

## 7. Environmental conditions of the study area

### 7-1. Height

#### Table 4.

The height above the chart datum of each quadrat (QD, see Fig. 1d) was measured in April 1986. For each quadrat, the height at the four corners (NE, north-east; SE, south-east; NW, north-west; SW, south-west) is shown. The point of one corner belongs to 1-4 quadrats, and thus the same value often appears in the rows of different quadrats (e.g., SW of A1, NW of A2, SE of B1, and NE of B2).

Table 4												
QD	NE	SE	NW	SW	Mean		QD	NE	SE	NW	SW	Mean
A 1	141	121	166	150	145		E 1	225	147		155	176
A 2	121	129	150	123	131		E 2	147	153	155	150	151
A 3	129	152	123	140	136		E 3	153	151	150	156	153
A 4	152	150	140		147		E 4	151	139	156	142	147
A 5	150	155		158	154		E 5	139	115	142	83	120
A 6	155	134	158	157	151		E 6	115	139	83	107	111
A 7	134	148	157	168	152		E 7	139	138	107	106	123
A 8	148	29	168	159	126		E 8	138	127	106	102	118
B 1	166	150	121	104	135		E 9	127	159	102	100	122
B 2	150	123	104	117	124		E 10	159	102	100	78	110
B 3	123	140	117	144	131		E 11	102	93	78		91
B 4	140		144	152	145		E 12	93	82		7	61
B 5		158	152	163	158		E 13	82	64	7		51
B 6	158	157	163	167	161		F 1		155	159	135	150
B 7	157	168	167	157	162		F 2	155	150	135	141	145
B 8	168	159	157	161	161		F 3	150	156	141	133	145
B 9	159		161	106	142		F 4	156	142	133	68	125
B 10			106	87	97		F 5	142	83	68	29	81
C 1	121	104	168	138	133		F 6	83	107	29	73	73
C 2	104	117	138	139	125		F 7	107	106	73	64	88
C 3	117	144	139	157	139		F 8	106	102	64	43	79
C 4	144	152	157	154	152		F 9	102	100	43	39	71
C 5	152	163	154	157	157		F 10	100	78	39		72
C 6	163	167	157	152	160							
C 7	167	157	152	132	152							
C 8	157	161	132	152	151							
C 9	161	106	152	130	137							
C 10	106	87	130	122	111							
C 11	87	93	122	106	102							
C 12	93	20	106	113	83							
C 13	20	39	113	97	67							
C 14	39		97	40	59							
D 1	168	138	225	147	170							
D 2	138	139	147	153	144							
D 3	139	157	153	151	150							
D 4	157	154	151	139	150							
D 5	154	157	139	115	141							
D 6	157	152	115	139	141							
D 7	152	132	139	138	140							
D 8	132	152	138	127	137							
D 9	152	130	127	159	142							
D 10	130	122	159	102	128							
D 11	122	106	102	93	106							
D 12	106	113	93	82	99							
D 13	113	97	82	69	90							
D 14	97	40	69		69							

## 7-2. Water flow

Table 5.

The intensity of water flow in each quadrat (QD, see Fig. 1d). Water flow was measured as the percentage loss of weight of a plaster lump (120–130 g) fixed at each corner of a quadrat (NE, north-east; SE, south-east; NW, north-west; SW, south-west) during 24 h in a spring tide (April 26–27, 2005). The point of one corner belongs to 1–4 quadrats and thus the same value often appears in the rows of different quadrats.

