

## Appendix S1

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Title: Resilience in coastal dune grasslands: pH and SOM effects on P nutrition, plant strategies and soil communities

Authors: Annemieke M. Kooijman, Elly Morriën, Gerard Jagers op Akkerhuis, Anna Missong, Roland Bol, Erwin Klumpp, Rutger van Hall, Mark van Til, Karsten Kalbitz and Jaap Bloem

Table S1. Coordinates of the 50 sampling localities.

Sample	pH class	SOM class	Coordinates
<b>P-nutrition study</b>			
1	high	low	N 52°20'09 E 4°30'44
3	high	low	N 52°20'02 E 4°30'38
5	high	low	N 52°19'46 E 4°30'22
8	high	low	N 52°19'39 E 4°30'19
9	high	low	N 52°19'41 E 4°30'18
2	high	intermediate	N 52°20'04 E 4°30'40
4	high	intermediate	N 52°20'00 E 4°30'37
6	high	intermediate	N 52°19'47 E 4°30'27
7	high	intermediate	N 52°19'56 E 4°30'32
10	high	intermediate	N 52°19'34 E 4°30'11
11	high	high	N 52°18'56 E 4°32'05
12	high	high	N 52°18'56 E 4°32'05
13	high	high	N 52°18'56 E 4°32'05
14	high	high	N 52°18'56 E 4°32'05
15	high	high	N 52°18'56 E 4°32'05
18	low	low	N 52°18'19 E 4°31'47
19	low	low	N 52°18'19 E 4°31'47
20	low	low	N 52°18'10 E 4°31'47
21	low	low	N 52°18'15 E 4°31'54
22	low	low	N 52°18'14 E 4°31'54
16	low	intermediate	N 52°18'41 E 4°32'00
23	low	intermediate	N 52°18'56 E 4°31'32
24	low	intermediate	N 52°18'30 E 4°31'36
29	low	intermediate	N 52°18'49 E 4°32'02
30	low	intermediate	N 52°18'49 E 4°32'03
17	low	high	N 52°18'54 E 4°32'06
25	low	high	N 52°18'35 E 4°31'47
26	low	high	N 52°18'37 E 4°31'49
27	low	high	N 52°18'40 E 4°31'54
28	low	high	N 52°18'42 E 4°31'57
<b>soil communiy study</b>			
TPL1	high	low	N 52°20'48 E 4°30'57
TPL2	high	low	N 52°20'49 E 4°30'58
TPL3	high	low	N 52°20'49 E 4°31'01
TPL4	high	low	N 52°20'49 E 4°31'03
TPL5	high	low	N 52°20'50 E 4°31'03
TPH1	high	intermediate	N 52°20'50 E 4°31'00
TPH2	high	intermediate	N 52°20'50 E 4°31'01
TPH3	high	intermediate	N 52°20'49 E 4°31'02
TPH4	high	intermediate	N 52°20'49 E 4°31'03
TPH5	high	intermediate	N 52°20'50 E 4°31'04
DHL1	low	low	N 52°19'09 E 4°33'06
DHL2	low	low	N 52°19'09 E 4°33'07
DHL3	low	low	N 52°19'10 E 4°33'07
DHL4	low	low	N 52°19'07 E 4°33'10
DHL5	low	low	N 52°19'06 E 4°33'10
DHH1	low	intermediate	N 52°19'08 E 4°33'06
DHH2	low	intermediate	N 52°19'08 E 4°33'08
DHH3	low	intermediate	N 52°19'08 E 4°33'09
DHH4	low	intermediate	N 52°19'08 E 4°33'10
DHH5	low	intermediate	N 52°19'08 E 4°33'11

Table S2. Statistical analysis of basic soil characteristics in different coastal dune grasslands, conducted with three-way General linear models, with study (P nutrition or soil community study), pH (calcareous or acidic) and SOM (low, intermediate or high soil organic matter content) as independent variables. The numbers given are F-values, which are significant when followed by asterisks: \* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ .

