SOTEAG

Survey of the rocky shores

in Sullom Voe

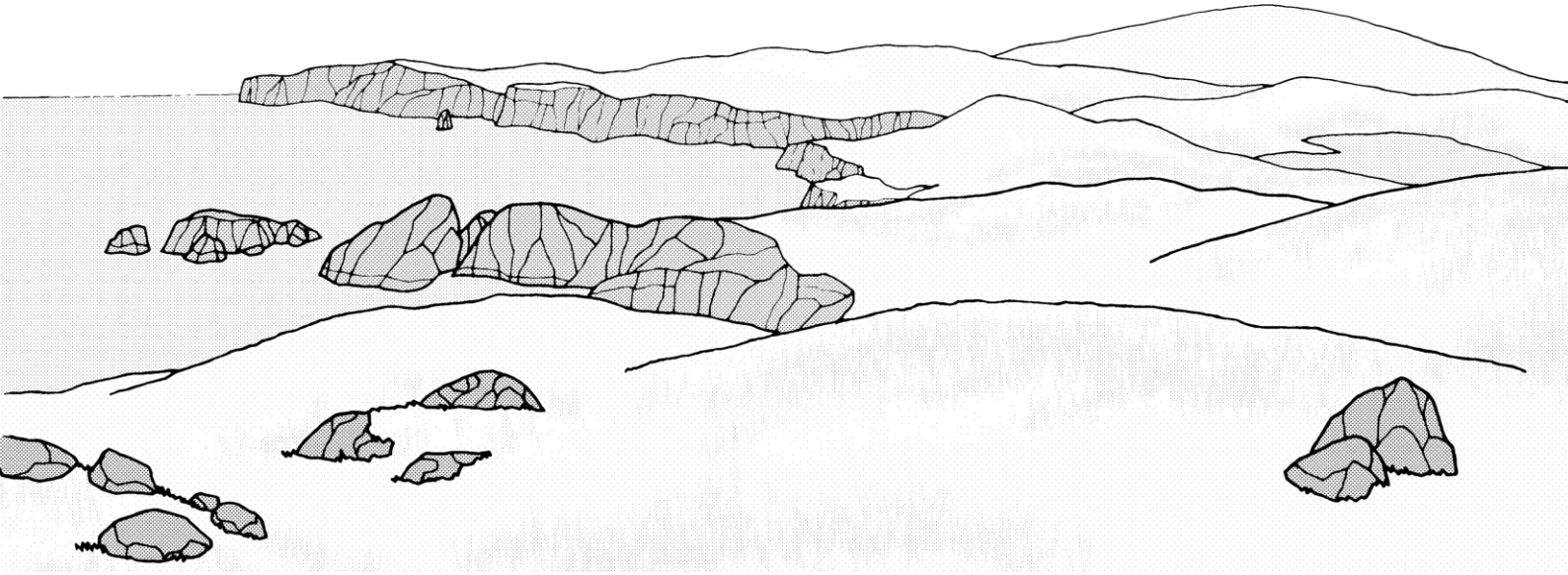
2020

A report to the Shetland Oil Terminal

Environmental Advisory Group

by

Aquatic Survey and Monitoring Ltd



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Survey of the rocky shores in the region of Sullom Voe, Shetland, August 2020

A report for SOTEAG

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Data access

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Summary

Biological monitoring of rocky shore communities in Sullom Voe has been carried out annually since 1976. Annual reports to SOTEAG have described the changes from year to year and assessed the effects of the terminal operation. This report summarises the work carried out in August 2020 – the 43rd survey since the programme's inception.

The 2020 survey was carried out with a methodology and strategy adopted in 1993. Earlier data is still directly comparable for analyses. Fourteen transects in Sullom Voe and ten reference transects outside the Voe were re-surveyed, and the abundances of all conspicuous species (algae, lichens and invertebrates) were recorded at five stations along each transect. A photographic record of each site was made. One transect (Scatsta Ness (cleared)) was not re-surveyed due to a relocation error.

New markers to aid future relocation of transects and individual stations were installed at most sites.

Comparisons of recorded abundances, field notes and photographs from the 2020 survey with those from the 2019 survey and previous surveys have been carried out.

Rocky shore communities at the twenty-four sites in 2020 were generally similar to those surveyed in 2019. The most noteworthy features of interest are listed below:

- A notable settlement of juvenile keel worms *Spirobranchus* was seen at sites in Sullom Voe. Long term data suggests a possible trend of increasing abundance of these worms.
- Abundances of the barnacle *Semibalanus balanoides* were well within the normal range of fluctuations, but barnacle spat were relatively sparse.
- Limpet, *Patella vulgata*, densities were also very similar to 2019, though juveniles were less abundant. Increases at Jetty 2 transect suggest that shore has stabilised after disturbances from the physical rearrangement of boulders in 2016.
- Average abundance of edible winkles *Littorina littorea* fell in Sullom Voe in 2020, but not at the reference sites. The reduction was due mainly to fewer records at marginal stations. It is considered likely that this is a natural fluctuation.
- A continued decline in the abundance of rough winkles *Littorina saxatilis* is apparent.
- Percentage cover of mussels *Mytilus edulis* was relatively low in 2020 and data suggest there may be downward trend in their abundance over the last few years.
- Abundance of the red alga *Dumontia contorta* had markedly declined since the start of the programme and was very low in 2009, but records and percentage cover have started to increase again in recent years.
- There was a surprisingly large increase in percentage cover of encrusting coralline algae in 2020, due to moderate increases at many sites and stations.
- Numbers of records of the filamentous brown alga *Elachista fucicola* in Sullom Voe were the highest ever recorded in 2020.
- Abundance of knotted wrack *Ascophyllum nodosum* increased at reference sites in 2020 but was stable within Sullom Voe.
- There was a further increase in the average abundance of bladder wrack *Fucus vesiculosus* and in 2020, across the Sullom Voe sites, it was higher than in any previous year
- Abundance of green algae remained relatively low, compared to the early 2000s, but there were modest increases in *Ulva* and *Cladophora*.

One very small oil pollution event was reported in the period between July 2019 and August 2020, but was very unlikely to have caused any notable ecological effects. No signs of pollution impact were seen.

Contents

1 Introduction

The potential environmental impacts of operations at the Sullom Voe oil terminal were recognised when construction of the complex began in 1975. A monitoring programme was devised by the Shetland Oil Terminal Environmental Advisory Group (SOTEAG). The rocky shore element of this monitoring programme began in 1976 and, apart from a break of two years (1982-83), the rocky shores in Sullom Voe have been surveyed annually. It is thought to be the longest running continuous programme of rocky shores surveys anywhere in the world. The programme was designed to assess gross changes in the plant and animal populations and the survey sites are centred on the oil terminal.

The survey methodology has been modified over this 42-year period, with various changes to the suite of sites and stations, but the species abundance data are comparable throughout.

This report describes the results of the survey in August 2020, highlighting changes that have occurred since the survey in August 2019 and discusses any notable longer-term fluctuations or trends.

Note: An associated programme of surveys of dogwhelk populations at rocky shore sites around Sullom Voe and Yell Sound is carried out every two or three years and was carried out during the August 2018 survey (Moore, Anderson & Mercer, 2018). Appendix 2 lists the dogwhelk survey years.

2 Methods

2.1 Methodological changes during the monitoring programme

Between 1976 and 1981 'full' surveys were carried out in all stations at between 23 and 43 sites, with field surveyors recording onto blank recording forms – i.e. with no reference to previous results. Between 1984 and 1992, following a review of the programme (Hiscock 1983), the methodology was changed and the survey at each site took the form of a rapid visual assessment of the shore to identify gross changes. This involved: comparing, in the field, abundances of species along the fixed transects with records from the most recent full survey, viewing longer sections of the shores from the sea or by walking, and comparing photographs taken from defined viewpoints with those taken in previous years.

In 1993, following suggestions from the SOTEAG monitoring committee, the methodology was modified to allow a more detailed and objective analysis of the data. The number of survey sites in Sullom Voe was reduced to fifteen and five reference sites were established outside the Voe in Yell Sound. Full surveys, rather than rapid visual assessment surveys, were carried out at just five stations along each transect, representing the main zones. This methodology has been used annually since 1993, but in 2017 five additional reference sites were established in Yell Sound (see Section 2.2.1).

The various changes in sites, transect stations surveyed, survey month and survey personnel that have occurred over the 42 years of the SOTEAG rocky shore monitoring programme are summarised in Appendix 2.

Moore (2013) provides a more detailed summary of the rocky shore transect monitoring programme (1976 to 2012), including a description of the methodologies, the methodological changes that had occurred over the course of the programme to 2012, the database and the limitations of the data.

2.2 Field survey, August 2020

Fieldwork was carried out by Jon Moore and Tom Mercer between the 1st and 10th August 2020, with assistance from Cait Moore. Table 1 details the sites and the transect stations surveyed, and Figure 1 shows the location of the sites. All surveys were carried out within three hours of low water.

2.2.1 Site and station location

Fifteen sites are located within, or at the entrance to, Sullom Voe to enable monitoring of the effects of oil terminal activities. A further ten sites are distributed around Yell Sound, Lunna and Vidlin Voe to act as Reference sites for the natural changes that occur in rocky shore populations. Five of those reference sites have been within the monitoring programme since 1993, but five were added during the 2017 survey, following a review of the programme that highlighted the unbalanced survey design. The additional sites (green dots in Figure 1) were chosen to improve the balance of the survey design (i.e. increased proportion of reference sites to Sullom Voe sites) and to better represent the environmental character and variability of the Sullom Voe sites. The site selection and establishment procedures are described in the 2017 annual report (Moore and Bunker 2017).

Access to sites was either by car and foot, or by boat as appropriate. A workboat was supplied by EnQuest. A hand-held GPS receiver and site location sheets, containing maps, colour photographs and written notes in laminated plastic, were used to aid relocation.

The site numbering system is based on the wave exposure of the shore. The first number (ranging from 1 to 6) is based on the Ballantine scale (Ballantine, 1961), which uses the biological communities on the shore to estimate the wave exposure (where 1 = extremely exposed, 5 = extremely sheltered, 6 = boulder / cobble shores). The second number is a consecutive number at that exposure.

Table 1 Rocky shore transect sites surveyed in August 2020, with the stations surveyed on each transect.

No.	Site name	Stations surveyed	Survey date	OS Grid Ref.
Sullom Voe sites				
1-1	W. of Mioness	15, 18, 21, 24, 27	03/08/2020	HU 41828 79071
2-3	Roe Clett	8, 11, 14, 17, 20	04/08/2020	HU 39437 78127
3-3	Noust of Burraland	1, 3, 5, 7, 10	05/08/2020	HU 37201 75186
3-4	Gluss Island East	6, 9, 11, 13, 15	02/08/2020	HU 37711 77551
3-5	S. of Swarta Taing	4, 7, 10, 12, 15	05/08/2020	HU 40160 77901
4-1	Grunn Taing	3, 5, 7, 9, 11	02/08/2020	HU 37942 78992
4-3	The Kames	5, 7, 9, 12, 15	09/08/2020	HU 38437 76459
4-6	Voxter Ness	5, 8, 10, 12, 14	09/08/2020	HU 36084 70089
5-1	S. of Skaw Taing	9, 12, 15, 18, 20	04/08/2020	HU 39621 78236
5-2	Jetty 3	5, 7, 9, 11, 13	10/08/2020	HU 38594 75578
5-5	Mavis Grind	3, 5, 7, 9, 12	01/08/2020	HU 34054 68462
6-1	Fugla Ayre	3, 5, 7, 9, 11	07/08/2020	HU 37342 74182
6-2	S. of Jetty 2	3, 6, 9, 11, 13	06/08/2020	HU 39163 75089
6-12	Scatsta Ness (cleared)	**Wrong location**	07/08/2020	HU 38874 73544
6-13	Scatsta Ness (uncleared)	4, 5, 8, 10, 12	07/08/2020	HU 38976 73524
	Orka Voe bund		04/08/2020	
Reference sites				
2-9	Riven Noust	13, 17, 19, 22, 24	05/08/2020	HU 50774 73063
3-8	Vidlin Ness	5, 7, 9, 10, 12	06/08/2020	HU 47998 66267
3-12	Burgo Taing	3, 6, 9, 11, 13	08/08/2020	HU 37381 89088
6-11	Kirkabister	4, 6, 8, 10, 12	06/08/2020	HU 48460 66257
6-14	N. Burra Voe	4, 6, 8, 10, 12	08/08/2020	HU 37220 89378
New reference sites				
3-10	Ola's Ness	4, 7, 9, 11, 13	06/08/2020	HU 35332 83092
4-7	West Sandwick	1, 2, 3, 4, 5	06/08/2020	HU 44583 86955
5-8	West Lunna Pund South	1, 2, 3, 4, 5	07/08/2020	HU 47829 69044
6-3	Croo Taing	7, 9, 11, 12, 14	03/08/2020	HU 43282 78645
6-15	West Lunna Pund North	1, 2, 3, 4, 5	07/08/2020	HU 47926 69094

The sites are termed 'transect sites': defined as a line of fixed stations, distributed at height intervals from supralittoral (lichen zone) to extreme low water. A fixed datum (pat of concrete, paint mark or other durable and conspicuous feature) marks the top of each transect. The line of the transect is defined by a bearing and by reference to conspicuous marks (permanent rock features and distant landmarks) shown in the photographs on the individual site location sheet. A tape may be laid down the shore from the fixed datum marker at the top of the transect, to provide a visible reference.

Originally, at the programme's inception, the fixed stations were located at equal intervals of 20cm vertical height (i.e. 1 tenth of the tidal range) from the fixed datum, with Station 1 at the top. Stations were originally established and relocated using a cross staff level (Baker and Crothers, 1987) with 20cm leg. The number of stations on a transect varies between sites, from 10 (sites with no lichen zone) to 29 (W. of Mioness; wave exposed site with extensive lichen zone). However, as explained in Section 2.2.1, only five stations per transect are monitored annually in the current programme. [Note: for the reference transects established in 2017, only five fixed stations were established, without any attempt to measure 20cm intervals].

