Severe reduction of carbon, alkalinity and nutrient fluxes in the southern Baltic Sea caused by dragging of trawl ropes across the seafloor

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Table S1: Station list of the multiple cores (MUC), benthic landers (BIGO), CTD, and DSR deployments.

Station	Gear number	Date (2024)	Latitude	Longitude	Location
1	CTD-1	19 Jul	54° 12.137' N	11° 42.341' E	North of HI
4	MUC-1	19 Jul	54° 11.944' N	11° 42.568' E	HI
5	MUC-2	19 Jul	54° 11.925' N	11° 42.160' E	HI
7	CTD-2	19 Jul	54° 11.990' N	11° 42.236' E	HI
12	MUC-5	20 Jul	54° 12.029' N	11° 42.144' E	HI
13	BIGO-1-1	20 Jul	54° 12.006' N	11° 42.501' E	HI
14	MUC-6	21 Jul	54° 12.026' N	11° 42.364' E	HI
15	MUC-7	21 Jul	54° 11.945' N	11° 41.216' E	CL
17	BIGO-2-1	21 Jul	54° 12.043' N	11° 41.958' E	HI
18	DSR-1	21-23 Jul	54° 11.958' N	11° 42.319' E	HI
20	MUC-9	22 Jul	54° 11.932' N	11° 42.582' E	HI
28	MUC-12	25 Jul	54° 12.062' N	11° 41.252' E	CL
29	BIGO-2-2	25 Jul	54° 12.056' N	11° 41.104' E	CL
30	DSR-2	25 - 27 Jul	54° 11.979' N	11° 41.376' E	CL
31	CTD-3	26 Jul	54° 12.050' N	11° 41.240' E	CL
34	BIGO-1-2	26 Jul	54° 11.961' N	11° 42.377' E	HI
37	MUC-15	27 Jul	54° 12.022' N	11° 42.172' E	HI
45	MUC-20	28 Jul	54° 11.934' N	11° 41.230' E	CL
46	DSR-3	28-30 Jul	54° 11.935' N	11° 42.340' E	HI
47	CTD-4	29 Jul	54° 11.938' N	11° 42.315' E	HI
48	MUC-21	29 Jul	54° 11.934' N	11° 42.575' E	HI
49	MUC-22	29 Jul	54° 12.018' N	11° 42.366' E	HI
50	BIGO-1-3	29 Jul	54° 12.016' N	11° 42.323' E	HI
52	MUC-23	30 Jul	54° 11.948' N	11° 41.212' E	CL
53	BIGO-2-3	30 Jul	54° 12.040' N	11° 41.037' E	CL
55	DSR-4	30 Jul - 2 Aug	54° 11.935' N	11° 41.029' E	CL
60	BIGO-1-4	31 Jul	54° 12.025' N	11° 42.672' E	HI
62	MUC-26	1 Aug	54° 12.036' N	11° 41.220' E	CL
64	CTD-5	1 Aug	54° 11.964' N	11° 42.177' E	HI
65	CTD-6	1 Aug	54° 11.999' N	11° 41.243' E	CL
69	MUC-28	3 Aug	54° 12.025' N	11° 42.101' E	HI
70	MUC-29	3 Aug	54° 12.039' N	11° 42.345' E	HI
72	BIGO-1-5	3 Aug	54° 11.964' N	11° 42.330' E	HI
73	DSR-5	3 - 5 Aug	54° 11.984' N	11° 42.102' E	HI
75	CTD-7	4 Aug	54° 11.943' N	11° 41.230' E	CL
76	MUC-31	4 Aug	54° 11.949' N	11° 41.225' E	CL
78	MUC-33	4 Aug	54° 11.942' N	11° 42.594' E	HI
79	BIGO-2-4	4 Aug	54° 11.930' N	11° 41.199' E	CL
84	DSR-6	5 - 8 Aug	54° 12.025' N	11° 42.435' E	HI
85	BIGO1-6	5 Aug	54° 12.025' N	11° 42.615' E	HI

Table S2: Mean and standard deviation of particulate concentrations at the study site. Bolded numbers indicate statistically significant differences between the control (CL) and High Impact (HI) sites.

