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Priority Marine Feature Surveys within the Small Isles MPA and surrounding Waters

Scottish Marine and Freshwater Science Vol 14 No 1

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Annex Materials

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Priority Marine Feature Surveys within the Small Isles MPA and surrounding Waters

Annex Materials

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Abstract

The Small Isles Marine Protected Area (MPA) is one of Scotland's biggest inshore MPAs, covering more than 800 km^2 and containing a complex mosaic of habitats. The six-year survey programme (2012 – 2017) conducted by Marine Scotland collected imagery of the seafloor within the Small Isles MPA: 9,374 digital images and 3,690 minutes of high definition video footage. This imagery was analysed to determine baseline abundances of eight seafloor invertebrate species with conservation importance related to Priority Marine Features. These imagery data showed that the Sound of Canna provides important habitat within the MPA. There were sufficient data to model changes in abundance over time for two species in four survey locations. The abundance of the Tall seapen (*Funiculina quadrangularis*) reduced after 2014, whilst the abundance of the Northern sea fan (*Swiftia pallida*) was stable over time. The potential impact of bottom-contacting towed fishing gear on the distribution of the Tall seapen in the wider area of the Minch, Inner Sound and Sea of Hebrides was also investigated. There was no evidence that fishing activity caused reductions in seapen abundance. However the analysis was limited by the available fishing data, which was at a broader scale (over space and time) than the abundance data. Finer scale fishing data would be needed for future studies to assess the impact of fishing activities on the abundance of seafloor invertebrate species. The results of this study provide a more extensive biological baseline of the Small Isles MPA than previously available, including more survey locations and repeat surveys over time. The Small Isles dataset strengthens the biological evidence base underpinning the Scottish MPA network by improving our understanding of where species occur and identifying important locations for different species. The abundance data can help establish management measures to support an ecologically coherent MPA network by identifying where the abundances of some species, such as the Tall seapen, have reduced. Continued surveying of the Small Isles MPA and the surrounding region is discussed with respect to monitoring changes in species abundance over space and time and assessing the effectiveness of any future management measures.

Contents

Annex A: Data Tables

The full Marine Scotland Small Isles MPA dataset (2012 – 2017) including the data used to create this report is archived and stored in accordance with the Scottish Government’s Open Data Strategy. Data relating to Priority Marine Features (PMFs) were provided to the Geodatabase of Marine features adjacent to Scotland (GeMS) curated by NatureScot. Access to the full dataset and associated information can be gained via the Marine Scotland Data Portal; DOI: 10.7489/1614-1.

The following data tables are referred to and described in detail within the Main Report by Greathead et al. (2023).

Table A.1.

Summary table for the Marine Scotland digital stills (DSI) surveys of the Small Isles MPA. Abbreviations for target features and species are SP: *Swiftia pallida*; FQ: *Funiculina quadrangularis*; BM: burrowed mud; BS: burrowed mud with seapens; AS: *Arachnanthus sarsi*; PM: *Pachycerianthus multiplicatus*; PA: *Parazoanthus anguicomus*; LC: *Leptometra celtica*; MM: *Modiolus modiolus*; AF: *Atrina fragilis*. Target features are distributed amongst five indicative habitat types adopted for the purposes of survey design: soft sediment (SS), mixed sediment (MS), mixed sediment with cobbles (MSC), mixed sediments with cobbles and boulders (MSCB), and bedrock with mixed cobbles and boulders (CBR). *Protection status relates to the Small Isles MPA boundary (‘Outside MPA’) or the proposed fisheries management measures (‘Inside Measures’ or ‘Outside Measures’). **Number of DSI from each year that were suitable for analysis (< 25% of the image obscured). ***Viewed seabed area for each year. [1]Boxes where repeat surveys were not conducted because they did not contain the target species or habitat, or because they were too difficult or dangerous to survey.

Box ID	**Target feature**	**Secondary target feature**	**Protection status***	**Location**	**Mean depth (m)**	**Sediment**	**Years surveyed**	**Number of DSI****	**Total viewed area (m^2)*****
B14[1]	*Atrina fragilis*		Inside Measures	Sound of Canna	123	MSCB	2014	37	48
B15[1]	Burrowed mud with *Funiculina quadrangularis*		Inside Measures	Sound of Canna	189	SS	2014	160	191
S01[1]	Burrowed mud with Seapens		Inside Measures	Canna Harbour	57	MSC	2012	194	200
S03	*Atrina fragilis*	*Modiolus modiolus* beds	Inside Measures	East of Canna	200	MSC	2012	139	143
S04	*Modiolus modiolus* beds	*Atrina fragilis*	Inside Measures	Sound of Canna	227	MSC	2012	90	93
S05	Burrowed mud with Seapens	Burrowed mud with *Pachycerianthus multiplicatus*	Outside Measures	Sound of Canna	75	SS	2012, 2017	108, 82	111, 112

S06	*Leptometra celtica* Aggregations	Burrowed mud with Seapens	Inside Measures	South of Sanday	123	MSC	2012	241	248
S07	Burrowed mud with *Funiculina quadrangularis*	Burrowed mud with Seapens	Outside Measures	South of MPA	89	SS	2012, 2014, 2015, 2016, 2017	251, 139, 252, 250, 124	259, 175, 327, 381, 157
S08	Burrowed mud with *Funiculina quadrangularis*	Burrowed mud with Seapens	Outside Measures	South of MPA	97	SS	2012, 2014, 2015, 2016, 2017	193,146, 255, 249, 58	199, 184, 331, 369, 75
S09	Burrowed mud with Seapens	Burrowed mud with *Funiculina quadrangularis*	Outside Measures	South of Canna	72	SS	2012, 2014	83, 147	86, 190
S10	Burrowed mud with *Funiculina quadrangularis*	Burrowed mud with *Pachycerianthus multiplicatus*	Outside MPA	South of MPA	114	SS	2012, 2014, 2017	225, 242, 98	232, 311, 134
S11	Burrowed mud with *Funiculina quadrangularis*	Burrowed mud with Seapens	Outside Measures	North of Rum	108	SS	2012, 2014	221, 250	228, 325
S12	Burrowed mud with *Funiculina quadrangularis*	Burrowed mud with *Pachycerianthus multiplicatus*	Outside MPA	SE of Rum	88	SS	2012, 2014, 2016, 2017	106, 244, 243, 74	109, 315, 373, 92
S14[1]	*Atrina fragilis*		Inside Measures	Sound of Canna	155	MSC	2014	54	70
S15	*Atrina fragilis*	*Arachnanthus sarsi*	Inside Measures	Sound of Canna	167	MSC/MS	2016, 2017	246	374
S16	*Swiftia pallida* and Sponges	*Leptometra celtica* Aggregations	Inside Measures	South of Soay	54	CBR	2013	10	13
S17	*Leptometra celtica* Aggregations	*Parazoanthus anguicomus*	Outside Measures	Sound of Canna	101	CBR/MSC B	2012	177	182
S19	Burrowed mud with *Funiculina quadrangularis*	*Swiftia pallida* and Sponges	Inside Measures	West of Rum	103	SS	2015, 2016, 2017	212, 152, 70	275,229,8 9

S23	Burrowed mud with *Funiculina quadrangularis*	Burrowed mud with Seapens	Outside MPA	SW of Rum	90	SS	2015, 2016, 2017	250, 140, 144	324, 212, 197
S40	Burrowed mud with *Funiculina quadrangularis*	*Leptometra celtica* Aggregations	Inside Measures	North of Rum	117	SS/MS	2015, 2016, 2017	250, 249, 230	323, 377, 326
S41	*Swiftia pallida* and Sponges	*Parazoanthus anguicomus*	Inside Measures	South of Sanday	112	MSCB	2012	173	178
S51	Burrowed mud with *Funiculina quadrangularis*	Burrowed mud with Seapens	Outside Measures	North of Rum	81	SS	2017	110	154
S67	*Leptometra celtica* Aggregations	*Swiftia pallida*	Inside Measures	Sound of Canna	86	MSCB/ CBR	2014	25	32
S68	*Swiftia pallida* and Sponges	*Parazoanthus anguicomus*	Inside Measures	West of Rum	96	MSCB/ CBR	2015, 2016	139, 86	180, 132
V04[1]	Burrowed mud with *Funiculina quadrangularis*	Burrowed mud with Seapens	Inside Measures	North of Rum	208	SS	2014	144	187
V05	*Swiftia pallida* and Sponges	*Leptometra celtica* Aggregations	Inside Measures	West of Soay	80	MSCB/ CBR	2014	62	76
V11	*Atrina fragilis*	*Swiftia pallida* and Sponges	Outside MPA	SE of Muck	204	CBR/ MSCB/ MSC	2014	147	190
V12[1]	*Swiftia pallida*		Outside Measures	North of Canna	79	MS	2014, 2017	141, 25	182, 32
					Totals across surveys			8137	10333

Table A.2.

Summary table for the Marine Scotland high-definition video (HDV) surveys of the Small Isles MPA, using a drop camera frame. Abbreviations for target features and species are SP: *Swiftia pallida*; FQ: *Funiculina quadrangularis*; BM: burrowed mud; BS: burrowed mud with seapens; AS: *Arachnanthus sarsi*; PM: *Pachycerianthus multiplicatus*; PA: *Parazoanthus anguicomus*; LC: *Leptometra celtica*; MM: *Modiolus modiolus*; AF: *Atrina fragilis*. Target features are distributed amongst five habitat types adopted for the purpose of survey design: soft sediment (SS), mixed sediment (MS), mixed sediment with cobbles (MSC), mixed sediments with cobbles and boulders (MSCB), and bedrock with mixed cobbles and boulders (CBR). *Protection status relates to the Small Isles MPA boundary ('Outside MPA') or the proposed fisheries management measures ('Inside Measures' or 'Outside Measures'). **Number of 1 minute HDV segments from each year. ***Viewed seabed area for each year.

Box ID	Target feature	Secondary target feature	Protection status*	Location	Mean depth (m)	Mean tow speed (knots)	Sediment	Years surveyed	Total video mins**	Total viewed area (m^2)***
S04	*Modiolus modiolus*	*Atrina fragilis*	Inside Measures	Sound of Canna	227	0.67	MSC	2015, 2017	159, 132	1902, 1967
S06	*Leptometra celtica* Aggregations	Burrowed mud with Seapens	Inside Measures	South of Sanday	128	0.70	MSC	2015, 2016, 2017	185, 250, 126	2795, 4178, 2453
S09	Burrowed mud with Seapens	Burrowed mud with *Funiculina quadrangularis*	Outside Measures	South of Canna	77	0.96	SS	2017	67	1283
S15	*Atrina fragilis*	*Arachnanthus sarsi*	Inside Measures	Sound of Canna	171	0.92	MSC/MS	2015, 2017	174, 90	4614, 1505
S16	*Swiftia pallida* and Sponges	*Leptometra celtica* Aggregations	Inside Measures	South of Soay	39	0.62	CBR	2015	204	3312
S17	*Leptometra* Aggregations	*Pachycerianthus multiplicatus*	Outside Measure	Sound of Canna	105	0.76	CBR/ MSCB	2015, 2016, 2017	14, 40, 124	233, 750, 1394

S40	Burrowed mud with *Funiculina quadrangularis*	*Leptometra celtica* Aggregations	Inside Measure	North of Rum	114	0.41	SS/MS	2015	122	1282
S41	*Swiftia pallida* and Sponges	*Pachycerianthus multiplicatus*	Inside Measures	South of Sanday	120	0.65	MSCB/ CBR	2015, 2017	194, 109	3416, 1153
S46	*Swiftia pallida* and Sponges	*Pachycerianthus multiplicatus*	Inside Measures	West of Rum	142	0.70	MSCB	2015, 2016, 2017	70, 109, 97	1135, 2156, 1193
S51	Burrowed mud with *Funiculina quadrangularis*	Burrowed mud with Seapens	Outside Measures	North of Rum	84	0.59	SS	2015	83	1274
S64	*Leptometra celtica* Aggregations	*Arachnanthus sarsi*	Outside MPA	South of Rum	165	0.61	MSCB/ MS	2015, 2016	141, 92	1574, 1961
S66	*Parazoanthus anguicomus*	*Swiftia pallida* and Sponges	Outside Measures	East of Rum	77	0.32	MSCB/ CBR	2015	169	1407
S67	*Leptometra celtica* Aggregations	*Swiftia pallida* and Sponges	Inside Measures	Sound of Canna	110	0.72	MSCB/ CBR	2015, 2016, 2017	28, 59, 144	411, 1025, 923
S68	*Swiftia pallida* and Sponges	*Pachycerianthus multiplicatus*	Inside Measures	West of Rum	98	0.42	MSCB/ CBR	2015, 2016	156, 58	698, 870
V05	*Swiftia pallida* and Sponges	*Leptometra celtica* Aggregations	Inside Measures	West of Soay	106	0.60	MSCB/ CBR	2016	234	3913
V11	*Atrina fragilis*	*Swiftia pallida* and Sponges	Outside MPA	SE of Muck	197	0.70	CBR/ MSCB/ MSC	2015, 2016, 2017	126, 76, 86	1269, 1281, 1316
						Totals across surveys			3690	54644

Table A.3.

