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A REVIEW OF A POSSIBLE UPWELLING SITUATION OFF PORT MACDONNELL S.A.

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CONTENTS

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Abstract

Occurrence of surface cold water (less than 14.5°C) accompanied by decreases in salinity and increases in nitrate, is a particular feature, during January to March, of the oceanographical situation off the Cape Northumberland region, South Australia. It has been found that these particular cold water events occur as climax situations during an overall less marked decline in surface sea temperatures.

The evidence is not adequate to show upwelling as the prime cause of these climax events. However the wind direction and the offshore current direction at certain times (January-March) are clearly favourable for upwelling.

The surface nitrate values associated with this cold water event are much less than those caused by upwelling off northern New South Wales. The biological consequences could be expected to be less.

1. *INTRODUCTION*

This paper is the second of a series examining existing evidence for upwelling or other enrichment processes in the coastal waters of Australia. The first paper in this series (Rochford 1977) dealt with upwelling off Lakes Entrance (Victoria).

This paper examines a cold water enrichment feature off Port Macdonnell, S.A.

2. *DATA AND METHODS*

The data have been obtained from:-

(a) Merchant ship observations of surface temperature and salinity on passage through western Bass Strait to Adelaide and to Fremantle (Fig. 1). These have been used as monthly averages within the ½° x ½° square 38-38°30'S, 140°30'-141°E, or as individual cruise results within the area.

(b) Results from a CSIRO monitoring station off Pt MacDonnell, (38°10'S, 140°41'E Fig. 1) and off Warrnambool (38°37'S, 142°30'E).

(c) Results from a sea surface temperature buoy operated by Bureau of Meteorology (38°04'S, 140°40'E Fig. 1).

(d) Various CSIRO oceanographical cruises in the general area.

The data from (a), (b) and (d) are available now or in the immediate future from World Data Centres A and B;

those from (c) by application to the Bureau of Meteorology, Melbourne.

3. *THE COLD WATER EVENT*

The changes in surface temperatures and salinity and, for some years, of surface nitrates at the three observing sites off Pt Macdonnell (Section 1) since 1970 show (Fig. 2):

(a) In all years surface temperatures, to a varying extent, decreased during the period when normally summer sea temperatures increase (compare observed and dashed lines January-April Fig. 2).

(b) Since 1973 surface salinities also decreased during January-April of each year somewhat in proportion to the extent of the decrease in temperature.

(c) Surface nitrates in 1975 and 1976 increased during January-April more or less in proportion to the extent of the decrease in temperature.

The more extensive buoy surface temperatures show (Fig. 3) that the observed cold water events off Pt Macdonnell (Fig. 2) are most likely climax situations in a general oscillatory but downward trend in surface temperatures from January through to March. Possibly three major (A, B and C, Fig. 3) and minor (A^1 and B^1, Fig. 3) climax situations occurred during January to March 1976.

Figure 2 indicates that only during January-April and rarely into May does a cold water event of a short or longer term duration occur.

The duration of each climax event, from beginning to end is around a month near the coast (Fig. 3) but possibly shorter further offshore (Fig. 4). However the minimum temperature of each climax event may not persist for more than several days (Fig. 3).

The only direct evidence that upwelling rather than vertical mixing could be responsible for the cold water events off Pt Macdonnell is afforded by a temperature section off Rivoli Bay (See Figure 1 for location). Along this section in March 1961 the isotherms sloped upward into the near coastal region (Fig. 5).

However until a series of similar sections off Pt Macdonnell itself, spanning the duration of a climax cold water event, is available, the cause of such a cold water event and the general lowering of temperatures during January-April cannot be wholly ascribed to upwelling.

Area affected by the cold water event

Along the steamer track to and from Adelaide (Fig. 1) cold water (less than 14.5°C) was found around the middle of January, February and March 1976 (Fig. 4) at much the same time as the three major cold water events near the coast (Fig. 3). These cold water events offshore were only observed within a narrow longitude band from 140°40'E to 140°50'E.

Onshore it is not possible to establish the longshore extent of the cold water events.

However a chart of the averaged surface sea temperatures in January 1974 (Fig. 6) shows that a substantial cold water event had occurred to the north west of Pt Macdonnell around 37°S. The duration of this event could have been at least 9 days (steamer observations on the 17th and 25th January only). Unfortunately the available observations off Pt Macdonnell in January 1974 cannot establish (Fig. 2) whether a cold water event also occurred in that location at about the same time. Off Warrnambool, some 90 miles to the east of Pt Macdonnell, relatively cold water (16-17°C) was found at the surface in late January and March 1976 (Fig. 7).

In summary therefore it is impossible to decide:-

(a) The onshore longshore extent of the cold water event off Pt Macdonnell, although offshore the event appears to be restricted to a region 10-30 miles in longshore extent.

(b) The possible connection in time and space of the sparsely documented cold water events off 37°S (Fig. 6) and off Warrnambool, with those off Pt Macdonnell.