Depth (cm)		0.5	1.5	2.5	3.5	4.5	5.5	7	9	11	13	16	20	24	28	31
POC wt.%	CL	**3.85±0.65**	**3.58±0.72**	3.29±0.52	2.98±0.17	2.88±0.39	2.88±0.22	2.7±0.46	2.2±0.4	1.88±0.36	1.46±0.17	1.63±0.28	1.84±0.48	2.15±0.27	1.96±0.17	1.67±0.3
	HI	**2.77±0.7**	**2.51±0.91**	2.7±0.67	2.85±0.74	2.81±0.86	2.66±0.51	2.13±0.43	1.69±0	1.81±0.5	1.63±0.5	1.43±0.32	1.85±0.53	1.92±0.5	2.03±0.22	
PON wt.%	CL	**0.57±0.1**	**0.53±0.13**	0.48±0.08	0.43±0.03	0.41±0.06	0.4±0.04	0.36±0.08	0.29±0.06	0.23±0.06	0.18±0.02	0.2±0.03	0.23±0.05	0.27±0.04	0.25±0.02	0.22±0.04
	HI	**0.41±0.11**	**0.36±0.14**	0.39±0.1	0.4±0.12	0.51±0.32	0.37±0.07	0.29±0.07	0.22±0	0.24±0.07	0.22±0.07	0.19±0.04	0.24±0.07	0.24±0.07	0.26±0.03	
C/N	CL	7.84±0.13	7.88±0.34	8.08±0.32	8.07±0.36	8.18±0.29	8.37±0.15	8.72±0.44	8.98±0.28	9.48±0.5	9.23±0.55	9.31±0.59	9.39±0.58	9.14±0.2	9.2±0.51	8.7±0.01
	HI	7.85±0.41	8.15±0.49	8.12±0.46	8.49±0.58	7.75±2.32	8.37±0.5	8.54±0.62	8.9±0	8.85±0.59	8.81±0.47	8.74±0.69	9.05±0.67	9.36±0.9	9.33±0.65	
CaCO3 wt.%	CL	**5.49±1.13**	**5.26±2.05**	3.94±1.73	3.18±0.6	2.88±0.94	2.69±0.4	2.46±0.96	1.86±0.52	1.22±0.63	1.14±0.66	1±0.46	1.05±0.82	1.98±0.34	1.61±0.71	2.34±0.33
	HI	**3.84±0.9**	**2.94±1.45**	3.21±1.22	2.36±1.74	2.71±2.25	2.99±2.74	1.92±0.84	1.12±0	1.34±0.72	1.22±0.6	0.96±0.43	1.43±0.7	1.33±0.57	1.54±0.42	
TS wt.%	CL	0.66±0.13	**0.58±0.09**	0.58±0.08	0.65±0.09	0.69±0.13	0.82±0.1	0.84±0.09	0.78±0.09	0.74±0.1	0.74±0.14	0.99±0.22	0.9±0.18	1.04±0.17	1.02±0.07	0.86±0.1
	HI	0.49±0.15	**0.43±0.2**	0.52±0.14	0.71±0.24	0.81±0.28	0.78±0.15	0.7±0.15	0.45±0	0.67±0.13	0.78±0.15	0.91±0.24	1.02±0.22	0.89±0.25	0.98±0.1	

Table S3: Mean and standard deviation of porewater solute concentrations at the study site. Bolded numbers indicate statistically significant differences between the control (CL) and High Impact (HI) sites.

