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## Scottish Marine and Freshwater Science Vol 12 No 14

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This report presents the results of marine and freshwater scientific work carried out by Marine Scotland Science.

# The Scottish Coastal Observatory Dataset: 1997 – 2020

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## Executive Summary

The Scottish Coastal Observatory (SCObs) monitors environmental parameters in Scottish coastal waters, generating data to fulfil the Scottish Government's statutory monitoring obligations under the Marine (Scotland) Act 2010, the UK Marine Strategy and Oslo Paris Commission (OSPAR) Quality Status Assessments. It also provides information about how the coastal marine ecosystem in Scottish waters is changing. A selection of parameters including temperature, salinity, turbidity, nutrients, ocean acidification, dissolved oxygen, chlorophyll 'a', and the composition of phytoplankton and zooplankton communities are monitored weekly at a number of sites around the Scottish coast since 1997. The SCObs dataset is quality controlled and data from 1997 - 2020 is accessible online at the Marine Scotland website. This report provides an update on SCObs sampling locations, analytical methodologies and quality control. It also contains supportive information to end users who are considering analysis of the SCObs dataset.

**Contents**

## 1. Introduction

The Scottish Coastal Observatory (SCObs) has monitored the waters around Scotland's coast since 1997. A selection of parameters including temperature, salinity, turbidity, nutrients, ocean acidification, dissolved oxygen, phytoplankton, chlorophyll 'a', and the composition of phytoplankton and zooplankton communities are monitored weekly at a number of sites. These data fulfil the Scottish Government's statutory monitoring obligations under the Marine (Scotland) Act 2010, the UK Marine Strategy and Oslo Paris Commission (OSPAR) Quality Status Assessments as well as providing information about how the coastal marine ecosystem is changing in Scottish waters. In 2016 a dataset of monthly means of individual parameters from the start of the SCObs dataset to the end of 2013 was published online, with temperature minilogger data updated at the end of 2019 (http://marine.gov.scot/data/scottish-coastal-observatory-data). A full description of the sampling sites, quality control procedures, sampling and analytical methodologies alongside seasonal and interannual patterns in the different environmental parameters, was also published (Bresnan et al., 2016).

The full dataset of weekly entries from 1997 until the end of 2020 is accessible at the Marine Scotland Monitoring webpage. This report provides the supporting metadata necessary for users to fully understand how the data was collected and quality controlled, and supplements the SCObs information published in an earlier report (Bresnan et al., 2016). Changes in site location, sampling and analytical methodologies since 2013, as well as events which have influenced assignment of quality flags (QFs) to the full SCObs dataset, are summarised here.

## 2. Site Descriptions

Figure 1 shows the locations of the monitoring sites included in the SCObs monitoring programme. A summary list of locations is given in Table 1 and the parameters measured at each site in Table 2. A full description of each site including any changes that have occurred since monitoring began until the end of 2013 is described in Bresnan et al., (2016). Changes to site locations since 2013, as well as descriptions of the St. Abbs and St. Kilda sites which joined the programme in 2013 and 2020 respectively, are detailed in section 2.1.

At all sites where water is collected for analysis, the sampling frequency is weekly, however there are instances where there are gaps in the dataset for some of the parameters. This is due to a number of operational factors, such as bad weather,

boat repairs or sampler availability which prevents the samples being taken. In some instances gaps in individual parameters can be due to issues such as sample integrity or problems with instrumentation for the analytical methods.

