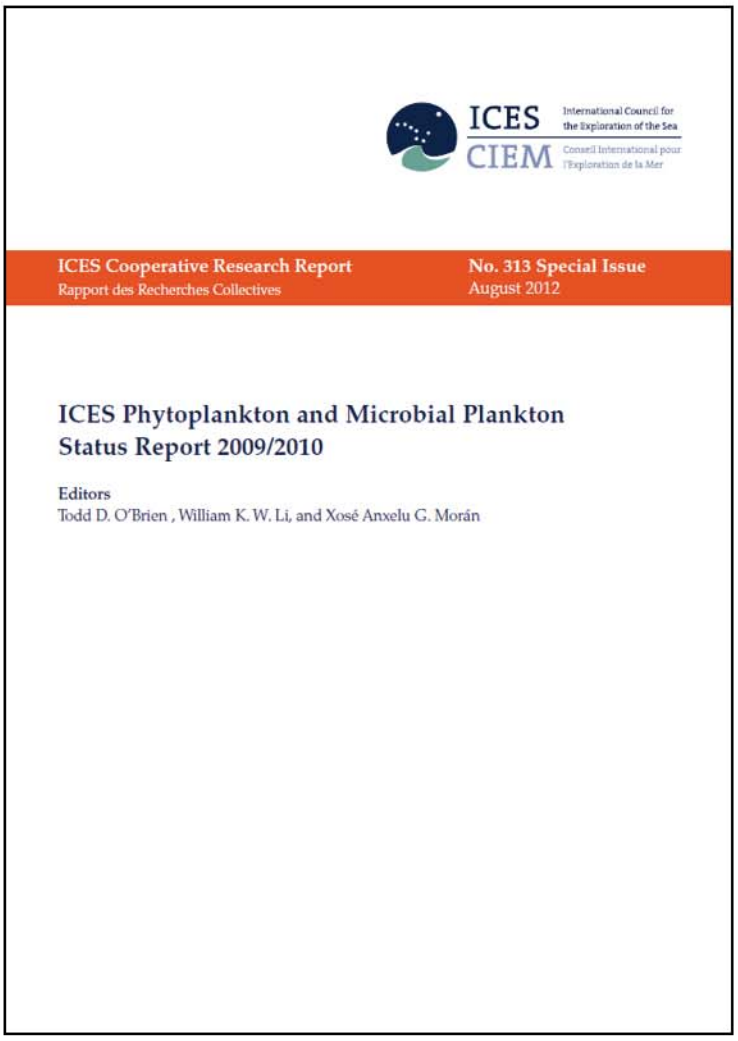

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O'Brien, T. D., Li, W. K. W., and Morán, X. A. G. (Eds). 2012.
ICES Phytoplankton and Microbial Plankton Status Report 2009/2010.
ICES Cooperative Research Report No. 313. 196 pp.

The time-series analyses and figures used in this report were created using COPEPODITE:
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7.5 Irish National Phytoplankton Monitoring (Sites 41–45)

