

**Potential impacts of marine urbanization on
benthic macrofaunal diversity**

- Supplementary data -

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Supplementary figures

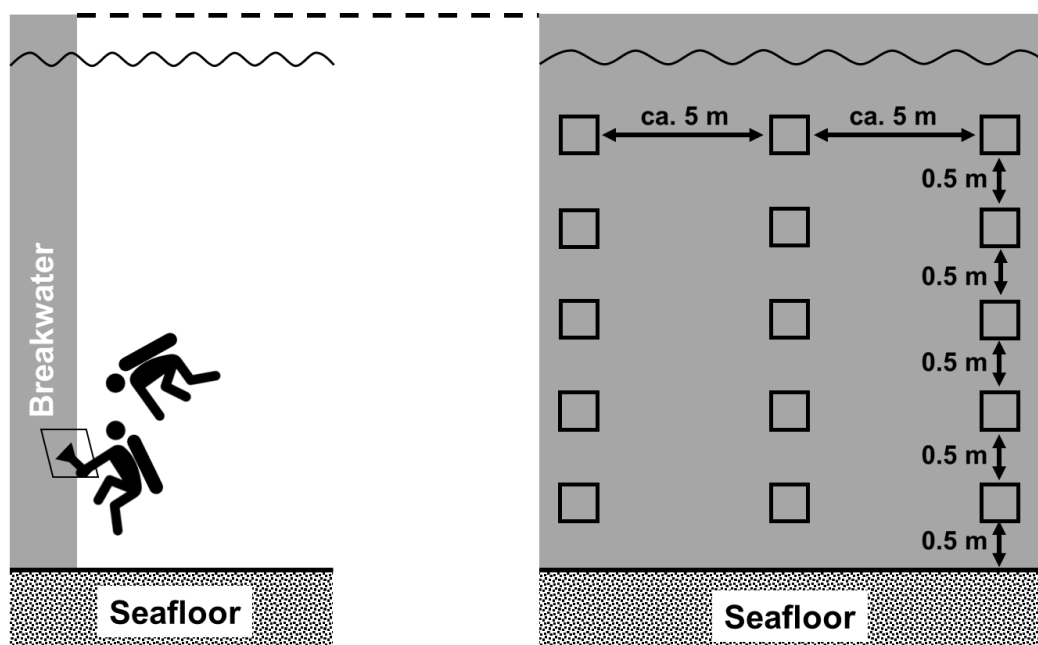


Figure S1. Schematic diagram showing the arrangement of sampling points (unfilled squares) at the breakwater wall habitat. The left panel shows a cross-sectional view and the right panel a plan view of the breakwater wall.

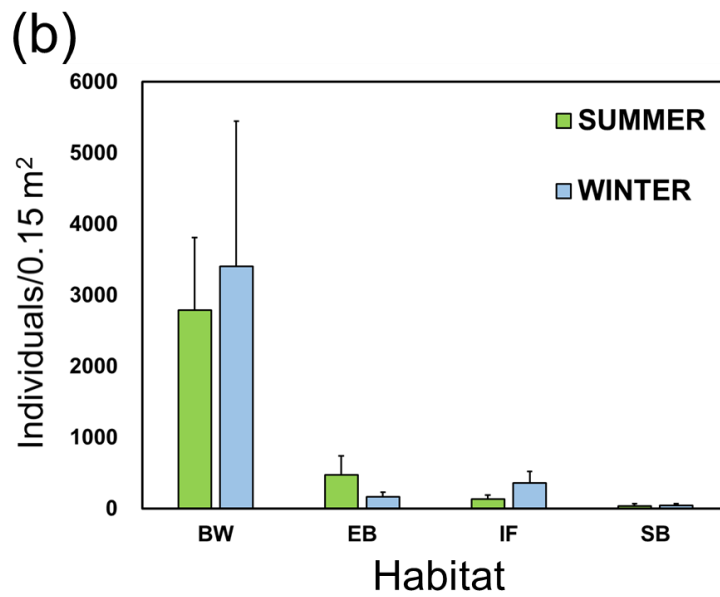
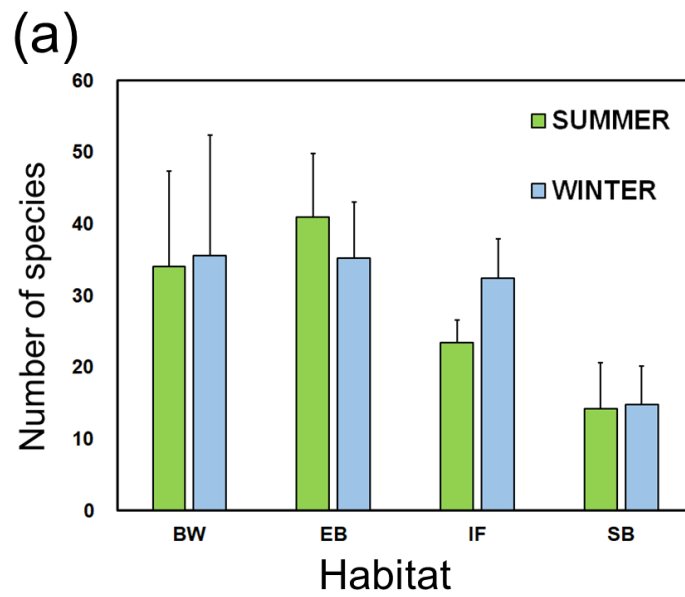