<u>Nutrient enrichment</u>

Figure 2 indicates that surface nitrates increased to a maximum of 2.8 µgat/l during the pronounced temperature decreases in January and February 1976. Whilst comparable with that observed off NE Victoria (Rochford 1977) at similar surface temperatures, it is much less than nitrate values during upwelling off the north coast of NSW (Rochford 1972, 1975).

The biological consequences of this enrichment off Pt Macdonnell could be expected therefore to be less than off northern NSW.

In coastal waters of the southern margin of Australia, it is probable that any enrichment process dependent upon vertical transfer of offshore waters from depths shallower than 200 m will not greatly increase the surface nutrients beyond 2.5-3.0 µgat/l. This is because of a suspected annual convective overturn to depths of at least 200 m in these offshore waters (Rochford 1977). This does not permit the accumulation of nutrients in the upper 200 m column to nearly the same extent as in the Coral Sea, which ultimately provides the upwelled water off northern NSW.

4. *METEOROLOGICAL CONDITIONS*

Winds to the west and north west would induce an Ekman drift offshore in the vicinity of Cape Northumberland (Fig. 1). Such winds comprised 37% of all winds in January, 67% in February, 43% in March but only 16% in April 1976 (Data supplied by Bureau of Meteorology, Melbourne). Figure 8 prepared from these same wind data shows the relationship between the wind vectors and the periods A - C (Fig. 3) when cold water events were recorded. In general these cold water events occurred during or soon after a period of sustained winds to the north west. The exception appears to be the event A^1.

Moreover winds to the south and south east which would induce, if anything, surface drifts onshore, were quite infrequent in January-March but common in April (Fig. 8) when no cold water events were observed.

5. *DISCUSSION AND CONCLUSIONS*

Bye (1970) has shown that the "Flinders" current flows past Cape Northumberland to the north west in summer (November-December onwards) of each year, where Bye claims it is strengthened by the predominant winds to the north west and by upwelling near the coast.

This paper shows that abnormally cold water does occur off the Victorian and South Australian coastlines around Cape Northumberland in support of Bye's claim about upwelling. However it has not shown conclusively that upwelling is responsible at all times for this cold water event, nor has it been able to show a clear association in time on all occasions between winds to the north west and the onset of a cold water event. In other upwelling areas around Australia (e.g. Rochford 1972, 1975, 1977) it is thought that certain features of the local bottom topography, particularly indentations towards the coast, may be important in the final stages of the upwelling process.

However off the Cape Northumberland area there is no indication of such a feature in the bottom relief (Fig. 1).

In summary therefore it seems that, although the causal steps cannot be shown in detail, the following features of the region must be of major importance in the time and place of this cold water occurrence.

(a) During January to March the existence of a longshore current to the NW, the "Flinders" current, causes a general upward tilt of the density structure towards the coast.

(b) During January to March the prevalence of a wind to the NW induces an Ekman surface drift away from the coast, and facilitates an ingress of cold subsurface waters, into the surface layer.

(c) During January to March, there is an almost complete absence of winds to the S and SE which would cause an onshore Ekman drift and oppose upwelling.

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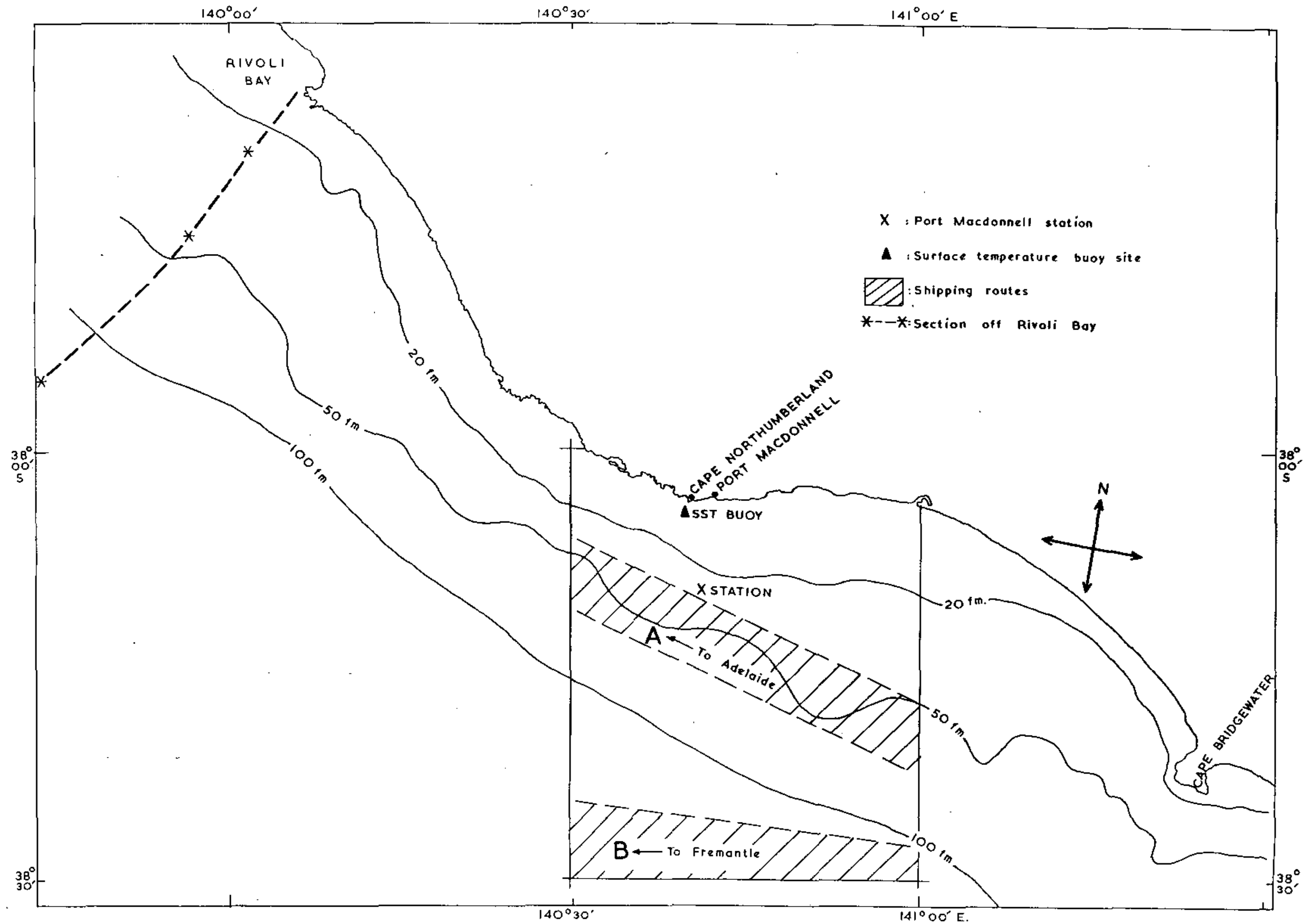

