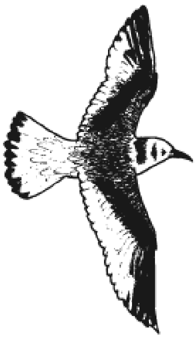
SOTEAG

Survey of the rocky shores in Sullom Voe

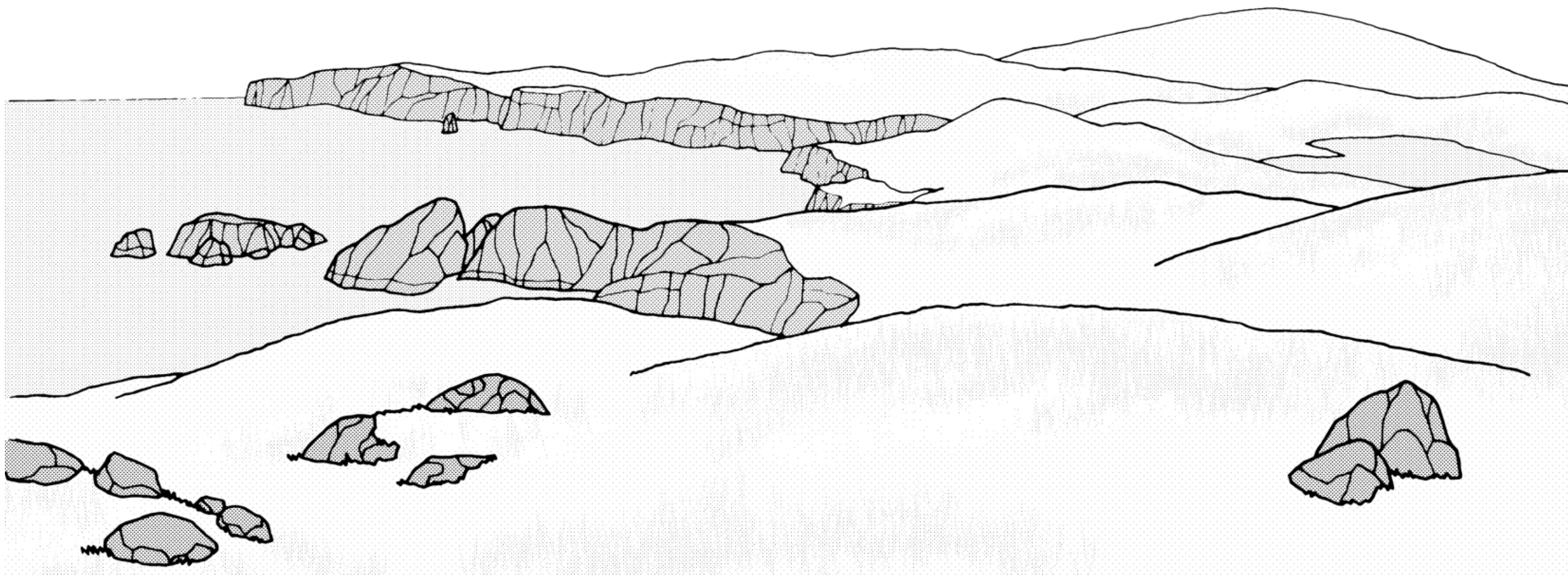


2018

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 2018

A report for SOTEAG

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Acknowledgements

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Data access

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 2018 – the 41st survey since the programme's inception.

The 2018 survey was carried out with a methodology and strategy adopted in 1993. Earlier data is still directly comparable for analyses. The fifteen original transects in Sullom Voe and the 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.

Comparisons of recorded abundances, field notes and photographs from the 2018 survey with those from the 2017 survey and previous surveys have been carried out.

Rocky shore communities at the twenty-five sites in 2018 were generally very like 2017. The most notable features are listed below:

- A single specimen of the southern barnacle *Chthamalus montagui* was recorded from a reference site on north mainland. Possibly the most northerly record for the species.
- Abundance of the barnacle *Semibalanus balanoides* increased at all survey sites, but this was due in part to seasonal difference in survey time (later than usual by approximately one month). Barnacle spat abundances were lower than usual.
- Limpet, *Patella vulgata*, densities in Sullom Voe were very similar to 2017, but abundances at Reference sites showed a notable decrease. However, this is considered to be within the cycle of natural population fluctuations.
- Abundances of both *Littorina littorea* and *Littorina obtusata* / *fabalis* increased slightly.
- Populations of dogwhelks between the Sullom Voe terminal jetties had increased again and are now back to abundances similar to pre-TBT[1] levels. Recovery of the populations at a site in Vidlin Voe is also continuing, but numbers are not yet back to pre-TBT levels.
- More records of the red alga *Dumontia contorta* have been recorded in recent years, but not yet as many as there were before 2002.
- The long-term trend of increasing abundance of fucoid algae (including *Pelvetia canaliculata*, *Fucus* (*spiralis*/*guiryi*), *Fucus vesiculosus*, *Ascophyllum nodosum*, *Fucus serratus*) continues. There were more potential records of the newly described species *Fucus guiryi*, but identification has not yet been confirmed.
- Numbers of records of the low shore alga *Himanthalia elongata* has decreased slightly in recent years.
- Numerous records of the green alga *Acrosiphonia arcta* have been obtained at various sites in the last three years. Previous records have been sparse.

All of the changes summarised above are considered to be within the bounds of natural fluctuations.

No oil spills were reported in the period between July 2017 and August 2018, and there were no observed impacts on rocky shore communities from terminal activities.

[1] Tributyltin.

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 41-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 2018, highlighting changes that have occurred since the survey in July 2017 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 and five reference sites were established outside the Voe. 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.

The various changes in sites, transect stations surveyed, survey month and survey personnel that have occurred over the 41 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 2018

Fieldwork was carried out by Jon Moore and Tom Mercer between the 10th and 16th August 2018, with assistance from Cait Moore, Kirsten Laurenson and Michael Barnes on some days. 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 2018, 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	12/08/2018	HU 41828 79071
2-3	Roe Clett	8, 11, 14, 17, 20	12/08/2018	HU 39437 78127
3-3	Noust of Burraland	1, 3, 5, 7, 10	13/08/2018	HU 37201 75186
3-4	Gluss Island East	6, 9, 11, 13, 15	11/08/2018	HU 37711 77551
3-5	S. of Swarta Taing	4, 7, 10, 12, 15	12/08/2018	HU 40160 77901
4-1	Grunn Taing	3, 5, 7, 9, 11	11/08/2018	HU 37942 78992
4-3	The Kames	5, 7, 9, 12, 15	14/08/2018	HU 38437 76459
4-6	Voxter Ness	5, 8, 10, 12, 14	14/08/2018	HU 36084 70089
5-1	S. of Skaw Taing	9, 12, 15, 18, 20	13/08/2018	HU 39621 78236
5-2	Jetty 3	5, 7, 9, 11, 13	16/08/2018	HU 38594 75578
5-5	Mavis Grind	3, 5, 7, 9, 12, 14	12/08/2018	HU 34054 68462
6-1	Fugla Ayre	3, 5, 7, 9, 11	13/08/2018	HU 37342 74182
6-2	S. of Jetty 2	3, 6, 9, 11, 13	16/08/2018	HU 39163 75089
6-12	Scatsta Ness (cleared)	2, 4, 6, 7, 8	15/08/2018	HU 38874 73544
6-13	Scatsta Ness (uncleared)	4, 5, 8, 10, 12	15/08/2018	HU 38976 73524
	Orka Voe bund		14/08/2018	
Reference sites				
2-9	Riven Noust	13, 17, 19, 22, 24	13/08/2018	HU 50774 73063
3-8	Vidlin Ness	5, 7, 9, 10, 12	15/08/2018	HU 47998 66267
3-10	Ola's Ness	4, 7, 9, 11, 13	11/08/2018	HU 35332 83092
3-12	Burgo Taing	3, 6, 9, 11, 13	16/08/2018	HU 37381 89088
4-7	West Sandwick	1, 2, 3, 4, 5	10/08/2018	HU 44583 86955
5-8	West Lunna Pund South	1, 2, 3, 4, 5	14/08/2018	HU 47829 69044
6-3	Croo Taing	7, 9, 11, 12, 14	10/08/2018	HU 43282 78645
6-11	Kirkabister	4, 6, 8, 10, 12	15/08/2018	HU 48460 66257
6-14	N. Burra Voe	4, 6, 8, 10, 12	16/08/2018	HU 37220 89378
6-15	West Lunna Pund North	1, 2, 3, 4, 5	14/08/2018	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 2018. The stations surveyed are listed in Table 1.

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.

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.

2.3 Data analysis

The data from the survey were entered into a computer spreadsheet (*Microsoft Excel*). They were then transferred to a more versatile database package (*Microsoft Access*) that holds the data from previous surveys, for further analysis. 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 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 2017 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, the numbers should not be summed or averaged. 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 monitoring stations is 75 (15 sites x 5 stations). The maximum number of reference stations is 25 (5 sites x 5 stations). Data from the new reference sites are not yet included in the average abundance calculations because they are inadequate (i.e. too few years) for useful temporal analysis. 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.

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 full copy of the database, up to 2016, 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.

Figure 1 Location of rocky shore transect sites. Surveys of rocky shores in the region of Sullom Voe, Shetland, August 2018. ★ Sullom Voe sites, ★ old Reference sites (established 1993), ★ new Reference sites (established 2017).

Table 3 Changes in categorical abundance of selected species between 2017 and 2018 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 reduced in abundance by three categories at 9% of stations.

	Abundance changes in Sullom Voe stations										
	-5	-4	-3	-2	-1	0	1	2	3	4	5
Spirorbinae		3	6	3	6	68	3		3	6	
Cirripedia (spat)			9	16	16	3	14	9			
Cirripedia (dead)			2		15	5	17	8			
Semibalanus balanoides					2	4	32	18			
Patella (juvenile, <10mm)				9		64	9	14	5		
Patella vulgata				6	23	4	13	6	3		
Littorina littorea			7	2	13	3	15	13	9	4	
Littorina obtusata				15	10	42	8	12	6	8	
Littorina saxatilis (eco. neglecta)		1		3	9	6	12	4	6		
Littorina saxatilis			5	14	16	47	8	5	3	1	
Nucella lapillus		2	4	10	10	51	8	6	2	6	
Mytilus edulis			2	13	13	57	9	6			
Porphyra		2		8	2	70	8	4	6		
Dumontia contorta			7	7	3	72	3	3	3		
Corallinaceae (encrusting)			2	2	17	4	13	15	4	2	
Corallina					21	55	10	10	3		
Mastocarpus stellatus				2	2	84		5	7		
Chondrus crispus		3	6	3	6	56	9	15	3		
Lomentaria articulata				16	5	79					
Osmundea hybrida				10		70	5	15			
Osmundea pinnatifida				4	4	6	16	8	4		
Fucus (spiralis/guiryi)			2		5	76	7	7	2		
Fucus serratus				3	17	53	11	6	3	8	
Fucus vesiculosus			2	2	15	62	9	2	4	4	
Pelvetia canaliculata				3	14	52	10	17	3		
Ulva (tubular)		2	3	7	8	5	18	5		2	
Cladophora				4	6	5	17	19	2		
Verrucaria		1	5	12	29	2	17	4	4		

	Abundance changes in Reference stations										
	-5	-4	-3	-2	-1	0	1	2	3	4	5
Spirorbinae					13	75		4	4	4	
Cirripedia (spat)		2	10	22	15	37	12	2			
Cirripedia (dead)			2	5	10	56	17	10			
Semibalanus balanoides					12	45	43				
Patella (juvenile, <10mm)		4	4	17	9	61		4			
Patella vulgata				10	35	53	3				
Littorina littorea			7	7	7	48	19	4	4	4	
Littorina obtusata				11	11	49	17	6	6		
Littorina saxatilis (eco. neglecta)				5	13	71	3	5	3		
Littorina saxatilis		2	2	20	9	52	2	13			
Nucella lapillus		3	3	16	6	34	19	9	6		3
Mytilus edulis			3	14	21	48	10	3			
Porphyra				5		50	1	15	15		5
Dumontia contorta						73		13	13		
Corallinaceae (encrusting)		3	3	7	10	53	17	3	3		
Corallina				8		23	3	15	15		
Mastocarpus stellatus			5	14	27	50			5		
Chondrus crispus						42	1	26	16	5	
Lomentaria articulata				8	15	38	2	15			
Osmundea hybrida					17	58	17	8			
Osmundea pinnatifida					11	56	22	11			
Fucus (spiralis/guiryi)		5		5	14	45	5	18	5	5	
Fucus serratus				5	16	47	16	11	5		
Fucus vesiculosus			7	3	3	50	20	3	10	3	
Pelvetia canaliculata					19	38	38	6			
Ulva (tubular)			3	8	11	54	16	8			
Cladophora				3	19	42	1	13	6		
Verrucaria	2	2	2	17	25	25	13	8	4	2	

3 Results

3.1 Fluctuations in abundance of selected species

Table 3 provides a summary of the abundance changes that occurred between July 2017 and August 2018 for the most frequently recorded taxa. The majority of these changes continued to reflect natural variability from year to year, but there were notable changes in some species and at some sites.

The following sections describe the results for selected characterising species and others that have shown notable changes. The mean abundance graphs have been prepared using the methodology described in Section 2.3, for Sullom Voe sites and Reference sites.