Figure S2. Mean (a) species richness and (b) total abundances at each habitat. Error bars show standard deviations. Habitat abbreviations are as in Fig. 1.

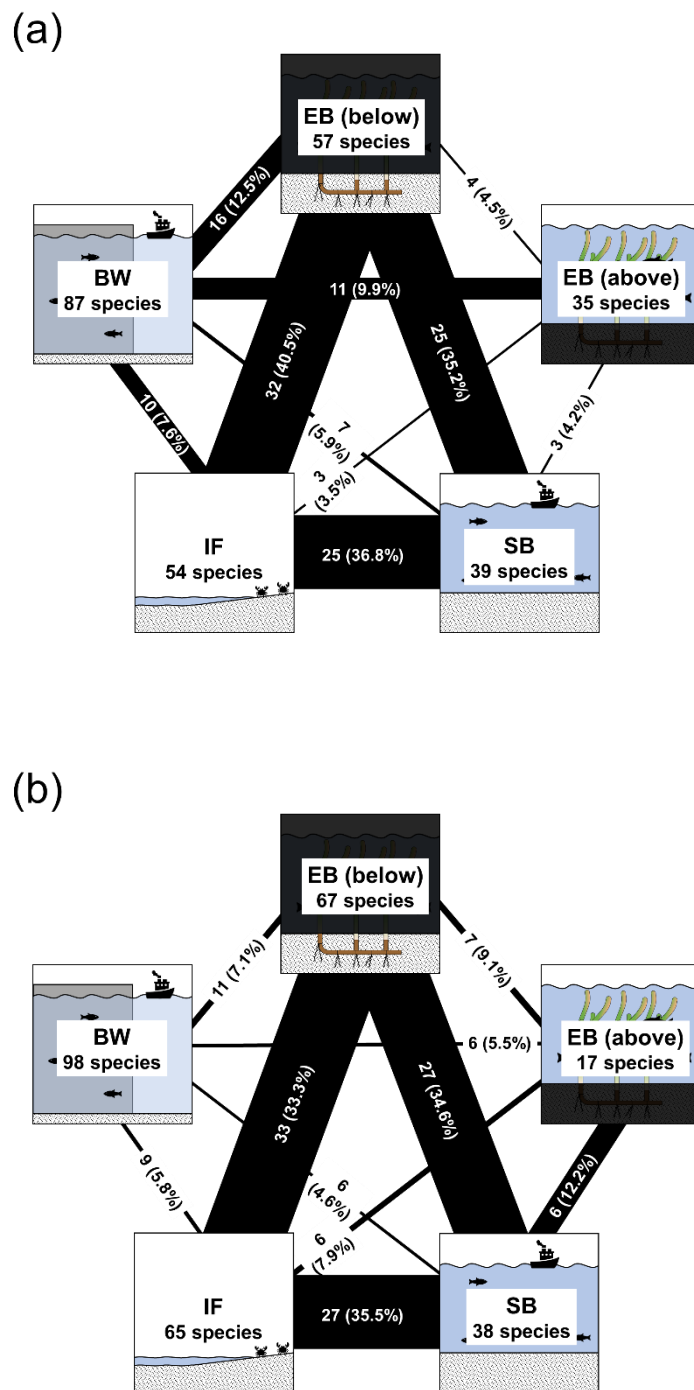


Figure S3. Shared species among habitat pairs in (a) summer and (b) winter. The eelgrass bed (EB) was separated into above- and belowground communities. Black numbers in each box indicate total numbers of species collected in each habitat. White or black

