

This report not to be cited without prior reference to the authors.

International Council for
the Exploration of the Sea

C.M. 1993/L:18
Biological Oceanography Committee

Upwelling and the phytoplankton ecology of southwest Irish coastal waters.

R. Raine, B. Joyce, J.W. Patching, University College, Galway, Ireland.
T. McMahon, F.R.C., Dublin, Ireland.
C. Roden, Redbank Shellfish Company, Newquay, Co. Clare, Ireland.

Abstract

Surface temperatures of coastal waters of southwest Ireland in the vicinity of the Fastnet Rock can be exceptionally cool ($<11^{\circ}\text{C}$) in mid-summer. This is now known to be due to a coastal upwelling system which has only recently been identified. The upwelling is, however, highly variable in both its periodicity and magnitude, whereby events may prevail over time-scales of several days or weeks, providing an alternation of conditions between upwelling and fully stratified.

These events in mid-summer have a profound effect on the planktonic ecosystem. When upwelling is absent, the water structure is similar to that of the adjacent stratified Atlantic shelf and dinoflagellates, particularly *Ceratium* species are commonly found. When upwelling occurs to any extent diatoms flourish and typical spring bloom diatoms such as *Thalassiosira rotula/gravida*, and *Lauderia borealis* can be surprisingly common. The more typical situation is intermediate between these two extremes and a variety of summer diatoms such as *Chaetoceros* spp., *Rhizosolenia setigera* and *Nitzschia seriata* are all common. The upwelling zone will be separated from the surrounding stratified water by a system of fronts. Their presence as the possible the source of red tides of *Gyrodinium aureolum* recorded from the area is discussed.

Introduction

Upwelling areas are regions of high productivity due to the upward transport of nutrients into the euphotic zone at or near the sea surface. The southwest of Ireland has been shown to be influenced by upwelling in summer (Raine *et al.*, 1990a), yet recent evidence suggests that the upwelling is irregularly periodic (Raine *et al.*, 1993a). There is historic evidence that the southwest coast enjoyed a thriving pilchard fishery which was most likely linked to upwelling in the region (Went, 1946). The precise physical mechanisms driving the upwelling have yet to be elucidated.

Given that the upwelling around southwest Ireland is intermittent, the water column structure of the region in late summer (July/August) varies from unstratified and very cold (<11°C) to fully stratified with a temperature difference between top and bottom of 5°C. This paper presents data on how the range of physical distributions found off southwest Ireland influences the phytoplankton ecology of the region.

Methods

Studies were carried out in the coastal waters of southwest Ireland (Figure 1) in late summer (July/August) over the period 1985-1992. Conventional CTD and water bottle stations were sampled for nutrients, chlorophyll and phytoplankton. The latter samples were preserved in Lugol's Iodine and examined using an inverted microscope. Details of all sampling and analytical techniques may be found in Raine *et al.* (1990a; 1993a).

Phytoplankton nomenclature is in accordance with Dodge (1985) for dinoflagellates and Parke and Dixon (1976) for all other groups.

Results

Physical oceanographic results from August, 1985 are presented in Figure 2. Upwelling had resulted in surface water temperatures of approximately 11°C in waters in the vicinity of the Fastnet Rock with surface to bottom temperature differences (ΔT) of 0.6 to 1.2°C. The water column had begun to stratify at the outermost station, 25 miles offshore, yet surface temperatures there were still only 12.7°C, well below a typical value of 16°C for surface stratified zones of the Celtic Sea or Atlantic Shelf. Chlorophyll levels (Figure 2c) were elevated inshore with a highest value of 10.5 mg.m⁻³ at station 4.

The phytoplankton comprised of diatoms. Only a few small dinoflagellates were present, contributing less than 6% of the total cell concentration with the exception of one sample containing 21,000 cells.l⁻¹ of the naked dinoflagellate *Aureodinium pigmentosum* (10% of total cells). Five diatom species were chosen from the data due to their numerical dominance and their distributions are shown in Figure 3. Several features are apparent. First, it should be noted that the colder regions are occupied by species which are common in spring, such as *Lauderia borealis*, *Chaetoceros debile* and *C. curvisetum*. *Thalassiosira rotula/gravida*, another diatom typical of the spring bloom was also recorded at station 1. Moving away from the coast, increasing numbers of *Nitzschia seriata* were present at the surface, a diatom commonly found in the area in early summer (Roden *et al.*, 1981). *Rhizosolenia setigera* is another diatom found in coastal waters to the west of Ireland, appearing in early summer, which can also persist through to September (Roden, 1984). Finally, numbers of *Rhizosolenia alata* were recorded at the pycnocline as stratification started to develop at station 3. *R. alata* is known to be common in the surface layers above the pycnocline in midsummer (Holligan, 1981). The data strongly suggest diatom succession

starting from the species found in spring through to summer as water temperatures rise away from the coast.

