Supplementary information

Impact of shorebird predation on intertidal macroinvertebrates in a key North African Atlantic wintering site: an experimental approach
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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          | *Calidris minuta*      | 21          | 18          | Authors’ data        |
| Curlew sandpiper      | *Calidris ferruginea*  | 51          | 5           | Authors’ data        |
| Dunlin                | *Calidris alpina*      | 43          | 118         | Authors’ data        |
| Red knot              | *Calidris canutus*     | 125         | 6           | Authors’ data        |
| Black-tailed godwit   | *Limosa limosa*        | 260         | 3           | Authors’ data        |
| Bar-tailed godwit     | *Limosa lapponica*     | 240         | 4           | Authors’ data        |
| Whimbrel              | *Numenius phaeopus*    | 415         | unknown     | Cramp (1983)         |
| Curlew                | *Numenius arquata*     | 965         | unknown     | Cramp (1983)         |
| Turnstone             | *Arenaria interpres*   | 93          | 6           | Authors’ data        |
| Ringed plover         | *Charadrius hiaticula* | 48          | 13          | Authors’ data        |
| Kentish plover        | *Charadrius alexandrinus* | 36    | 8           | Authors’ data        |
| Common sandpiper      | *Actitis hypoleucos*   | 50          | unknown     | Cramp (1983)         |
| Greenshank            | *Tringa nebularia*     | 209         | unknown     | Cramp (1983)         |
| Redshank              | *Tringa totanus*       | 110         | 44          | Authors’ data        |
| Grey plover           | *Pluvialis squatarola* | 211         | 7           | Authors’ data        |
| Oystercatcher         | *Haematopus ostralegus*| 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 |
|                          | n  | ind. m⁻² | n  | ind. m⁻² | n  | ind. m⁻² | n  | ind. m⁻² | n  | ind. m⁻² |
| Calidris minuta          | 12 | 0.04     | 16 | 0.05     | 5  | 0.01     | 26 | 0.08     | 21 | 0.06     | 4  | 0.01     |
| Calidris ferruginea      | 0  | 0.00     | 15 | 0.04     | 6  | 0.02     | 103| 0.31     | 82 | 0.24     | 16 | 0.05     |
| Calidris alpina          | 28 | 0.08     | 429| 1.28     | 435| 1.30     | 994| 2.97     | 938| 2.80     | 499| 1.49     |
| Calidris canutus         | 0  | 0.00     | 0  | 0.00     | 10 | 0.03     | 3  | 0.01     | 0  | 0.00     | 4  | 0.01     |
| Limosa limosa            | 2  | 0.01     | 17 | 0.05     | 57 | 0.17     | 17 | 0.05     | 3  | 0.01     | 0  | 0.00     |
| Limosa lapponica         | 17 | 0.05     | 15 | 0.04     | 2  | 0.01     | 14 | 0.04     | 25 | 0.07     | 30 | 0.09     |
| Numenius phaeopus        | 2  | 0.01     | 1  | 0.00     | 4  | 0.01     | 5  | 0.01     | 1  | 0.00     | 0  | 0.00     |
| Numenius arquata         | 3  | 0.01     | 1  | 0.00     | 3  | 0.01     | 5  | 0.01     | 4  | 0.01     | 4  | 0.01     |
| Arenaria interpres       | 8  | 0.02     | 19 | 0.06     | 21 | 0.06     | 29 | 0.09     | 23 | 0.07     | 29 | 0.09     |
| Charadrius hiaticula     | 43 | 0.13     | 86 | 0.26     | 134| 0.40     | 154| 0.46     | 96 | 0.29     | 82 | 0.24     |
| Charadrius alexandrinus  | 83 | 0.25     | 125| 0.37     | 83 | 0.25     | 58 | 0.17     | 18 | 0.05     | 12 | 0.04     |
| Actitis hypoleucos       | 0  | 0.00     | 2  | 0.01     | 0  | 0.00     | 0  | 0.00     | 1  | 0.00     | 0  | 0.00     |
| Tringa nebularia         | 1  | 0.00     | 16 | 0.05     | 9  | 0.03     | 8  | 0.02     | 5  | 0.01     | 6  | 0.02     |
| Tringa totanus           | 57 | 0.17     | 42 | 0.13     | 59 | 0.18     | 72 | 0.21     | 48 | 0.14     | 39 | 0.12     |