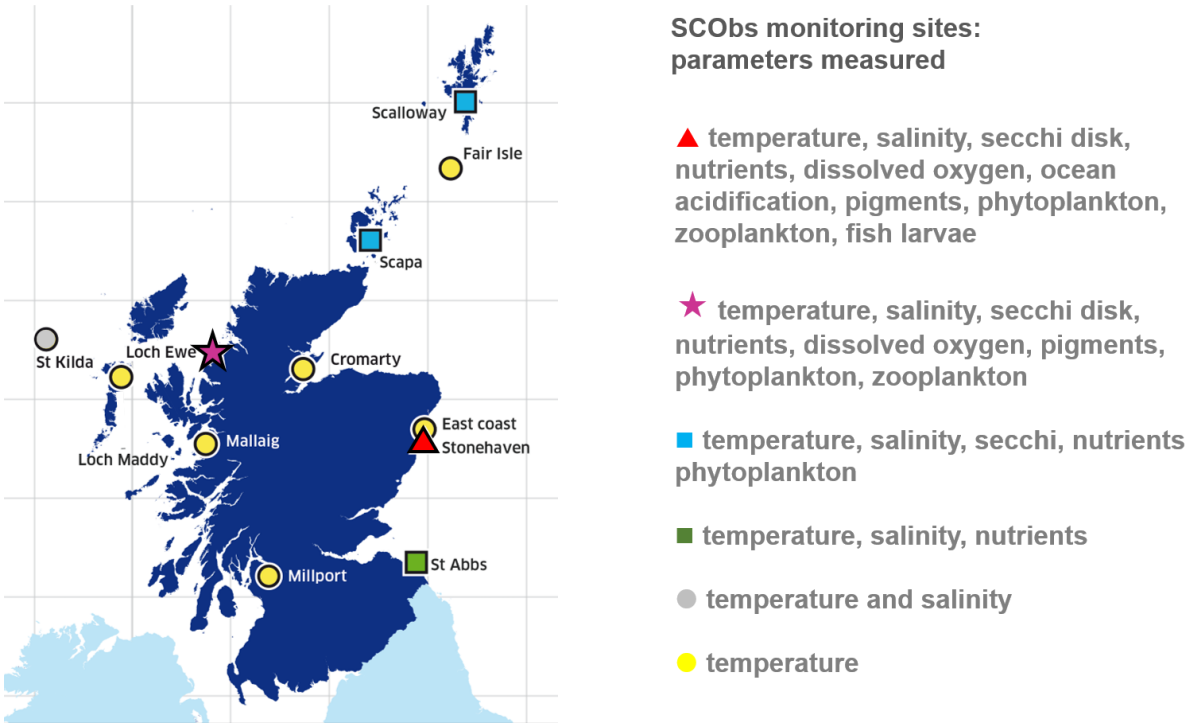


**Figure 1.** Map of the sampling locations in SCObs and parameters measured.

## Changes to the site positions since 2013

Scalloway

The SCObs monitoring site in Shetland was initially located at Clift Sound with sampling commencing in 2000. In December 2001 the sampling site was moved to a different location on the floating pontoon at the boat club in Scalloway for ease of sampling. In 2019 the minilogger moved a little way again, although still on a floating jetty at the Scalloway boat club. Changes to the latitude and longitude at this sampling site are provided in Table 1. Sampling for salinity, nutrients and phytoplankton stopped at this site at the end of 2018 due to resource limitations. Sampling for these parameters recommenced in Jan 2021.

St. Abbs

Temperature monitoring at St Abbs began in 2013 with the deployment of a minilogger (Vemco) in St Abbs Harbour. This minilogger is maintained by St. Abbs Marine Centre. It is fixed to a seawater intake pipeline and sits 2 meters below the lowest tide level. Volunteers at this site scuba or snorkel down to the change-over

the minilogger every three months. The minilogger is secured in a fixed 1.5 inch seawater intake pipe with drilled holes for water flow with a ball valve in the end.

In 2017 a more comprehensive sampling programme was started by the St. Abbs Marine Centre, with water collected weekly for salinity and nutrient analysis. Water for these analyses is taken over the break-harbour wall in St. Abbs at high tide and is collected using a bucket and rope. The bucket is rinsed three times and filled on the fourth. The sample bottles are also rinsed three times before being filled. The sampling location is quite exposed to high winds and waves occasionally break over the harbour wall. Sampling is performed each Monday, weather permitting.

St. Kilda

A temperature and salinity minilogger (Star-Oddi) was deployed in Village Bay, St. Kilda, in May 2021 and is maintained by National Trust Scotland with the support of Kilda Cruises personnel. This is the first use of a combined temperature and salinity logger at any of the SCObs sites. The logger is attached at 4m depth to the Kilda Cruises mooring line standing in 8m of water. Due to the deployment depth, the changeover of logger needs to be done by SCUBA or snorkel. Access to St Kilda is highly seasonal and so the logger will remain deployed for up to a year at a time. The initial deployment was enabled through a Small Grant from the Marine Alliance for Science and Technology Scotland Coastal Forum to expand and upgrade the SCObs monitoring sites.

## Table 1

Position of Scottish Coastal Observatory Monitoring Sites.

| | Site | Location Name | Latitude (degrees minutes) N | | Longitude (degrees minutes) W | |
|---|---|---|---|---|---|---|
| 1 | Millport | Keppel Pier | 55 | 44.97 | 004 | 54.33 |
| | | Fairlie Channel | 55 | 44.61 | 004 | 54.32 |
| 2 | Mallaig | Fishery Pier | 57 | 00.40 | 005 | 49.50 |
| 3 | Loch Maddy | Ferry Pier | 57 | 35.77 | 007 | 09.34 |
| | | nr Hamarsay | 57 | 03.09 | 007 | 08.48 |
| 4 | Loch Ewe | Mooring | 57 | 50.14 | 005 | 36.61 |
| | | Mouth Loch Ewe | 57 | 50.99 | 005 | 38.97 |
| 5 | Scapa | Scapa Pier | 58 | 57.42 | 002 | 58.37 |
| 6 | Fair Isle | North Haven Pier | 59 | 32.28 | 001 | 36.23 |
| 7 | Scalloway | Clift Sound | 60 | 07.04 | 001 | 16.87 |
| | | Boat Club Pontoon from 2001 | 60 | 08.07 | 001 | 16.95 |
| | | Boat Club Pontoon 2 from 2019 | 60 | 07.92 | 001 | 17.27 |
| 8 | Cromarty | Cromarty Pier | 57 | 40.98 | 004 | 02.39 |
| 9 | East coast | Findon | 57 | 03.81 | 002 | 06.25 |
| | | Cove | 57 | 05.74 | 002 | 04.59 |
| | | Stonehaven Harbour | 56 | 57.61 | 002 | 12.01 |
| 10 | Stonehaven | Offshore | 56 | 57.81 | 002 | 06.78 |
| 11 | St Abbs | St Abbs Harbour | 55 | 53.98 | 002 | 07.70 |
| 12 | St. Kilda | Village Bay | 57 | 48.34 | 008 | 33.59 |