The five stations currently monitored on each transect were selected to represent the five major shore zones of upper shore (Station A), upper middle shore (Station B), middle shore (Station C), lower middle shore (Station D) and lower shore (Station E) as defined by their relative height above chart datum and their assemblages of plants and animals. At two sites (Mavis Grind and Voxter Ness), it has become routine to attempt an additional station in the sublittoral fringe (Station F). However, tides and time did not allow for this in 2020. The stations surveyed are listed in Table 1.

A mistake, not noticed until the data and photographs were being analysed, was made while laying the transect line at Scatsta Ness (cleared) so the survey stations were wrongly placed (approx. 5m west and 3m up shore). While the shore gradient and habitat patchiness at this site are not severe, notable differences that are attributed to the shift are apparent in the species abundance data. As this report focuses on the condition of the sites in 2020, it was decided to exclude all data from this site (i.e. from all years) for the analyses in this report (see paragraph at end of Section 2.3).

Since 1993, precise relocation of the monitored stations is made mainly with annotated close-up photographs; except on gradually sloping boulder / shingle shores where measured distances are used. The photographs and other relocation information are provided in the 'site location sheets' for each site. New relocation information was developed during the 2020 survey (see Section 2.2.4).

2.2.2 *In situ* species recording

Comprehensive surveys by the two surveyors, one surveying animals the other surveying algae and lichens, were made of all conspicuous species at each station. The categorical (semi-quantitative) abundance score for each species was noted and recorded from a 3-metre horizontal strip (1.5 m each side from the relocated station mark). The width of the strip varies depending on the slope of the substrata, aiming to represent the 10 cm height band lying below the relocated station mark. On vertical rock surfaces the band is therefore 10 cm high; but a broader band, to a maximum of 30 cm, is surveyed on gradually sloping areas. Precise relocation can be difficult over the full 3 m length but can be improved with the aid of a 3 m length of leaded line laid horizontally by eye along the top of the station. Records were written into a standard pro-forma on waterproof paper, with checklists of species for animals and plants. Categorical abundance scores are assigned from a series of abundance scales, described in Baker and Crothers (1987) (see Appendix 1), which have been used since the inception of the programme in 1976. The surveyors carry a copy of these abundance scales to refer to during the survey. Thus, in each station, species of algae, lichen and some colonial animals are each assigned a categorical abundance score based on percentage cover, while species of mobile and other non-colonial animals are each assigned a categorical abundance score based on numbers of individuals per unit area.

Protocol and rationale for estimating categorical abundance scores: Estimation of abundance for each species found is by eye and is necessarily rapid. Most species have a very patchy distribution across the long narrow (3m x 10cm) strip, many are cryptic and require some searching and many are not easy to identify rapidly and *in-situ*. Abundance estimation, averaged across the whole strip, therefore requires some mental collation of species occurrences as the surveyor works back and forth through it. Methodical use of the species checklists and occasional use of small quadrats (e.g. 10cm x 10cm) aid the process, but accurate quantitative measurement of abundance is not achievable for most species in the available time and is not recorded. Assignment to the less precise categorical abundance scores is quicker and achievable, though errors and inconsistencies in estimates may still occur. Survey time at each station depends on species richness and habitat complexity, so the time required to survey a dense algal turf habitat on the low shore takes a lot more time than upper shore bedrock covered in a few encrusting lichens. To relocate and survey a site (five stations) takes approximately 1 hour (not including travel time between sites).

Any points of interest on the shores or relating to the populations observed were also noted on the recording form.

2.2.3 Photography

Photographs were taken of each transect from different viewpoints and angles, usually the same as on the site location sheet, and close-ups of selected stations. The equipment used was an Olympus TG5 digital compact camera. Digital images (high resolution jpgs) were recorded and copies are filed with SOTEAG and ASML.

2.2.4 Site and station relocation markers

New markers, notes and imagery, to improve the ease of site and station relocation were made during the 2020 survey. While GPS, photographs and the ASML surveyors' familiarity with the sites have been, and can continue to be, reliable for relocation, it was decided that additional markers would make it quicker and easier, particularly for anyone less familiar with them.

Site markers: Most of the bedrock sites already have a small concrete marker at the top of the transect, but they are not conspicuous (with almost no remnants of the original yellow paint markings). Some sites had a short wooden stake in the turf at the top of the shore but the few remaining were rotten. New wooden stakes were therefore knocked in with a lump hammer at all sites where suitable ground was available (see photo below).

Wooden stake marking Grunn Taing monitoring site (left) and stainless steel screw and washer marking mid shore station at Ola's Ness (right).

Station markers: For many years, relocation of the individual stations has been with photographs, at different scales, that show the rock features and allow precise relocation of the top centre of the 3m x 10cm band. Now, most of the stations on bedrock are marked by stainless steel screws [A4 stainless screws 4.5mm x 35mm, with A2 stainless washers M4 x 20mm x 1.5mm and red rawl plugs. See photo above]. Holes were drilled with a cordless hammer drill. A few stations were missed due to inadequate battery power, but most have the centre point marked and some have additional screws to mark the ends of the 3m wide band. The boulder stations were not marked, so tape distances will continue to be used for their relocation.

Additional notes and imagery: A tape measure was then used to measure the distance, to the nearest centimetre, with tape held taut, between the centre markers of each station, and usually between the top station and a mark at the top of the transect (stake or concrete). Lastly, short pieces of video were recorded of each station, with voice-over, to show the new screw locations and provide a further aid to future relocation.

It is hoped that additional screws can be installed to mark the stations that were missed, during the next survey. Additional relocation photographs showing the new markers are also required for some of the sites.

2.3 Data analysis

The data from the survey were entered into a Microsoft Access database, with a bespoke data entry module, which holds the data from previous surveys. Each record comprises the species name and taxonomic code (based on Howson & Picton, 1997), station number, site number, year and recorded abundance scores. The abundance scores are recorded as the numerical equivalent of the categories, e.g. 4 = Common (see Appendix 1).

All taxonomic nomenclature used in the database and this report has been continually revised and updated according to the World Register of Marine Species (www.marinespecies.org).

Tabulated printouts from the database and simple graphical presentations (graphs in Section 3.1) were used to compare the 2020 species abundances with previous years. In addition, the field notes and the photographs were compared with those from previous years and any notable changes described.

Because each abundance value is based on a semi-quantitative category, summing or averaging the numbers can give misleading results. However, a method has been devised to calculate mean abundances from these values by replacing the abundance scores with the midpoint value on the appropriate scale (Table 2). Thus, a score of 'Common' for barnacles, corresponding to 10 to 99 per 0.01 m^2, was converted to a value of 50 per 0.01 m^2. These values were then converted to natural logs. Absence at a station was valued as a population density an order of magnitude less than the minimum density defined in the scale. For each species, average log-transformed abundance was calculated, then anti-logged (exponential) to provide a single time series. As most species show a strong zonation pattern that restricts their vertical range, the abundances were then multiplied by a factor calculated from the maximum number of stations at which the species was ever recorded, to give typical average abundance values from within their range.

Whilst it should be appreciated that this methodology will introduce some errors into the data, the transformation of the densities will reduce the scale of this inaccuracy by taking better account of shifts at both ends of the abundance scale. The mean abundance graphs are a useful means of presenting trends that have been identified by a detailed scrutiny of the data. For some groups of taxa, including epiphytic bryozoa on fucoid algae and red algal turf species, the abundance data can also be summed and graphed to look for any trends across those whole groups. The methodologies for calculating and presenting mean abundances have been improved since the 2015 survey report. The calculations are

applied as queries to the raw long-term monitoring data held in the Access database and the modifications have made it easier to identify trends and notable changes.

Table 2 Median values used in calculations for each abundance category

		Abundance category						
Scale	**Units**	**R**	**O**	**F**	**C**	**A**	**S**	**Ex**
1	No./0.01m2	0.005	0.5	5	50	200	400	600
2	No./0.01m2	0.005	0.05	0.5	5	55	200	350
3	No./0.1m2	0.05	0.25	0.75	2.5	7.5	15	30
4	No./0.1m2	0.05	0.5	2.5	7.5	15	35	60
5	No./1m2	0.25	0.5	2.5	7.5	25	75	130
6	% cover	0.1	1	2.5	12	35	65	90
7	No./0.01m2	0.005	0.05	0.5	25	60	-	-
8	No./0.01m2	0.005	0.05	0.5	50	150	-	-
9	% cover	0.1	1	2.5	12	25	-	-
10	% cover	0.1	0.5	2.5	10	35	65	90
11	% cover	0.2	1	2.5	17	45	75	95

In addition to the graphs of average abundance plotted from the above analysis, lines showing changes in the number of stations from which the species was recorded have also been plotted. Values for the latter are given on a second y-axis (on the right of the graph). The maximum number of Sullom Voe stations is 75 (15 sites x 5 stations). The maximum number of Reference stations is 25 (5 sites x 5 stations). The maximum number of New stations is 25 (5 sites x 5 stations). Data from the new reference sites have been included on graphs for selected species where they show interesting trends in recent years. The number of years given along the x-axis of the graphs varies between species, depending on their known (and reliable) inclusion in the survey. For example, epiphytic bryozoa (e.g. *Alcyonidium hirsutum*) were not surveyed before 1993. Also, the earliest year used is 1980, because Mavis Grind was only established in 1980 and the Scatsta Ness sites were only established in 1979.

Note: The exclusion of data from Scatsta Ness (cleared) in this report (see explanation in Section 2.2.1) means that mean abundances and counts of records are based on a maximum of only 70 Sullom Voe stations (14 x 5 stations). In future reports it will be possible to include data from Scatsta Ness (cleared) and indicate the missing 2020 data in other ways.

2.4 Data archive

The master data are held in two *Microsoft Access* database files, one for species abundance data (currently 108,815 records) and one for the photograph catalogue (currently 7,987 photos), that are updated after each survey. ASML send copies to SOTEAG after completion of the annual report. In 2015 both databases were restructured to make them fully compliant with metadata standards developed by the Marine Environmental Data and Information Network (MEDIN). SOTEAG have sent a copy of the databases, and an update each year, to the Archive for Marine Species and Habitats Data (DASSH) (www.dassh.ac.uk). The photographs are all in high resolution digital format (jpg and tiff) (including scans of the slides and prints from the earlier surveys). Complete sets are held by ASML and SOTEAG.

Note: species records are held in the database under the name to which they were identified (or the currently accepted name in the World Register of Marine Species). However, for the purposes of long term analysis, which often requires species data to be aggregated upwards to a more reliably identified taxon, a field in the species dictionary provides the taxon for these aggregations.

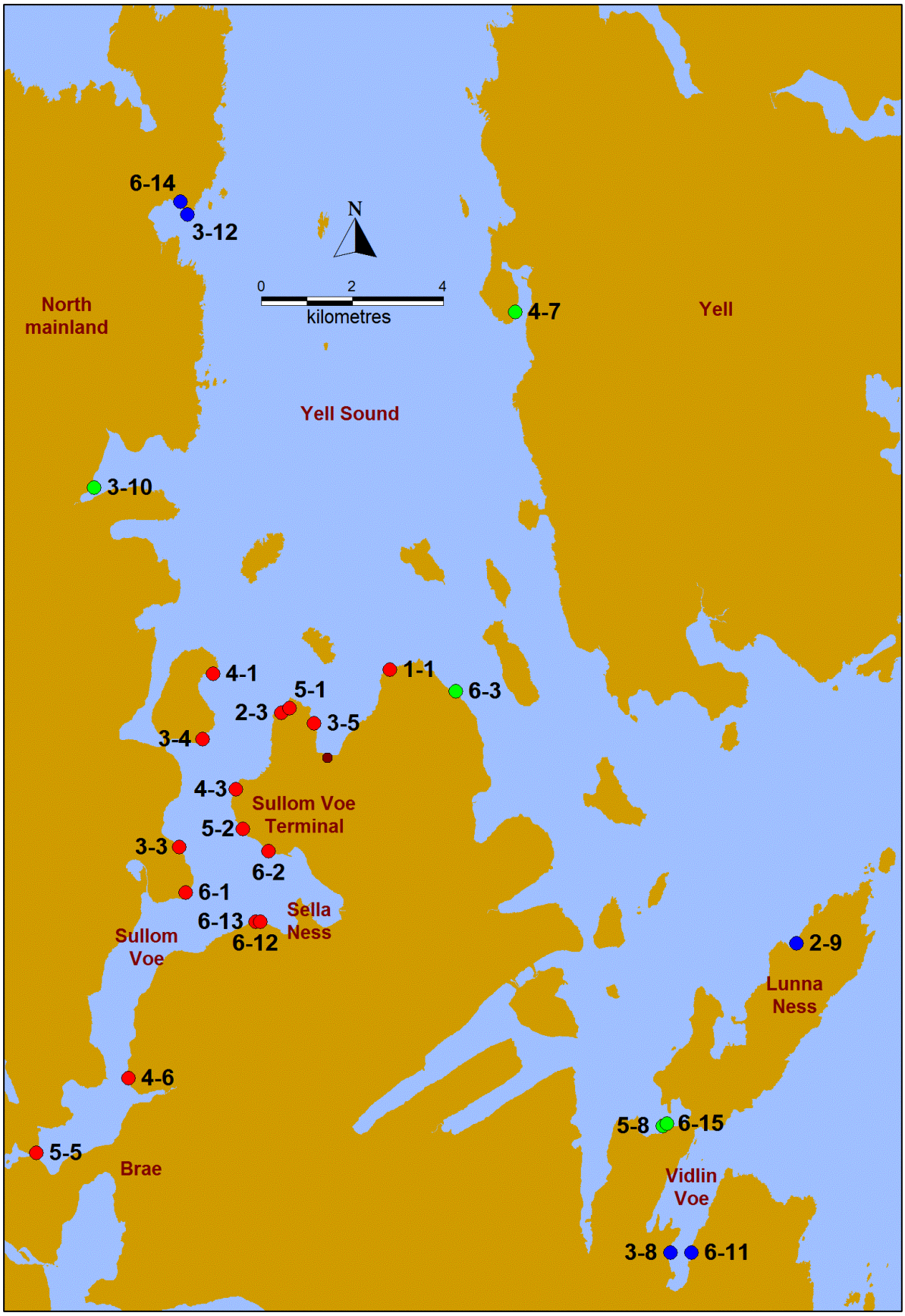


Figure 1 Location of rocky shore transect sites. Surveys of rocky shores in the region of Sullom Voe, Shetland, August 2020. ● Sullom Voe sites, ● old Reference sites (established 1993), ● new Reference sites (established 2017).

