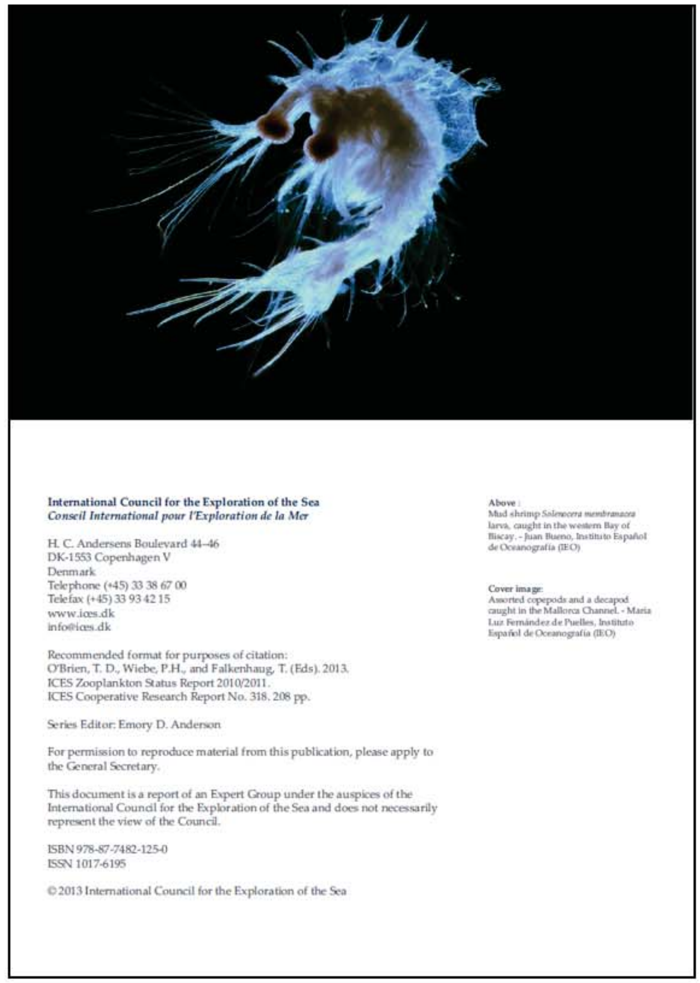

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Above :
Mud shrimp *Solenocera membranacea* larva, caught in the western Bay of Biscay. - Juan Bueno, Instituto Español de Oceanografía (IEO)

Cover image:
Assorted copepods and a decapod caught in the Mallorca Channel. - Maria Luz Fernández de Puelles, Instituto Español de Oceanografía (IEO)

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7.3 Stonehaven (Site 46)

Kathryn Cook

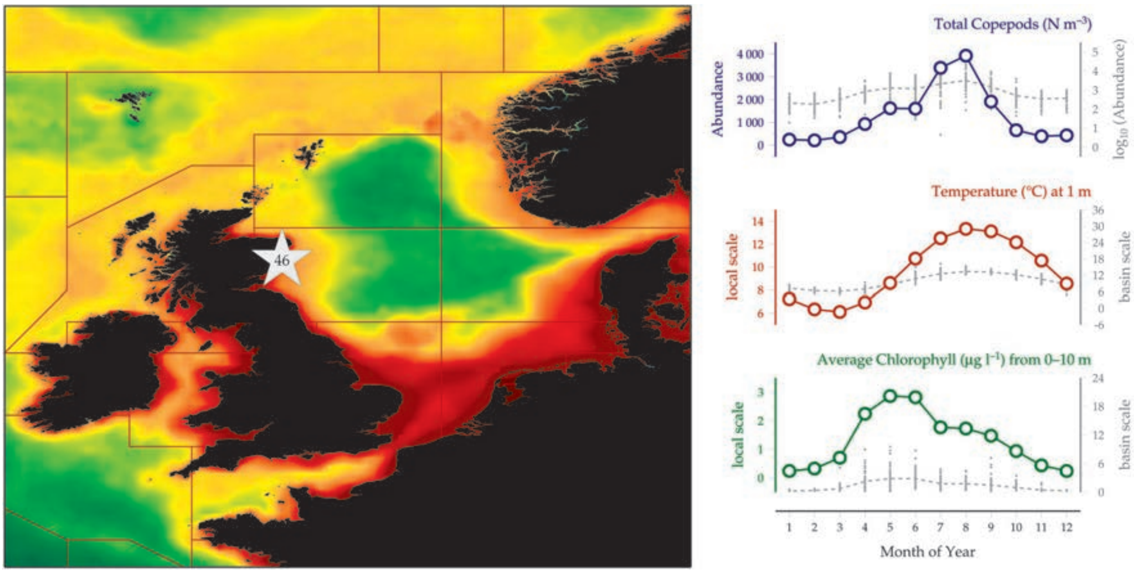


Figure 7.3.1
Location of the Stonehaven monitoring area (Site 46) plotted on a map of average chlorophyll concentration, and its corresponding seasonal summary plot (see Section 2.2.1).