Depth (cm)		0	0.5	1.5	2.5	3.5	4.5	5.5	7	9	11	13	16	20	24	28
TA (mM)	CL	2.17±0.05	2.91±0.25	**3.37±0.38**	**3.4±0.38**	**3.53±0.41**	**3.86±0.45**	**4.12±0.45**	4.38±0.33	4.69±0.22	5.04±0.18	5.28±0.14	5.51±0.1	5.75±0.23	5.88±0.37	6.16±0.28
	HI	2.18±0.06	2.69±0.24	**2.92±0.36**	**2.94±0.32**	**3.04±0.35**	**3.3±0.35**	**3.53±0.35**	3.92±0.43	4.32±0.6	4.74±0.81	5.06±0.84	5.41±1.09	5.78±1.01	6.31±0.9	6.93±1.41
NH_4^+ (µM)	CL	6±3.1	**85±25.6**	**143±35.3**	**166±30.4**	180±36.6	**212±27.7**	221±28.6	**246±11.7**	**263±31.3**	289±18.9	284±28.4	313±19.8	327±26.3	330±47	361±47.8
	HI	7±4	**58±23.2**	**92±33**	**116±40**	124±65.8	**151±43.1**	176±47.3	**208±52.4**	**229±63.9**	271±89.7	277±76.4	314±85.6	352±100.5	385±79.7	382±129.4
PO_4^{3-} (µM)	CL	1.3±0.2	69.1±43.1	101±32.4	**72.1±20.1**	59.3±19.1	**63.1±20**	67.1±20.4	**70.3±14.6**	**74.5±12.4**	75.6±13.1	72.2±16.5	68.4±13.8	70±12.8	70.1±13.2	72.9±14.9
	HI	1.1±0.3	46.4±57.7	60±55.8	**49.4±25.7**	41.3±14.4	**45±11**	45±6.8	**51.2±7.5**	**60±11.4**	63.6±13.2	69.8±14.2	73.4±15.4	78.4±17.9	81.6±16.3	100.1±28.4
NO_3^- (µM)	CL	6.81±1.84	1.21±1.19	1.51±1.28	1.69±1.56	1.71±1.33	1.34±1.53	0.99±0.85	1.6±0.27							
	HI	6.13±0.89	0.45±0.43	0.6±0.41	0.68±0.56	0.87±0.85	0.48±0.34	0.39±0.21	0.6±0.4							
NO_2^- (µM)	CL	0.24±0.01	1.02±0.5	1.49±0.46	0.62±0.37	0.21±0.18	0.17±0.15	0.2±0.18	0.28±0.19							
	HI	0.2±0.07	0.72±0.62	0.85±0.43	0.43±0.28	0.26±0.26	0.26±0.22	0.28±0.29	0.27±0.3							
H_2S (µM)	CL	0.4±0.1	5.8±3.3	4.9±1.3	6.2±2.1	8.3±2.9	15.2±2.9	31.9±8.3	47.2±18.2	76.4±33.8	95.3±49.4	104.7±64.4	111.5±76	130.4±69.2	167.5±85.4	180.9±114.1
	HI	0.3±0.1	4.6±2.1	3.8±1.3	5.2±1.3	8.6±3.7	15.3±7.8	30.5±18.9	55.7±26.5	83.3±55.1	113.7±66.7	142.1±86.9	156.3±91.9	182.2±102.3	195.8±114.6	250.8±47.2
Fe^{2+} (µM)	CL	0.5±0.1	157.9±73.6	173±66.8	103.1±59.6	28±30.4	5.6±4.5	1.6±0.8	1.5±0.6	1.6±0.7	1.3±0.4	1.1±0.3	1±0.3	0.9±0.4	1.1±0.4	0.8±0.5
	HI	0.5±0.3	86.5±82.8	135.3±56.1	67.7±46.3	14.5±16	6.6±8.6	1.4±1	1.1±0.4	1.6±1.1	1.3±0.5	1±0.5	0.8±0.5	0.8±0.4	0.9±0.4	
$Si(OH)_4$ (µM)	CL	47±6	400±72	526±59	505±90	500±91	**536±63**	540±50	572±43	632±46	622±54	657±76	653±65	714±63	725±57	750±81
	HI	46±11	352±77	453±79	442±69	436±54	**476±33**	498±50	547±47	600±71	672±83	695±86	714±91	721±94	753±89	836±127
SO_4^{2-} (mM)	CL	21.7±0.6	21.3±0.6	21±0.7	20.8±0.6	**20.5±0.7**	20.1±0.6	19.7±0.5	19.1±0.6	18.6±0.4	18.4±0.5	18.3±0.5	18.5±0.5	18.5±0.5	18.5±0.5	18.6±0.5

	HI	21.9±0.5	21.8±0.4	21.6±0.5	21.3±0.5	**21.2±0.6**	20.7±0.4	20.2±0.4	19.5±0.6	18.8±0.5	18.6±0.7	18.4±0.7	18.5±0.8	18.5±0.8	18.2±0.8	17.7±0.9

Table S4: Fluxes of solutes (mmol m^{-2} d^{-1}) across the sediment-water interface calculated from lander data (BIGO) and porewater profiles (PW) at the control and high-impact sites. Positive fluxes are directed into the water column and vice versa. Also listed are the POC remineralization rates (mmol C m^{-2} d^{-1}), R_{DEN}, and R_{NIT} (mmol N m^{-2} d^{-1}).