	Study	pH	SOM	Study* pH	Study* SOM	pH* SOM	Study* pH*SOM
Lime content (%)	0.06	35.07***	3.14	0.19	1.91	3.63*	1.91
pH	0.05	429.51***	21.13***	1.57	2.22	11.07***	7.09*
LOI (%)	1.73	5.94*	137.28***	8.03**	2.69	1.96	1.39
Soil C (kg m <sup>-2</sup> )	52.48***	6.10*	99.29***	6.82*	1.32	0.18	0.62
Soil N (kg m <sup>-2</sup> )	110.19***	41.48***	92.30***	14.97***	3.10	1.39	0.35
Soil C:N ratio (g g <sup>-1</sup> )	51.06***	46.66***	0.24	0.65	0.12	0.73	0.01
Humin (% soil C)	-	185.86***	7.29**	-	-	6.84**	-
Humic acids (% soil C)	-	256.75***	2.37	-	-	14.19***	-
Fulvic acids (% soil C)	-	31.95***	15.20***	-	-	2.79	-

Table S3. Statistical analysis of vegetation characteristics in different coastal dune grasslands, conducted with three-way General linear models, with study (P nutrition or soil community study), pH (calcareous or acidic) and SOM (low, intermediate or high soil organic matter content) as independent variables. The numbers given are F-values, which are significant when followed by asterisks: \* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ .

	Study	pH	SOM	Study* pH	Study* SOM	pH* SOM	Study* pH*SOM
Total plant species	19.17***	122.00***	4.92*	32.96***	1.86	12.52***	0.13
Vascular plant species	14.26***	172.73***	3.37*	31.76***	2.70	13.18***	0.67
Cryptogam species	4.03	0.71	2.91	2.30	0.02	0.46	4.05
AM plant species	41.72***	324.37***	9.07***	26.62***	0.11	5.52**	0.01
NM plant species	0.02	0.00	0.40	9.92***	4.29*	15.87***	7.62**
AM species (% herb species)	11.00**	95.95***	3.95*	0.94	0.00	4.59*	5.51*
NM species (% herb species)	11.00**	95.95***	3.95*	0.94	0.00	4.59*	5.51*
Total cover (%)	0.00	4.64*	68.43***	0.01	5.81*	2.72	4.70*
Bare sand (%)	0.00	4.64*	68.43***	0.01	5.81*	2.72	4.70*
Herb cover (%)	32.07***	9.98**	121.22***	3.20	0.84	1.11	11.89***
Cryptogam cover (%)	27.70***	1.68	6.54**	3.89	4.90*	8.02**	27.08**
AM plant cover (%)	29.91***	52.30***	44.98***	0.46	3.18	8.80***	0.93
NM plant cover (%)	1.73	164.79***	51.52***	2.73	11.24**	23.89***	12.84***
AM cover (% herb layer)	1.57	264.48***	3.42*	2.26	1.14	5.60**	3.47
NM cover (% herb layer)	1.57	264.48***	3.42*	2.26	1.14	5.60**	3.47
Aboveground biomass (g m <sup>-2</sup> )	-	13.06**	36.12***	-	-	4.81*	-
Plant N-content (mg g <sup>-1</sup> )	38.63***	17.96***	1.86	4.41*	20.34***	6.31**	13.72***
Plant P-content (mg g <sup>-1</sup> )	11.14**	15.91***	1.00	0.10	8.38**	2.28	8.11**
Plant N:P ratio	1.37	1.60	1.50	0.51	0.02	0.15	0.53
<i>Carex</i> N-content (mg g <sup>-1</sup> )	-	14.80**	0.03	-	-	3.45	-
<i>Carex</i> P-content (mg g <sup>-1</sup> )	-	18.93***	6.12*	-	-	2.53	-
<i>Carex</i> N:P ratio	-	35.89***	2.76	-	-	0.76	-

Table S4. Statistical analysis of different forms of P in the soil of different coastal dune grasslands, conducted with two-way General linear models, with pH (calcareous or acidic) and SOM (low, intermediate or high soil organic matter content) as independent variables. The numbers given are F-values, which are significant when followed by asterisks: \* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ .

	pH	SOM	pH*SOM
Total P (g m <sup>-2</sup> )	19.19 ***	2.29	0.60
Inorganic P (g m <sup>-2</sup> )	33.30***	8.81**	1.65
Inorganic P (% total P)	18.07***	53.31***	4.07*
Organic P (g m <sup>-2</sup> )	1.26	25.17***	0.52
Organic P (% total P)	17.82***	52.58***	3.85*
Sorbed P (g m <sup>-2</sup> )	0.65	3.58*	0.54
Sorbed P (% total P)	40.20***	4.13*	2.79
Inorganic P minus sorbed P (g m <sup>-2</sup> )	41.68***	21.04***	3.39
Minimum estimate solid inorganic P (g m <sup>-2</sup> )	28.82***	20.38***	1.74
Minimum estimate sorbed organic P (g m <sup>-2</sup> )	13.64**	3.47*	3.74*
Mehlich-extractable P (g m <sup>-2</sup> )	10.90**	1.30	1.45
Total 'dissolved' P (g m <sup>-2</sup> )	14.34**	3.16	1.13
Soluble P (g m <sup>-2</sup> )	4.40	1.08	2.30
Colloidal P (g m <sup>-2</sup> )	13.60**	3.23	1.71

Fig. S1. Soil P fractions in coastal dune grasslands in calcareous and acidic dunes with different SOM in the Netherlands. Light orange bars = low SOM; orange bars = intermediate SOM and brown bars = high SOM. Values given are means (n = 5) and standard deviations. Different letters in the upper row indicate significant differences for a particular parameter between calcareous and acidic dunes ( $p < 0.05$ ). Different letters in the lower row indicate significant differences for a particular parameter between all six soil types.

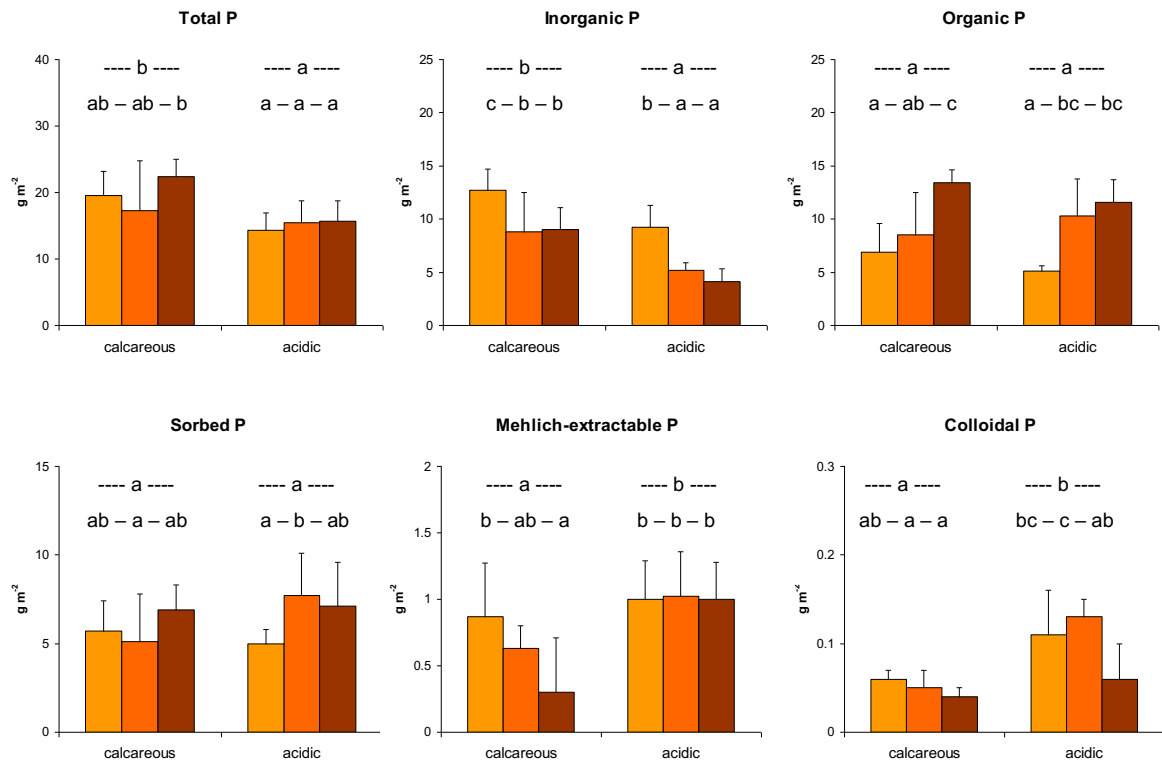


Table S5. Statistical analysis of different forms of Ca, Fe and Al in the soil of different coastal dune grasslands, conducted with two-way General linear models, with pH (calcareous or acidic) and SOM (low, intermediate or high soil organic matter content) as independent variables. The numbers given are F-values, which are significant when followed by asterisks: \* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ .

	pH	SOM	pH*SOM
Total amorphous Fe ( $\text{g m}^{-2}$ )	0.62	9.08**	1.11
Inorganic amorphous Fe ( $\text{g m}^{-2}$ )	23.15***	1.72	9.35**
Inorganic amorphous Fe (% total Fe)	39.04***	4.59*	13.70***
Organic amorphous Fe ( $\text{g m}^{-2}$ )	33.77***	17.08***	7.48**
Organic amorphous Fe (% total Fe)	39.04***	4.59*	13.70***
Total 'dissolved' Fe ( $\text{g m}^{-2}$ )	3.49	4.62*	2.90
Soluble Fe ( $\text{g m}^{-2}$ )	5.72*	2.70	2.78
Colloidal Fe ( $\text{g m}^{-2}$ )	0.63	4.51*	1.64
Total amorphous Al ( $\text{g m}^{-2}$ )	15.95***	13.33***	2.90
Inorganic amorphous Al ( $\text{g m}^{-2}$ )	1.50	3.42*	5.51*
Inorganic amorphous Al (% total Al)	0.67	1.56	11.12***
Organic amorphous Al ( $\text{g m}^{-2}$ )	10.68**	8.87**	12.84***
Organic amorphous Al (% total Al)	0.67	1.56	11.12***
Total 'dissolved' Al ( $\text{g m}^{-2}$ )	9.65**	4.85*	1.89
Soluble Al ( $\text{g m}^{-2}$ )	8.71*	3.77	1.33
Colloidal Al ( $\text{g m}^{-2}$ )	8.79*	5.29*	2.32
Total amorphous Fe+Al ( $\text{mol m}^{-2}$ )	0.01	10.00***	0.36
Inorganic amorphous Fe+Al ( $\text{mol m}^{-2}$ )	20.45***	2.09	8.69**
Inorganic amorphous Fe+Al (% total Fe+Al)	55.61***	9.73***	19.92***
Organic amorphous Fe+Al ( $\text{mol m}^{-2}$ )	30.02***	17.12***	10.99***
Organic amorphous Fe+Al (% total Fe+Al)	54.69***	9.75***	19.84***
Total 'dissolved' Ca ( $\text{g m}^{-2}$ )	45.42***	0.42	0.31
Soluble Ca ( $\text{g m}^{-2}$ )	46.32***	0.40	0.25
Colloidal Ca ( $\text{g m}^{-2}$ )	3.62	2.40	1.15

Fig. S2. Fractions of soil Fe and Al in coastal dune grasslands in calcareous and acidic dunes with different SOM in the Netherlands. Light orange bars = low SOM; orange bars = intermediate SOM and brown bars = high SOM. Values given are means (n = 5) and standard deviations. Different letters in the upper row indicate significant differences for a particular parameter between calcareous and acidic dunes ( $p < 0.05$ ). Different letters in the lower row indicate significant differences for a particular parameter between all six soil types.