numbers on the black lines indicate the numbers of species that were shared between each habitat pair, with percentages based on Jaccard indices shown in parentheses. The thickness of each black line is proportional to the percentage of species shared. Habitat abbreviations are as shown in Fig. 1.

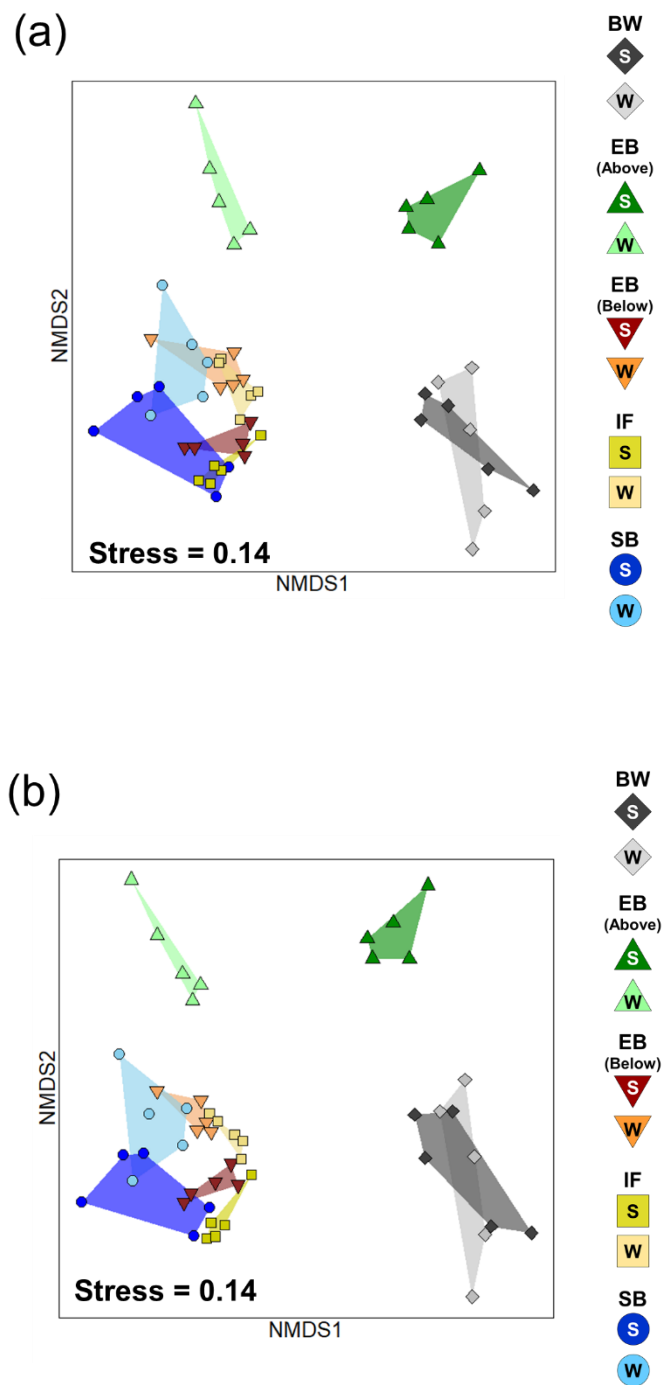


Figure S4. Non-metric multidimensional scaling (NMDS) ordinations of (a) species compositions based on Jaccard dissimilarities calculated from presence/absence data, and (b) species compositions and abundances based on Bray–Curtis dissimilarities calculated

from fourth-root transformed abundance data. The four different symbols indicate subsites in each habitat. Convex hulls enclosed by symbols indicate the dispersion of community composition within habitats. Habitat abbreviations are as shown in Fig. 1.