## Table 2

Details of parameters measured at the SCObs sites. The date indicates the start of monitoring. A finish date is entered when sampling for a particular parameter at a site has ceased. Parameters measured are: Temp - temperature; Sal - salinity; Sec - secchi depth; DIP - dissolved inorganic phosphorus; DSi - dissolved inorganic silicate; TOxN - total oxidised nitrogen; Amm - ammonia; Nit – Nitrite; TA - total alkalinity; DIC - dissolved inorganic carbon; DO – dissolved oxygen; Phyto – phytoplankton community; $Phyto_{tox}$ – toxin producing phytoplankton; $Al_{tox}$ - dissolved algal toxins; Chl - chlorophyll '*a*'; Zoo – zooplankton community.

| Site | Physics | | | Chemistry | | | | | | | | Biology | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temp | Sal | Sec | DIP | DSi | TOxN | Amm | Nit | TA | DIC | DO | $Phyto_{tox}$ | Phyto | $Al_{tox}$ | Chl | Zoo |
| 1 Millport | 1997 - | | | | | | | | | | | 2005-2013 | 2005-2013 | | | |
| 2 Mallaig | 1999 - | | | | | | | | | | | | | | | |
| 3 Loch Maddy | 2003 | 2003-2011 | | 2003-2011 | 2003-2011 | 2003-2011 | 2003-2011 | | | | | 2003-2011 | 2003-2010 | | | |
| 4 Loch Ewe | 1999 | 2003 | 2008 | 2003 | 2003 | 2003 | 2003 | 2013 | | | 2018 | 1999 | 2001 | 2005-2016 | 2002 | 2002 |
| 5 Scapa | 1999 | 1999 | 2019 | 1999 | 1999 | 1999 | 1999 | 2007 | | | | 1997 | 2000 | 2011-2016 | | |
| 6 Fair Isle | 1997-2000<br>2004 | | | | | | | | | | | | | | | |
| 7 Scalloway | 2000 | 2000 | 2019 | 2000-2018<br>2021 | 2000-2018<br>2021 | 2000-2018<br>2021 | 2000-2018<br>2021 | 2007 | | | | 2000 – 2018<br>2021 | 2001 – 2018<br>2021 | 2011-2016 | | |
| 8 Cromarty | 2004 | | | | | | | | | | | | | | | |
| 9 East coast | 1997 | | | | | | | | | | | | | | | |
| 10 Stonehaven | 1997 | 1997 | 2002 | 1997 | 1997 | 1997 | 1997 | 2013 | 2008 | 2008 | 2018 | 1997 | 1997 | | 1997 | 1997 |
| 11 St Abbs | 2013 | 2017 | | 2017 | 2017 | 2017 | 2017 | 2017 | | | | | | | | |
| 12 St. Kilda | 2021 | 2021 | | | | | | | | | | | | | | |

## 3. Quality Control and Quality Flagging

All data undergoes a data quality check for analytical errors using the criteria associated with UKAS ISO 17025 accreditation and the Marine Scotland Joint Code of Practice. Quality flags (QF) have been assigned to all metadata and data, according to the Seadatanet quality flag system (SEADATANET 2010, Table 3). A SCObs data quality group comprising experts in oceanography, chemistry and plankton science meet annually to review and finalise the quality flags.

**Table 3**

SeaDataNet measured qualifier flags (SEADATANET, 2010)