Table 5												
QD	NE	SE	NW	SW	Mean		QD	NE	SE	NW	SW	Mean
A 1		12	12	11	12		E 1		11		15	13
A 2	12	12	11	10	11		E 2	11	13	15	13	13
A 3	12	11	10	11	11		E 3	13	13	13	13	13
A 4	11	10	11		11		E 4	13	17	13	20	16
A 5	10	11		9	10		E 5	17	17	20	19	18
A 6	11	16	9	10	12		E 6	17	19	19	20	19
A 7	16	26	10	17	17		E 7	19	25	20	26	23
A 8	26		17	20	21		E 8	25	22	26	30	26
B 1	12	11			12		E 9	22	33	30	36	30
B 2	11	10			11		E 10	33	28	36	37	34
B 3	10	11		11	11		E 11	28	32	37		32
B 4	11		11	11	11		E 12	32	50			41
B 5		9	11	12	11		E 13	50	100			75
B 6	9	10	12	14	11		F 1		15	15	11	14
B 7	10	17	14	15	14		F 2	15	13	11	15	14
B 8	17	20	15	18	18		F 3	13	13	15	16	14
B 9	20		18	33	24		F 4	13	20	16	28	19
B 10			33	29	31		F 5	20	19	28	18	21
C 1			12	10	11		F 6	19	20	18	20	19
C 2			10	11	11		F 7	20	26	20	23	22
C 3		11	11	12	11		F 8	26	30	23	28	27
C 4	11	11	12	13	12		F 9	30	36	28		31
C 5	11	12	13	16	13		F 10	36	37			37
C 6	12	14	16	17	15							
C 7	14	15	17	17	16							
C 8	15	18	17	24	19							
C 9	18	33	24	38	28							
C 10	33	29	38	38	35							
C 11	29	40	38	59	42							
C 12	40		59	64	54							
C 13			64	100	82							
C 14			100		100							
D 1	12	10		11	11							
D 2	10	11	11	13	11							
D 3	11	12	13	13	12							
D 4	12	13	13	17	14							
D 5	13	16	17	17	16							
D 6	16	17	17	19	17							
D 7	17	17	19	25	20							
D 8	17	24	25	22	22							
D 9	24	38	22	33	29							
D 10	38	38	33	28	34							
D 11	38	59	28	32	39							
D 12	59	64	32	50	51							
D 13	64	100	50	100	79							
D 14	100		100	100	100							

### 7-3. Pool coverage

Table 6.

The coverage with pools in each quadrat (QD; Fig. 1d) during April or May from 2005 to 2010. Coverage was estimated visually at low tide and assigned to one of the following four classes: 1 (<25%), 2 (25–50%), 3 (50–75%), or 4 (>75%). –, no data.

Table 6														
QD	2005	2006	2007	2008	2009	2010			2005	2006	2007	2008	2009	2010
A 1	1	1	1	1	1	1		E 1	1	1	1	1	2	2
A 2	2	2	2	2	2	2		E 2	1	2	1	1	1	1
A 3	2	2	2	2	2	2		E 3	1	1	2	1	1	2
A 4	3	2	2	2	2	2		E 4	1	1	1	1	1	1
A 5	3	3	1	3	1	3		E 5	1	1	1	1	1	1
A 6	3	3	3	2	3	3		E 6	1	1	1	1	1	1
A 7	2	2	2	2	2	2		E 7	1	1	1	2	1	1
A 8	2	1	1	1	1	1		E 8	2	2	2	2	2	1
B 1	3	2	2	3	3	1		E 9	1	1	2	1	1	1
B 2	2	3	3	3	3	3		E 10	1	1	2	1	1	1
B 3	4	4	4	4	4	4		E 11	1	2	1	1	2	1
B 4	2	3	2	3	2	3		E 12	1	1	1	1	1	1
B 5	1	2	1	2	1	2		E 13	1	1	1	1	—	1
B 6	2	2	2	2	1	2		F 1	1	1	1	1	1	1
B 7	2	2	2	1	1	2		F 2	1	1	1	1	1	1
B 8	1	1	2	2	1	2		F 3	1	1	1	1	1	1
B 9	1	1	3	1	1	1		F 4	1	1	1	1	1	1
B 10	1	1	1	1	1	1		F 5	1	1	1	1	1	1
C 1	3	3	3	3	2	2		F 6	1	1	1	1	1	1
C 2	4	4	4	3	3	3		F 7	1	1	1	1	1	1
C 3	3	2	2	3	3	3		F 8	1	2	1	1	2	2
C 4	1	1	1	1	1	1		F 9	2	2	1	2	2	2
C 5	1	1	1	1	1	1		F 10	3	1	2	2	1	2
C 6	1	1	1	1	1	1								
C 7	1	1	1	1	1	1								
C 8	2	1	2	1	1	1								
C 9	2	2	1	1	2	1								
C 10	1	1	1	1	1	1								
C 11	1	1	1	1	1	1								
C 12	1	1	1	1	1	1								
C 13	1	1	1	1	1	1								
C 14	1	1	1	2	1	1								
D 1	1	1	1	1	1	1								
D 2	1	1	1	2	1	2								
D 3	1	2	1	2	2	2								
D 4	1	1	1	1	1	1								
D 5	1	1	1	1	1	1								
D 6	2	1	1	1	1	1								
D 7	2	1	2	1	1	1								
D 8	2	2	3	3	3	2								
D 9	1	1	1	1	1	1								
D 10	2	1	1	1	1	1								
D 11	1	1	1	1	1	1								
D 12	1	1	1	1	1	1								
D 13	1	1	1	1	1	1								
D 14	1	1	1	1	1	1								

#### 7-4. Algal cover

Table 7.