The Marine Scotland Stonehaven sampling site is located at 56°57.80'N 02°06.20'W (Figure 7.3.1), approximately 5 km offshore from Stonehaven, a small town 28 km south of Aberdeen, Scotland, in a water depth of 50 m. Since January 1997, samples for the determination of surface and near-seabed hydrographic parameters and concentrations of inorganic chemical nutrients have been taken using water bottles and reversing digital thermometers, and integrated (0–10 m) phytoplankton and chlorophyll samples have been collected using a Lund tube (see Lund and Talling, 1957). Mesozooplankton samples (200 µm mesh) were collected by a vertical deployment of a 30 cm diameter Bongo net until 10 March 1999, after which time these samples have been collected by vertical deployment of a 40 cm diameter Bongo net. Since 1999, detailed taxonomic analysis has been carried out on the mesozooplankton and phytoplankton samples. Fine-mesh zooplankton samples (95 µm mesh from 1997 to April 2001, then 68 µm mesh to the present) have also been collected using a bongo net, but these are currently archived and not analysed because of the limited availability of trained staff. Macrozooplankton (350 µm mesh) is sampled using a 1 m ringnet deployed with a double oblique tow at 2 knots. These samples are also archived, although a current project is analysing these macroplankton samples using a ZooScan system and automated species-group recognition. Other short-term sampling at the site is done in support of a variety of time-limited research projects that study aspects of the coastal species or ecology in more detail. The objective of the time-series is to establish a monitoring base for assessing the status of the Scottish coastal ecosystem and to gauge responses to climate change. Some of these data are available online at https://sites.google.com/site/mssmonitoring/home.

Seasonal and interannual trends (Figure 7.3.2)

The origins of the water passing down the Scottish east coast lie mainly north and west of Scotland and are a variable mix of coastal and oceanic Atlantic waters. Water movement is generally southerly, with fairly strong tidal currents and a local tidal excursion of about 10 km. The water column at the sampling site remains well mixed throughout much of the year, with the exception of summer and early autumn, when surface heating and calm weather can cause temporary thermoclines to appear. Occasional haloclines are transient and depend largely on periods of extensive river and land run-off to surface layers in the coastal area. The seasonal minimum temperature of about 6°C generally occurs in late February to early March and rises to about 12–14°C in August. Throughout late summer and autumn, the increased salinity measured at Stonehaven indicates a variable, but often significant, increase in the proportion of Atlantic water passing the site. Comparison of the results with archive regional data on temperature, salinity, nutrients, and chlorophyll *a* indicates that the site provides a reliable index of the state of wider Scottish coastal waters (Heath *et al.*, 1999).

At the Stonehaven site, seasonal cycles are evident in all of the measured variables. The concentration of nitrate, a vital nutrient for phytoplankton growth, falls as chlorophyll increases with the onset of the spring phytoplankton bloom in March–April. Zooplankton, in turn, feed on phytoplankton and on each other and increase in abundance after the spring phytoplankton bloom. Throughout summer, phytoplankton growth relies on regenerated nitrate and ammonia supplied by microbial action and zooplankton excretion. After a late summer peak in August–September, which coincides with the highest water temperature, zooplankton abundance declines as food becomes scarce because phytoplankton growth is light and temperature limited. The nitrate concentration then begins to rise as it is replenished during winter by resuspension from the sediment due to storm action and increased river and land run-off. In order to survive winter, some species such as the large copepod genus *Calanus* and euphausiids build up oil reserves, whereas others rely on resting eggs or simply survive on whatever they find to eat through winter (e.g. the copepod *Oithona spp*.). Some species (e.g. the copepod *Calanus finmarchicus*, Figure 7.3.2) are not resident at Stonehaven throughout winter, but are reseeded each year by the influx of waters from the north or from areas south and west of Scotland.

Although the patterns are broadly consistent, the dynamics of seasonal cycles vary between years for both the environmental and species components of the ecosystem. Temperature has generally been higher than average since 2003, although 2010 was a cold year, whereas salinity appears to have been decreasing during this time. There are no obvious patterns in the annual concentration of nitrate, but chlorophyll has been higher than average since 2005. Overall, copepod abundance increased between 1997 and 2003, and since has fluctuated around the long-term average. This is in contrast to the decreasing trend seen in the offshore CPR data from the region (Figure 7.3.3), particularly since 2005. 2010 was a year of lower-than-average copepod abundance at the Stonehaven site, but higher-than-average copepod abundance in the CPR data. The causes of this discrepancy are not understood, but it is probably the result of differences in sampling methods and in the hydrographic influences at the nearshore Stonehaven station, compared with the much wider and offshore region encompassed by the adjacent CPR survey tracks. It is notable that anomalies in the interannual abundance of the arrow worms (Chaetognatha), which feed on copepods and their larvae, follow interannual patterns similar to those of their main prey at Stonehaven (Figure 7.3.2). However, this is not seen in the abundance of the cnidarians, also predators of copepods, at Stonehaven which have decreased since 2006.

