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Resources of the Sea

THE PHYSICAL SETTING

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(with 13 text-figures)

ABSTRACT

The summer and winter temperatures, phosphates, dynamic heights and water masses, of Tasmanian surface waters have been charted. Differences in the characteristics of coastal and offshore waters and of the contribution of upwelling, convective overturn and cyclonic eddies to the surface phosphate concentrations are examined. It is concluded that limited entry of surface sub-Antarctic waters, in combination with a prevalence of sub-tropical waters, maintains nutrient concentrations in Tasmanian surface waters at levels only marginally richer than Australian ocean waters in general.

INTRODUCTION

Southern Tasmania because of its latitude (43-44^{o}S) could be thought to obtrude into the same fertile sub-Antarctic waters as southern New Zealand and contain somewhat similar marine resources. However the opposite viewpoint, that Tasmania is wholly dominated by sub-tropical waters largely originating within an extension of the East Australian Current, is not uncommon. This paper examines a selection of the available data to determine the basic physical characteristics of Tasmanian marine waters and of their water mass origins and chemical fertility status. Such information permits a better comparison of Tasmanian marine waters with those from other parts of Australia and from neighbouring countries.

DATA - METHODS

The following published CSIRO cruise data have been used in the preparation of figures in the section on the Oceanic Environment.

Summer (January - March) OCR 8 (CSIRO - 1963b); OCR 10 (CSIRO - 1966); OCR 32 (CSIRO - 1967c); OCR 35 (CSIRO - 1967d); OCR 45 (CSIRO - 1969).

Winter (August - October) OCR 19 (CSIRO - 1967a); OCR 29 (CSIRO - 1967b); OCR 39 (CSIRO - 1967e); OCR 42 (CSIRO - 1968b).

In the contouring of summer data the February values have been given maximum weight, and in the contouring of winter data the August values have been given maximum weight.

The published Maria Is. station data used in the preparation of figures in sections on the Coastal Environment and Enrichment processes are contained in:

OSL 4 (CSIRO - 1951); OSL 14 (CSIRO - 1953a); OSL 17 (CSIRO - 1953b); OSL 18 (CSIRO - 1954); OSL 24 (CSIRO - 1956); OSL 27 (CSIRO - 1957a); OSL 30 (CSIRO - 1957b); OSL 33 (CSIRO - 1958); OSL 40 (CSIRO - 1960a); OSL 45 (CSIRO - 1960b); OSL 51 (CSIRO - 1963a); OSL 88 (CSIRO - 1968a).

All data since 1968 have been deposited with World Data Centres A and B.

Figure 1 shows the density of CSIRO stations in the Tasmanian region, used in this paper. It is evident that west and south of Tasmania the density is wholly inadequate. Data from foreign oceanographic expeditions into the region e.g. *Eltanin* are either outside of the two seasons considered or are too old in respect of compatibility with the modern situation.