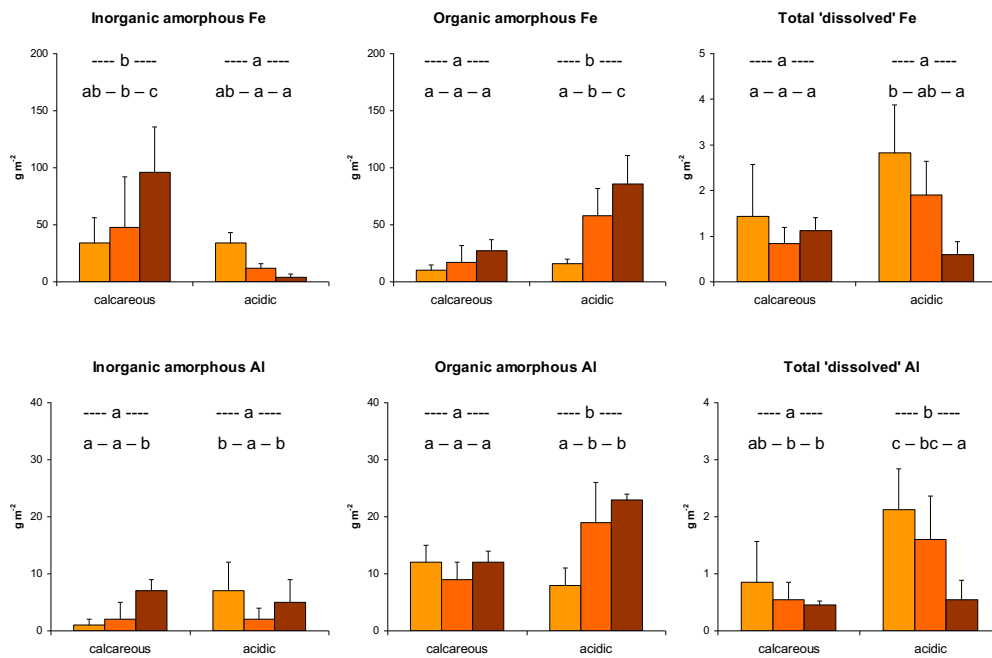




Table S6. Statistical analysis of microbial characteristics in different coastal dune grasslands, conducted with three-way General linear models, with study (P nutrition or soil community study), pH (calcareous or acidic) and SOM (low, intermediate or high soil organic matter content) as independent variables. The numbers given are F-values, which are significant when followed by asterisks: \* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ .

	Study	pH	SOM	Study* pH	Study* SOM	pH* SOM	Study* pH*SOM
Microbial C fresh soil ( $\text{g m}^{-2}$ )	23.69***	14.42***	24.88***	9.14**	0.12	6.75**	5.38*
Microbial N fresh soil ( $\text{g m}^{-2}$ )	11.89**	26.55***	23.82***	3.76	0.01	11.95***	1.91
Respiration ( $\text{g m}^{-2} \text{ day}^{-1}$ )	33.39***	0.04	1.25	2.71	0.63	5.80**	1.71
Respiration quotient ( $\text{mg C g}^{-1} \text{ C}$ )	0.35	1.94	10.99***	1.09	0.36	0.23	5.55*
Net N mineralization ( $\text{g m}^{-2} \text{ day}^{-1}$ )	5.82*	0.38	1.79	0.37	2.36	2.32	0.02
N mineralization per g C respired	3.72	0.17	1.74	0.17	4.06	5.46**	0.66

Table S7. Statistical analysis of microbial characteristics in the soil of different coastal dune grasslands, conducted with two-way General linear models, with pH (calcareous or acidic) and SOM (low, intermediate or high soil organic matter content) as independent variables. The numbers given are F-values, which are significant when followed by asterisks: \* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ .

	pH	SOM	pH*SOM
Microbial C fresh soil ( $\text{g m}^{-2}$ )	15.99***	14.11***	6.09**
Microbial C incubated ( $\text{g m}^{-2}$ )	10.61**	2.70	1.30
Microbial C uptake during incubation ( $\text{g m}^{-2}$ )	1.25	0.15	0.04
Respiration ( $\text{g m}^{-2}$ )	0.67	0.86	4.53*
Total microbial C release ( $\text{g m}^{-2}$ )	2.24	0.38	3.12
Microbial N fresh soil ( $\text{g m}^{-2}$ )	18.10***	13.43***	8.17**
Microbial N incubated ( $\text{g m}^{-2}$ )	1.73	3.64*	0.27
Microbial C:N ratio fresh soil ( $\text{g g}^{-1}$ )	0.17	4.17*	6.24**
Microbial C:N ratio incubated soil ( $\text{g g}^{-1}$ )	8.38**	0.11	0.08
Microbial N uptake during incubation ( $\text{g m}^{-2}$ )	7.04*	0.09	1.19
Net N mineralization ( $\text{g m}^{-2}$ )	0.02	2.07	1.19
Total microbial N release ( $\text{g m}^{-2}$ )	4.07	0.88	0.71
Microbial P fresh soil ( $\text{g m}^{-2}$ )	19.92***	3.10	2.68
Microbial P incubated ( $\text{g m}^{-2}$ )	2.42	2.37	0.72
Microbial C:P ratio fresh soil ( $\text{g g}^{-1}$ )	8.55**	1.94	0.57
Microbial C:P ratio incubated soil ( $\text{g g}^{-1}$ )	6.15*	2.18	0.99
Microbial N:P ratio fresh soil ( $\text{g g}^{-1}$ )	3.59	2.46	1.70
Microbial N:P ratio incubated soil ( $\text{g g}^{-1}$ )	0.65	3.00	0.24
Microbial P uptake during incubation ( $\text{g m}^{-2}$ )	6.95*	3.00	0.95
Net P mineralization ( $\text{g m}^{-2}$ )	4.77*	0.66	0.48
Total microbial P release ( $\text{g m}^{-2}$ )	5.44*	2.62	0.78