Fig. 1. Chart showing the location of the sampling sites, and general features of the bottom topography in the Cape Northumberland coastal region of South Australia.

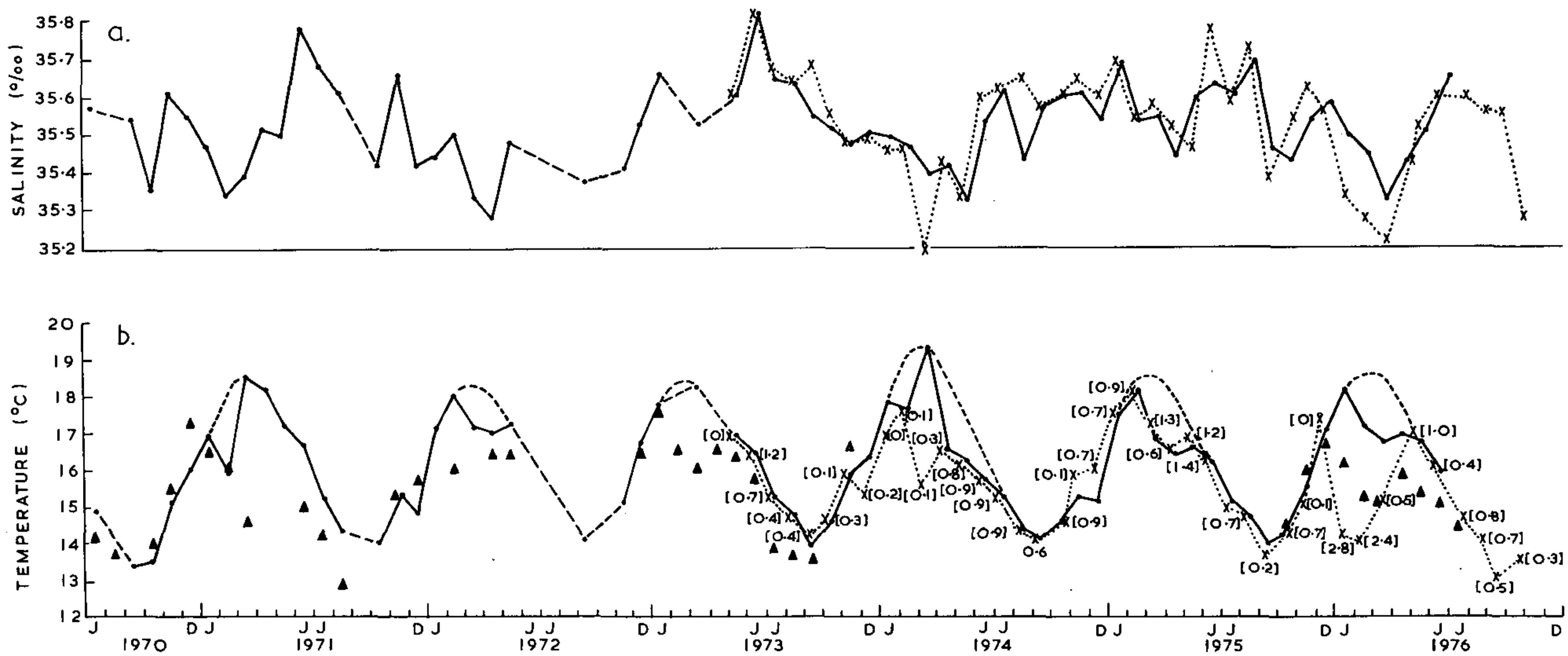

Fig. 2. Changes with time in the surface water characteristics (a) Salinity (b) Temperatures (Nitrates μgat/1 as bracketed values) of:

(●) Steamer observations as monthly averages within the square 38°- 38°30'S, 140°30'-141°E (V Fig. 1).