| Pluvialis squatarola     | 32 | 0.10     | 47 | 0.14     | 77 | 0.23     | 77 | 0.23     | 65 | 0.19     | 70 | 0.21     |
| Haematopus ostralegus     | 0  | 0.00     | 1  | 0.00     | 1  | 0.00     | 0  | 0.00     | 0  | 0.00     | 0  | 0.00     |
| Total                    | 297| 0.89     | 840| 2.51     | 936| 2.79     | 1747| 5.21     | 1339| 4.00     | 839| 2.50     |
|                          | 984| 2.94     | 1239| 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    |
| Hydrobia ulvae              | 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 |
| Abra terius                 | 836 322.1 1.2 0.6 | 356 254.9 0.6 0.5 | 512 264.9 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 |
| Nassarius pfeiferi          | 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 |
| Corophium volutator         | 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 |
| Gibbula pennanti            | 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 |
| Oligochaeta 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 |
| Cerastoderma edule          | 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 |
| Amphipholis squamata        | 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 |
| Actinia equina              | 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 |
| Melita palmate              | 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 |
| Capitella capitata          | 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 |
| Heteromastus filiformis     | 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 |
| Tanais dulongii             | 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 |
| Monodonta 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 |
| Cerithium vulgatum          | 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 |
| Euclymene palmaritana       | 52 42.2 0.0 0.0 | 4 4.0 0.0 0.0 | – – – – | – – – – | – – – – | 12 12.0 0.0 0.0 |
| Tapes decussatus            | 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 |
| Hediste diversicolor         | 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 |
| Nemeritiens 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 |
| Platyhelminthes 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 |

**Note:** D = density, SE = standard error, B = biomass (g AFDW m\(^{-2}\)).
| Species                  | August 2011 |     |     |     |     | November 2011 |     |     |     |     | January 2012 |     |     |     |     |
|--------------------------|-------------|-----|-----|-----|-----|---------------|-----|-----|-----|-----|---------------|-----|-----|-----|-----|
|                          | D           | SE  | B   | SE  |     | D             | SE  | B   | SE  |     | D             | SE  | B   | SE  |     |
| **Prionospio tentaculata** | 44          | 34.3| 0.0 | 0.0 | 0.0 | 8             | 4.9 | 0.0 | 0.0 | 0.0 | 8             | 4.9 | 0.0 | 0.0 | 0.0 |
| **Idotea chelipes**      | 24          | 16.0| 0.0 | 0.0 | 0.0 | 20            | 15.5| 0.0 | 0.0 | 0.0 | 124           | 38.7| 0.1 | 0.0 | 0.0 |
| **Chironomidae spp.**    | 24          | 7.5 | 0.0 | 0.0 | 0.0 | 16            | 4.0 | 0.0 | 0.0 | 0.0 | 44            | 13.3| 0.0 | 0.0 | 0.0 |
| **Abra alba**            | 20          | 12.6| 0.4 | 0.3 | 0.1 | 12            | 4.9 | 0.2 | 0.1 |     | –             | –   | –   | –   |     |
| **Cyathura carinata**    | 20          | 12.6| 0.2 | 0.2 | 0.2 | 12            | 12.0| 0.0 | 0.0 | 0.0 | 20            | 15.5| 0.0 | 0.0 | 0.0 |
| **Lagis keroni**         | 20          | 15.5| 0.0 | 0.0 | 0.0 | 12            | 8.0 | 0.0 | 0.0 | 0.0 | 72            | 30.1| 0.2 | 0.1 |     |
| **Glycera tridactyla**   | 16          | 9.8 | 0.0 | 0.0 | 0.0 | 12            | 12.0| 0.0 | 0.0 | 0.0 | 4             | 4.0 | 0.0 | 0.0 | 0.0 |