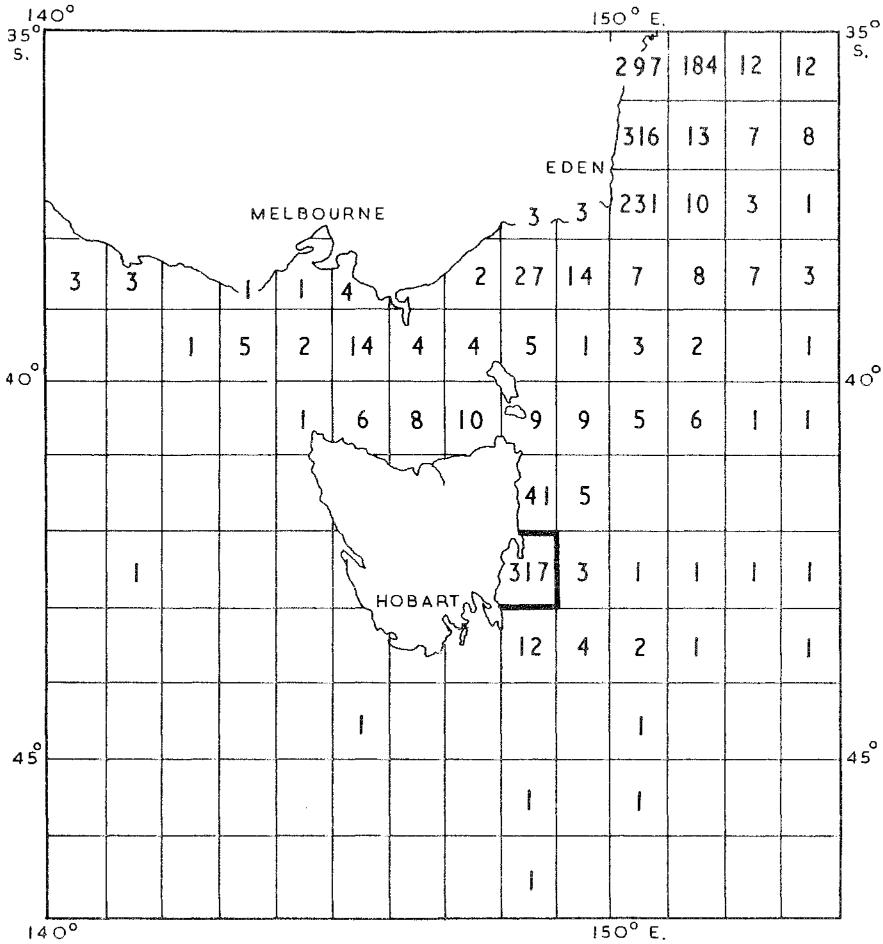

FIG. 1.- CSIRO Subsurface oceanographical stations occupied during 1960 - 1973.

THE OCEANIC ENVIRONMENT

Surface Temperature

(i) Summer (fig. 2).

Warm waters (20-21°C) drift southward across eastern Bass Strait and maintain warmer (2°C) temperatures along the eastern relative to western sides of Tasmania. Intrusions northward of cold waters occur off south-east Tasmania and complicate the surface temperature pattern. However the data are inadequate to decide how regularly these intrusions occur every summer.

(ii) Winter (fig. 3).
The southward drift of warm waters (>15°C) has a limited effect on water temperatures south of 39°S. Warm water accumulation in the eastern approaches of Bass Strait could be a result of this warm water drift. Without knowledge of winter temperatures off the west coast of Tasmania however it is not possible to decide the extent of this drift, southward of 40°S. The north-eastern and northern coastal waters of Tasmania are colder in winter than waters to the east and north respectively.

Surface circulation
(i) Summer (fig. 4). The circulation is dominated by two large anticyclonic eddies, one off southern N.S.W. the other off S.E. Tasmania. The dynamic height contours indicate large (2-3 knot) peripheral velocities associated with the northern but quite small with the southern eddy. These eddies are breakaways from the general curvature of the East Australian Current to the east around 34°S (Boland and Hamon 1970). They provide the mechanism for the slow drift southward (miles per day) of East Australian Current water in summer.

The low temperature intrusion off S.E. Tasmania is associated with the northward drift of small cyclonic eddies. It is not known however whether these cyclonic eddies are a regular feature of the summer circulation pattern. Off western Tasmania the very limited data show a general northward drift. This drift forms part of the Flinders Current (Bye 1972) and is the eastern boundary current for an anticyclonic gyre covering the region south of Australia to around 45°S.

In summer the dynamic contours show that East Australian Current waters move westward into eastern Bass Strait. This westward movement extends through Bass Strait (Vaux and Olsen 1961).

(ii) Winter (fig. 5). The circulation is dominated by two large cyclonic eddies off eastern Tasmania and southern N.S.W. The spacing of the dynamic contours indicates however that the peripheral velocities of these eddies would be small.

These cyclonic eddies carry within their central core colder nutrient richer southern waters and are important in the nutrient economy of the region. Unfortunately the data are too limited, particularly off eastern Tasmania, to show dynamic features of the cyclonic eddy. Moreover it is not known how regularly these eddies move through the region in every winter.

Surface Phosphates
(i) Summer (fig. 6). The surface waters of the whole S.W. Tasman Sea and Bass Strait are all very low (0.1 - 0.2 μg-at./1.) in phosphates. The only exceptions occur with the northward intrusion of cold water off S.E. Tasmania.

In general the waters off the west coast of Tasmania have higher, but only marginally greater (0.3 - 0.4 μg-at./1.) values of surface phosphates.

(ii) Winter (fig. 7). Surface phosphates in general are higher in winter (0.3 - 0.4 g-at./1.) than summer. However the S.W. Bass Strait waters have much the same phosphate concentration in winter as summer.