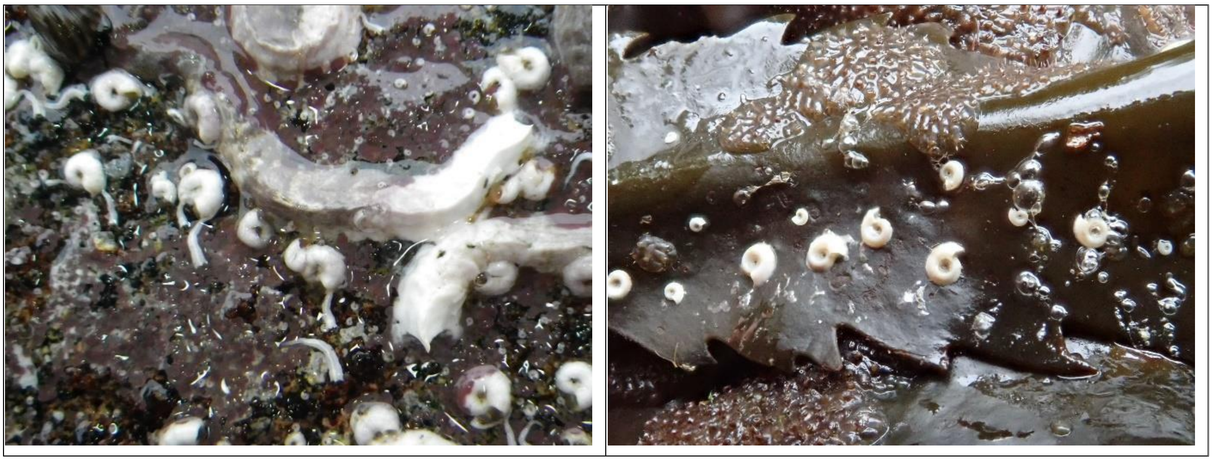
Other tables of data have been prepared from the species abundance data, with colour coding (conditional formatting features in Excel) to highlight patterns in those abundances between years, sites and species.

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).

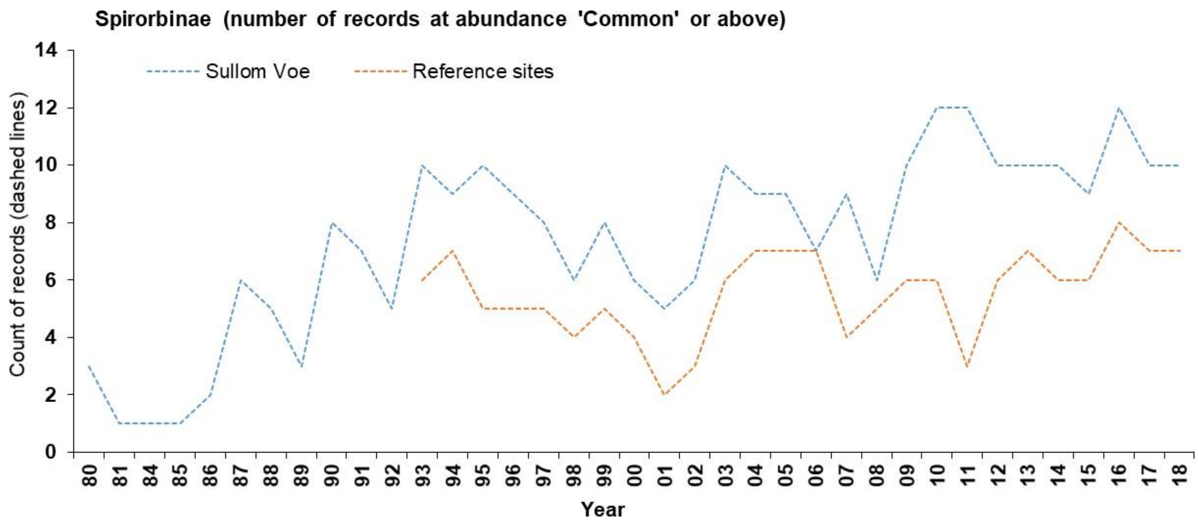
Note: for readers with the electronic version of this report, the species names in the section headings below contain hyperlinks to relevant pages on their biology on the MarLIN website.

3.1.1 Spirorbid worms (Spirorbinae)

Spirorbinae include a number of tube dwelling worms that can be common on various lower intertidal substrata (particularly *Fucus serratus* fronds, various red algae and shaded rock, (see photos below)). They are recorded as the aggregate group because identifying and apportioning abundances to the individual species would take too much time. Furthermore, their life span is short (usually less than one year, with multiple generations per year (Kupriyanova *et al.* 2001)) and recorded abundances fluctuate considerably. Interpretation of change has therefore had limited value and they are rarely mentioned in the annual reports. They are included now as another example of some of the considerable variety of species that are recorded in the surveys, and because it was noticed that numbers of records were relatively much lower prior to 1993 (see graph below). The graph below only includes records at abundances greater then 'Frequent' because records at lower abundance are unreliable (inconspicuous). The reliability of recording, even at high abundance, before 1993, is not certain, though they have been listed on the recording forms in all surveys.



Spirobid worms (small spirals) and Keel worms (Spirobranchus sp.), at Mavis Grind. On rock (left) and on Fucus serratus (right)



3.1.2 **Chthamalus stellatus** & **Chthamalus montagui**

Records of these southern species of barnacles (see photos below) have been reported from various sites along the open coasts of Shetland, but they are uncommon (at the northern edge of their biogeographic range) and the first record of *Chthamalus stellatus* on a monitoring site was at Gluss island East in 2011. More records of C. stellatus have been recorded subsequently, particularly at two of the relatively wave exposed reference sites (Riven Noust and Burgo Taing) where small numbers of individuals have been recorded every year since 2015. The first record of *C. montagui* on a transect site was in 2018: a single individual, also at Burgo Taing. According to the NBN Atlas (www.nbnatlas.org) this is the most northerly confirmed (published) record in the UK!

Barnacles: Chthamalus stellatus at West of Mioness (left), Chthamalus montagui at Burgo Taing (right).

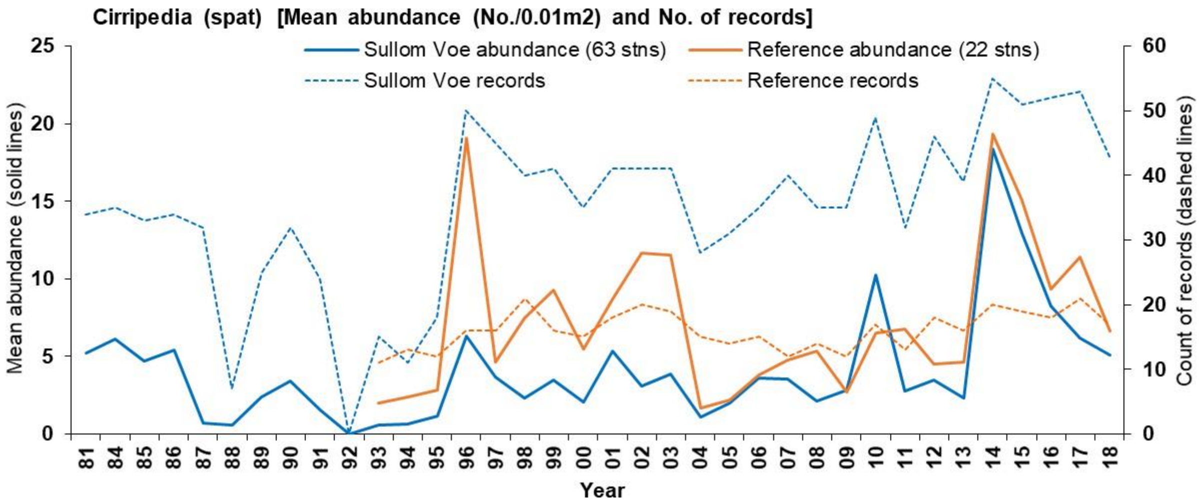
3.1.3 **Austrominius modestus**

Small populations of this immigrant barnacle (see photo below) persist in low densities (typically <10 per m^2 in upper shore zones) at some sites within the Voe, but in 2018 they were only recorded from one site, Voxter Ness.

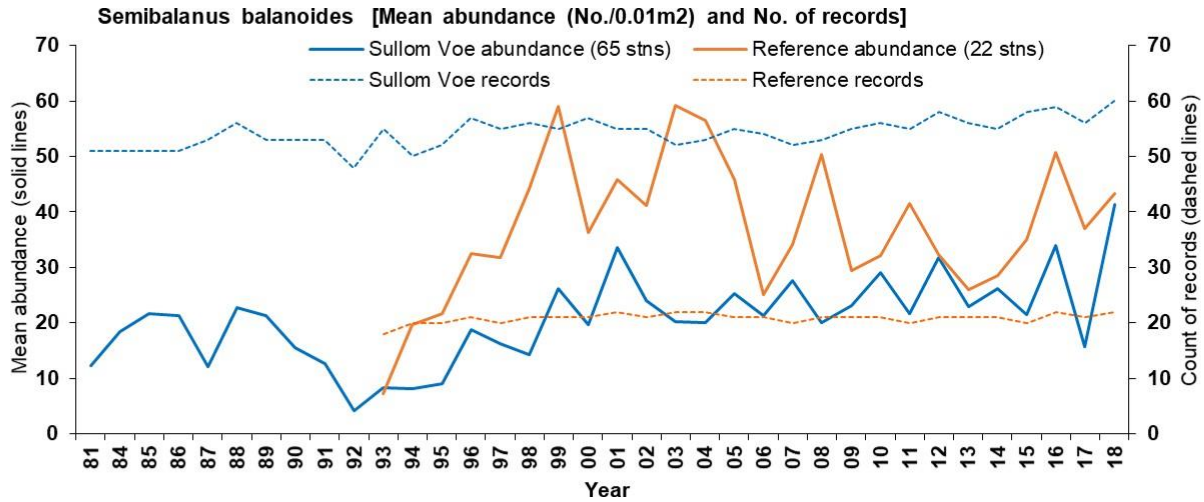
3.1.4 **Semibalanus balanoides**

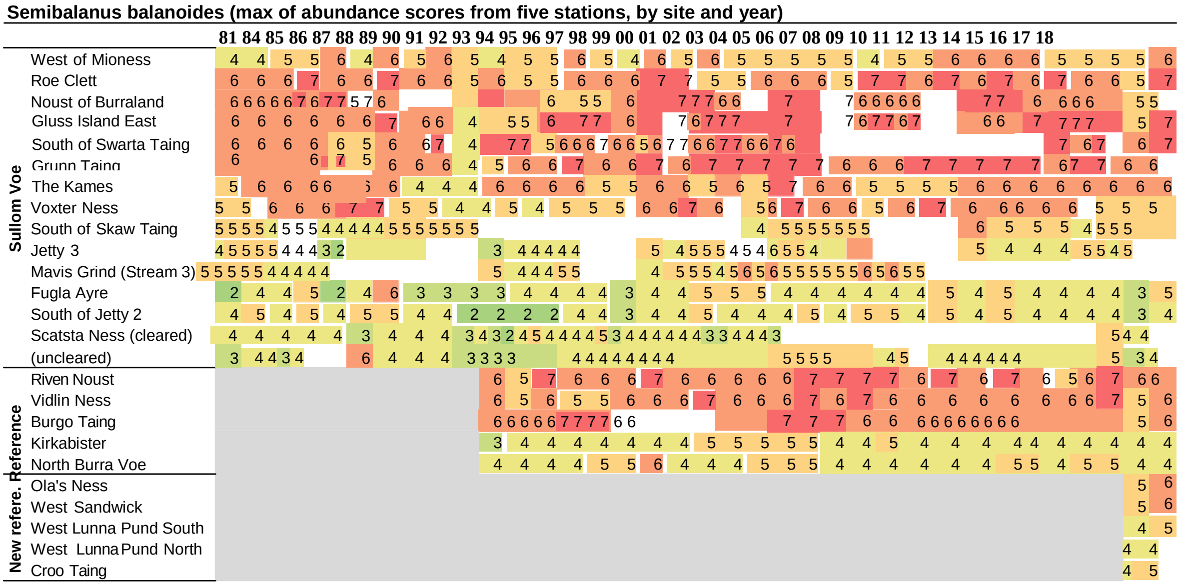
There was a further notable decrease in the average densities of barnacle spat recorded during the 2018 survey, compared to 2017. This was at least partly due to a seasonal effect of the 2018 survey being later (mid-August) compared to 2017 and other recent years (mid to late July), so a higher proportion of the barnacle spat had developed into juveniles barnacles or died. Decreases in abundance were recorded from almost every site. The influence of survey timing was discussed in the 2017 report and is illustrated well by this data.

Barnacles: Austrominius modestus at Mavis Grind (left) and Semibalanus balanoides (spat, juveniles and adult) at Riven Noust (right).



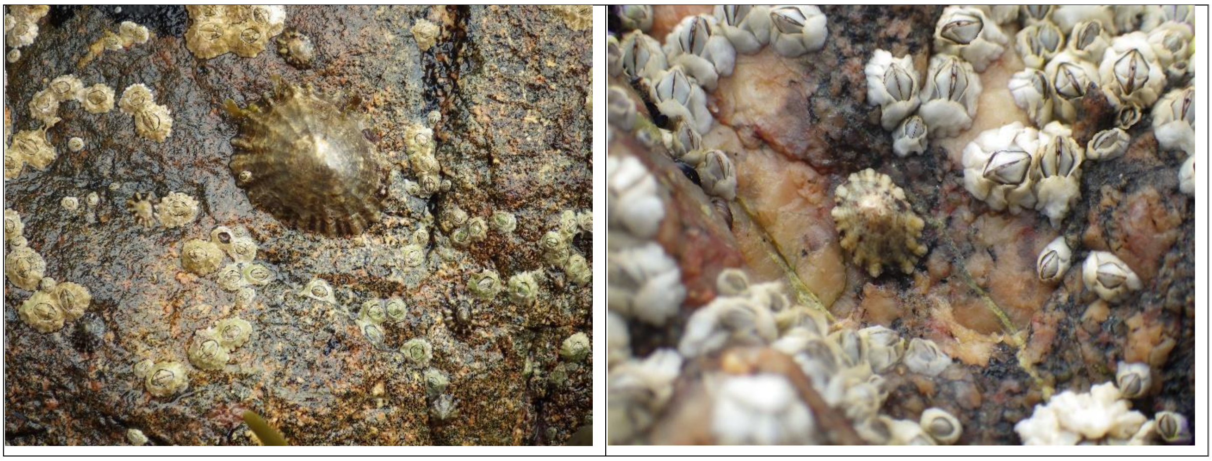
The seasonal effect on the barnacle spat densities, described above, is also apparent in the increased average densities of *Semibalanus balanoides*, which included numerous recently recruited juveniles (with clearly visible plates, see photo above). Increased abundances were recorded at every site and the average density across Sullom Voe sites in 2018 rose to a higher level than any previous year. Other ecological factors are also likely to have been involved and it was noticeable that there had been good survival of old barnacles from 2017. The average density at the reference sites had also increased, though not as much.



