The occurrence of the red-tide organism, *Gyrodinium aureolum* Hulburt (Dinophyceae), around the south and west of Ireland in August and September, 1979.

by

Ian R. Jenkinson
Department of Oceanography, University College, Galway

and

Pat Paul Connors
Sherkin Island Marine Station, Baltimore, Co. Cork

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INTRODUCTION

Gyrodinium aureolum Hulburt is the dinoflagellate which was responsible for red tides along the south coast of Ireland in 1976 (Ottway, Parker, McGrath and Crowley, 1979), in 1978 (Roden, Ryan and Lennon, 1980; C. Pybus, 1980; I. R. Jenkinson, unpublished) and again in 1979.

It is known to achieve high concentrations in stratified waters (Holligan and Harbour, 1977), particularly within sharp density discontinuities, and especially near fronts (Pingree, Pugh, Holligan and Forster, 1975; Pingree, Holligan, Mardell and Head, 1976; Pingree, Maddock and Butler, 1977). On the south-west coast of Norway in 1966, red tides occurred with *G. aureolum* concentrations of up to 70×10^6/l, and during this episode, fish in cages were killed (Tangen, 1977). In 1976 there were again blooms of high concentration off the south-west of Norway (Tangen, *loc. cit.*) in localities where fronts had previously been found (Eggvin, 1940).

In 1978 a red tide occurred during late August in Dunmanus Bay, south-western Ireland, and this was associated with deaths of caged fish (Parker, 1980) and many invertebrates (Leahy, 1980). On passage aboard r.v. *Lough Beltra* on August 27-28, 1978 (I. R. Jenkinson, unpublished) strongly brown water was observed in the bay off Kinsale, and patches occurred along the coast as far as Dursey Head. In samples taken along the route, *G. aureolum* occurred from Kinsale to the Blaskets, but not further north. Later the same year, C. Pybus (1980) found *G. aureolum* in numbers up to 10^6/l in Kinsale Bay, and daytime oxygen saturation values up to 170%.

Gonyaulax polyedra, in lower concentrations than *G. aureolum*, was reported in water samples from Dunmanus Bay, after the fish kill in 1978; it was suggested that *G. polyedra* might have been the lethal agent, rather than *G. aureolum*.

In June and July, 1979, *G. aureolum* was again increasing in Roaringwater Bay (C. M. Roden and others, in preparation). Moreover it was realised that the extent of *G. aureolum* blooms around the coast of Ireland was not known. Nor had the location nor extent of low concentrations of this dinoflagellate been documented. So as to provide a background against which to assess the effects of *G. aureolum* (and other red-tide organisms), investigations of their coastal and offshore concentrations were begun in August, 1979.

METHODS

Samples were gathered from as wide an area as possible, with the help of interested people both onshore and from boats.

Bottles, numbered and containing Lugol's iodine as a preservative (Holligan and Harbour, 1977) were distributed with information sheets, forms for documenting samples and recording data (Table 1) and, usually, a thermometer.

Table 1:
Data requested with each sample

Sample number
Date and time
Sampling position (with request to be quite clear)
Sea temperature
Sea colour
Wind direction
Wind force
Other observations

Except for the following, only surface samples were collected: during sampling from r.v. *Lough Beltra*, water was pumped to the deck from about 1m deep whilst on passage; in Dunmanus Bay, samples were taken by Institute of Oceanographic Sciences water bottles; in Horseshoe Harbour, Sherkin Island, samples were collected by snorkel divers, and for these shallow waters the depths were estimated.

The following results represent only that small proportion of the samples so far examined.

RESULTS

Fig. 1 shows a profile of water temperature on August 10, 1979, south of Sherkin Island. It shows an example of the front dividing nearshore water with a relatively mixed water column from offshore water with a fairly well developed thermocline.

The positions of samples collected from r.v. *Lough Beltra* on August 13 are shown in Fig. 2, as are some of those collected on August 15. The corresponding temperatures and *Gyrodinium aureolum* concentrations are shown in Fig. 3. On August 13, surface *G. aureolum* concentration was positively related to surface temperature. Also, while temperatures and *G. aureolum* concentrations were relatively high off Courtmacsherry Bay and Clonakilty Bay, off the Old Head of Kinsale and Galley Head both temperatures and counts were lower. On the night of August 13 there was a severe gale. By August 15 temperatures were lower and the relationship indicated for August 13 between temperature and *G. aureolum* concentration had broken down. Over the outer stations, 26 to 30, although the temperatures increased from 12.0^{o}C to 14.0^{o}C, a value similar to those on August 13, the numbers of *G. aureolum* decreased.

The positions of the remainder of the samples taken on August 15 and of those taken on August 18 are shown in Fig. 4. The corresponding temperatures and *G. aureolum* concentrations are shown in Fig. 5. North of Dursey Head, *G. aureolum* concentrations remained below 10^5/l: very low numbers were obtained off Bray Head, the Blaskets and in Tralee Bay.

In Fig. 6 are shown the positions and concentrations of samples collected between August 19 and 25. Noteworthy counts of 10^5 to 10^6/l were recorded from south of Cork Harbour, in Bantry Bay and off Dursey Head; counts of up to 1.7×10^4/l were recorded from west of Blacksod Bay. In Blacksod Bay, of two samples collected, one contained 2.6×10^4/l and none was recorded from the second sample (limit of detection about 100 to 200 cells/l).

The positions and *G. aureolum* concentrations of samples collected between August 26 and 30 are shown in Fig. 7. Around the south coast, concentrations offshore and on the coasts near headlands were between 10^5 and 10^6/l, except for one count of zero west of Dursey Head. In bays (e.g. Bantry Bay, Roaringwater Bay, Clonakilty Bay and Cork Harbour) they were more variable: some counts were less than 10^4/l, while others in Roaringwater Bay exceeded 10^6/l. Specimens were again present in low numbers west of Blacksod Bay, and a second count of zero was obtained from Donegal Bay.

In Fig. 8, concentrations between September 1 and 6 are shown from Roaringwater Bay, Dunmanus Bay and Bantry Bay. In all of these bays, some counts exceeded 10^6 /l. Dunmanus Bay is considered further below.

On August 26, the first instance of onshore red tide in 1979 reported to us (by M. Precious) was in Barley Cove, near Mizzen Head. A sample from there contained 6.8×10^5 /l. On the same day a sample collected from a red tide on the north side of Horseshoe Harbour, on the south-east corner of Sherkin Island (by H. J. Lennon) contained 4.3×10^6 cells/l.

Later on August 26, in Horseshoe Harbour, the most discoloured area had moved to a cove on the south-east of the "harbour". Samples were collected by snorkel divers. The concentrations of *G. aureolum* in these samples are shown in Fig. 9. The brownish colour was chiefly confined within a layer between the surface and 30 to 50cm deep: below this the water appeared green. In the brown layer, many small bubbles were suspended, appearing to be motionless as if trapped. Where the brown layer washed over rocks, barnacles were actively feeding and periwinkles, *Littorina* sp., were moving about.

