

Supplementary information

Impact of shorebird predation on intertidal macroinvertebrates in a key North African Atlantic wintering site: an experimental approach

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African Journal of Marine Science 41(1)

<https://doi.org/10.2989/1814232X.2018.1552193>

Table S1: Shorebird biomass (g) expressed as average winter values, derived from birds at Sidi Moussa coastal lagoon, Morocco, captured by the authors (2011–2012) or from data published in Cramp (1983)

Species	Scientific name	Biomass (g)	Sample size	Source
Little stint	<i>Calidris minuta</i>	21	18	Authors' data
Curlew sandpiper	<i>Calidris ferruginea</i>	51	5	Authors' data
Dunlin	<i>Calidris alpina</i>	43	118	Authors' data
Red knot	<i>Calidris canutus</i>	125	6	Authors' data
Black-tailed godwit	<i>Limosa limosa</i>	260	3	Authors' data
Bar-tailed godwit	<i>Limosa lapponica</i>	240	4	Authors' data
Whimbrel	<i>Numenius phaeopus</i>	415	unknown	Cramp (1983)
Curlew	<i>Numenius arquata</i>	965	unknown	Cramp (1983)
Turnstone	<i>Arenaria interpres</i>	93	6	Authors' data
Ringed plover	<i>Charadrius hiaticula</i>	48	13	Authors' data
Kentish plover	<i>Charadrius alexandrinus</i>	36	8	Authors' data
Common sandpiper	<i>Actitis hypoleucos</i>	50	unknown	Cramp (1983)
Greenshank	<i>Tringa nebularia</i>	209	unknown	Cramp (1983)
Redshank	<i>Tringa totanus</i>	110	44	Authors' data
Grey plover	<i>Pluvialis squatarola</i>	211	7	Authors' data
Oystercatcher	<i>Haematopus ostralegus</i>	587	unknown	Cramp (1983)

Reference

Cramp S (ed.). 1986. *Handbook of the birds of Europe, the Middle East and North Africa: the birds of the Western Palearctic: waders to gulls*, vol. 3. Oxford: Oxford University Press.

Table S2: Shorebird numbers (*n*) and densities (ind. m⁻²) in the study area at Sidi Moussa lagoon, Morocco, during the experimental procedure

Species	2011												2012			
	July		August		September		October		November		December		January		February	
	<i>n</i>	ind. m ⁻²	<i>n</i>	ind. m ⁻²	<i>n</i>	ind. m ⁻²	<i>n</i>	ind. m ⁻²	<i>n</i>	ind. m ⁻²	<i>n</i>	ind. m ⁻²	<i>n</i>	ind. m ⁻²	<i>n</i>	ind. m ⁻²
<i>Calidris minuta</i>	12	0.04	16	0.05	5	0.01	26	0.08	21	0.06	4	0.01	4	0.01	7	0.02
<i>Calidris ferruginea</i>	0	0.00	15	0.04	6	0.02	103	0.31	82	0.24	16	0.05	10	0.03	0	0.00
<i>Calidris alpina</i>	28	0.08	429	1.28	435	1.30	994	2.97	938	2.80	499	1.49	567	1.69	724	2.16
<i>Calidris canutus</i>	0	0.00	0	0.00	10	0.03	3	0.01	0	0.00	4	0.01	19	0.06	0	0.00
<i>Limosa limosa</i>	2	0.01	17	0.05	57	0.17	17	0.05	3	0.01	0	0.00	0	0.00	0	0.00
<i>Limosa lapponica</i>	17	0.05	15	0.04	2	0.01	14	0.04	25	0.07	30	0.09	34	0.10	27	0.08
<i>Numenius phaeopus</i>	2	0.01	1	0.00	4	0.01	5	0.01	1	0.00	0	0.00	0	0.00	4	0.01
<i>Numenius arquata</i>	3	0.01	1	0.00	3	0.01	5	0.01	4	0.01	4	0.01	8	0.02	6	0.02
<i>Arenaria interpres</i>	8	0.02	19	0.06	21	0.06	29	0.09	23	0.07	29	0.09	36	0.11	32	0.10
<i>Charadrius hiaticula</i>	43	0.13	86	0.26	134	0.40	154	0.46	96	0.29	82	0.24	89	0.27	141	0.42
<i>Charadrius alexandrinus</i>	83	0.25	125	0.37	83	0.25	58	0.17	18	0.05	12	0.04	13	0.04	38	0.11
<i>Actitis hypoleucos</i>	0	0.00	2	0.01	0	0.00	0	0.00	0	0.00	1	0.00	1	0.00	0	0.00
<i>Tringa nebularia</i>	1	0.00	16	0.05	9	0.03	8	0.02	5	0.01	6	0.02	8	0.02	8	0.02
<i>Tringa totanus</i>	57	0.17	42	0.13	59	0.18	72	0.21	48	0.14	39	0.12	35	0.10	43	0.13
<i>Pluvialis squatarola</i>	32	0.10	47	0.14	77	0.23	77	0.23	65	0.19	70	0.21	74	0.22	88	0.26
<i>Haematopus ostralegus</i>	0	0.00	1	0.00	1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	297	0.89	840	2.51	936	2.79	1 747	5.21	1 339	4.00	839	2.50	984	2.94	1 239	3.70