Table 3 Changes in categorical abundance of selected species between 2019 and 2020 at monitoring stations in Sullom Voe (left) and at Reference stations (right) (including stations at the 5 new reference sites). Values are the percentage number of stations at which there was a change in abundance shown in the top row of the table. Example: Cirripedia (spat) were reduced in abundance by three categories at 10% of Sullom Voe stations.

	Abundance changes in Sullom Voe stations											Abundance changes in Reference stations									
Name	**-5**	**-4**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	**5**	**-4**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	**5**
Cirripedia (spat)	2	3	10	21	17	34	9	3				2	10	26	19	33	7		2		
Cirripedia (dead)				9	22	54	11	4					2	7	20	61	5	5			
Verrucaria		3	3	10	32	38	13	1					4	6	20	36	24	6	4		
Littorina littorea			4	12	18	59	2	6					3	13	10	37	23	10	3		
Littorina saxatilis (neglecta)				8	14	67	5	6						8	16	66	5	5			
Mytilus edulis				6	10	60	19	4						21	10	55	7	7			
Hildenbrandia				13	16	41	18	9	3				2	12	24	37	16	6	2		
Osmundea pinnatifida						78	9	13						33		44	22				
Semibalanus balanoides			2	5	18	58	13	3						2	16	60	16	5			
Chondrus crispus				10	23	39	16	10	3					9	17	65		4		4	
Porphyra		2	2	2	12	63	6	8	4					8	17	58	13	4			
Spirorbinae				4		81	7	4	4				4	4	4	71	17				
Nucella lapillus			2	16	4	56	11	4	4	2		6		6	3	52	15	15		3	
Littorina obtusata		4	2	25	8	27	13	17	4				6	8	8	42	19	8	6		3
Pelvetia canaliculata				4	15	59	15	7						6	6	71	12		6		
Patella vulgata			2	5	14	46	27	7					3	8	13	50	18	5	3	3	
Patella (juvenile, <10mm)		5	3	5	5	65	8	10					4	12	12	42		27	4		
Osmundea hybrida						90	5	5						8		75		17			
Elachista fucicola				8	19	44	11	11	6						16	56	16	12			
Ulva (tubular)				4	14	59	11	9	4						8	72	8	10	3		
Corallina				4	4	73	8	12						14		43	29	14			
Fucus spiralis			5	3	8	66	11	8							4	65	13	9	9		
Dumontia contorta				8	12	56	4	16	4						6	63	25	6			
Littorina saxatilis		1	1	10	6	49	22	9		1				11	9	39	13	24	4		
Mastocarpus stellatus				3	3	68	10	15	3				4	4	9	57	9	9	9		
Cladophora		2		7	5	63	9	7	7					6	12	39	21	18	3		
Ceramiaceae (fine filamentous)				8	10	62	8	13						4	4	46	17	25	4		
Fucus serratus			3	3	6	52	12	9	9	3	3				24	43	29	5			
Lomentaria articulata					11	68	11	11							29	29	7	29	7		
Ulva (flat)						76	9	12	3						8	54	17	21			
Corallinaceae (encrusting)			2	5	12	31	29	17	5			3			9	22	47	9	9		
Fucus vesiculosus				2	11	57	17	4	4	4						50	16	22	13		

3 Results

3.1 Fluctuations in frequency and abundance of selected species

Table 3 provides a summary of abundance changes that occurred between August 2019 and August 2020 for 32 of the most characteristic taxa of these Shetland rocky shore communities.

Table 4 provides a summary of changes in numbers of records (from the 15 Sullom Voe sites only) over the last 25 years, for 66 of the most frequently recorded taxa. [Note: Comparable data for reference sites are not shown as there were too few sites and stations to provide good representation over that period].

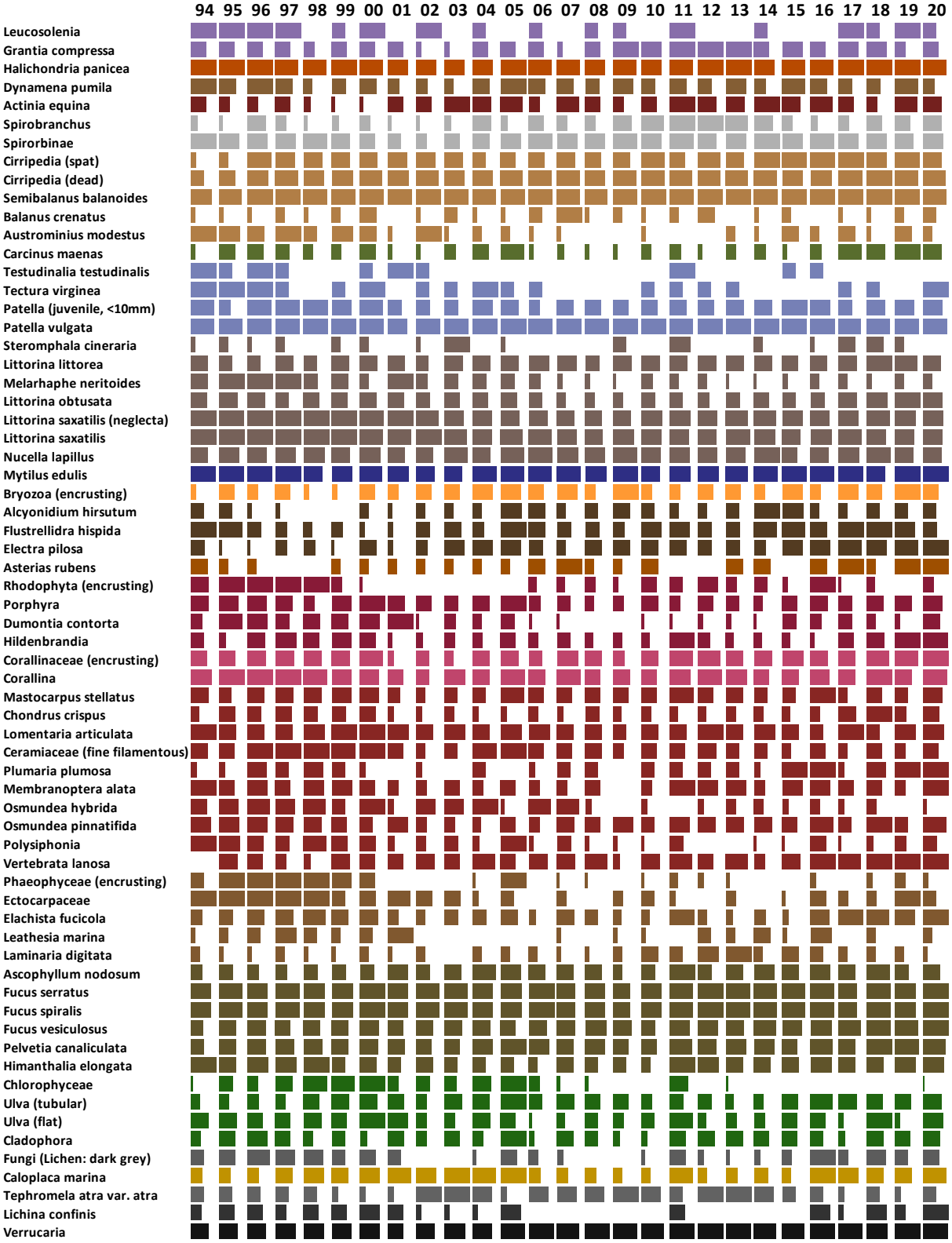
Between them, those tables show that fluctuations in the frequency and abundance of most taxa occur every year and that some of them are substantial. Analyses and interpretation over the course of the programme have indicated that the majority of those fluctuations reflect natural variability, but there have been notable changes in some years, sites and species. The following sections describe the results for selected characterising species and others that have shown notable changes in the last year.

The mean abundance graphs have been prepared using the methodology described in Section 2.2.4, for Sullom Voe sites and Reference sites. Other tables of data have been prepared from the species abundance data, with colour coding (conditional formatting features in Excel) to highlight patterns in those abundances between years, sites and species.

Appendix 1 provides the abundance scales used for each species. The fixed monitored stations, representing the five shore zones, are referred to in the text and some tables as follows: upper shore (A), upper middle shore (B), middle shore (C), lower middle shore (D), lower shore (E) and sublittoral fringe (F).

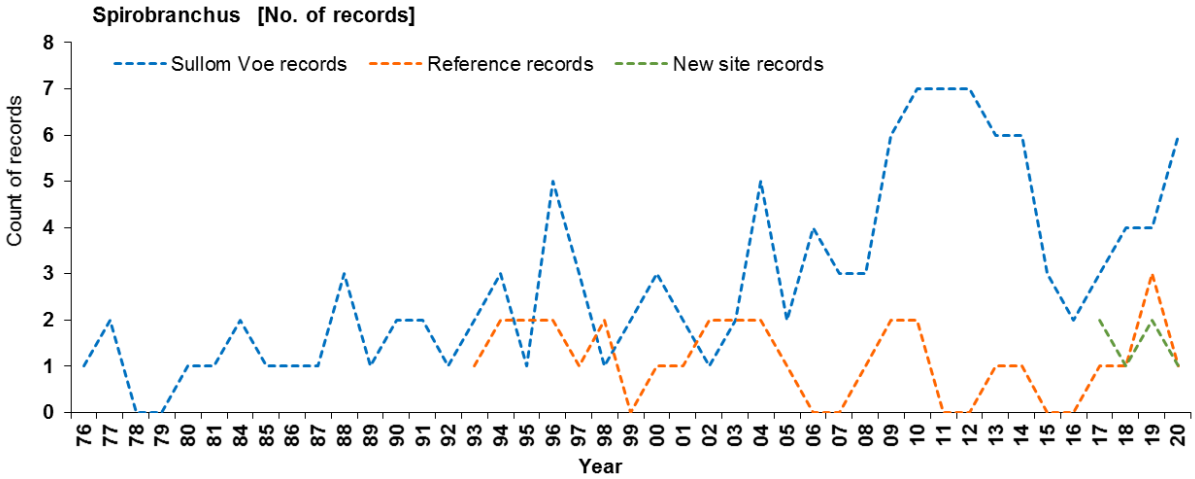
Note: for readers with the electronic version of this report, the species names in the section headings below contain hyperlinks to relevant pages on their biology on the MarLIN website.

Table 4 Proportional changes in numbers of records of most frequently recorded taxa from sites in Sullom Voe (15 sites, 75 stations), 1994 to 2020. Length of coloured bars are calculated from the number of records in that year divided by the maximum number recorded in any year. Abundances recorded as Rare are not included. Colours indicate different taxa and taxonomic groups.



3.1.1 *Spirobranchus* (keel worm)

Keel worms, *Spirobranchus* (previously called *Pomatoceros*), are found in low densities on the lower shore of a few sites, typically on the boulder shores where they are an indicator of scouring. Two species (*S. lamarcki* and *S. triqueter*) occur in the area but are difficult to distinguish reliably *in-situ*. As densities are normally low, numbers of records are the best measure for describing temporal change. The graph below shows large fluctuations, at least some of which will be due to a greater or lesser effort to search for them by the surveyors (particularly in the period from 1979 to 1987). However, the apparent trend of increase since the methodology changed in 1993 is interesting. A notable settlement of young worms was seen at a few sites in Sullom Voe in 2020, particularly Scatsta Ness (uncleared) and South of Jetty 2, with large numbers of small tubes on the boulders and stones.

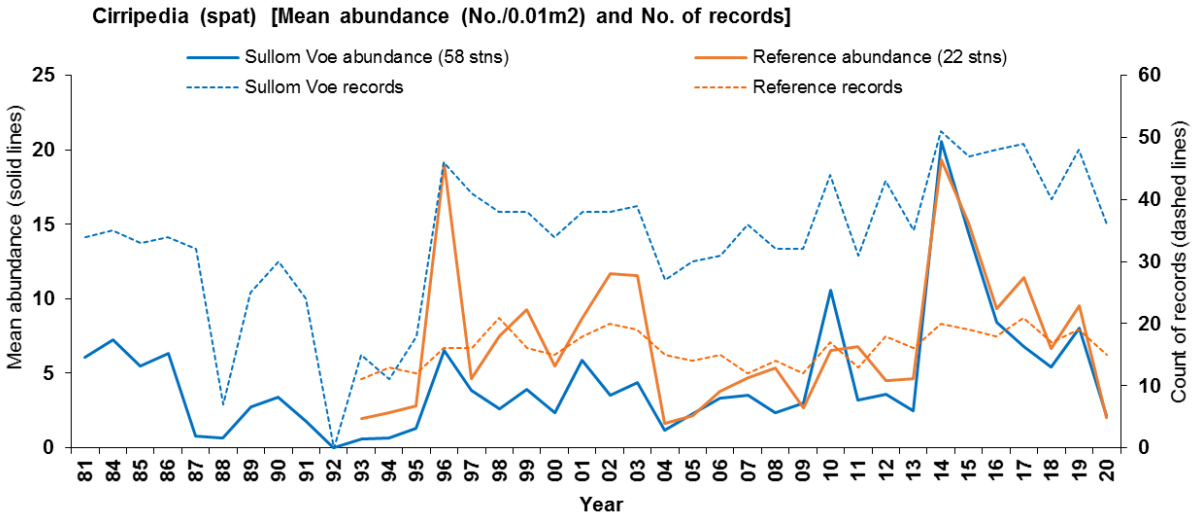


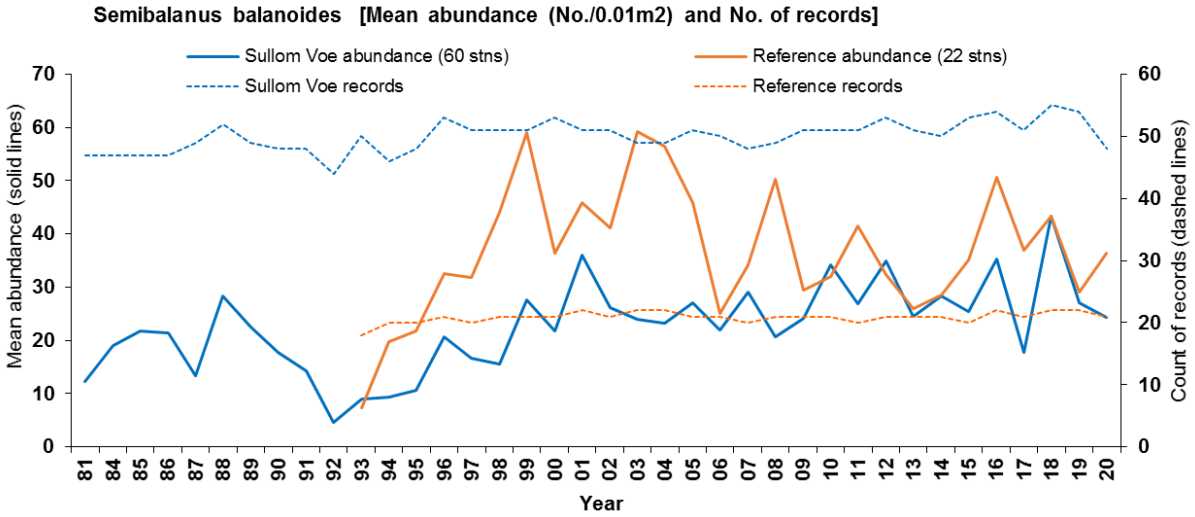
3.1.2 *Semibalanus balanoides* (barnacle)

