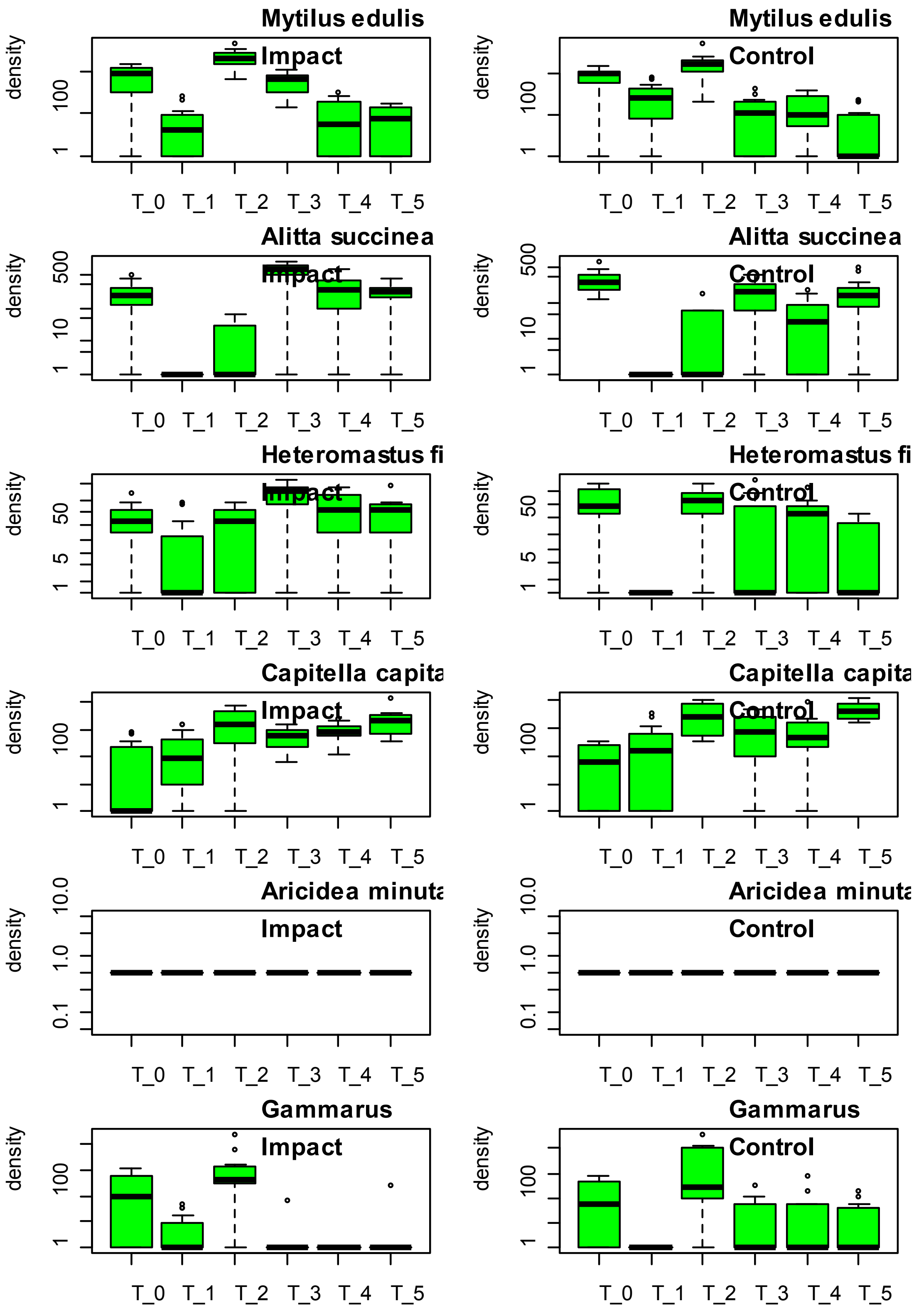
**Visjagersgaatje
2009-11-23**

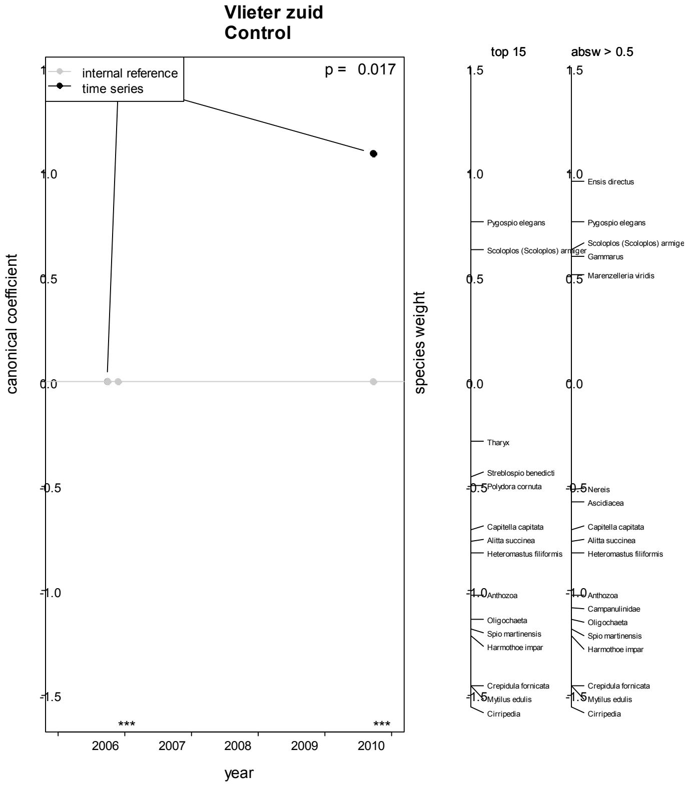


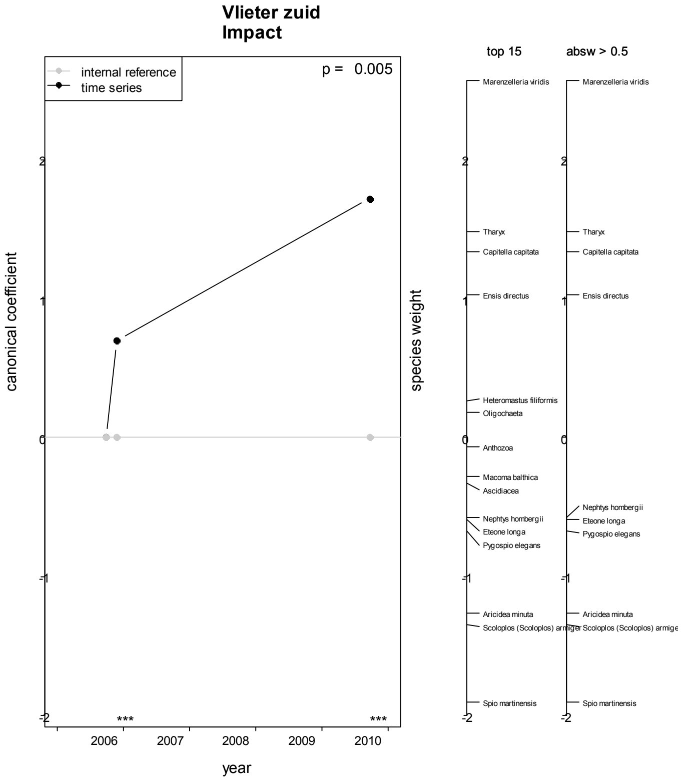
**Visjagersgaatje
2010-09-26**

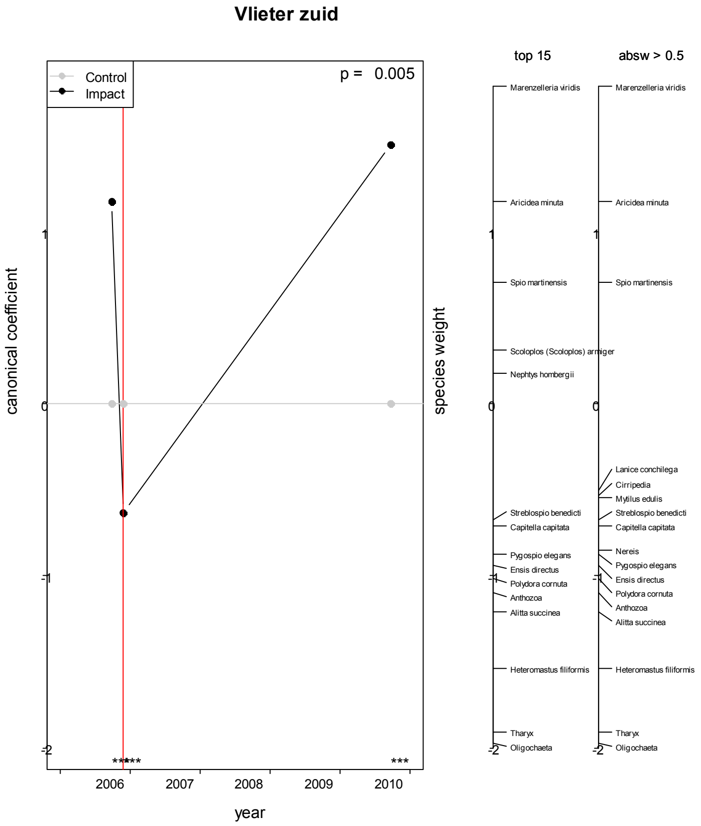


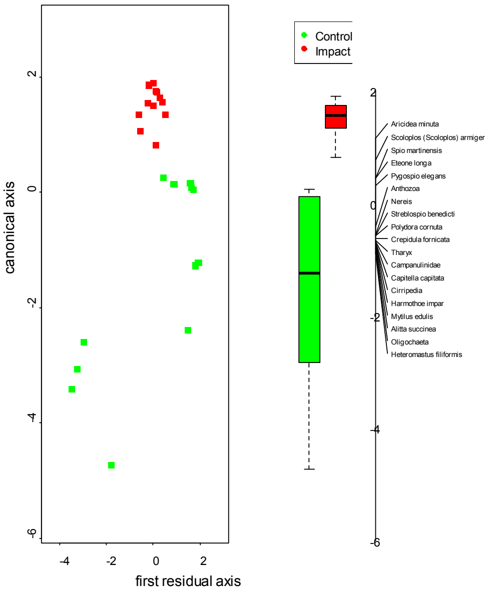
Visjagersgaatje



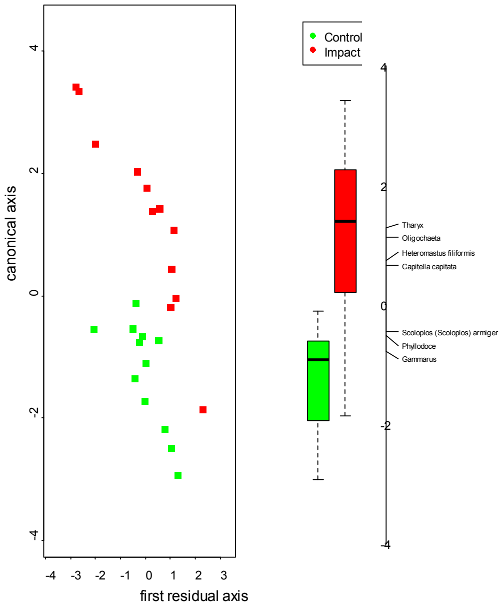

Vlieter zuid
Control
internal reference
time series
p = 0.017
canonical coefficient
1.0
0.5
0.0
-0.5
-1.0
-1.5
***
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
Pygospio elegans
Scoloplos (Scoloplos) armiger
Tharyx
Streblospio benedicti
Polydora cornuta
Capitella capitata
Alitta succinea
Heteromastus filiformis
Anthozoa
Oligochaeta
Spio martinensis
Harmothoe impar
Crepidula fornicata
Mytilus edulis
Cirripedia
Ensis directus
Pygospio elegans
Scoloplos (Scoloplos) armige
Gammarus
Marenzelleria viridis
Nereis
Ascidiacea
Capitella capitata
Alitta succinea
Heteromastus filiformis
Anthozoa
Campanulinidae
Oligochaeta
Spio martinensis
Harmothoe impar
Crepidula fornicata
Mytilus edulis
Cirripedia


Vlieter zuid
Impact
internal reference
time series
p = 0.005
canonical coefficient
2
1
0
-1
-2
***
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