Coverage with macroalgae and the dominant macroalgal taxa in each quadrat (QD; Fig. 1d) during April or May of 2005 to 2010. Coverage (CV) was estimated visually at low tide, and assigned to one of the following four classes: 1 (<25%), 2 (25–50%), 3 (50–75%), or 4 (>75%). The dominant taxa (DT) are shown using the following abbreviations: R (red algae, Rhodophyta), B (brown algae, Phaeophyta), and G (green algae, Chlorophyta). The order of coverage by these taxa was determined intuitively in the field, and is shown using >. When two or three groups were equally abundant, the alphabetical abbreviations were punctuated. –, no data.

Table 7-1												
	2005		2006		2007		2008		2009		2010	
QD	CV	DT	CV	DT	CV	DT	CV	DT	CV	DT	CV	DT
A 1	1	G	2	G	1	G	1	G	2	G	1	G
A 2	3	G	3	G	2	G>R	4	G>R	4	G>R	2	G>R
A 3	1	G	2	G	1	G	2	G>R	2	G>R	3	G>R
A 4	1	R>G	1	G	1	B>G	1	G>R	2	G>B	1	G>R
A 5	1	G	2	G	2	C>B	1	G>R	1	G>R	3	G>R
A 6	1	G, R	2	G	2	G>R	1	G>R	2	G>R	2	R>B
A 7	1	R	1	R	1	R>G	1	R>G	1	R>G	1	R>B
A 8	1	B>R	-	R>B	2	B>R	2	G>R	2	B>R	2	B>R
B 1	1	G	1	G	1	B	2	G	3	G	3	G
B 2	2	G	1	G	2	B	2	G>R	2	G>R	2	G>R
B 3	1	G	3	G	2	G>R	2	G>R	3	G>R	1	G>R
B 4	1	G	2	G	1	G>R	1	G>R	1	G>R	2	G>R
B 5	1	0	1	G	1	R	1	R	1	G>B	1	G>R
B 6	1	R	1	G	1	R>G	1	G>R	1	G>B	1	G>R
B 7	1	G	1	G	1	G	1	G	1	G	1	G>R
B 8	1	G	1	G	1	G	1	G	1	G>R	1	G>R
B 9	1	R, B	-	R	1	B	1	R>B	1	R>G	1	R>G
B 10	2	R>B	2	R	1	R>B	2	R>B	2	B>R	2	R>B
C 1	1	G	-	G	2	G	1	G	2	G	2	G
C 2	1	G	3	G	2	G>R	2	G>R	1	G>R	1	G>R
C 3	1	G	2	G	1	G>R	3	G>R	1	G>R	1	G>R
C 4	1	0	1	G	1	0	1	0	1	G	1	G>R
C 5	1	G	1	G	1	G	1	G	1	G	1	G
C 6	1	G	1	G	1	G>R	1	G	1	G	1	G
C 7	1	G	1	G	1	G>R	1	G	1	G	1	G
C 8	1	G	1	G	1	G>R	1	G>R	1	G>R	1	G>R
C 9	1	R>G	-	R	1	G	1	G>R	1	G>R	1	R>G
C 10	1	R	1	R	1	R>G	1	G>R	1	R>G	1	R>G
C 11	3	B>R	3	R, B	3	R>B	1	B>R	1	B>R	2	R>B
C 12	1	B	1	B	1	G, B, R	1	B>R	1	R>G	1	R>G
C 13	2	B	1	B	2	B>R	1	B>R	1	B>R	2	B>R
C 14	1	B>R	2	R	2	R>B	4	B>R	2	B>R	2	R>B
D 1	1	G	1	G	1	G	1	G	1	G	2	G
D 2	1	G	1	G	1	G	1	G	1	G	1	G
D 3	1	G	1	G	1	G	1	G	1	G	3	G
D 4	1	G	1	G	1	G	1	G	1	G	2	G
D 5	1	G	1	G	1	G>R	1	G>R	2	G>R	1	G
D 6	1	G	1	G	1	G, R	1	G	2	G	1	G
D 7	2	G	1	G	3	G>R	2	G	3	G>R	1	G>R
D 8	1	G	1	R>G	2	G>R	2	G>R	3	G>R	3	G>R
D 9	1	R, B, G	1	R, B	1	G>R	2	G>B	2	G>R	2	G>R
D 10	1	R	1	R	1	R	1	R>G	2	G>R	1	R
D 11	1	B	2	R, B	1	R	1	B>R	1	B>R	1	R>B
D 12	1	R, B	1	R, B	1	B>R	1	B>R	1	B>R	1	B>R
D 13	1	B	1	B>R	1	R>B	1	B	1	B>R	1	B>R
D 14	3	R, B	3	R>B	3	R>B	4	R>B	4	R>B	4	R>B