Fish kill

On the night of September 1-2, the entire stock of rainbow trout, *Salmo gairdneri* Richardson, held in cages at a fish farm in Dunbeacon Harbour, Dunmanus Bay, died. Only some preliminary observations are given here. The area near the fish farm was visited on September 5. The water colour was brown and the water temperature by the beach was 15.9°C. On the shore or at the water's edge were seven species of dead fish; an eel was alive

Table 2:
List of Fish species found dead
at shore near Dunmanus Bay Fish Farm
5 and 6 September, 1979

Anguilla anguilla :r	Eel
Atherina presbyter	Sand-smelt
Blennius montagui	Montagu's blenny
Crenilabrus melops	Corkwing wrasse
Gobius niger	Black goby
Gobius paganellus	Rock goby
Gobiusculus flavescens	Two-spotted goby
Hyperoplus lanceolatus	Greater sandeel
Lipophrys pholis	Shanny
Molva molva	Ling
Pomatoschistus minutus	Sand goby
Pomatoschistus pictus	Painted goby
Sygnathus acus	Greater pipe-fish
Taurulus bubalis	Sea scorpion
Trachurus trachurus	Horse mackerel or shad

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but easily picked up. Lugworms, *Arenicola marina*, were alive, lying on the sand surface or being rolled about at the water's edge. On September 6 and 7, eleven species of fish were found dead. Including the trout, 16 species of fish are known to have died in Dunmanus Bay in association with the red tide (Table 2). Six species of bivalves, four species of gastropods and six species of polychaetes were also affected. The crustaceans, *Carcinus maenas* and unidentified amphipods, seemed unaffected (except for one *Palaemon serratus* found dead).

Phytoplankton samples were collected, mostly from the surface, but also a series from several depths (Fig. 10). The highest *Gyrodinium aureolum* concentration found was 49×10^6 /l.

Although *Gonyaulax polyedra* was searched for throughout this study, only one specimen, possibly of this species, was seen: it was in the samples from Dunmanus Bay. In none of the samples examined in this study was *Noctiluca* encountered.

DISCUSSION

As *Gyrodinium aureolum* was found throughout the area sampled, except possibly for Donegal Bay, the present results do not define the extent of its occurrence around the south and west of Ireland in August and September, 1979.

The association of high surface concentrations of *G. aureolum* with high surface temperatures along the south coast on August 13, before the gale (Figs. 2 and 3, Stations 1 to 10) reflects a similar relationship found in Roaringwater Bay in 1978 and 1979 (Roden *et al.*, 1980; C. M. Roden and others, in preparation). It may result from an association of higher surface temperature with greater stratification in the area, and the association of *G. aureolum* with stratified water (Pingree *et al.*, 1975, 1976, 1977; Holligan and Harbour, 1977). The lower surface temperatures in an adjacent area (Figs. 2 and 3, Stations 11 to 26) after the August 13 gale may have been caused chiefly by wind-induced mixing. The lack of a relationship between *G. aureolum* concentration and temperature at these stations supports this idea.

The lower *G. aureolum* concentrations associated with higher surface temperatures well offshore on August 15 (Figs. 2 and 3, Stations 27 to 30) may signify a different body of water, where the gale had not stirred up the water column as much as at Stations 11 to 26.

Pingree (1975, 1978a) has predicted that the Celtic Sea south of Fastnet would become stratified before April 1, and would become mixed again during November. James (1980) showed that the development from a mixed water column to a stratified one in the central Celtic Sea took place during late April and early May, 1978. In view of the association between stratification and the blooming of *G. aureolum*, nearshore-offshore oceanographic profiles should be worked to follow spring development and autumn breakdown of stratification. Associated with these should be surveys to determine the distribution of *G. aureolum* from March to December.

Fig. 11 represents a speculative, generalised profile off sheltered bays to the south and south-west of Ireland, when the main body of the Celtic Sea is stratified. It is based: firstly on the data used to draw Fig. 1; secondly on other oceanographic data collected in 1979 south of Roaringwater Bay (C. M. Roden and others, in preparation); thirdly on the structure of the Celtic Sea/Irish Sea Front (James, 1977, Figs 2 and 3), which appears in satellite photographs as if drawn out along the south coast of Ireland, sometimes as far as Fastnet (e.g. Simpson and Pingree, 1978, Figs. 4 and 5; Pingree, 1978b).

Even when *G. aureolum* red tides are occurring offshore and/or in bays, the inshore, mixed water (Fig. 11) does not support a high population of *G. aureolum*, and its phytoplankton is consistantly dominated by diatoms (C. M. Roden and others, in preparation). When *G. aureolum* is blooming in the offshore stratified water but not in the bays, it is not known how red tides suddenly appear on coasts.

One possible mechanism may be as follows. During times of high heat input and light winds, a temporary superficial thermocline may develop on the inshore zone of mixed water. (On one sunny day, in the zone of normally mixed water south of Sherkin Island, there was a greater temperature difference between the surface and 1m deep than between 1m deep and the bottom.) If the development of such a superficial thermocline were accompanied or followed by light winds from the appropriate direction (see Pond and Pickard, 1978, Chapter 9) these might serve to blow a shallow layer of *Gyrodinium aureolum*-rich water across the normally mixed zone and into the area of "bay" water (Fig. 11). The role of frontal oscillations, perhaps including intrusive fingers and/or baroclinic eddies (Pingree, 1978b, 1979) may also be important in transferring populations of *G. aureolum* across the mixed zone.

The presence of small bubbles suspended almost stationary in layers of concentrated *G. aureolum* red tides (M. Parker, personal communication; H. J. Lennon, personal communication; present results) suggests high viscosity at very low shear rates and/or a yield stress mechanism caused by secreted water-soluble substances — perhaps mucopolysaccharides. In many biological fluids which contain long-chain molecules, at sufficiently low shear rates, bonds form between the organic molecules, causing increased viscosity and sometimes gelling, depending on the types of bonds. Conversely if shear stress is then increased enough to break the bonds, any gelling tends to be reversed, the molecules become alligned parallel to the direction of shear and the viscosity decreases (see Burnes and Macdonald, 1975, p. 196).

The bubbles, presumably of oxygen formed by photosynthesis, may explain the high oxygen concentrations so far found in red tides caused by *G. aureolum* (C. Pybus, 1980; P. Leahy, personal communication). If concentrated patches of *G. aureolum* do form cohesive mats, the entrapped bubbles will confer on the mats a density lower than that of the surrounding water, thus helping them to rise and to stay at the surface.

The behaviour of fish and other animals during the red tide in Dunmanus Bay in 1979 suggested oxygen deficiency (D. Precious, personal communication). Oxygen needed by aquatic animals diffuses to their respiratory surfaces from the microlayer of water or mucus in contact with them. Normally the oxygen is replenished by diffusion from the surrounding water which is being continually replaced. If the viscosity were increased or the water next to the microlayer in contact with the respiratory surfaces gelled sufficiently, two (in some animals three) compounding effects would be expected: the first is that the replacement of oxygen-depleted water next to the microlayer would be reduced or even prevented; secondly, in those animals which actively pump water over their respiratory surfaces, more work, and hence oxygen, would be required to do this; thirdly, since the molecular diffusivity of a gas in a liquid is inversely proportionate to viscosity (Burnes and Macdonald, 1975, p. 198), the oxygen diffusion rate would also be reduced.

In the present study and in that of Ottway *et al.* (1979) decapod crustaceans seem to have been notably unaffected by *C. aureolum* red tides. "Since the majority of reptantians are bottom-dwelling and include many burrowers, a variety of mechanisms have evolved to prevent clogging of the gills with silt and detritus . . . The gills are cleaned in crabs by the fringed epipodites of the three pairs of maxillipeds. These processes . . . sweep up and down the surface of the gills, removing detritus." (Barnes, 1975, p. 455). The sweeping of these stiff, fringed processes which, in *Carcinus maenas*, normally occurs many times per minute (I. R. Jenkinson, unpublished), is likely to provide locally high rates of shear within the crab's gill cavities, thereby discouraging gelling and/or the development of high viscosity. This behaviour could be particularly beneficial to the crab if time dependent viscosity effects were important.