(X) Pt Macdonnell station (V Fig. 1).

(▲) Cape Northumberland buoy (V Fig. 1).

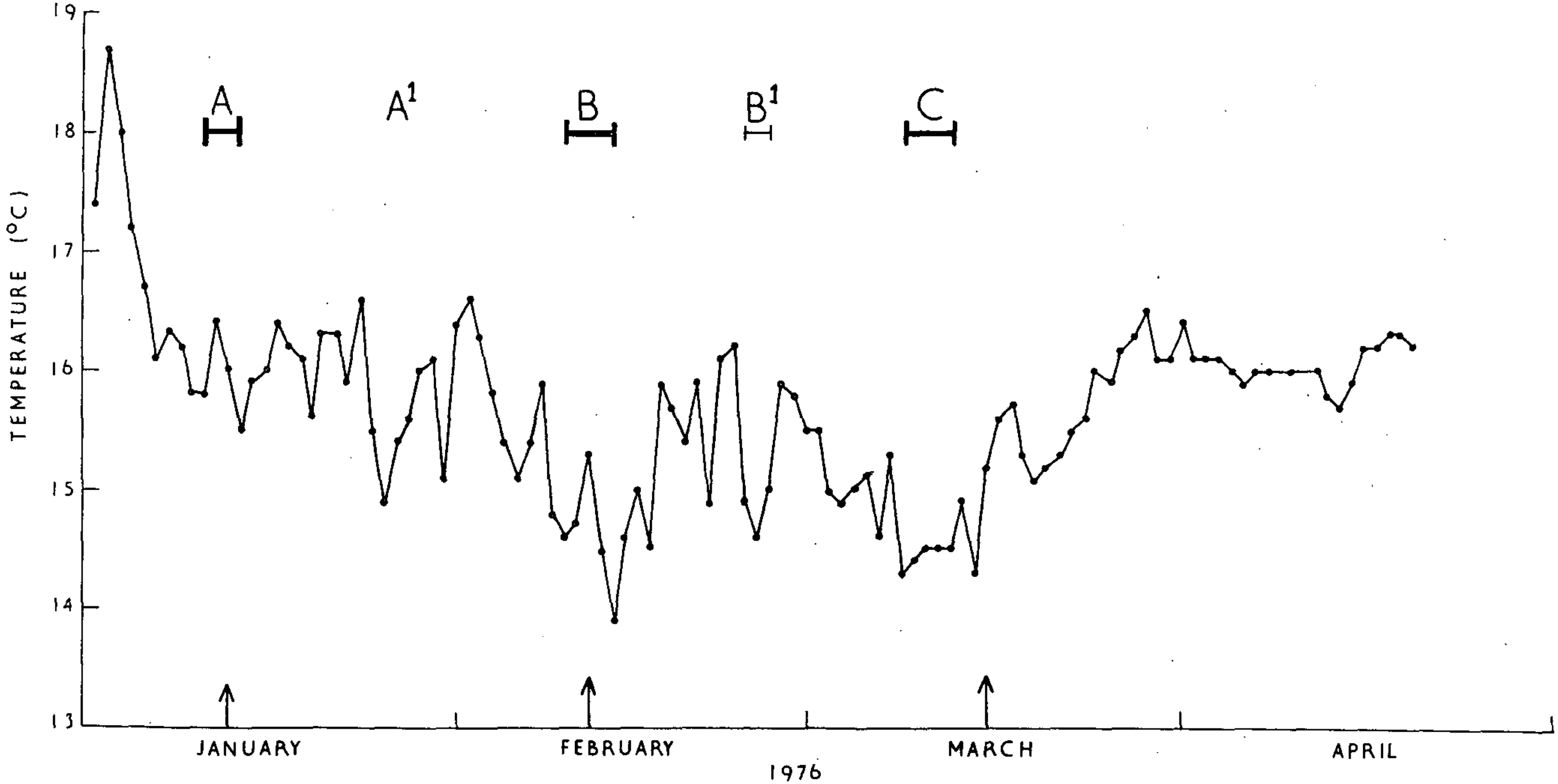

Fig. 3. Daily (mean sunrise-sunset values) sea surface temperatures observed at the Cape Northumberland buoy site (Fig. 1) during January-April

Cold water events at Pt Macdonnell station. Intervals A-C indicate periods of substantial temperature decrease.