2
1
0
-1
-2
Marenzelleria viridis
Tharyx
Capitella capitata
Ensis directus
Heteromastus filiformis
Oligochaeta
Anthozoa
Macoma balthica
Ascidiacea
Nephtys hombergii
Eteone longa
Pygospio elegans
Aricidea minuta
Scoloplos (Scoloplos) armiger
Spio martinensis
Marenzelleria viridis
Tharyx
Capitella capitata
Ensis directus
Nephtys hombergii
Eteone longa
Pygospio elegans
Aricidea minuta
Scoloplos (Scoloplos) armige
Spio martinensis

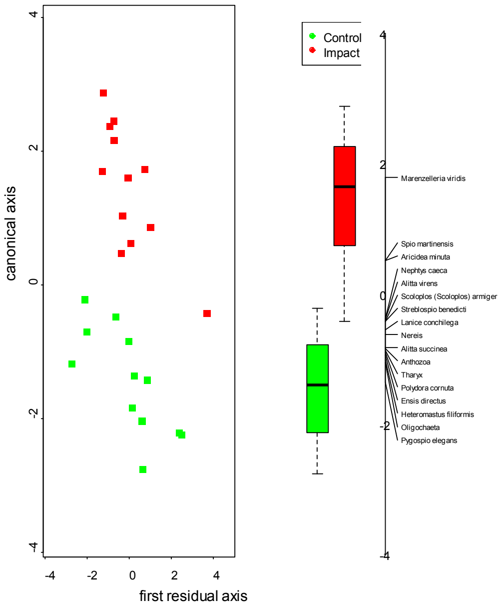

Vlieter zuid
Control
Impact
p = 0.005
canonical coefficient
1
0
-1
-2
*****
***
2006
2007
2008
2009
2010
year
species weight
top 15
Marenzelleria viridis
Aricidea minuta
Spio martinensis
Scoloplos (Scoloplos) armiger
Nephtys hombergii
Streblospio benedicti
Capitella capitata
Pygospio elegans
Ensis directus
Polydora cornuta
Anthozoa
Alitta succinea
Heteromastus filiformis
Tharyx
Oligochaeta
absw > 0.5
Marenzelleria viridis
Aricidea minuta
Spio martinensis
Lanice conchilega
Cirripedia
Mytilus edulis
Streblospio benedicti
Capitella capitata
Nereis
Pygospio elegans
Ensis directus
Polydora cornuta
Anthozoa
Alitta succinea
Heteromastus filiformis
Tharyx
Oligochaeta