Measurements of the visco-elastic properties, including time-dependent effects (thixotropy/antithixotropy) of water affected by *G. aureolum* red tides, as well as studies of oxygen diffusivity, should make it possible to say whether the physical properties of the water would be lethal. If the properties were harmful it should be possible from these considerations to predict whether any particular type of mechanical agitation, near organisms at risk for example, would significantly reduce the harmful effects of a dense bloom of *Gyrodinium aureolum.*

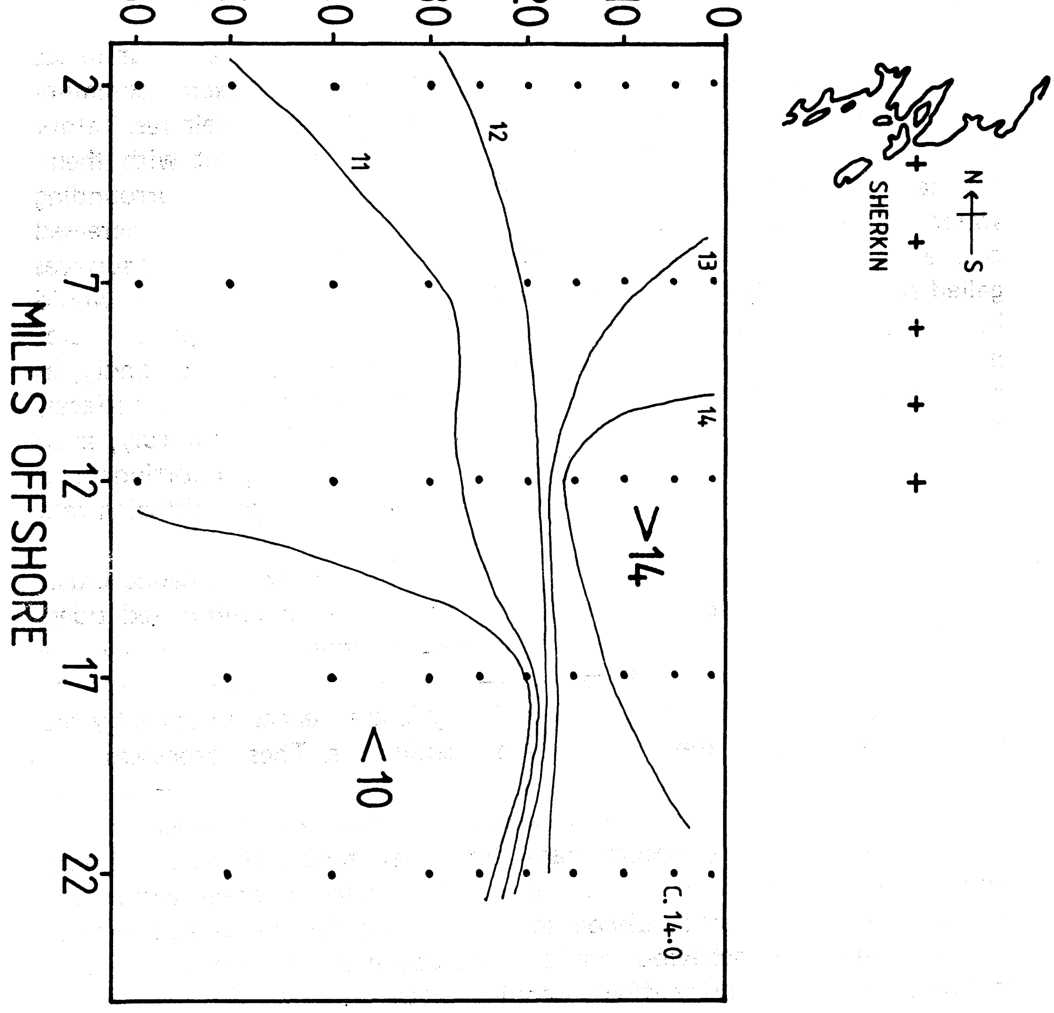


Fig. 1 Profile of water temperature south of Sherkin Island on 10 August, with positions of stations.

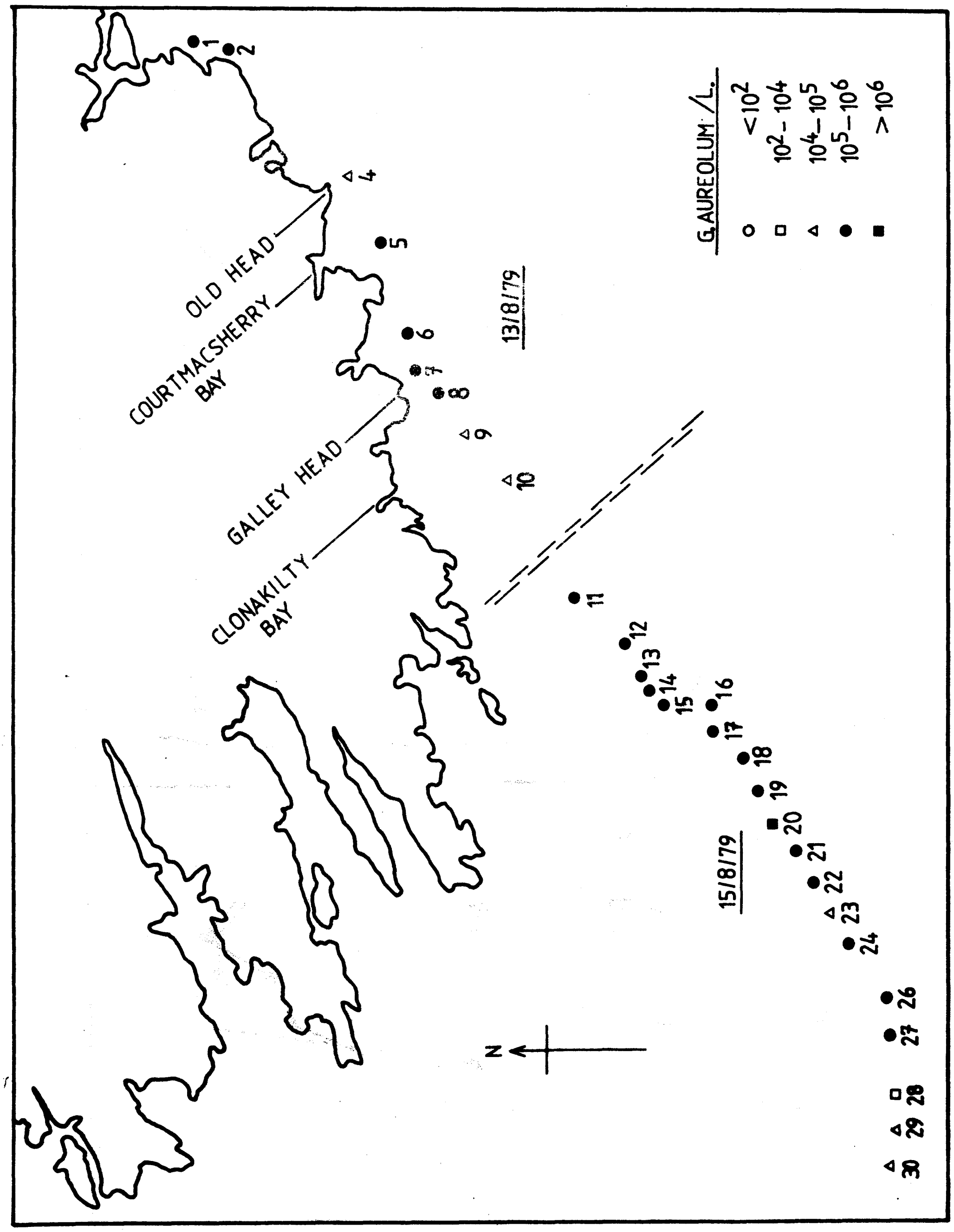


Fig. 2 Positions of samples and their *G. aureolum* concentrations taken on 13 August and some of those taken on 15 August, showing their *G. aureolum* concentrations.