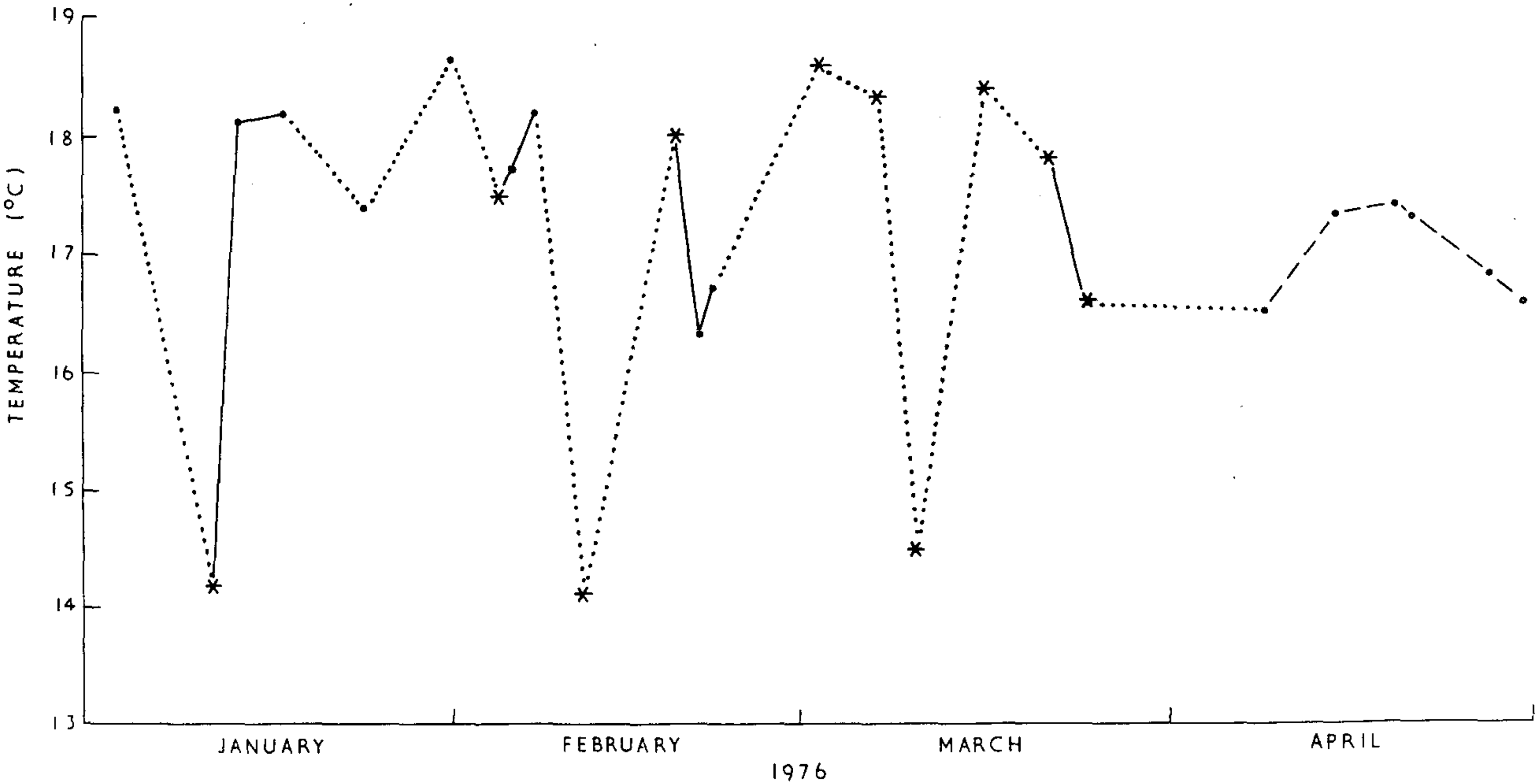

Fig. 4. Sea surface temperatures observed along the steamer route to and from Adelaide (Fig. 1) during January-April 1976.
* Values observed within the longitude band 140°40'-140°50'E.