The phytoplankton flora is completely different in the absence of upwelling. In this more stable situation the surface waters are warm and the plankton is dominated by dinoflagellates, in particular *Ceratium* spp. In the warm summers of 1989-1991 *C. furca* predominated in the region in late July, 1989 (Raine *et al.*, 1990b), *C. lineatum* was dominant in July-August 1990 (Joyce, 1991), and in 1991 dominance shifted from *C. lineatum* in late July to *Gyrodinium aureolum* in "red tide" concentrations at the beginning of August (Raine *et al.*, 1993b). The bulk of the dinoflagellate biomass was associated with the pycnocline in all these cases.

Compatible observations were made by Roden *et al.* (1981) in August 1979 in the region around the Fastnet Rock (Figure 1). They describe what may have been an upwelling zone inshore (interpreted by Roden *et al.* (1981) as a mixed zone) and stratified waters further offshore separated by a frontal system. Diatoms such as *Nitzschia* and *Chaetoceros* spp. were abundant in the inshore unstratified zone, while dinoflagellates, particularly *G. aureolum*, were present in stratified water and at the front. In the light of more recent investigations the data of Roden *et al.* (1981) suggest that upwelling close to the coast had forced the pycnocline, together with its associated dinoflagellate community, towards the surface. Increased illumination, and nutrients present in the frontal zone would encourage the phytoplankton at the front to flourish, and here probably lies the explanation for the large populations of *G. aureolum* recorded in the area in 1978 (Roden *et al.*, 1980), 1979 (Roden *et al.*, 1981), 1981 and 1987 (Raine *et al.*, 1990a). It is relatively simple to explain the advection of the bloom onshore by wind-driven processes (see Raine *et al.*, 1993b).

Conclusions

Upwelling of coastal waters of southwest Ireland causes the area to be quite productive. Both diatom- and dinoflagellate-dominated communities have been recorded in the area, and the flora provides a good indication of physical conditions. The diatom communities found there can range from a composition similar to that of the spring bloom to one more typical of early summer. In the absence of upwelling dinoflagellates are found associated with the pycnocline. Upwelling can promote dinoflagellate blooms by forcing the pycnocline towards the surface where increased irradiance levels encourage extensive growth. It is hypothesised that advection of the frontal zone onshore is the mechanism for the appearance of red tides noted in the area.

Acknowledgements

This paper draws on fieldwork carried out since 1985, and to mention all those who gave their assistance would be virtually impossible. The authors would, however, like to thank in particular Dr. J. O'Mahony, Ms. M. Moloney and the captain and crew of the R/V Lough Beltra.