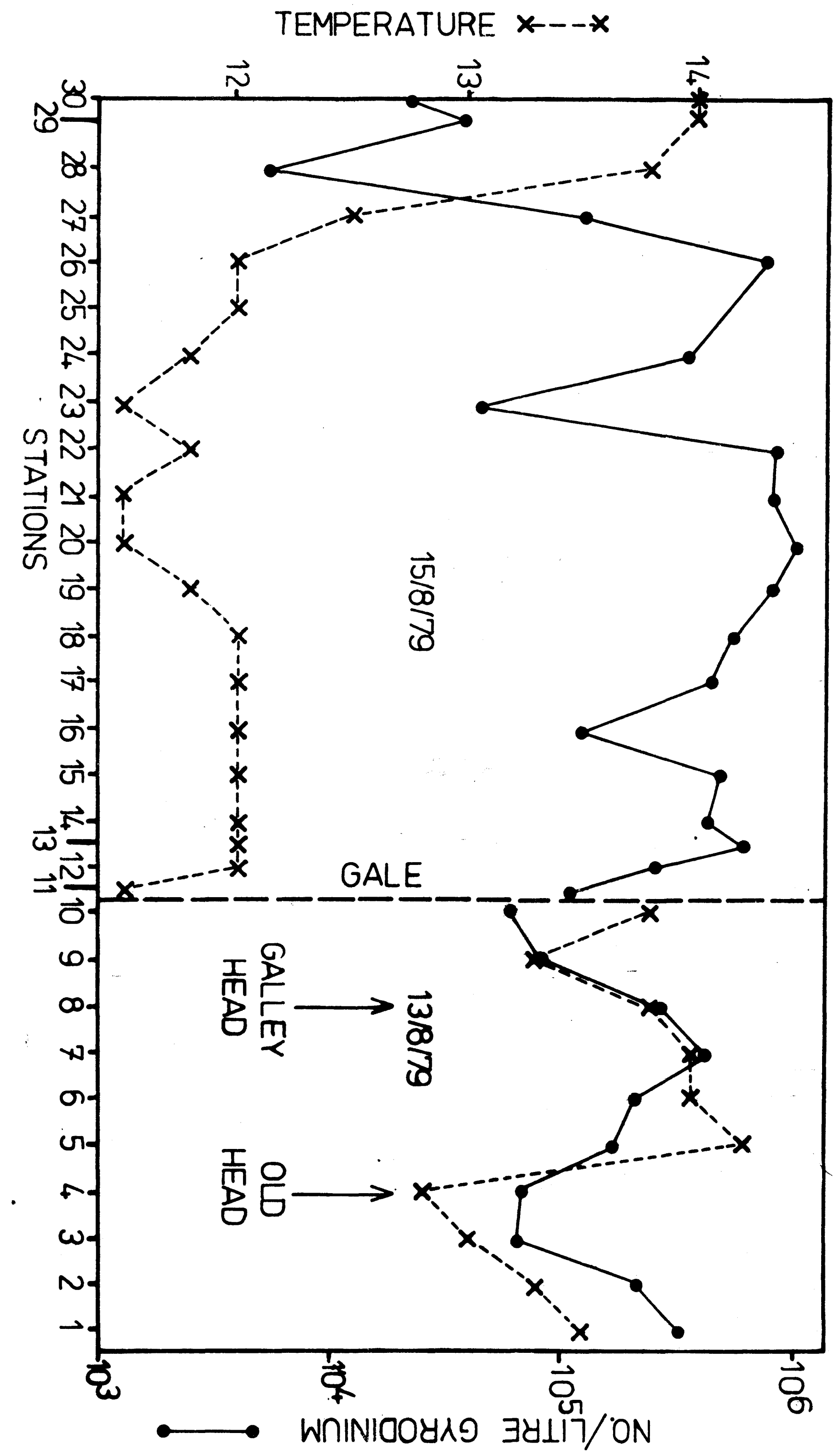
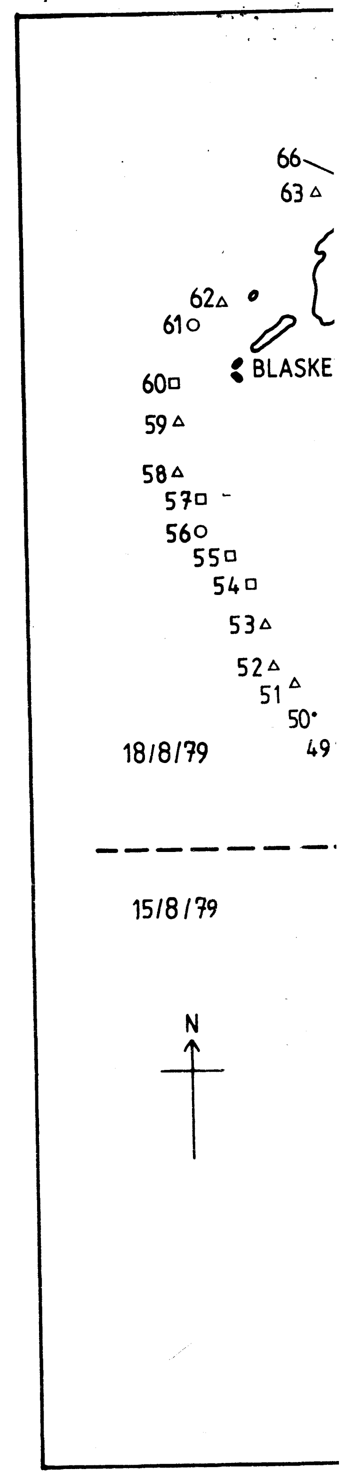


Fig. 3 Temperatures and *G. aureolum* concentrations on 13 August and some of those on 15 August.