| **Microdeutopus clifer** | 16          | 9.8 | 0.0 | 0.0 | 0.0 | 4             | 4.0 | 0.0 | 0.0 | 0.0 | 4             | 4.0 | 0.0 | 0.0 |     |
| **Lysianassa ceratina**  | 12          | 12.0| 0.0 | 0.0 | 0.0 | 32            | 20.6| 0.0 | 0.0 | 0.0 | 4             | 4.0 | 0.0 | 0.0 | 36 |
| **Glyceria tridactyla**  | 8           | 4.9 | 0.0 | 0.0 | 0.0 | 4             | 4.0 | 0.0 | 0.0 | 0.0 | 4             | 4.0 | 0.0 | 0.0 | 11.7 |
| **Carcinus maenas**      | 8           | 4.9 | 0.0 | 0.0 | 0.0 | 24            | 11.7| 0.7 | 0.6 | 0.0 | 4             | 4.0 | 0.0 | 0.0 | 8 |
| **Notomastus latericeus**| 8           | 8.0 | 0.0 | 0.0 | 0.0 | 8             | 8.0 | 0.0 | 0.0 | 0.0 | –             | –   | –   | –   | – |
| **Aonides oxycephala**   | 8           | 8.0 | 0.0 | 0.0 | 0.0 | 12            | 8.0 | 0.0 | 0.0 | 0.0 | 28            | 17.4| 0.0 | 0.0 | 16 |
| **Polyplacophora spp.**  | 8           | 4.9 | 0.0 | 0.0 | 0.0 | 4             | 4.0 | 0.0 | 0.0 | 0.0 | 12            | 8.0 | 0.0 | 0.0 | 8 |
| **Scrobicularia plana**  | 4           | 4.0 | 1.7 | 1.7 | 1.7 | 12            | 8.0 | 2.3 | 1.7 |     | 12            | 12.0| 0.6 | 0.6 | 16 |
| **Upogebia pusilla**     | 4           | 4.0 | 1.4 | 1.4 | 1.4 | 8             | 8.0 | 0.1 | 0.1 | 0.1 | 4             | 4.0 | 0.2 | 0.2 | 4 |
| **Natancia sp.**         | 4           | 4.0 | 0.1 | 0.1 | 0.1 | –             | –   | –   | –   | –   | 4             | 4.0 | 0.2 | 0.2 | – |
| **Asticella sp.**        | 4           | 4.0 | 0.0 | 0.0 | 0.0 | –             | –   | –   | –   | –   | –             | –   | –   | –   | – |
| **Diopatra neapollitana**| 4           | 4.0 | 0.0 | 0.0 | 0.0 | –             | –   | –   | –   | –   | 12            | 8.0 | 0.2 | 0.2 | – |
| **Amphithoe ferox**      | 4           | 4.0 | 0.0 | 0.0 | 0.0 | –             | –   | –   | –   | –   | 4             | 4.0 | 0.1 | 0.1 | – |
| **Prionospio malongreni**| 4           | 4.0 | 0.0 | 0.0 | 0.0 | 8             | 8.0 | 0.0 | 0.0 | 0.0 | –             | –   | –   | –   | – |
| Species                  | August 2011 | November 2011 | January 2012 |
|--------------------------|-------------|---------------|--------------|
|                          | D | SE | B | SE | D | SE | B | SE | D | SE | B | SE | D | SE | B | SE | D | SE | B | SE |
| **Haminoea navicula**    | – | – | – | – | 4 | 4.0 | 0.0 | 0.0 | – | – | – | – | 8 | 4.9 | 0.0 | 0.0 | – | – | – | – | 16 | 7.5 | 0.0 | 0.0 |
| **Lekanesphaera levii**  | – | – | – | – | – | – | – | – | 12 | 8.0 | 0.0 | 0.0 | – | – | – | – | 4 | 4.0 | 0.0 | 0.0 | – | – | – | – | – | – | – |
| **Loripes lucinalis**    | – | – | – | – | 4 | 4.0 | 0.1 | 0.1 | 4 | 4.0 | 0.2 | 0.2 | – | – | – | – | 12 | 12.0 | 0.0 | 0.0 | – | – | – | – | – | – | – |
| **Lumbrineris lateilli** | – | – | – | – | 4 | 4.0 | 0.0 | 0.0 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Malacoceros fuliginosus** | – | – | – | – | 16 | 11.7 | 0.0 | 0.0 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Merceralia enigmatica** | – | – | – | – | – | – | – | – | – | – | – | – | 4 | 4.0 | 0.0 | 0.0 | 12 | 8.0 | 0.0 | 0.0 | – | – | – | – | – | – | – | – | – | – |
| **Nassarius reticulatus** | – | – | – | – | 4 | 4.0 | 0.2 | 0.2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Nephtys cirrosa**      | – | – | – | – | – | – | – | – | – | – | – | – | 4 | 4.0 | 0.2 | 0.2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Paracentrotus lividus** | – | – | – | – | 4 | 4.0 | 0.0 | 0.0 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Solen marginatum**     | – | – | – | – | 4 | 4.0 | 3.5 | 3.5 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Sthenelais boa**       | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
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.