Semibalanus balanoides at W. of Mioness (left) and Riven Noust (right), including adults, spat and empty cases (likely eaten by dogwhelks)

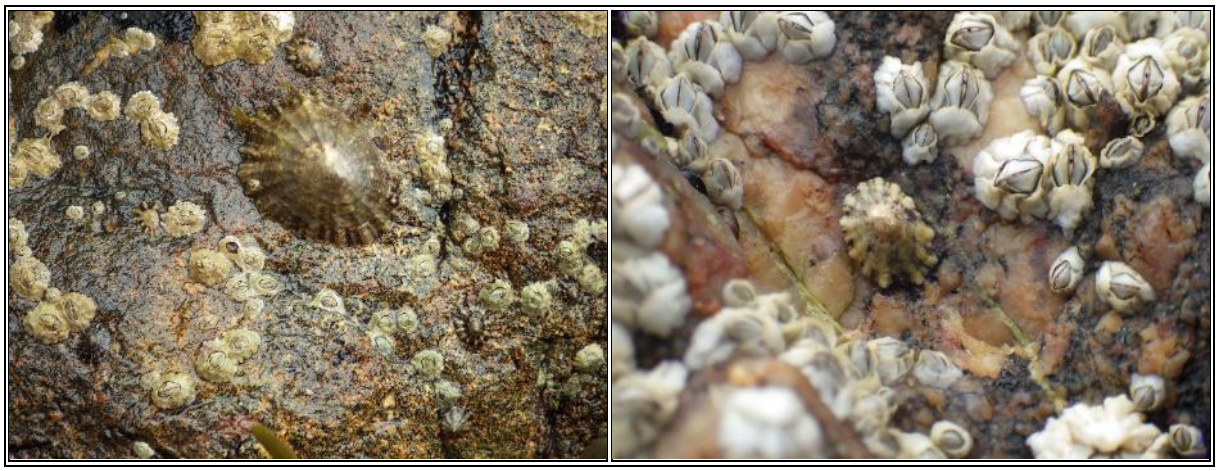
Average densities of barnacles *Semibalanus balanoides* did not change much between 2019 and 2020 and were well within the normal range of fluctuations at both Sullom Voe and Reference sites (see graph below). However, there was a larger reduction across the five new reference sites.

Densities of barnacle spat have fallen in recent years, after a peak in 2014, and they were relatively sparse at all sites in 2020. Interpretation of these data is not straightforward as they only represent the later settlement of these barnacles, i.e. near the end of their season.





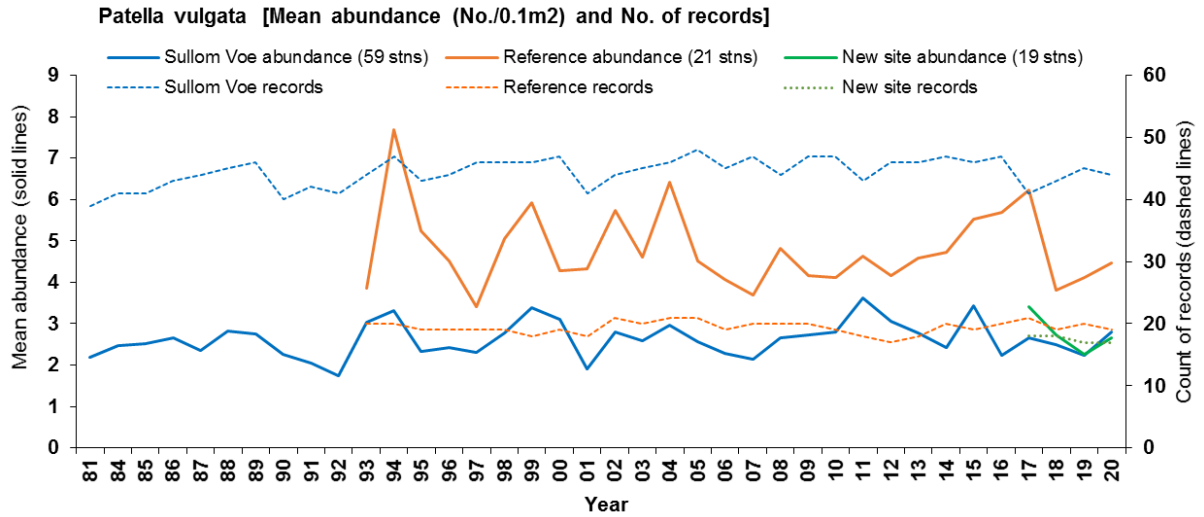
3.1.3 *Patella vulgata* (limpet)



Patella vulgata, adult and juveniles, amongst barnacles at Mavis Grind.

Limpet populations at the Sullom Voe sites continued to show a typical range of fluctuations, with average densities of adults and juveniles remaining fairly stable (see graph below). Modest increases on the Jetty 2 transect over the last two years suggest that shore is stabilizing after disturbances from the

physical rearrangement of boulders in 2016 (see table below). Numbers of juveniles were relatively low at numerous sites, but were particularly high at Ola's Ness.

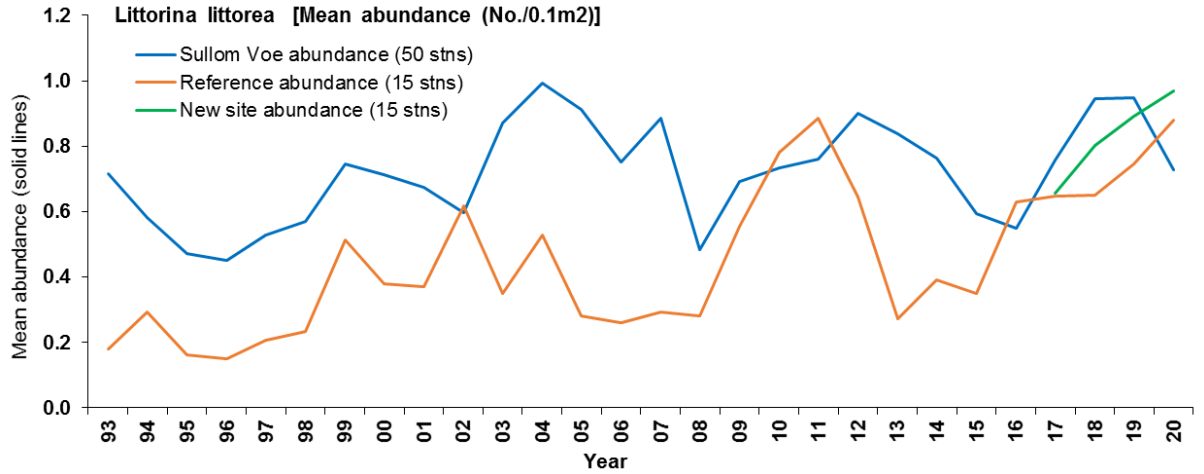


Patella vulgata 6-2 South of Jetty 2

	81	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
UMS				2														2		2	2	2		2		3	2	2			3					2	3	3
MS					4	1	1			1	2	1		3	3	2	2	3	1	3	4	3	4	3	2	2	3	3	3	4	4	2	2				3	4
LMS	4			3	1	2	2					3	2	3	2	3	4	1			4	3	3	2	3	3	3	3	3	3	4	4	2	4	3	2	3	4
LS						2		2				2	3	2		2	3	2		3	4	3	2	2	2	2		3	2	2		3	2	4	4	2	4	3

3.1.4 *Littorina littorea* (edible winkle)

Edible winkles (see photo below) are most abundant at the relatively sheltered sites, particularly on the boulder shores. A trend of increasing abundance of these snails has been apparent for many years and may be linked to increases in fucoids and algal detritus (see discussion in Section 4.1). The graph below shows a drop in mean abundance in Sullom Voe in 2020, but not at the reference sites. The table of summed abundance scores from each site (below the graph) shows that 2020 abundances were similar to 2019, but there was a notable reduction in the number of records of *L. littorea* in 2020 from numerous sites. Those losses were from marginal stations for these winkles, i.e. with limited amounts of algae, suggesting that conditions were not as good for the species this year. It is considered likely that this is a natural fluctuation. Note: the missing data from Scatsta Ness (cleared) in 2020 (see Section 2.2.1) stands out in the table below, as *L. littorea* is typically very abundant on the midshore there; but it does not affect the graph because data from that site was excluded.



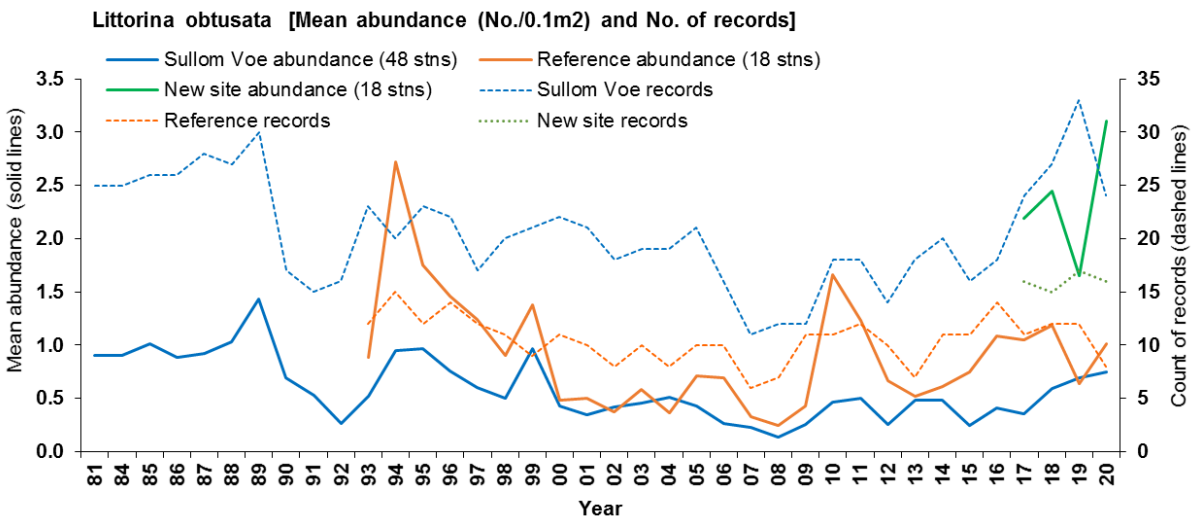
Littorina littorea (sum of abundance scores from five stations, by site and year)

		81	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
Sullom Voe	West of Mioness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roe Clett	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	2	0	2	0	2	0	2	2	2
	Noust of Burraland	2	2	2	2	2	2	3	1	1	0	2	3	0	0	12	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	2	2	2	0	13	5	2
	Gluss Island East	0	0	0	0	0	0	4	0	0	0	3	5	4	5	5	4	3	5	5	0	2	6	5	7	7	7	4	7	7	6	6	5	3	2	6	10	8	5
	South of Swarta Taing	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	3	0	4	0	2	0	0	2	3	2	0
	Grunn Taing	0	0	0	0	0	0	0	0	0	4	2	2	4	2	0	6	4	5	2	2	5	6	4	6	8	1	2	4	7	8	0	6	2	4	7	8	6	5
	The Kames	1	1	1	1	1	2	2	2	2	0	2	0	2	3	4	0	6	0	3	0	8	3	6	2	7	2	4	3	5	3	3	2	3	2	3	7	4	3
	Voxter Ness	9	9	9	9	9	11	11	13	13	10	17	11	7	9	9	11	11	16	12	10	12	13	18	13	13	11	9	10	2	10	10	8	6	9	13	14	11	11
	South of Skaw Taing	3	3	3	3	4	5	13	4	5	5	5	9	6	4	5	6	4	4	5	4	6	7	6	9	5	4	5	8	5	8	6	5	7	6	8	4	6	5
	Jetty 3	2	2	2	7	6	9	7	6	7	9	11	11	12	12	8	12	13	7	11	14	12	16	11	13	13	11	11	14	14	11	14	11	15	16	13	12	16	14
	Mavis Grind (Stream 3)	8	8	8	9	9	5	5	5	6	7	9	9	2	6	5	7	11	14	11	8	17	13	10	12	11	11	13	5	8	4	2	3	6	2	6	13	9	7
	Fugla Ayre	2	2	6	2	4	7	9	8	8	2	7	5	2	0	2	0	4	3	7	5	7	5	3	0	0	0	3	3	3	3	7	2	0	0	0	3	5	0
	South of Jetty 2	5	5	5	5	7	8	6	6	5	7	7	14	11	13	14	14	17	16	15	12	18	15	18	13	15	8	20	18	17	19	23	21	14	11	19	12	14	15
	Scatsta Ness (cleared)	11	11	11	13	11	15	13	14	14	15	14	11	16	14	16	14	16	15	18	13	18	17	13	17	16	11	16	16	18	21	16	16	19	22	18	15	19	
	Scatsta Ness (uncleared)	10	10	10	10	11	8	15	11	11	7	12	9	12	8	12	11	14	16	12	13	8	14	14	14	14	14	16	15	19	19	19	19	18	17	15	18	17	16
Reference	Riven Noust											0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Vidlin Ness											7	0	0	0	2	0	0	2	0	0	0	0	2	2	0	0	2	6	7	2	0	2	7	5	7	6	8	10
	Burgo Taing											0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	2	0
	Kirkabister											6	10	9	7	7	10	10	10	11	15	12	16	11	8	11	11	15	18	19	18	14	14	7	14	14	12	13	13
	North Burra Voe											0	6	2	3	5	2	8	3	6	6	3	6	2	3	5	4	4	3	2	2	0	3	3	5	7	8	12	11
New refere.	Ola's Ness																																			0	0	1	0
	West Sandwick																																			0	0	3	0
	West Lunna Pund South																																			6	10	13	12
	West Lunna Pund North																																			13	13	11	15
	Croo Taing																																			7	7	4	8