References

- Dodge, J.D. 1985. Marine Dinoflagellates of the British Isles. HMSO, London. 303pp.
- Holligan, P.M. 1981. Biological implications of fronts on the northwest European continental shelf. *Phil. Trans. R. Soc. Lond.*, A302, 547-562.
- Joyce, B. 1991. Phytoplankton results, south west Ireland, 1990. Unpublished report, University College Galway, 129pp.
- Parke, M. and Dixon, P.S. 1976. Check-list of British marine algae - third revision. *J. mar. biol. Ass. UK*, 56, 527-594.
- Raine, R., O'Mahony, J., McMahon, T. and Roden C. 1990a. Hydrography and phytoplankton of waters off southwest Ireland. *Estuarine, Coastal and Shelf Sci.*, 30: 579-592.
- Raine, R., McMahon, T., O'Mahony, J., Moloney, M. and Roden, C. 1990b. Water Circulation and Phytoplankton populations in two estuaries on the west coast of Ireland. *In* *Estuarine Ecotoxicology*. pp.19-28. Ed. by P.L. Chambers and C.M. Chambers. JAPAGA, Ashford, Wicklow, Ireland. 161 pp.
- Raine, R., Joyce, B., Richard, J., Pazos, Y., Moloney, M., Jones, K., and J.W. Patching. 1993a. The development of a large bloom of the dinoflagellate *Gyrodinium aureolum* on the south west Irish coast. *ICES J. mar. Sci.*, in the press.
- Raine, R., Joyce, B., Patching, J.W., Jones, K. and J. Richard. Upwelling around the southwest Irish coast: Near-surface dynamics and blooms of the dinoflagellate *Gyrodinium cf. aureolum* (Hulbert). *ICES C.M.* 1993/L:17.
- Roden, C.M. 1984. The 1980/1981 phytoplankton cycle in the coastal waters off Connemara, Ireland. *Est. Coast. Shelf Sci.*, 18, 485-497.
- Roden, C.M., Ryan, T., and Lennon, H.J. 1980. Observations on the 1978 red tide in Roaring Water Bay, Co. Cork. *J. Sherkin Island*, 1: 105-118.
- Roden, C.M., Lennon, H.J., Mooney, E., Leahy, P. and Lart, W. 1981. Red tides, water stratification and phytoplankton species succession around Sherkin Island, south-west Ireland, in 1979. *J. Sherkin Island*, 1: 50-68.
- Went, A.E.J. 1946. The Irish pilchard fishery. *Proc. Roy. Irish Acad.*, B51, 81-120.