Supplementary tables

Table S1. Water, sediment, and eelgrass conditions (mean \pm standard deviation) at each habitat in summer and winter. ORP: oxidation-reduction potential; D₅₀: median particle size. Habitat abbreviations are as in Fig. 1.

Factor	BW	EB	IF	SB
Water conditions				
<i>Summer</i>				
Water temperature (°C)	27.2	27.2 \pm 0.3	27.2 \pm 0.1	27.2 \pm 0.6
Salinity (psu)	30.9	30.7 \pm 0.1	30.8 \pm 0.1	31.3 \pm 0.2
pH	8.1	8.1 \pm 0.1	8.1 \pm 0.0	8.0 \pm 0.1
Dissolved oxygen (mg/L)	6.5	5.3 \pm 0.2	6.2 \pm 0.4	4.9 \pm 1.0
<i>Winter</i>				
Water temperature (°C)	11.9	13.5 \pm 0.2	10.5 \pm 0.3	12.2 \pm 0.7
Salinity (psu)	31.4	30.8 \pm 0.1	30.9 \pm 0.1	31.3 \pm 0.2
pH	8.3	8.3 \pm 0.0	8.4 \pm 0.1	8.3 \pm 0.0
Dissolved oxygen (mg/L)	9.3	8.6 \pm 0.2	9.3 \pm 0.1	9.2 \pm 0.5
Sediment conditions				
<i>Summer</i>				
Sediment temperature (°C)	—	26.6 \pm 0.6	27.4 \pm 0.9	26.7 \pm 0.1
pH	—	7.6 \pm 0.1	7.6 \pm 0.1	7.6 \pm 0.0
ORP (mV)	—	-197 \pm 39	-189 \pm 23	-168 \pm 13
Water content (%)	—	52.4 \pm 20.3	41.5 \pm 20.2	59.7 \pm 8.8
D ₅₀ (mm)	—	0.02 \pm 0.01	0.08 \pm 0.09	0.01 \pm 0.00
<i>Winter</i>				
Sediment temperature (°C)	—	13.1 \pm 0.2	9.8 \pm 0.4	11.9 \pm 1.7
pH	—	7.7 \pm 0.1	7.5 \pm 0.1	7.4 \pm 0.1
ORP (mV)	—	-123 \pm 6	-150 \pm 60	-167 \pm 28
Water content (%)	—	47.7 \pm 21.6	43.8 \pm 17.4	59.7 \pm 18.9
D ₅₀ (mm)	—	0.02 \pm 0.01	0.02 \pm 0.01	0.01 \pm 0.00

Table S1. Continued.

Factor	BW	EB	IF	SB
Eelgrass conditions				
<i>Summer</i>				
Shoot density (inds. m ⁻²)	—	45.0 ± 17.3	—	—
Shoot mass (wet g m ⁻²)	—	132.9 ± 84.5	—	—
<i>Winter</i>				
Shoot density (inds. m ⁻²)	—	87.0 ± 20.2	—	—
Shoot mass (wet g m ⁻²)	—	5.1 ± 2.7	—	—

Table S2. Species list with abundances and functional traits (PFT: primary feeding type; CLF: common life form) across habitats and seasons.

Species marked “(D)” were deemed dominant species for functional composition analysis. Functional groups are abbreviated as follows:

Primary feeding types: *Ca*, carnivore; *Dp*, deposit feeder; *Dt*, detritus feeder; *FS*, filter/suspension feeder; *Gr*, grazer; *He*, herbivore; *Om*, omnivore; *Sc*, scavenger; *Sy*, symbiont. **Common life forms:** *BU*, burrowing; *FL*, free-living; *PA*, parasite; *SE*, sedentary; *TM*, tube/mucus-sheath building. Habitat abbreviations are as shown in Fig. 1.