The quite high values (0.8 μg-at./1.) off S.E. Tasmania are associated with the very cold core water of a cyclonic eddy. Drift northward of these eddies carries these phosphate richer waters to at least 40°S.

Surface water masses
(i) Summer. The movement and intermixing of three water masses maintain the surface characteristics of the region in summer (fig. 8). These are:
(a) The water mass complex carried southward by the East Australian Current and

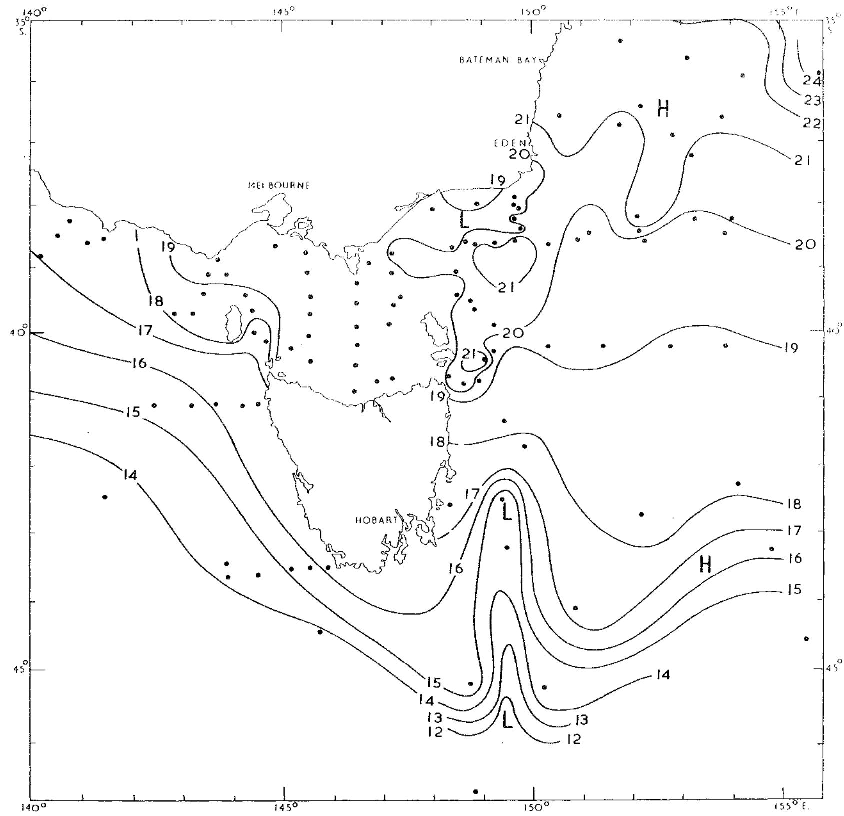

FIG. 2. - The surface temperatures (°C) in summer. H and L refer to high and low dynamic height centres (fig. 4).

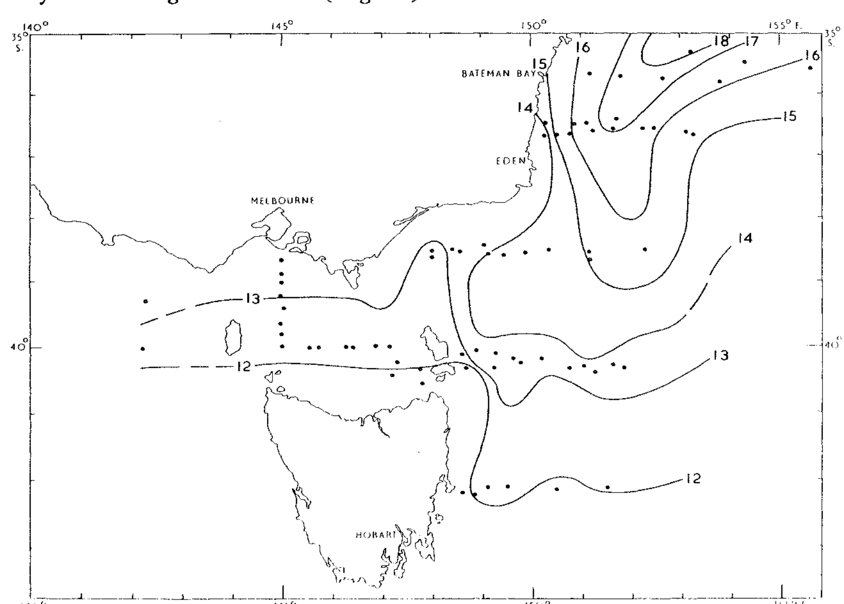

FIG. 3. - The surface temperatures (°C) in winter.