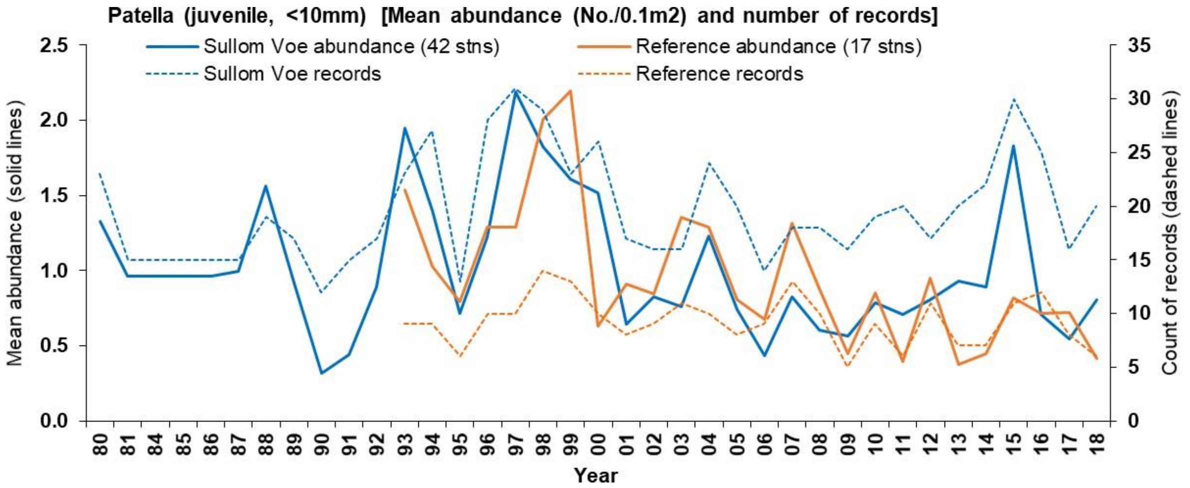


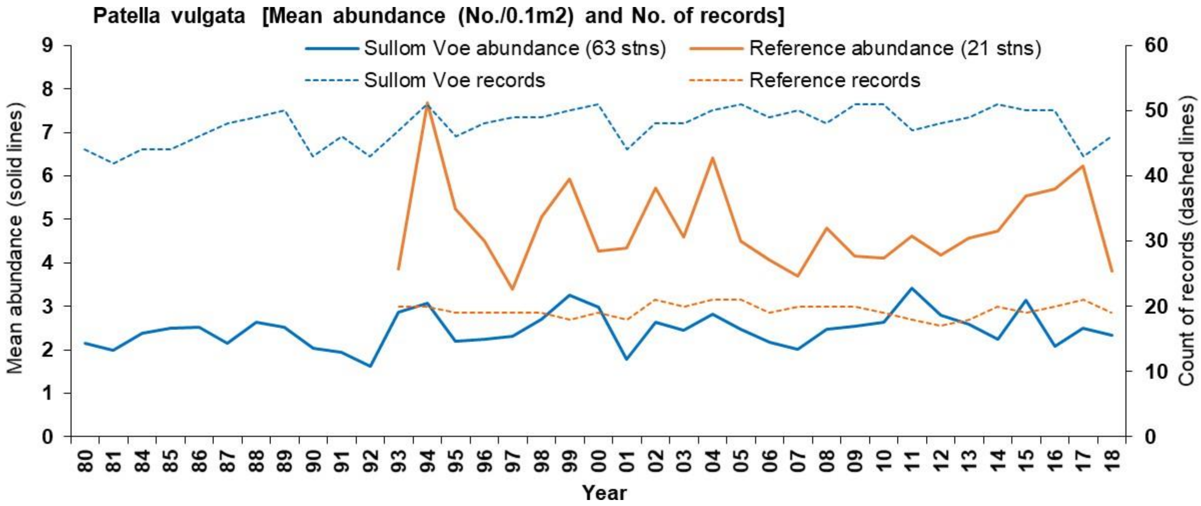
3.1.5 Patella vulgata

Populations of limpets (see photos below) at sites in Sullom Voe fluctuated slightly with very little notable change in average abundance overall sites. However, there was an apparent notable decline in average densities of adult limpets, and to a lesser extent of juveniles, across the reference sites (see graphs below). Inspection of the data shows that the changes in adult abundance were mostly of just one abundance category in each station, but that virtually every change was a decrease. The graph does not include the new reference sites, but the trend at those sites was also a notable decline. Table 3 provides additional information, showing that decreases in adult abundance were recorded at 45% of reference stations, while increases were only recorded at 3%. Table 3 also shows that there were more decreases than increases at the Sullom Voe sites, but the difference is much less striking. This apparent reduction in abundance is surprising, but it is assumed to be a natural fluctuation.



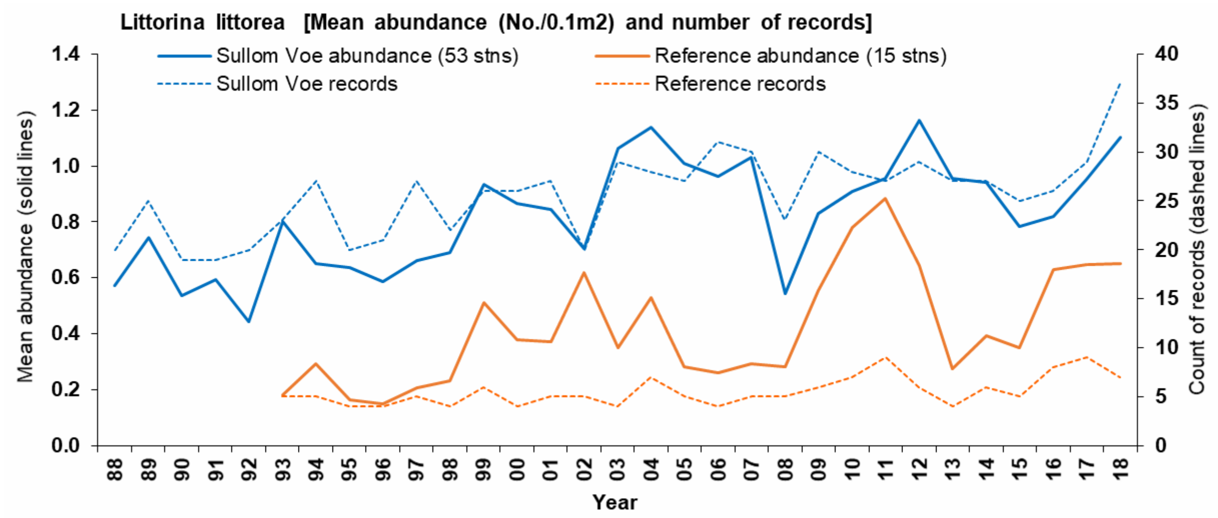
Patella vulgata, adult and juveniles, amongst barnacles at Mavis Grind.

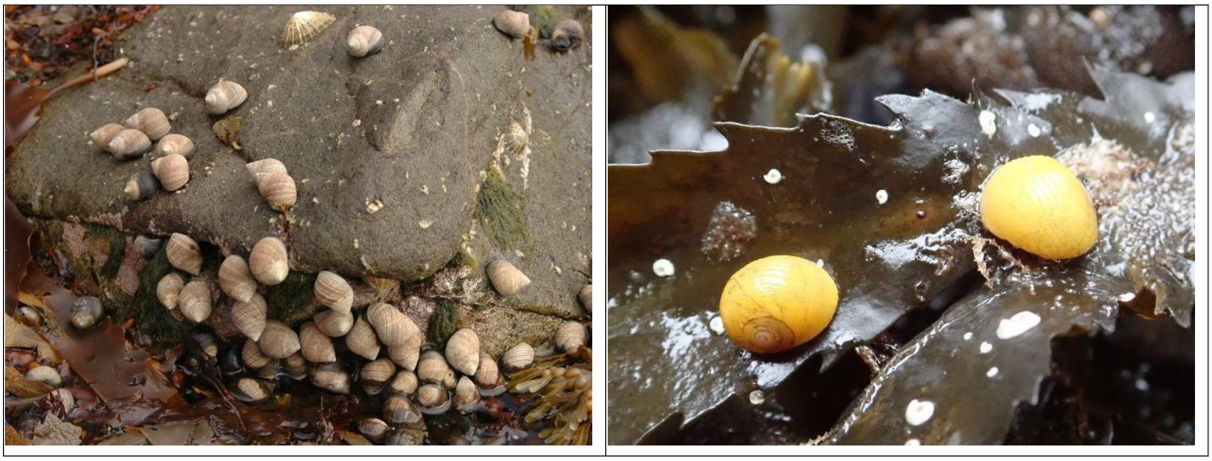




3.1.6 Littorina littorea

Edible winkles (see photo below) are most abundant at the relatively sheltered sites, particularly on the boulder shores. Annual fluctuations of two or three abundance categories are not uncommon in the midshore stations, but fluctuations in the average abundance across all of the Sullom Voe sites is less marked. The overall trend in 2018 was of increasing abundance and numbers of records, at Sullom Voe sites and Reference sites.

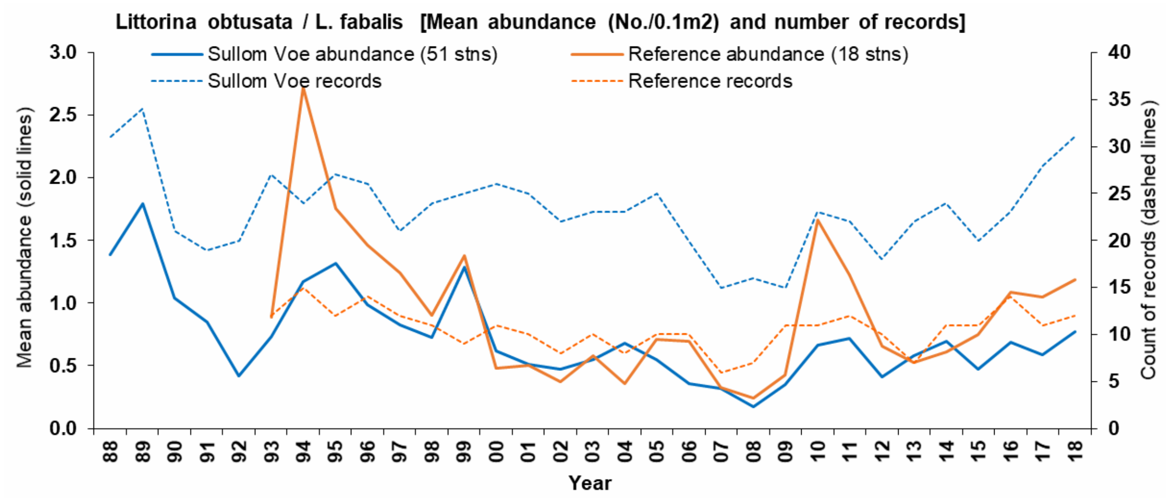




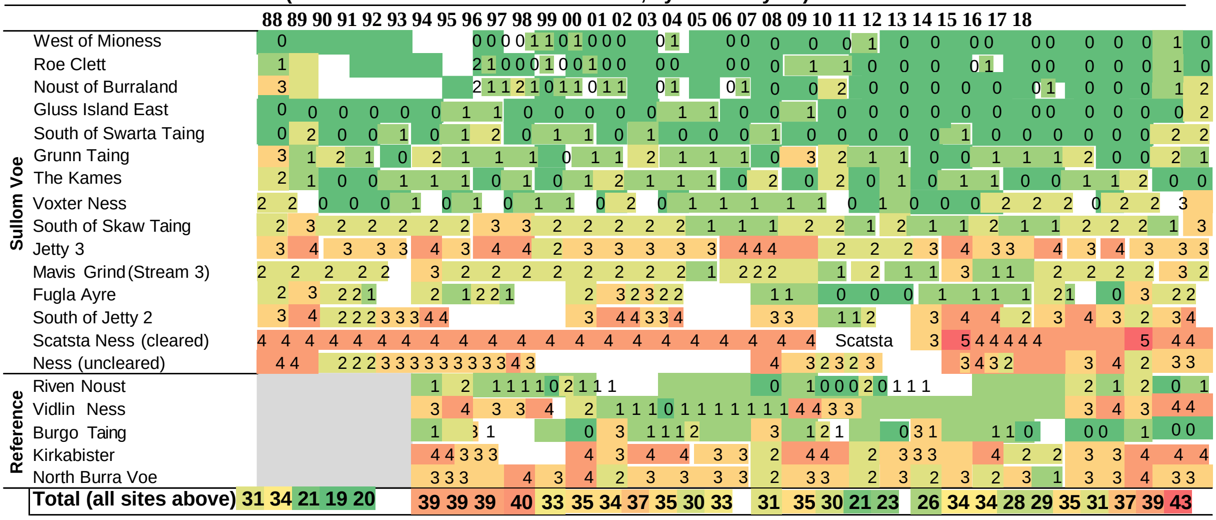
Littorina littorea (left). Littorina fabalis on Fucus serratus (right)

3.1.7 Littorina obtusata / L. fabalis

The average densities and numbers of records of flat winkles (see photo above) increased compared to 2017 and the graph below suggests an upward trend, at both Sullom Voe sites and Reference sites, back towards the levels recorded in the1980s and 90s. This may be expected, as their occurrence is naturally linked to the abundance of their main food, fucoid algae, which has also been increasing. This is discussed in Section 4. The table below shows that there were decreases as well as increases at some sites.