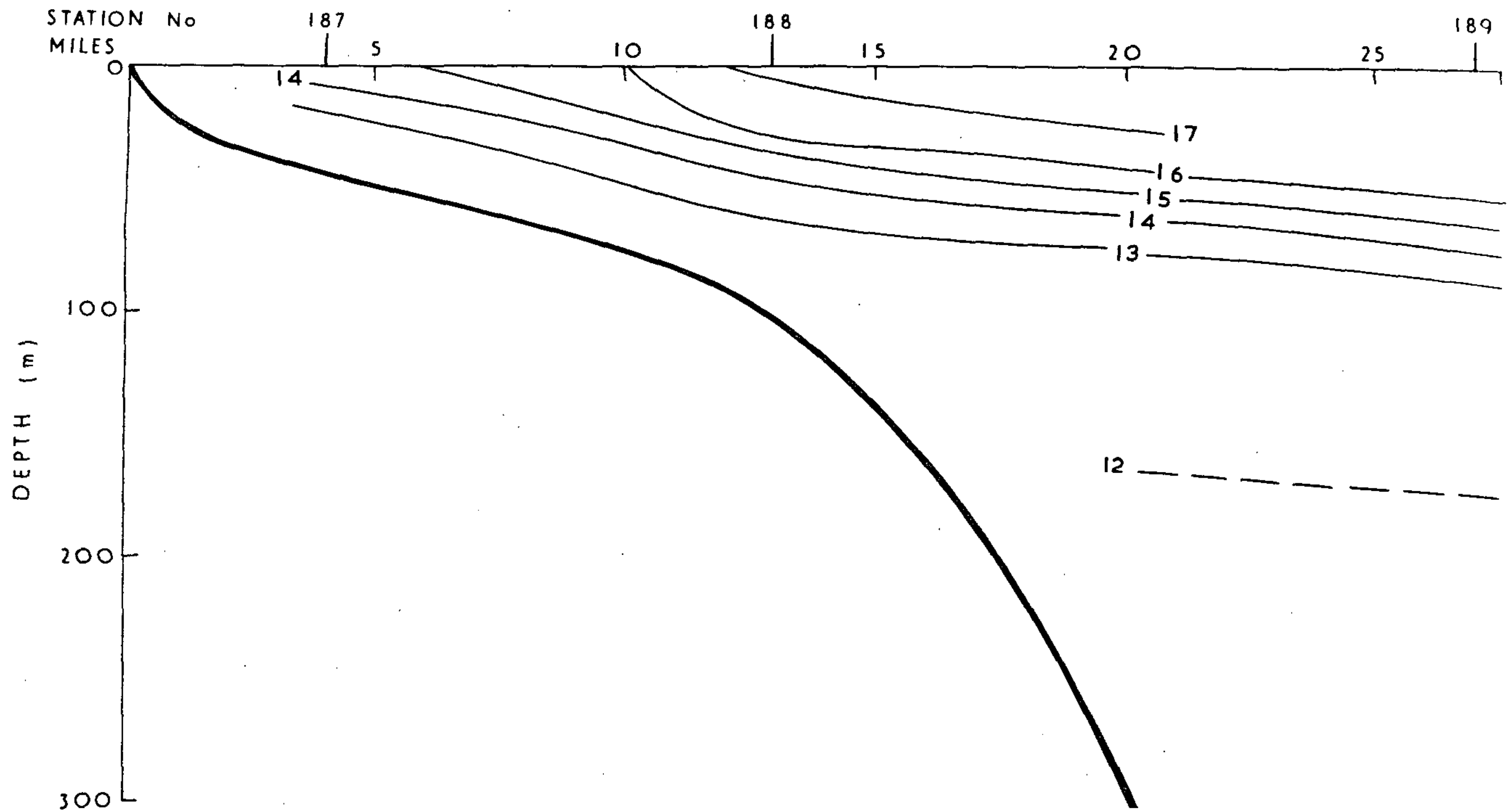

Fig. 5. The temperature distribution along a section off Rivoli Bay, S.A. (Fig. 1) on the 12/3/'61.