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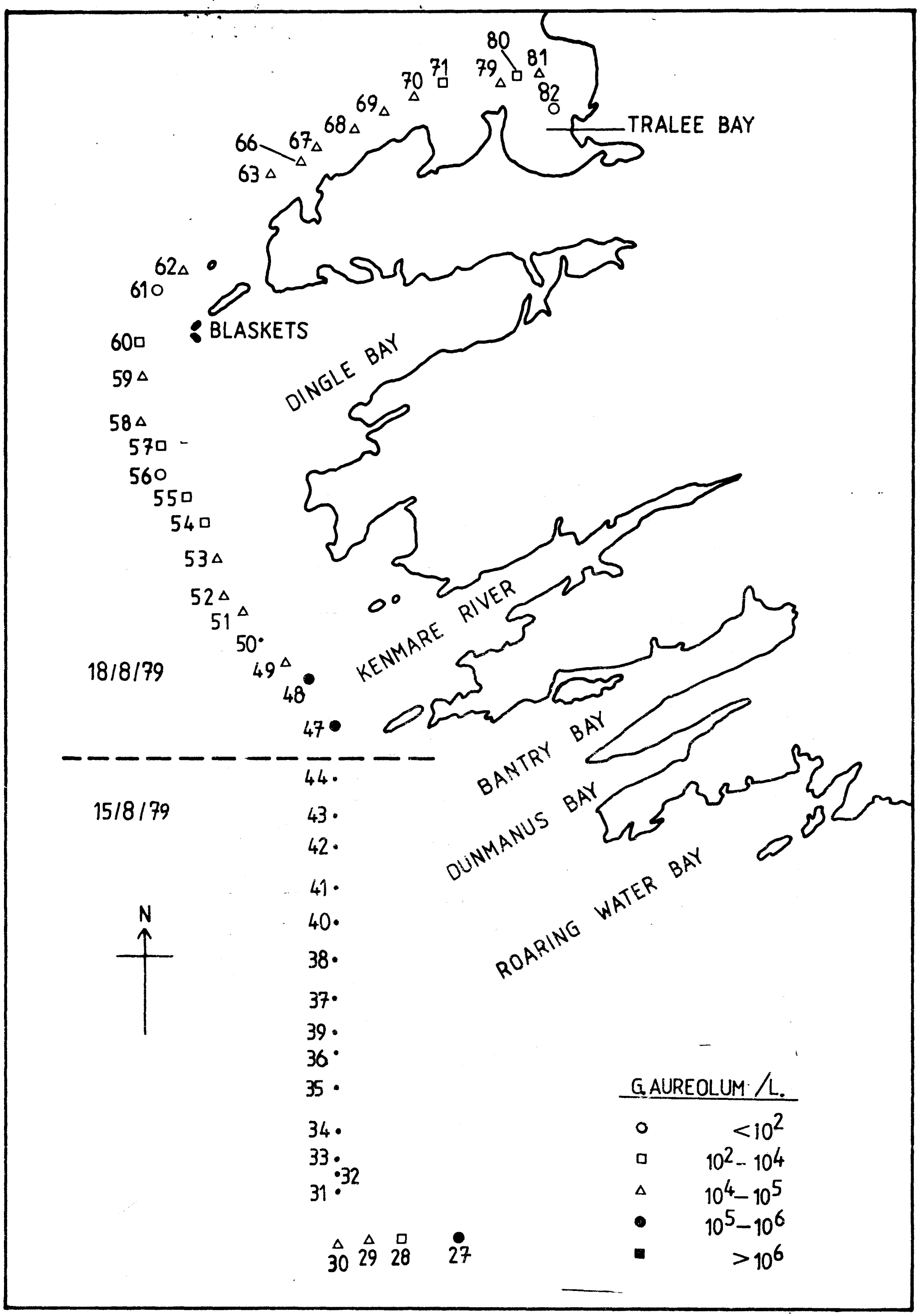


Fig. 4 Positions of remainder of samples taken on 15 August with those taken on 18 August showing their concentrations of *G. aureolum.* Small dots represent stations for which concentrations of *G. aureolum* could not be determined.

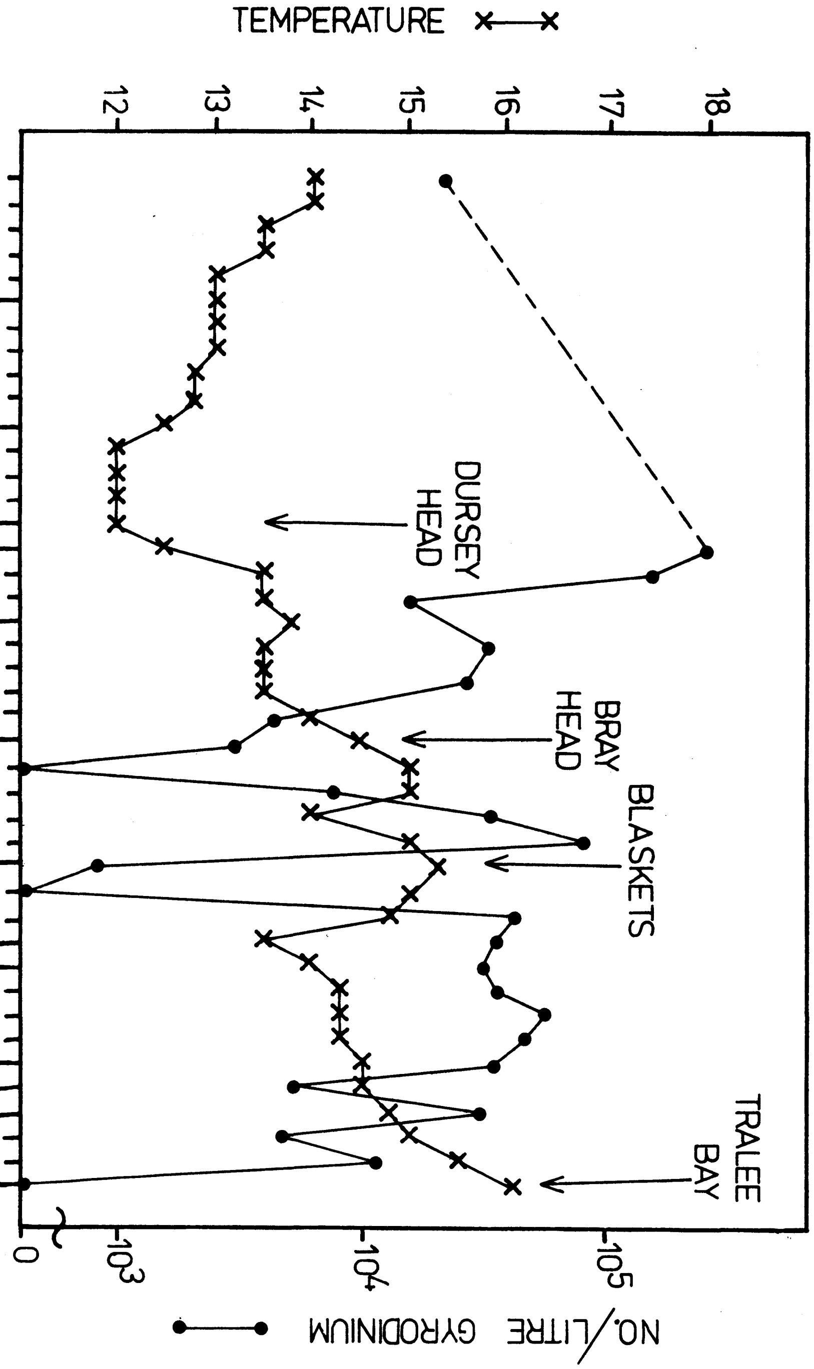


Fig. 5 Temperatures and concentrations of *G. aureolum* for remainder of samples taken on 15 August and for those taken on 18 August.