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
Polychaeta											
Ampharetidae sp. (D)			9	6			1	1	Dp	TM	e
Amphinomidae sp. (D)				1					Ca	FL	e
<i>Armandia lanceolata</i> (D)		2	9						Dp	FL	e
<i>Asychis disparidentata</i>		2	1			1					
<i>Branchiomma cingulatum</i>	8	1			4						
Capitellidae sp. (D)	1	27	9	7		11	8	2	Dp	TM	e
Chaetopteridae sp. (D)			1				1	2	Dp	TM	e
<i>Chone</i> sp. (D)		5	1	1		2	28		FS	SE	e
Chrysopetalidae sp.		3	1		29		2				
Cirratulidae sp. (D)	496	1			153		6		Dp	FL	e
<i>Cirriformia tentaculata</i> (D)	100				276				Dp	FL	e

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
Dorvilleidae spp.		1			17						
<i>Eteone longa</i> (D)						5	8	2	Ca	FL	e
<i>Eulalia viridis</i> (D)		1			1	14	3	5	Ca	FL	e
<i>Eunice</i> sp.	3										
Eunicidae sp.					2						
Flabelligeridae sp. (D)		1	18	1			1		Dp	TM	e
<i>Glycera chirori</i> (D)		9	10	6		4	6	2	Ca	BU	e
<i>Glycera</i> sp.		2	1			1					
Glyceridae sp.						1					
<i>Goniada</i> sp. (D)						7	52	6	Ca	BU	e
<i>Hemipodia</i> sp. (D)			17			2		1	Ca	BU	e
Hesionidae sp. (D)	15	1	3	3	1	7	10	1	Ca	FL	c; e
<i>Hydroides ezoensis</i> (D)	78				240				FS	SE	e
<i>Hydroides</i> sp.	3										
<i>Lagis bocki</i> (D)		2	5			2	2	2	Dp	TM	e
<i>Lepidonotus elongatus</i> (D)	321				165				Ca	FL	e; h
<i>Lepidonotus tenuisetosus</i>					30						
Lumbrineridae sp.			1		1						
<i>Lysidice collaris</i>	4				4						

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
<i>Maldanidae</i> sp. (D)		17				1	1		Dp	TM	e; g; j
<i>Neanthes acuminata</i> (D)		8				9			Om	TM	e
<i>Nectoneanthes oxypoda</i> (D)						24		6	Om	TM	e
<i>Nectoneanthes</i> sp. (D)				1					Om	TM	e
Nephtyidae sp. (D)								1	Ca	FL	e; j
<i>Nephtys</i> sp. (D)		3	5	5		25	45	23	Ca	FL	e; j
<i>Nereiphylla castanea</i>	60				36						
<i>Nereis</i> sp.					10						
<i>Notomastus latericeus</i> (D)		1	8				9	1	Dp	TM	e
Opheliidae sp.						1	10				
Orbiniidae sp.			1			2					
<i>Oxydromus angustifrons</i> (D)			6	1			4		Ca	FL	c; e
Paraonidae sp.		3				1					
<i>Perinereis cultrifera</i>	22				1	1					
<i>Perinereis nuntia brevicirris</i>					1						
<i>Phyllodoce maculata</i> (D)		5				10			Ca	FL	e
Phyllodocidae sp.	2	7			5	3					
<i>Platynereis bicanaliculata</i> (D)		32				3			Om	TM	e
<i>Platynereis</i> sp. (D)	16	104				1			Om	TM	e

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
Poecilochaetidae sp. (D)		1	1	3			2	1	FS	TM	e
Polynoidae sp.	49	3	1		17	3	6				
<i>Polyophthalmus pictus</i>		3			1						
<i>Praxillella affinis pacifica</i> (D)		19	75	30		3	21		Dp	TM	e; g; j
<i>Prionospio pulchra</i>						1					
<i>Prionospio</i> sp. (D)		1				9	1	6	Dp	TM	e
<i>Pseudopolydora kemp</i> (D)						50			Dp	TM	e
<i>Pseudopolydora paucibranchiata</i> (D)						64			Dp	TM	e
<i>Pseudopolydora</i> sp. (D)	254	2	4		613	14	148	17	Dp	TM	e
<i>Pseudopotamilla</i> sp. (D)	743				932				FS	SE	e
Sabellariidae sp.							1				
Sabellida sp.		10									
Sabellidae sp. (D)	4	6			190	5	7	1	FS	SE	e
<i>Scolelepis</i> sp. (D)	1	2	3	1		3	1		Dp	TM	e
<i>Scoletoma longifolia</i> (D)		168	38	20		127	38	5	Ca	BU	e
Serpulidae sp.	9				20						
Sigalionidae sp. (D)		4	2	9		13	4	16	Ca	FL	e
<i>Sigambra</i> sp. (D)		3		3		5	21	9	Om	FL	c; e; h; j
<i>Simplisetia erythraeensis</i> (D)			19			2	1		Om	TM	e
Spionidae sp.		4									