Vlieter zuid
2006-09-24

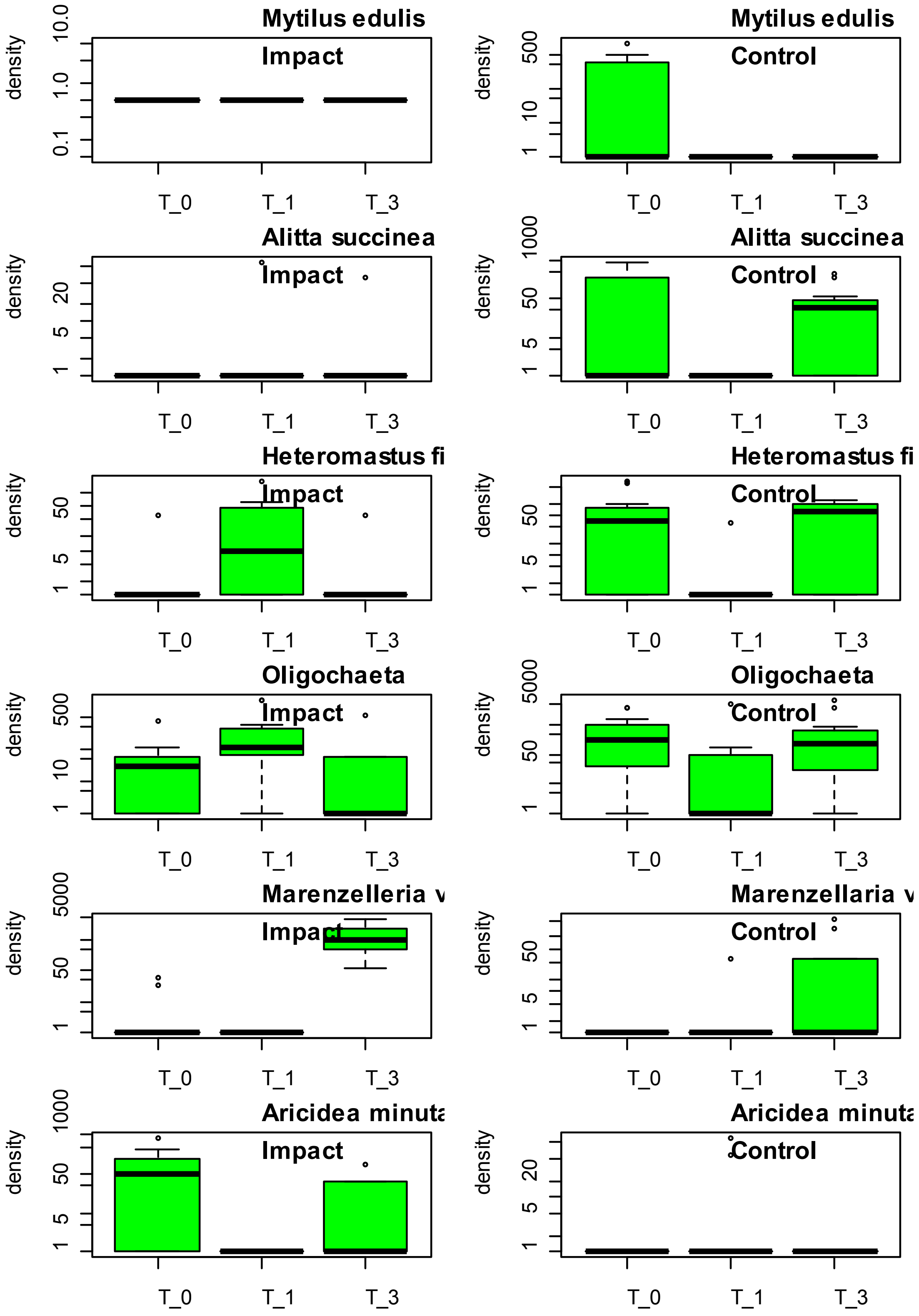


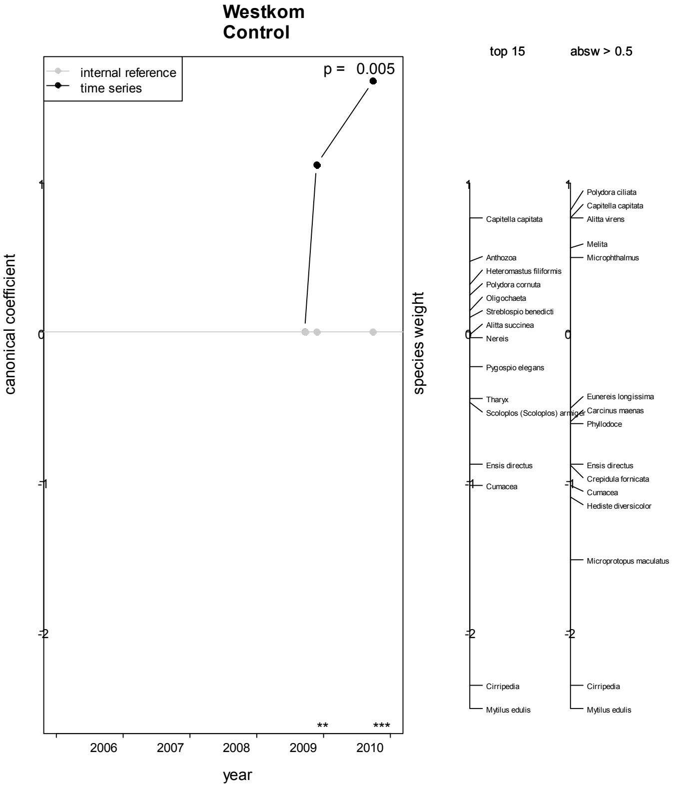
Vlieter zuid
2006-11-24



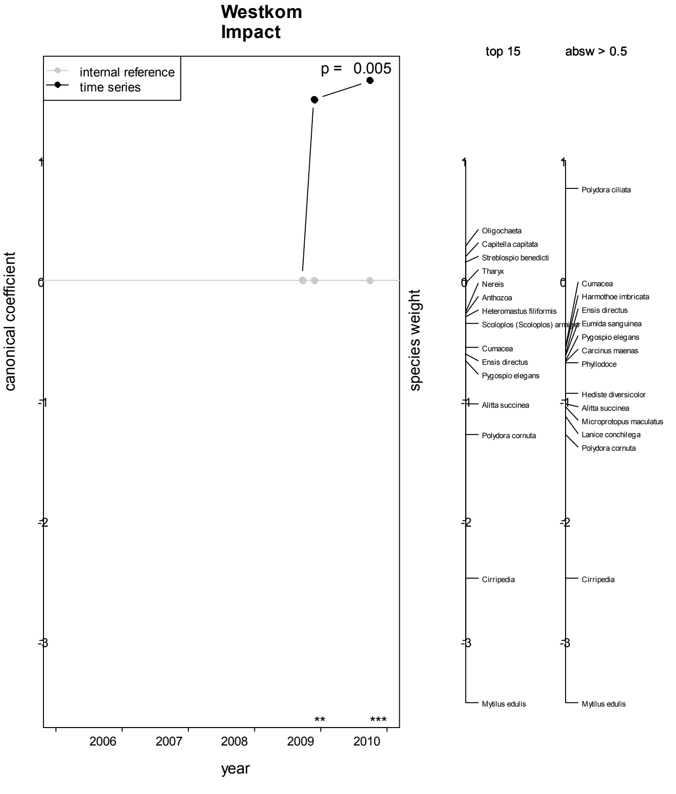
Vlieter zuid
2010-09-20

Vlieter zuid

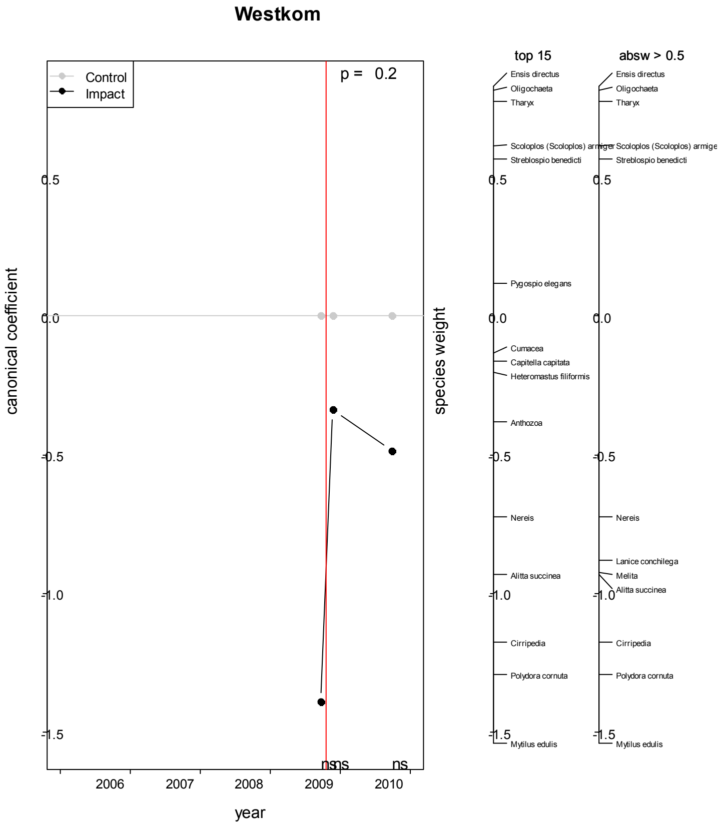


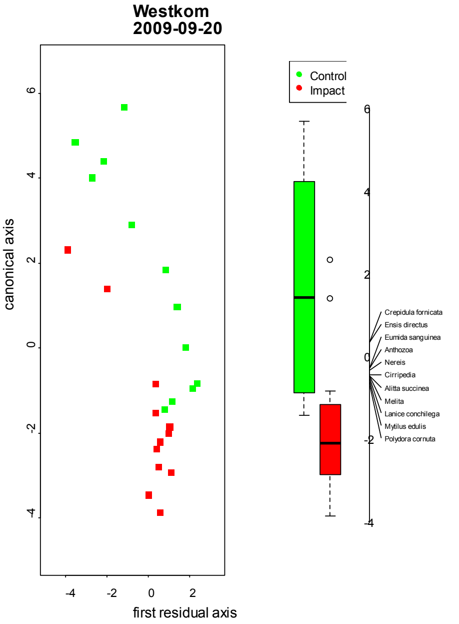


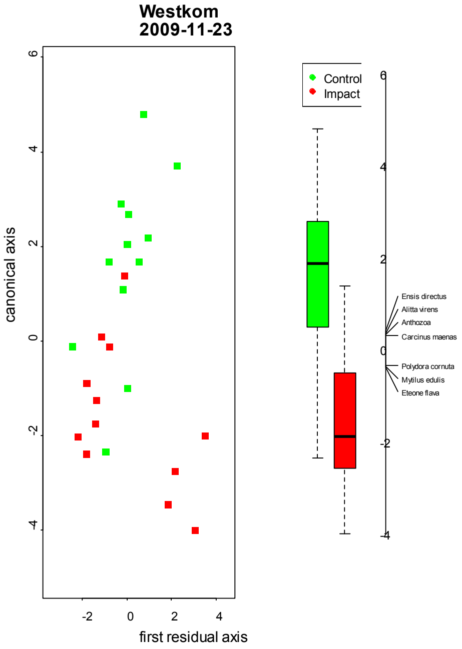
Westkom
Control

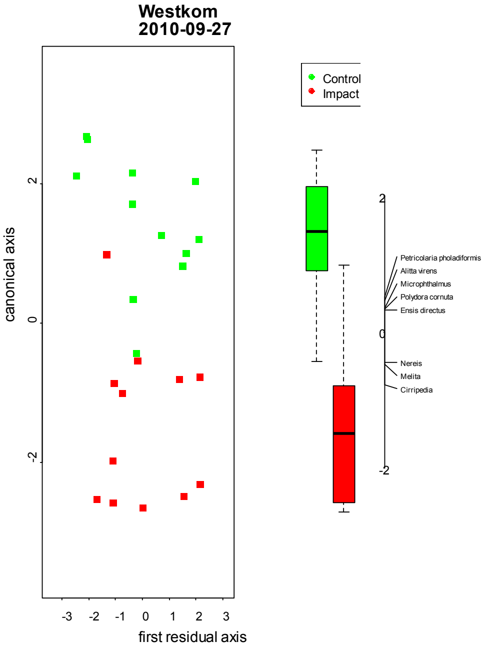


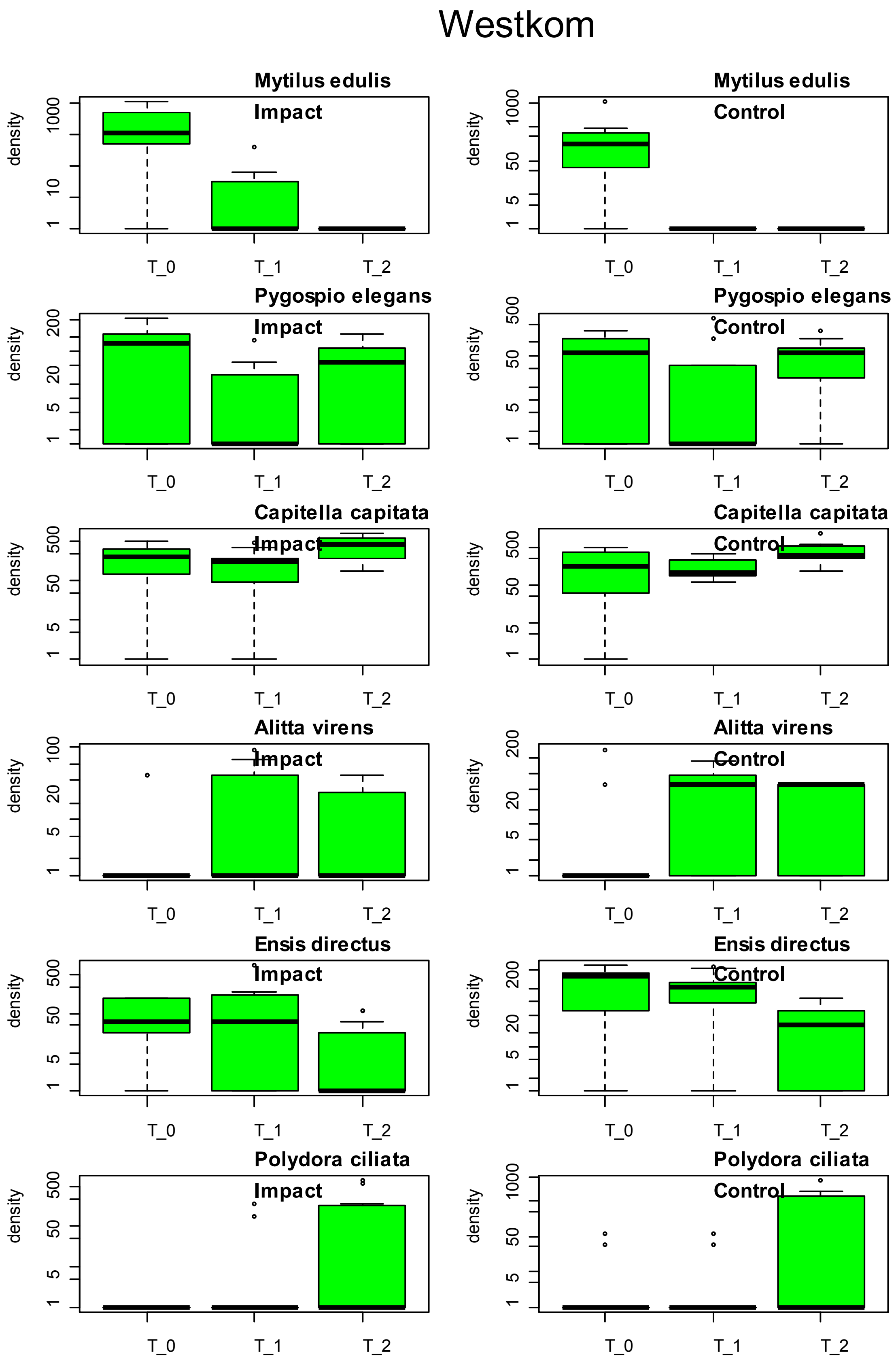
Westkom
Impact

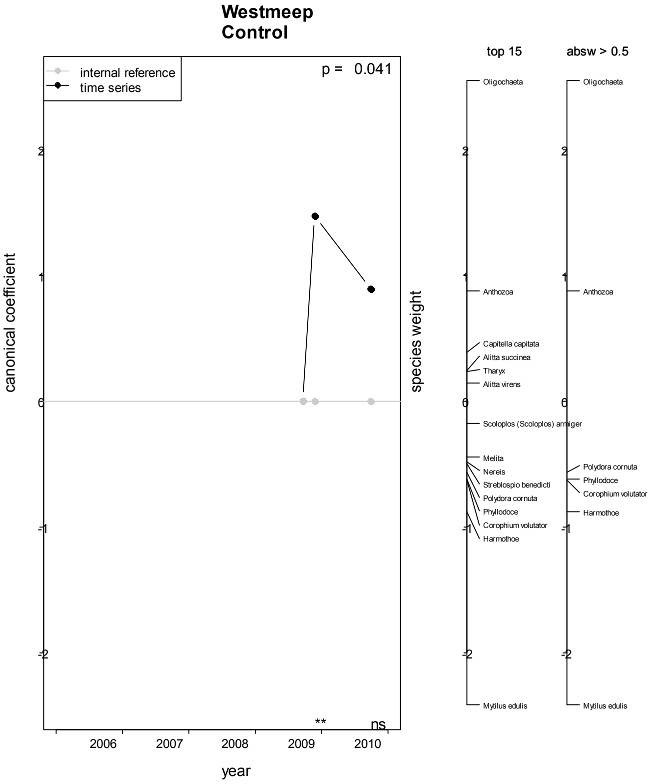

Westkom
Control