Table S3: Average and standard error (SE) of the means of density (D; ind. m⁻²) and biomass (B; g ash-free dry weight [AFDW] m⁻²) of all benthic macroinvertebrate species per month and per treatment, during the experimental procedure at Sidi Moussa lagoon, Morocco

Species	August 2011								November 2011								January 2012							
	Control				Exclosure				Control				Exclosure				Control				Exclosure			
	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE
<i>Hydrobia ulvae</i>	4 668	1 172	3.9	1.0	5 736	2 330	5.0	2.2	3 760	795.7	2.7	1.2	3 656	2 323	2.0	1.3	5 060	1 301	4.4	0.7	4 644	2 155	2.6	1.0
<i>Abra tenuis</i>	836	322.1	1.2	0.6	356	254.9	0.6	0.5	512	284.9	0.5	0.3	476	219.4	0.9	0.4	408	250.4	1.5	0.7	568	129.1	0.8	0.2
<i>Nassarius pfeifferi</i>	544	208.7	17.8	6.9	200	113.7	5.3	3.5	2 936	497.1	56.6	16.6	556	70.8	6.6	1.1	2 144	988.3	48.9	24.8	388	103.7	4.7	1.1
<i>Corophium volutator</i>	436	210.7	0.2	0.2	396	281.5	0.1	0.0	52	21.5	0.0	0.0	4	4.0	0.0	0.0	–	–	–	–	4	4.0	0.0	0.0
<i>Gibbula pennanti</i>	420	186.1	4.7	2.4	28	15.0	0.8	0.6	248	90.0	3.1	1.0	44	19.4	0.5	0.2	128	33.8	4.6	2.7	176	60.5	2.6	0.9
<i>Oligochaeta</i> spp.	420	257.8	0.4	0.3	908	409.8	0.3	0.1	236	91.5	0.0	0.0	120	61.6	0.1	0.0	300	151.3	0.0	0.0	344	173.4	0.0	0.0
<i>Cerastoderma edule</i>	356	131.2	72.5	33.0	252	98.9	36.8	15.7	280	80.5	28.8	16.0	592	207.9	40.0	16.4	396	182.0	88.2	54.9	876	378.5	28.0	11.5
<i>Amphipholis squamata</i>	308	273.9	0.1	0.1	112	73.1	0.2	0.2	32	10.2	0.0	0.0	24	11.7	0.0	0.0	4	4.0	0.0	0.0	12	8.0	0.0	0.0
<i>Actinia equine</i>	232	89.6	1.8	1.0	80	24.5	3.3	2.4	72	22.4	1.4	0.7	172	37.7	2.8	0.6	76	30.6	1.5	0.7	156	73.6	1.3	0.7
<i>Melita palmate</i>	220	200.1	0.1	0.1	60	29.7	0.0	0.0	–	–	–	–	64	29.9	0.0	0.0	8	8.0	0.0	0.0	36	14.7	0.0	0.0
<i>Capitella capitata</i>	176	65.5	0.1	0.0	72	38.3	0.0	0.0	72	27.3	0.1	0.0	32	12.0	0.0	0.0	88	50.8	0.1	0.0	28	15.0	0.0	0.0
<i>Heteromastus filiformis</i>	124	54.2	8.1	8.0	48	22.4	0.0	0.0	48	24.2	0.2	0.2	64	29.3	0.1	0.1	140	69.6	0.5	0.3	96	26.4	0.3	0.1
<i>Tanais dulongii</i>	100	68.7	0.0	0.0	48	27.3	0.0	0.0	32	13.6	0.0	0.0	132	56.1	0.1	0.0	20	15.5	0.0	0.0	148	58.9	0.1	0.0
<i>Monodonta</i> sp.	64	54.6	7.0	6.4	36	36.0	1.1	1.1	148	92.9	2.2	1.2	40	17.9	1.1	0.6	–	–	–	–	4	4.0	0.1	0.1
<i>Cerithium vulgatum</i>	64	41.7	4.1	3.9	12	12.0	0.1	0.1	12	8.0	2.1	1.5	4	4.0	0.1	0.1	4	4.0	0.3	0.3	12	8.0	0.0	0.0
<i>Euclymene palermitana</i>	52	42.2	0.0	0.0	4	4.0	0.0	0.0	–	–	–	–	–	–	–	–	–	–	–	–	12	12.0	0.0	0.0
<i>Tapes decussata</i>	48	21.5	12.5	7.4	52	17.4	16.9	6.2	44	11.7	4.7	1.9	44	4.0	10.3	3.8	44	13.3	4.5	1.5	40	17.9	3.4	1.8
<i>Hediste diversicolor</i>	44	7.5	1.1	0.7	12	8.0	0.1	0.1	168	118.4	0.5	0.4	44	21.4	1.1	0.5	20	11.0	0.1	0.0	20	15.5	0.6	0.5
<i>Nemertians</i> spp.	44	23.2	0.4	0.4	12	8.0	0.0	0.0	4	4.0	0.0	0.0	12	12.0	0.0	0.0	20	11.0	0.0	0.0	16	7.5	0.0	0.0
<i>Platyhelminthes</i> species	44	24.0	0.1	0.1	–	–	–	–	20	20.0	0.0	0.0	4	4.0	0.0	0.0	4	4.0	0.0	0.0	4	4.0	0.0	0.0