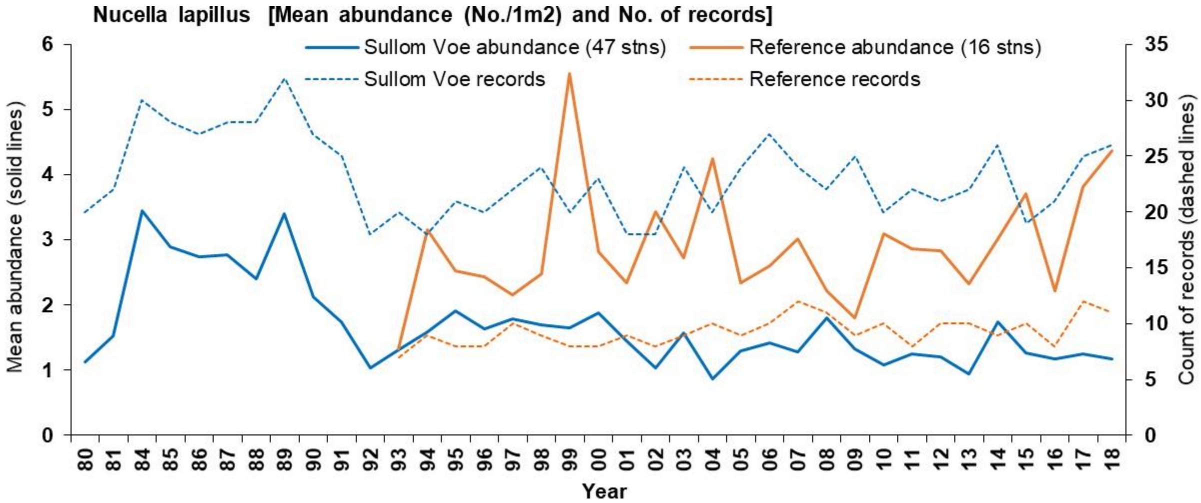


Littorina obtusata / L. fabalis (number of records from five stations, by site and year)



3.1.8 [Nucella lapillus]

A gradual recovery of dogwhelk populations, 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.



Populations of dogwhelks on the two SV terminal jetty transects, Jetty 3 and South of Jetty 2, had increased again and are now back to abundances similar to pre-TBT levels. Numerous juveniles were present under boulders on the lower and middle shore (see photos below).

Numbers of dogwhelks had also increased slightly at Vidlin Ness, one of the reference sites in Vidlin Voe. This site has also been characterised by a notable lack of dogwhelks since the early 1990s (see Moore and Bunker 2017 for more details and discussion). Abundances at the site have not yet returned to the levels recorded in the late 1970s/early 80s.

For more information on dogwhelk populations see the associated report from SOTEAG's dogwhelk monitoring programme, which was repeated in 2018 (Moore, Anderson & Mercer, 2018).

Nucella lapillus (max of abundance scores from five stations, by site and year). **Rows in bold indicate sites of particular interest**

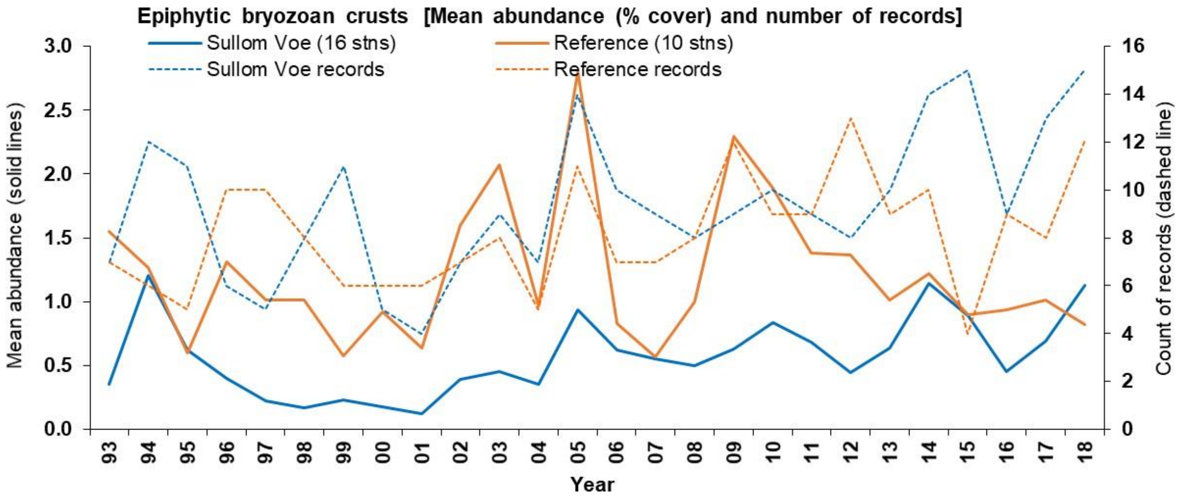
Years: 76 77 78 79 80 81 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18

Group	Site	Scores (in printed order)
Sullom Voe	West of Mioness	4 6 7 5 4 5 7 7 6 5 7 5 7 7 6 7 6 7 6 6 6 5 6 5 5 5 5 5 5 5 5 5 6 5 4 6 6 7 6 6 5 5
Sullom Voe	Roe Clett	4 7 5 0 3 5 5 5 5 7 7 7 5 5 2 5 0 2 4 4 4 5 4 3 3 4 3 3 3 5 5 3 3 4 4 4 5 5 5 2 4
Sullom Voe	Noust of Burraland	4 3 5 3 5 4 4 4 5 4 4 5 4 4 5 5 5 3 4 4 4 5 5 5 5 3 3 3 3 3 3 3 4 5 4 4 3 3 4 4 2
Sullom Voe	Gluss Island East	3 4 4 4 4 4 6 4 6 7 5 7 5 5 6 5 6 7 5 5 5 3 4 4 5 4 3 4 3 5 5 4 0 3 3 2 2 3 3 2 3
Sullom Voe	South of Swarta Taing	4 3 3 4 3 5 5 5 3 3 5 5 5 3 3 4 5 5 5 5 4 0 5 5 4 3 3 4 4 2 3 4 3 3 3 2 4 4 3 4 3
Sullom Voe	Grunn Taing	5 5 7 5 4 5 5 6 6 6 3 6 6 5 7 6 7 7 7 5 5 5 5 6 3 4 3 5 5 6 6 5 6 5 5 5 4 5 5 3 4
Sullom Voe	**The Kames**	**4 6 4 3 3 5 5 4 4 5 5 5 2 2 0 1 0 0 0 0 0 0 0 0 0 0 0 0 4 3 3 3 3 4 4 4 4 5 4 3 4**
Sullom Voe	Voxter Ness	4 4 4 4 2 5 5 5 5 6 5 4 3 3 3 2 4 5 5 5 5 5 5 5 5 4 3 5 4 5 5 5 4 0 5 3 4 0 3 4 2
Sullom Voe	South of Skaw Taing	3 3 3 2 4 4 5 5 6 5 5 4 6 6 3 4 5 3 2 5 3 5 2 3 3 5 5 5 4 3 5 3 5 4 4 3 6 3 3 2 4
Sullom Voe	**Jetty 3**	**3 2 2 0 0 0 1 1 2 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 2 0 0 0 0 0 0 4**
Sullom Voe	Mavis Grind (Stream 3)	0 0 3 3 0 0 4 4 4 4 3 0 0 2 3 3 1 3 5 4 4 4 3 3 3 2 2 0 0 0 0 0 2 3 2 2 2
Sullom Voe	Fugla Ayre	2 2 2 0 0 1 2 1 1 1 0 5 0 0 0 0 0 0 0 0 0 0 0 0 0 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Sullom Voe	**South of Jetty 2**	**2 2 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 0 0 2 0 2 0 4**
Sullom Voe	Scatsta Ness (cleared)	3 3 0 5 5 5 5 4 4 4 3 2 1 3 4 2 5 4 5 4 4 5 5 4 4 5 3 5 4 2 3 5 5 2 3 4 5 5
Sullom Voe	Scatsta Ness	3 0 0 3 0 0 3 3 2 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 2 3 5 3 3 4 4 4 3 2 5 0 5 3 2
Reference	Riven Noust	4 5 5 6 5 5 5 5 5 5 5 5 6 5 5 5 3 5 5 5 5 5 5 5 5 5 6
Reference	**Vidlin Ness**	**3 3 4 3 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 2**
Reference	Burgo Taing	5 7 7 6 6 5 7 7 6 5 6 5 5 5 5 5 5 5 5 5 4 5 5 5 5 5
Reference	Kirkabister	4 3 0 2 0 0 0 0 1 0 0 0 0 0 0 3 4 6 3 3 2 0 3 4 4 3 4 0 3 5
Reference	North Burra Voe	3 4 2 4 4 4 5 3 3 5 3 4 3 3 4 4 4 5 5 4 4 2 4 3 4 4
New refere.	Ola's Ness	3 3 0
New refere.	West Sandwick	5 5
New refere.	West Lunna Pund South	5 4
New refere.	West Lunna Pund North	2 3
New refere.	Croo Taing	4 2 4 5

Dogwhelks: Adults feeding on barnacles (left). Juveniles under boulder on Jetty 3 transect.

3.1.9 *Flustrellidra hispida* & *Alcyonidium* spp.

Epiphytic bryozoa, growing on serrated wrack and other lower shore algae (see photos below), were found in relatively high abundances at Sullom Voe sites, but relatively low abundances at Reference sites. However, both were within the normal range of variability of previous years and are considered to be natural fluctuations.



Flustrellidra hispida is the most abundant and frequently recorded species at the transect sites, but *Alcyonidium hirsutum* and *A. gelatinosum* are often present. Selected data for *Flustrellidra hispida* are tabulated below.

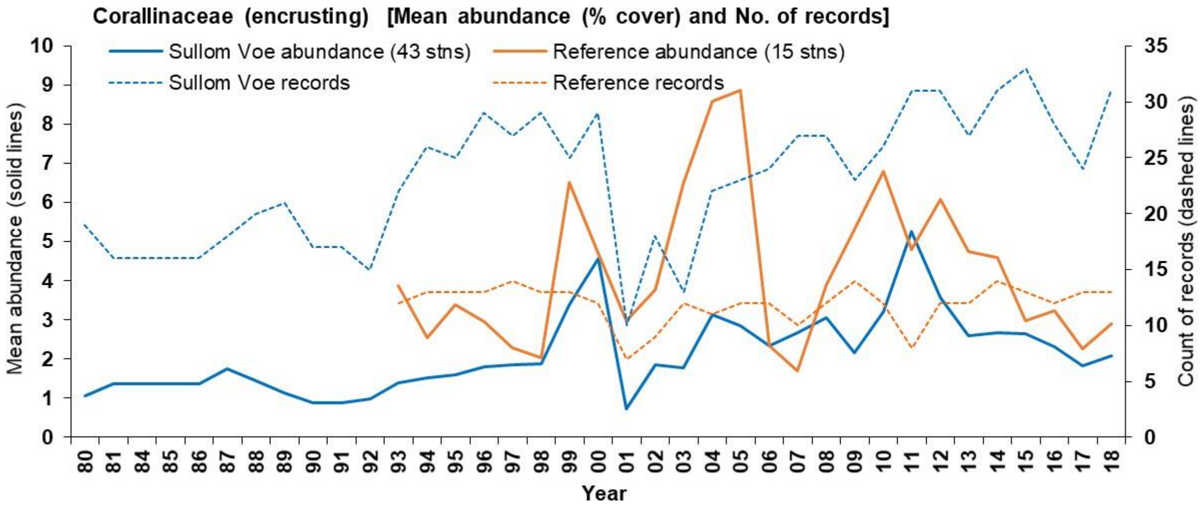
Flustrellidra hispida (abundance in lower shore stations, by year at selected sites)