Table S8. Statistical analysis of characteristics of the soil community in different coastal dune grasslands, conducted with two-way General linear models, with pH (calcareous or acidic) and SOM (low or high soil organic matter content) as independent variables. The numbers given are F-values, which are significant when followed by asterisks: \* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ .

	pH	SOM	pH*SOM
Fungal biomass based on PLFA (g m <sup>-2</sup> )	6.85*	4.04	0.07
Fungal biomass based on counts (g m <sup>-2</sup> )	37.43***	13.10**	0.87
Active hyphae based on counts (g m <sup>-2</sup> )	1.51	2.63	0.54
Melanized hyphae based on counts (g m <sup>-2</sup> )	26.44***	4.32	1.27
Bacterial biomass based on counts (g m <sup>-2</sup> )	1.12	0.01	0.76
Incorporation of leucine (pmol g <sup>-1</sup> h <sup>-1</sup> )	0.36	4.27	0.04
Incorporation of thymidine (pmol g <sup>-1</sup> h <sup>-1</sup> )	10.11**	1.12	1.37
Bacterial biomass based on PLFA (g m <sup>-2</sup> )	1.70	16.16**	1.42
G+ bacteria based on PLFA (g m <sup>-2</sup> )	3.15	24.52***	0.75
G- bacteria based on PLFA (g m <sup>-2</sup> )	0.10	18.55***	0.58
Gram+ : Gram- bacteria ratio	37.18***	0.14	7.17*
F:B ratio (based on PLFA)	13.31**	29.02**	3.74
Protists (nr m <sup>-2</sup> )	9.66**	0.97	4.90*
Flagellates (nr m <sup>-2</sup> )	10.37**	1.83	5.48
Amoeba (nr m <sup>-2</sup> )	0.26	1.55	0.03
Microarthropods (nr m <sup>-2</sup> )	0.18	26.64***	2.33
Acari (nr m <sup>-2</sup> )	0.01	37.56***	2.54
Collembola (nr m <sup>-2</sup> )	4.16	8.90**	0.24
Herbivores (nr m <sup>-2</sup> )	0.13	15.32**	0.78
Herbivorous grazers (nr m <sup>-2</sup> )	1.55	18.25***	8.56**
Herbivorous browsers (nr m <sup>-2</sup> )	0.01	11.39**	0.06
Fungivores (nr m <sup>-2</sup> )	5.10*	10.58**	0.04
Fungivorous grazers (nr m <sup>-2</sup> )	1.44	20.44***	0.91
Fungivorous browsers (nr m <sup>-2</sup> )	5.59*	4.11	0.54
Omnivores (nr m <sup>-2</sup> )	3.21	30.67***	15.13**
Opportunists (nr m <sup>-2</sup> )	0.01	4.61*	0.00
Herbofungivores (nr m <sup>-2</sup> )	5.10*	28.08***	25.77***
Predators (nr m <sup>-2</sup> )	0.04	18.12***	0.99
General predators (nr m <sup>-2</sup> )	0.00	13.74**	3.83
Arthropod predators (nr m <sup>-2</sup> )	0.12	17.32***	0.02