Joe Silke and Caroline Cusack

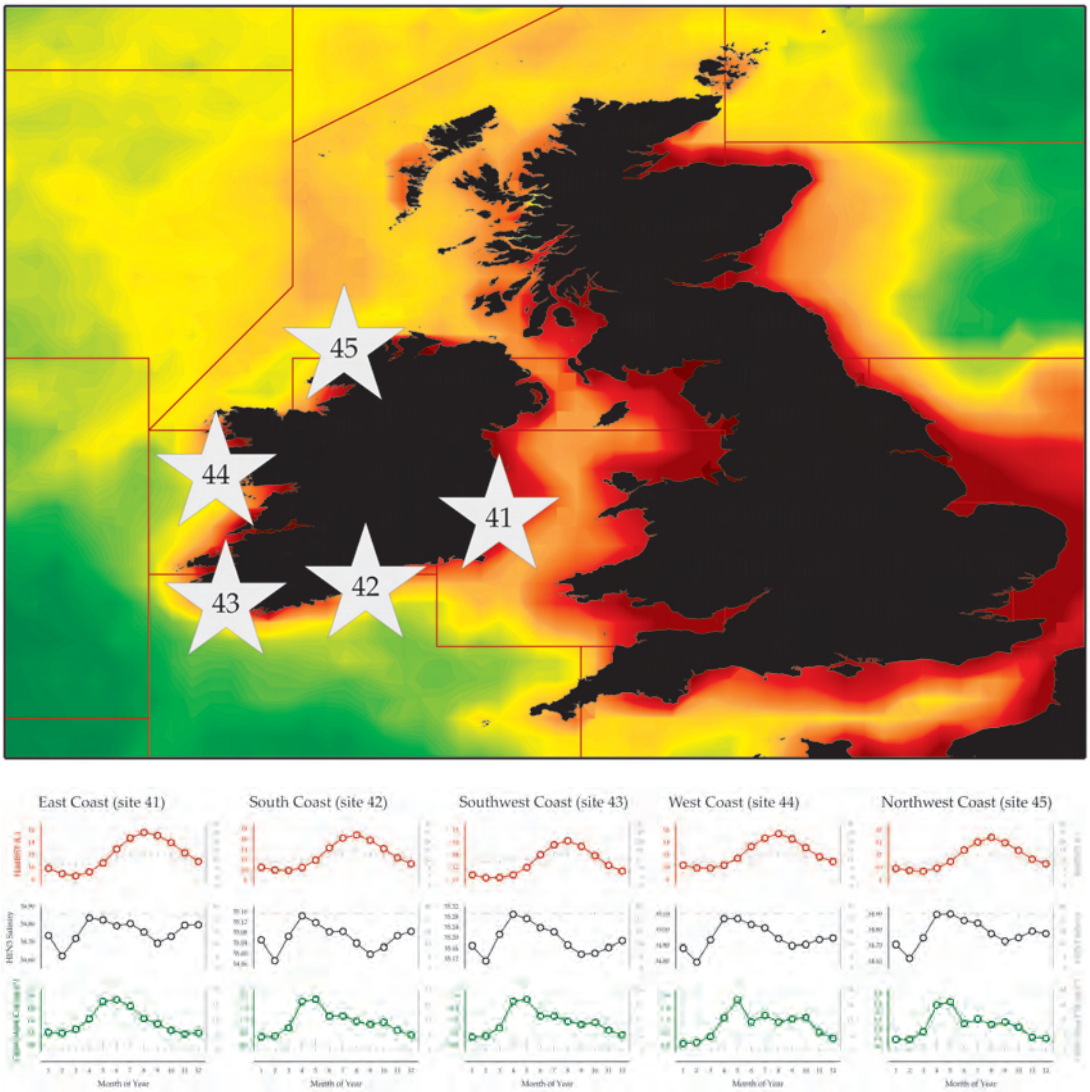

Figure 7.5.1
Locations of Ireland's national phytoplankton monitoring areas (Sites 41–45) area and their corresponding environmental summary plots (see Section 2.2.1).

The Marine Institute in Ireland carries out a national phytoplankton monitoring programme which extends back to the late 1980s. This includes a harmful algal blooms (HABs) monitoring service that warns producers and consumers of concentrations of toxic plankton in Irish coastal waters that could contaminate shellfish or cause fish deaths.

Cusack *et al.* (2001, 2002) summarized the objectives of the monitoring programme. This programme is primarily located along the Atlantic seaboard and Celtic Sea. Scientists working on this monitoring programme have developed an understanding of phytoplankton populations and dynamics around the Irish coastline, especially in relation to those that cause shellfish toxicity. Particular emphasis is put on the detection and enumeration of harmful species; however, the importance of phytoplankton as an indicator of water quality is also studied and is a key component of the European Water Framework.

Since 1990, data have been captured in a systematic manner and logged into an electronic database. Many of the sites were only analysed for toxic and harmful species, because this was the main purpose of the monitoring programme. In addition, however, there were a selected number of sites around the country analysed for total phytoplankton. Over the years, these sentinel sites changed periodically for a number of reasons, mainly the unavailability of persons to take regular samples. Therefore, in order to construct time-series for this report, it was decided to construct regional groups of all of the sentinel sites in the complete database, based on

a principal component analysis of the dataset. This resulted in five groups of sentinel sites, which are presented in these maps and graphs as regional locations (Figure 7.5.2). Based on the data extracted and amalgamated from these regions, it is deemed to be a good representation of the phytoplankton flora for these regions. The number of sites used to construct each region varies from region to region, and also within each region over time as sites came and went.

Sites were sampled by a variety of methods, either surface samples, discrete Ruttner sampling bottles, or tube samplers. They were preserved on site with neutral Lugol's iodine, and returned to the laboratory where 25 ml samples were settled for 24 h in Utermöhl chambers before analysis on an inverted microscope. Species were identified and enumerated and cell counts were expressed in cells l^{-1}.

Average sea surface temperatures for western and southern waters of Ireland range from 8 to 10°C in winter to 14–17°C in summer (Lee and Ramster, 1981; Elliott, 1991), and temperatures tend to be several degrees higher compared with the eastern waters. This difference is the result of the entry of warm Atlantic water onto the western Irish Shelf. In winter, Irish coastal and shelf waters are vertically well mixed, with little difference in the surface-to-bottom distribution of temperature within the water column. As the water column stratifies in summer, a surface-to-bottom temperature difference of up to 6°C is typical of waters along the Atlantic Shelf and Celtic Sea (Cooper, 1967; Raine and McMahon, 1998). Along the coast, turbulent tidal currents are sufficient to prevent establishment of stratification, and the water remains mixed throughout the year. The boundary between mixed and stratified waters in summer is marked by tidal fronts that influence the composition and density of phytoplankton community in these areas.

Further information on the sampling programme and results of individual locations can be accessed at the Marine Institute's HABs website http://www.marine.ie/habs.