Species	August 2011								November 2011								January 2012							
	Control				Exclosure				Control				Exclosure				Control				Exclosure			
	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE
<i>Audouinia tentaculata</i>	44	34.3	0.0	0.0	8	4.9	0.0	0.0	8	4.9	0.0	0.0	12	8.0	0.1	0.1	20	8.9	0.0	0.0	4	4.0	0.1	0.1
<i>Idotea chelipes</i>	24	16.0	0.0	0.0	20	15.5	0.0	0.0	32	17.4	0.0	0.0	124	38.7	0.1	0.0	20	8.9	0.1	0.0	88	33.8	0.1	0.1
Chironomidae spp.	24	7.5	0.0	0.0	8	4.9	0.0	0.0	16	4.0	0.0	0.0	44	13.3	0.0	0.0	24	14.7	0.0	0.0	52	24.2	0.1	0.0
<i>Abra alba</i>	20	12.6	0.4	0.3	8	4.9	0.1	0.1	12	4.9	0.2	0.1	–	–	–	–	4	4.0	0.0	0.0	4	4.0	0.0	0.0
<i>Cyathura carinata</i>	20	12.6	0.2	0.2	12	12.0	0.0	0.0	4	4.0	0.0	0.0	20	15.5	0.0	0.0	8	4.9	0.0	0.0	12	4.9	0.0	0.0
<i>Lagis koneri</i>	20	15.5	0.0	0.0	12	8.0	0.0	0.0	72	30.1	0.2	0.1	108	45.9	0.3	0.2	52	21.5	0.2	0.1	56	29.9	0.3	0.1
<i>Gamarella fusicola</i>	16	9.8	0.0	0.0	12	12.0	0.0	0.0	4	4.0	0.0	0.0	8	4.9	0.0	0.0	–	–	–	–	–	–	–	–
<i>Microdeutopus clifer</i>	16	9.8	0.0	0.0	4	4.0	0.0	0.0	4	4.0	0.0	0.0	–	–	–	–	4	4.0	0.0	0.0	–	–	–	–
<i>Lysianassa ceratina</i>	12	12.0	0.0	0.0	32	20.6	0.0	0.0	4	4.0	0.0	0.0	36	11.7	0.0	0.0	–	–	–	–	–	–	–	–
<i>Glycera tridactyla</i>	8	4.9	0.0	0.0	4	4.0	0.1	0.1	4	4.0	0.0	0.0	4	4.0	0.0	0.0	24	11.7	0.3	0.1	–	–	–	–
<i>Carcinus maenas</i>	8	4.9	0.0	0.0	24	11.7	0.7	0.6	4	4.0	0.0	0.0	8	8.0	0.2	0.2	4	4.0	0.2	0.2	8	4.9	0.1	0.1
<i>Notomastus latericeus</i>	8	8.0	0.0	0.0	8	8.0	0.0	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Aonides oxycephala</i>	8	8.0	0.0	0.0	12	8.0	0.0	0.0	28	17.4	0.0	0.0	16	11.7	0.0	0.0	108	36.7	0.2	0.1	32	23.3	0.1	0.0
Polyplacophora spp.	8	4.9	0.0	0.0	4	4.0	0.0	0.0	12	8.0	0.0	0.0	8	4.9	0.0	0.0	8	4.9	0.0	0.0	–	–	–	–
<i>Scrobicularia plana</i>	4	4.0	1.7	1.7	12	8.0	2.3	1.7	12	12.0	0.6	0.6	16	7.5	3.2	1.7	16	9.8	2.6	1.9	4	4.0	0.2	0.2
<i>Upogebia pusilla</i>	4	4.0	1.4	1.4	8	8.0	0.1	0.1	–	–	–	–	4	4.0	0.2	0.2	–	–	–	–	–	–	–	–
<i>Natancia</i> sp.	4	4.0	0.1	0.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Astecilla</i> sp.	4	4.0	0.0	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Diopatra neapolitana</i>	4	4.0	0.0	0.0	–	–	–	–	12	8.0	0.2	0.2	–	–	–	–	–	–	–	–	–	–	–	–
<i>Amphithoe ferox</i>	4	4.0	0.0	0.0	–	–	–	–	4	4.0	0.1	0.1	–	–	–	–	–	–	–	–	–	–	–	–
<i>Prionospio malmgreni</i>	4	4.0	0.0	0.0	8	8.0	0.0	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Species	August 2011								November 2011								January 2012							
	Control				Exclosure				Control				Exclosure				Control				Exclosure			
	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE	D	SE	B	SE
<i>Haminoea navicula</i>	–	–	–	–	4	4.0	0.0	0.0	–	–	–	–	8	4.9	0.0	0.0	–	–	–	–	16	7.5	0.0	0.0
<i>Lekanesphaera levii</i>	–	–	–	–	–	–	–	–	12	8.0	0.0	0.0	12	4.9	0.0	0.0	4	4.0	0.0	0.0	–	–	–	–
<i>Loripes lucinalis</i>	–	–	–	–	–	–	–	–	4	4.0	0.1	0.1	4	4.0	0.2	0.2	–	–	–	–	12	12.0	0.0	0.0
<i>Lumbrineris latreilli</i>	–	–	–	–	4	4.0	0.0	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Malacoceros fuliginosus</i>	–	–	–	–	–	–	–	–	16	11.7	0.0	0.0	–	–	–	–	–	–	–	–	4	4.0	0.0	0.0
<i>Merceralia enigmatica</i>	–	–	–	–	–	–	–	–	–	–	–	–	4	4.0	0.0	0.0	12	8.0	0.0	0.0	4	4.0	0.0	0.0
<i>Nassarius reticulatus</i>	–	–	–	–	–	–	–	–	4	4.0	0.2	0.2	–	–	–	–	–	–	–	–	–	–	–	–
<i>Nephtys cirrosa</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	4.0	0.2	0.2	–	–	–	–
<i>Paracentrotus lividus</i>	–	–	–	–	4	4.0	0.0	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Solen marginatum</i>	–	–	–	–	4	4.0	3.5	3.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Sthenelais boa</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	4.0	0.0	0.0