Littorina littorea (left). Littorina fabalis on Fucus serratus (right)

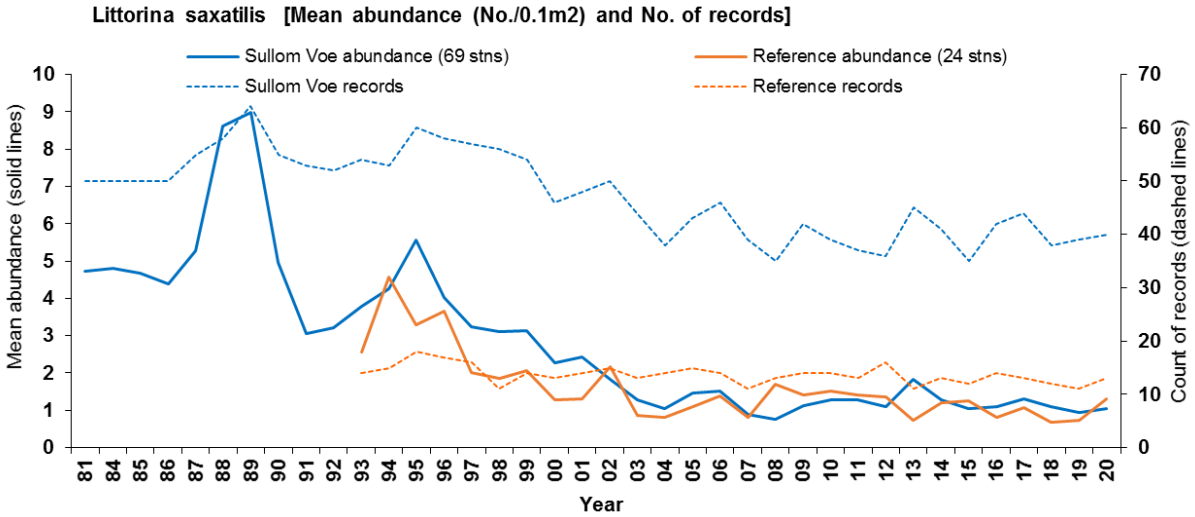
3.1.5 *Littorina obtusata* / *L. fabalis* (flat winkle)

Abundances and numbers of records of flat winkles (photo above) showed moderately large fluctuations at some sites, but average densities were similar to 2019 in Sullom Voe. Particularly large decreases and increases have been recorded from Croo Taing, which are the main cause for the fluctuations at New reference sites shown in the graph below.



3.1.6 *Littorina saxatilis* (rough winkle)

Rough periwinkles (not including the small ecotype *var. neglecta* which are recorded separately) are often common in crevices and under stones, particularly in the upper shore zones (see photo below), but recorded abundances were much higher pre-2000. Examples, from Jetty 3 and Kirkabister are shown in the tables below the graph. Some inconsistency in recording is likely and weather conditions also have a notable effect (i.e. they hide in dry conditions), but records of high densities appear to be much less common and are very obvious when they are found.



Littorina saxatilis 5-2 Jetty 3

	81	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
US	6	6	6	6	6	2	2	3	2	2	5	5	2	4	2	3	5	2	2	3	3	2	2		3	4	3	2	3	2	2	2	2	2	2	2	3	2	6
UMS	5	5	5	5	5	2	2			2	2	4			2	3	3	2		2	2		3	3			2		2	2		2	2	2	3		2	
MS	5	5	5	5	5	7	5			3	3	3	4	3	3	2	3		2			3	4	3	2	4	2				2			2	2			
LMS	5	5	5	5	5	4	4	4		6	4	7	2	4	2	3	4	2	4	4	3	3	5	4	3	5	5		5	4		3	4	5	4	3	3	4
LS							3	4	3	3	3	4	2	2	2	2	3		4	3			3	3	3		3	3							3			

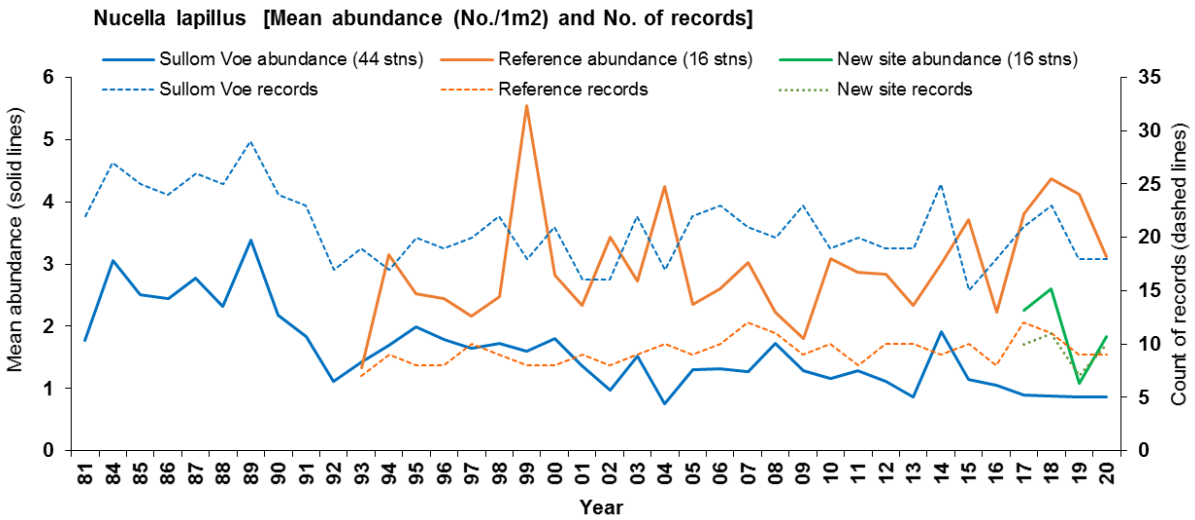
Littorina saxatilis 6-11 Kirkabister

	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
US	5	7	5	6	5	6	6	3	3	5	6	4	5	5	2	2	5	5	3	3		3	5	5	3	3	2	3
UMS	4	7	7	6	6	6	7	4	4	6	5	5	4	3	3	4	4	6	4	4	3	6	5	3	5	4	4	6
MS	6	7	4	5	6	5	2	3	4	5	3	3		4	3	6	7	3	3	5	3	2	4	2	2		2	3
LMS	4	7	4	5	4	5	3	3	4	4			3	4	3	6	4	3	2	3			3	2		2	2	3
LS			2	4												4									2	2		

Rough periwinkles, on upper shore at Riven Noust (left). Adult and juvenile dogwhelks feeding on barnacles (right).

3.1.7 *Nucella lapillus* (dogwhelk)

A gradual recovery of dogwhelk populations (see photo above), following their decline at sites impacted by TBT antifouling paints, has been described in recent years from sites close to the oil terminal. However, their average abundance across the Sullom Voe sites still appears to be lower than it was in the 1980s. Moderately large fluctuations in average abundance continue to be seen at the reference sites, but with no notable trend. There were also large changes at some Sullom Voe sites, but also without any obvious trend.



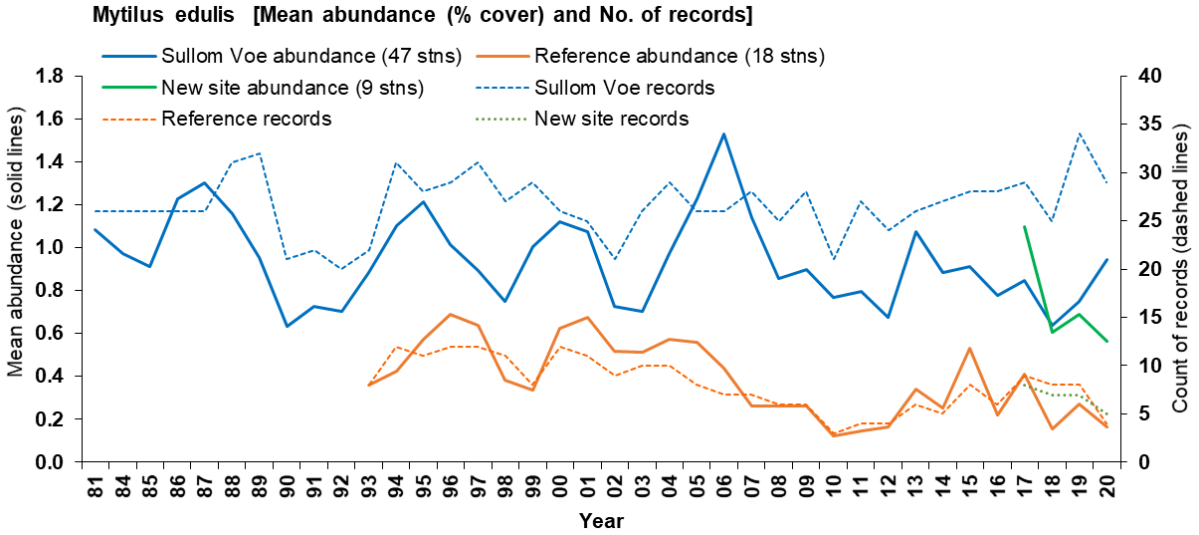
For more information on dogwhelk populations see the associated report from SOTEAG's dogwhelk monitoring programme, which was last repeated in 2018 (Moore, Anderson & Mercer, 2018). The next dogwhelk survey is planned for 2021.

3.1.8 *Mytilus edulis* (mussel)

Adult mussels (Mytilus edulis) at Voxter Ness (left); and juvenile mussels at West of Mioness (right).

Mussels (see photos below) have been recorded, at some time during the rocky shore programme, at almost every station on every site, but often only as juveniles. Sometimes, at some sites, these juvenile mussels can cover a high proportion of the rock surface, colonising space between the barnacles and limpets but rarely surviving to maturity. Adult mussels are regularly recorded from a relatively small number of sites and stations, Voxter Ness being the most notable. Juveniles and adults are not recorded separately, so the fluctuations and trends shown in the graph below are for both. It suggests that percentage cover of mussels was relatively low at reference sites in 2020 and were trending low at Sullom Voe sites until a recent increase. The table below shows that cover has been

generally lower in the last few years at most sites (particularly Voxter Ness), but it is not clear if this is a trend.



Mytilus edulis (sum of abundance scores from five stations, by site and year)

		81	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
Sullom Voe	West of Mioness	12	9	9	11	11	11	11	7	7	8	11	9	9	11	8	9	9	11	11	10	8	9	10	11	10	10	10	8	10	7	9	9	10	10	7	8	6	7
	Roe Clett	8	8	8	8	12	11	11	3	7	5	5	9	9	8	6	7	6	7	8	8	8	9	12	10	11	10	10	10	10	9	7	7	9	7	8	6	6	8
	Noust of Burraland	7	7	7	7	7	7	6	8	8	3	6	8	7	8	6	6	7	5	7	5	6	6	5	8	5	5	8	6	4	8	10	7	10	5	9	6	8	9
	Gluss Island East	7	7	7	8	9	7	10	9	9	11	6	6	7	6	7	7	9	11	9	2	7	8	8	9	7	4	6	7	9	0	10	8	7	7	7	7	7	7
	South of Swarta Taing	6	6	6	7	6	9	8	5	5	3	5	6	8	7	6	6	7	8	8	7	4	7	6	7	7	5	5	5	5	5	5	6	4	4	6	6	5	7
	Grunn Taing	8	9	8	9	8	5	6	5	5	5	8	9	11	7	7	6	7	6	8	6	5	7	8	11	7	5	4	2	4	7	3	5	5	5	5	7	8	9
	The Kames	0	0	0	0	3	2	2	0	0	2	3	5	5	7	4	3	5	6	5	5	4	4	5	6	5	4	6	6	4	4	7	4	6	7	6	1	4	6
	Voxter Ness	11	11	11	11	11	11	8	11	11	10	13	12	12	11	12	12	11	10	8	9	9	10	9	9	9	7	6	9	9	7	8	9	9	9	7	7	4	5
	South of Skaw Taing	1	1	1	1	1	2	1	0	0	0	0	0	2	2	2	0	1	1	0	0	1	3	0	2	2	2	2	0	2	2	2	2	2	2	4	0	1	2
	Jetty 3	4	4	4	4	4	3	2	2	2	3	0	4	0	2	4	0	1	2	1	0	0	0	2	2	2	2	2	0	0	2	1	5	4	2	4	3	4	4
	Mavis Grind (Stream 3)	1	1	1	1	1	4	4	3	3	2	4	2	4	7	5	5	6	7	7	5	6	9	7	6	5	6	8	6	6	6	7	6	7	6	6	7	9	8
	Fugla Ayre	1	1	1	1	1	2	3	0	0	1	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
	South of Jetty 2	2	2	2	2	0	4	1	0	0	0	0	1	4	0	4	0	1	0	0	0	2	0	0	0	3	2	4	0	2	2	4	2	0	1	2	0	6	2
	Scatsta Ness (cleared)	3	3	3	3	3	7	5	2	2	3	0	6	2	7	5	3	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Scatsta Ness (uncleared)	0	0	0	0	0	1	1	0	0	0	0	4	2	0	3	2	2	0	0	0	0	1	4	0	2	2	0	0	0	0	0	0	0	2	0	0	2	0
Reference	Riven Noust											4	5	4	8	4	3	4	3	6	3	1	3	4	0	1	4	2	0	1	0	2	2	0	1	3	3	2	0
	Vidlin Ness											5	4	7	7	8	6	6	8	8	6	9	5	7	8	5	4	6	4	4	6	5	2	7	4	6	4	6	4
	Burgo Taing											7	4	5	5	7	3	4	4	5	2	2	4	2	2	2	2	2	2	2	0	4	2	4	2	2	2	4	0
	Kirkabister											0	6	3	2	4	5	1	6	4	6	5	9	4	5	3	0	0	0	0	0	3	3	6	2	5	1	2	2
	North Burra Voe											0	2	4	4	2	2	0	4	2	2	4	0	2	2	2	2	2	0	0	2	0	2	2	2	2	1	0	2
New refere.	Ola's Ness																																			7	6	7	7
	West Sandwick																																			4	3	4	0
	West Lunna Pund South																																			4	0	0	0
	West Lunna Pund North																																			3	4	3	4
	Croo Taing																																			0	0	0	0

3.1.9 *Porphyra* (purple laver)

Percentage cover of this red algae (see photo below), sometimes known as purple laver, can fluctuate dramatically. It is usually present in moderate or low abundance at many sites, but sometimes it can opportunistically smother areas of mid shore bedrock. The table below shows that these smothering events have occurred at several sites, most notably at Gluss Island East and South of Swarta Taing. They occurred frequently in the early 2000s, but less frequently in recent years.