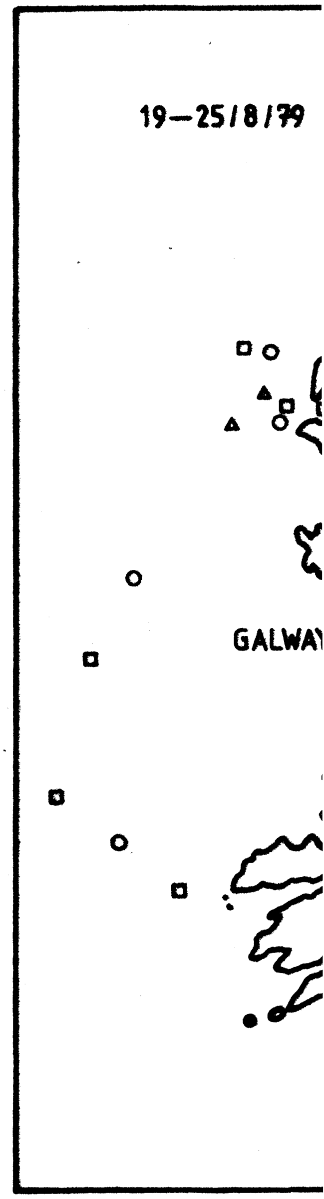


Fig. 6 Concentrations

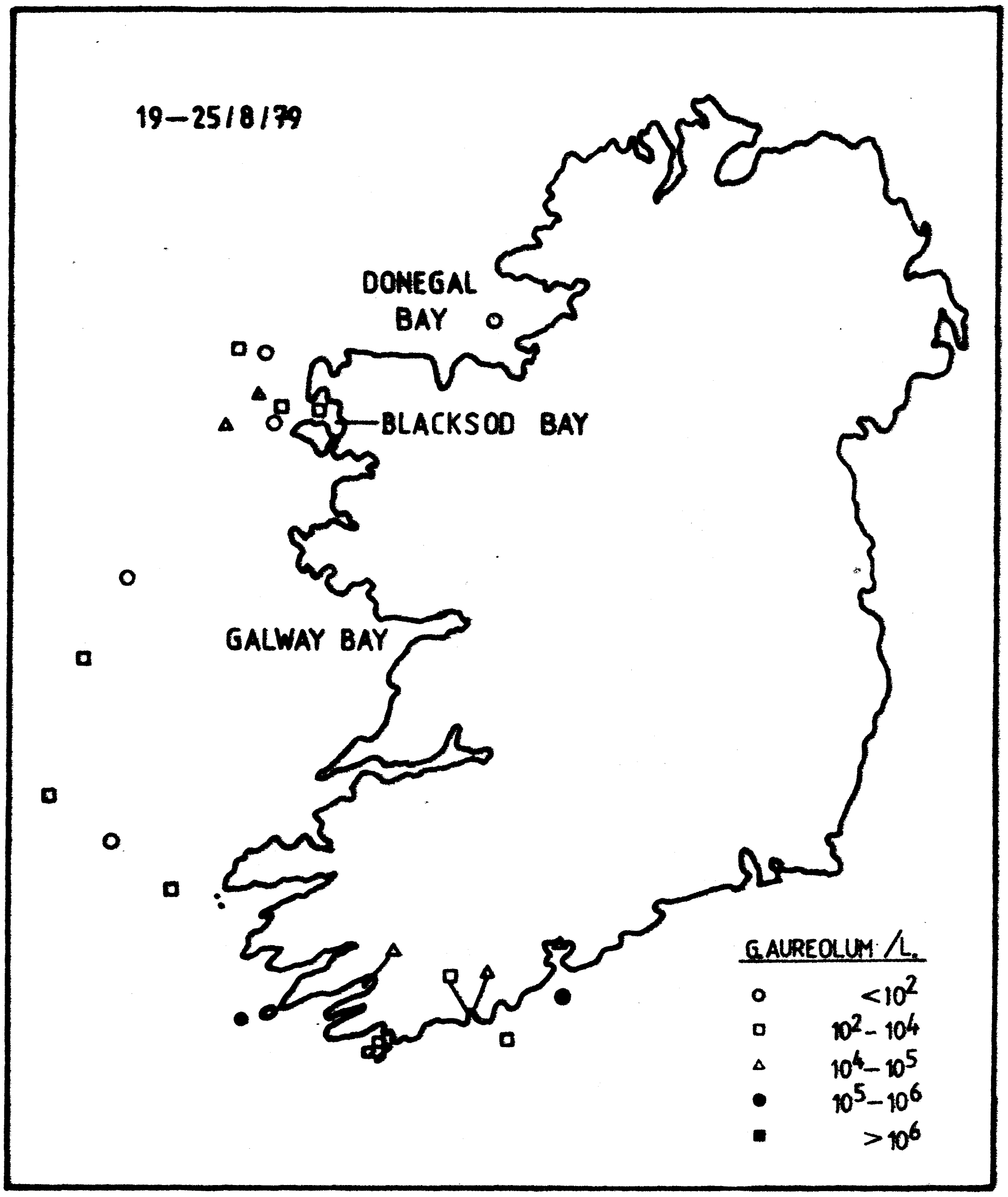


Fig. 6 Concentrations of *G. aureolum* between 19 and 25 August.

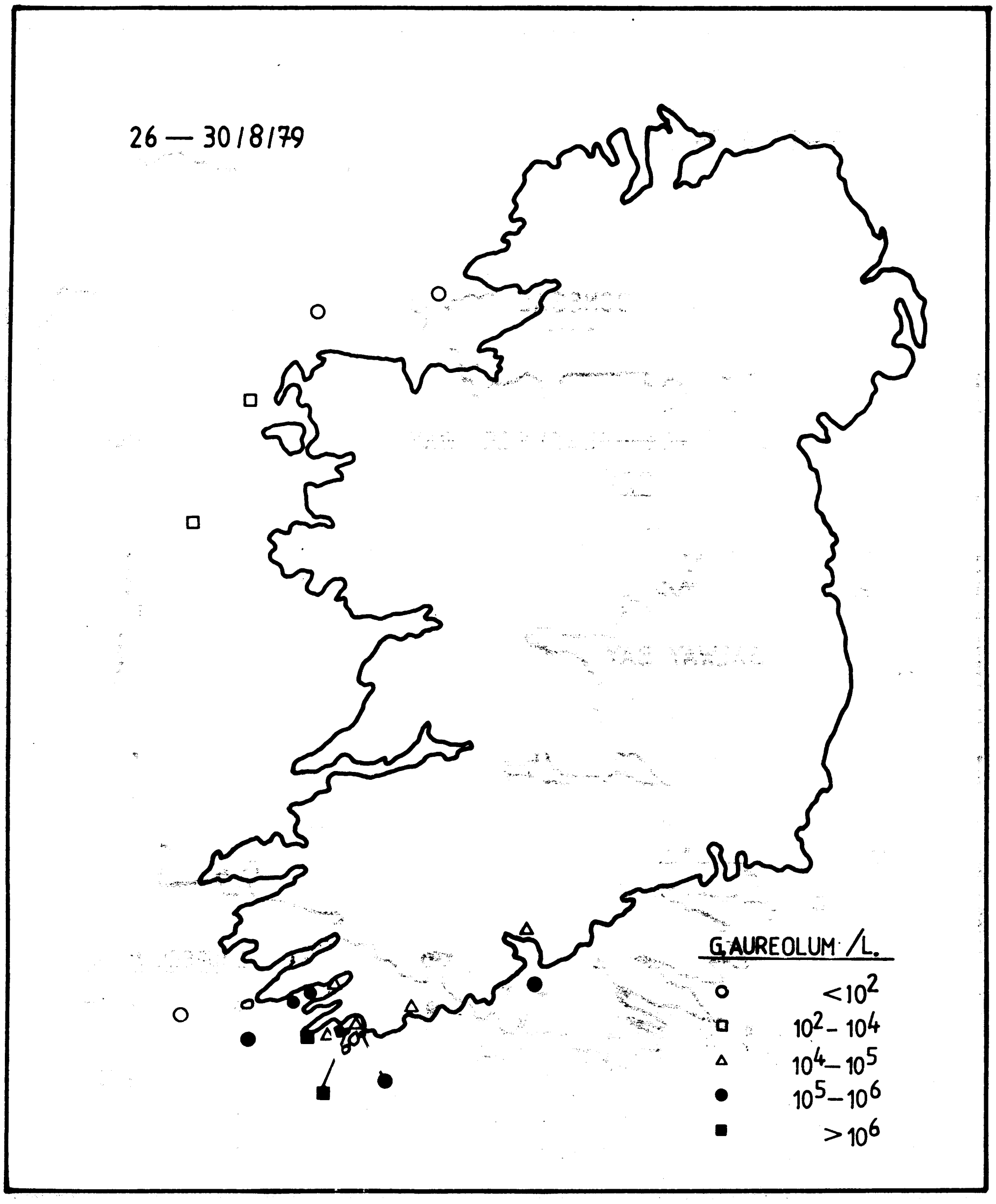


Fig. 7 Concentrations of *G. aureolum* between 26 and 30 August.