| Key | Entry Term | Abbreviated term | Term definition |
|---|---|---|---|
| 0 | no quality control | none | No quality control procedures have been applied to the data value. This is the initial status for all data values entering the working archive. |
| 1 | good value | good | Good quality data value that is not part of any identified malfunction and has been verified as consistent with real phenomena during the quality control process. |
| 2 | probably good value | probably_good | Data value that is probably consistent with real phenomena but this is unconfirmed or data value forming part of a malfunction that is considered too small to affect the overall quality of the data object of which it is a part. |
| 3 | probably bad value | probably_bad | Data value recognised as unusual during quality control that forms part of a feature that is probably inconsistent with real phenomena. |
| 4 | bad value | bad | An obviously erroneous data value. |
| 5 | changed value | changed | Data value adjusted during quality control. Best practice strongly recommends that the value before the change be preserved in the data or its accompanying metadata. |
| 6 | value below detection | BD | The level of the measured phenomenon was too small to be quantified by the technique employed to measure it. The accompanying value is the detection limit for the technique or zero if that value is unknown. |
| 7 | value in excess | excess | The level of the measured phenomenon was too large to be quantified by the technique employed to measure it. The accompanying value is the measurement limit for the technique. |
| 8 | interpolated value | interpolated | This value has been derived by interpolation from other values in the data object. |
| 9 | missing value | missing | The data value is missing. Any accompanying value will be a magic number representing absent data. |
| A | value phenomenon uncertain | ID_uncertain | There is uncertainty in the description of the measured phenomenon associated with the value such as chemical species or biological entity. |

Within the datasets all values that have been assessed to have a QF A are marked with a QF 10 to facilitate the use of computer code during processing.

All data is flagged QF 0 until an annual review is undertaken by the SCObs data quality group. This ensures that combined oceanographic, chemical and biological expertise are utilised to assign the appropriate flag by evaluating all parameters together, and checking to see whether it has been a natural event or an procedural/analytical error. The final QFs are assigned once the data analysis for the previous calendar year is completed and the seasonal cycle can be examined. All data including data which has been flagged as QF 0, QF 3 and QF 4 have been included in the SCObs dataset.

Quality flags for temperature, salinity and nutrient data are assigned using a MATLAB script to examine their seasonal trends. Data points prior to any transformation, falling outside +/- 2 standard deviations of the seasonal mean are flagged for further review. Anomalous data points (e.g. bottom salinity lower than surface) are also flagged. QFs will be assigned to the salinity and nutrient data from St. Abbs after five years of data have been collected.

Temperature, salinity, chlorophyll 'a' and nutrient data are all considered in relation to one another when accepting or editing the QF values that have been assigned automatically. For example, a spike in TOxN values flagged by the MATLAB code as anomalous are reviewed in relation to salinity, DIP and DSi values. If the spike of TOxN occurs at the same time as a decline in salinity and an increase in DIP and DSi values, this is likely to be the result of freshwater inflow and this datapoint is assigned a QF 2.

In the 'Environmental Data' datasets, temperature, salinity, DO, nutrient and pigment data are in columns where the parameter name is prefixed with a 'D' and the QFs for each parameter are in columns prefixed with 'F'. All data collected, including QF 3, 'potentially bad', and QF 4, 'bad', are provided within the final dataset and the end user should remove these 'bad' data prior to data analysis.

# 4. Temperature and Salinity

## 4.1 Introduction

All sites within SCObs measure temperature and in some sites it is the only variable measured. Salinity is currently measured at five sites; Loch Ewe, Scapa, Scalloway, Stonehaven and St. Abbs (Figure 1, Table 2).

## 4.2 Methods and Data Quality Control

Sampling methods for temperature and salinity vary between sites; but the quality control methods are the same between locations. For full details refer to Bresnan et al., (2016).

At some sites (e.g. Scapa, Scalloway, St. Abbs), temperature measurements were not made at the same point as the discrete water sample but were measured continuously using a temperature minilogger (Vemco) located nearby. Where possible, temperature values associated with the collection of each water sample for salinity and nutrient analysis are interpolated from hourly averages of the minilogger temperature data. It should be noted that the sample times are not always recorded with high precision and may differ by up to +/- one hour of the actual sample. In such cases the temperature has been recorded with a data QF of 8, indicating an interpolated sample. This QF infers 'good' data.

## 4.3 Data Quality Notes

At Loch Ewe, during 2007, some additional temperature and salinity measurements were taken for an alternative project not at the standard location; for this reason they have not been quality controlled and have been assigned a QF 0.

Salinity analysis was accredited by the United Kingdom Accreditation Service (UKAS) to ISO 17025 standard in early 2016. No salinity data prior to 2016 is flagged as QF1 'good' - due to an issue with the plastic inserts that are used to prevent evaporation of water in the stored salinity sample bottles (see Berx et al., 2017). Data points have been flagged as QF 2 unless considered not of good quality by the data quality team and flagged with a QF 3 'probably bad' or QF 4 'bad'.

In 2019 and 2020 instrumentation difficulties with the salinometer used to analyse the salinity samples resulted in some samples being analysed outside of its accreditation period. If the values still fell within the +/- 2 stds in the MATLAB code and where in line with the recorded nutrient values they were assigned a QF 2.

# 5. Secchi Depth

## 5.1 Introduction

A secchi disk is used to measure turbidity at Stonehaven, Loch Ewe, Scalloway and Scapa.