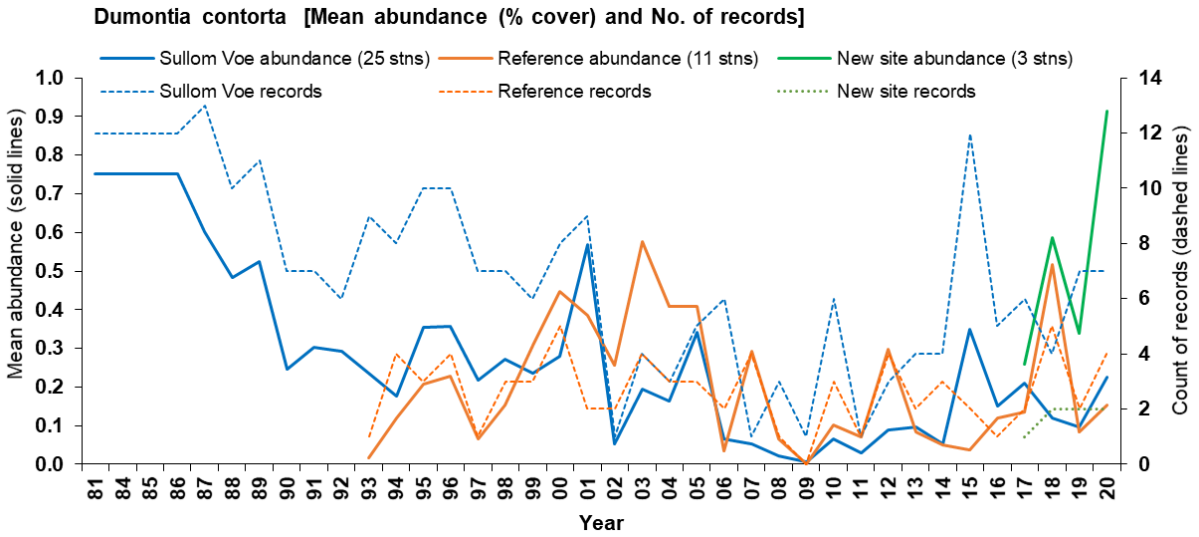
Porphyra (max of abundance scores from five stations, by site and year)

		81	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
Sullom Voe	West of Mioness	3	3	3	3	3	3	3	4	0	0	0	4	3	4	3	4	2	4	5	4	0	0	3	1	1	1	3	4	0	3	0	4	2	3	2	3	2	3
	Roe Clett	3	3	3	3	5	4	2	0	0	2	1	4	5	3	2	1	5	5	4	4	3	3	5	1	4	3	0	5	1	3	2	0	3	4	4	4	3	4
	Noust of Burraland	0	0	0	0	0	0	0	0	0	0	1	2	2	2	0	0	2	2	0	0	0	0	3	0	1	1	0	0	0	2	2	1	0	0	0	1	1	0
	Gluss Island East	1	0	0	1	5	0	1	1	1	6	1	2	1	2	4	4	5	6	5	3	4	6	6	5	0	1	2	6	5	1	4	4	2	4	6	4	3	2
	South of Swarta Taing	4	4	4	5	4	4	4	5	2	4	2	6	6	4	4	3	4	7	5	5	4	4	5	5	4	4	5	5	2	4	5	4	4	5	5	3	3	4
	Grunn Taing	3	2	3	3	5	3	3	3	3	2	1	4	3	2	3	4	5	5	4	4	4	4	5	2	2	3	2	3	3	4	4	5	4	3	4	4	4	2
	The Kames	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	1	3	3	0	3	0	0	3	0	0	1	2	1	2	3	1	0	3	0	0	3	1	2
	Voxter Ness	3	3	3	3	0	3	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	South of Skaw Taing	1	1	1	1	1	2	2	2	2	0	0	2	3	4	4	4	4	4	4	3	0	0	0	0	2	2	0	1	1	0	0	0	5	2	0	1	3	3
	Jetty 3	2	0	2	2	2	1	1	1	1	3	3	3	4	2	0	0	4	2	0	0	5	3	3	0	3	3	2	0	0	0	3	2	0	0	0	2	3	2
	Mavis Grind (Stream 3)	0	0	0	0	0	3	3	0	0	0	1	0	2	3	2	0	4	4	2	0	3	3	4	3	2	0	0	0	0	0	0	1	0	0	2	0	0	0
	Fugla Ayre	2	2	2	4	2	6	2	0	0	0	0	0	0	0	1	0	1	3	0	0	0	0	0	1	2	2	2	2	2	2	1	0	2	2	0	3	0	0
	South of Jetty 2	0	0	0	0	0	1	1	2	0	1	0	0	0	2	3	0	1	2	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0
	Scatsta Ness (cleared)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Scatsta Ness (uncleared)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reference	Riven Noust											2	2	4	5	3	2	3	4	4	4	3	7	3	2	2	4	2	4	3	3	1	3	3	3	2	3	1	2
	Vidlin Ness											3	4	2	2	5	5	5	4	4	4	3	4	3	1	3	3	6	0	5	2	2	1	0	4	2	5	2	0
	Burgo Taing											2	4	3	4	3	2	3	4	4	3	3	3	3	1	3	2	3	4	4	3	5	3	4	4	2	2	2	2
	Kirkabister											0	1	0	1	0	2	3	2	0	3	2	3	3	0	1	1	4	0	0	0	0	0	0	0	0	0	0	0
	North Burra Voe											0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
New refere.	Ola's Ness																																			0	3	0	0
	West Sandwick																																			0	3	1	2
	West Lunna Pund South																																			0	0	0	0
	West Lunna Pund North																																			0	0	0	0
	Croo Taing																																			0	0	2	2

Porphyra smothering midshore bedrock at South of Swarta Taing (left); and Dumontia contorta at Vidlin Ness (right).

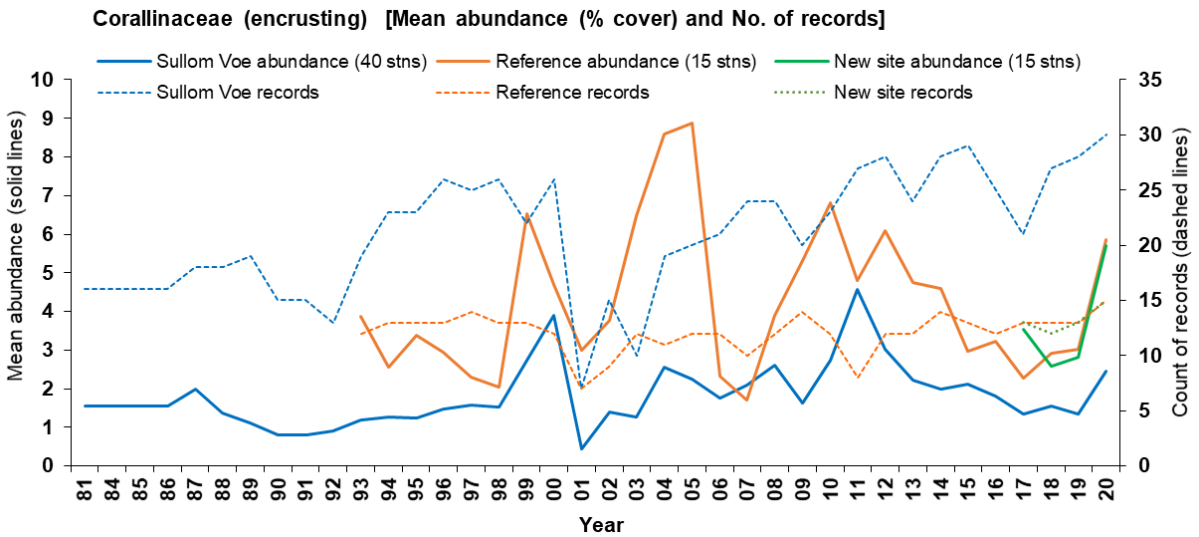
3.1.10 *Dumontia contorta* (a red alga)

It was noted in the 2018 report that the numbers of records of this red alga had increased slightly. An increase is now very apparent, as shown in the graph below. Notable increases in abundance have been recorded at South of Swarta Taing and Ola's Ness.



3.1.11 Encrusting coralline algae

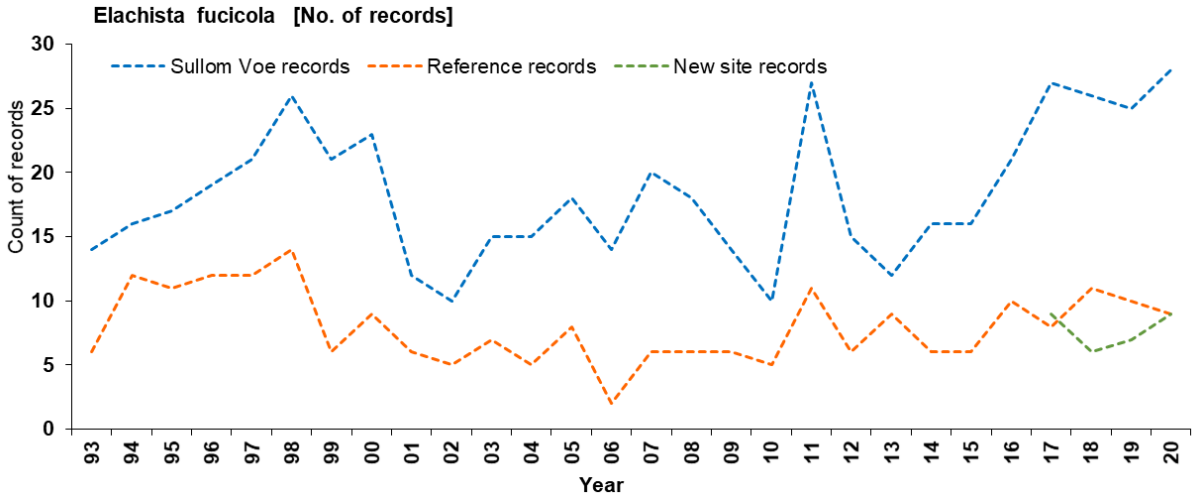
Encrusting corallines are common on lower shore rock (see photo below) and in other places on the shore which are permanently wet. As relatively slow growing species their recorded abundances fluctuate much more than expected. Consistency of recording is difficult to achieve as the crusts are often temporarily hidden beneath other fauna and flora and their appearance can range from striking pink to very pale and drab and inconspicuous. The records in some years are also possibly influenced by changes in algal surveyor. Nevertheless, the graph below shows a notable increase in average cover in 2020 and further inspection shows that this is due to moderate increases at many sites and stations. There were also more records of encrusting corallines in 2020 than in any previous survey for this programme. The increases were seen in Sullom Voe and the reference sites.



Encrusting coralline algae on the low shore at South of Skaw Taing (left); and tufts of Elachista fucicola on Fucus serratus at South of Skaw Taing (right).

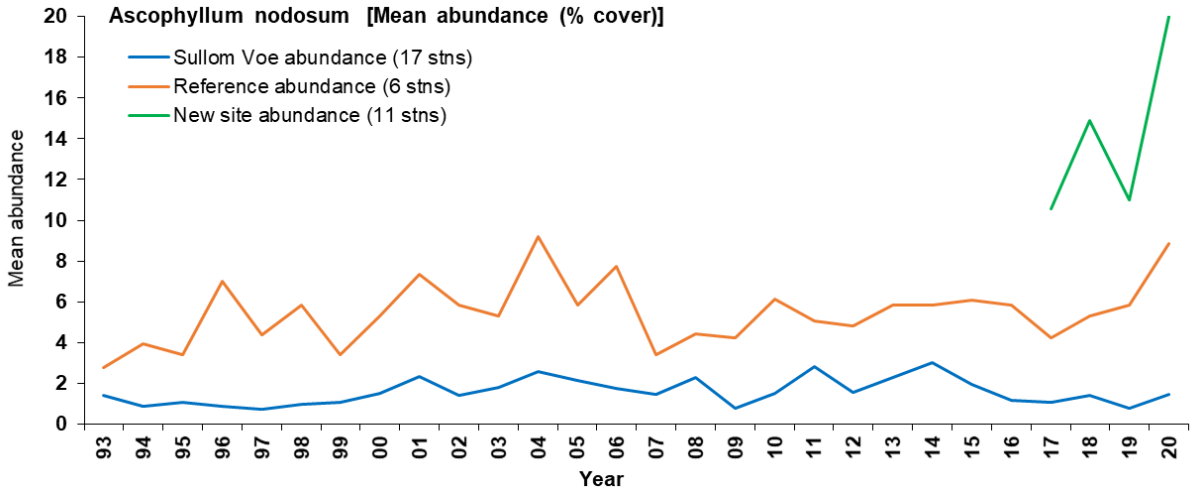
3.1.12 Elachista fucicola (brown filamentous alga)

Tufts of this filamentous brown alga (see photo above) are common epiphytes on the fronds of some lower shore fucoid algae. Estimating their abundance (percentage cover) is difficult, but numbers of records should be relatively consistent. The graph below shows that numbers of records in Sullom Voe have been increasing in recent years and were the highest ever recorded in 2020. Although this apparent trend was not seen at the reference sites it is considered to be a natural change.