Station Name	Chamber	Area	PO_4^{3-}	NO_3^-	NO_2^-	NH_4^+	$Si(OH)_4$	TOU	DIC	TA	$RPOC_{TOT}$	R_{DEN}	R_{NIT}
BIGO-I-1	K1	HI	0.02	-0.08	0.023	0.49	2.70	-8.52	12.20	1.23	7.38	0.63	0.49
	K2	HI	0.06	-0.23	0.030	1.34	3.30	-8.84	-	-	8.31	0.06	-0.15
BIGO-I-2	K1	HI	-0.03	-0.22	0.034	1.04	3.29	-9.34	10.21	4.34	8.54	0.38	0.14
	K2	HI	0.03	-0.16	0.037	1.12	4.38	-9.06	12.75	5.60	8.28	0.21	0.05
BIGO-I-3	K1	HI	-0.01	-0.30	0.013	1.34	4.01	-7.80	8.68	6.35	7.53	0.03	-0.24
	K2	HI	0.04	-0.35	0.008	1.56	3.49	-8.11	8.82	4.42	7.97	-0.09	-0.39
BIGO-I-4	K1	HI	0.05	-0.38	0.003	1.42	3.23	-6.70	8.76	6.94	6.76	-0.09	-0.42
	K2	HI	0.02	-0.30	0.012	1.51	3.19	-5.61	9.84	5.24	5.84	-0.38	-0.61
BIGO-I-5	K1	HI	0.03	-0.36	0.001	0.97	2.47	-3.12	8.64	9.45	3.53	-0.11	-0.42
	K2	HI	0.07	-0.41	0.005	1.78	3.10	-3.59	9.16	9.23	4.47	-0.73	-1.02
BIGO-I-6	K1	HI	0.04	-0.39	0.007	1.32	3.40	-5.40	6.04	0.77	5.64	-0.14	-0.47
	K2	HI	0.06	-0.37	0.019	1.50	3.92	-5.98	11.67	7.78	6.21	-0.25	-0.55
BIGO-II-1	K1	HI	0.01	-0.27	0.032	1.13	3.10	-11.81	14.03	3.14	10.66	0.65	0.34
	K2	HI	0.01	-0.17	0.038	1.10	2.93	-9.04	13.38	6.09	8.26	0.24	0.06
BIGO-II-2	K1	CL	0.04	-0.26	0.043	1.33	5.11	-9.69	14.31	8.05	9.05	0.18	-0.08
	K2	CL	0.07	-0.35	0.052	1.36	4.23	-9.08	11.59	6.81	8.66	0.18	-0.15
BIGO-II-3	K1	CL	0.37	-0.27	0.028	2.29	4.55	-10.55	21.06	15.60	10.36	-0.59	-0.77
	K2	CL	0.04	-0.25	0.020	1.56	3.95	-8.93	13.54	9.58	8.56	-0.13	-0.34
BIGO-II-4	K1	CL	0.22	-0.78	-0.111	4.63	5.00	-	25.01	14.66			
	K2	CL	0.06	-0.37	-0.002	1.82	3.60	-6.49	31.75	18.54	6.84	-0.51	-0.79
MUC1		HI	-	-	-	1.23	7.05	-	-	8.45			
MUC2		HI	-	-	-	0.87	8.22	-	-	5.44			
MUC5		HI	-	-	-	0.48	2.27	-	-	3.95			
MUC6		HI	-	-	-	0.64	2.45	-	-	5.18			
MUC9		HI	-	-	-	0.57	3.43	-	-	3.86			
MUC15		HI	-	-	-	0.26	0.73	-	-	0.73			