Densities (n.m^{-2}) of *Funiculina quadrangularis* within the Small Isles region sampled between 2012 and 2017. Densities are calculated at the survey box scale, i.e., all counts within each box for each year divided by the viewed area of seafloor within that box that year. Densities are calculated for digital stills images (DSI) and high-definition video (HDV). *Densities calculated from HDV; **Densities calculated from DSI in a year when HDV data are also available. Any empty cell ('-') denotes years in which no data are available for that survey box. Densities are reported to three decimal places; a value of '0' indicates that *F. quadrangularis* was not observed from the seabed surveyed in that box and year.

Survey Box	2012	2013	2014	2015	2016	2017
B14	-	-	0.021	-	-	-
B15	-	-	0.010	-	-	-
S01	0	-	-	-	-	-
S03	0	-	-	-	-	-
S04	0	-	-	0*	-	0*
S05	0.018	-	-	-	-	0.009
S06	0.048	-	-	0.006*	0.006*	0.016*
S07	0.058	-	0.074	0.003	0.003	0.006
S08	0.060	-	0.087	0.006	0	0
S09	0	-	0	-	-	0.002*
S10	0.285	-	0.303	-	-	0.082
S11	0.149	-	0.182	-	-	-
S12	0.430	-	0.295	-	0.056	0.510
S14	-	-	0	-	-	-
S15	-	-	-	0.008*	0.019	0.012*
S16	-	0	-	0*	-	-
S17	0.011	-	-	0.026*	0.005*	0.002*
S19	-	-	-	0.029	0.031	0.011
S23	-	-	-	0.006	0	0.005
S40	-	-	-	0.047**	0.034	0
S41	0	-	-	0*	-	0*
S46	-	-	-	0*	0*	0*
S51	-	-	-	0.075*	-	0.045
S64	-	-	-	0.073*	0.083*	-
S66	-	-	-	0.030*	-	-
S67	-	-	0	0.024*	0.017*	0.005*
S68	-	-	-	0.006**	0.008**	-
V04	-	-	0.048	-	-	-
V05	-	-	0	-	0.230*	-
V11	-	-	0.005	0.006*	0.002*	0.010*
V12	-	-	0	-	-	0

Table A.4.

Densities (n.m^{-2}) of *Swiftia pallida* within the Small Isles region sampled between 2012 and 2017. Densities are calculated at the survey box scale, i.e., all counts within each box for each year divided by the viewed area of seafloor within that box that year. Densities are calculated for digital stills images (DSI) and high-definition video (HDV). *Densities calculated from HDV; **Densities calculated from DSI in a year when HDV data are also available. Any empty cell ('-') denotes years in which no data are available for that survey box. Densities are reported to three decimal places; a value of '0' indicates that *S. pallida* was not observed from the seabed surveyed in that box and year.

Survey Box	2012	2013	2014	2015	2016	2017
B14	-	-	0	-	-	-
B15	-	-	0	-	-	-
S01	0	-	-	-	-	-
S03	0.007	-	-	-	-	-
S04	0	-	-	0*	-	0*
S05	0	-	-	-	-	0
S06	0.193	-	-	0.345*	0.124*	0.106*
S07	0	-	0	0	0	0
S08	0	-	0	0	0	0
S09	0	-	0	-	-	0*
S10	0	-	0	-	-	0
S11	0	-	0	-	-	-
S12	0	-	0	-	0	0
S14	-	-	0	-	-	-
S15	-	-	-	0*	0.011	0*
S16	-	5.317	-	0.215*	-	-
S17	0.110	-	-	0*	0.004*	0.192*
S19	-	-	-	0.636	0.319	0
S23	-	-	-	0	0	0
S40	-	-	-	0**	0	0
S41	0.146	-	-	0.225*	-	0.193*
S46	-	-	-	0.011*	0.005*	0.023*
S51	-	-	-	0*	-	0
S64	-	-	-	0.021*	0*	-
S66	-	-	-	0.102*	-	-
S67	-	-	0	0.479*	0.098*	0.470*
S68	-	-	-	3.316**	0.615**	-
V04	-	-	0	-	-	-
V05	-	-	1.777	-	0.302*	-
V11	-	-	0.352	0.682*	0.265*	0.613*
V12	-	-	0.798	-	-	0.403

Table A.5.

Densities (o.m^{-2}) of *Parazoanthus anguicomus* within the Small Isles region sampled between 2012 and 2017. Densities are calculated at the survey box scale, i.e., all counts within each box for each year divided by the viewed area of seafloor within that box that year. Densities are calculated for digital stills images (DSI) and high-definition video (HDV). *Densities calculated from HDV; **Densities calculated from DSI in a year when HDV data are also available. Any empty cell (‘-’) denotes years in which no data are available for that survey box. Densities are reported to three decimal places; a value of ‘0’ indicates that *P. anguicomus* was not observed from the seabed surveyed in that box and year.

Survey Box	2012	2013	2014	2015	2016	2017
B14	-	-	0	-	-	-
B15	-	-	0	-	-	-
S01	0	-	-	-	-	-
S03	0	-	-	-	-	-
S04	0	-	-	0*	-	0*
S05	0	-	-	-	-	0
S06	0.004	-	-	0.015*	0.005*	0.003*
S07	0	-	0	0	0	0
S08	0	-	0	0	0	0
S09	0	-	0	-	-	0*
S10	0	-	0	-	-	0
S11	0	-	0	-	-	-
S12	0	-	0	-	0	0
S14	-	-	0	-	-	-
S15	-	-	-	0*	0	0*
S16	-	0	-	0*	-	-
S17	0.038	-	-	0*	0*	0.002*
S19	-	-	-	0.029	0	0
S23	-	-	-	0	0	0
S40	-	-	-	0**	0	0
S41	0.219	-	-	0.011*	-	0.007*
S46	-	-	-	0.025*	0.001*	0.013*
S51	-	-	-	0*	-	0
S64	-	-	-	0*	0*	-
S66	-	-	-	0.109*	-	-
S67	-	-	0	0.017*	0.002*	0.020*
S68	-	-	-	0.039**	0.030**	-
V04	-	-	0	-	-	-
V05	-	-	0	-	0.002*	-
V11	-	-	0	0*	0*	0*
V12	-	-	0	-	-	0

Table A.6.

Densities (n.m^{-2}) of *Atrina fragilis* within the Small Isles region sampled between 2012 and 2017. Densities are calculated at the survey box scale, i.e., all counts within each box for each year divided by the viewed area of seafloor within that box that year. Densities are calculated for digital stills images (DSI) and high-definition video (HDV). *Densities calculated from HDV; **Densities calculated from DSI in a year when HDV data are also available. Any empty cell ('-') denotes years in which no data are available for that survey box. Densities are reported to three decimal places; a value of '0' indicates that *A. fragilis* was not observed from the seabed surveyed in that box and year.

Survey Box	2012	2013	2014	2015	2016	2017
B14	-	-	0	-	-	-
B15	-	-	0	-	-	-
S01	0	-	-	-	-	-
S03	0.691	-	-	-	-	-
S04	0.075	-	-	0.040*	-	0.025*
S05	0	-	-	-	-	0
S06	0	-	-	0*	0*	0*
S07	0	-	0	0	0	0
S08	0	-	0	0	0	0
S09	0	-	0	-	-	0*
S10	0	-	0	-	-	0
S11	0	-	0	-	-	-
S12	0	-	0	-	0	0
S14	-	-	0	-	-	-
S15	-	-	-	0.012*	0.011	0.007*
S16	-	0	-	0*	-	-
S17	0	-	-	0*	0*	0*
S19	-	-	-	0	0	0
S23	-	-	-	0	0	0
S40	-	-	-	0**	0	0
S41	0	-	-	0*	-	0*
S46	-	-	-	0*	0*	0*
S51	-	-	-	0*	-	0
S64	-	-	-	0*	0*	-
S66	-	-	-	0*	-	-
S67	-	-	0	0*	0*	0*
S68	-	-	-	0**	0**	-
V04	-	-	0	-	-	-
V05	-	-	0	-	0*	-
V11	-	-	0.005	0.001*	0.001*	0*
V12	-	-	0	-	-	0

Table A.7.

Densities (n.m^{-2}) of *Leptometra celtica* within the Small Isles region sampled between 2012 and 2017. Densities are calculated at the survey box scale, i.e., all counts within each box for each year divided by the viewed area of seafloor within that box that year. Densities are calculated for digital stills images (DSI) and high definition video (HDV). *Densities calculated from HDV; **Densities calculated from DSI in a year when HDV data are also available. Any empty cell ('-') denotes years in which no data are available for that survey box. Densities are reported to three decimal places; a value of '0' indicates that *L. celtica* was not observed from the seabed surveyed in that box and year.

Survey Box	2012	2013	2014	2015	2016	2017
B14	-	-	0	-	-	-
B15	-	-	0	-	-	-
S01	0	-	-	-	-	-
S03	0	-	-	-	-	-
S04	0	-	-	0*	-	0*
S05	0	-	-	-	-	0
S06	3.336	-	-	1.217*	0.805*	1.221*
S07	0	-	0	0	0	0
S08	0	-	0	0.006	0	0
S09	0	-	0	-	-	0*
S10	0	-	0	-	-	0
S11	0	-	0	-	-	-
S12	0	-	0	-	0	0
S14	-	-	0.014	-	-	-
S15	-	-	-	0.020*	0	0.001*
S16	-	0	-	0.062*	-	-
S17	1.660	-	-	4.236*	1.640*	0.504*
S19	-	-	-	0	0.044	0
S23	-	-	-	0	0	0
S40	-	-	-	0**	0.156	0.015
S41	0.219	-	-	0.479*	-	0.117*
S46	-	-	-	0.198*	0*	0.129*
S51	-	-	-	0*	-	0
S64	-	-	-	0.090*	0.039*	-
S66	-	-	-	0.514*	-	-
S67	-	-	1.139	0.479*	0.760*	0.10*
S68	-	-	-	0.311**	0**	-
V04	-	-	0	-	-	-
V05	-	-	0	-	0.242*	-
V11	-	-	0	0*	0*	0*
V12	-	-	0	-	-	0

Table A.8

Densities (n.m^{-2}) of *Modiolus modiolus* within the Small Isles region sampled between 2012 and 2017. Densities are calculated at the survey box scale, i.e., all counts within each box for each year divided by the viewed area of seafloor within that box that year. Densities are calculated for digital stills images (DSI) and high definition video (HDV). *Densities calculated from HDV; **Densities calculated from DSI in a year when HDV data are also available. Any empty cell ('-') denotes years in which no data are available for that survey box. Densities are reported to three decimal places; a value of '0' indicates that *M. modiolus* was not observed from the seabed surveyed in that box and year.

Survey Box	2012	2013	2014	2015	2016	2017
B14	-	-	0	-	-	-
B15	-	-	0	-	-	-
S01	0	-	-	-	-	-
S03	0.677	-	-	-	-	-
S04	12.868	-	-	0.525*	-	0*
S05	0	-	-	-	-	0
S06	0	-	-	0*	0*	0*
S07	0	-	0	0	0	0
S08	0	-	0	0	0	0
S09	0	-	0	-	-	0*
S10	0	-	0	-	-	0
S11	0	-	0	-	-	-
S12	0	-	0	-	0	0
S14	-	-	0	-	-	-
S15	-	-	-	0*	0	0*
S16	-	0	-	0*	-	-
S17	0	-	-	0*	0*	0*
S19	-	-	-	0	0	0
S23	-	-	-	0	0	0
S40	-	-	-	0**	0	0
S41	0	-	-	0*	-	0*
S46	-	-	-	0*	0*	0*
S51	-	-	-	0*	-	0
S64	-	-	-	0*	0*	-
S66	-	-	-	0*	-	-
S67	-	-	0	0*	0*	0*
S68	-	-	-	0**	0**	-
V04	-	-	0	-	-	-
V05	-	-	0	-	0*	-
V11	-	-	0	0*	0*	0*
V12	-	-	0	-	-	0

Table A.9.