The important copepod genus *Calanus* is represented by two species in Scottish seas: *C. finmarchicus* and *C. helgolandicus*. The Arctic–boreal *C. finmarchicus* has a spring influx arising from the winter diapause in deeper waters off the edge of the continental shelf. Historically, *C. finmarchicus* has been the dominant *Calanus* species in the northern North Sea, providing food for many fish larvae in spring. However, in recent decades, the proportion of the more southerly *C. helgolandicus*, generally most productive in summer and autumn, has increased rapidly (Beaugrand, 2009), so that it is now approximately tenfold more abundant than *C. finmarchicus*. At Stonehaven, the pattern in annual abundance anomalies has been the same for both *Calanus* species: abundance has increased between 1997 and 2008, and 2009–2010 have been years of lower abundance. A similar pattern is also seen in the *Oithonidae* spp. copepod.

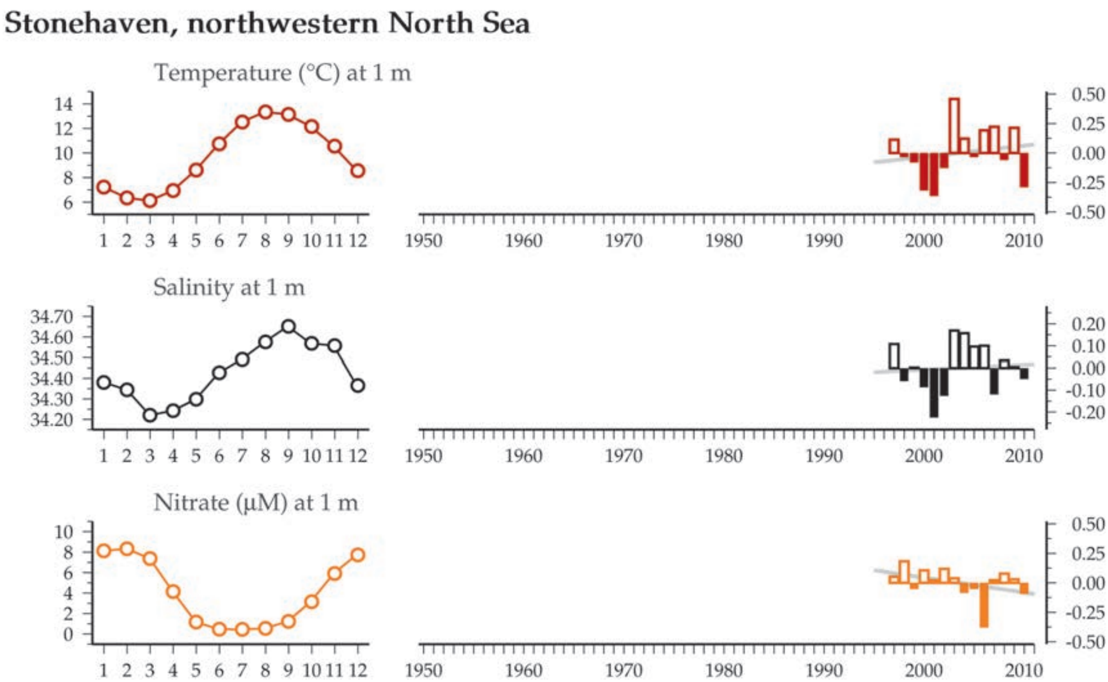


Figure 7.3.2
Multiple-variable comparison plot (see Section 2.2.2) showing the seasonal and interannual properties of select cosampled variables at the Stonehaven monitoring area.

Additional variables are available online at: http://WGZE.net/time-series.