3.1.13 *Ascophyllum nodosum* (knotted wrack)

Knotted wrack (see photo below) is only found in abundance at a few wave-sheltered sites. It suffered from various damaging activities associated with the terminal at sites in Sullom Voe during the 1970s (see Moore and Howson 2015, for more details) but populations recovered considerably and were likely back to pre-impact levels at all sites by 2013. More recent fluctuations in its abundance have been described in recent reports, and in 2020 there was a notable increase in average cover at the reference sites (see graph and table below).



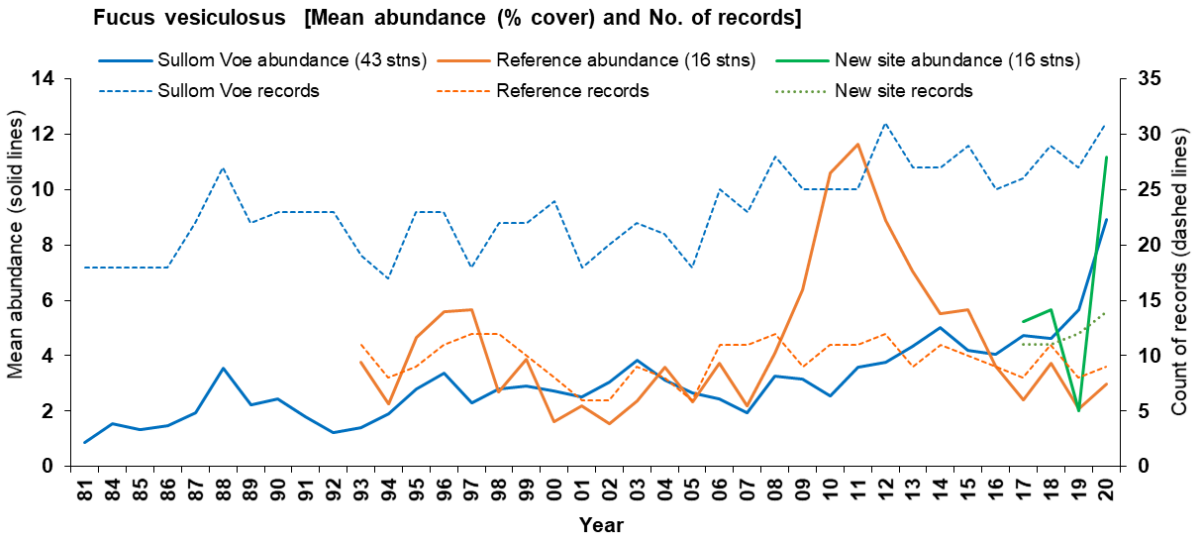
Ascophyllum nodosum (sum of abundance scores from five stations, by site and year)

		76	77	78	79	80	81	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
SV	Mavis Grind (Stream 3)					0	4	6	4	4	9	5	5	7	7	6	11	9	9	9	10	9	10	10	9	9	9	9	9	9	9	10	9	9	11	10	8	10	9	8	8	10	6	7
SV	South of Jetty 2	9	5	0	0	0	0	0	0	0	0	1	2	1	2	0	7	0	0	0	0	0	0	2	4	4	4	8	7	3	2	4	1	4	10	4	9	9	8	5	3	7	0	4
SV	Scatsta Ness (cleared)				8	3	6	6	6	6	8	7	6	8	9	7	6	4	7	8	8	5	9	10	12	8	11	12	13	13	10	10	10	15	16	12	17	14	18	15	14	15	9	
SV	Scatsta Ness (uncleared)				13	9	9	9	9	9	9	11	10	9	6	8	8	5	9	7	5	8	9	10	13	9	12	12	12	13	12	13	5	9	11	8	10	13	10	10	8	9	9	12
R	North Burra Voe																12	13	13	17	14	16	13	15	18	16	15	15	16	14	13	16	15	17	10	14	16	16	17	16	15	15	16	20
New	West Lunna Pund South																																								13	13	14	15
New	West Lunna Pund North																																								10	13	10	14
New	Croo Taing	16	14																																						16	20	15	20

Ascophyllum nodosum at Scatsta Ness (left). Fucus vesiculosus at South of Jetty 2.

3.1.14 *Fucus vesiculosus* (bladder wrack)

There was another notable increase in the average abundance of bladder wrack (see photo above) at Sullom Voe sites and also at the new reference sites, but only a small increase at the other reference sites (see graph below). The average abundance across the Sullom Voe sites was higher than any previous year, although the table below shows that abundances have been higher at a few individual sites.



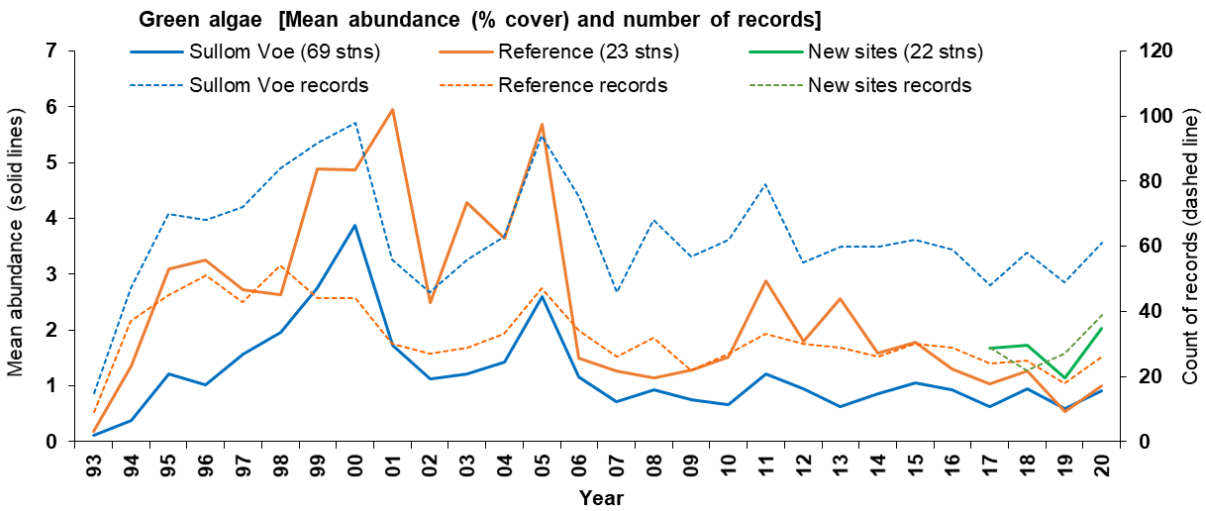
Fucus vesiculosus (sum of abundance scores from five stations, by site and year)

		76	77	78	79	80	81	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
Sullom Voe	West of Mioness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roe Clett	0	0	1	0	0	0	0	0	0	0	3	0	1	1	0	0	0	1	1	0	0	0	4	4	3	0	0	0	1	0	3	0	2	4	3	2	0	3	8	7	5	3	8
	Noust of Burraland	2	1	0	4	3	3	3	3	3	3	9	5	4	4	4	4	1	7	7	5	3	1	5	0	3	3	7	4	4	7	5	4	5	4	4	4	6	6	4	5	9	7	9
	Gluss Island East	0	0	1	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	3	3	0	0	0	3	6	1	3	3	2	1	2	2	0	4	5	6	10	9	9	9
	South of Swarta Taing	1	0	3	2	3	1	5	5	3	2	3	2	2	2	1	0	1	3	0	0	1	2	3	4	5	4	4	0	5	0	4	2	1	2	5	2	4	3	3	7	6	9	9
	Grunn Taing	6	10	7	12	7	1	1	1	1	6	12	3	10	9	4	5	4	3	2	0	3	3	3	0	3	7	9	4	9	9	8	8	2	2	4	1	5	5	4	7	8	7	11
	The Kames	2	0	1	1	4	0	0	0	0	2	0	0	0	0	0	1	1	1	2	3	4	3	2	0	0	1	3	0	4	3	7	7	5	4	8	7	4	3	3	4	3	4	6
	Voxter Ness	4	4	1	0	1	7	7	9	7	7	9	7	6	5	4	1	0	3	2	5	6	6	6	6	8	8	7	8	7	6	6	7	6	9	11	9	10	11	8	8	7	9	12
	South of Skaw Taing	3	4	3	3	3	2	2	2	2	5	2	5	5	5	5	6	5	5	13	6	5	5	4	5	4	5	6	5	6	6	11	11	11	8	8	10	9	9	10	6	8	8	8
	Jetty 3	5	9	6	0	0	1	5	6	6	16	17	16	15	11	9	16	14	17	15	14	16	17	12	13	15	13	10	15	13	11	11	15	19	17	15	18	15	15	13	13	14	13	14
	Mavis Grind (Stream 3)					6	13	13	13	13	10	12	11	8	8	9	0	8	10	9	9	7	8	8	4	5	9	3	5	8	7	8	6	3	7	5	7	8	9	7	7	7	7	8
	Fugla Ayre	10	13	13	11	9	7	7	5	8	5	9	6	10	9	10	9	7	7	13	5	11	9	12	14	13	13	7	4	1	4	4	3	0	7	9	15	15	10	10	9	11	10	10
	South of Jetty 2	7	8	0	2	8	7	11	7	14	11	9	10	9	8	5	7	10	17	16	15	17	15	13	12	13	16	16	14	10	9	15	15	17	17	14	15	16	13	13	12	13	17	17
	Scatsta Ness (cleared)				8	4	21	24	21	21	22	18	16	19	19	16	16	12	15	17	19	16	16	16	15	15	16	15	17	18	15	19	17	18	17	17	21	21	19	19	14	19	16	
	Scatsta Ness (uncleared)				12	5	4	5	5	4	6	14	15	14	10	11	12	14	15	16	15	15	17	12	13	13	16	15	13	14	13	14	16	15	16	14	16	15	14	16	14	12	13	14
Reference	Riven Noust		0														0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Vidlin Ness		8	7	4	4											10	5	11	13	13	9	9	1	3	3	7	3	0	2	4	8	10	19	15	16	11	14	14	9	8	11	8	12
	Burgo Taing																6	6	9	9	10	10	6	6	5	4	6	13	5	11	8	9	9	14	9	9	9	8	9	5	4	8	6	7
	Kirkabister		14	15	14	12											15	12	14	13	14	13	17	12	14	13	13	16	15	11	11	14	17	18	21	19	17	17	12	17	14	16	10	11
	North Burra Voe																7	6	5	8	9	6	7	6	4	3	8	4	8	14	10	9	8	5	5	9	9	6	6	6	4	7	6	6
New refere.	Ola's Ness		5																																						9	9	7	10
	West Sandwick																																								12	11	8	15
	West Lunna Pund South																																								4	6	5	10
	West Lunna Pund North																																								13	14	11	14
	Croo Taing	7	6																																						6	4	3	10

3.1.15 Green algae

Green algae, comprising *Ulva* (tubular and flat forms), *Cladophora*, *Codium* and various other taxa, showed modest increases in average abundance (percentage cover) at Sullom Voe sites and reference sites (see graph below). Much of the increases were due to Ulva (tubular and flat) (see photo below), but there were also notable increases in Cladophora (see photo below), particularly on the lower shore at The Kames where it was recorded as Abundant. In general, however, abundances of green algal were still low compared to some previous years.

Acrosiphonia arcta was again recorded on the low shore at Roe Clett.



Ulva (flat) at Riven Noust (left). Cladophora rupestris at Riven Noust (right).

3.2 Site-specific descriptions

3.2.1 Orka Voe bund

Orka Voe bund: EOR pipeline crossing (left). View along bund from the EOR pipeline (right).

The bund, created when Orka Voe was filled in during the construction of the terminal in the late 1970s, is visited during the annual survey for a brief assessment of the condition of the rocky shore

communities present. Attention is paid to the area of disturbance caused by the installation of the Magnus EOR pipeline in 2004/2005.

There were no notable changes in habitat or communities along the bund or at the EOR pipeline crossing compared to recent years.

3.2.2 Additional reference sites

The five additional reference sites were relocated and surveyed successfully. Site specific changes will be considered in future reports when there is more data to analyse.

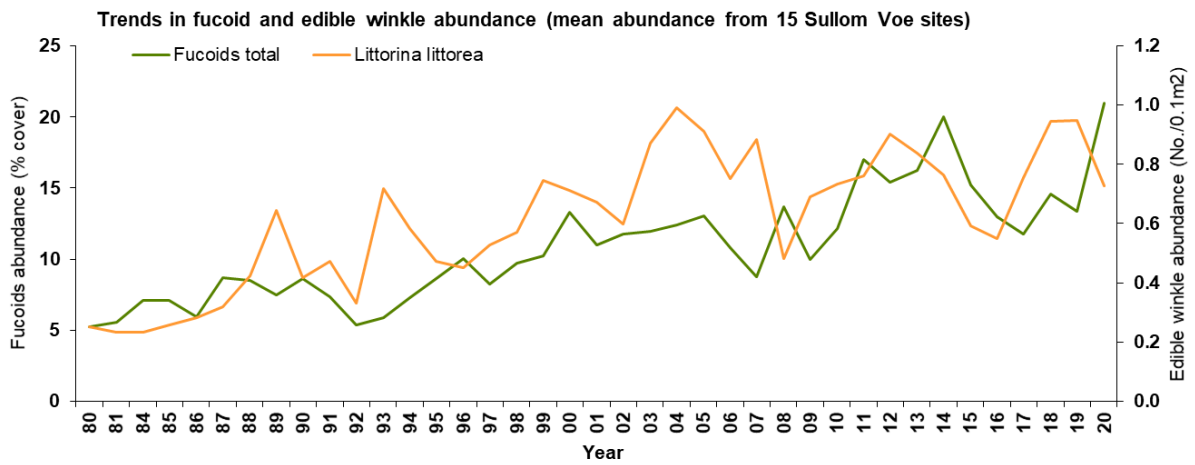
4 Discussion

4.1 Changes in rocky shore communities

There were few notable changes in rocky shore communities around Sullom Voe between 2019 and 2020. All of the fluctuations described in the results sections are considered to be natural and mostly within typical levels for those shores and the survey methodology.