Impact
p = 0.2
canonical coefficient
0.5
0.0
-0.5
-1.0
-1.5
ns
ns
ns
2006
2007
2008
2009
2010
year
species weight
top 15
Ensis directus
Oligochaeta
Tharyx
Scoloplos (Scoloplos) armiger
Streblospio benedicti
Pygospio elegans
Cumacea
Capitella capitata
Heteromastus filiformis
Anthozoa
Nereis
Alitta succinea
Cirripedia
Polydora cornuta
Mytilus edulis
absw > 0.5
Ensis directus
Oligochaeta
Tharyx
Scoloplos (Scoloplos) armige
Streblospio benedicti
Nereis
Lanice conchilega
Melita
Alitta succinea
Cirripedia
Polydora cornuta
Mytilus edulis

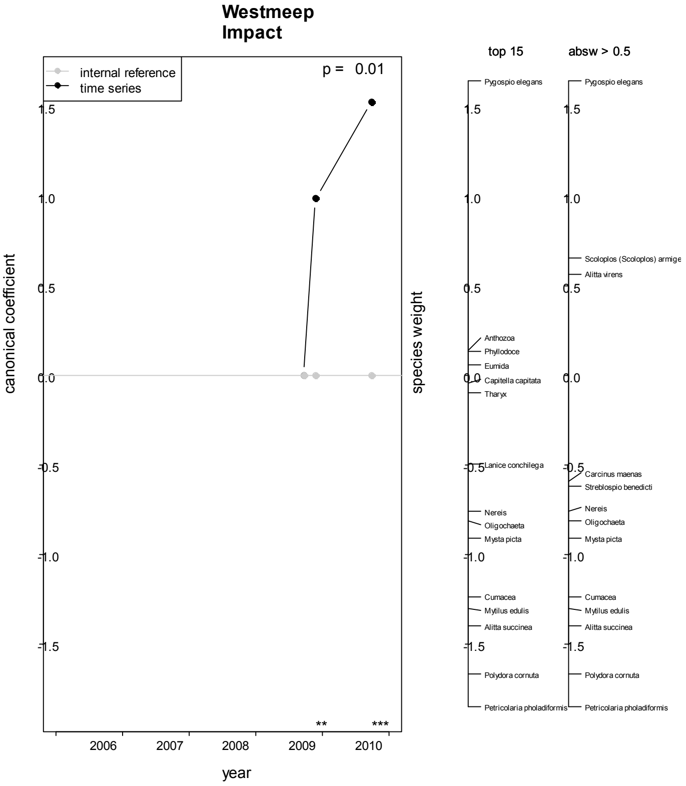

Westkom
2009-09-20
canonical axis
first residual axis
-4
-2
0
2
4
6
Control
Impact
Crepidula fornicata
Ensis directus
Eumida sanguinea
Anthozoa
Nereis
Cirripedia
Alitta succinea
Melita
Lanice conchilega
Mytilus edulis
Polydora cornuta

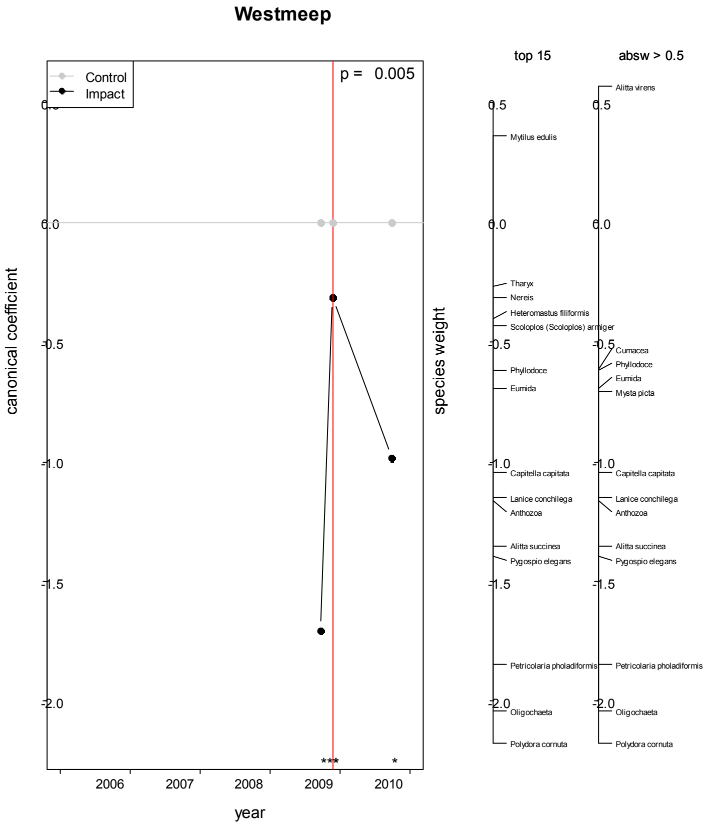

Westkom
2009-11-23
canonical axis
first residual axis
-4
-2
0
2
4
6
Control
Impact
Ensis directus
Alitta virens
Anthozoa
Carcinus maenas
Polydora cornuta
Mytilus edulis
Eteone flava