Densities (n.m^{-2}) of *Arachnanthus sarsi* within the Small Isles region sampled between 2012 and 2017. Densities are calculated at the survey box scale, i.e., all counts within each box for each year divided by the viewed area of seafloor within that box that year. Densities are calculated for digital stills images (DSI) and high definition video (HDV). *Densities calculated from HDV; **Densities calculated from DSI in a year when HDV data are also available. Any empty cell ('-') denotes years in which no data are available for that survey box. Densities are reported to three decimal places; a value of '0' indicates that *A. sarsi* was not observed from the seabed surveyed in that box and year.

Survey Box	2012	2013	2014	2015	2016	2017
B14	-	-	0	-	-	-
B15	-	-	0	-	-	-
S01	0	-	-	-	-	-
S03	0.007	-	-	-	-	-
S04	0	-	-	0*	-	0*
S05	0	-	-	-	-	0
S06	0	-	-	0*	0*	0*
S07	0	-	0	0	0	0
S08	0	-	0	0	0	0
S09	0	-	0	-	-	0*
S10	0	-	0	-	-	0
S11	0	-	0	-	-	-
S12	0	-	0	-	0.005	0
S14	-	-	0	-	-	-
S15	-	-	-	0.002*	0*	0.015*
S16	-	0	-	0*	-	-
S17	0.005	-	-	0*	0*	0.001*
S19	-	-	-	0	0	0
S23	-	-	-	0	0	0
S40	-	-	-	0**	0	0
S41	0	-	-	0*	-	0*
S46	-	-	-	0*	0*	0.002*
S51	-	-	-	0*	-	0
S64	-	-	-	0.004*	0.001*	-
S66	-	-	-	0.001*	-	-
S67	-	-	0	0*	0.001*	0.002*
S68	-	-	-	0**	0**	-
V04	-	-	0	-	-	-
V05	-	-	0	-	0*	-
V11	-	-	0	0.001*	0*	0.006*
V12	-	-	0	-	-	0

Table A.10.

Densities (n.m^{-2}) of *Pachycerianthus multiplicatus* within the Small Isles region sampled between 2012 and 2017. Densities are calculated at the survey box scale, i.e., all counts within each box for each year divided by the viewed area of seafloor within that box that year. Densities are calculated for digital stills images (DSI) and high definition video (HDV). *Densities calculated from HDV; **Densities calculated from DSI in a year when HDV data are also available. Any empty cell ('-') denotes years in which no data are available for that survey box. Densities are reported to three decimal places; a value of '0' indicates that *P. multiplicatus* was not observed from the seabed surveyed in that box and year.

Survey Box	2012	2013	2014	2015	2016	2017
B14	-	-	0	-	-	-
B15	-	-	0	-	-	-
S01	0	-	-	-	-	-
S03	0	-	-	-	-	-
S04	0	-	-	0*	-	0*
S05	0	-	-	-	-	0.009
S06	0.004	-	-	0.001*	0*	0*
S07	0	-	0	0	0	0
S08	0	-	0	0	0	0
S09	0	-	0	-	-	0*
S10	0	-	0	-	-	0.007
S11	0	-	0	-	-	-
S12	0.009	-	0	-	0	0
S14	-	-	0	-	-	-
S15	-	-	-	0*	0	0*
S16	-	0	-	0*	-	-
S17	0	-	-	0*	0.003*	0.002*
S19	-	-	-	0	0	0
S23	-	-	-	0	0	0
S40	-	-	-	0**	0.003	0
S41	0	-	-	0*	-	0*
S46	-	-	-	0*	0*	0.001*
S51	-	-	-	0*	-	0
S64	-	-	-	0.001*	0.003*	-
S66	-	-	-	0*	-	-
S67	-	-	0	0.002*	0.001*	0*
S68	-	-	-	0**	0**	-
V04	-	-	0	-	-	-
V05	-	-	0	-	0*	-
V11	-	-	0	0*	0*	0*
V12	-	-	0	-	-	0

Table A.11.

Mean densities and surface Swept Area Ratio (SAR) by 1 x 1.5 km survey box for the wider *Funiculina quadrangularis* survey conducted in 2017, reported to two decimal places. Where these boxes are located within the larger survey boxes used in the wider multiyear PMF study, the alternative box ID is also given in the 'Associated PMF survey box' column.

FQ survey box ID	Mean Density (n.m^{-2})	Mean surface swept area ratio (SAR)	Associated PMF survey box	Area
F01	0.02	22.00	S05	Sea of Hebrides
F02	0.00	21.85	S07	Sea of Hebrides
F03	0.00	27.41	S08	Sea of Hebrides
F04	0.37	10.90	S10	Sea of Hebrides
F05	0.94	24.14	S12	Sea of Hebrides
F06	0.00	18.32	S15	Sea of Hebrides
F07	0.03	27.77	S19	Sea of Hebrides
F08	0.02	17.26	S23	Sea of Hebrides
F09	0.00	22.34	S40	Sea of Hebrides
F10	0.16	23.42	S51	Sea of Hebrides
F11	0.00	23.36	V12	Sea of Hebrides
F12	0.07	26.62	-	Minch
F13	0.00	46.85	-	Minch
F14	0.29	24.36	-	Minch
F15	0.30	43.78	-	Minch
F16	3.80	2.718	-	Minch
F17	1.00	2.35	-	Minch
F18	0.27	29.10	-	Inner Sound
F19	0.93	21.58	-	Inner Sound
F20	0.63	5.37	-	Inner Sound
F21	0.07	12.86	-	Inner Sound
F22	0.23	2.76	-	Inner Sound
F23	0.30	27.89	-	Inner Sound
F24	0.27	29.38	-	Inner Sound
F25	0.60	29.51	-	Minch
F26	0.63	5.33	-	Inner Sound
F27	0.77	21.58	-	Inner Sound
F28	0.37	33.13	-	Inner Sound
F29	0.00	6.75	-	Minch

Annex B: Research surveys and classifications

The following research survey and classifications tables are referred to within the Main Report by Greathead et al. (2023).

Table B.1.

Surveys conducted and equipment used during the Marine Scotland Small Isles Marine Protected Area survey programme.

Cruise year	Cruise month	Frames Used	Digital still images	High definition video	Lighting
2012	June	Pyramid Lander	Kongsberg 14-408	SUBC 1cam HD mk3	Seatronics SeaLED, MK3
2013	September	Pyramid Lander	Kongsberg 14-408	SUBC 1cam HD mk3	Seatronics SeaLED, MK3
2014	October	Pyramid Lander	Kongsberg 14-408	SUBC 1cam HD mk3	Seatronics SeaLED, MK3
2015	October	Pyramid Lander and square drop frame	Kongsberg 14-408	SUBC 1cam HD mk3	Seatronics SeaLED, MK3
2016	October	Combination Square Frame	Kongsberg 14-408	SUBC 1cam HD mk5	C-Tecnics CT4004 LED lamps
2017	June	Combination Square Frame	Kongsberg 14-408	SUBC 1cam HD mk5	C-Tecnics CT4004 LED lamps

Table B.2.

List of surveys conducted by Marine Scotland within the Small Isles Marine Protected Area (SMI MPA) and surrounding areas. Abbreviations are DSI – digital stills images; HDV – high definition video; BACI – before, after, control, impact; VMS – vessel monitoring system.

Survey	Description
1012a (2012)	Reconnaissance survey using high definition DSI and HDV of the SMI MPA and Wester Ross MPA. Sampling areas were based on previous Marine Scotland dump site monitoring survey data and a survey of the Sound of Canna carried out by NatureScot in 2010. This survey was used as a scoping survey for the method, species present and habitat distribution.
1213a (2013)	Survey was to establish a second “before” time point of a BACI study using DSI and HDV of the SMI MPA and Wester Ross MPA. Only one box in the SMI MPA was surveyed due to vessel inoperability.
1714a (2014)	Survey monitoring sites previously visited in 2012, 2013, 2014 to further consolidate the “before” aspect of the BACI study. Additional boxes identified as potentially containing *Atrina fragilis* were also surveyed.
1515a (2015)	Survey monitored sites previously visited in 2012, 2013, 2014 and 2015 around the SMI MPA. Survey boxes were modified to increase likelihood of encountering target species and habitats. Initial tests of the stereo imagery cameras were carried out in Loch Nevis. A new drop frame was introduced to video rough hard ground unsuitable for the lander frame.
1816a (2016)	Survey of sites previously visited in 2012, 2013, 2014 and 2015 around the SMI MPA, utilising both the lander frame and the drop frame. A secondary objective was to trial the collection of stereo video imagery of *Funiculina quadrangularis* within Loch Nevis.
1517a (2017)	Survey of the waters around Lochinver and North Minch/Skye to collect stereo video imagery of *Funiculina quadrangularis* within survey boxes with different VMS characteristics. Sites previously visited in 2012-2016 around the SMI MPA were also surveyed.
1617a (2017)	Continuation of 1517a where sites previously visited in 2012-2016 around the SMI MPA were surveyed to determine the effect of MPAs and to contribute to a BACI study.
0718a (2018)	Survey repeating SMI MPA drop frame protocols within the SMI MPA and a wider area search for *Atrina fragilis*. The survey sites previously visited in 2012-2017 around the SMI MPA were returned to as further consolidation of the “before” component of a BACI study and as a general time series for target species and habitats within the MPA. *Funiculina quadrangularis* and *Atrina fragilis* were specifically targeted. Data from this survey were not analysed for this report.

Annex C: Methods detail

The following Methods section is referred to within the Main Report by Greathead et al. (2023).

1. Background

The data presented and analysed in the report '*Priority marine feature surveys within the Small Isles MPA and surrounding waters*' were collected as part of a multi-year survey campaign in and around the Small Isles MPA. These surveys were designed to provide the temporal and spatial context for monitoring changes to the marine environment, and to inform the design of appropriate management measures for the Small Isles MPA.

To collect the high-quality imagery data needed, Marine Scotland developed next generation technology to monitor Scotland's Seas. Innovative approaches were employed to provide quality assessment and control for the datasets generated to ensure their robustness. Modelling approaches and statistical tests were also refined and implemented to provide detailed analysis of the datasets.

For future datasets and analyses to be compatible with this time series, sufficient methods detail needs to be recorded to ensure the survey and data analysis approaches used in the report can be replicated. Annex C thus provides a detailed account of the methods used to generate the report.

The full Marine Scotland Small Isles MPA dataset (2012 – 2017) including the data used to create this report is archived and stored in accordance with the Scottish Government's Open Data Strategy. Data relating to Priority Marine Features (PMFs) were provided to the Geodatabase of Marine features adjacent to Scotland (GeMS) curated by NatureScot. Access to the full dataset and associated information can be gained via the Marine Scotland Data Portal; DOI: 10.7489/1614-1.

2. Methods

2.1 Baseline benthic monitoring

Imagery data in the form of DSI and HDV were recorded from inside the areas covered by proposed fisheries management measures, inside the wider SMI MPA, and in areas outside the MPA boundary. Imagery collection from these locations was designed to provide baseline data necessary for the subsequent detection of changes over time between 1) control areas, 2) locations where fishing would continue, and 3) potentially impacted areas, where current fishing activities would be prohibited.

Imagery surveys used lander frames, which were set down on the substrate to collect DSI, and more traditional drop camera frames that drifted over the substrate at a fixed height. Lander frames had the advantage of offering a fixed focal length, producing stable images of a known area, but were not suitable for very rough ground. The lander and drop frames were fitted with a downward pointing DSI camera and an HDV camera. Light was supplied by an array of LED lights positioned around the frame in a way that allowed the seabed to be evenly lit. Upgrades to the system over the study period meant that no single camera specification was used throughout the period (Annex B, Table B.1). Lander frames, when resting on the seabed, provided a fixed focal length of 1.8 m and a standard photographic area for each DSI. The underwater field of view for each DSI was calibrated using a metal grid. An integrated lander and drop frame, the latter drifting approximately 80 cm over the seabed instead of "landing" on it, was used from 2015 onwards to record HD video across harder substrates. The integrated nature of this bespoke frame meant that survey methods could be quickly altered depending on weather and seabed type.

Obtaining HDV using the towed drop frame, although not as stable as the lander and DSI, also increased the area under survey over hard substrates. The drop frame was fitted with two parallel laser beam lines that provided a fixed width for quantifiable analysis. Time, depth, and vessel position were recorded for both types of deployment, lander and drop frame. Annex B, Table B.1 summarises the year and month of each cruise and information on the equipment used for each cruise. DSI and HDV footage were collected from both the lander and drop frame configurations. Due to the differences in operation and variability in focal length, only HDV were analysed in the drop frame configuration and only DSI were analysed in the lander configuration. The HDV collected by lander and DSI collected by drop frame were stored as back-up imagery data for habitat or species identification, if needed.