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
<i>Spirobranchus kraussii</i> (D)	1157				1584				FS	SE	e
<i>Spirobranchus tetraceros</i>	3				5						
<i>Sternaspis scutata</i> (D)				10		43		1	Dp	BU	j; p (cf. Terebellida)
Syllidae sp. (D)	5	8			144				Ca	TM	c; e
<i>Syllis</i> sp. (D)	535					9	1	6	Dp	TM	e
Terebellidae sp. (D)	834	2			879	1			Dp	TM	e
<i>Thelepus setosus</i>					28						
Amphipoda											
<i>Ampithoe</i> sp.	3				9						
<i>Ampithoidae</i> sp.		4									
Aoridae sp.		5									
<i>Aoroides columbiae</i> (D)						155	9	2	Om	TM	c; n; p
<i>Byblis japonicus</i>		3				3					
<i>Caprella</i> sp. (D)		6			8	4			FS	FL	c; n; p
Corophiidae sp. (D)						1		1	FS	TM	c; n
<i>Corophium</i> sp. (D)			2				210		FS	TM	c; n
<i>Dexaminidae</i> sp.		2									
<i>Erichthonius pugnax</i> (D)	3	1						2	FS	TM	c; p
<i>Grandidierella japonica</i>							9				
<i>Hyale</i> sp.	1				9						

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
Leucothoidae sp.					6						
<i>Monocorophium acherusicum</i> (D)	145				3071				FS	TM	c; n
<i>Nippopisella nagatai</i> (D)			34	1			6		He	FL	c; p (cf. Hadzioidea)
Oedicerotidae sp.						2					
Cumacea											
<i>Dimorphostylis</i> sp.						1	1				
Isopoda											
<i>Dynoides dentisinus</i>	3				1						
<i>Gnorimosphaeroma rayi</i> (D)	3				192	1			Om	FL	m
<i>Ianiropsis longiantennata</i>					4						
<i>Ligia</i> sp.	6										
Munnidae sp.					32						
<i>Paranthuridae</i> sp.		7									
<i>Sphaeroma sieboldii</i>	168				137						
Tanaidacea											
<i>Zeuxo normani</i> (D)		307							FS	TM	c; d (cf. Tanaidacea)
Ostracoda											
Myodocopina sp.		11			7	1					
Podocopida sp. (D)		32				1			Om	FL	c; p
<i>Vargula hilgendorffii</i> (D)		7	1			3			Om	FL	c; p

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
Hexanauplia											
Harpacticoida sp.						5					
Porcellidiidae sp. (D)		550							Dt; Gr	FL	c; p
Decapoda											
Alpheidae sp.	4	2									
<i>Actaea</i> sp.	1										
<i>Alpheus brevicristatus</i>								1			
<i>Alpheus</i> sp. (D)			7	2	3				Om	FL	k; p (cf. Caridea)
<i>Athanas</i> sp. (D)		4	8	1			1		Om	FL	k; p (cf. Caridea)
<i>Camptandrium sexdentatum</i> (D)		2	31	5		1	4		Om	BU	k; p (cf. Pleocyemata)
<i>Charybdis japonica</i>	1										
<i>Charybdis</i> sp.			1								
Decapoda sp.		2									
<i>Hayashidonus japonicus</i>		1									
<i>Hexapinus</i> sp. (D)				2					Om	PA	i; p (cf. Pleocyemata)
Hexapodidae sp.				1			1				
<i>Latreutes laminirostris</i>		1									
<i>Latreutes planirostris</i>							1				
<i>Latreutes</i> sp.					1						
<i>Macromedaeus distinguendus</i>	154				134						