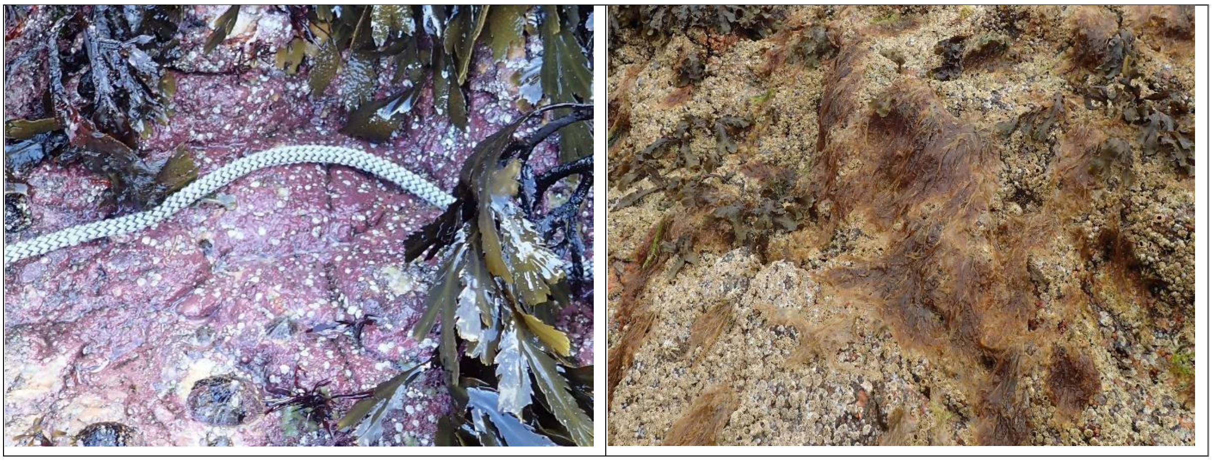
		93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18
Sullom Voe	Noust of Burraland	0	3	2	0	0	0	0	0	0	0	2	0	2	2	2	2	3	2	2	0	0	2	2	0	0	2
	South of Swarta Taing	4 4	3	3	2	2	2 2	The		0	2	3 3	3 3	3 3	4 4	4 2	3 4	3	3 3	3							
	Kames	0	2 2	0 2	2 2	0				1	2	2 2	3 3	4 2	2 3	3 2	3 3	3	2 3								2
	South of Skaw Taing	3 3	2	3 2	1	2 2	2	2 2	3 3	3	2 0	0	2 2	3	2 3	2	2 2										4
	Jetty 3	0	4	3 0	0 0	2	0 0	0	0				2	3	2	1	0	0	2	2	0	0	2	2	2	2	2
	Fugla Ayre	1	3 2	2 2	1 0	0	0				3	3	0	2	2	0	2	0	3	2	3	4	0	0	3	0	2
Reference	Riven Noust	2	3 2	3 2	1 0	0				1	3	3	2	3	3	3	3	3	3	3	2	3	3	3	3	2	2
	Vidlin Ness	4	4	3	3	4	5	4	5	4	5	5	5	5	3	3	4	5	5	4	3	4	4	4	3	4	3
	Burgo Taing	3	4	3	3	2	2	2	2	2	2	3	0	4	3	2	2	3	3	0	3	2	2	3	3	3	2
	Kirkabister	5	2	3	3	2	2	0	2	2	6	5	3	5	3	0	2	4	4	2	0	2	2	0	3	2	2
	North Burra Voe	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	2	2	3	0	3	0	3	0	2	2	2
New	West Lunna Pund South																									0	3
	Croo Taing																									3	2

Flustrellidra hispida (left). Alcyonidium gelatinosum (right). Both on Fucus serratus at Vidlin Ness.

3.1.10 Encrusting coralline algae

Pink encrusting coralline algae are common on lower shore rock (see photo below) and other places on the shore which are permanently wet. As relatively slow growing species their recorded abundances fluctuate much more than expected (see graph below). 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 drab and inconspicuous. The records in some years are also likely influenced by changes in algal surveyor. The scale of the fluctuations shown in the graph may not be reliable. However, the populations in 2018 appeared to be in good condition at all sites.

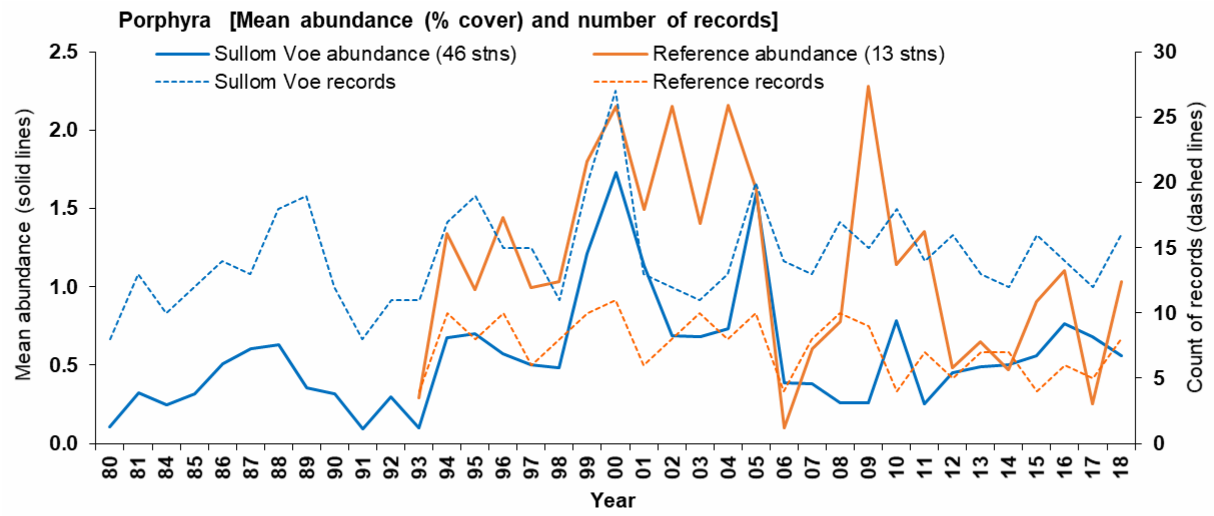




Encrusting coralline algae on lower shore at Noust of Burraland (left). Porphyra, smothering barnacles on lower mid shore at South of Swarta Taing (right).

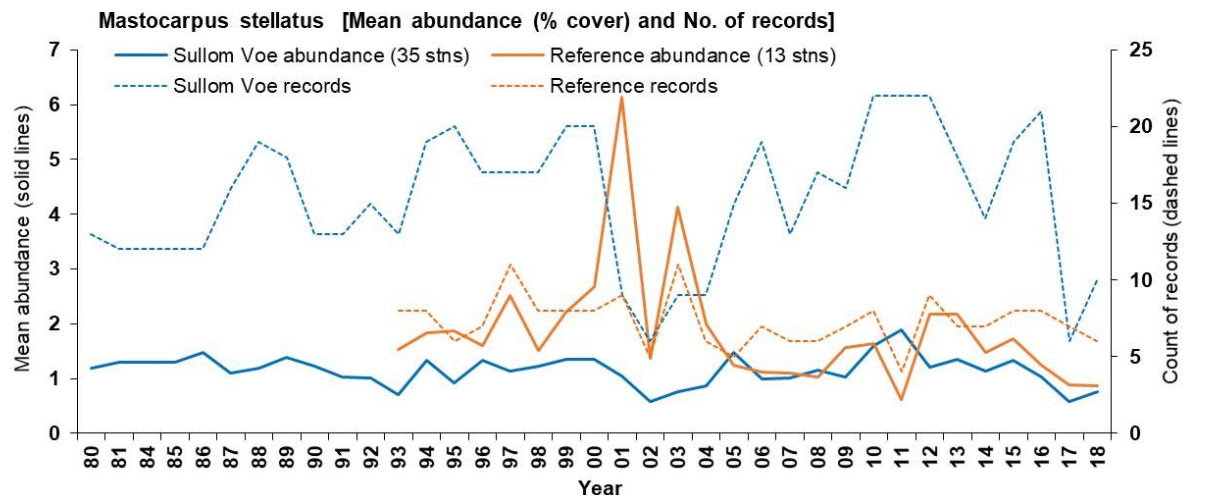
3.1.11 Porphyra

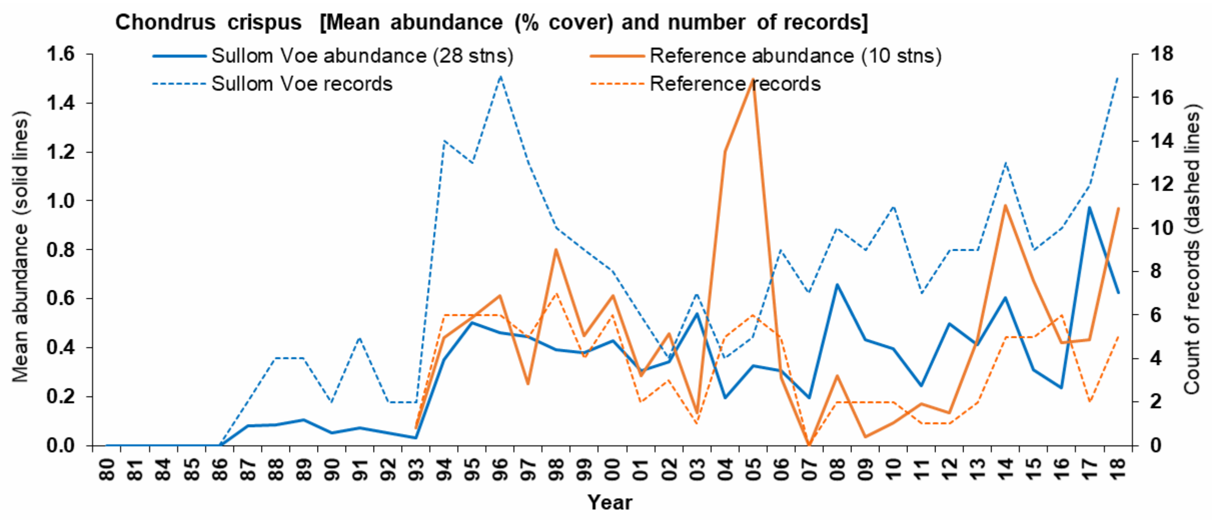
This fast-growing membranous red alga is commonly found on exposed and moderately exposed shores, primarily below mid tide level, where it can cover large areas of rocky shore including barnacles and other fauna (see photo above). Typically, for ephemeral species, its abundance can fluctuate dramatically, and some surveys have been characterised by particularly high or particularly low abundances overall sites. The graph below shows the scale of fluctuations and that average abundance in 2018 was moderate.

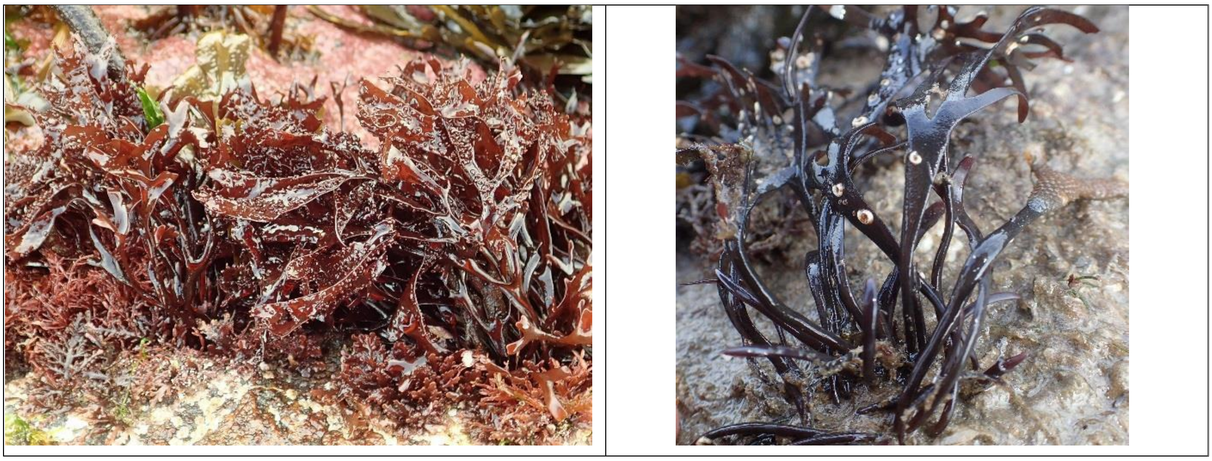


3.1.12 Mastocarpus stellatus and *Chondrus crispus*

The red algae False Irish moss (*Mastocarpus stellatus*) and Irish moss/Carrageen (*Chondrus crispus*) (see photos below) are both common on rocky shores in Shetland. Distinguishing between them is not always easy and a particularly large discrepancy was described in the 2017 report (Moore and Bunker 2017). In 2018, the average recorded abundance of *M. stellatus* was still relatively low compared to previous year, while that of *Chondrus crispus* was still relatively high. Reliably identified plants of both species were present and in good condition at many sites.



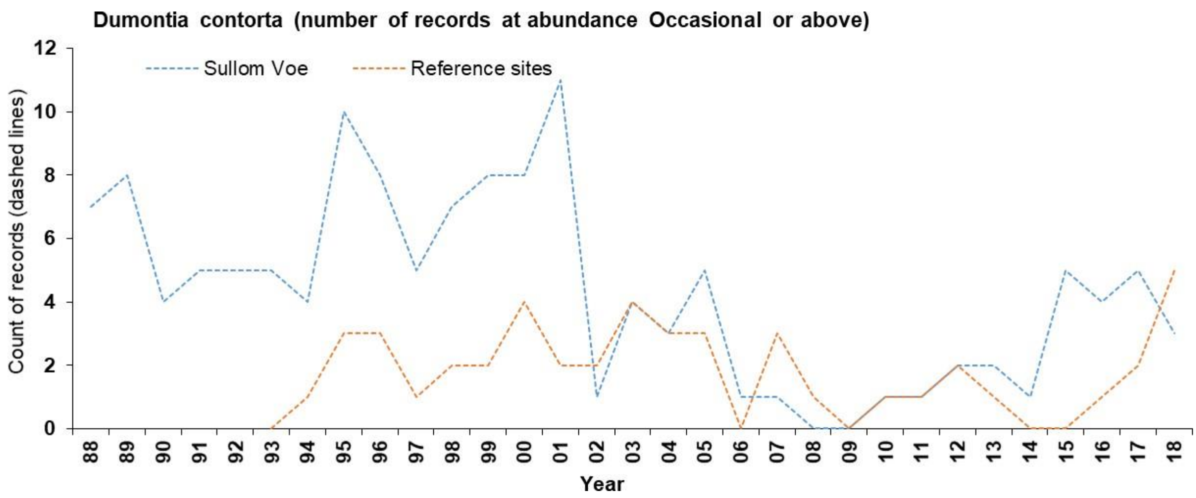




Mastocarpus stellatus at Riven Noust (left). Chondrus crispus (right).