Depths surveyed ranged from 50 to 250 m (see Annex A, Tables A.1 and A.2). Transects for HDV lasted a minimum of 10 minutes at a target speed of less than 1 knot, with mean tow speeds in the different survey boxes ranging from 0.32 to 0.96 knots (see Annex A, Table A.2). A minimum of three DSI stations were recorded in each transect (start, middle and end), with five DSI captured at each station. Field notes were made during each HDV and DSI camera deployment, noting station and sample metadata and real-time observations of substrate and taxa. Time and position were recorded using GPS TrackMaker (Geo Studio Technology, 2013).

There was limited prior information on the distribution of species and habitats over the entirety of the SMI MPA, thus surveys conducted during 2012 and 2013 served as scoping surveys that informed later refinements to the size and location of survey boxes. The 2012 and 2013 surveys used information provided by NatureScot and seabed morphological data from the ship's sounders considered related to the occurrence of PMF species or habitat components. SDMs produced by Marine Scotland of several PMF species or habitat components enabled the identification of additional survey areas not yet known to contain such records (e.g., Greathead et al., 2015; Stirling et al., 2016), widening the area of survey. Over time this process allowed the delineation of survey boxes that were more likely to include species or habitats listed as PMFs or components of PMFs.

During the study period, some survey boxes were rejected if they did not contain target species or habitat or if they were too difficult or dangerous to survey. This approach resulted in the selection of 25 survey boxes from the original 31 (Fig. C.1a, C.1b). These 25 boxes were designed to capture ten feature groupings relevant to PMFs and were included within different levels of protection (inside/outside proposed measures and outside the SMI MPA) (Table C.1; Annex A, Tables A.1 and A.2). More detailed notes on each research survey are contained in Annex B, Table B.2.

Survey boxes were subdivided by seven primary target features (BS: seapens, including *Virgularia mirabilis* and *Pennatula phosphorea*; BF: burrowed mud with *Funiculina quadrangularis*; MM: *Modiolus modiolus* beds; SC: *Swiftia pallida* communities; LC: *Leptometra celtica*; PA: *Parazoanthus anguicomus*; and AF: *Atrina fragilis*) and three secondary target features (BM: burrowed mud; BP: burrowed mud with *Pachycerianthus multiplicatus*; and AS: *Arachnanthus sarsi*) (Table C.1). In addition to division by target features, survey boxes were also assigned to one of five major habitat types adopted for the purposes of survey design (soft sediment; mixed sediment; mixed sediment with cobbles; mixed sediments with cobbles and boulders; and cobbles, boulders, and bedrock) and one of three site categories (inside/outside measures within the MPA and outside the MPA: see Table C.1). Although it was not possible to find suitable survey boxes for each category, the survey design allows comparison between several possible categories inside/outside proposed measures or the SMI MPA for each target feature.

Table C.1.

Small Isles MPA survey boxes for ten target feature groupings, including: three priority marine feature (PMF) habitats, three biotopes of the burrowed mud PMF habitat, and four shellfish and other invertebrate PMF species (NatureScot, 2020b). Target features were distributed amongst five broad substrate types adopted for the purposes of survey design: soft sediment (SS), mixed sediment (MS), mixed sediment with cobbles (MSC), mixed sediment with cobbles and boulders (MSCB), and bedrock with mixed cobbles and boulders (CBR). Three site categories are identified for the target features: inside/outside management measures within the MPA and outside the MPA.

Feature code	Target feature	Feature type	Substrate type	Survey boxes		
				Inside measures	Outside measures	Outside MPA
BM	Burrowed mud	PMF habitat	SS	S06, S40	S09, S17	S10
BS	Seapens and burrowing megafauna in circalittoral fine mud	PMF biotope of BM habitat	SS	S06, S40	S05, S07, S08, S09, S11, S51	S10, S64, S23, V11
BF	Burrowed mud with Tall seapen (*Funiculina quadrangularis*)	PMF biotope of BM habitat	SS	S19, S40	S05, S07, S08, S11, S51	S10, S12, S23
BP	Burrowed mud with Fireworks anemone (*Pachycerianthus multiplicatus*)	PMF biotope of BM habitat	SS/MS	S06, S15, S40, S67	S05, S17	S10, S12, S64
MM	Horse mussel (*Modiolus modiolus*) beds	PMF habitat	MSC	S03, S04		
SC	Northern seafan (*Swiftia pallida*) and sponge communities, (occasionally with *Caryophyllia smithii*)	PMF habitat	MSCB/ CBR	S16, S41, S46, S68 V05	S17, S66	V11
AS	*Arachnanthus sarsi*	PMF species	MS	S03, S15, S67	S17	S12, S64, V11
PA	*Parazoanthus anguicomus*	PMF species	MSCB/ CBR	S06, S41, S46, S68	S17, S66	
LC	*Leptometra celtica* aggregations (on mixed sediment or Rock)	PMF species	MS/ MSC or MSCB/ CBR	S06, S40, S46, S67	S17, S66	S64
AF	*Atrina fragilis*	PMF species	MSC	S03, S04, S15		V11

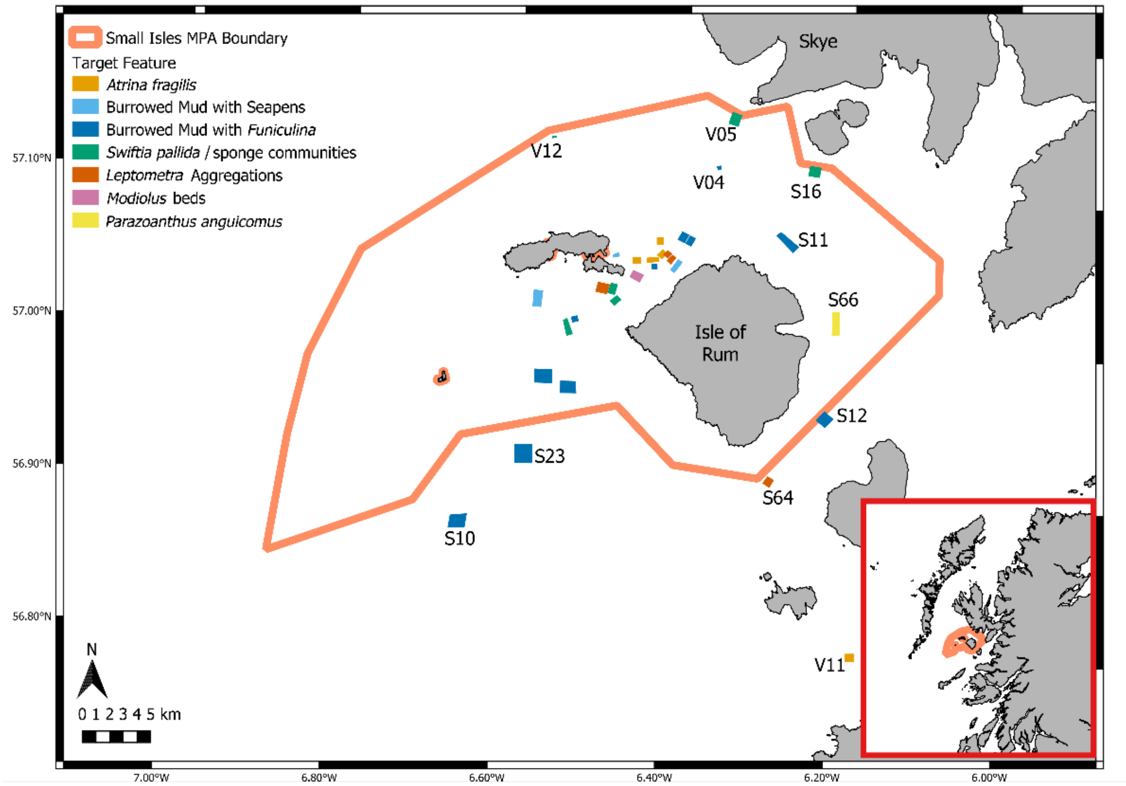

Figure C.1a. Small Isles (SMI) MPA survey boxes with their target features. A detailed view of the survey boxes in the Sound of Canna is provided in Fig. C.1b.

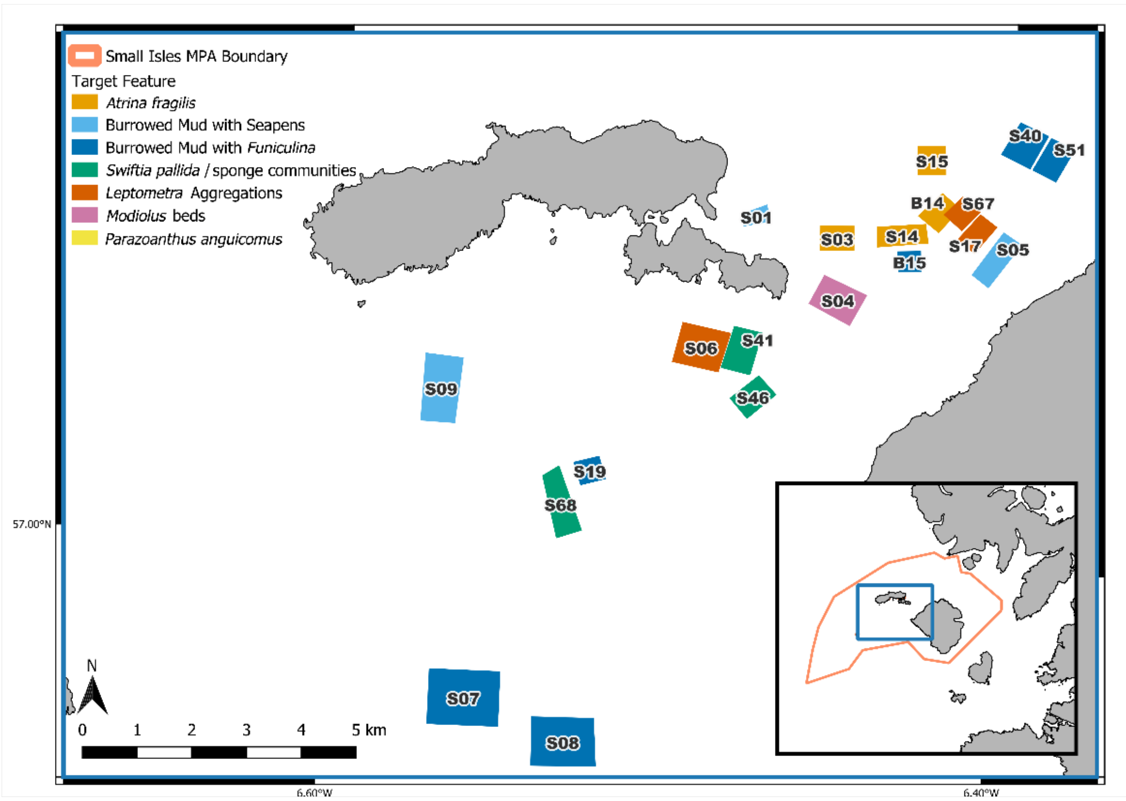

Figure C.1b. Small Isles (SMI) MPA survey boxes within the Sound of Canna.

2.1.1 Species identification

Species identification was standardised using identification keys based on existing taxonomic works (Hayward and Ryland, 1990; Manuel, 1988) and modified to emphasise identification features that could be distinguished from digital formats. Electronic annotation (within Photoshop Elements 12: Adobe Inc., 2013) was used to ensure that each DSI could be re-analysed to confirm identification, where necessary. All target species identified in the video transects were assigned a time code so that they could be easily found again for identification verification. As a rule, only features identifiable at a size of 10 mm or more were included in the analysis. Where some species were identifiable to genus level at smaller sizes (e.g., *Caryophyllia* sp.), such species were classified where there was a high confidence in being able to consistently identify the feature.