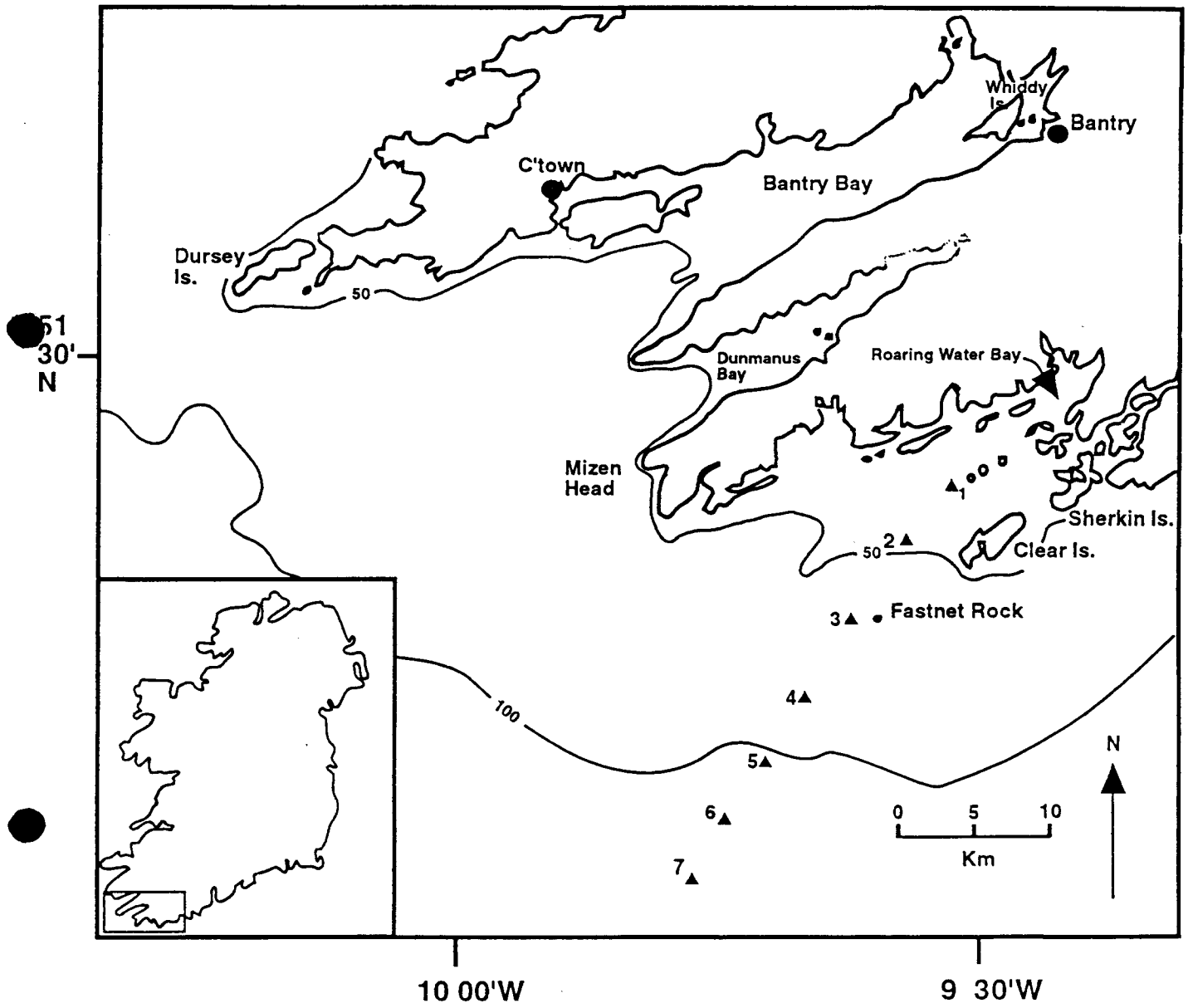


Figure 1. Map of study area, showing station positions sampled in August, 1985.

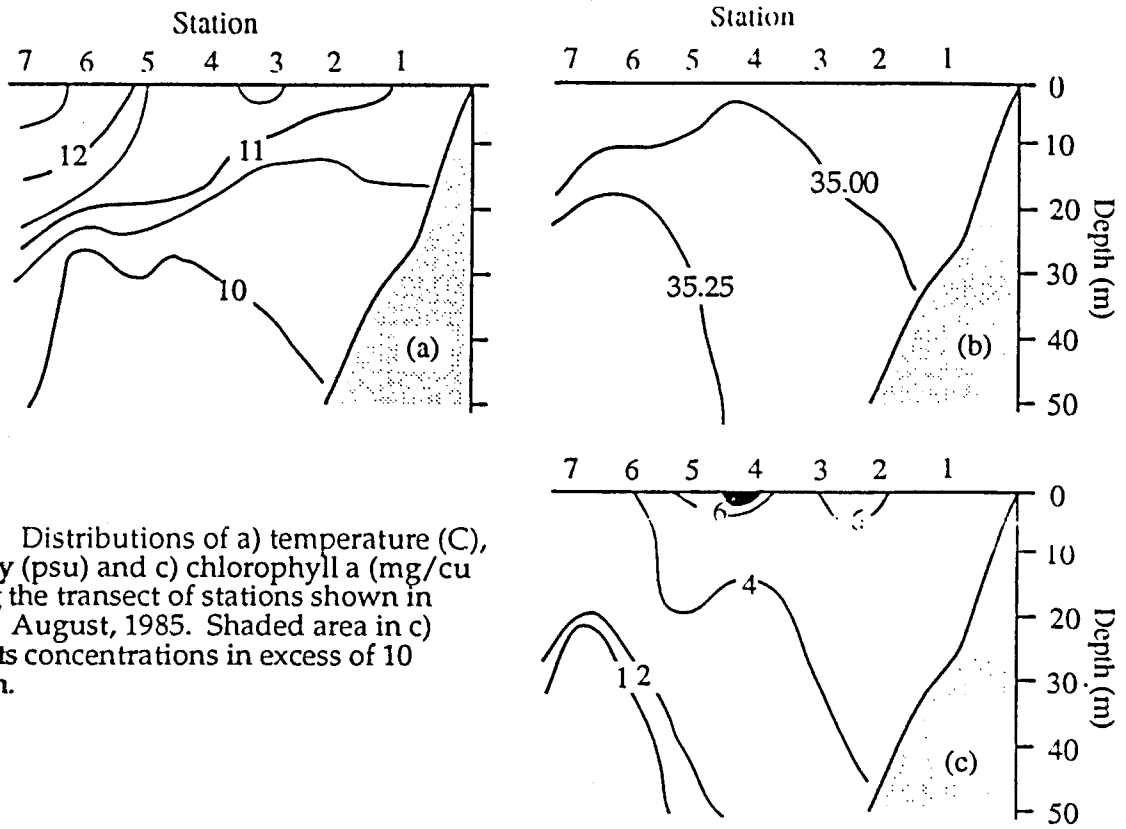


Figure 2. Distributions of a) temperature (C), b) salinity (psu) and c) chlorophyll a (mg/cu m) along the transect of stations shown in Figure 1, August, 1985. Shaded area in c) represents concentrations in excess of 10 mg/cu m.