3.1.13 Dumontia contorta

This red alga (see photo below) is an example of a species that is not very common in Shetland but was recorded more frequently and in higher abundances in Sullom Voe before 2002. However, there have been a few more records in the last three years.



Dumontia contorta at Vidlin Ness (left). Ascophyllum nodosum at West Lunna Pund South (right).

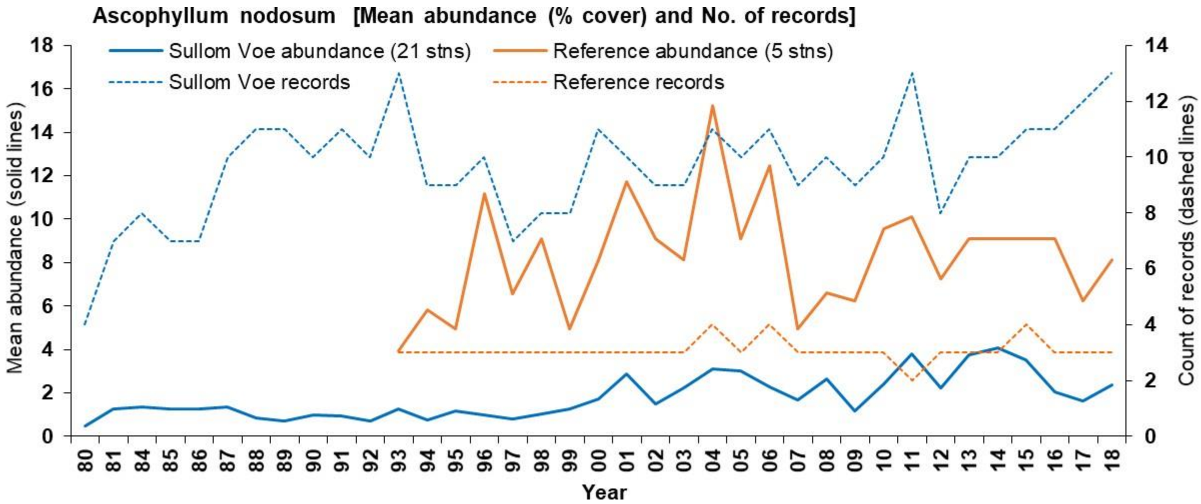
3.1.14 *Ascophyllum nodosum*

The knotted wrack (see photo above) prefers very sheltered conditions, so it is only abundant on four of the Sullom Voe sites and one of the Reference sites. It is also abundant at three of the new Reference sites, which will provide a more balanced comparison of Sullom Voe versus Reference sites in future years.

Average abundance at Sullom Voe sites has been higher since 2001 and the number of records has risen in recent years.

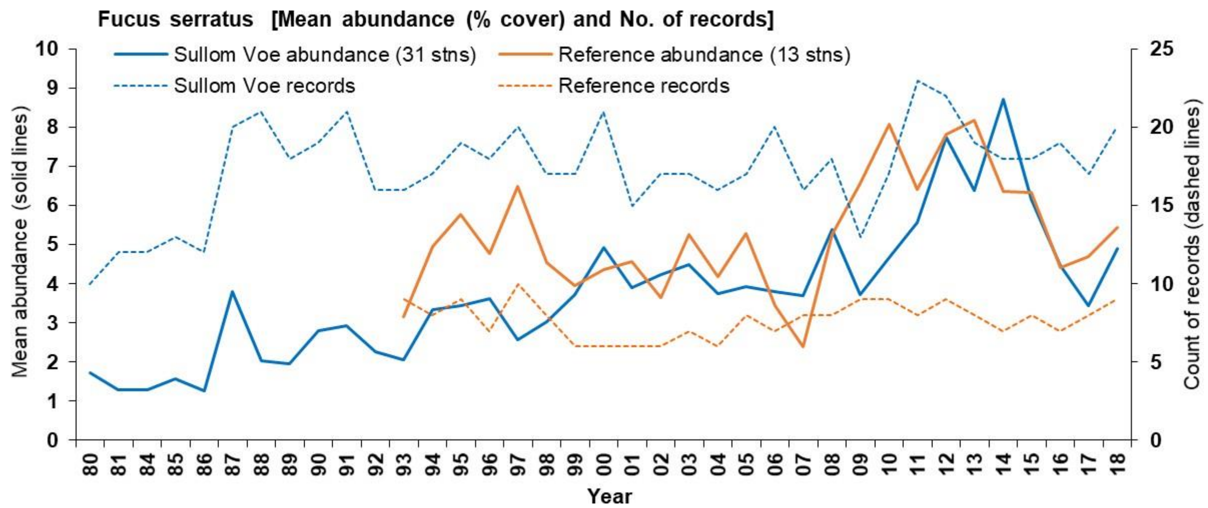
Ascophyllum nodosum (number of records from five stations, by site and year)

Site	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
Mavis Grind (Stream 3)	0 1 2 1 1 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3
South of Jetty 2	2 2 0 0 0 0 0 0 0 0 Scatsta 1 1 1 2 0 4 0 0 0 0 0 0 1 1 1 1 2 2 2 1 1 1 1 3 1 2 2 3 2 2 3
Ness (cleared)	3 1 3 3 3 3 4 3 3 3 3 3 3 3 2 4 3 2 3 3 3 3 3 3 3 4 3 3 4 4 4 3 4 3 4 4
Scatsta Ness (uncleared)	3 2 2 2 2 2 2 3 3 2 2 3 3 2 3 3 2 3 3 3 3 3 3 3 3 3 3 3 2 3 3 2 2 3 2 3 3 3
North Burra Voe	3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 2 3 3 3 4 3 3 3
West Lunna Pund South	3 3
West Lunna Pund North	2 3
Croo Taing	3 3 4 4



3.1.15 *Fucus serratus*

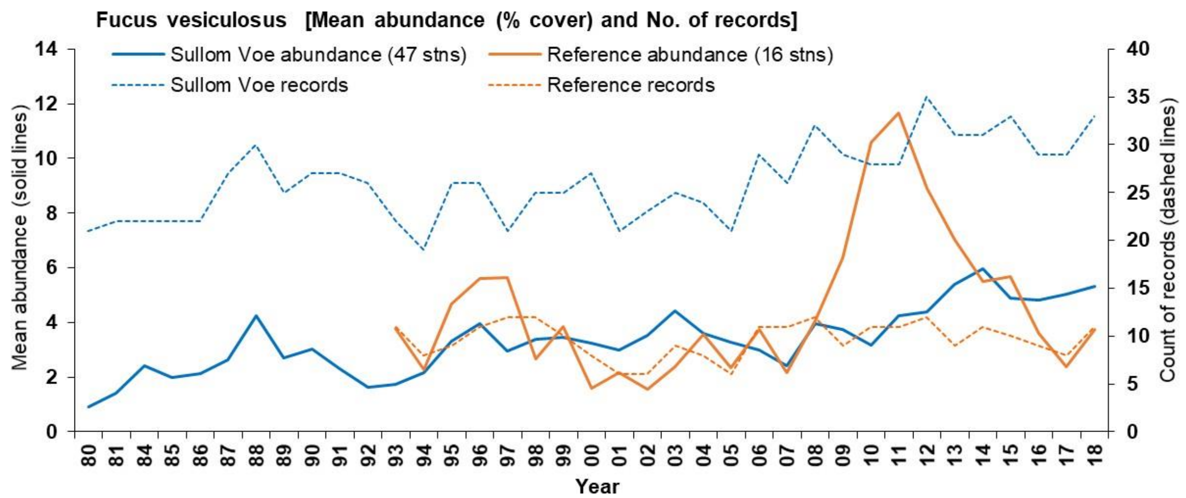
Average abundance of serrated wrack (see photo below) on lower shores increased across Sullom Voe sites and Reference sites in 2018, halting the large reductions seen since 2014. Percentage covers are notably greater than those recorded in the early years of the programme.

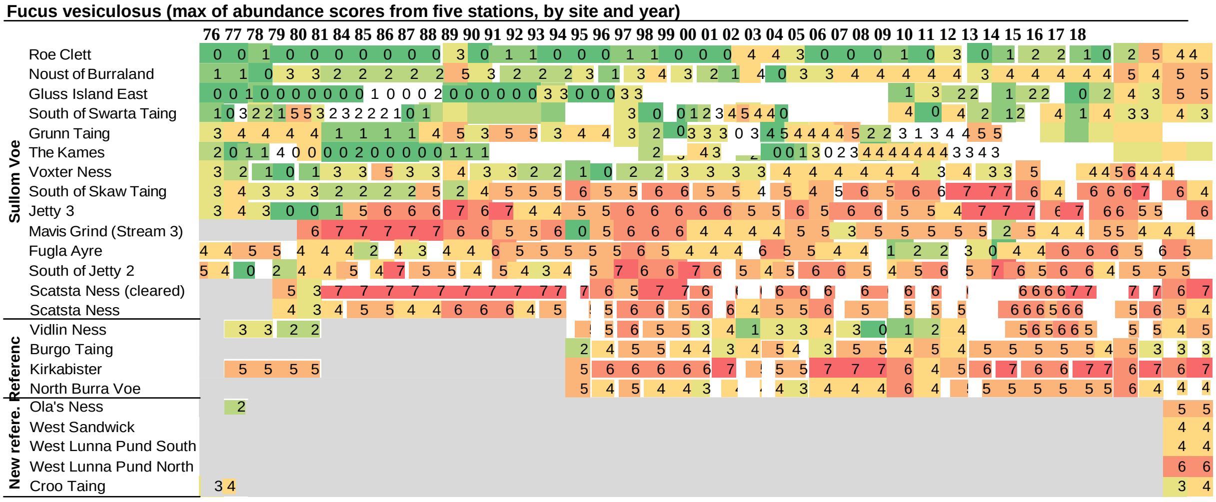


Fucus serratus at The Kames (left). Fucus vesiculosus at South of Jetty 2.

3.1.16 Fucus vesiculosus

There was little change in the average abundance of bladder wrack (see photo above) at the Sullom Voe sites and it remained at fairly high levels compared to earlier years. However, there was a slight increase in average abundance at the Reference sites, following the notable decrease since 2011.

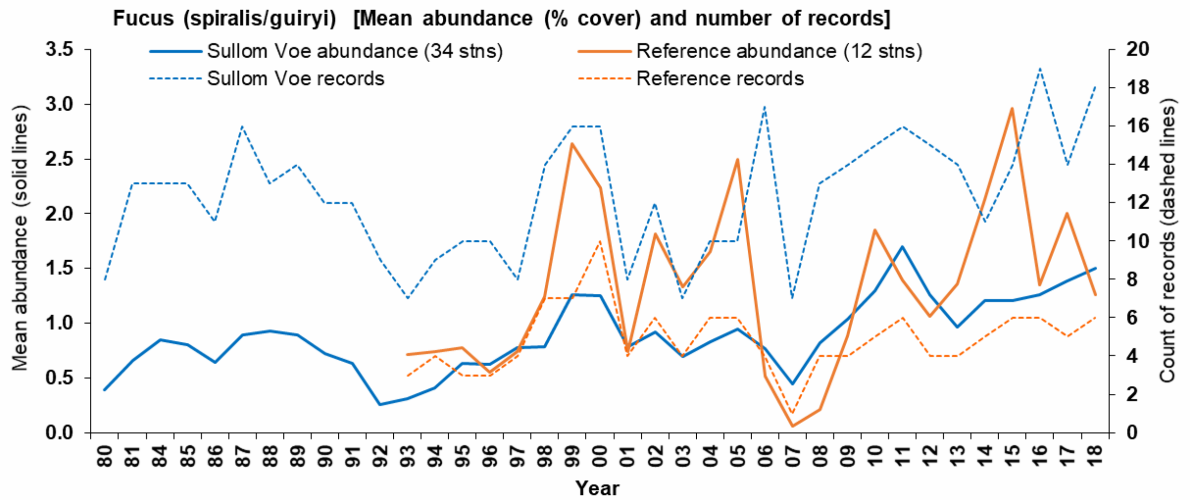




3.1.17 Fucus spiralis and *Fucus guiryi*

Spiral wrack, *Fucus spiralis* is common on upper shore bedrock of sheltered and moderately sheltered sites in Shetland. *Fucus guiryi* is a recently described species, very similar to *Fucus spiralis* (see photos below), that has been recorded elsewhere in UK (Zardi *et al.* 2011). Specimens from monitoring sites in Sullom Voe that appear to fit the description of *F. guiryi* were sent to a specialist for identification, but the results had not been received at the time of writing. Even if its presence is confirmed, distinguishing the two species in the field is difficult, so the records are aggregated.

Some fairly large fluctuations in the abundance of *F. spiralis* have been recorded over the course of the programme, but there has been a general trend of increasing average abundance across all of the Sullom Voe sites. The scale of fluctuations in average abundance across the Reference sites is too large to see trends, due to the relatively few stations where *F. spiralis* is found.