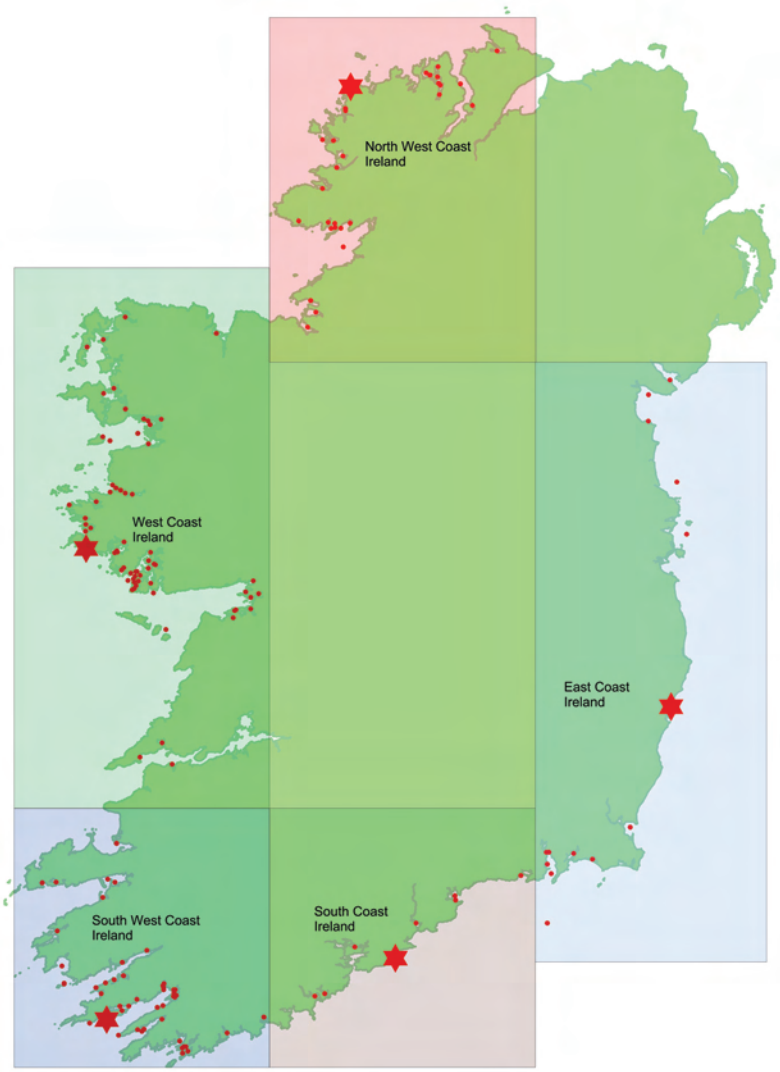

Figure 7.5.2
Combined regions of Irish phytoplankton monitored sites, showing the location of individual sites combined into each region represented in this report.

Seasonal and interannual trends along the east coast (Site 41, Figure 7.5.3)

Seasonal diatom abundances peaked in June, with a second but smaller peak in September. The seasonal abundance of dinoflagellates also peaked in September. The diatoms:diatoms+dinoflagellates ratio is lowest during the warm-water summer period, but the phytoplankton remain dominated by diatoms, such as *Leptocylindrus danicus*, *Chaetoceros* spp., and *Rhizosolenia styliformis*. Total diatom abundance has been decreasing since 1992, possibly correlated with increasing water temperatures over the same period. Long-term trends in the dinoflagellates were inconclusive, following a large peak in the early 1990s.

There is very little shellfish aquaculture along the east coast, apart from the fjord-like inlet of Carlingford Lough, and some mussel fishing in the Wexford and Waterford areas of the southeast coastline. Because of this, there has been limited sampling activity in the region by the Marine Institute for phytoplankton.

There have been some historical studies carried out in the region, notably a study by Gowen *et al.* (2000), where the temporal distribution of phytoplankton and chlorophyll data were described from coastal waters adjacent to the mouth of the Boyne estuary between March and October 1997. During the spring bloom, peak chlorophyll levels up to 11.4 mg l^{-1} were reported during late April–early May. The dominant species at this time was the diatom *Guinardia delicatula*, which represented more than 90% of total phytoplankton abundance (excluding microflagellates). It was also reported that blooms of *Phaeocystis* spp. and other microflagellates occurred before the spring peak in diatoms.

The presence of *Phaeocystis* was also observed occasionally in the Marine Institute time-series with very high counts of up to 48 × 10^6 cells l^{-1} observed in spring and early summer months. Other high counts including *Chaetoceros* spp. (up to 6.2 × 10^6 cells l^{-1}), *Leptocylindrus danicus* (up to 4.2 × 10^6 cells l^{-1}), *Asterionellopsis glacialis* (up to 2.4 × 10^6 cells l^{-1}), and *Prorocentrum balticum/minimum* (up to 2.2 × 10^6 cells l^{-1}) were observed during summer.