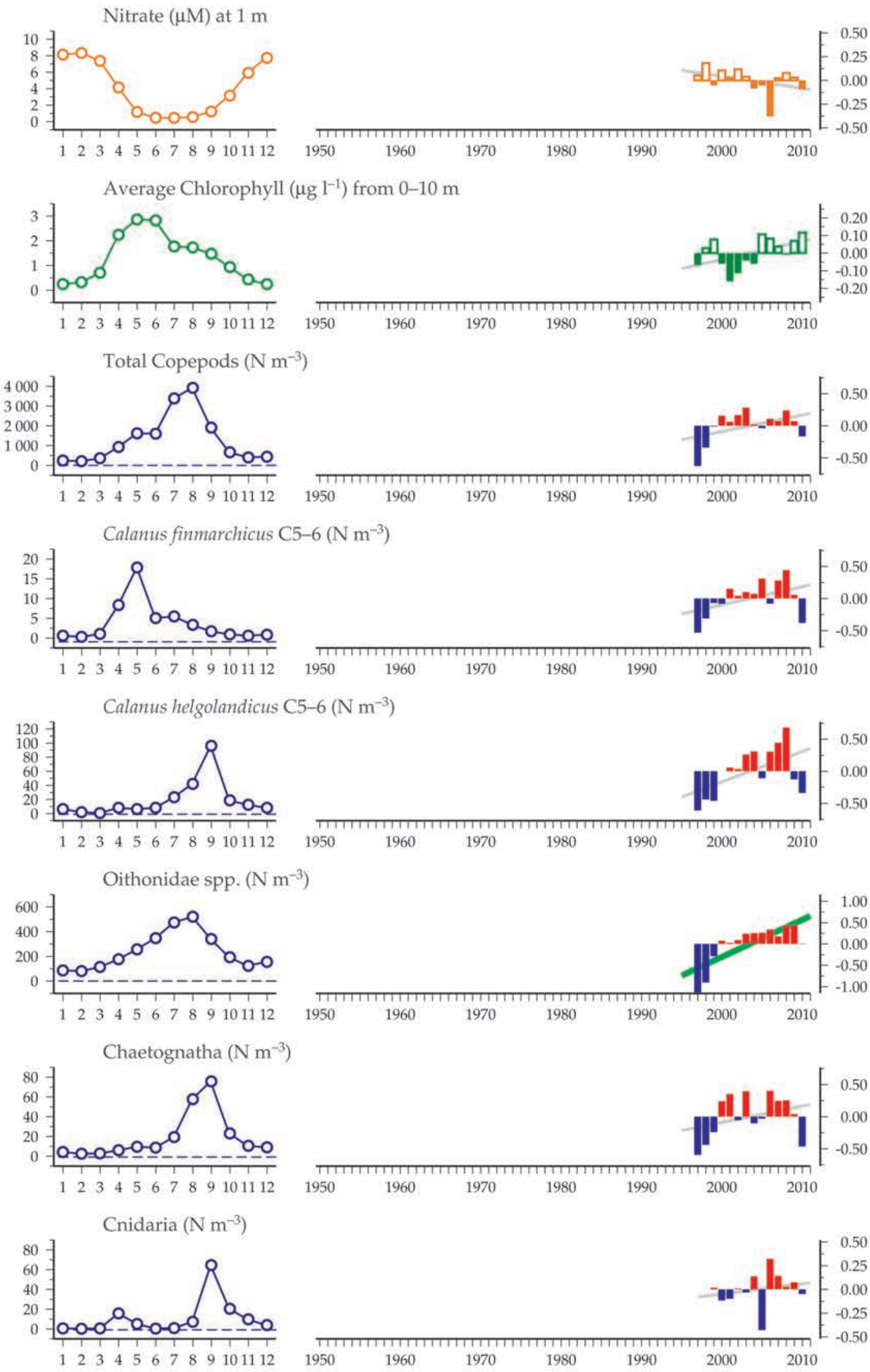
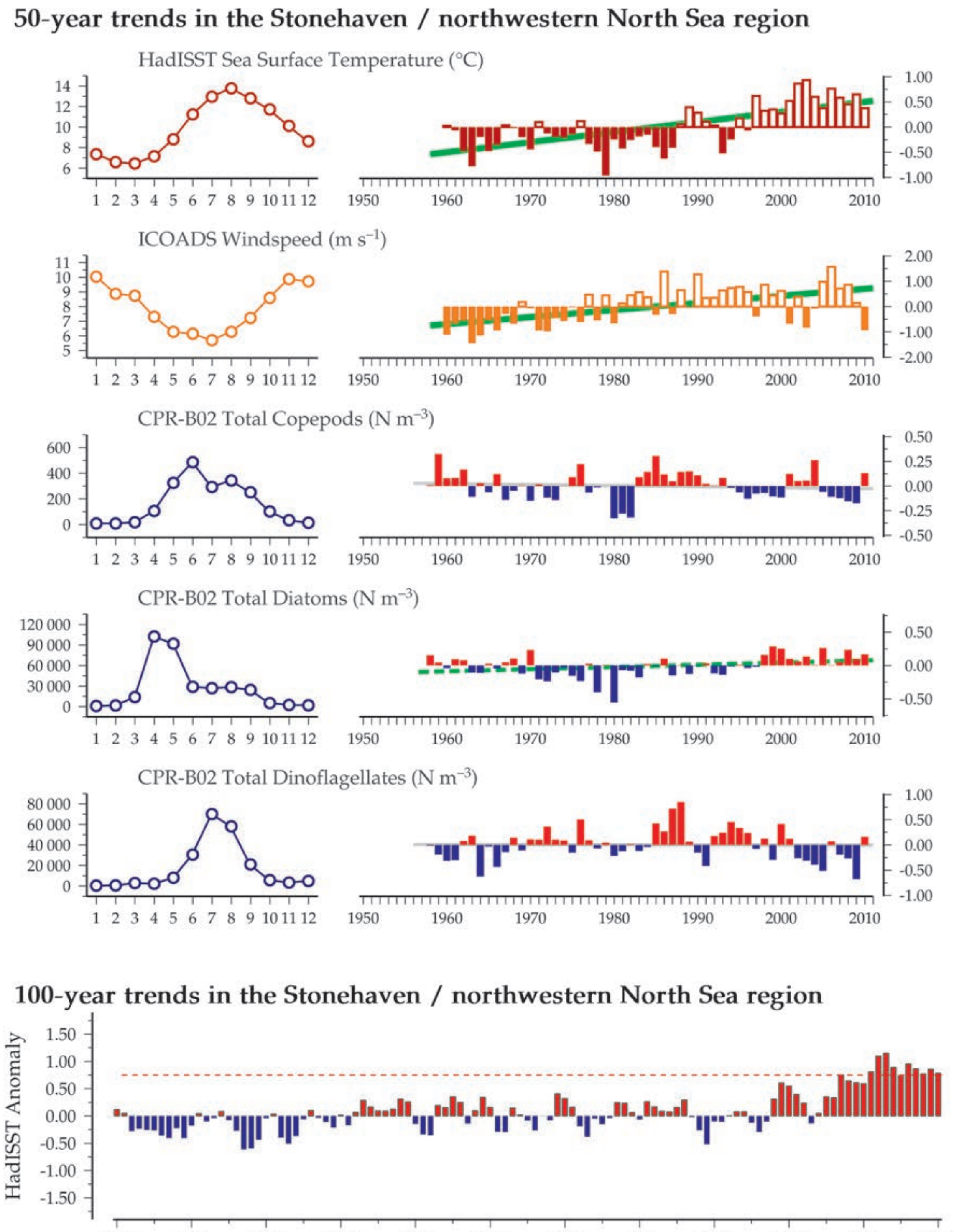