Fig. 8 Concentrations of

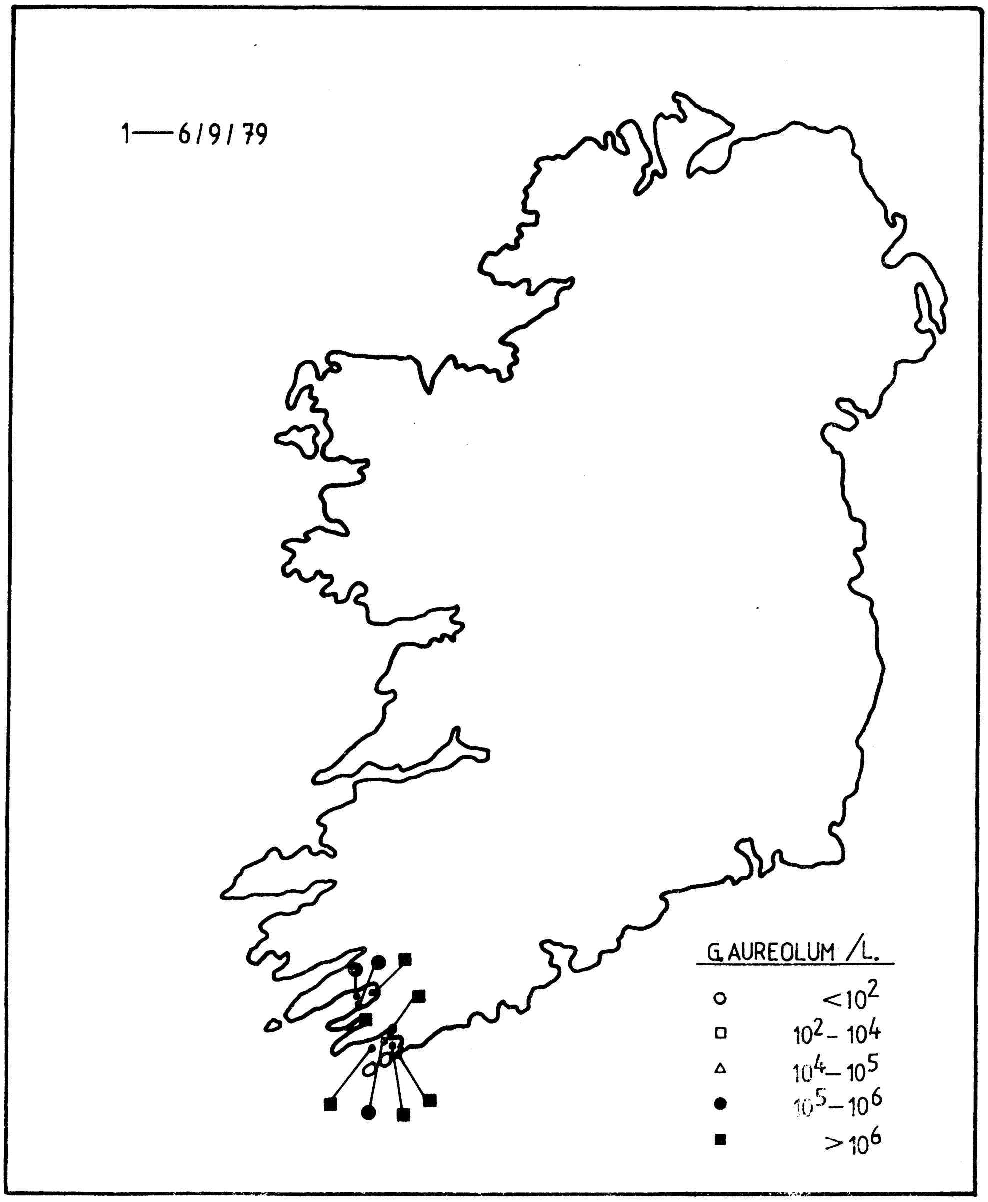


Fig. 8 Concentrations of *G. aureolum* between 1 and 6 September.

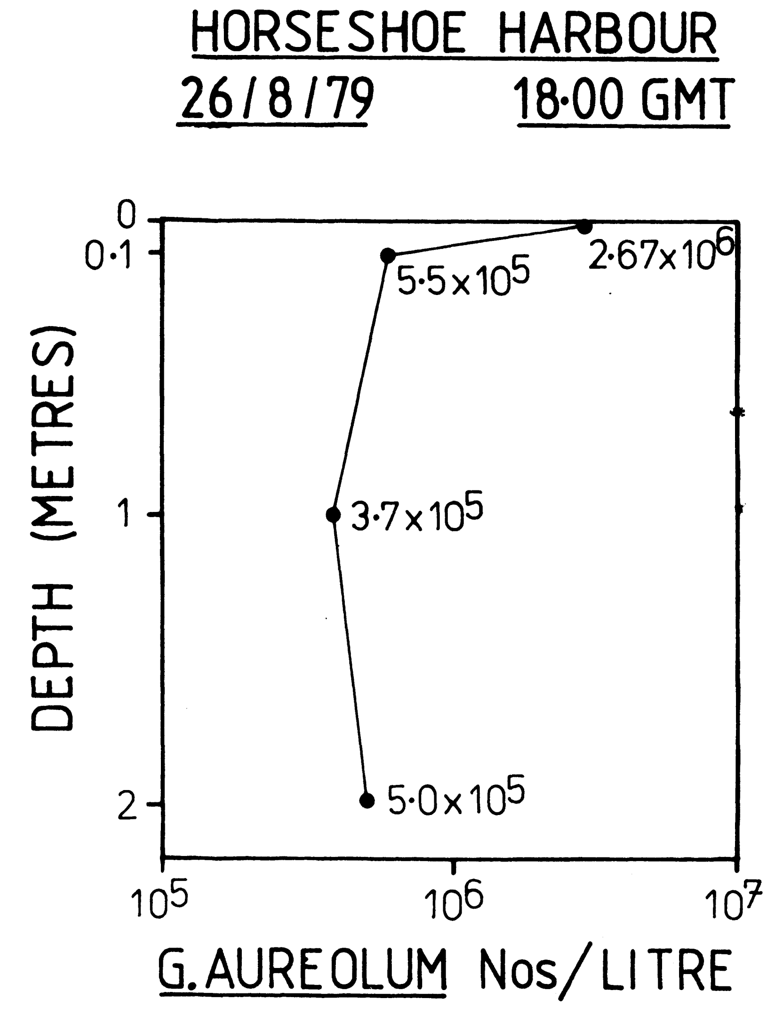
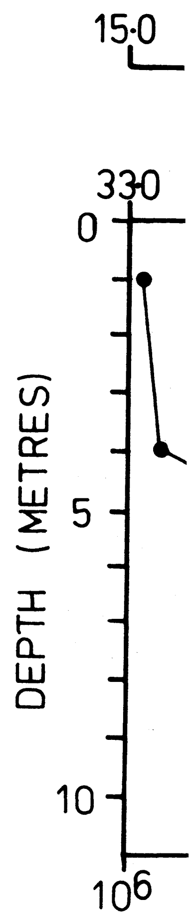


Fig. 9 Concentrations of *G. aureolum* plotted against depth for Horseshoe Harbour, 26 August.