Table 7-2												
	2005		2006		2007		2008		2009		2010	
QD	CV	DT	CV	DT	CV	DT	CV	DT	CV	DT	CV	DT
E 1	1	0	1	G	1	G	1	0	1	0	1	G
E 2	1	G	-	G	1	G	1	0	1	0	1	G
E 3	1	G	-	G	1	G	1	0	1	G	1	G
E 4	1	G	1	G	1	G > R	1	G	1	G	2	G
E 5	1	G	1	R > G	2	G > R	2	G, R	3	G > R	3	G
E 6	1	G	2	R, B	2	G > R	2	G > R	3	G > R	3	G > R
E 7	1	G	1	G	3	G > R	2	G > B	-	G > R	1	G > R
E 8	3	R > G	3	R, B	3	R > G	1	G > B	2	G > R	3	R > G
E 9	1	R > B	2	R > B	2	R > B	2	B > G	1	R > G	2	R > G
E 10	1	R	2	R > B	3	R > G	2	R > B	1	R > B	2	R > G
E 11	3	B > R	-	B	2	B > R	2	B > R	3	B > R	2	B > R
E 12	3	B	4	B	2	B > R	1	B > R	3	B > R	3	B > R
E 13	3	B	2	B	2	B > R	2	B > R	-	-	2	B > R
F 1	1	G	1	G	1	G	1	G	1	G	2	G > R
F 2	1	0	1	G > C	1	G	1	G	1	G	2	G > R
F 3	1	R	1	C > R	1	R	1	G > R	1	G, R	2	G > R
F 4	2	R	2	R > C	2	R > G	2	R > B	2	G, R	2	G > R
F 5	1	R	1	R > G	2	R > G	2	G > R	2	G > R	1	G > R
F 6	1	R	1	G > R	1	G > R	1	G > R	2	G, R	2	R > G
F 7	1	R	1	G > R	1	G > R	1	G > R	2	G > R	1	B > R
F 8	2	B > R	3	B > R	2	B > R	2	B > R	2	B > R	3	R > B
F 9	2	B	3	B > R	2	B > R	2	B > R	2	B > R	3	B > R
F 10	4	B > R	3	B > G	2	B > R	3	B > R	2	B > R	3	B > R

## 7-5. Climatic and oceanographic data

Table 8.

Summary of the oceanographic data from 1984 to 2010 around the study site. AT, the monthly mean air temperature based on the values measured daily at St. 1 (Fig. 1b). Typhoon, the number of typhoons that entered within 1000 km and 200 km (in brackets) circles of the study site during April to November each year. These data were obtained from the website of the Japan Meteorological Agency (<http://www.data.jma.go.jp>). Nearshore WT, monthly mean of the water temperature measured daily at St. 2 (Fig. 1b) by the Seto Marine Biological Laboratory of Kyoto University. Offshore WT, water temperature measured once a month at 50 m depth at 9 offshore stations (2–20km from the coast, cross marks in Fig. 1a). Sal, salinity at 10 m depth at St. 3 (Fig. 1b). The offshore temperature and salinity were measured once a month by the Fisheries Experimental Station of Wakayama Prefecture. Kuroshio, the annual mean distance of the Kuroshio Current from Cape Shionomisaki (Fig. 1a) reported by the Maritime Safety Agency of Japan. COD, SS, T-N (total nitrogen), and T-P (total phosphorous) were measured at the surface layer of six points around St 4 (Fig. 1b) once a year between July and September by the Shirahama Municipality Government, and the mean of the six values is shown for each parameter. –, no data.