Figure 7.3.2
continued

Figure 7.3.3
Regional overview plot (see Section 2.2.3) showing long-term sea surface temperatures and windspeeds in the general region surrounding the Stonehaven monitoring area, along with data from the adjacent CPR B02 Standard Area.



7.4 Loch Ewe (Site 47)

Kathryn Cook

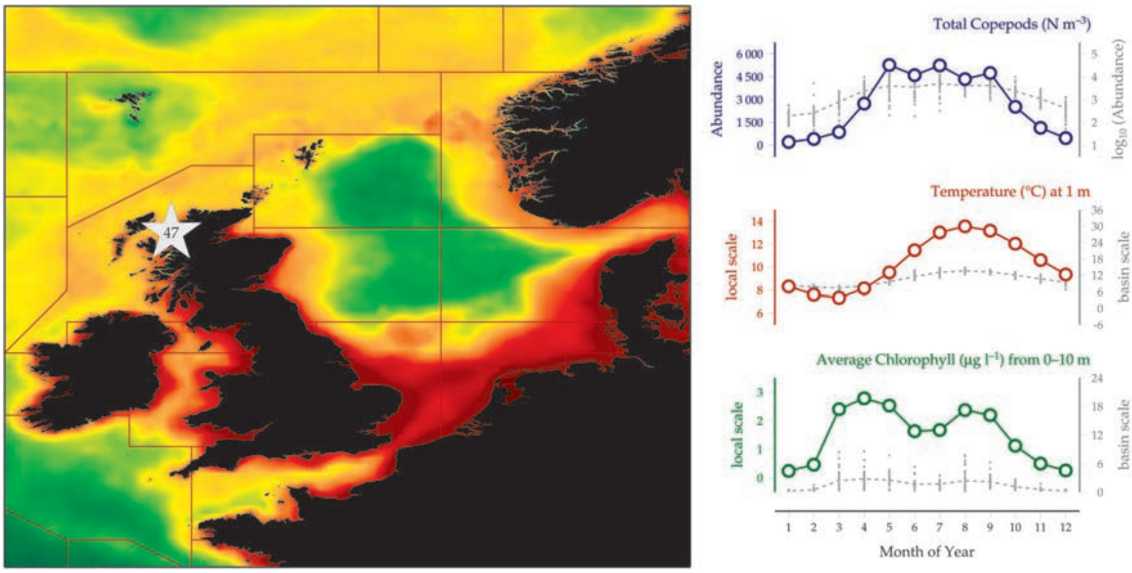


Figure 7.4.1
Location of the Loch Ewe monitoring area (Site 47) plotted on a map of average chlorophyll concentration, and its corresponding seasonal summary plot (see Section 2.2.1).