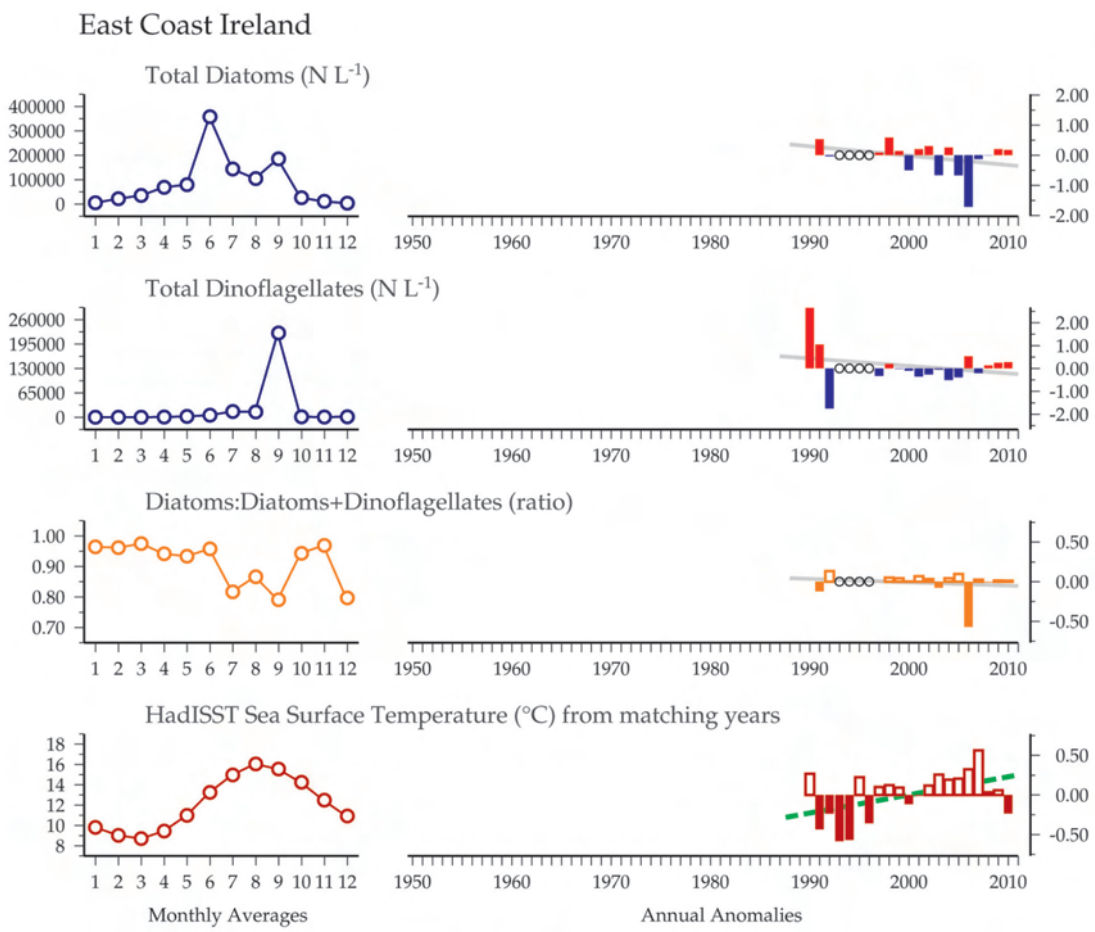

Figure 7.5.3
Multiple-variable comparison plot (see Section 2.2.2) showing the seasonal and interannual properties of select cosampled variables at the east coast of Ireland plankton monitoring site. Additional variables from this site are available online at http://wgpme.net/time-series.

Seasonal and interannual trends along the south coast (Site 42, Figure 7.5.4)

Seasonal diatom abundance peaked in July/August, with a smaller peak in March/April. The seasonal abundance of dinoflagellates peaked in October. The diatoms:diatoms+dinoflagellates ratio is lowest in June, and has been increasing since 1990. Total diatoms have also been increasing since 1990. Dinoflagellate abundance was variable over this time span, with no clear trend.

Historical information regarding phytoplankton is sparse for this region apart from some studies on *Alexandrium* spp. in Cork Harbour and descriptions of phytoplankton communities in the Celtic Sea. Pingree *et al.* (1976) and Fasham *et al.* (1983) observed that the spring bloom and the seasonal cycle of phytoplankton production in the Celtic Sea are related to the stratification of the water column. Spring blooms develop in April south of Ireland in an area of weak tidal streaming, with increases in phytoplankton biomass tracking the spatial development of stratification. The Celtic Sea Front forms a boundary between mixed and stratified waters of the southern Irish Sea, and there have been some observations of exceptional blooms of *Karenia mikimotoi* during summer on the stratified side of this front (Holligan *et al.*, 1980). This may be a source for blooms that extend around the west coast using the transport mechanism of the Irish Coastal Current to move the bloom around the coast in a clockwise direction, where it establishes blooms as observed in years such as 2005 (Silke *et al.*, 2005). Other large numbers of important dinoflagellates, particularly *Dinophysis acuminata* (up to 125 cells ml^{-1} in July 1992) and *K. mikimotoi* (up to 4300 cells ml^{-1} in August 1994 and 1995), appear to be associated with a region of slack residual flow located off the southern Irish coast. The presence of blooms of toxic species establishing in this area is important for the downstream aquaculture bays to the southwest (Raine and McMahon, 1998).

The north channel of Cork Harbour is also an area of particular note in this region because of the presence of a population of *Alexandrium tamarense* and *A. minutum*. It has been the presence of *A. minutum* (counts of up to 845 000 cells l^{-1}) in this area that has resulted in the only detection of PSP toxins in shellfish in Ireland that exceeded the EU threshold and required closure of the shellfishery (Marine Institute, unpublished data; Touzet *et al.*, 2007).

Notable blooms detected from samples analysed for the national phytoplankton monitoring programme in this region include *Heterocapsa triquetra* (36×10^6 cells l^{-1}), *Prorocentrum balticum/minimum* (20×10^6 cells l^{-1}), *Phaeocystis pouchetii* (16×10^6 cells l^{-1}), *Bacteriastrum* (7.5×10^6 cells l^{-1}), undetermined coccolithophorids (4×10^6 cells l^{-1}), *Leptocylindrus danicus* (3.3×10^6 cells l^{-1}), and *Asterionellopsis glacialis* (3×10^6 cells l^{-1}).