2.1.1.1 Digital still images (DSI) and the identification of taxa

The DSI were analysed using an UltraHD monitor (Resolution: 3840 x 2160) in conjunction with Photoshop Elements image editing software (version 12.0; Adobe Inc., 2013), which allowed the images to be annotated with a scaled cursor. Additionally, a 10 x 10 grid overlay (available in the Photoshop Elements package: version 12.0; Adobe Inc., 2013) was used to estimate the percentage of each DSI that was unusable (due to silt, poor light etc.) and the percentage cover of encrusting species. The abundance (n) of all visible benthic megafaunal invertebrates down to 10 mm, identified to the lowest taxonomic level possible, was recorded for each DSI. Distinct species identifiable to at least genus level were also counted (e.g., *Caryophyllia* sp., probably *C. smithii*[1]). Due to the difficulty of identifying hydroids and bryozoans to species level from the photographic images, all aggregations of erect bryozoan and hydroid species were assessed collectively as “faunal turfs” (Boulcott et al., 2014). These were quantified as a percentage of the visible area of the quadrat, determined by counting the number of squares of the 10 x 10 grid overlay that were occupied by faunal turfs (FT). Unidentifiable encrusting fauna, such as encrusting sponges and ascidians, were combined into one category “unidentified encrusting fauna” (UEnF), where each individual colony with a diameter over 10 mm was counted. *Parazoanthus anguicomus* was enumerated using several techniques: 1) counts of individuals visible in the DSI (n); 2) percentage cover derived as for faunal turfs (%); and 3) counts of occurrences, i.e., spatially distinct groupings of *P. anguicomus* (o). The latter technique for DSI was the most comparable with how

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[1] '*Caryophyllia smithii*' Stokes & Broderip, 1828 is an alternate representation for this species; '*Caryophyllia (Caryophyllia) smithii*' Stokes & Broderip 1828 is the accepted name in the World Register of Marine Species.

P. anguicomus was quantified from HDV and so was used to generate the results in this report. The abundance data generated using the other two techniques are available in the full dataset.

The biotopes for Northern sea fan and sponge communities PMF habitat include a range of components including *C. smithii*, *S. pallida*, mixed turf of hydroids and large ascidians, and deep sponge communities (NatureScot 2020). Counts for some of these biotope components were also presented as aggregated values, to provide information on the abundance of aggregations. For *C. smithii*, this taxon was recorded as present as an aggregation (CSAgg) when there were more than ten *C. smithii* in one DSI. Unidentifiable large erect branching or globular species of sponges (e.g., *Stelligera stuposa*, *Raspailia hispida*) and ascidians (e.g., *Ascidia mentula* and *Diazona violacea*) were counted separately (ULSp and ULAs respectively) and combined into one category (ULSpAs). Large goblet-shaped sponges (e.g., *Phakellia ventilabrum* and *Axinella infundibuliformis*) were recorded as UGbSp due to the difficulty in its identification to species level. Therefore *S. pallida* was recorded 1) as counts of individuals and 2) as a community (SC) when there were *S. pallida* and ULSpAs and/or UGbSp and/or CSAgg in the same DSI. Complete records of CSAgg, ULSp, ULAs, ULSpAs and UGbSp are available in the full dataset, should further analysis be required for these groups, but are not included in this report.

All burrows ≥ 10 mm were counted as a component feature of the burrowed mud (BM) PMF habitat (NatureScot, 2020). This size is appropriate as the burrowing crustaceans that are characteristic of this habitat tend to construct burrows that are larger than 10 mm in diameter. There is not an agreed standard for the density of burrows and seapens do not necessarily need to be observed for the burrowed mud PMF habitat to be considered present (Scottish Natural Heritage, 2014; Benson et al. 2021). Burrowed mud with seapens (BS) (a biotope of the burrowed mud PMF habitat – NatureScot, 2020) was considered present when one or more seapens and more than ten burrows were in the same DSI. A single DSI was considered a reasonable frame of reference, as the viewed area from each DSI was similar across boxes and years. In the 8137 DSI where less than 25% of the image was obscured, the mean viewed area was 1.62 m^2, with a standard deviation of 0.19 m^2 and median of 1.30 m^2. Further analyses of burrow density were not conducted for this report, although the data are included in the full dataset.

Each DSI was assigned a community code and a complex sediment code, which are retained in the full dataset but are not analysed in this report. To aid the stratification of survey boxes, DSI from each survey box were also assigned to one of five simplified informal substrate codes: soft sediment (SS); mixed sediment (MS); mixed sediment with cobbles (MSC); mixed sediment with cobbles and boulders (MSCB); and cobbles and boulders with rocky outcrops (CBR) (see Annex A, Table A1). The available data for each DSI therefore includes the abundance of all species or features recorded, image depth (m), complex substrate type, and community type.

2.1.1.2 High definition video (HDV) and the identification of taxa

HD video transects from the drop frame were analysed using an UltraHD monitor (Resolution: 3840 x 2160) at one minute intervals within a suitable video player (e.g., Media Player Classic-Home Cinema). For each 1-minute segment of video, only the abundance of target features observed within the laser tramlines were recorded, applying the same categorisations used for the DSI. Embedded HDV file time codes were extracted and superimposed onto the video using Visual AVCHD Time Stamp (version 3.5.0; DTS8888, 2017). The times of any unusable sections of the transect were noted and removed from the GPS log, allowing total viewed area (m^2) to be estimated for each transect by multiplying GPS-derived track length by the distance between the laser lines. Other species or aggregations associated with the target features, such as aggregations of *Caryophyllia* sp., aggregations of large ascidians and sponges and burrows ≥ 10 mm diameter, were recorded as present for each 1-minute segment of video they occurred in, following the same rules for feature definition applied to DSI. Complete records of ULSp, ULAs, ULSpAs, UGbSp and BS are available in the full dataset but are not presented here.

Total abundance for each target species or feature was calculated from 1-minute video segments. As for DSI data, video segments were assigned a community code and a complex sediment code, which were retained in the underlying dataset but not analysed in this report. The video segments from each survey box were also assigned to one of five informal substrate codes: SS; MS; MSC; MSCB; and CBR (see Annex A, Table A.2), as previously noted. The available data for each video segment thereby includes the abundance of all species or features recorded, segment depth (m), complex substrate type, and community type.

2.1.2 Estimating species density

Two different survey methods were employed over the course of the study: a lander frame designed to land on softer sediments and record a calibrated DSI quadrat with a digital still camera; and a drop frame designed to record HDV from a frame that remains above harder substrates. DSI quadrats were produced from both the lander and drop frame configurations. Due to their fixed focal length and angle, DSI quadrats from the lander frame produced a known “area under view” and were preferentially used in the survey of soft sediment habitats. The drop frame was used for surveying harder substrates where high levels of ruggedness precluded landing a frame. The DSI area-under-view from the drop frame was not quantifiable and, therefore, these images were not used for analysis, but rather were used to verify species identification from the drop frame video transects. It should be noted that lander surveys in 2012, 2014 and 2015 also included areas of harder substrate, which from 2015 onwards were surveyed using HDV obtained from the drop frame. More information on the equipment used to collect imagery data across years is provided in Annex B, Table B.1; details on the imagery data types used to determine mean abundances for the different target species are provided in Annex A, Tables A.3 – A.10.

2.1.2.1 Lander surveys

To facilitate more accurate analyses for each target feature, the data were truncated to only include DSI quadrats with < 25% of the image obscured by, for example, sediment rising in the water column. This resulted in 1,237 of 9,374 records being removed, leaving 8,137 DSI. The DSI quadrats where there was the highest rate of images being obscured typically occurred in areas with soft sediment, particularly burrowed mud habitat containing *F. quadrangularis*. Most of the obscured DSI occurred during the 2017 survey. The cut-off for obscured images was chosen after analysis of associated HDV footage and DSI where *F. quadrangularis* could be clearly seen in lower levels of disturbance.

The data obtained from the Lander Survey DSI were:

- Total number of DSI in each box, minus any that were more than 75% obscured
- Abundance for each target species or feature in each DSI and the total abundance of each target species or feature in each survey box
- Total number of DSI in each box that contain each target species or feature
- Area of each DSI from calibration calculations (m^2)
- Obscured area of each DSI (%)
- Viewed area of each DSI (m^2)
- Density of each target species in each DSI ($n.m^{-2}$) [for *P. anguicomus* this is the number of occurrences - $o.m^{-2}$]
- Density of the eight target species calculated at the survey box-level using a custom R-script (version 4.1.3; R Development Core Team, 2022), based on abundance within individual DSI and the total viewed area of seabed within the survey box ($n.m^{-2}$) [for *P. anguicomus* this is the number of occurrences - $o.m^{-2}$]

- Total count for each target species or feature in each year and box combination
- Percentage of DSI containing burrows and aggregated taxa (%).

2.1.2.2 Drop frame surveys

The HDV data were used to calculate densities of target species per tow on hard substrata. The data obtained from the Drop Frame HDV surveys were:

- Number of drop frame tows per survey box
- Abundance of each target species or feature for each HDV tow in each survey box
- Total abundance of each target species or feature in each survey box
- Viewed area of each HDV tow and total viewed area for each survey box (m^2)
- Density of each target species or feature in each HDV tow ($n.m^{-2}$) [for *P. anguicomus* this is the number of occurrences - $o.m^{-2}$]
- Density of the eight target species calculated at the survey box-level using a custom R-script (version 4.1.3; R Development Core Team, 2022), based on abundance within individual HDV tows and the total viewed area of seabed within the survey box ($n.m^{-2}$) [for *P. anguicomus* this is the number of occurrences - $o.m^{-2}$]
- Total count of each target species or feature in each year and box combination.

2.1.2.3 Box-level density case study for *Funiculina quadrangularis* and *Swiftia pallida* drop frame surveys

To investigate whether survey box-level changes in density over time could be tested for using statistical analysis, a case study was produced using *F. quadrangularis* and *S. pallida* abundance information from a subset of survey boxes and years. The main results of this case study are presented under '3.1 Baseline Benthic Monitoring' of the main report; the full case study, including methods, is available in Annex D.

2.2 Assessing the impact of fishing activity on *Funiculina quadrangularis* abundance

To assess the possible impact of fishing on the distribution of *F. quadrangularis*, a wider survey across three adjoining areas, the Sea of the Hebrides, the Inner Sound, and the Minch was conducted in 2017. The survey areas were known to contain suitable substrates for *F. quadrangularis,* as indicated by SDMs (Greathead et al.,

2015) and confirmed during a subsequent Marine Scotland survey conducted in 2014. The survey areas were also known to vary in the intensity to which they were exposed to bottom-contacting towed gear.

To assess the effect of fishing intensity on the abundance of *F. quadrangularis*, study boxes across the wider West coast of Scotland were surveyed during September 2017 on the MRV *Alba na Mara* (Fig. C.2). The 29 survey boxes with available VMS data were used for further analysis, with each study box being approximately 1.5 x 1 km in size. The survey adopted the lander methodology described earlier, using DSI quadrats to determine counts of *F. quadrangularis*. Within each survey box, a minimum of four transect tows of the lander were made. Conditions permitting, each tow would comprise of approximately eight to ten stations of five DSI quadrat images. Quadrats within each station were placed according to the prevailing drift of the vessel and were all within 15 m of each other. This protocol aimed to collect a total of 30-50 stations (150 – 250 DSI quadrats) of known area in each box.