Fucus (spiralis/guiryi) (max of abundance scores from five stations, by site and year)

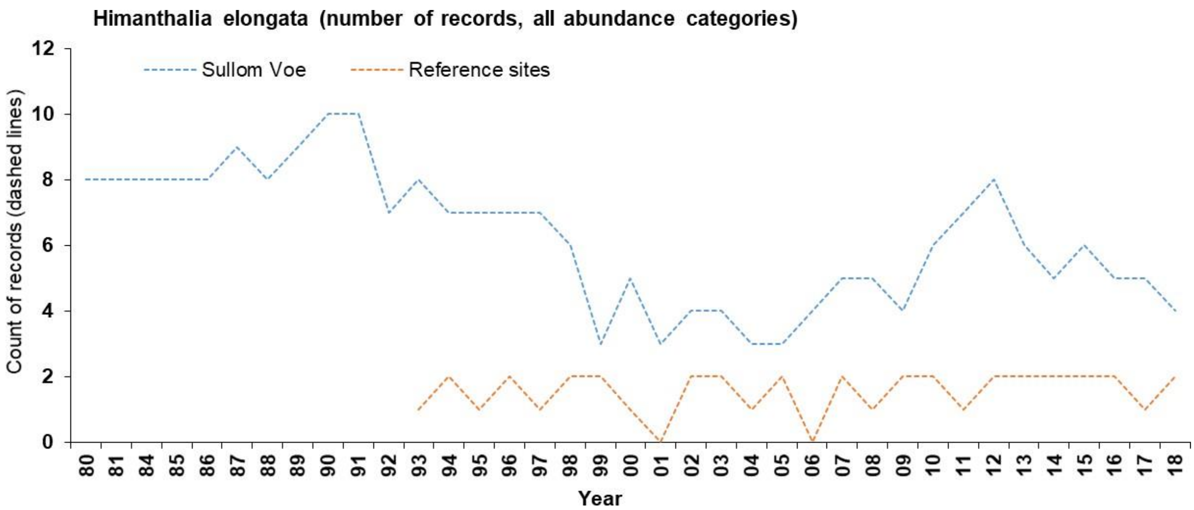
Group	Site	76	77	78	79	80	81	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
Sullom Voe	Gluss Island East	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	South of Swarta Taing	2	1	0	0	2	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0
	Grunn Taing	2	3	0	2	3	1	2	1	1	1	2	4	1	1	1	1	4	3	0	3	2
	The Kames	2	3	0	0	0	1	1	1	1	4	1	1	1	0	0	0	0	0	0	0	1
	Voxter Ness	0	0	0	1	0	3	3	3	3	3	3	2	1	1	0	0	0	1	2	2	3
	South of Skaw Taing	3 3 1 2 1 1 1 1 1 1 1												0	1	0 0 0 1 2 4 0 3 3 2 0 0 3 0 0 0 1 1 1 0 0 1 0 2 2 3 2						
	Jetty 3	3	4	3	1	2	6	7	6	4	6	6	6	6	5	2	0	4	6	6	5	5
	Mavis Grind (Stream 3)					4	4	4	4	4	4	5	5	5	4	2	4	2	4	3	2	2
	Fugla Ayre	0	1	0	2	3	2	2	2	2	2	3	1	3	3	2	3	2	3	2	4	4
	South of Jetty 2	3 3 0 0 0 0 0 0 0 3 0 3 1 2 2 2 0 3 4 6 6 6 5 4 4 4 4 3 2 0 4 5 5 5																				
	Scatsta Ness (cleared)				0 0 0 0 0 0 0 5 4 5 4 4 5 4 4 6 4 4																	
	Scatsta Ness				5	4	3	5	5	5	4	4	3	4	4	2	1	2	3	3	0	1
	Vidlin Ness		4	4	2	2											4	4	5	5	4	4
	Burgo Taing																0	0	0	0	0	2
	Kirkabister		1	2	2	2											4	4	4	3	4	5
	North Burra Voe																2 2 1 1 2 2 4 4 4 0 3 3 0 1 1 1 2 3 4 4 4					
New refere.	Ola's Ness		6																			
	West Sandwick																					
	West Lunna Pund South																					
	West Lunna Pund North																					
	Croo Taing	0	3																			

Group	Site	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18
Sullom Voe	Gluss Island East	0	0	0	0	0	0	3	4	3	2	0	1	2	1	1	3	3	3	4	4
	South of Swarta Taing	1	0	0	0	0	0	0	1	0	0	0	0	0	1	2	1	0	2	2	2
	Grunn Taing	3	4	0	3	0	3	5	4	0	1	3	1	2	3	3	4	3	3	3	3
	The Kames	3	3	0	2	0	3	3	1	0	1	3	1	2	1	1	0	1	3	3	3
	Voxter Ness	4	3	4	3	0	3	0	4	4	4	4	4	6	5	4	4	4	4	4	4
	South of Skaw Taing																				
	Jetty 3	4	4	5	4	4	6	5	4	3	5	6	6	6	4	4	5	5	5	4	4
	Mavis Grind (Stream 3)	2	3	4	0	3	3	3	1	2	5	4	4	5	4	4	5	5	5	4	4
	Fugla Ayre	4	5	4	3	4	0	0	1	0	1	3	0	4	4	4	5	4	3	4	4
	South of Jetty 2														6 4 5 3 3					3	5
	Scatsta Ness (cleared)	5	4 4 4 5 4 4						5 5 5 5 5					6	4 4 3 3 4					4	3
	Scatsta Ness	4	4	2	4	4	4	4	3	3	1	1	4	4	4	4	4	5	3	4	3
	Vidlin Ness	5	4	3	4	5	4	4	3	2	3	6	7	6	4	4	4	5	4	4	4
	Burgo Taing	4	5	0	4	0	0	4	1	0	0	0	0	1	0	0	2	4	3	4	3
	Kirkabister	6	3	0	0	5	5	5	4	0	1	4	5	5	5	5	6	5	4	5	4
	North Burra Voe																		3	4	2
New refere.	Ola's Ness																			5 5	
	West Sandwick																			0	3
	West Lunna Pund South																			4	3
	West Lunna Pund North																			4 4	
	Croo Taing																			6 6	

Fucus spiralis at Voxter Ness (left). Possible Fucus guiryi at Mavis Grind (right).

3.1.18 Himanthalia elongata

Thongweed (*Himanthalia elongata* - see photo below) is found on the lower shore at some moderately wave exposed sites. In some years, particularly during the early 1980s, it was found in higher abundances and sometimes further up the shore than usual. Typically, the mid shore records are only of the small button shaped thalli, without the long reproductive 'thongs'. There was also a peak in records in 2012 and relatively high abundances for another three years, but then a subsequent decline.



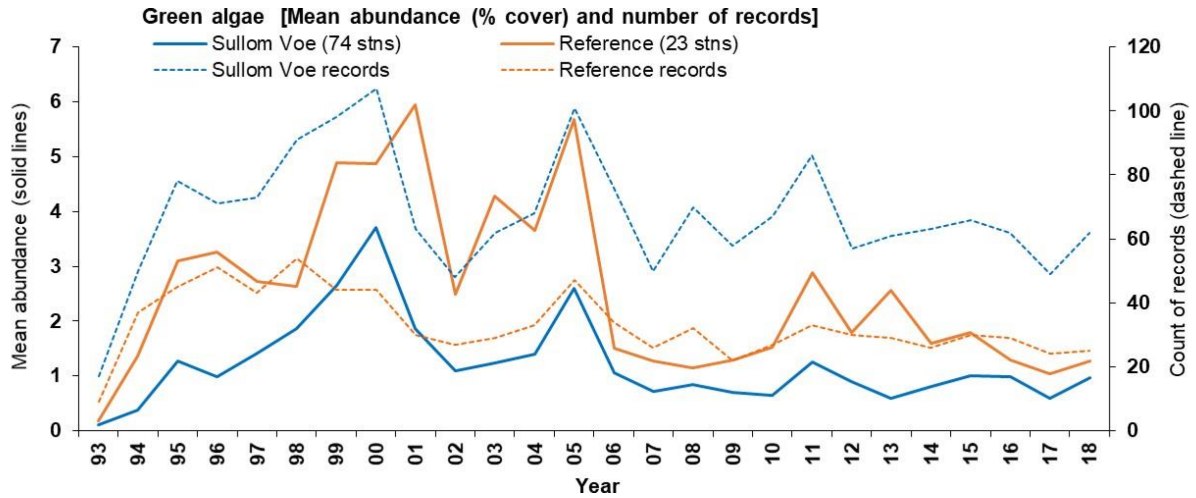
Himanthalia elongata (max of abundance scores from five stations, by site and year)

		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
Sullom Voe	Roe Clett	3	4	2	1	4	4	4	4	4	4	4	5	6	6	4	5	4	3	4	4	5	5	5	5	6	5	4	4	4	4	5	5	6	5	5	5	0	6	5	5	4
	Noust of Burraland	3	3	3	3	1	2	2	2	2	2	2	3	3	4	2	1	1	0	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Gluss Island East	0	2	0	3	3	2	2	2	2	2	2	2	2	2	2	2	5	1	1	1	2	0	2	0	0	0	0	0	1	0	0	0	0	1	2	1	2	3	0	2	2
	South of Swarta Taing	4	3	3	3	3	4	2	6	4	4	4	4	3	3	3	1	4	4	4	4	5	4	3	5	6	5	4	4	4	5	5	6	5	4	5	4	5	5	3	2	3
	Grunn Taing	0	5	3	5	5	4	4	5	5	4	4	4	3	3	4	4	4	3	3	3	2	0	0	0	0	1	0	0	0	1	1	0	1	4	1	2	4	5	4	4	4
	The Kames	0	0	1	2	2	3	3	3	3	3	0	3	3	1	5	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
	South of Skaw Taing	1	4	2	3	4	3	3	3	3	3	4	3	2	2	4	2	4	3	5	5	5	4	4	4	3	3	3	4	1	3	3	3	1	2	1	0	0	1	2	1	0
R	Burgo Taing																3	4	4	3	4	3	4	5	0	4	4	4	4	0	4	4	5	5	1	4	4	4	4	2	4	4

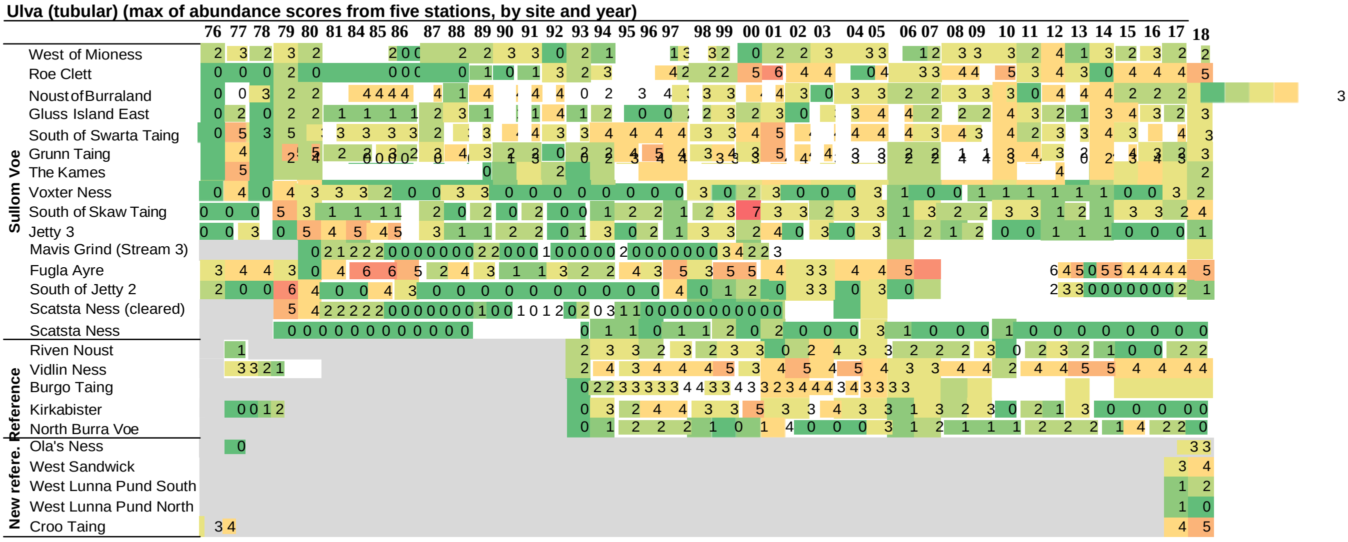
Himanthalia elongata at Roe Clett (left). Acrosiphonia arcta at West of Mioness (right).

3.1.19 Green algae

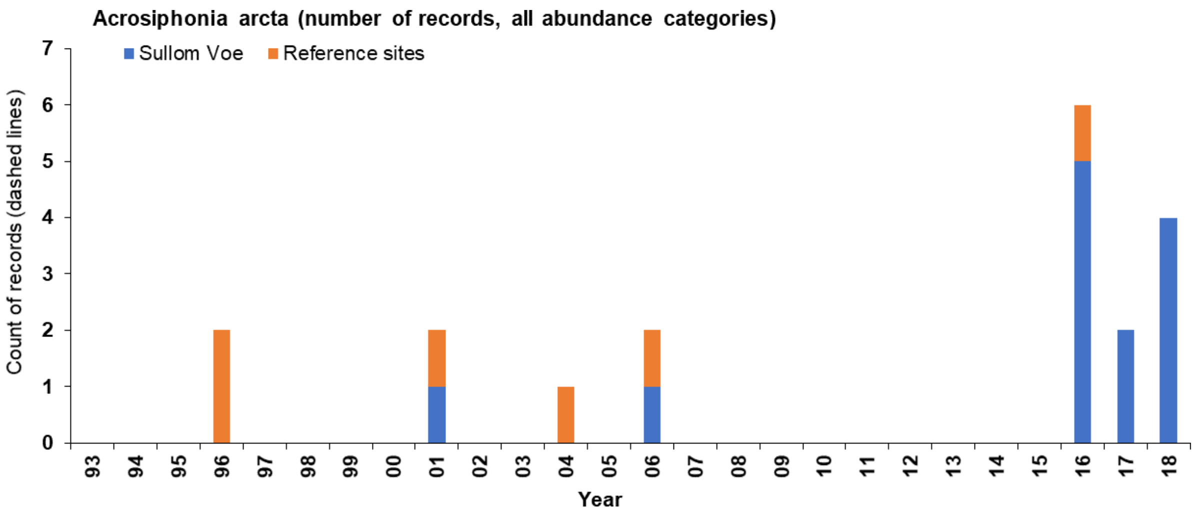
Green algae, comprising *Ulva* (tubular and flat forms), *Cladophora*, *Codium* and various other taxa, were again present in relatively low abundances, overall sites, compared to some previous years. However, as the table below shows, individual taxa, like Ulva (tubular) did reach high abundance in some stations.