MUC21	HI	-	-	-	0.48	3.65	-	-	5.68
MUC22	HI	-	-	-	1.27	4.22	-	-	6.42
MUC28	HI	-	-	-	0.44	7.80	-	-	2.85
MUC29	HI	-	-	-	1.39	7.28	-	-	13.69
MUC33	HI	-	-	-	1.42	7.09	-	-	11.79
MUC7	CL	-	-	-	1.54	7.44	-	-	11.04
MUC12	CL	-	-	-	1.08	3.62	-	-	6.17
MUC20	CL	-	-	-	2.40	8.78	-	-	9.68
MUC23	CL	-	-	-	2.24	7.55	-	-	19.59
MUC26	CL	-	-	-	0.95	4.19	-	-	4.93
MUC31	CL	-	-	-	2.20	7.84	-	-	14.21

Table S5: Pyrite concentrations (wt.%) in surface sediments (0–1 cm) at the study site

Station Name	Area	Pyrite (wt.%)
MUC1	HI	0.34
MUC2	HI	0.40
MUC5	HI	0.44
MUC6	HI	0.45
MUC9	HI	0.23
MUC15	HI	0.79
MUC21	HI	0.34
MUC22	HI	0.37
MUC28	HI	0.52
MUC29	HI	0.55
MUC33	HI	0.29
MUC7	CL	0.46
MUC12	CL	0.45
MUC20	CL	0.39
MUC23	CL	0.52
MUC26	CL	0.43
MUC31	CL	0.60

Table S6. Modified differential equations of water column DIC and TA used in the coupled sediment-water column box model. For the original equations and parameter definitions, see Table S10 – S12 in Kalapurakkal et al., (2025). Modifications made here are in bold.

Parameter	Value	Unit
DIC - natural condition	$\frac{dDIC}{dt} = (-R_{POCP} + F_{benDIC}(t) - F_{exDIC}(t) - F_{CO2} + \mathbf{F_{benDICCa}}(t))/thwc$	mmol cm^{-3} yr^{-1}
DIC - resuspension	$\frac{dDIC}{dt} = (-R_{POCP} + (1 - traw) * (F_{benDIC}(t) + \mathbf{F_{benDICCad}}) + traw * (F_{benDICd}(t)+) + F_{exDIC}(t) - F_{CO2})/thwc$	mmol cm^{-3} yr^{-1}
TA - natural condition	$\frac{dTA}{dt} = (F_{benTA}(t) - F_{exTA}(t) + \mathbf{F_{benTACa}})/thwc$	mmol cm^{-3} yr^{-1}
TA - resuspension	$\frac{dTA}{dt} = ((1 - traw) * (F_{benTA}(t) + \mathbf{F_{benTAd}}) + traw * F_{benTAd}(t) + F_{exTA}(t))/thwc$	mmol cm^{-3} yr^{-1}

Where:

$\mathbf{F_{benTACa}} = \frac{9}{10000} \cdot 365$ mmol cm^{-2} yr^{-1}

$\mathbf{F_{benDICCa}} = 0.5 \cdot \mathbf{F_{benTACa}}$ mmol cm^{-2} yr^{-1}

$F_{benDICCad} = R_{POCox} + \mathbf{F_{benDICCa}} - \mathbf{freTA(t)} \cdot (\mathbf{\frac{9.2}{10000} \cdot 365})$

$\mathbf{F_{benTACad}} = -fre(t) * \left(r_{TApyox} * k_{PYox} * CPYd(t) * thtr - r_{TApy} * r_{Pypoc} * k_{Poca} * CPOCd(t) * (thsd - thtr)\right) + r_{TApy} * (1 - fre(t)) * r_{Pypoc} * k_{Poca} * CPOCd(t) * thsd + \mathbf{F_{benTACa}} - \mathbf{freTA(t)} \cdot (\mathbf{\frac{6.7}{10000} \cdot 365})$

freTA(t) defines the frequency and duration of each resuspension event (Kalapurakkal et al., 2025).

References

Kalapurakkal, H. T., Dale, A. W., Schmidt, M., Taubner, H., Scholz, F., Spiegel, T., Fuhr, M., and Wallmann, K.: Sediment resuspension in muddy sediments enhances pyrite oxidation and carbon dioxide emissions in Kiel Bight, Commun Earth Environ, 6, 156, https://doi.org/10.1038/s43247-025-02132-4, 2025.