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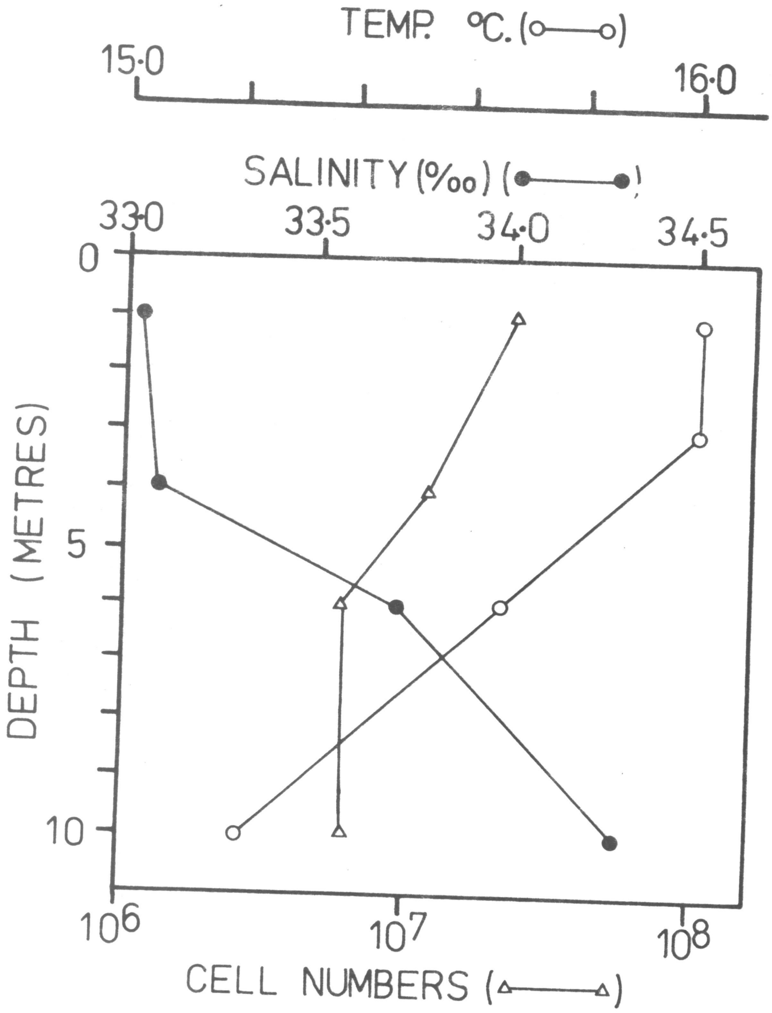

Fig 10 Temperature, salinity and concentration per litre of *G. aureolum* (cell numbers) plotted against depth, Dunbeacon Harbour, Dunmanus Bay, 7 September.

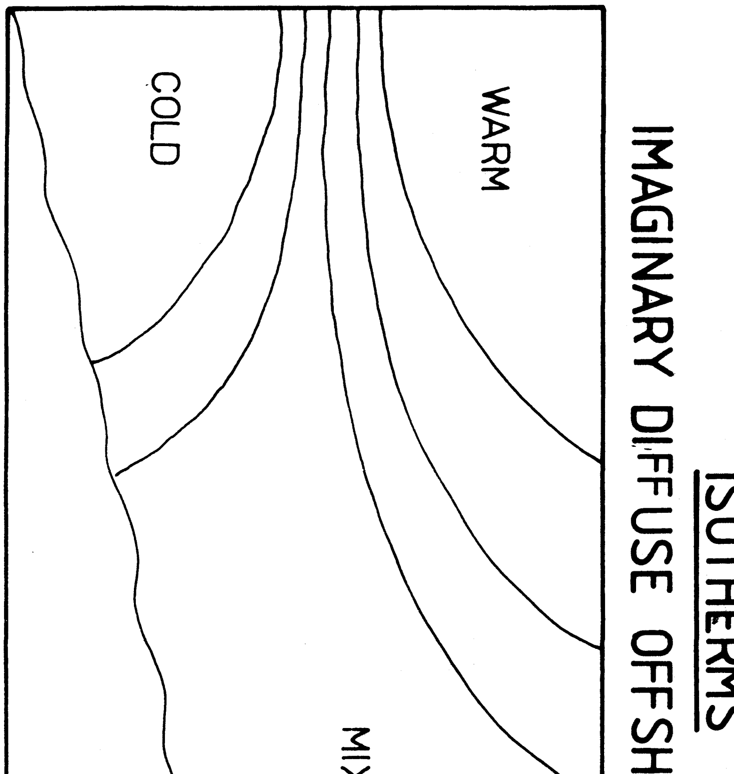

Fig. 11 Suggested generalised thermal profile off a bay on the south-west coast of Ireland in summer, to show different types of water. It is assumed that salinity differences play little part in modifying density.

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The Shores of West Cork

J. A. Quish

Oh, the beautiful shores of the West Coast of Cork
Are calling forever to me,
From the high hill o'er Schull and the Carbery islands
To the Fastnet way out in the sea,
To climb to the top of Brow Head on a Sunday,
See the sea birds nestle and glide.
To stand with a rod on the Shores of West Cork
And wait for the fish on the tide.

To Crook for the crack on a Saturday night,
'Tis there that your journey will end,
With tales of disaster and gay girlish laughter,
A wonderful time you will spend.
The folks they are happy, and healthy and kind
And have that sweet peace of content,
For there's nowhere at all like the Shores of West Cork
No matter where you go on Earth.

From all ports of Europe yachts sail to Crookhaven,
To Schull and to near Baltimore,
Sherkin Isle and West Skeam are really a dream,
And a hundred isles near to the shore.
When the weather is rough and the wind it blows up,
The seas are a sight to behold,
Mother Nature is tough on the Shores of West Cork,
But the calm it brings peace there once more.

To dive neath the sea with a mask on your face
Opens up a new world of delight.
Sea urchins and crabs and wild rocky crags
Are seen in the pale greeny light.
Survival is first as they lurk, dive or jump
In that wonderful world 'neath the waves.
For the beauty that lives 'neath the Shores of West Cork
Will be with you the rest of your days.

To walk with your lass on the road to the Mizen,
The view you will never forget.
To climb out the cliffs up to Three Castles Head,
Or to wait for the fish at Toor Pier.
So wherever you go in this rough tough old world,
There is surely no place you can find
As grand and content as the Shores of West Cork,
For all the time you are alive.

Chorus
O Beautiful Shores of West Cork,
You're calling forever to me,
Your fine sandy beaches and heathery reaches,
And your rocks jutting down to the sea.

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