## 5.2 Data Handling and Quality Control

A 9 week running mean has been applied to the data initially and data points outside of 2 standard deviations from this mean have been flagged as probably bad (QF 3). Flagged data points were considered alongside chlorophyll 'a' data as well as preceding/subsequent values to determine if the value was due to a natural event, and thus assigned a QF 2, or operator error, in which instance the QF 3 value was retained. All other data is flagged as good (QF 1). Data which has been flagged as QF 3, 'probably bad', and QF 4, 'bad', have also been included in the dataset and should be be removed prior to analysis.

## 5.3 Data Quality notes

The knotted rope attached to the secchi disk deployed to Scalloway only has knots for the first 10 m of rope. At Scalloway from 2021, if the secchi depth was greater than this it has been recorded as 11 m.

# 6. Dissolved Oxygen

Sampling for dissolved oxygen (DO) began in 2018 at Stonehaven and Loch Ewe. DO is determined in water samples using a Winkler titration method (Hansen 1999). The sample is fixed in the field with manganous chloride, followed by a solution of potassium iodide and sodium hydroxide (alkali iodide). The resultant manganous hydroxide precipitate reacts with the dissolved oxygen which oxidises manganese from the (III) to the (IV) state. The sample is then

acidified with hydrochloric acid and the oxidised manganese reacts with the iodide to liberate an amount of iodine equivalent to the dissolved oxygen present in the sample. The solution is titrated with a thiosulphate solution and the amount of iodine present determined using a starch indicator with the endpoint clearly marked by the change from blue to colourless. The amount of oxygen can then be computed from the titer: one mole of $O_2$ reacts with four moles of thiosulfate. This method is accredited by the United Kingdom Accreditation Services to ISO 17025 standard. Internal quality control procedures include the incorporation of laboratory reference materials (LRM) with each batch of samples. LRM data is monitored on a Shewhart chart using NWA Quality Analyst software with warning and action limits drawn at ± 2 x and ± 3 x the standard deviation of the mean.

# 7. Nutrients

## 7.1 Introduction

Water samples for nutrient analysis: Dissolved Inorganic Phosphate (DIP), Dissolved Inorganic Silicate (DSi), Total Oxidised Nitrogen (Nitrate, Nitrite, Ammonia) TOxN, Ammonia, Nitrite are collected at multiple sites (Figure 1). Data which have been flagged as QF 3, 'probably bad', and QF 4, 'bad', have also been included in the dataset and should be be removed prior to analysis.

## 7.2 Methods

Methodologies for sampling of inorganic nutrients are fully detailed in Bresnan et al., (2016). All methods are accredited by the United Kingdom Accreditation Service (UKAS) to ISO 17025 standard.

## 7.3 Data Quality Notes

Dissolved Inorganic Phosphate (DIP) data from water samples collected in 2004, 2005 and 2006 were assigned a QF of 4. During these years DIP concentrations tended to be higher than expected for the seasonal cycle. However, there was no obvious explanation for this as the analytical quality control (internal QC and external proficiency testing QC) was acceptable during this time period. Ammonia data from samples collected between 2006 and 2009 inclusive were also assigned a Quality Flag of 4 due to failures in external proficiency testing Quality Control which resulted in a change in analytical instrumentation. The

remaining Ammonia and Nitrite data has been flagged as QF 0 as the seasonal cycle is still being established.

# 8. Phytoplankton

## 8.1 Introduction

Phytoplankton samples were collected using a 10 m integrated tube sampler and a subsample was emurated using a number of different Utermöhl counting techniques (Bresnan et al., 2016). Each of these datasets are included in the SCObs online dataset. The SCObs phytoplankton dataset comprises of four separate spreadsheets for each site. Phytoplankton cells on a target species list, including toxin producing cells, were counted on the entire base plate at X200 magnification (Target Species spreadsheet). This was performed on all samples. From 1997 full community phytoplankton analysis was performed on Stonehaven samples by counting the first 400 cells at X400 (F400 spreadsheet). In 2000 an additional count of 10 fields of view across a transect at X200 was added to the full community analysis at Stonehaven and performed on the other sites where phytoplankton were analysed as they were entered the SCObs monitoring programme (FOV spreadsheet). The recording of the presence/absence of all phytoplankton cells on the base plate of the Utermöhl counting chamber was added to the phytoplankton analysis in Stonehaven in 2000, and the rest of the sites in 2005. Presence/Absence data from 2006 has been uploaded. In the spreadsheets presence is recorded as ‘1’ and absence as ‘0’ (Presence_absence spreadsheet). All data uploaded was reviewed, anomalous data checked and internally assigned a QF 1.

An Aphia identifier (https://www.marinespecies.org/) has been assigned to each taxonomic recording category to account for informal inhouse recording. These Aphia identifers are in line with those used in the Master Taxa list for the UK Pelagic Habitat working group (Ostle et al., 2021).

## 8.2 Data Handling and Quality Control

Target species analysis received UKAS ISO 17025 accreditation in 2005. The phytoplankton data is signed off annually, with the seasonal cycle examined and anomalous results queried. Analysts perform internal ring trials focussing on different species and species groups annually to ensure consistency of results between different analysts. Analysis also participate in external ring trials, such

as the International Phytoplankton Intercomparison exercise, for external validation.