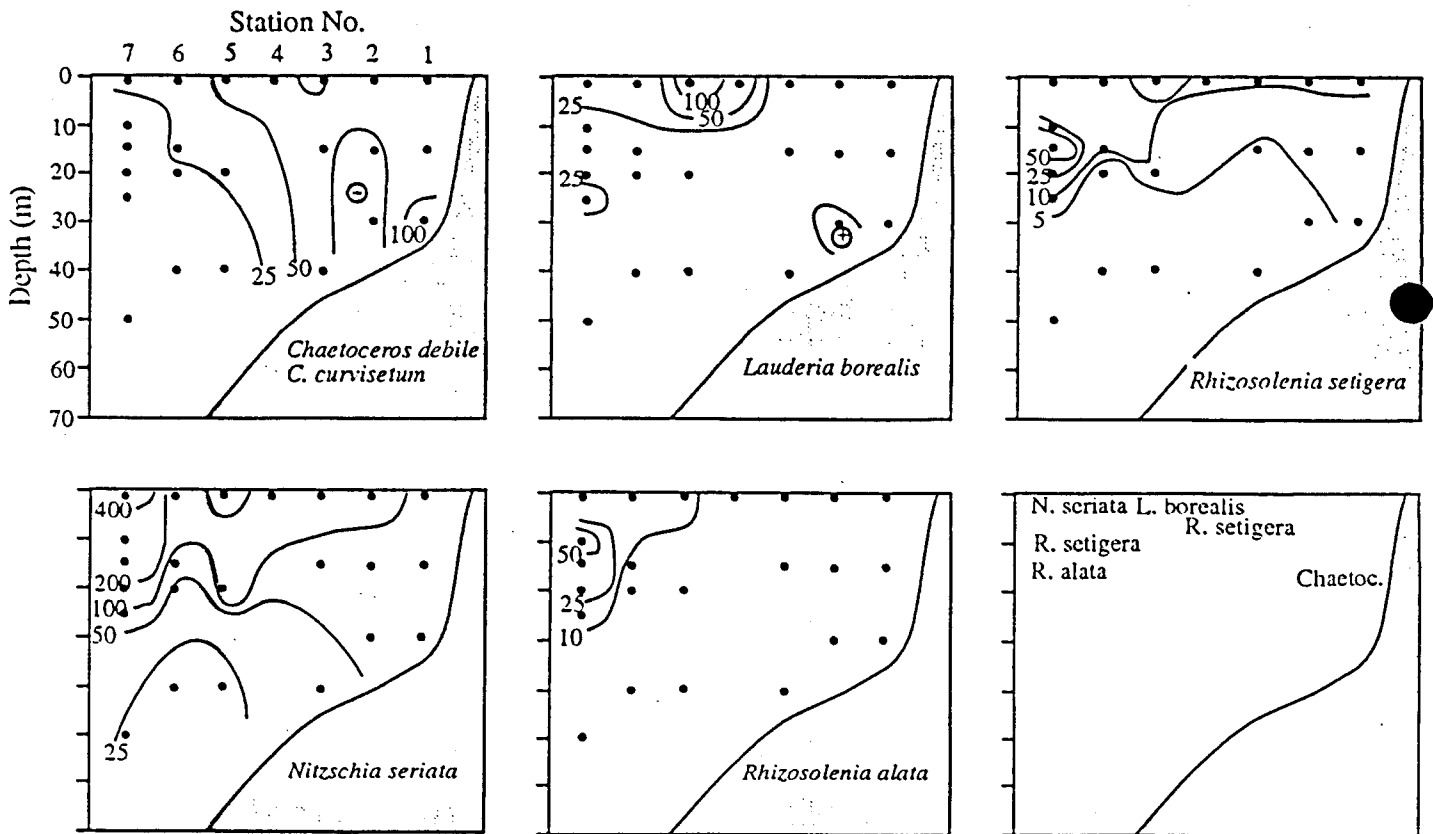


Figure 3. Distributions of five diatoms along the transect of stations shown in Figures 1 and 2. Numbers are concentrations in cells/ml. Lower left shows regions dominated by each species.