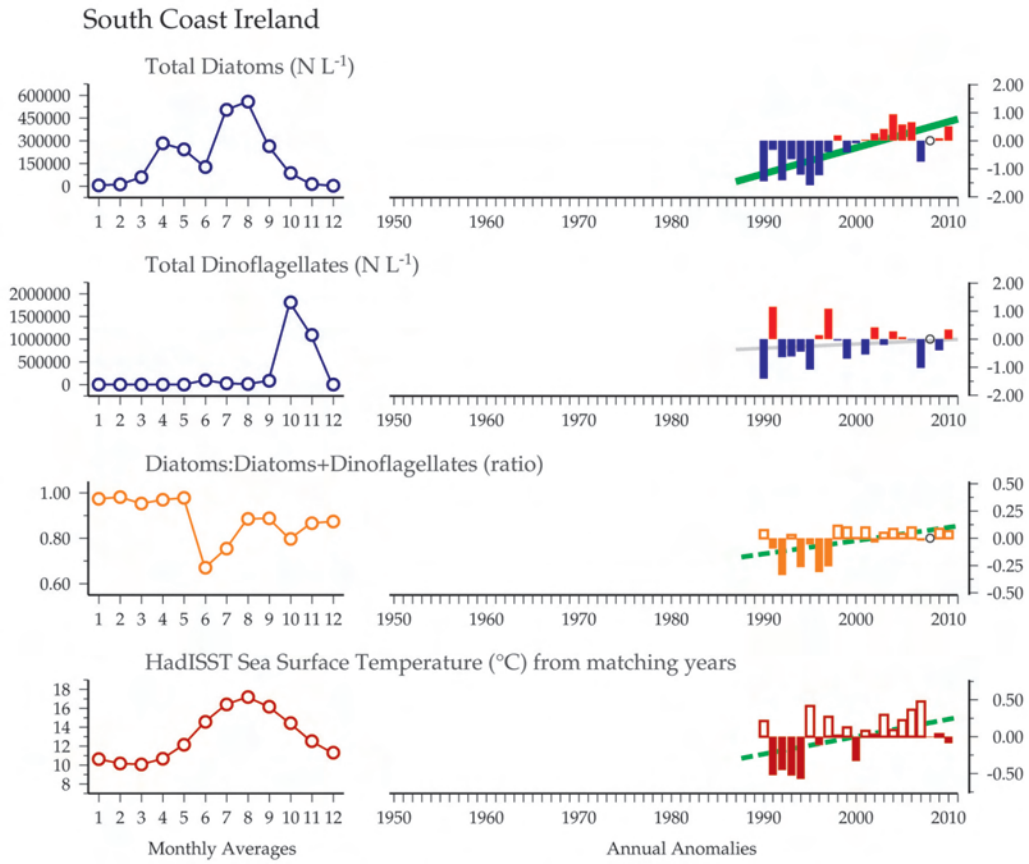

Figure 7.5.4
Multiple-variable comparison plot (see Section 2.2.2) showing the seasonal and interannual properties of select cosampled variables at the south coast of Ireland plankton monitoring site. Additional variables from this site are available online at http://wgpme.net/time-series.

Seasonal and interannual trends along the southwest coast (Site 43, Figure 7.5.5)

Seasonal diatom abundance peaked in May and July, whereas dinoflagellates peaked in September. The diatoms:diatoms+dinoflagellates ratio is lowest in August, and has been increasing since 1990. Total diatoms have also been increasing since 1990, whereas dinoflagellate abundance has been variable over this time-span, with no clear trend.

This area is dominated by a series of embayments (similar to the Gallician rías of northwest Spain) along the coast, which are glacial-flooded river valleys, orientated in a northwest–southwest direction. These sheltered bays have become the location for a successful shellfish aquaculture industry, predominated by the culture of blue mussels (*Mytilus edulis*). Rope culture in these bays accounts for 80% of the national production. The hydrography of the areas is characterized by coastal upwelling, which is highly variable in both its periodicity and magnitude. During periods when there is stable water structure in this area, the microalgal flora is typical of the greater Atlantic Shelf area. The other key feature of this area was described by Raine and McMahon (1998), who noted that the composition of phytoplankton in samples collected from shelf waters off the southwest coast between 1992 and 1995 changed markedly in relation to the position of the Irish Shelf Front. It has been demonstrated that the sudden appearance of blooms such as *Karenia mikimotoi* resulted from advection of offshore populations into the southwest bays. The transport mechanism of these blooms was not known until the presence of the seasonal jet-like Irish Coastal Current was established (Fernand *et al.*, 2006). The strength of this clockwise flow around the southwest tip of Ireland is modulated by the presence of the Shelf Front, which is close to the shore in the presence of dominant southwesterly winds. When these winds relax, the front is weakened and the Irish Coastal Current can establish, bringing populations of dinoflagellates from the Celtic Sea to the mouth of the southwest bays, where they can be advected inshore by wind-induced residual flow in a two-layered stratified system (Edwards *et al.*, 1996).

Historically, there have been several studies of the plankton in this region, owing to the aquaculture presence and importance to the regional economy. A study by Raine *et al.* (1990) presents results of investigations into the distribution of phytoplankton for coastal waters off the southwest coast of Ireland during summers of 1985–1987. In general, diatom populations were associated with the cooler regions, whereas dinoflagellates tended to predominate in stratified water. In 1985 and 1987, during upwelling events, diatoms dominated the flora in the vicinity of the Fastnet Rock and west of Bantry Bay, particularly species such as *Chaetoceros* spp., *Leptocylindrus danicus*, *Guinardia delicatula*, and *Thalassiosira* spp. In 1987, *Rhizosolenia alata* was the dominant diatom species. Farther offshore, where the water column was more stratified than in the previous two years, dinoflagellates increased in numbers, but *Proboscia alata* was still numerically dominant.

The National Monitoring Programme has identified some very dense blooms of diatoms and dinoflagellates between 1990 and 2010. These have included *Rhizosolenia* spp. (75 million cells l^{-1}) in July 1991, an unidentified *Microflagellate* sp. bloom (53 × 106 cells l^{-1}) in October 2007, and a bloom of *Skeletonema* spp. (26 × 10^6 cells l^{-1}) in May 1998. Other less numerically dense, but still significant, blooms included periodic blooms of *Phaeocystis* spp. (up to 17 × 10^6 cells l^{-1}), *Leptocylindrus minimus* (up to 12 × 10^6 cells l^{-1}), *Cylindrotheca closterium/Nitzschia longissima* (up to 10 × 10^6 cells l^{-1}), *Skeletonema* spp. (up to 9 × 10^6 cells l^{-1}),*Thalassionema nitzschioides* (up to 5.5 × 10^6 cells l^{-1}), *Noctiluca scintillans* (up to 5.2 × 10^6 cells l^{-1}), and *Thalassiosira* spp. (up to 4.8 × 10^6 cells l^{-1}).