### 8.3 Data Quality Notes

From April 2002 – March 2003 a project funded by Food Standards Scotland was undertaken in Loch Ewe and Scapa. During this time period, sites were sampled twice a week and three replicates samples for target species analysis were taken. Full community analysis was performed on one replicate only. The results from these analyses are included in the dataset.

The limitations of routine light microscopy, Lugol's iodine preservative and presence of resuspended sediment in phytoplankton samples make small phytoplankton cells difficult to identify. Small unidentified flagellates are recorded as part of the first 400 cell count, however, these values are used to distinguish when these cells are very plentiful or rare and should not be used as a strict cells per litre count.

*Phaeocystis* is difficult to count as preservation in Lugol's iodine and homogenisation of the sample prior to settling results in the colonies ripping, and thus many of the *Phaeocystis* cells are included as single cells in the small flagellate count.

Due to resource limitiations, sampling for phytoplankton analysis ended in Loch Maddy in 2011 and Millport in 2013. Sampling for phytoplankton at Scalloway ended in 2018 and recommenced in January 2021.

## 9. Chlorophyll '*a*'

### 9.1 Introduction

Water samples for pigment analysis have been collected from the Stonehaven monitoring sites using a 10 m integrated tube sampler since monitoring began in 1997. At Loch Ewe, water samples for pigment analysis were collected using a water bottle at 5 m depth from April 2003 – Dec 2007 and, additionally, at 30 m from April 2003 – Dec 2004. From Jan 2008 – Jun 2011 both 5 m water bottle and 10 m integrated tube samples were collected at Loch Ewe. From June 2011 only 10 m integrated tube samples were collected. Depending on the time of

year, a 500 mL to 2 L aliquot was filtered through a GF/F filter, frozen and stored at -80 $^{o}$C until analysis. Data which has been flagged as QF 3, 'probably bad', and QF 4, 'bad', were also included in the dataset and should be be removed prior to analysis.

### 9.2 Methods

Methodologies for analysis of chlorophyll are fully detailed in Smith et al., (2007). The chlorophyll method is accredited by the United Kingdom Accreditation Service (UKAS) to ISO 17025 standard.

## 10. Algal Toxins

### 10.1 Introduction

Solid Phase Absorption Toxin Tracking (SPATT) was used to measure liophilic shellfish toxins at Loch Ewe, Scapa and Scalloway (see Bresnan et al.,2016). This analysis stopped in 2016 due to resource limitations. Data uploaded has been quality controlled and assigned a QF 1.

### 10.2 Data Quality Notes

Deployment of SPATT bags at Scapa and Scalloway was not continuous and details of their deployment is given in Table 4.

**Table 4**
Summary of SPATT monitoring

| Site name | SPATT deployment period | Number of analysed SPATT |
|---|---|---|
| Loch Ewe | 04/04/2005 – 30/12/2013 | 452 |
| Scapa | 16/05/2011 – 09/12/2013 | 131 |
| Scalloway | 10/06/2011 - 09/09/2011 | 12 |
| | 04/05/2012 - 17/08/2012 | 10 |
| | 07/06/2013 - 31/12/2013 | 31 |

Vials containing the analysed SPATT sample extracts were re-capped after LC-MS analysis and were stored in a freezer up to two years. Additionally, aliquots (ca. 20 mL) of non-diluted SPATT extracts collected during the toxin extraction

process were stored in glass sample vials (Wheaton, Millville, NJ, USA) and kept at -20 ºC for five years in the eventuality of further required analyses.

# 11. Zooplankton

## 11.1 Introduction

Mesozooplankton have been sampled at Stonehaven on the east coast of Scotland since 1997 and at Loch Ewe on the west coast of Scotland since 2002. For a full description of sample collection and processing refer to Bresnan et al. (2016). The following notes refer to changes to sampling and analysis that have taken place throughout the duration of the time series.

## 11.2 Sample Collection and Processing

Zooplankton samples at Stonehaven and Loch Ewe are currently collected using 40 cm diameter bongo nets fitted with 200 µm mesh and filtering cod ends. It should be noted that from 15/01/1997 – 10/03/1999 bongo nets with a diameter of 30 cm were used.

At Stonehaven, most taxa were identified to a higher taxonomic level between 1997 - 1999. For example, from the grouping 'Calanoid copepods' only *Calanus finmarchicus*, *C. helgolandicus*, *Paraeuchaeta norvegica* and Metridinidae were identified during this period, with the remaining species grouped as Copepoda (C1-6). Similarly, all species of Cnidaria and Ctenophora were recorded as Coelenterata. Most taxa since 1999 have been identified to the lowest taxonomic level possible, however, some taxa are grouped into higher taxonomic levels e.g. Polychaeta larvae.