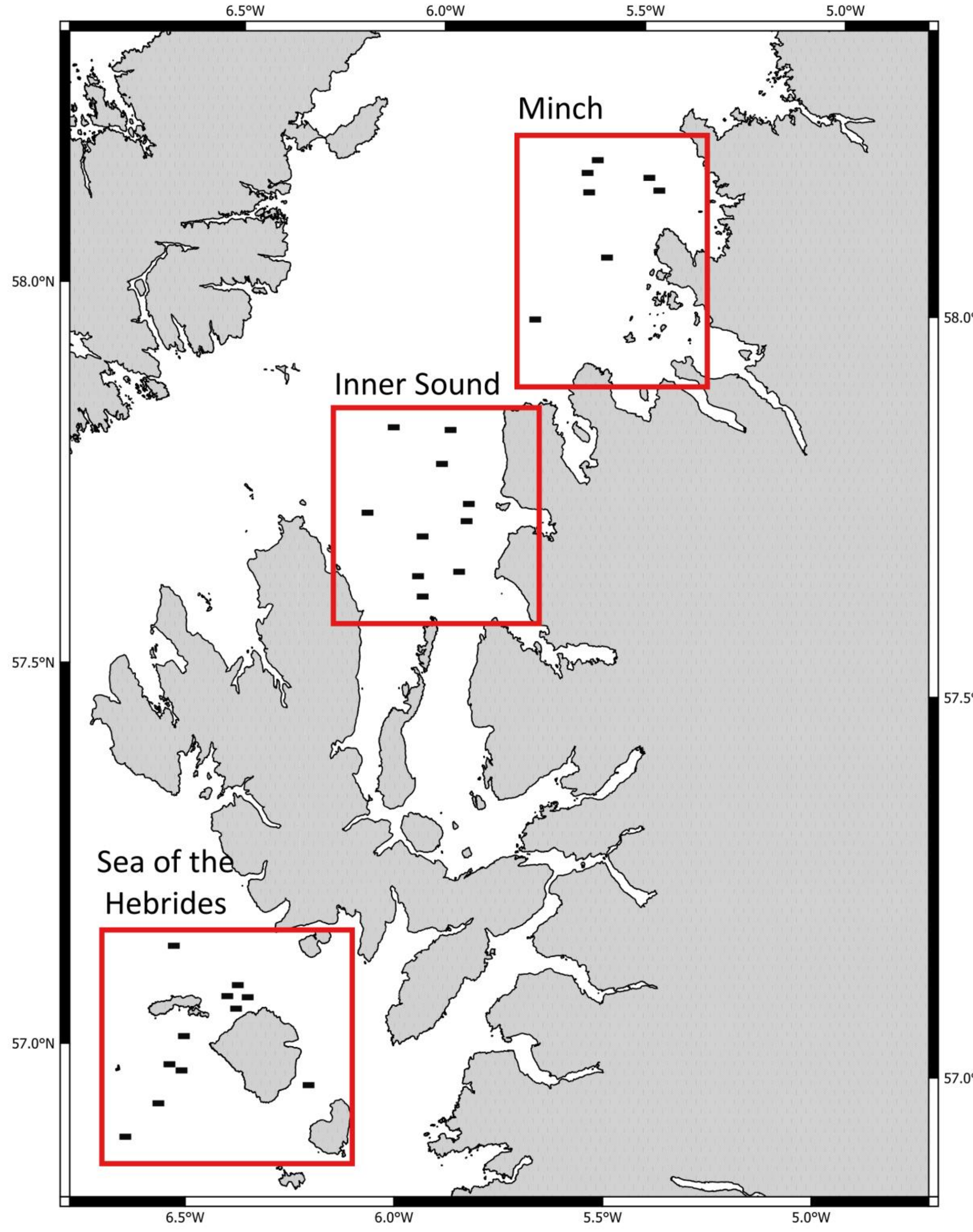

Figure C.2. Sea of the Hebrides, Inner Sound and Minch locations (red rectangles) and their survey boxes (solid, black rectangles) surveyed in 2017 to assess the impact of bottom-contacting towed gear on the distribution of *Funiculina quadrangularis*.

2.2.1 Deriving fishing intensity from Vessel Monitoring System data

A spatially resolved index of fishing intensity for bottom-contacting towed gear was derived from vessel monitoring system (VMS) data. Although VMS data presented the best available fishing data for the study period, it should be noted that there is no data requirement to collect VMS data for vessels shorter than 12 m in length and it is therefore an incomplete record. Fishing data for the years 2014 – 2016, the three years preceding the *F. quadrangularis* seafloor survey, were downloaded from the International Council for the Exploration of the Sea (ICES) website (ICES, 2018) on 9 March 2020. These layers were derived using a process based on the BENTHIS research project, now run by the ICES datacentre, which estimates the swept area of bottom-contacting towed gear using fishing hours, average speed and a relationship between vessel size and gear width (Eigaard et al., 2016). Each layer provides an estimate of the aggregate surface abrasion intensity across all towed-gear métiers[2] expressed as swept area ratio (SAR: swept area divided by the surface area of the grid cell) and is assigned to a 0.05 x 0.05 degree grid, about 15 km² at 60 °N latitude, using the c-square approach (Rees, 2003). The resolution of the c-square is set according to the minimum poling interval between VMS positions, which is currently 2 hrs.

Processing of the layers was done using QGIS (version 3.12.0; QGIS.org, 2020). Shapefiles were clipped to the area of interest (55.3 °N, 7.7 °W: 58.7 °N, 5.0 °W) and merged with the ‘merge vector layers’ algorithm. This combines multiple vector layers of the same geometry type into a single shapefile. The aggregate SAR layer for the 2014-2016 period used in subsequent analyses was then generated using the ‘Dissolve with stats’ plugin (version 0.6; Pierson, 2019) to group geometries by c-square and calculate the sum of the SAR field. C-square SARs are provided for both the seabed surface and subsurface; surface abrasion is defined as disturbance of surface features only (top 2 cm of sediment), and subsurface abrasion is penetration and/or disturbance of the sediment deeper than the surface of the seabed (≥ 2 cm). Due to *F. quadrangularis* being situated with three quarters of its body protruding above the sediment surface (Ager, 2003), and the nature of its interaction with towed fishing gear, only surface abrasion was included in further analyses.

[2] A ‘métier’ is a fishing activity targeting certain species by a certain gear in a certain area

2.2.2 Environmental data

Environmental variables known to affect the distribution and extent of *F. quadrangularis* (Greathead et al., 2015) were included in subsequent analyses. Environmental data layers were constructed in ArcMap (version 10.0, ESRI, CA, USA) for bathymetry (SeaZone, 2013), percentage mud, sand and gravel, and salinity (Table C.2). The bathymetry layer was then used to produce two additional environmental layers relating to the seabed, slope, and curvature, using the spatial analyst and the benthic terrain model tools in ArcGIS.

Sediment data were derived from grab samples collected within the study area by Marine Scotland and the British Geological Survey (BGS) (British Geological Survey, 2013). Three distinct rasterized sediment layers for percentage mud, sand, and gravel were constructed with the inverse distance weighting tool in ArcGIS, using the coastline as a barrier. The rock/hard substrate layer created for the BGS (Gafeira et al., 2010), was used to exclude substrates such as rock, boulder, or cobbles that are considered unsuitable substrates for seapens (Greathead et al., 2015).

Table C.2.

Environmental variables considered in the *Funiculina quadrangularis* analysis

Variable	Description	Source / Derivation
Depth	High resolution (25 m^2) digital terrain model of the subsea surface iteratively synthesized using high resolution multibeam bathymetry surveys.	SeaZone, 2013. Bathymetric Data historically supplied under licence 122006.004; data management tools in ArcMap 10.0.
Slope and curvature	Derived from depth at the final resolution.	Depth and spatial analyst tools in ArcMap 10.0.
Sediment: mud (%), sand (%), and gravel (%)	Sediment layers obtained after interpolation with inverse distance weighting, using the coastline as a barrier, grabs data from Marine Scotland and BGS.	Marine Scotland and BGS grabs; spatial analyst tools in ArcMap 10.0.
Salinity near bottom	Minimum values calculated for the period 1988–2004 using R and resampled to the final resolution using the bilinear resampling algorithm tool.	POLCOMS model (Holt et al., 2005); R package "ncdf" (Pierce, 2011); and data management tools in ArcMap 10.0.

2.2.3 Statistical analyses

The effects of fishing intensity, depth, sediment, salinity, slope and curvature, and study area (Sea of the Hebrides, the Inner Sound, and the Minch) on *F. quadrangularis* counts (FQ count) within each station were examined within a Generalised linear mixed model (GLMM) framework within the R package, lme4 (Bates et al., 2015). The data were centred relative to the median before analysis. Preliminary modelling indicated that little between-quadrat heterogeneity existed in the covariates within stations, favouring the use of station level data due to the low number of counts per quadrat. The full fixed effect model structure was:

$\text{FQ count}_{[\text{Station}]}$ ~ area + depth + fishing intensity + % mud + % gravel + salinity + slope + curvature

Survey box and station were included as random effects (McCulloch et al., 2008). Random-effects structures were compared with more parsimonious models within a GLMM framework that excluded the random effect component. Counts were modelled using a Poisson probability distribution and a log link function. Correlation between the explanatory variables was checked for collinearity using Spearman rank correlations and Variance Inflation Factors (Zuur et al., 2009). The full model was then simplified in a backwards stepwise procedure with model selection based on Akaike's Information Criteria (Akaike, 1974). The relative importance of each variable was assessed by a likelihood ratio test. Residual plots were examined for evidence of lack of fit or departures from the modelling assumptions. All statistical analyses were done in R (version 3.6.3; R Development Core Team, 2020).

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Annex D: Case study of density variation over time for the Tall seapen (*Funiculina quadrangularis*) and Northern seafan (*Swiftia pallida*)

The following case study is referred to within the Main Report by Greathead et al. (2023). Access to the full dataset and associated information can be gained via the Marine Scotland Data Portal; DOI: 10.7489/1614-1.

Key messages

- Assessing variation in species density is important as it allows us to determine if apparent changes in the density of species over time or space are significant at the box level.
- Significant reductions in Tall seapen (*Funiculina quadrangularis*) densities were detected, with decreases in density between 2014 and subsequent years for two survey boxes (S07 and S08).
- No significant changes in Northern seafan (*Swiftia pallida*) densities were detected between 2015, 2015 and 2017 for two survey boxes (S06 and S67).
- Whilst there are differences in where samples were taken within boxes between years, the results presented indicate that the reductions in density detected for *F. quadrangularis* are real.
- Significant changes in *S. pallida* density over time were not expected, however it is possible that significant change was not detected because of the survey design.
- Challenges in linking observed decreases in *F. quadrangularis* density to fishing activity suggest that greater spatial and temporal resolution of fishing pressure data is needed to assess the impacts of fishing activity.
- Where species such as *S. pallida* are reliant on habitats with patchy distributions that are difficult to survey repeatedly over time, the resolution of the data collected may not be sufficient to detect a change or deterioration in status over time or space, thus sentinel hypothesis-based monitoring may be less effective.

1. Rationale

Calculating species density at the box level provides a single value of density that allows general comparisons to be made for the same box across years to describe change over time. This approach also enables general comparisons to be made between different boxes within the same year to describe change across space. This approach does not provide a value of density variation within individual boxes and effectively masks variation occurring at smaller spatial scales. Many species have patchy distributions on the seafloor related to the availability of suitable habitat and potentially to the spatial distribution of disturbance from activities such as fishing. Whilst monitoring and environmental management decisions may be taken at the box level or higher, the processes determining the spatial distribution of species will occur across a range of scales, including sub-box spatial scales.

Understanding the scale of variation within survey boxes provides important context for the suitability of using the box level as a monitoring unit. This information also guides the survey design, to ensure that within-box spatial patterns in species density are consistently surveyed across years and that subsequently any changes in density detected over time reflect real changes, not artefacts of the survey approach. Being able to detect significant change in spatial and temporal patterns of species density is key to being able to effectively monitor for change in the condition of the Small Isles MPA (SMI MPA) protected features.

2. Methods

2.1 Species, location, and year selections

This case study uses density information for the Tall sea pen (*Funiculina quadrangularis*) and the Northern seafan (*Swiftia pallida*) from a sub-set of boxes and years within the SMI MPA to statistically test for significant changes in species density across years.

Species and box selection was primarily based on having sufficient density data over multiple years but also to test the approach for two species occurring in different habitats and surveyed using differed methods. *Funiculina quadrangularis* is a soft-sediment dwelling species, where density information was collected using digital still images (DSI). *Swiftia pallida* colonises hard substrate habitat, where density information was collected using DSI and high definition videos (HDV). See Annex C for full details on the methods used to generate density data.

Two survey boxes were selected for investigation for each species. The DSI tows for each year within S07 and S08 were mapped and overlain by the abundance of *F. quadrangularis* observed in each DSI, and the HDV tows for each year within S06 and S67 were mapped and overlain by the abundance of *S. pallida* observed in each HDV tow. These maps provide a visual representation of observed within-box variation in density over space and time for the two species, and differences in within-box sampling locations between years.

2.2 Statistical tests

Initially the number of *F. quadrangularis* was separately modelled for box S07 and S08 as a function of year as a categorical variable, using a Poisson generalised linear model (GLM) with a log link function and log of viewed area included as an offset. The DHARMa package (Hartig, 2020) was used to check the residuals for violations of model assumptions including dispersion. The DHARMa package uses a simulation approach to produce model residuals that can be easily checked (Hartig, 2020). Patterns in the residuals were checked using qq-plots, residuals against fitted values and residuals against year. The residual plots did not suggest the assumptions of a Poisson model were violated for the *F. quadrangularis* analysis. Spatial autocorrelation for the *F. quadrangularis* analysis was checked using Morans I test. The same approach was taken for *S. pallida* in boxes S06 and S67, however the diagnostic plots indicated that the data were over-dispersed and therefore the assumptions of a Poisson model were violated. A negative binomial GLM was fitted for *S. pallida*, which greatly improved the residual diagnostic plots, although the small sample size made it difficult to assess violations. Spatial autocorrelation could not be checked for the *S. pallida* data as the exact locations of observations along HDV transect lines were unknown.

Fitted models with the ‘Year’ term were compared to a model that only included the offset of the viewed area term and an intercept, using AIC and an ANOVA with Chi-squared test for each box individually. For *F. quadrangularis*, the model was also fitted with data from both boxes included in a single model with box and interaction between box and year added as explanatory variables. A post hoc pairwise comparison between means was also conducted for *F. quadrangularis* using Tukey comparisons with the multicomp package (Hothorn et al., 2008) to test for differences in densities between years.