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
<i>Macrophthalmus</i> sp.							6				
Majidae sp.	1	2									
<i>Nanosesarma minutum</i> (D)	216				263				Om	FL	k; p (cf. Pleocyemata)
Ocypodidae sp. (D)				1					Om	BU	k; p (cf. Pleocyemata)
<i>Ogyrides striaticauda</i> (D)			8				6		Om	FL	p (cf. Caridea)
Paguridae sp.	8				2						
<i>Petrolisthes</i> sp. (D)	254				69				FS	FL	c; k
<i>Pilumnopus makianus</i>	9										
<i>Pilumnus minutus</i>	1				23						
<i>Pinnotheres</i> sp.						1					
Pinnotheridae sp. (D)		4	1	2					Om	PA	c; k; p (cf. Pleocyemata)
Porcellanidae sp.			1								
<i>Portunus</i> sp.			1								
<i>Pseudopinnixa carinata</i>							1				
<i>Raphidopus ciliatus</i> (D)			1	4					FS	FL	c; k
<i>Sphaerozius nitidus</i>					1						
<i>Thalamita sima</i>	1										
<i>Typhlocarcinus</i> sp.			1								
<i>Upogebia major</i>						1					
Xanthidae sp. (D)	92				98				Om	FL	k; p (cf. Pleocyemata)
<i>Xenophthalmus pinnotheroides</i> (D)		3	2	2		1	1	1	Om	FL	a; p (cf. Pleocyemata)

Table S2. Continued.

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
Stomatopoda											
<i>Oratosquilla oratoria</i>								1			
Sessilia											
<i>Amphibalanus amphitrite</i> (D)	2422		1		1586				FS	SE	c; k; p (cf. Balanomorpha)
<i>Amphibalanus eburneus</i>	56				2						
<i>Amphibalanus reticulatus</i> (D)	67		136		12				FS	SE	c; k; p (cf. Balanomorpha)
<i>Balanus trigonus</i> (D)	2121				1001				FS	SE	c; k; p (cf. Balanomorpha)
<i>Chthamalus challenger</i>	128				36						
<i>Fistulobalanus albicostatus</i> (D)	1123				1374				FS	SE	c; k; p (cf. Balanomorpha)
Collembola											
Collembola sp.					1						
Insecta											
Chironomidae sp. (D)					72				Om	FL	b; c; f; o
Tipulidae sp.					76						
Gastropoda											
Aplysiidae sp.		8									
Cerithiidae sp.					46						
<i>Alaba</i> sp. (D)		36							Dt	FL	c (cf. Cerithioidea); l
<i>Alvania concinna</i>		10			2						
<i>Bedevina birileffi</i> (D)	18	3		2	60				Ca-Sc	FL	c; l; p

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
<i>Cantharidus japonicus</i>		2									
<i>Cellana toreuma</i>	1										
Columbellidae sp.		9									
<i>Cylichnatys angusta</i> (D)							121		Gr	FL	c; l; p
<i>Decorifer insignis</i> (D)							62		Ca	FL	c; l; p
<i>Diala semistriata</i>		6			1						
<i>Drupella margariticola</i> (D)						4		1	Ca-Sc	FL	c; l; p
<i>Elysia</i> sp.					2						
<i>Erato</i> sp.	1	1									
<i>Ergalatax</i> sp.	1										
Gastropoda sp.		17									
Haminoeidae sp. (D)		1				4			Gr	FL	c; l; p
<i>Lacuna</i> sp.						1					
<i>Littoraria articulata</i>					16						
<i>Littoraria</i> sp.	1										
<i>Littorina brevicula</i> (D)	145				188				Gr	FL	c; l
<i>Mitrella bicincta</i>	1										
<i>Mitrella</i> sp.		5									
<i>Muricidae</i> sp.	1				9						
<i>Nassarius livescens</i> (D)		9		19		5		1	Sc	FL	c; p

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
<i>Nassarius multigranulosus</i>						7					
<i>Nassarius praematuratus</i>						2					
<i>Nassarius</i> sp.		6	2								
<i>Notocochlis gualtieriana</i>							1				
<i>Nudibranchia</i> sp.						1					
Onchidiidae sp.					1						
<i>Peasiella habei</i>	160				100						
<i>Philine orientalis</i>			1								
Pyramidellidae sp.	1				88						
<i>Reishia bronni</i>					1						
<i>Reishia clavigera</i>	10				2						
<i>Reticunassa festiva</i> (D)	3	8	6	11		8	14	4	Sc	FL	c; p
<i>Reticunassa</i> sp.						1	1				
Rissoidae sp.		19									
<i>Siphonaria japonica</i>					2						
<i>Stenothyra edogawensis</i>							1				
<i>Thylacodes adamsii</i>	51				98						
Triphoridae sp.					1						
<i>Yokoyamaia ornatissima</i> (D)				7					Ca	FL	c; l; p
<i>Zafra mitriformis</i> (D)	20				134				Ca-Sc	FL	c; l; p
<i>Zafra</i> sp.		8				1					