Previous reports in this programme have highlighted the long-term trends of increasing abundance of various fucoid algae (*Fucus vesiculosus*, *F. serratus*, *Pelvetia canaliculata*). Recent literature (Burrows et al. 2017, Mieszkowska et al. 2020, Burrows et al. 2020) have shown that increases of those and other large brown macroalgae have occurred widely around Scotland and have linked the increases to climate change. The SOTEAG data has also shown long-term trends in other taxa, notably an increase in *Littorina littorea* densities, but any evidence of these trends outside Shetland are not known to the author.

The graph below shows an intriguingly high level of correlation between total fucoid cover and *Littorina littorea* densities. Whether this correlation is coincidental or due to a causal relationship (direct or indirect) is not known. Studies described in the literature (e.g. Lubchenco 1983, Janke 1990, Little et al. 2009) show that the ecological relationships between these species may be complex and different in different environments. *L. littorea* feeds mainly on green algae rather than fucoids, and one suggestion in the literature is that this grazing action can give an advantage to fucoids which compete for space with green algae.



4.2 Effects of terminal operations and oil spills

During the period 1st August 2019 to 31st August 2020 there was one very small pollution incident reported within Sullom Voe (Simon Skinner, pers. comm.):

- 11th October 2019 Rainbow sheen from oil (possibly marine diesel) impregnated within the mooring line from tanker Front Castor.

This pollution is unlikely to have caused any notable ecological impacts.

Terminal activities during the past 12 months appear to have had no obvious impacts upon the rocky shore communities of Sullom Voe.

4.3 Additional Reference sites

The recommended (Jenkins 2015) increase to the suite of Reference sites was implemented in 2017. The ten Reference sites will provide improved statistical comparisons with changes at the Sullom Voe sites. It will take a few years of surveys before the new sites provide sufficient data to become well integrated into the data analyses. Meanwhile, comparisons between data from 2019 and 2020 show levels of fluctuations that are typical for the monitoring sites in the SOTEAG rocky shore programme.

4.4 Methodology: site relocation

The relocation error at Scatsta Ness (cleared) was unfortunate, but it was interesting to see the scale of the differences in the survey data where the stations had been wrongly relocated. Table 5 shows the main species abundance differences between the correct and incorrect locations, 2019 and 2020 respectively. They emphasize the importance of correct transect relocation year on year.

Table 5 SACFOR abundances recorded at the five stations on the Scatsta Ness (cleared) transect in 2019 (the correct station locations) and 2020 (wrong locations) for selected taxa showing notable differences. Colours differentiate the zones

Zone	Species name	2019	2020
US	Pelvetia canaliculata	4	2
UMS	Actinia equina	3	
UMS	Littorina obtusata	6	3
UMS	Nucella lapillus	4	
UMS	Ascophyllum nodosum	3	
UMS	Fucus spiralis		5
UMS	Fucus vesiculosus	4	
UMS	Pelvetia canaliculata		3
MS	Carcinus maenas	3	
LMS	Steromphala cineraria	3	
LMS	Nucella lapillus	5	3
LMS	Gelidium pulchellum		3
LMS	Ascophyllum nodosum	2	4
LS	Patella vulgata		3
LS	Steromphala cineraria	4	
LS	Littorina obtusata	3	5
LS	Corallinaceae (encrusting)	6	4
LS	Chondrus crispus	3	1
LS	Ascophyllum nodosum		5
LS	Fucus serratus	7	3
LS	Fucus vesiculosus		7

The new site and station markers and new relocation information sheets will greatly reduce the risk of such errors in future surveys.

5 References

Baker, J.M. and Crothers, J.H. (1987) Intertidal rock. In: Baker, J.M. and Wolff, W.J. (eds.) *Biological Surveys of Estuaries and Coasts*. Estuarine and Brackish Water Sciences Association handbook. Cambridge University Press. 157-197.

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Appendix 1 Abundance scales used for intertidal organisms

Adapted slightly from Baker & Crothers 1987 (page 170).

1. Live barnacles (record adults, spat, cyprids separately); *Melarhaphe neritoides; Littorina saxatilis (ecotype neglecta)* 7 Ex 500 or more per 0.01 m^2, 5+ per cm^2 6 S 300-499 per 0.01 m^2, 3-4 cm^2 5 A 100-299 per 0.01 m^2, 1-2 per cm^2 4 C 10-99 per 0.01 m^2 3 F 1-9 per 0.01 m^2 2 O 1-99 per m^2 1 R Less than 1 per m^2	**7. *Spirobranchus* sp.** 5 A 50 or more tubes per 0.01 m^2 4 C 1-49 tubes per 0.01 m^2 3 F 1-9 tubes per 0.1 m^2 2 O 1-9 tubes per m^2 1 R Less than 1 tube per m^2
2. *Perforatus perforatus – not applicable in Shetland*	**8. Spirorbinae** 5 A 5 or more per cm^2 on appropriate substrata; more than 100 per 0.01 m^2 generally 4 C Patches of 5 or more per cm^2; 1-100 per 0.01 m^2 generally 3 F Widely scattered small groups; 1-9 per 0.1 m^2 generally 2 O Widely scattered small groups; less than 1 per 0.1 m^2 generally 1 R Less than 1 per m^2
3. *Patella* spp. 10 mm+, *Littorina littorea* (juv. & adults), *Littorina obtusata/fabalis* (adults), *Nucella lapillus* (juv., <3 mm). 7 Ex 20 or more per 0.1 m^2 6 S 10-19 per 0.1 m^2 5 A 5-9 per 0.1 m^2 4 C 1-4 per 0.1 m^2 3 F 5-9 per m^2 2 O 1-4 per m^2 1 R Less than 1 per m^2	**9. Sponges, hydroids, Bryozoa** 5 A Present on 20% or more of suitable surfaces. 4 C Present on 5-19% of suitable surfaces 3 F Scattered patches; <5% cover 2 O Small patch or single sprig in 0.1 m^2 1 R Less than 1 patch over strip; 1 small patch or sprig per 0.1 m^2
4. *Littorina 'saxatilis', Patella* <10 mm, *Anurida maritima, Hyale nilssoni* and other amphipods, *Littorina obtusata/fabalis* juv. 7 Ex 50 or more per 0.1 m^2 6 S 20-49 per 0.1 m^2 5 A 10-19 per 0.1 m^2 4 C 5-9 per 0.1 m^2 3 F 1-4 per 0.1 m^2 2 O 1-9 per m^2 1 R Less than 1 per m^2	**10. Flowering plants, lichens, encrusting coralline algae** 7 Ex More than 80% cover 6 S 50-79% cover 5 A 20-49% cover 4 C 1-19% cover 3 F Large scattered patches 2 O Widely scattered patches all small 1 R Only 1 or 2 patches
5. *Nucella lapillus* (>3 mm), *Gibbula* sp., *Actinia equina, Idotea granulosa, Carcinus* (juv. & recent settlement), *Ligia oceanica* 7 Ex 10 or more per 0.1 m^2 6 S 5-9 per 0.1 m^2 5 A 1-4 per 0.1 m^2 4 C 5-9 per m^2, sometimes more 3 F 1-4 per m^2, locally sometimes more 2 O Less than 1per m^2, locally sometimes more 1 R Always less than 1 per m^2	**11. Algae (non-encrusting)** 7 Ex More than 90% cover 6 S 60-89% cover 7 5 A 30-59% cover 4 C 5-29% cover 3 F Less than 5% cover, zone still apparent 2 O Scattered plants, zone indistinct 1 R Only 1 or 2 plants
6. *Mytilus edulis, Dendrodoa grossularia* 7 Ex 80% or more cover 6 S 50-79% cover 5 A 20-49% cover 4 C 5-19% cover 3 F Small patches, 5%, 10+ small individuals per 0.1 m^2, 1 or more large per 0.1 m^2 2 O 1-9 small per 0.1 m^2 1-9 large per m^2; no patches except small in crevices 1 R Less than 1 per m^2	**Other animal species**: record as percentage cover or approximate numbers within 0.01, 0.1 or 1 m^2

Appendix 2 Chronology of personnel changes and methodology during SOTEAG rocky shore monitoring programme

Contractors: Oil Pollution Research Unit (OPRU), Field Studies Council Research Centre (FSCRC), Cordah Ltd., BMT Cordah Ltd., Aquatic Survey & Monitoring Ltd. (ASML)

Survey staff: Annette Little (AL), Tony Thomas (AT), Ben James (BJ), Christine Howson (CH), Cait Moore (CM), David Emerson (DE), David Levell (DL), Francis Bunker (FB), Frank Fortune (FF), Harry Goudge (HG), Heather Howcroft (HH), John Addy (JA), Jenny Baker (JB), John Crothers (JC), John Hartley (JH), Jon Moore (JM), Keith Hiscock (KH), Kingsley Iball (KI), Kirsten Laurenson (KL), Kristofer Wilson (KW), Lou Luddington (LL), Peter Taylor (PT), Sue Hiscock (nee. Hainsworth) (SH), Tom Mercer (TM).

Sites: No. of sites within Sullom Voe and adjacent part of Yell Sound + No. of reference sites (*dogwhelks* refers to the associated monitoring of dogwhelks; see Moore *et al.* 2018)

Year	**Contractor**	**Survey staff**	**Sites**	**Stns**	**Methods** (see Moore 2013 for explanation)	**Month**
1976	OPRU	JB, KH, SH, DL, JA, JH	30 + 4	All	Full survey	May
1977	OPRU	JB, SH, KH, JC, DE, AT	34 + 9	All	Full survey	May
1978	OPRU	KH, JC, AT, AL	18 + 2	All	Full survey	May
1979	OPRU	KH, AT, DE, HH	21 + 2	All	Full survey	May
1980	OPRU	KH, JC, DE, AT	25 + 2	All	Full survey	May
1981	OPRU	KH, DE, AT, KI	25 + 2	All	Full survey	May/June
1982	Not surveyed					
1983	Not surveyed					
1984	OPRU	KH	25	All	Rapid survey	August
1985	OPRU	KH	25	All	Rapid survey	August
1986	OPRU	KH	25	All	Rapid survey	August
1987	OPRU	CH	23	All	Rapid survey	August
1988	FSCRC (OPRU)	CH, AL	23	All	Rapid survey, reestablishment of 6 transects	August
1989	FSCRC (OPRU)	AL, TM	23	All	Rapid survey, reestablishment of 2 transects	August
1990	FSCRC (OPRU)	JM, PT	23	All	Rapid survey	August
1991	FSCRC (OPRU)	JM, PT	23	All	Rapid survey (+ dogwhelks)	August
1992	FSCRC (OPRU)	PT, JM	23	All	Rapid survey	July/Aug
1993	FSCRC (OPRU)	JM, PT	15 + 5	5	Full survey (+ dogwhelks)	August
1994	FSCRC (OPRU)	JM, AL	15 + 5	5	Full survey	August
1995	FSCRC (OPRU)	JM, AL	15 + 5	5	Full survey (+ dogwhelks)	August
1996	OPRU	JM, AL	15 + 5	5	Full survey	August
1997	OPRU	JM, AL	15 + 5	5	Full survey (+ dogwhelks)	August
1998	Cordah	JM, BJ	15 + 5	5	Full survey	August
1999	Cordah	BJ, JM	15 + 5	5	Full survey (+ dogwhelks)	July/Aug
2000	Cordah	JM, BJ	15 + 5	5	Full survey	August
2001	BMT Cordah	FF, JM	15 + 5	5	Full survey (+ dogwhelks)	July/Aug
2002	BMT Cordah	FF, JM	15 + 5	5	Full survey	July
2003	BMT Cordah	FF, JM	15 + 5	5	Full survey	July/Aug
2004	BMT Cordah	JM, FF	15 + 5	5	Full survey (+ dogwhelks)	July/Aug
2005	BMT Cordah	JM, FF	15 + 5	5	Full survey	July
2006	ASML	JM, CH	15 + 5	5	Full survey	August
2007	ASML	JM, LL	15 + 5	5	Full survey (+ dogwhelks)	July/Aug
2008	ASML	JM, CH	15 + 5	5	Full survey	August
2009	ASML	JM, CH	15 + 5	5	Full survey (+ dogwhelks)	August
2010	ASML	JM, CH	15 + 5	5	Full survey	July/Aug
2011	ASML	JM, HG	15 + 5	5	Full survey (+ dogwhelks)	August
2012	ASML	JM, CH	15 + 5	5	Full survey	July

Year	**Contractor**	**Survey staff**	**Sites**	**Stns**	**Methods** (see Moore 2013 for explanation)	**Month**
2013	ASML	JM, CH	15 + 5	5	Full survey (+ dogwhelks)	July
2014	ASML	JM, CH	15 + 5	5	Full survey	July/Aug
2015	ASML	JM, CH	15 + 5	5	Full survey (+ dogwhelks)	July
2016	ASML	JM, TM	15 + 5	5	Full survey	July
2017	ASML	JM, FB, KL	15 + 10	5	Full survey (5 additional reference sites)	July
2018	ASML	JM, TM, CM, KL	15 + 10	5	Full survey (+ dogwhelks)	August
2019	ASML	JM, FB, CM, KW	15 + 10	5	Full survey	August
2020	ASML	JM, TM, CM	14 + 10	5	Full survey	August