3. Results

3.1 *Funiculina quadrangularis*

There were more than 100 DSI collected for each year and box combination, apart from in 2017 when only 58 DSI were available (Table D.1). The proportion of DSI that contained *F. quadrangularis* was small, particularly after 2014. Within S07, *F. quadrangularis* was only observed in one DSI in each subsequent year and was not observed at all in S08 after 2015.

For each year in both boxes, DSI tows were spread throughout the box with some variation in tow orientation between years. The direction of tows varied between years depending on the direction of the current. As a result, there is some spatial variability in DSI density within individual boxes (Fig. D.1).

Table D.1.

The total number of digital still images (DSI) available for each box and year combination and in brackets, the number of DSI where *Funiculina quadrangularis* was observed.

Survey Box	2012	2014	2015	2016	2017
S07	251 (14)	139 (12)	252 (1)	250 (1)	124 (1)
S08	193 (11)	146 (16)	255 (2)	249 (0)	58 (0)

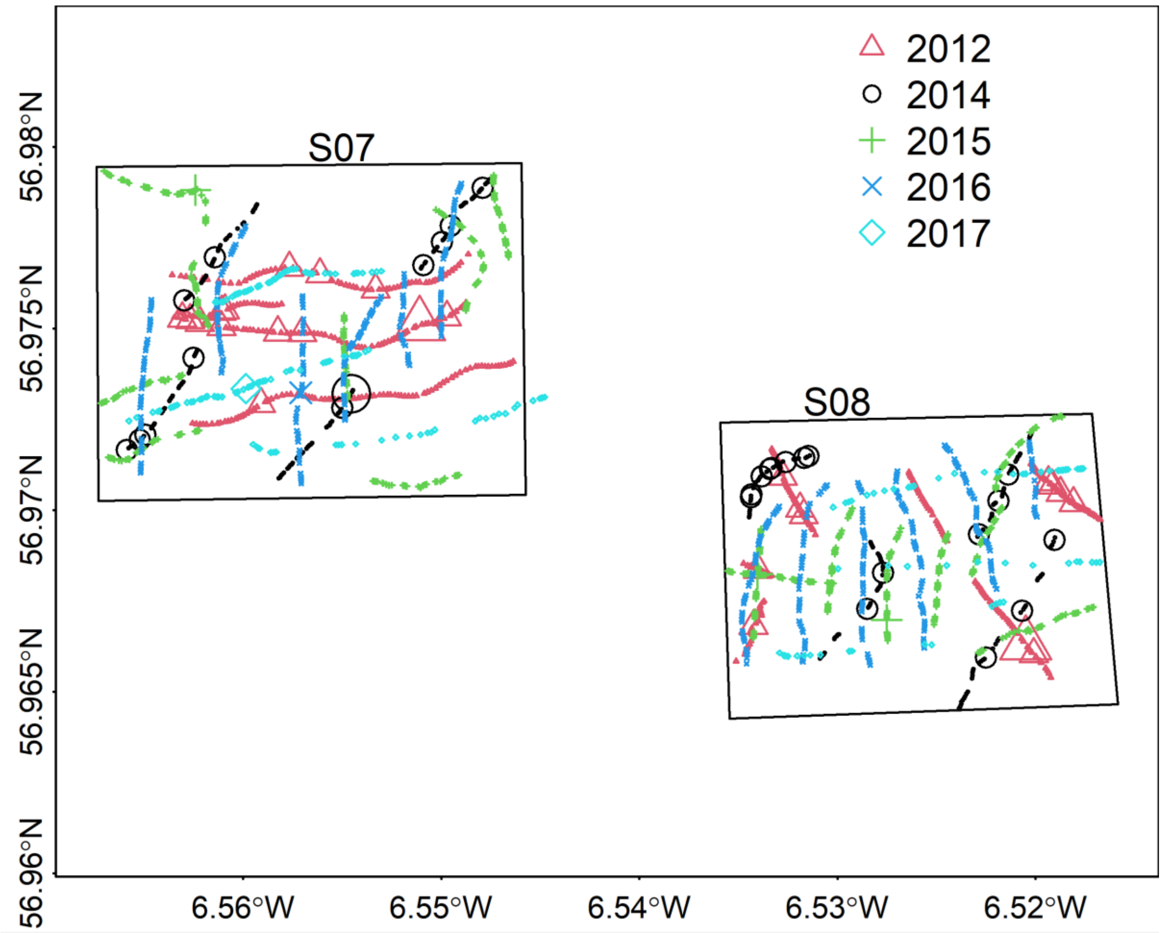

Figure D.1. The location of digital still images (DSI) in survey boxes S07 and S08 collected in different years. The size of symbol reflects the number of *Funiculina quadrangularis* observed.

‘Year’ was a significant term in the model for S07 (Deviance = 44.92, df = 4, $p < 0.001$) and for S08 (Deviance = 53.18, df = 4, $p < 0.001$) (Table D.2, Fig. D.2). Adding the ‘Year’ term to models for box S07 and S08 reduced the AIC from 289.51 to 252.59, and from 273.41 to 228.22 respectively. For both boxes the residual plots and Morans I test did not indicate any violation of model assumptions. As *F. quadrangularis* was not observed in 2016 or 2017 in Box S08, estimated standard errors and Z-values could not be reliably estimated.

Table D.2.

The results of Poisson generalised linear models for *Funiculina quadrangularis* in boxes S07 and S08. Estimated values are on the log link scale. Significance is indicated by asterisks: *** $p < 0.001$; ** $0.001 \le p < 0.01$; * $0.01 \le p < 0.05$. The year 2014 was used as the reference level for both survey boxes. NA: no individuals were observed in these years therefore standard errors and Z-values could not be reliably estimated.

S07	Estimate	Standard Error	Z-value	S08	Estimate	Standard Error	Z-value
2014	-2.6011	0.2774	-9.378	2014	-2.4430	0.2500	-9.772
2012	-0.2468	0.3789	-0.651	2012	-0.3653	0.3819	-0.956
2015	-3.1874	1.0377	-3.072**	2015	-2.6670	0.7500	-3.556***
2016	-3.3422	1.0377	-3.221**	2016	NA	NA	NA
2017	-2.4527	1.0377	-2.364*	2017	NA	NA	NA

The zero counts in 2016 and 2017 for Box S08 prevented post-hoc testing for differences between years when considering the two survey boxes separately. Models including all the data from both boxes, with an interaction term between box and year, along with year and an offset for viewed area, indicated that box and the box and year interaction were not significant. Therefore, to allow for post-hoc testing of the differences between years, the model was fitted to data from both boxes with survey year and an offset of area included as explanatory variables. The post hoc pairwise comparison identified significant differences in the densities of *F. quadrangularis* between years. Densities in 2012 were significantly higher than densities in 2015 and 2016, whilst densities in 2014 were significantly higher than densities in 2015, 2016 and 2017 (Table D.3).

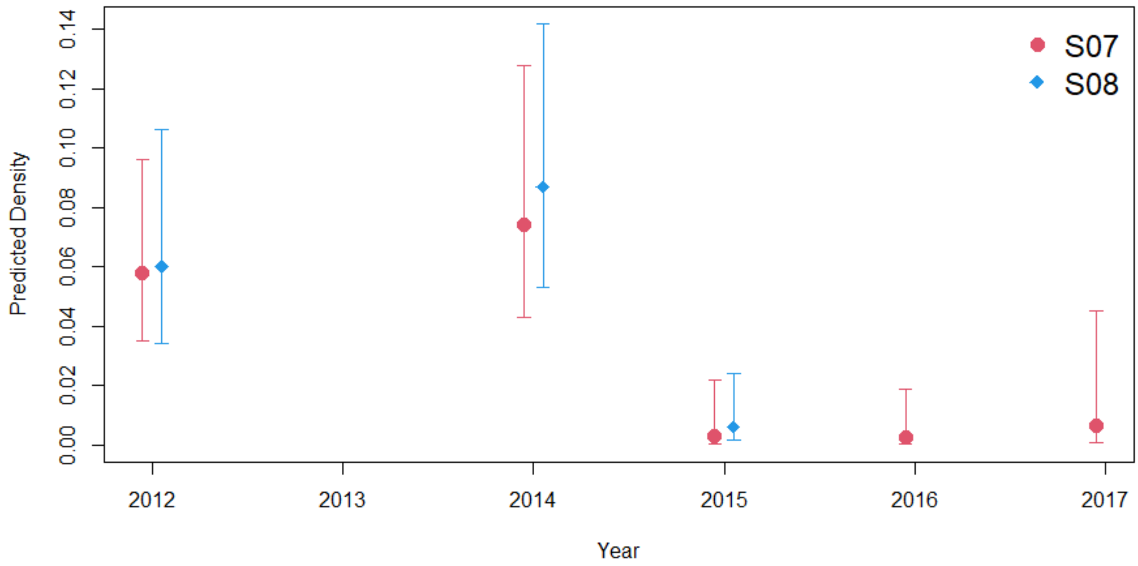

Figure D.2. The estimated density (counts per m^2) of *Funiculina quadrangularis* in survey boxes S07 (blue diamonds) and S08 (red circles) predicted by the model with ±1 one standard error (error bars). Predictions were only made for years where data were available. Predictions were omitted for S08 in 2016 and 2017 as standard errors could not be estimated reliably. Neither survey box was visited in 2013.

Table D.3.

The results of post-hoc pair wise comparisons of *Funiculina quadrangularis.* Significance levels: *** $p < 0.001$; ** $0.001 \le p < 0.01$; *$0.01 \le p < 0.05$; · $0.05 \le p < 0.1$; and - $p > 0.1$.

	2012	2014	2015	2016
2014	-			
2015	***	***		
2016	**	***	-	
2017	·	*	-	-

3.2 *Swiftia pallida*

There were four or more HDV tows collected for each year and box combination, except for S67 in 2015 when only two HDV tows were conducted (Table D.4). The proportion of HDV tows that contained *S. pallida* was generally high across years in both boxes. For each year in both boxes, HDV tows were spread throughout the box with some variation in tow orientation between years. The direction tows were conducted in varied between years depending on the direction of the current.

As a result, there is some spatial variability in HDV tow density within individual boxes (Fig. D.3).

Table D.4.

The total number of high definition video (HDV) tows available for each box and year combination and in brackets, the number of HDV tows where *Swiftia pallida* was observed.

Survey Box	2015	2016	2017
S06	10 (9)	8 (8)	4 (4)
S67	2 (1)	7 (3)	7 (4)

The model indicated that there were no significant differences in densities of *S. pallida* between years (Fig. D.4, Table D.5). ‘Year’ was not a significant term in the model for S06 (LR = 2.899, p = 0.235) or for S67 (LR = 0.807, p = 0.668). Adding the ‘Year’ term to models for box S06 and S67 increased the AIC from 243.26 to 244.36, and from 112.38 to 115.57 respectively. The residual diagnostics did not provide evidence of violations of model assumptions; however, this could partly be due to small sample sizes.