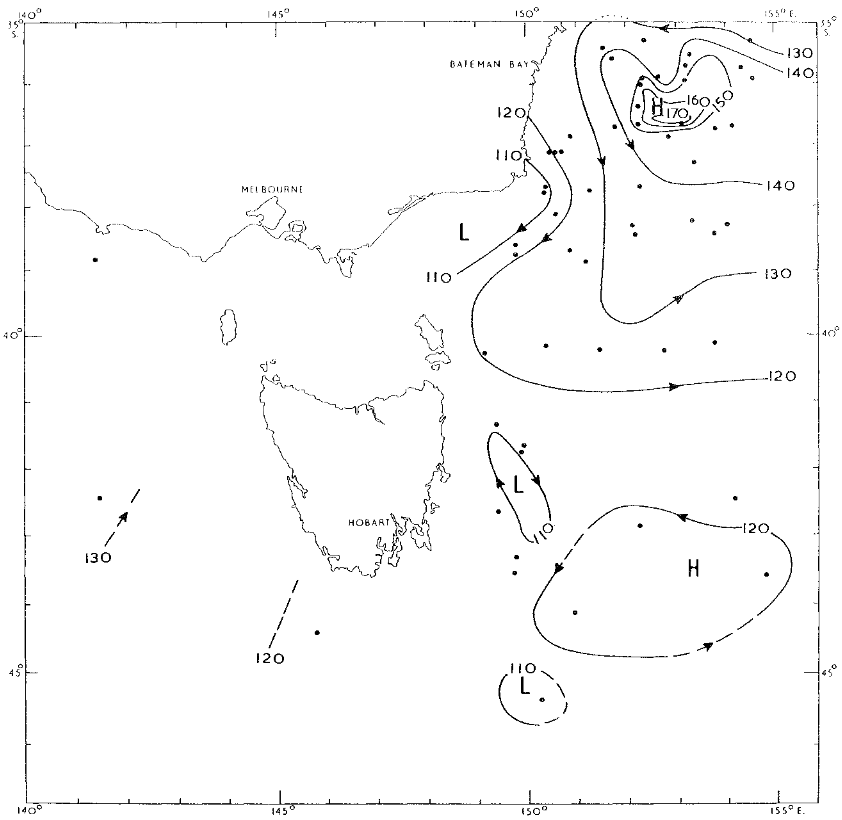

FIG. 4. - Dynamic heights ($^{\circ}/1000$) in dyn. cm in summer.
H and L centres of high and low dynamic height.

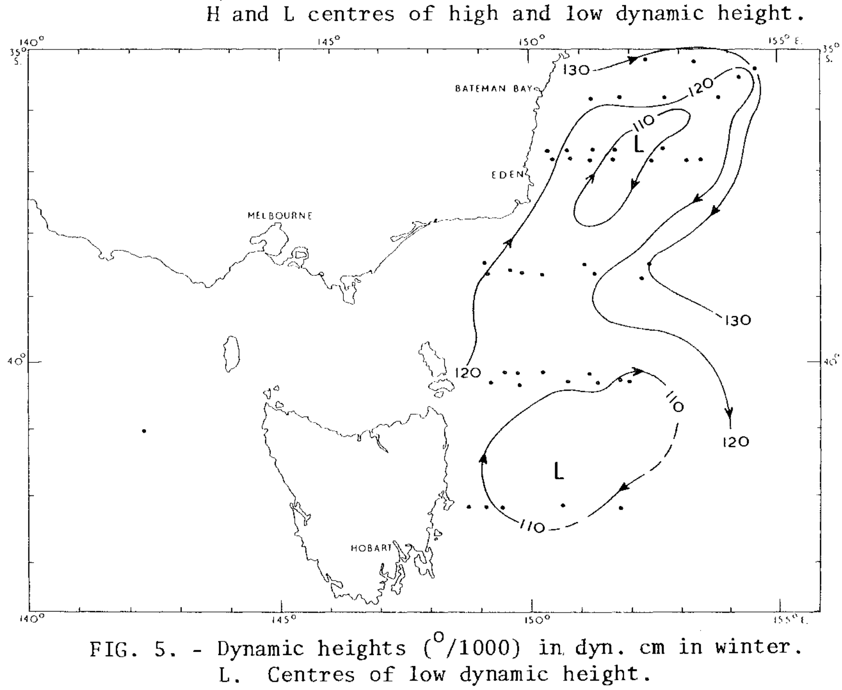

FIG. 5. - Dynamic heights ($^{\circ}/1000$) in dyn. cm in winter.
L. Centres of low dynamic height.