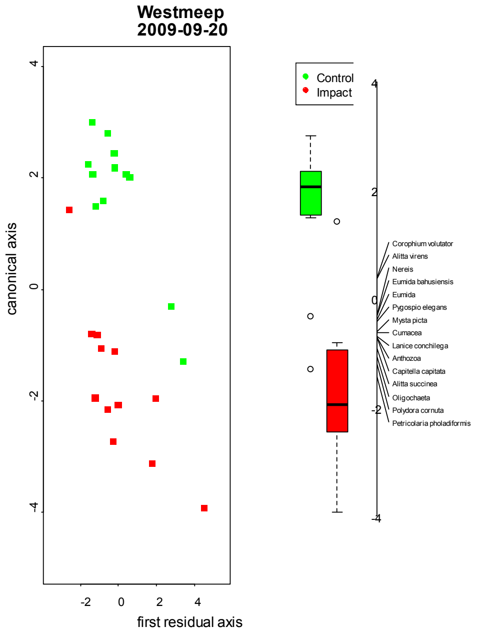

Westkom
2010-09-27
canonical axis
first residual axis
-3
-2
-1
0
1
2
3
Control
Impact
Petricolaria pholadiformis
Alitta virens
Microphthalmus
Polydora cornuta
Ensis directus
Nereis
Melita
Cirripedia

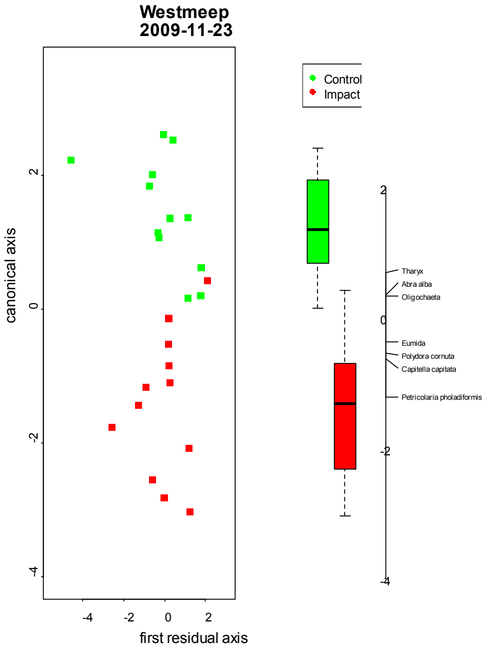

Westkom
Mytilus edulis
Impact
Control
Pygospio elegans
Impact
Control
Capitella capitata
Impact
Control
Alitta virens
Impact
Control
Ensis directus
Impact
Control
Polydora ciliata
Impact
Control
density
1
5
10
20
50
100
200
500
1000
T_0
T_1
T_2

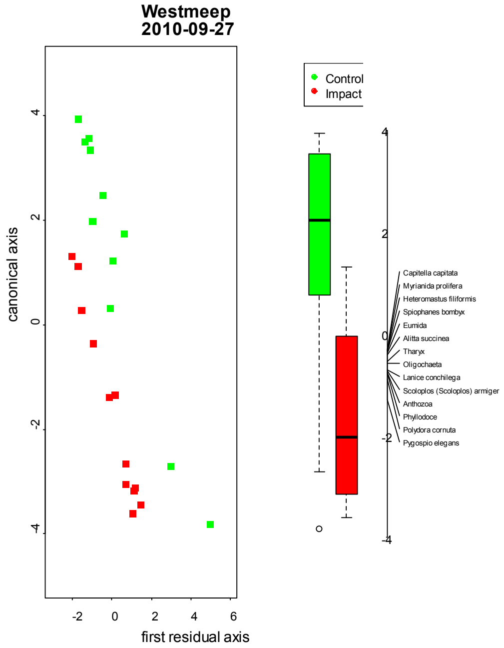

Westmeep
Control
internal reference
time series
p = 0.041
canonical coefficient
2
1
0
-1
-2
**
ns
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Oligochaeta
Anthozoa
Capitella capitata
Alitta succinea
Tharyx
Alitta virens
Scoloplos (Scoloplos) armiger
Melita
Nereis
Streblospio benedicti
Polydora cornuta
Phyllodoce
Corophium volutator
Harmothoe
Mytilus edulis
Oligochaeta
Anthozoa
Polydora cornuta
Phyllodoce
Corophium volutator
Harmothoe
Mytilus edulis

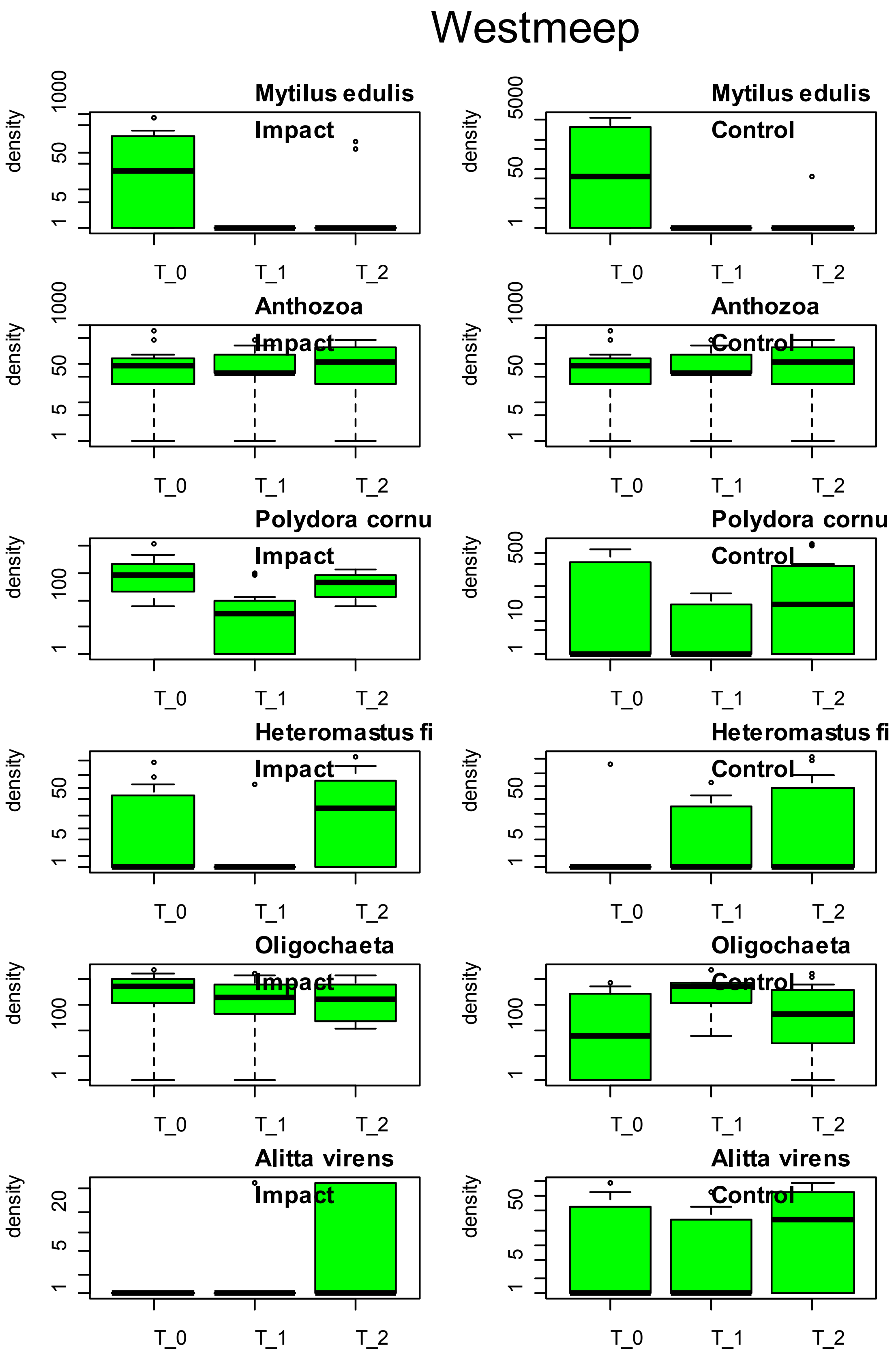

Westmeep
Impact
internal reference
time series
p = 0.01
canonical coefficient
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
**
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Pygospio elegans
Anthozoa
Phyllodoce
Eumida
Capitella capitata
Tharyx
Lanice conchilega
Nereis
Oligochaeta
Mysta picta
Cumacea
Mytilus edulis
Alitta succinea
Polydora cornuta
Petricolaria pholadiformis
Pygospio elegans
Scoloplos (Scoloplos) armige
Alitta virens
Carcinus maenas
Streblospio benedicti
Nereis
Oligochaeta
Mysta picta
Cumacea
Mytilus edulis
Alitta succinea
Polydora cornuta
Petricolaria pholadiformis