The Marine Scotland Loch Ewe sampling site is located at 57°50.99′N 05°38.97′W (Figure 7.4.1) approximately 0.5 km offshore in a Scottish west coast sea loch in a water depth of 35–40 m. To the north, the loch opens into the Scottish coastal sea basin of the North Minch and then to the open eastern Atlantic. Sampling, which began in April 2002, is similar to that at the Stonehaven site and is also carried out weekly. Samples for the determination of surface and near-seabed hydrographic parameters and concentrations of inorganic chemical nutrients are taken using water bottles and reversing digital thermometers, and integrated (0–10 m) phytoplankton and chlorophyll samples have been collected using a Lund tube. Mesozooplankton samples (200 µm mesh) are collected by the vertical deployment of a 40 cm diameter bongo net. Detailed taxonomic analysis is carried out on the mesozooplankton and phytoplankton samples. Fine-mesh zooplankton samples (68 µm mesh) are also collected using a bongo net, but these are currently archived and not analysed because of the limited availability of trained staff. Other short-term sampling at the site is done in support of a variety of time-limited research projects that study aspects of the coastal species or ecology in more detail. The objective of the time-series is to establish a monitoring base for assessing the status of the Scottish coastal ecosystem and to gauge responses to climate change. Although this time-series is too short for full statistical analysis of interannual patterns, it already provides data on seasonality and can be compared with other longer-term monitoring data. Some of these data are available online at https://sites.google.com/site/mssmonitoring/home.

Seasonal and interannual trends (Figure 7.4.2)

Water movement in this fjordic loch is complex and strongly influenced by wind and tide. The loch faces north and has quite strong tidal currents, with variable exchange with the coastal sea of the North Minch. The origins of the water that exchanges into the loch are not simply the Scottish Coastal Current waters that flow north along the Scottish west coast shelf. The North Minch is affected by influxes of oceanic Atlantic water from the northwest, particularly into the deeper basin. When strong, this influx may influence exchange between the loch and the adjacent coastal waters, varying the environment, sometimes quite suddenly, and thus affecting the composition of flora and fauna in the loch. The diversity of zooplankton species is higher at Loch Ewe compared to Stonehaven on the east coast of Scotland, owing to the more direct influence of waters and communities of southern origin. Most of the water column at the Loch Ewe site is well mixed throughout the year, although in summer and early autumn, surface heating and calm weather can cause temporary thermoclines to appear. The seasonal minimum temperature of about 8°C generally occurs in mid-March and rises to about 12–14°C in August–September. Winter temperatures in the loch are generally about 1.5°C higher than in the exposed North Sea site at Stonehaven on the Scottish east coast. It is also noticeable that the sea cools more slowly through autumn and winter in this semi-enclosed loch than at the Stonehaven site. As the Loch Ewe site lies in a semi-enclosed sea loch, it is affected by river and land run-off, which is reflected in the surface water as lower salinities, particularly in autumn–winter, when freshwater inputs are high.

Seasonal cycles, very similar to those seen at the Stonehaven site, are evident in all of the measured variables (Figure 7.4.2). The concentration of nitrate, a vital nutrient for phytoplankton growth, falls as chlorophyll increases with the onset of the spring phytoplankton bloom in March–April. Zooplankton, in turn, feed on phytoplankton and on each other and increase in abundance after the spring phytoplankton bloom (see Figure 7.4.1, right subpanel). Throughout summer, phytoplankton growth relies on regenerated nitrate and ammonia supplied by microbial action and zooplankton excretion. After a late-summer peak in August–September, which coincides with the highest water temperature, zooplankton abundance declines as food becomes scarce because phytoplankton growth is light and temperature limited. The nitrate concentration then begins to rise as it is replenished during winter by resuspension from the sediment due to storm action and increased river and land run-off. In order to survive winter, some species, such as the large copepod genus *Calanus* and euphausiids build up oil reserves, whereas others rely on resting eggs or simply survive on whatever they find to eat through winter (e.g. the copepod *Oithonidae* spp.). Some species (e.g. the copepod *Calanus finmarchicus*, Figure 7.4.2) are not resident in Loch Ewe throughout winter, but are reseeded each year by the influx of waters from the north or from areas south and west of Scotland.

Although the patterns are broadly consistent, the dynamics of seasonal cycles vary between years for both the environmental and species components of the ecosystem. Temperature has generally been slightly higher than average since monitoring began in 2002, although 2010 was a cold year. Salinity appeared to be decreasing between 2002 and 2007, but in 2010, salinity was higher than the long-term average. The concentration of nitrate has been increasing since 2002, although in 2010, nitrate concentration was much lower than in 2009, but there are no obvious patterns in the annual concentration of chlorophyll. Overall, copepod abundance has been fluctuating around the long-term average since monitoring began, although 2009 had the lowest copepod abundance and 2010 had the highest copepod abundance. 2010 also saw the highest abundance of *Oithonidae* copepods since the beginning of the time-series. This is in contrast to the decreasing trend seen in the offshore CPR data from the region (Figure 7.4.3) during this time-period. However, copepod abundance was much higher in 2010 compared to 2009 in both datasets. As at Stonehaven, the causes of this discrepancy are not understood, but it is probably the result of differences in sampling methods and in the hydrographic influences at the semi-enclosed Loch Ewe station, compared with the much wider and offshore region encompassed by the adjacent CPR survey tracks. In contrast to the Stonehaven site, interannual abundance of the arrow worms (Chaetognatha), which feed on copepods and their larvae, do not follow interannual patterns similar to those of their main prey (Figure 7.4.2). In fact, the abundance of Chaetognatha has been decreasing since 2005. The abundance of cnidarians, also predators of copepods, at Loch Ewe does not show the decrease since 2006 seen at Stonehaven. 2003 was a year of high cnidarian abundance, but values have since fluctuated around the long-term mean.