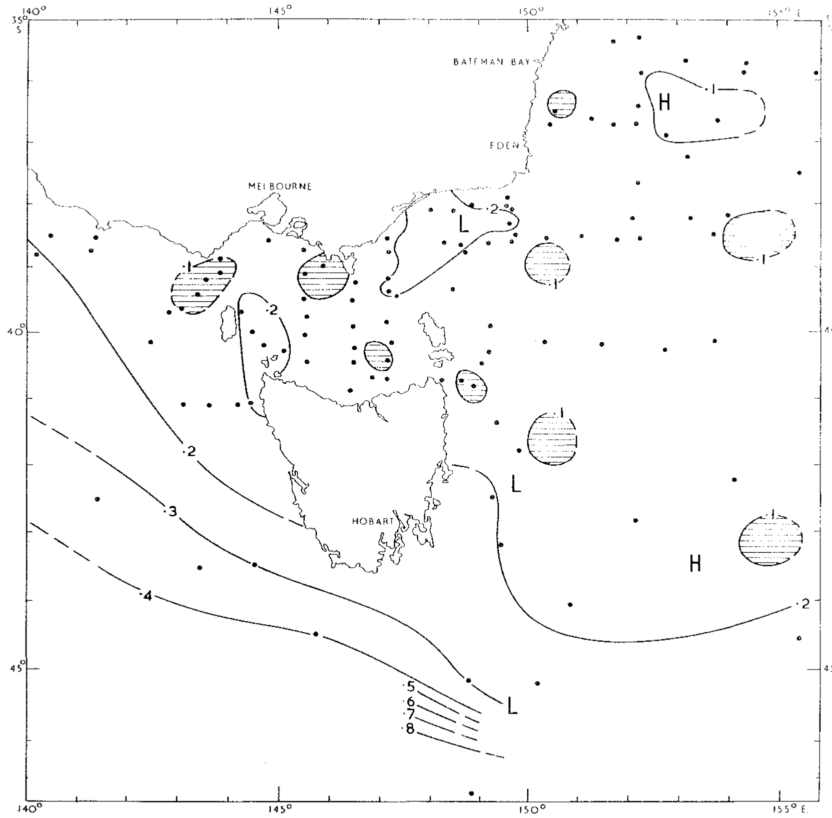

FIG. 6. - The surface inorganic phosphates (μg-at./1.) in summer. H and L centres of high and low dynamic height.

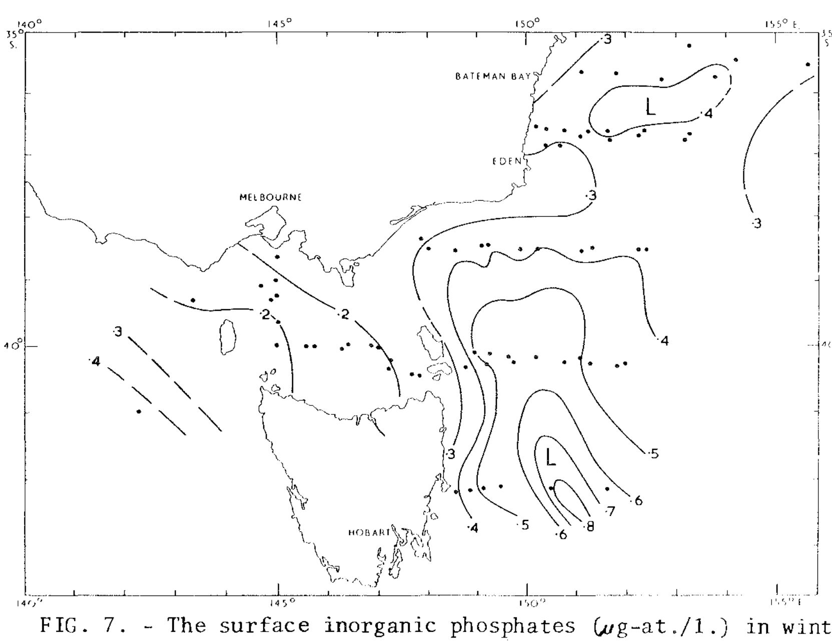

FIG. 7. - The surface inorganic phosphates (μg-at./1.) in winter. L. Centres of low dynamic height.

called East Australian Current water.