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



Included within the graph above are data for the striking green alga *Acrosiphonia arcta* (see photo above). It has been recorded sporadically in the past (as *Spongomorpha*) but there have been more records in the last 3 years. Shetland is within its geographic range, which stretches from the Atlantic coasts of Spain to Norway, but it is rarely recorded in high abundance.



Acrosiphonia arcta (max of abundance from five stations, by site and year)

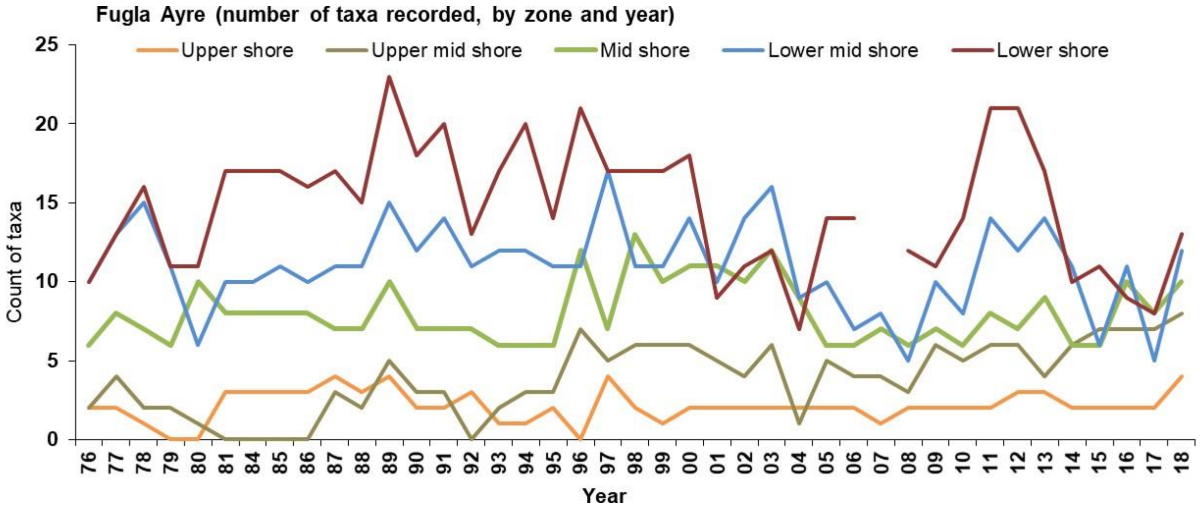
		93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18
Sullom Voe	West of Mioness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
	Roe Clett	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
	Noust of Burraland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
	Gluss Island East	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Grunn Taing	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	0
	Voxter Ness	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ref	Vidlin Ness	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	0
	Burgo Taing	0	0	0	2	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	North Burra Voe	0	0	0	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N	West Sandwick																									1	0

3.2 Site-specific descriptions

3.2.1 Fugla Ayre

This cobble/boulder shore is situated half way down Sullom Voe but sticks out into the Voe. and the substrata are fairly mobile. The lower shore is also strongly influenced by sand from the subtidal.

Species richness and abundance has always been relatively low compared to other sites, but it has been observed in recent years that the site appeared more scoured and that both richness and abundance had declined, particularly on the lower shore where the amount of sand appears to have increased. The graph below shows that species richness has fluctuated, and some periods are characterised by higher or lower richness, possibly due to changes in storminess. It also suggests that 2017 was a fairly low point and that 2018 was better.



Fugla Ayre: View down shore from top of transect (left). Lower shore station (right).

3.2.2 Orka Voe bund

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.

Orka Voe bund: View east from EOR pipeline crossing (left). View west (right).

3.2.3 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.

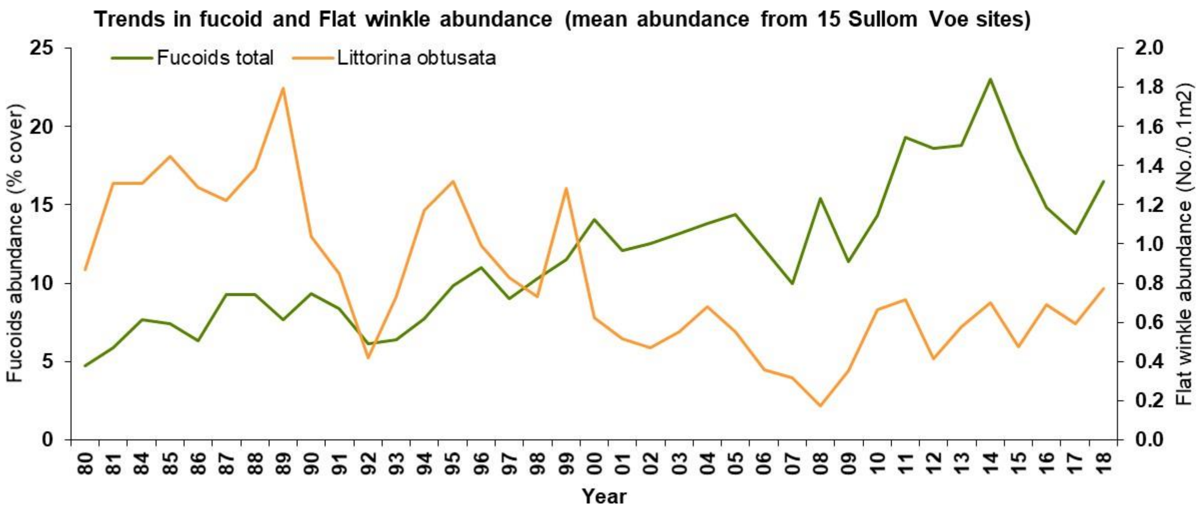
4 Discussion

4.1 Changes in rocky shore communities

There were few notable changes in rocky shore communities around Sullom Voe between 2017 and 2018. The fluctuations described in the results sections are all considered to be natural and mostly within typical levels for those shores and the survey methodology. None of the recorded fluctuations are considered to be related to the terminal.

A few of the fluctuations are larger than normally expected. The reductions in limpets at numerous Reference sites (Section 3.1.5) is a noteworthy example. All of the reductions in recorded abundance were small, which is well within the levels of natural variability (and surveyor's recording variability) when each site is taken in isolation. However, such a wide scale reduction across all of the Reference sites, distributed across a large geographic area, is unexpected. It is nevertheless, considered to be natural. If enough statistics of natural fluctuations are analysed, then it is inevitable that some examples like this will arise. It is also worth appreciating that the apparent scale of fluctuations across Reference sites, in the graphs of average abundance, are generally larger than those for the Sullom Voe sites. This is because the averages are calculated from only five Reference sites (with multiple stations, depending on the range of tidal zones that the species inhabits), compared with 15 Sullom Voe sites.

In Section 3.1.7 the relationship between the abundance of flat winkles and the fucoid algae that they feed upon is mentioned. The graph below shows no correlation between the average count of *Littorina obtusata* and the average percentage cover of fucoid algae (sum of average abundances for *Pelvetia canaliculata*, *Fucus* (*spiralis*/*guiryi*), *Fucus vesiculosus*, *Ascophyllum nodosum*, *Fucus serratus*) across the 15 Sullom Voe sites. The relationship between them is therefore more complicated. The graph also shows the general trend of increasing abundance of fucoid algae that has been discussed in previous reports.



4.2 Effects of terminal operations and oil spills

During the period 1st July 2017 to 31st August 2018 there were no pollution incidents reported within Sullom Voe (Simon Skinner, pers. comm.).

On the South of Jetty 2 transect (site 6.2), where there were notable effects from the movement of large boulders in 2016 (see Moore and Bunker 2017), there were no signs of continued impacts and the communities present in the affected area were similar to adjacent unaffected areas of that stony habitat.

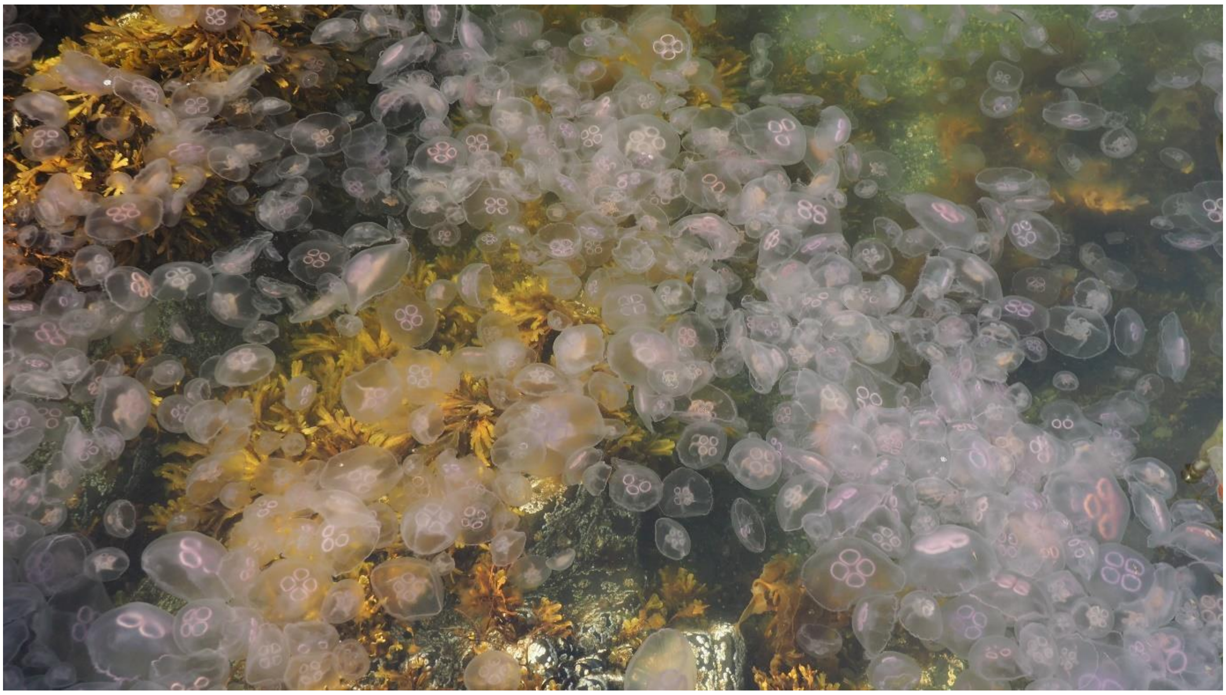
Terminal activities during the past 12 months appear to have had no obvious impacts upon the rocky shore communities of Sullom Voe.

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 2017 and 2018 show levels of fluctuations that are typical for the monitoring sites in the SOTEAG rocky shore programme.

4.4 Other features of marine interest in 2018

A notable marine biological feature of the 2018 survey was an impressive bloom of the moon jellyfish *Aurelia aurita* in Sullom Voe:



Bloom of moon jellyfish *Aurelia aurita* on the eastern shore of Sullom Voe, 19/08/18

5 References

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Ballantine, W.J. (1961). A biologically-defined exposure scale for the comparative description of rocky shores. Field Studies, 1, 1-19.

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Howson, C.M. and Picton, B.E. (eds.) (1997). *The species directory of the marine fauna and flora of the British Isles and surrounding seas*. Ulster Museum and the Marine Conservation Society. Belfast. 508 pp.

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Kupriyanova, E. K.; Nishi, E.; ten Hove, H. A.; Rzhavsky, A. V. (2001). Life history patterns in serpulimorph polychaetes: ecological and evolutionary perspectives. *Oceanography and Marine Biology, Annual Review*. 39: 1-101

Moore, J. (2013). *Sullom Voe rocky shore transects monitoring, 1976 to 2012: summary of survey methods and database*. A report to SOTEAG from Aquatic Survey & Monitoring Ltd., Cosheston, Pembrokeshire. 16 pp + iii

Moore, J., Anderson, H. and Mercer, T. (2018). *Surveys of dogwhelks Nucella lapillus in the vicinity of Sullom Voe, Shetland, August 2018*. A report to SOTEAG from Aquatic Survey & Monitoring Ltd., Cosheston, Pembrokeshire and Marine Scotland Science, Aberdeen. 43 pp +iv.

Moore, J. and Bunker, F. (2017). *Survey of the rocky shores in the region of Sullom Voe, Shetland, July 2017*. A report to SOTEAG from Aquatic Survey & Monitoring Ltd., Cosheston, Pembrokeshire. 43 pp + iv

Zardi GI, Nicastro KR, Canovas F, Ferreira Costa J, Serra˜o EA, *et al.* (2011) Adaptive Traits Are Maintained on Steep Selective Gradients despite Gene Flow and Hybridization in the Intertidal Zone. *PLoS ONE* **6**(6): e19402. doi:10.1371/journal.pone.0019402

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

2. *Perforatus perforatus – not applicable in Shetland*

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

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

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

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

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

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

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

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

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

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, Field Studies Council Research Centre, Cordah Ltd., BMT Cordah Ltd., Aquatic Survey & Monitoring Ltd.

Survey staff: Annette Little (AL), Tony Thomas (AT), Ben James (BJ), Christine Howson (CH), 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), 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
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	15 + 10	5	Full survey	July
2018	ASML	JM, TM	15 + 10	5	Full survey (+ dogwhelks)	August