At Loch Ewe, as at Stonehaven, the important copepod genus *Calanus* is represented by two species: *C. finmarchicus* and *C. helgolandicus*. The Arctic–boreal *C. finmarchicus* has a spring influx arising from the winter diapause in deeper waters off the edge of the continental shelf, and the species provides food for many fish larvae in spring. However, in recent decades, the proportion of the more southerly *C. helgolandicus*, generally most productive in summer and autumn, has increased rapidly (Beaugrand, 2009) so that it is now approximately tenfold more abundant than *C. finmarchicus*. At Loch Ewe, as at Stonehaven, the pattern in annual abundance anomalies has been the same for both *Calanus* species: abundance has increased between 2002 and 2008, and 2009–2010 have been years of lower abundance (Figure 7.4.2).

Loch Ewe, Scottish west coast

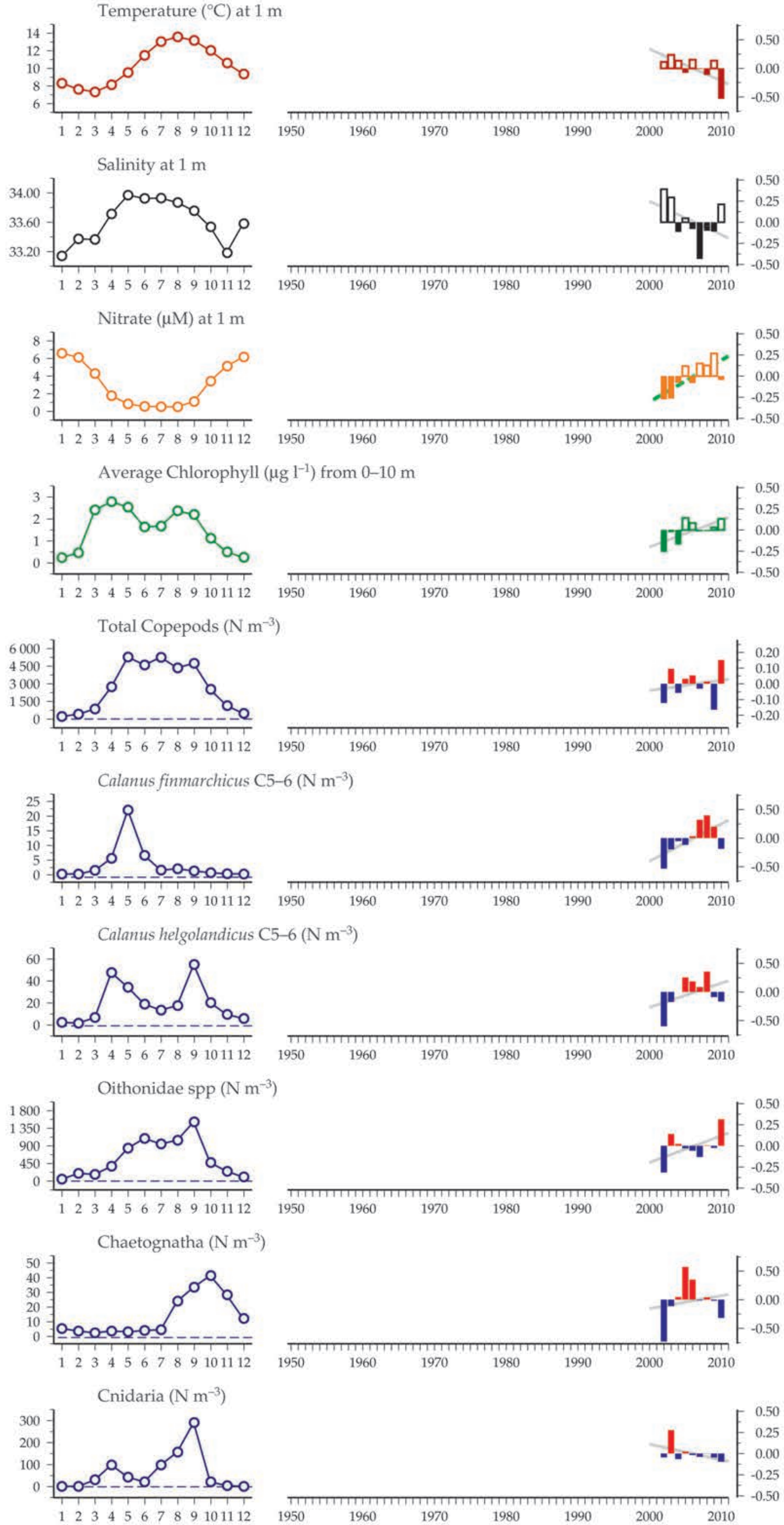


Figure 7.4.2
Multiple-variable comparison plot (see Section 2.2.2) showing the seasonal and interannual properties of select cosampled variables at the Loch Ewe monitoring area.

Additional variables are available online at: http://WGZE.net/time-series.

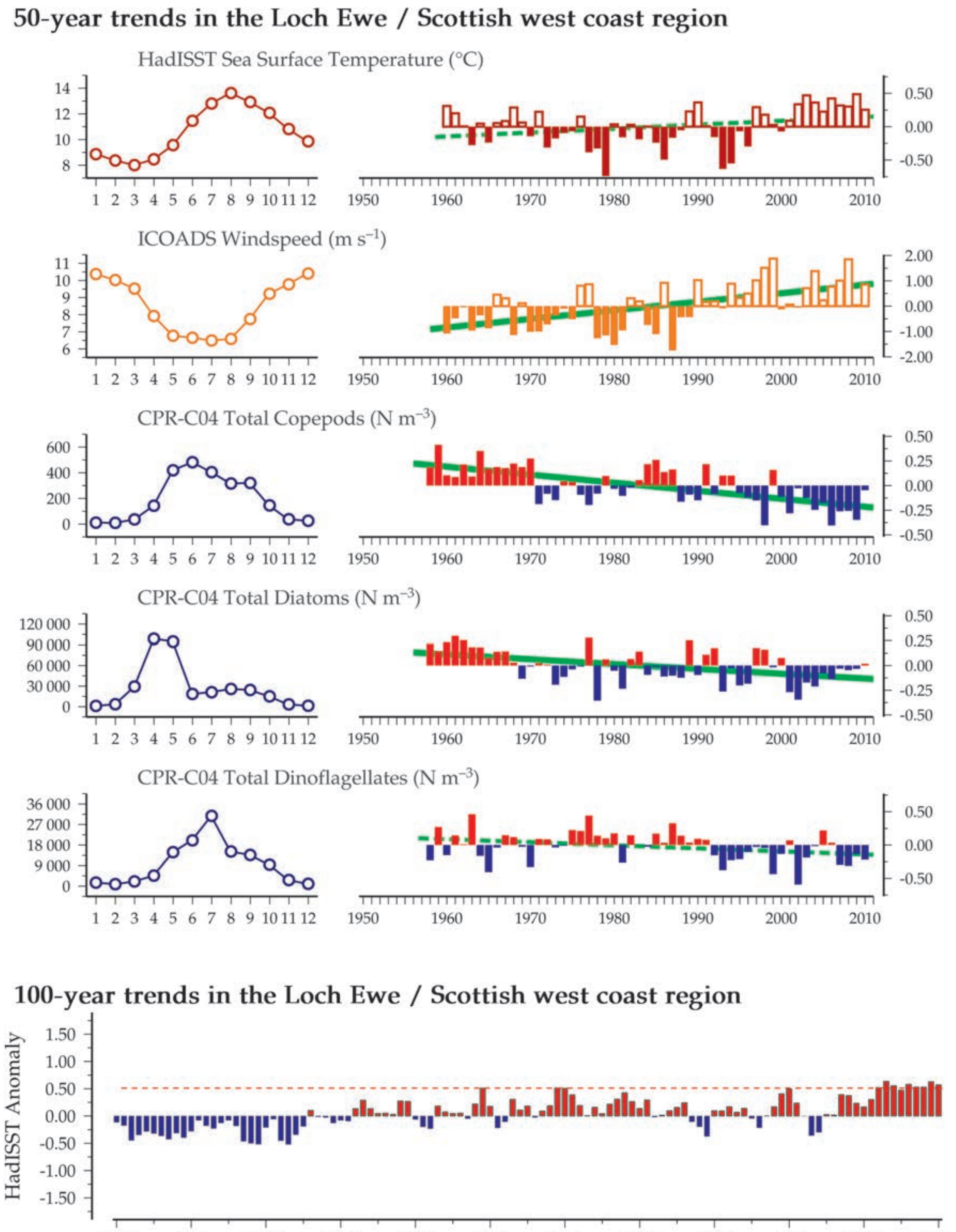


Figure 7.4.3
Regional overview plot (see Section 2.2.3) showing long-term sea surface temperatures and windspeeds in the general region surrounding the Loch Ewe monitoring area.