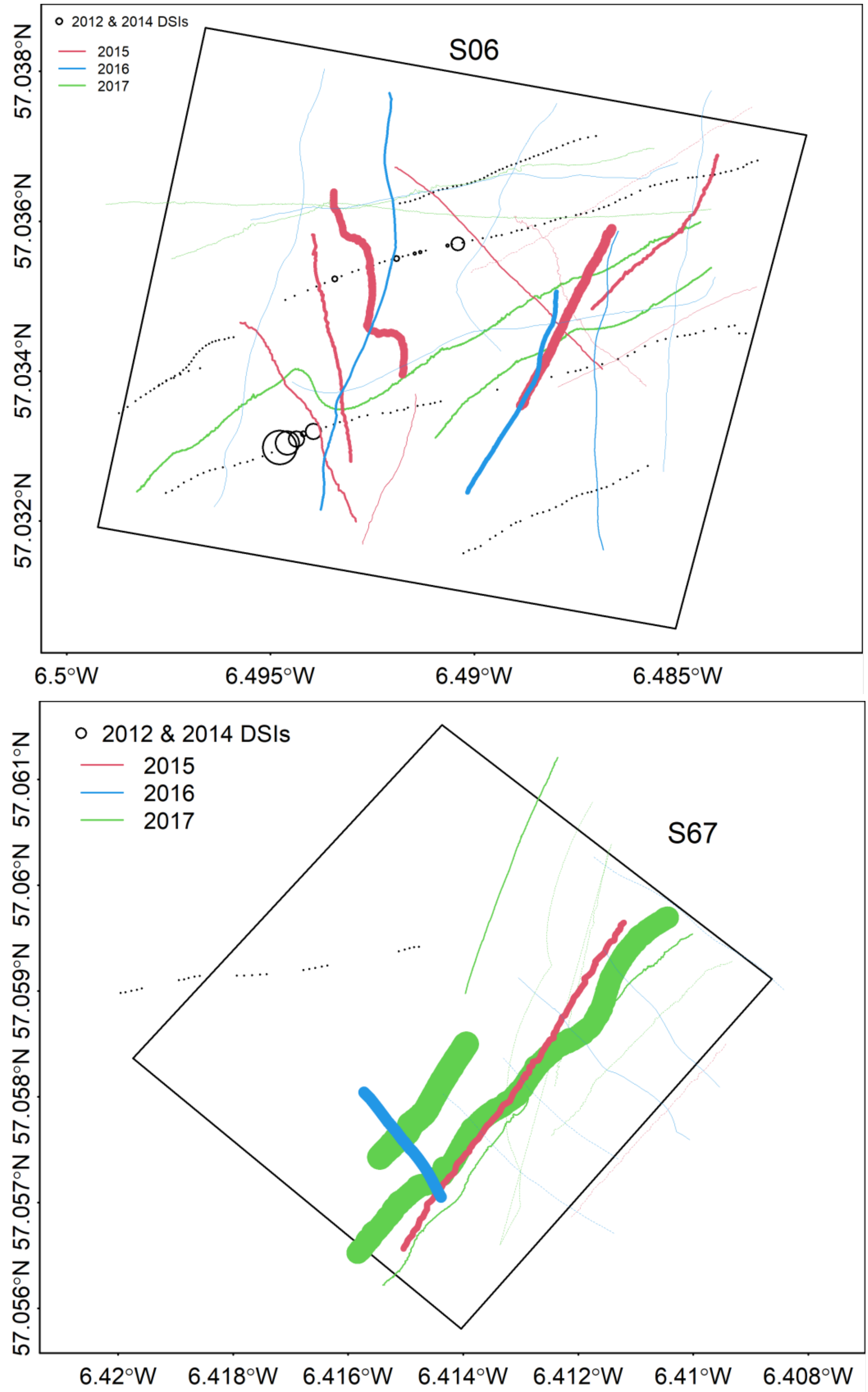

Figure D.3. The location of digital still images (DSI) and high definition video (HDV) tows in survey boxes S06 (top) and S67 (bottom) collected in different years. The size of the circle (DSI) or width of the line (HDV) is proportional to the density of *Swiftia pallida* observed. Dotted lines are tows where no *S. pallida* were observed.

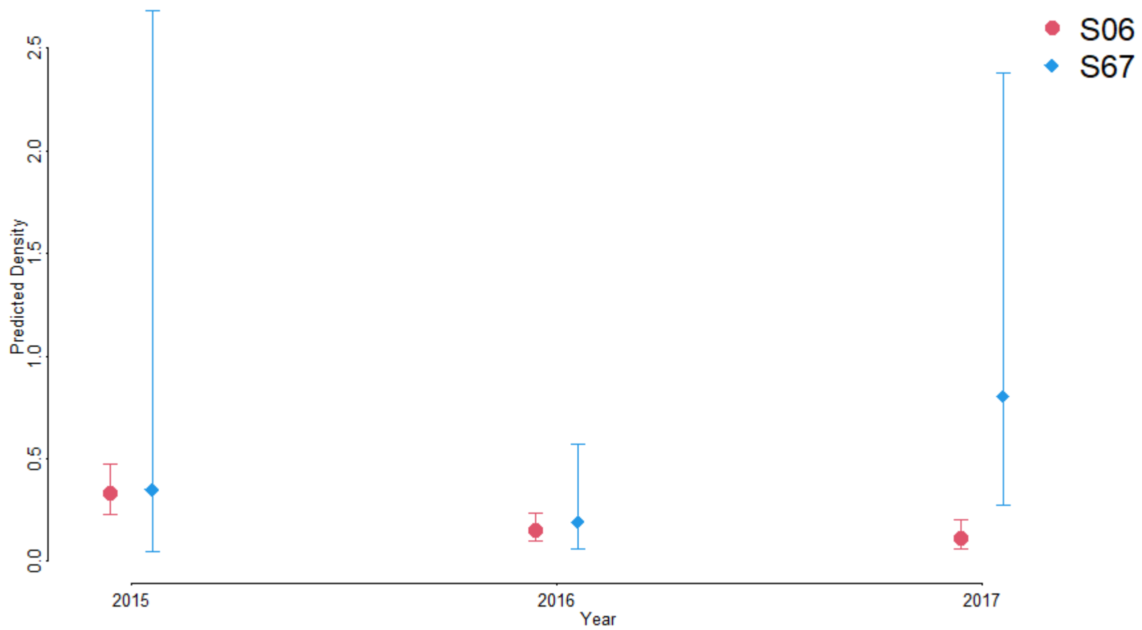

Figure D.4. The estimated density (counts per m^2) of *Swiftia pallida* in survey boxes S06 (blue diamonds) and S67 (red circles) predicted by the model with ±1 one standard error (error bars). Predictions were only made for years where HDV data were available.

Table D.5.

The results of Negative binomial generalised linear models for *Swiftia pallida* in boxes S06 and S67. Estimated values are on the log link scale. The year 2015 was used as the reference level for both survey boxes. Significance is indicated by asterisks: *** < 0.001; ** < 0.01; * < 0.05.

S06	Estimate	Standard Error	Z-value	S67	Estimate	Standard Error	Z-value
2015	-1.1106	0.3690	-3.010**	2015	-1.0476	2.0325	0.515
2016	-0.7589	0.5537	-1.371	2016	-0.6057	2.3061	0.263
2017	-1.0646	0.6911	-1.541	2017	0.8282	2.3046	0.359

4. Potential reasons for the reduction in *Funiculina quadrangularis* densities

4.1 Differences in spatial coverage of surveys

Given that no single point on the seabed will be included in multiple DSI in the same year, differences in *F. quadrangularis* density in a box could potentially reflect variation in density over space instead of time. For example, from Fig. D.1, *F. quadrangularis* was observed in multiple DSI in the northwest corner of box S08 but this location was not visited after 2014. However, the strong similarity in patterns between the boxes indicate the results are probably not the result of fine scale spatial variation.

4.2 Differences in survey or image analysis conditions

Variability in local hydrographic conditions, such as current or turbidity, across years could potentially reduce the probability of detecting *F. quadrangularis* in later surveys (2015 – 2017). For example, surveys in 2017 had a greater number of obscured images. However, checks conducted on back-up HDV footage from 2017 indicated that *F. quadrangularis* was not missed due to higher turbidity.

4.3 Exposure to fishing pressure

The VMS data is aggregated to c-square, and a swept area ratio is provided for each c-square for each year (ICES, 2018). C-squares are large relative to the survey boxes. Survey box S07 intersects with two c-squares; 7500:466:495:3 and 7500:466:495:4. Survey box S08 is completely within 7500:466:495:3. There is some evidence to suggest fishing pressure in the survey boxes increased in 2015 and 2016 (Fig. D.5). However, it is not known exactly where the fishing activity occurred relative to the *F. quadrangularis* records or when it occurred relative to the surveys. Whilst the peak in fishing pressures occurred in 2016, the sharpest decrease in *F. quadrangularis* happened between 2014 and 2015 surveys. It is therefore not possible to determine if fishing activity contributed to the observed decreases in densities for the two survey boxes.

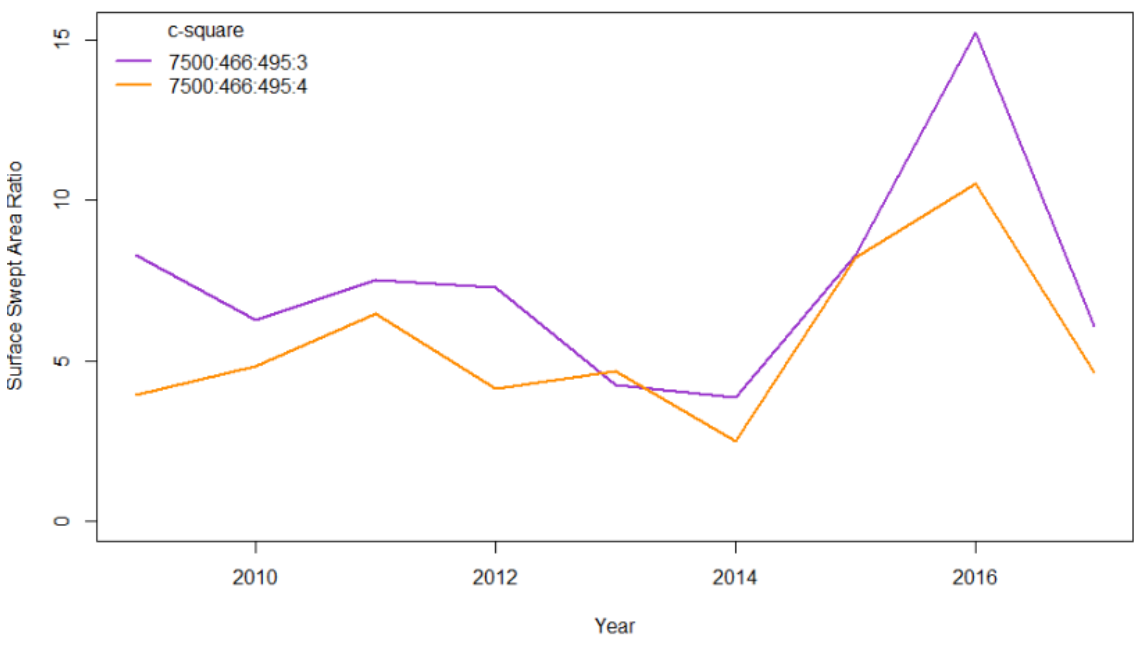

Figure D.5. The surface swept area ratios between 2009 and 2017 for the ICES 0.05 by 0.05 ICES c-squares that overlap with the survey boxes in this case study (ICES, 2018).

5. Potential reasons for no detectable pattern in *Swiftia pallida* densities

5.1 Small sample sizes reduce the ability to detect change

Given that the surveys were conducted as part of the "before" stage for a BACI (before, after, control and impact) study, changes in *S. pallida* density over time were not expected. However, small sample sizes (2 – 8 HDV transects) for each box and year combination could make it difficult to detect change if it had occurred.

Recent power analyses conducted for other marine environments indicate that very large areas with multiple replicates may need to be surveyed to detect changes in benthic species in response to anthropogenic impacts (Ardron et al., 2019). The small sample sizes available from HDV for *S. pallida* in the SMI MPA limit the power of statistical tests and make it less likely that real differences in *S. pallida* density between years can be detected.

5.2 Spatial patchiness complicates density assessments

The absence in density patterns for *S. pallida* within the two boxes across years (2015, 2016 and 2017) could reflect the biological traits of this species, in particular a reliance on patchily distributed hard substrates such as rocks and boulders (Wilson, 2007). Hard substrates were often highly localised in the SMI MPA, interspersed by larger areas of habitat that would be regarded as unsuitable for many species requiring hard substrate.

Standard benthic survey methods relying on the drift of the vessel during the deployment of equipment, such as the surveys conducted on the MRV *Alba na Mara*, are unlikely to target small areas of suitable habitat very well, or may miss habitat patches purely by chance, which could increase variation in estimates of box-level density between years or sites. Subsequently, any real differences in *S. pallida* density between years are less likely to be detected.

Conclusions

Given that significant decreases in *F. quadrangularis* were detected in two separate boxes (S07 and S08) that were surveyed using the same methods across the same years, it is likely that the observed decrease in density is real and not an artefact of differences in survey coverage. A causal link between the significant reduction in density *F. quadrangularis* and an increase in fishing effort in the wider area could not be established. Challenges in linking observed decreases in species density to fishing activity suggest that greater spatial and temporal resolution of fishing pressure data is needed to assess the impacts of fishing activity.

The data available do not provide evidence of a change in the density of *S. pallida* in the two boxes (S06 and S67). It is not possible to say whether the absence of a detectable pattern reflects reality or is due to lack of statistical power to detect change with the available data. Future surveys could look to use smaller sampling units for HDV tows to increase the overall sample size and to reduce the effect of within-tow density variation of *S. pallida*. Collecting higher spatial and temporal resolution of biological data in future surveys would help to detect density changes for species reliant on patchily distributed habitat. Alternative survey technologies that enable patchy habitats to be reliably re-visited in multiple years could enable more robust density comparisons to be made between years. Where species are difficult to survey repeatedly over time, data resolution may not be sufficient to detect a change or deterioration in status over time or space, thus sentinel hypothesis-based monitoring may be less effective for these species.

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