	AT (°C)		Typhoon		Nearshore WT (°C)		Offshore WT (°C)		Sal (psu)		Kuroshio km	COD	SS	T-N	T-P
	Feb.	Aug.	Feb.	Aug.	Feb.	Aug.	Feb.	Aug.	Feb.	Aug.					
1984		27.5		9 (1)		27.7		19.0		33.40	54	2.0	1.0	0.24	0.02
1985	7.7	27.3	13.5	11 (1)	28.0	15.3	21.2	34.55	33.25	49	1.2	2.3	2.3	0.55	0.01
1986	5.1	27.1	14.0	9 (1)	27.9	15.7	18.5	34.70	33.87	64	2.2	2.7	2.7	0.39	0.03
1987	7.9	27.6	14.6	10 (2)	26.8	16.0	19.5	34.61	33.98	125	1.5	3.7	3.7	1.05	0.07
1988	6.4	26.8	13.5	12 (3)	27.5	15.4	23.2	34.36	33.09	59	1.3	1.9	1.9	0.42	0.04
1989	9.3	27.0	15.9	11 (2)	27.9	17.0	26.2	34.55	33.72	49	1.4	4.2	4.2	0.38	0.01
1990	10.1	27.8	14.7	10 (5)	27.7	16.5	19.1	34.34	33.45	77	1.2	2.1	2.1	0.54	0.05
1991	6.8	27.0	13.2	12 (1)	27.0	15.9	26.4	34.48	33.70	33	1.0	2.9	2.9	0.40	0.03
1992	7.3	26.8	14.7	11 (1)	26.9	17.2	20.9	34.51	33.94	32	2.3	2.2	2.2	1.36	0.18
1993	8.6	26.5	14.5	11 (2)	26.2	17.4	17.2	34.75	33.52	45	1.0	3.3	3.3	0.61	0.03
1994	7.2	27.8	14.2	11 (1)	28.3	17.1	26.1	34.75	33.97	34	1.6	4.9	4.9	0.58	0.03
1995	7.1	28.6	14.4	7 (0)	27.6	17.2	18.8	34.75	33.98	41	1.9	1.9	1.1	1.06	0.06
1996	6.4	27.5	13.5	11 (0)	27.6	16.7	20.1	34.61	33.76	33	1.5	4.7	4.7	0.53	0.04
1997	7.3	27.2	13.9	11 (2)	26.9	15.9	23.3	34.72	33.53	33	1.5	2.1	2.1	0.58	0.03
1998	9.5	28.5	15.8	7 (3)	28.8	18.3	21.4	34.73	33.11	40	2.1	1.2	1.2	0.58	0.05
1999	7.1	27.7	14.5	10 (0)	28.1	16.4	25.0	34.55	33.36	45	2.0	1.2	1.2	0.24	0.02
2000	5.9	27.4	15.7	10 (1)	27.7	16.4	18.7	34.58	33.66	73	1.6	1.2	1.2	0.35	0.11
2001	7.9	27.3	14.9	8 (1)	28.2	17.0	19.9	34.54	33.77	58	1.7	1.7	1.7	0.17	0.02
2002	8.3	27.4	15.1	12 (3)	28.2	17.2	24.8	34.71	34.02	39	1.8	3.2	3.2	0.33	0.03
2003	7.9	27.4	14.9	10 (1)	27.9	16.6	23.1	34.49	33.68	43	1.6	0.9	0.9	0.36	0.02
2004	8.7	27.3	15.2	15 (7)	27.9	16.4	26.2	—	34.05	101	1.4	1.8	1.8	0.29	0.01
2005	7.4	27.2	13.6	7 (1)	26.9	15.8	16.7	—	34.03	82	1.6	2.0	2.0	0.20	0.02
2006	8.6	28.1	15.2	9 (1)	28.7	16.5	20.4	34.66	33.21	33	2.0	4.2	4.2	0.25	0.02
2007	9.7	28.2	15.6	8 (2)	28.2	17.9	20.7	34.47	33.40	48	1.3	1.2	1.2	0.25	0.04
2008	6.1	27.5	14.6	8 (1)	28.3	16.5	17.5	34.69	33.47	45	1.6	0.9	0.9	0.25	0.02
2009	9.8	27.2	15.2	7 (3)	27.8	16.81	18.5	—	33.39	45	1.0	1.1	1.1	0.17	0.02
2010	9.2		15.0		15.86			34.46							