Zooplankton counts are converted to abundance (number of individuals per cubic metre) by calculating the volume of water filtered by the bongo net. The volume filtered was estimated from the vertical distance towed, net mouth area and a 70 % filtration efficiency (MSS unpublished data) until 2018 for Stonehaven and 2017 for Loch Ewe. Calibrated flow meters (with back stop) have been used since 2018 at Loch Ewe and 2019 at Stonehaven, with the volume of water filtered through the nets calculated using the weekly flow meter readings.

## 11.3 Data quality, Handling and Archiving

Zooplankton quality assurance follows the MSS joint code of practice (Bresnan et al., 2016) and all analysts participate in NMBAQC external identification trials. All data entries into the zooplankton database are double checked by a second analyst every month. Only authorised staff are able to edit information on the database. At the end of each year, the calculated abundances of each zooplankton category are checked against a nine week running mean and any value that is greater than ±3 standard deviations from the mean is checked and, if necessary, the sample reanalysed.

### 11.4 Data Quality Notes

Since 2016, sample information, zooplankton count and abundance data from the taxonomic analyses of samples from Stonehaven and Loch Ewe have been moved from an Access to a LIMS database, which provided an opportunity for a thorough review of the dataset.

The following changes have been made to Stonehaven and Loch Ewe published data (10.7489/610-1 Stonehaven and 10.7489/948-1 Loch Ewe):

- Stonehaven Coelenterata data after 1999 were moved to the category 'Cnidaria' after checks of analysis notes. Unidentified gelatinous entries with a note 'Scyphozoa ephyra' were moved to relevant category. Coelenterata data at Stonehaven from 1997 to 1998 include both Cnidaria and Ctenophora. For Loch Ewe, if there was a comment on the analysis notes for unidentified gelatinous taxa such as "small but probably *Lizzia blondina*" then the entry was moved to the category for the relevant order 'Anthoathecata' or 'Leptothecata.'
- *'Hydractinia* spp.' was changed to '*Podocoryna* spp.'
- *'Cosmetira pilosella'* was added to the species list and entries from 'Leptomedusa' moved to a new species column for the following samples collected at Stonehaven during 2016: 06/05/2016, 10/05/2016, 06/04/2017, 19/09/2017, and Loch Ewe on 11/06/2007, 18/06/2007, 29/07/2013, 06/07/2015.
- Samples with 'Ctenophora remains' entries have been moved to the '*Pleurobrachia pileus'* category in the following samples from Stonehaven collected on 31/08/2015, 15/09/2015, 23/09/2015, 30/09/2015, 12/10/2015, 19/10/2015, 30/10/2015, 03/11/2015, 23/05/2016,

30/05/2016, 06/06/2016, 26/07/2016, 01/08/2016, 10/08/2016, 15/08/2016, 22/08/2016, 07/09/2016, 15/09/2016, 28/09/2016.

- The category 'Siphonophorae' was removed from Loch Ewe samples 07/09/2015 and 14/09/2015 as they were nectophores.
- Note the category 'Podonidae', was used for all taxa of this family at Stonehaven from 1997 to 1998 (as *Podon* spp.) but from 1999 is used only for unidentified specimens.
- The category 'Halocyprididae' was changed to 'Ostracoda Halocypridina spp.'
- The category 'Other copepoda' added at Stonehaven to include copepods recorded pre 1999 when most copepods were not identified to species or genus level. From 2016 to present, copepodite stages C1, C2, C3, C4, C5 are no longer recorded but pooled in "C1-5" categories for the following taxa: '*Paracalanus parvus parvus'*, '*Pseudocalanus* spp.', '*Microcalanus pusillus'*, '*Diaixis hibernica*,' '*Temora longicornis'*, '*Metridia lucens lucens'*, '*Centropages hamatus'*, '*Centropages typicus'*, '*Candacia armata*', '*Acartia (Acartiura) clausi'*, '*Oithona* spp.'
- Stonehaven and Loch Ewe records of '*Clausocalanus* spp.' C1-6 were moved to the categories '*Clausocalanus* spp.' C6F, C6M and C1-5.
- In the data from the Loch Ewe 21/10/2002 sample, entries for 'Calanoida C1-6' were moved to '*Calocalanus* spp.' C6F and C1-5.
- Stonehaven records of '*Paracalanus parvus parvus* C5F' were added to '*Paracalanus parvus parvus* C5.'
- Stonehaven and Loch Ewe records of '*Paracalanus parvus parvus* C5M' were added to '*Paracalanus parvus parvus* C5.'
- Stonehaven records of '*Paraeuchaeta norvegica'* were moved to 'Euchaetidae C1-6.'
- Stonehaven records of '*Temora longicornis* C5F' were added to '*Temora longicornis* C5.'
- Stonehaven and Loch Ewe records of '*Temora longicornis* C5M' were added to '*Temora longicornis* C5.'
- Stonehaven records of '*Temora longicornis* N1-6' were added to 'Calanoida N1-6.'
- Stonehaven and Loch Ewe records of '*Centropages hamatus* C5F' were added to '*Centropages hamatus* C5.'
- Stonehaven records of '*Centropages hamatus* C5M' were added to '*Centropages hamatus* C5.'