Blooms of *Dinophysis acuta* and *D. acuminata* were observed in the bays during most summers, but never in particularly dense blooms or dominating the phytoplankton community. They are of particular note, however, because they resulted in closures of shellfish farming most years, for periods of time ranging from weeks to several months. The transport mechanism of the Irish Coastal Current and its control by the Irish Shelf Front is believed to be important in the delivery of *Dinophysis* to these aquaculture bays (Raine *et al.*, 2010).

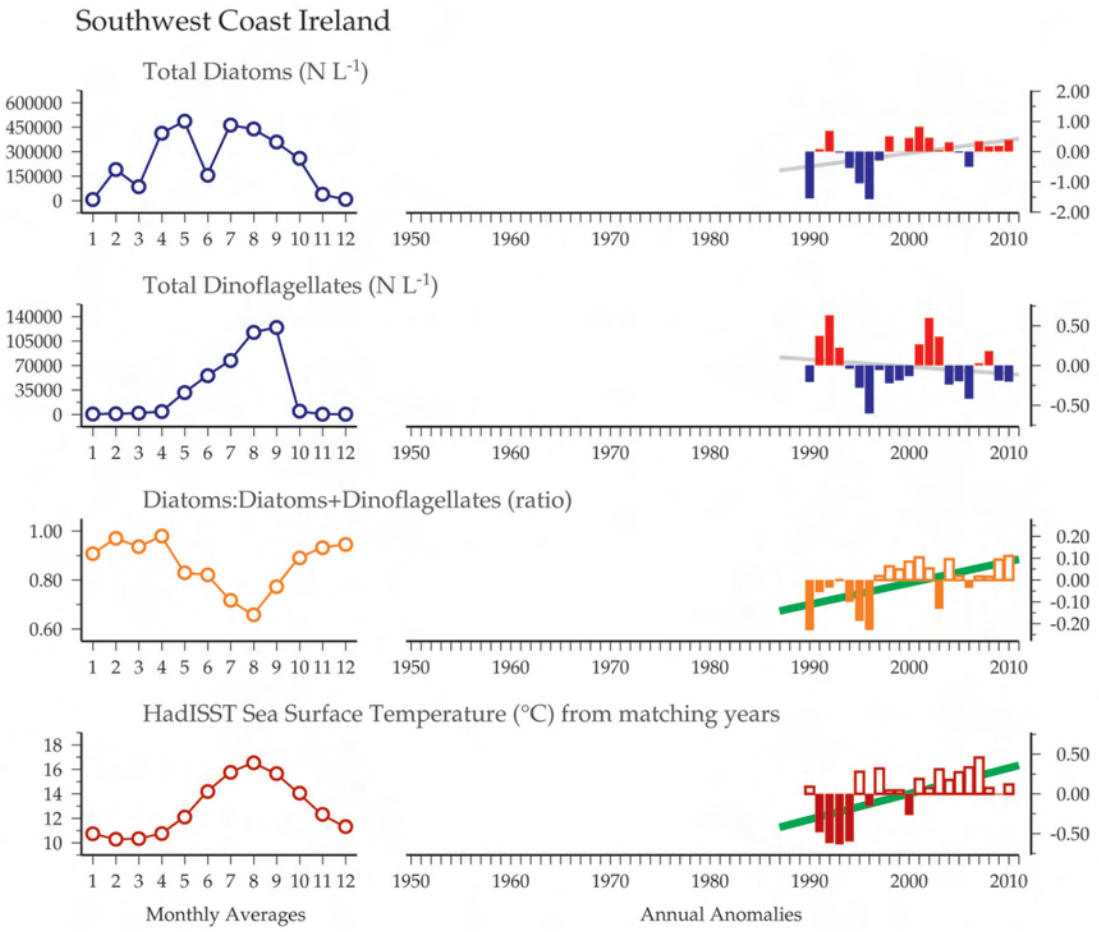

Figure 7.5.5
Multiple-variable comparison plot (see Section 2.2.2) showing the seasonal and interannual properties of select cosampled variables at the southwest coast of Ireland plankton monitoring site. Additional variables from this site are available online at http://wgpme.net/time-series.

Seasonal and interannual trends along the west coast (Site 44, Figure 7.5.6)

Seasonal diatom abundance peaked in August, followed by a dinoflagellate peak in September. The diatoms:diatoms+dinoflagellates ratio is lowest in July. Diatoms, dinoflagellates, and their ratio have been increasing since 1990, but none of the trends were statistically significant.

The west-of-Ireland region covers the coastline from the mouth of the Shannon River north to the northern coastline of County Mayo. This area is made up of exposed coastline open to the Atlantic Shelf waters to the west, and several coastal embayments offering sheltered shallow waters, where both shellfish farming and finfish farming industries have successfully operated.

The spring phytoplankton of the area is typical of that investigated by O'Boyle (2002), who reported that the spring bloom in Galway Bay occurred in mid-April, when a maximum chlorophyll concentration of just over 11 mg l^{-1} was recorded. The spring bloom was dominated by diatom species including *Thalassiosira* spp. and *Chaetoceros* spp., with maximum cell numbers of 167 and 39 cells ml^{-1}, respectively. In May, this assemblage was replaced by other diatom species, such as *Dactyliosolen fragilissima, Leptocylindrus danicus, Leptocylindrus minimus, Pseudo-nitzschia* spp., and *Ceratualina pelagica*. Microflagellates were common throughout the study period, with cell numbers ranging from 2 to 27 × 10^3 cells ml^{-1}.

