Table S1. Case studies of sea urchin species exhibiting the effects of environmental changes as an increase (+) or decrease (–) in population density

Species	Effect	Cause	Locality	References
Diadema antillarum	–	Disease	Caribbean, Panama	Lessios et al.1984a,b, Lessios 1988, 1995
Paracentrotus lividus	–	Disease	Mediterranean Sea, France	Boudouresque et al. 1980
	–	Dinoflagellate blooms	NE Atlantic, Ireland	Cross & Southgate 1980
	–	Oceanographic condition	NE Atlantic, Ireland	Barnes et al. 2001, 2002, Verling et al. 2005
	–	Predation	Mediterranean Sea, Spain	Hereu et al. 2005
Strongylocentrotus droebachiensis	–	Disease	NW Atlantic, Canada	Scheibling & Stephenson 1984, Scheibling et al. 2013
	+	End of disease	NW Atlantic, Canada	Brady & Scheibling 2005
	–	Overfishing	NW Atlantic, Canada	Steneck et al. 2002, 2004
	–	Predation	NW Atlantic, Canada	Steneck et al. 2002, 2004, 2013
	–	Predation	NE Pacfic, USA	Estes & Duggins 1995
Strongylocentrotus polyacanthus	–	Predation	NE Pacfic, USA	Estes & Palmisano 1974
	+	Predator removal	NE Pacfic, USA	Estes & Palmisano 1974, Simenstad et al. 1978, Estes et al. 1998, Steneck et al. 2002
Strongylocentrotus purpuratus	–	Predation	NE Pacfic, USA	Estes & Duggins 1995
	+	Predator removal	NE Pacfic, USA	Tegner & Levin 1983, Dayton et al. 1998, Tegner & Dayton 2000, Lafferty 2004
Mesocentrotus franciscanus	–	Disease	NE Pacfic, USA	Pearse & Hines 1979
	–	Predation	NE Pacfic, USA	Estes & Duggins 1995
	–	Overfishing	NE Pacfic, USA	Tegner & Dayton 1991
	+	Predator removal	NE Pacfic, USA	Tegner & Levin 1983, Dayton et al. 1998, Tegner & Dayton 2000, Lafferty 2004
Mesocentrotus nudus	+	Recruitment	Sea of Japan, Japan	Agatsuma et al. 1998, Agatsuma 2014

Table S2. Details of sampling sites, dates and depths

Locality	Site	Abbr.	N	E	Date			Depth (m)			Tidal observatory	N	E
					2012	2013	2014	2012	2013	2014			
Kuji	Kujihama	KJ-A	40°13'	141°84'	ND	19 Aug.	ND	ND	0.1–3.0	ND	Kuji	40°12'	141°48'
	Futago	KJ-B	40°18'	141°80'	ND	20 Aug.	ND	ND	−0.3–4.7	ND			
	Oshiri	KJ-C	40°18'	141°82'	ND	19−20 Aug.	ND	ND	0.2–4.7	ND			
Kesennuma	Oya	KS	38°81'	141°56'	ND	15 May	19 Aug.	ND	0.1	0.1	Oofunato	39°01'	141°45'
Sizugawa Bay	Nojima	SZ-A	38°68'	141°51'	ND	19 Sep.	9 Sep.	ND	0.5–7.6	−0.1–4.6	Ayukawa	38°18'	141°30'
	Arato	SZ-B	38°68'	141°49'	ND	19 Sep.	9 Sep.	ND	−0.8–6.9	0.1–7.1			
	Kurosaki	SZ-C	38°66'	141.45'	ND	19 Sep.	9 Sep.	ND	0.7–7.7	0.5–7.2			
	Takihama	SZ-D	38°63'	141°49'	ND	11 Oct.	16 Sep.	ND	−1.2–6.1	−0.8–6.6			
	Terahama	SZ-E	38°64'	141°52'	ND	11 Oct.	16 Sep.	ND	−0.8–5.7	−0.2–7.8			
Onagawa Bay	Takenoura	ON-A	38°44'	141°50'	12 Sep	13 Sep.	22 Oct.	0–10.0	0–10.0	0–10.0	Ayukawa	38°18'	141°30'
	Onagawa	ON-B	38°44'	141°44'	9 Sep.	13 Sep.	23 Oct.	0–5.0	0–5.0	0–5.0			
	Yokoura	ON-C	38°41'	141°46'	10 Sep.	14 Sep.	24 Oct.	0–10.0	0–10.0	0–10.0			
	Ooishihara	ON-D	38°40'	141°46'	11 Sep.	14 Sep.	23 Oct.	0–4.0	0–4.0	0–4.0			
	Nonohama	ON-E	38°39'	141°47'	13 Sep.	15 Sep.	24 Oct.	0–5.0	0–5.0	0–5.0			
	Tsukahama	ON-F	38°40'	141°50'	14 Sep.	12 Sep.	22 Oct.	0–10.0	0–10.0	0–10.0			
	Enoshima	ON-G	38°40'	141°58'	15 Sep.	12 Sep.	25 Oct.	0–10.0	0–10.0	0–10.0			
Higashi-Matsushima	Tsukihama	HM	38°32'	141°16'	ND	ND	16 Jul.	ND	ND	3.1–4.1	Shiogama	38°19'	141°02'
Shinchi	Otohama	SN	37°52'	140°56'	ND	ND	29 Jul.	ND	ND	4.0–5.0	Souma	37°50'	140°58'

Depths were calculated at the level of the shallowest water according to the tide tables of the tidal observatorys nearest each locality (Japan Meteorological Agency 2024). ND, no data.

Table S3. Methods and areas for denity survey of 2011 yr-class of *Meocentrotus nudus*

Locality	Method	Site	Area surveyed (m^2)		
			2012	2013	2014
Kuji	A 100 m transect with 1 m wide at intervals of 5 m long plot	KJ-A	ND	100	ND
		KJ-B	ND	100	ND
		KJ-C	ND	100	ND
Kesennuma	Haphazard collection in 2013 A 1 m × 1 m quadrat in 2014	KS	ND	ND	7
Sizugawa Bay	A 100 m transect with 1 m wide at intervals of 5 m long plot	SZ-A	ND	100	100
		SZ-B	ND	100	100
		SZ-C	ND	100	100
		SZ-D	ND	100	100
		SZ-E	ND	100	100
Onagawa Bay	Ten 1 m × 1 m quadrats every 1 m depth up to 10 m depth except for them with > 90 % sediment coverage at depths of > 5 m of ON-B and ON-E, and > 4 m of ON-D	ON-A	110	110	110
		ON-B	56	58	58
		ON-C	110	110	110
		ON-D	42	43	43
		ON-E	55	53	60
		ON-F	110	110	110
		ON-G	110	110	110
Higashi-Matsushima	A 1 m × 1 m quadrat	HM	ND	ND	22
Shinchi	Haphazard collection	SN	ND	ND	ND

ND, no data.