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
Bivalvia											
<i>Anomia Chinensis</i>	1				1						
<i>Arcuatula senhousia</i> (D)	27	673	118	3	5	28	716	4	FS	SE	c; l
<i>Bivalvia</i> sp.		9									
<i>Chama japonica</i>	2				3						
<i>Crassostrea gigas</i>	19										
<i>Cyclina sinensis</i>							2				
<i>Fulvia hungerfordi</i>			1			3	3	2			
<i>Irus irus</i>	1										
<i>Irus</i> sp.	2				1						
<i>Lasaea undulata</i> (D)	1015				644				FS	BU	c; l; p (cf. Galeommatoidea)
<i>Laternula gracilis</i>							10				
<i>Leptomya minuta</i>						1					
<i>Leucosphaera oyamai</i>						1					
<i>Lima</i> sp.	1										
<i>Lutraria sieboldii</i>							4				
<i>Macoma incongrua</i>							2				
<i>Macoma</i> sp.							2				
<i>Moerella rutila</i> (D)			14				83		FS-Dp	BU	c; l; p
Mytilidae sp.					1						

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
<i>Nitidotellina lischkei</i> (D)		2	2			1	3		FS-Dp	BU	c; l; p
Ostreidae sp.					109						
<i>Paratapes undulatus</i> (D)				3					FS	BU-SE	c; l
<i>Petricola japonica</i>					10						
<i>Petricola</i> sp.	12										
<i>Ruditapes philippinarum</i> (D)			9				8		FS	BU	c
<i>Solemya pusilla</i> (D)		19		2					Sy	BU-SE	l; p
<i>Solen brevissimus</i>				1							
<i>Theora lata</i> (D)		2	1			91	35	88	Dp	BU	c; l; p
Thraciidae sp. (D)		1	1	10					FS	BU	c (cf. Bivalvia); p
<i>Timoclea micra</i>						1					
<i>Xenostrobus atratus</i> (D)	577				740				FS	BU	c; l
Polyplacophora											
<i>Acanthochitona achates</i>	35				18						
<i>Liolophura japonica</i>					1						
Ischnochitonidae sp.	1										
Brachiopoda											
<i>Discradisca</i> sp.	7				9						
Echinodermata											
<i>Temnopleurus toreumaticus</i>	3										

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
<i>Amphioplus (Lymanella) japonicus</i>						1					
<i>Amphiura (Ophiopeltis) aestuarii</i>							2				
Amphiuridae sp. (D)		3		2				1	Dt	FL	c; k
Ophiothrix sp.					4						
Ophiurida sp.		1				1	14				
Ophiuroidea sp.	2										
Synaptidae sp. (D)		6	10	4		2	3	1	Dt	BU	c (cf. Holothuroidea); p
Bryozoa											
<i>Watersipora cucullata</i>	1	1			15						
Nemertea											
Nemertea sp. (D)	5	4	6	5	78	4	5	4	Ca	FL	c; j
Sipuncula											
Sipuncula sp.							1	1			
Actiniaria											
Actiniaria sp.	13	3					1				
<i>Diadumene lineata</i>					8						
Asciidiacea											
Asciidiidae sp.					2						
<i>Polyandrocarpa</i> sp.					5						
Pyuridae sp.	2				5						

Table S2. *Continued.*

Species	SUMMER				WINTER				Functional traits		
	BW	EB	IF	SB	BW	EB	IF	SB	PFT	CLF	Reference
<i>Styela plicata</i>	1										
Styelidae sp.	1										
Chaetognatha											
Sagittoidea sp.						3					
Platyhelminthes											
Platyhelminthes sp. (D)	112	68			144				Ca	FL	c
Porifera											
<i>Halichondria (Halichondria) japonica</i>					6						
<i>Halichondria (Halichondria) okadai</i>					27						
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Table S2. *Continued.*

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