Summer distribution of phytoplankton in Atlantic Shelf waters west of Ireland was reviewed by Raine *et al.* (1993), who concluded that the pattern of change in phytoplankton populations can be divided into two temporal phases separated by the full development of the thermocline, which can obtain a depth of 35–40 m by mid-July. In early summer, before the water column becomes fully stratified, intermittent vertical mixing promotes a series of diatom blooms that are usually dominated by *Chaetoceros* spp. and *Rhizosolenia setigera*, with dinoflagellate numbers remaining low, with the possible exception of *Scrippsiella*. Following stratification, these species are replaced by dinoflagellates including *Ceratium* spp., and also the diatoms *Proboscia alata* and *Leptocylindrus mediterraneus*.

A notable bloom in 2005 of *Karenia mikimotoi* extended along the west coast for most of the summer and resulted in severe benthic in-faunal and pelagic mortalities of macroinvertebrates and fish (Silke *et al.*, 2005). A second bloom was detected in a later period of summer in the southwest, and was present the following year on both the east and west coasts of Scotland.

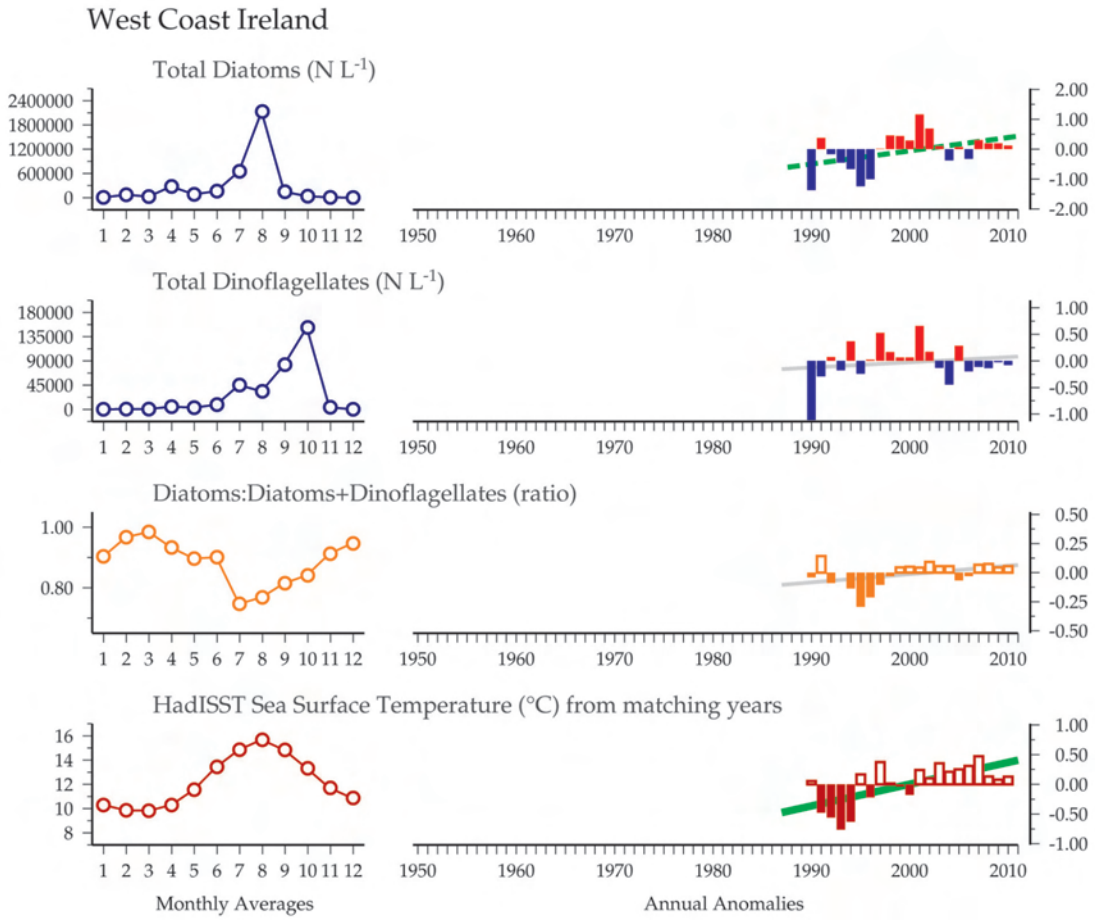

Figure 7.5.6
Multiple-variable comparison plot (see Section 2.2.2) showing the seasonal and interannual properties of select cosampled variables at the west coast of Ireland plankton monitoring site. Additional variables from this site are available online at http://wgpme.net/time-series

Seasonal and interannual trends along the northwest coast (Site 45, Figure 7.5.7)

Seasonal diatom abundance peaked in March and July, whereas dinoflagellates peaked in November. The diatoms:diatoms+dinoflagellates ratio is lowest in November/December. Diatoms have been increasing since 1990. Dinoflagellates also show a positive, but non-significant, trend. The diatoms:diatoms+dinoflagellates ratio was almost completely flat at this site.

This region represents sites from Sligo Bay up to the most northerly bay in Ireland: Trabreaga Bay. The rugged coastline of Counties Sligo and Donegal represents a diverse environment ranging from long shallow sandy bays of Sligo and sheltered coves along the north coast, to exposed bays and rocky shorelines in Donegal. These waters are all fully saline, with little significant freshwater input in the region.