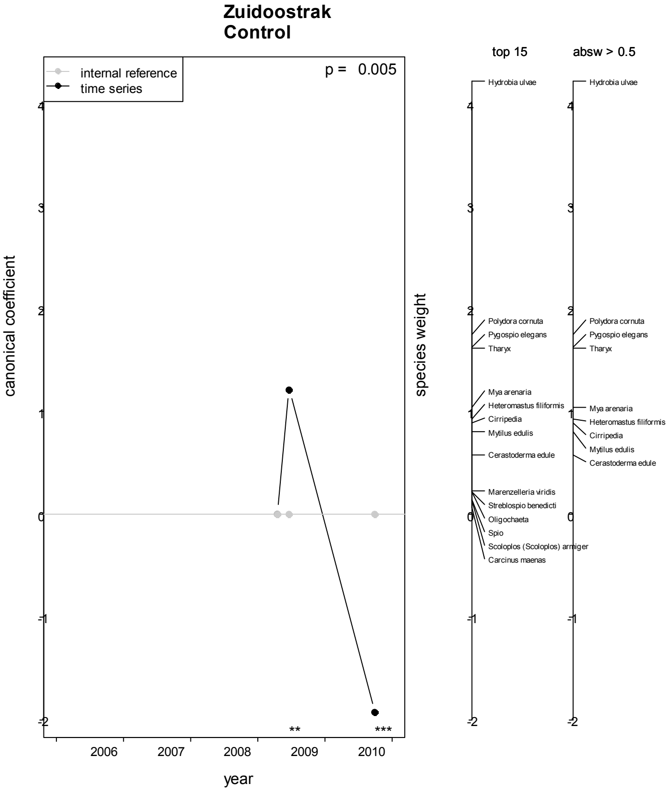

Westmeep
Control
Impact
p = 0.005
canonical coefficient
0.5
0.0
-0.5
-1.0
-1.5
-2.0
***
*
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Mytilus edulis
Tharyx
Nereis
Heteromastus filiformis
Scoloplos (Scoloplos) armiger
Phyllodoce
Eumida
Capitella capitata
Lanice conchilega
Anthozoa
Alitta succinea
Pygospio elegans
Petricolaria pholadiformis
Oligochaeta
Polydora cornuta
Alitta virens
Cumacea
Phyllodoce
Eumida
Mysta picta
Capitella capitata
Lanice conchilega
Anthozoa
Alitta succinea
Pygospio elegans
Petricolaria pholadiformis
Oligochaeta
Polydora cornuta

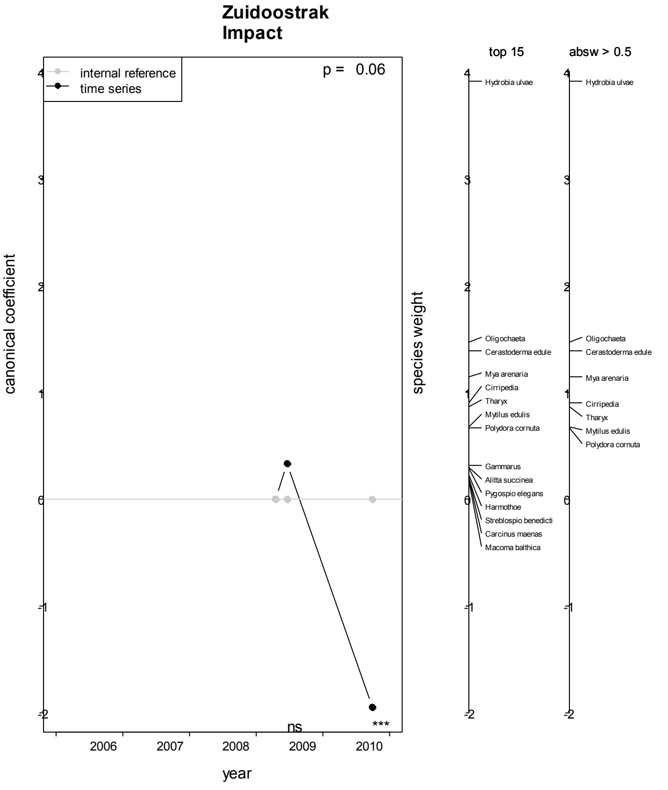

Westmeep
2009-09-20
canonical axis
first residual axis
4
2
0
-2
-4
-2
0
2
4
Control
Impact
4
2
0
-2
-4
Corophium volutator
Alitta virens
Nereis
Eumida bahusiensis
Eumida
Pygospio elegans
Mysta picta
Cumacea
Lanice conchilega
Anthozoa
Capitella capitata
Alitta succinea
Oligochaeta
Polydora cornuta
Petricolaria pholadiformis

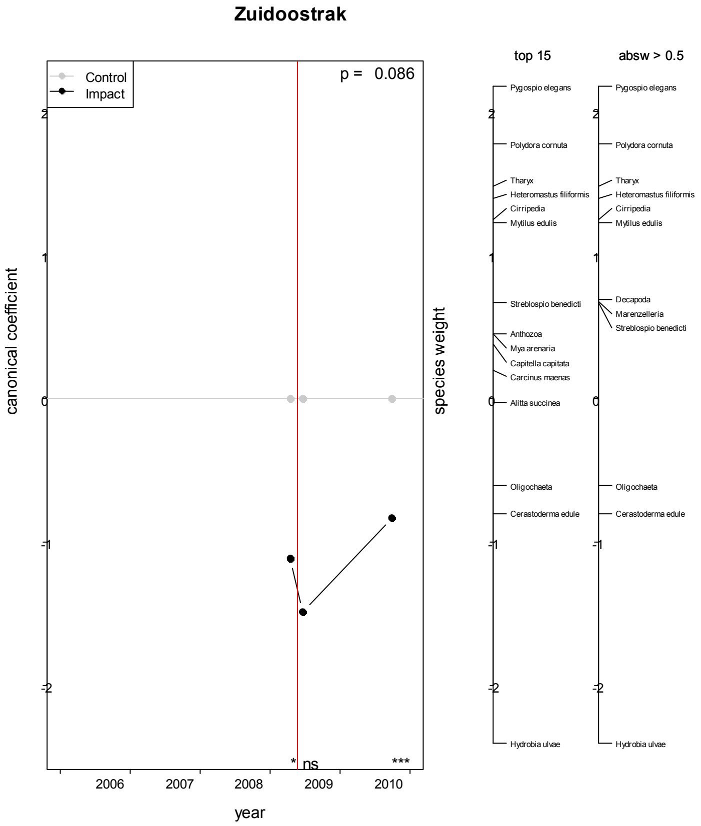

Westmeep
2009-11-23
canonical axis
first residual axis
2
0
-2
-4
-4
-2
0
2
Control
Impact
2
0
-2
-4
Tharyx
Abra alba
Oligochaeta
Eumida
Polydora cornuta
Capitella capitata
Petricolaria pholadiformis