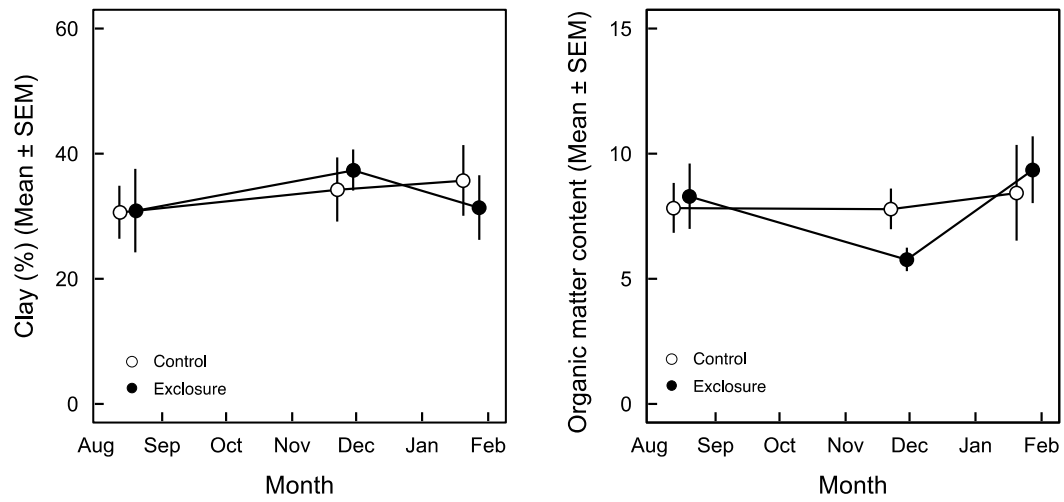


Figure S1: Variation of the weight of clay and organic matter (percentage) during the exclosure experiment at Sidi Moussa lagoon, Morocco, 2011–2012. Average values and standard error of the mean (SEM) per treatment are shown