The distribution of phytoplankton in this area has been demonstrated to be related to the main oceanographic features of the region (O'Boyle and Raine, 2007). In that study, the authors presented the results of observations along the northwest coast in 1999. Inshore of the Irish Shelf Front, the phytoplankton species composition was dominated by diatoms, such as *Leptocylindrus danicus, Guinardia flaccida*, and *Pseudo-nitzschia* spp. The flora of the shelf region between the front and the outer shelf was characterized by the presence of *Halosphaera minor, Oscillatoria* sp., *Ptychodiscus noctiluca, Ceratium fusus*, and *Amphidoma caudata*. Farther offshore along the margins of the continental shelf, the floral assemblage was marked by the presence of *Gonyaulax polygramma, Ceratium furca, Oxytoxum scolopax, Podolampes palmipes, Prorocentrum compressum*, and *Prorocentrum dentatum*. The highest *Karenia mikimotoi* cell concentrations of up to 100 cells ml^{-1} were found in proximity to bottom density fronts located inshore. Chlorophyll

a concentrations (not shown) are generally low at 1.0 mg l^{-1} throughout the survey area, with the exception of some inshore coastal stations where values ranged from 1.8 to 3.4 mg l^{-1}, particularly in inlets along the west coast of Donegal.

The data extracted from the Marine Institute database demonstrates that coastal areas exhibit periodic blooms of both diatoms and dinoflagellates. The most frequent of these were *Asterionellopsis* spp., with cell counts above 14 × 10^6 cells l^{-1}. A significant dinoflagellate bloom of *Prorocentrum balticum* occurred off the north coast in 1997, with counts of up to 11 × 10^6 cells l^{-1} recorded. Other notable diatoms in this area include *Chaetoceros* spp. and *Skeletonema* spp., which have frequently bloomed with densities recorded up to 17 × 10^6 cells l^{-1}. Dinoflagellate blooms are also recorded in this region, including blooms of *Heterocapsa triquetra, Gymnodinium* spp., and *Karenia mikimotoi*.

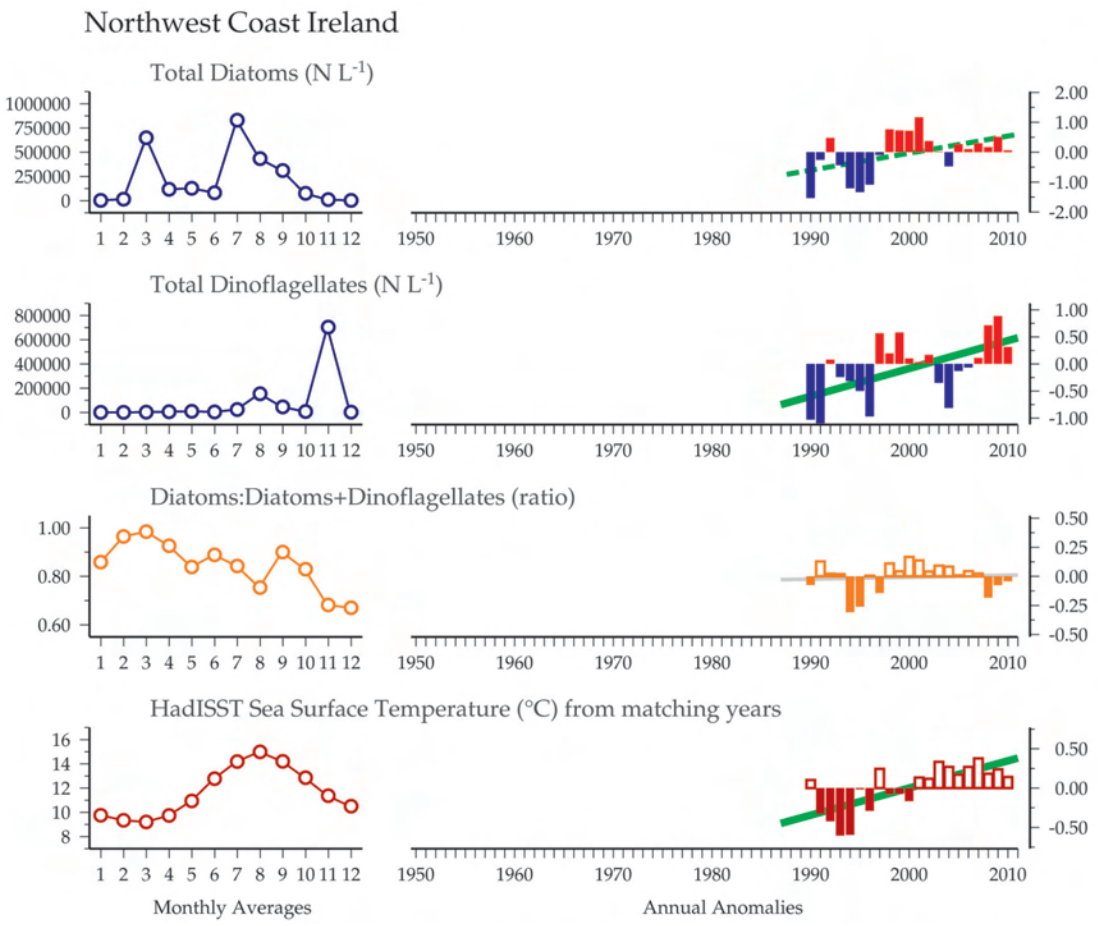

Figure 7.5.7
Multiple-variable comparison plot (see Section 2.2.2) showing the seasonal and interannual properties of select cosampled variables at the northwest coast of Ireland plankton monitoring site. Additional variables from this site are available online at http://wgpme.net/time-series.