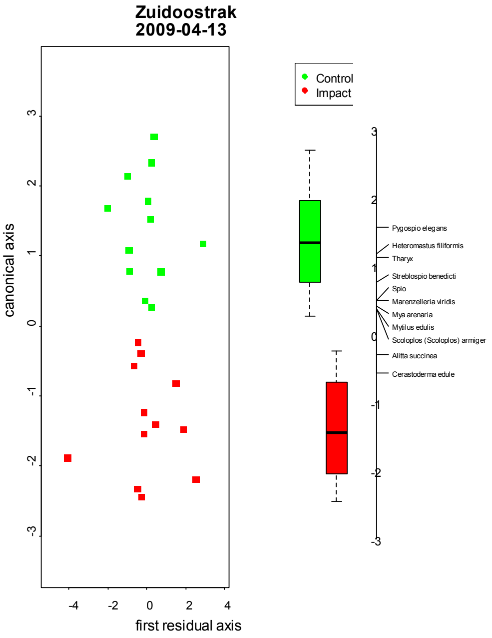

Westmeep
2010-09-27
canonical axis
first residual axis
4
2
0
-2
-4
-2
0
2
4
6
Control
Impact
4
2
0
-2
-4
Capitella capitata
Myrianida prolifera
Heteromastus filiformis
Spiophanes bombyx
Eumida
Alitta succinea
Tharyx
Oligochaeta
Lanice conchilega
Scoloplos (Scoloplos) armiger
Anthozoa
Phyllodoce
Polydora cornuta
Pygospio elegans

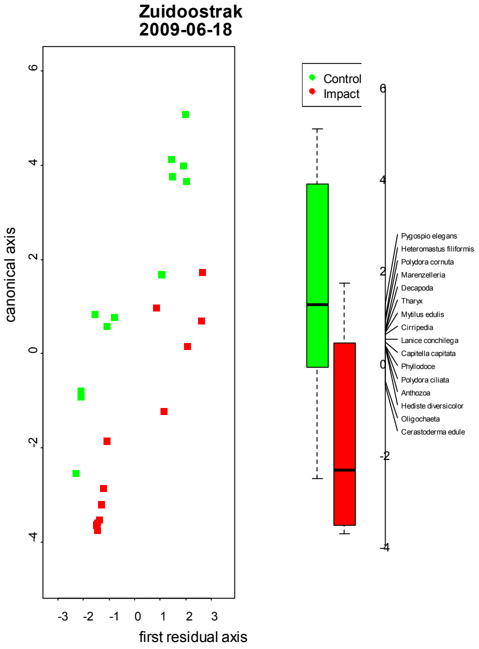

Westmeep
Mytilus edulis
Impact
density
1
5
50
1000
T_0
T_1
T_2
Mytilus edulis
Control
density
1
50
5000
T_0
T_1
T_2
Anthozoa
Impact
density
1
5
50
1000
T_0
T_1
T_2
Anthozoa
Control
density
1
5
50
1000
T_0
T_1
T_2
Polydora cornu
Impact
density
1
100
T_0
T_1
T_2
Polydora cornu
Control
density
1
10
500
T_0
T_1
T_2
Heteromastus fi
Impact
density
1
5
50
T_0
T_1
T_2
Heteromastus fi
Control
density
1
5
50
T_0
T_1
T_2
Oligochaeta
Impact
density
1
100
T_0
T_1
T_2
Oligochaeta
Control
density
1
100
T_0
T_1
T_2
Alitta virens
Impact
density
1
5
20
T_0
T_1
T_2
Alitta virens
Control
density
1
5
50
T_0
T_1
T_2

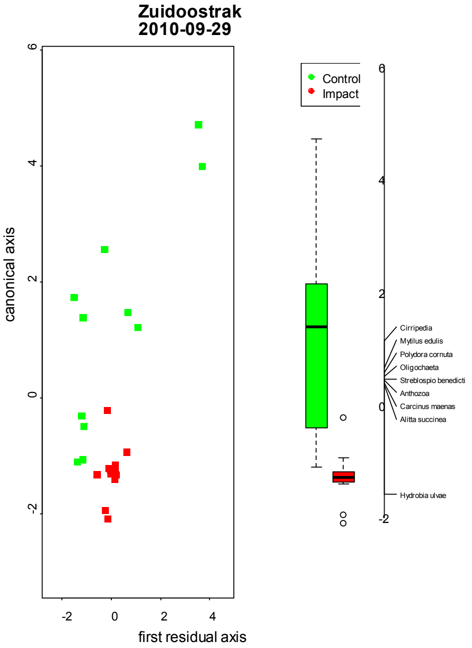

Zuidoostrak
Control
internal reference
time series
p = 0.005
canonical coefficient
year
2006
2007
2008
2009
2010
**
***
4
3
2
1
0
-1
-2
top 15
absw > 0.5
species weight
Hydrobia ulvae
Polydora cornuta
Pygospio elegans
Tharyx
Mya arenaria
Heteromastus filiformis
Cirripedia
Mytilus edulis
Cerastoderma edule
Marenzelleria viridis
Streblospio benedicti
Oligochaeta
Spio
Scoloplos (Scoloplos) armiger
Carcinus maenas


Zuidoostrak
Impact
internal reference
time series
p = 0.06
canonical coefficient
year
2006
2007
2008
2009
2010
ns
***
4
3
2
1
0
-1
-2
top 15
absw > 0.5
species weight
Hydrobia ulvae
Oligochaeta
Cerastoderma edule
Mya arenaria
Cirripedia
Tharyx
Mytilus edulis
Polydora cornuta
Gammarus
Alitta succinea
Pygospio elegans
Harmothoe
Streblospio benedicti
Carcinus maenas
Macoma balthica


Zuidoostrak
Control
Impact
p = 0.086
canonical coefficient
2
1
0
-1
-2
* ns
***
2006
2007
2008
2009
2010
year
species weight
top 15
absw > 0.5
Pygospio elegans
Polydora cornuta
Tharyx
Heteromastus filiformis
Cirripedia
Mytilus edulis
Streblospio benedicti
Anthozoa
Mya arenaria
Capitella capitata
Carcinus maenas
Alitta succinea
Oligochaeta
Cerastoderma edule
Hydrobia ulvae
Pygospio elegans
Polydora cornuta
Tharyx
Heteromastus filiformis
Cirripedia
Mytilus edulis
Decapoda
Marenzelleria
Streblospio benedicti
Oligochaeta
Cerastoderma edule
Hydrobia ulvae


Zuidoostrak
2009-04-13
canonical axis
first residual axis
-4
-2
0
2
4
3
2
1
0
-1
-2
-3
🟩 Control
🟥 Impact
Pygospio elegans
Heteromastus filiformis
Tharyx
Streblospio benedicti
Spio
Marenzelleria viridis
Mya arenaria
Mytilus edulis
Scoloplos (Scoloplos) armiger
Alitta succinea
Cerastoderma edule


Zuidoostrak
2009-06-18
canonical axis
first residual axis
-3
-2
-1
0
1
2
3
6
4
2
0
-2
-4
🟩 Control
🟥 Impact
Pygospio elegans
Heteromastus filiformis
Polydora cornuta
Marenzelleria
Decapoda
Tharyx
Mytilus edulis
Cirripedia
Lanice conchilega
Capitella capitata
Phyllodoce
Polydora ciliata
Anthozoa
Hediste diversicolor
Oligochaeta
Cerastoderma edule


Zuidoostrak
2010-09-29
canonical axis
first residual axis
-2
0
2
4
6
4
2
0
-2
🟩 Control
🟥 Impact
Cirripedia
Mytilus edulis
Polydora cornuta
Oligochaeta
Streblospio benedicti
Anthozoa
Carcinus maenas
Alitta succinea
Hydrobia ulvae

Zuidoostrak