- Stonehaven records of '*Acartia (Acartiura) clausi* C5F' were added to '*Acartia (Acartiura) clausi* C5.'
- Stonehaven records of '*Acartia (Acartiura) clausi* C5M' were added to '*Acartia (Acartiura) clausi* C5.'
- Stonehaven records of '*Acartia (Acartiura) clausi* N1-6' were added to 'Calanoida N1-6.'
  *'Mesocalanus tenuicornis'* data were moved from 'Calanoida C1-6' to its own category for Loch Ewe samples collected on the following dates: 14/04/2008, 16/08/2010, 23/08/2010, 02/07/2012, 21/04/2014, 09/06/2014, 11/04/2016.
- *'Tortanus* spp.' C6F, C6M, C1-5 and *Tortanus* egg data from Stonehaven were moved from' Calanoida' and 'unidentified eggs' categories to relevant named categories.
- From the start of 1997 to 16/10/2002 and from 13/05/2015 to end of 2018 the category 'Oithonidae C1-6' was used to record all *Oithona* spp. stages from Stonehaven samples. From the start of 2019 onwards the category is used for recording unidentified specimens of *Oithona* spp. only. At Loch Ewe the category 'Oithonidae C1-6' from 2002 to 2015 and from 2018 onwards, is used to record unidentified *Oithona* and from 04/01/2016 to end of 2017 it was used to record all *Oithona* spp. Stages.
- 'Monstrillidae C1-6' category was changed to 'Monstrilloida C1-6', the 'Copepoda C1-6' entry for Loch Ewe sample 03/11/2014 moved to 'Monstrilloida C1-6.'
- All '*Caligus* spp.' records from Stonehaven were moved to 'Caligidae C1-6'
- *'Mormonilla* spp. C1-6' entries were moved from 'Copepoda C1-6' for Loch Ewe samples collected on the following dates: 28/04/2014, 05/05/2014, 03/08/2015.
- The category 'Malacostraca' at Stonehaven was used to record most Crustacea until the end of 1998 but from 1999 this category was used to record unidentified Crustacea only.
- '*Hyperia* spp.' data from 14/05/2018 to 17/12/2018 at Stonehaven has been moved to the new category 'Hyperiidae'.
- The category 'Mollusca' at Stonehaven was used to record most Mollusca until the end of 1998 but from 1999 this category was used to record unidentified Mollusca only.
- The category '*Limacina retroversa'* was changed to '*Limacina* spp.'

- Data in the category 'Lamellaria eggs' was combined with data in the category '*Lamellaria* spp.' larva for samples collected from Stonehaven at the following dates: 07/06/1999, 19/09/2017, 05/04/2018.
- Gymnosomata larvae records at Stonehaven were moved from the category 'unidentified benthic larvae' to the newly created database category for this group - 'Gymnosomata larvae'.
- The category 'Chaetognatha' (previously recored as 'Sagittidae') at Stonehaven was used to record mostly adults and juveniles of '*Parasagitta* spp.' until the end of 1998. From the beginning of 1999 it was used only for unidentified specimens.

## 12. Additional datasets from SCObs sites

### 12.1 Flow Cytometry Data

Data on pico and nanoplankton has been collected since 2015 at Stonehaven as part of a research project ST0160. Samples are collected using a 10 m integrated tube sampler. A 1.8 mL aliquot is preserved with 0.2 ml paraformaldehyde, flash frozen in liquid nitrogen and stored at -80 $^{o}$C before transport to Plymouth Marine Laboratory for analysis using the flow cytometry method as described in Tarran and Bruun (2015). Results are presented as cells $mL^{-1}$.

The categories recorded by this analysis are;

*Synechococcus*
Picoeukaryotes
Nanoplankton
Coccolithophores
Cryptophyes
High nucleic acid bacteria
Low nucleic acid bacteria
Potential single *Phaeocystis* cells (cf. *Phaeocystis*)

### 12.2 Fish Larvae

Zooplankton samples have been collected since 2000 at Stonehaven with a 1 m diameter ring net fitted with a 350 µm mesh and a non filtering cod end. Only selected fish larvae are identified to family (gadoids, clupeids) or species level

(sandeels) and are enumerated and preserved in 80% isopropanol. The remaining zooplankton sample is fixed with 4% borax buffered formaldehyde and stored without any further processing. The fish larvae data are entered in a LIMS database and are available on request.

### 12.3 Temperature

At Stonehaven, temperature data has also been collected weekly throughout the water column using a Conductivity, Temperature, Depth (CTD) profiler since 2000, and these data are available upon request.

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