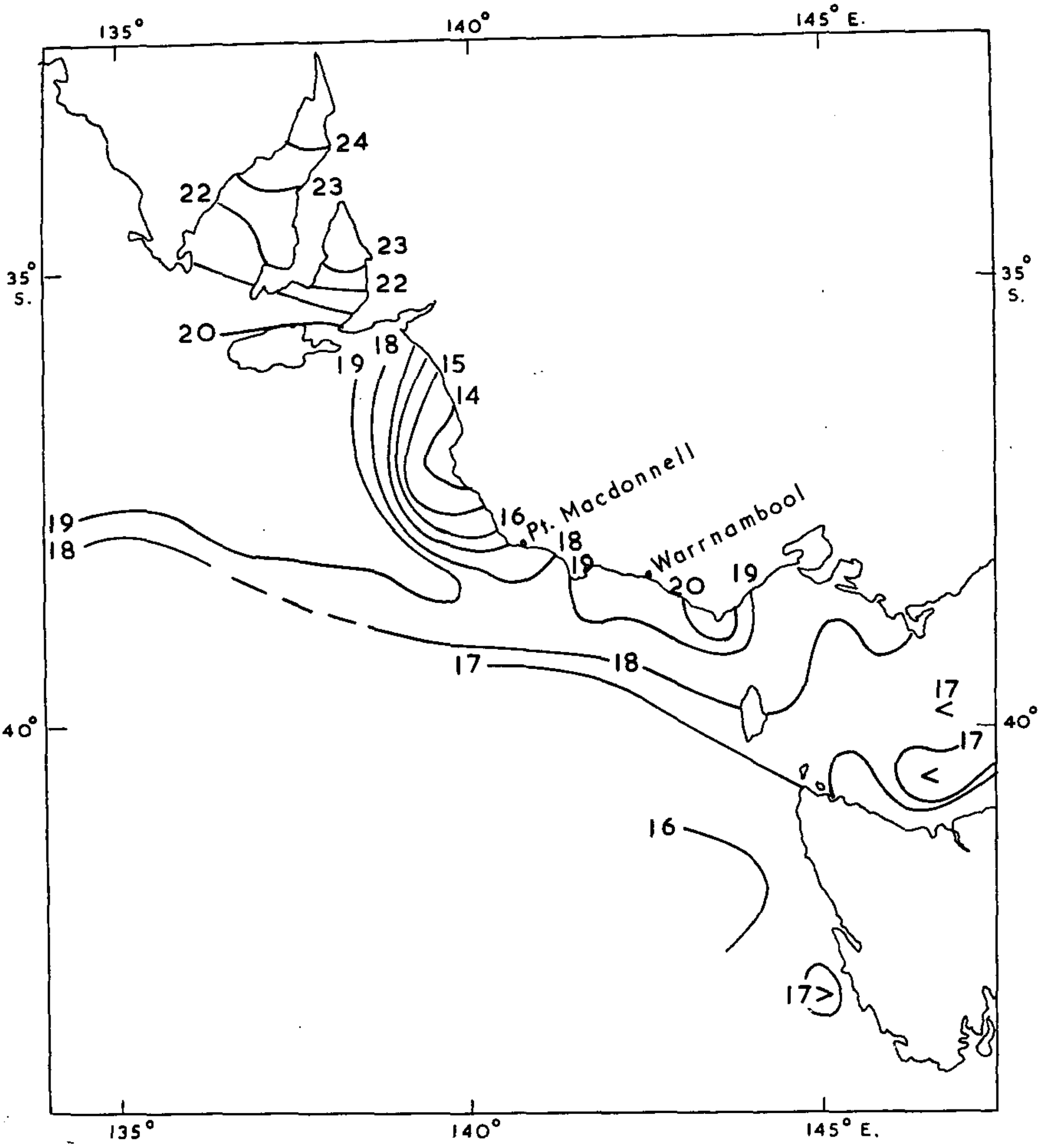

Fig. 6. The mean surface temperature pattern for January 1974 based upon steamer observations on routes to and from Adelaide and to and from Fremantle through Bass Strait.

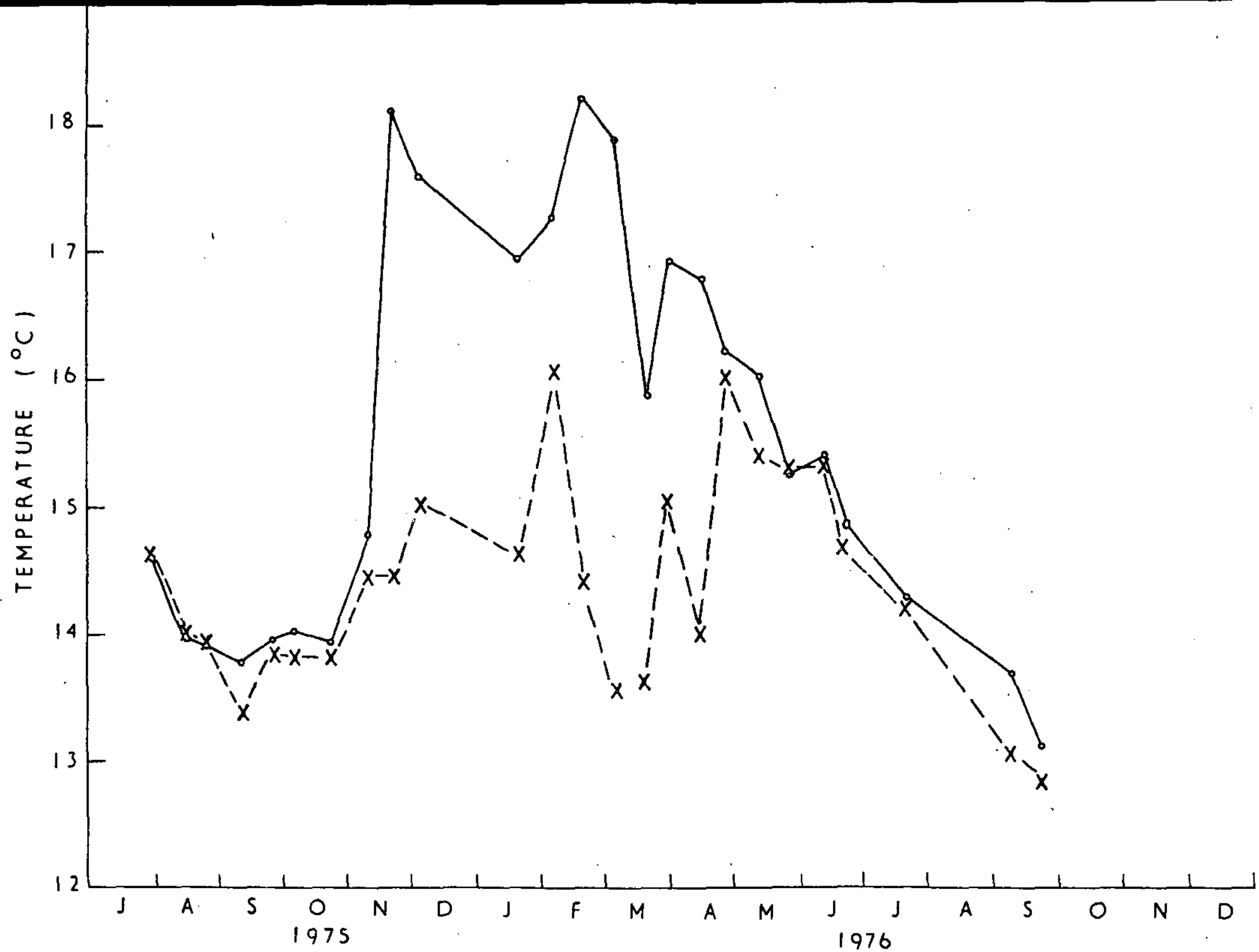

Fig. 7. The surface (•) and 50 m (X) values of sea temperatures at the Warrnambool station (Fig. 6 for location) July 1975-September 1976.

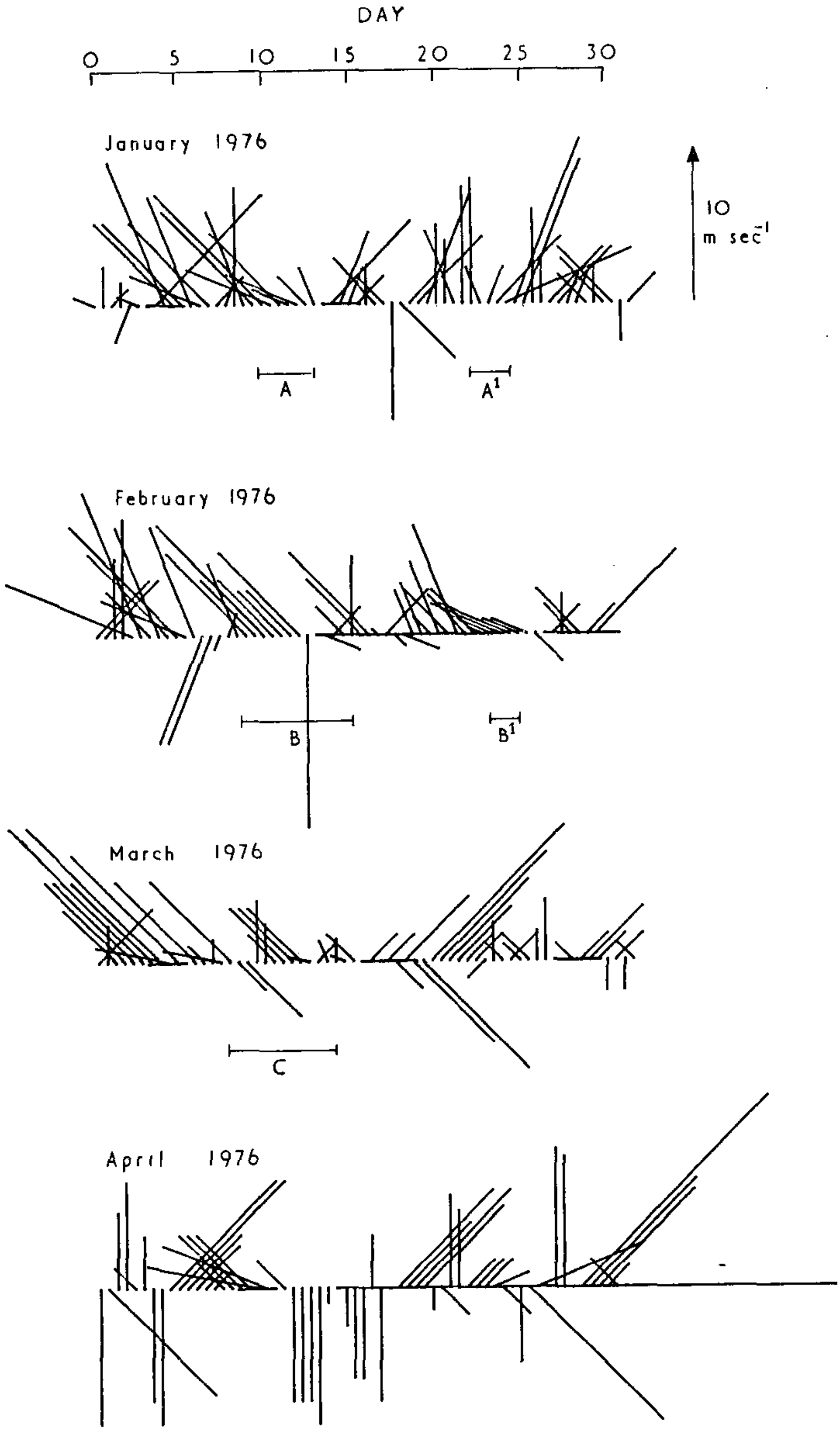

Fig. 8. Daily wind vectors (0900 and 1500 hr values) at Cape Northumberland during January-April 1976.

(|—|) Periods of substantial temperature decrease (Fig.3).