(b) The high salinity water carried westward and southward into the Tasman Sea from the Central South Pacific. This has been referred to as Central Tasman.

(c) The low temperature water carried northward into the southern part of the region having as its ultimate origin the surface sub-Antarctic waters south of the Sub-tropical Convergence (45-46°S). This has been referred to as Sub-Antarctic water.

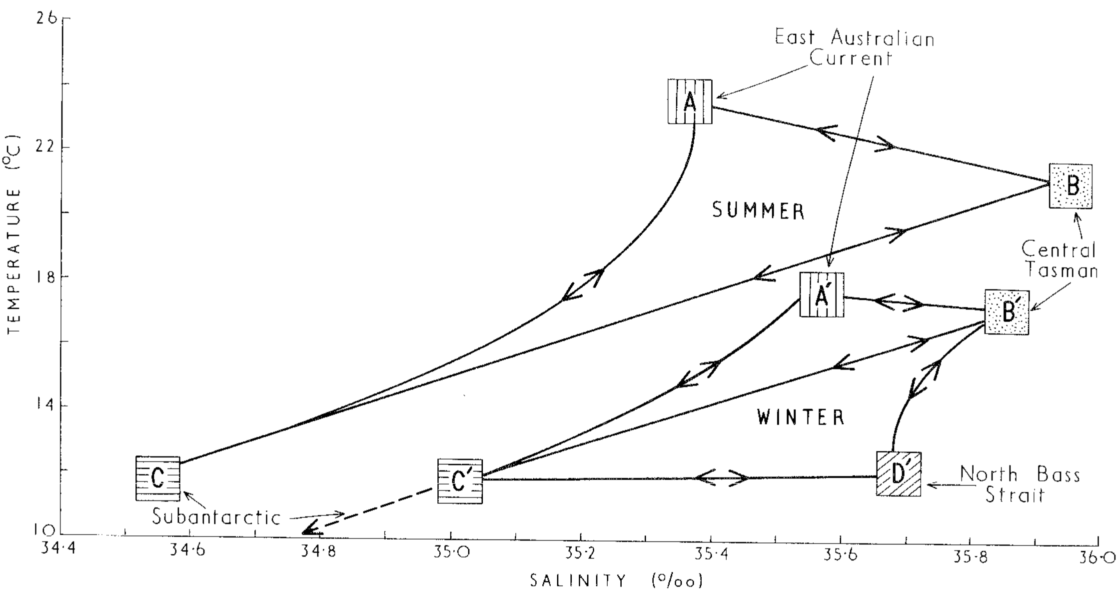

FIG. 8. - The surface water masses and their S°/oo.-Temperature relationships in summer and winter.

The regions of entry of these three water masses and of the distribution of various mixtures between them during summer are summarized in figure 9. As they move into the area these water masses, because of different densities, sink beneath each other with the Sub-Antarctic at the deepest level. The distribution of these water mass mixtures is in conformity with the surface currents (fig. 4) with mixtures of the northern water masses predominantly to around 40°S, and of the colder water mass mainly with the Central Tasman water mass, southward again. Off western Tasmania the water mass composition indicates that the same waters occur there as off the east coast, showing that westward flow southward off Tasmania must occur although the dynamic contours (fig. 4) were inadequate to show it.

In northern Bass Strait the water mass composition shows clearly the westward drift of water mass mixtures originating largely in the northern Tasman Sea. The inclusion of some cold sub-Antarctic waters in this mixture is attributable to upwelling or vertical mixing of this water mass into the westward flow at the eastern approach to Bass Strait (fig. 9). The effect of this upwelling-mixing on the general nutrient economy of Bass Strait is however very limited (fig. 6).

(ii) Winter. The same three water masses, cooled and varied slightly in salinity by air sea exchange, maintain the surface characteristics of the S.W. Tasman Sea in winter as in summer (fig. 8). However to the north-west of Tasmania and within Bass Strait the water characteristics indicate another water mass called North Bass Strait water (fig. 8) which drifts eastward along the Victorian coast (fig. 10). Its origin

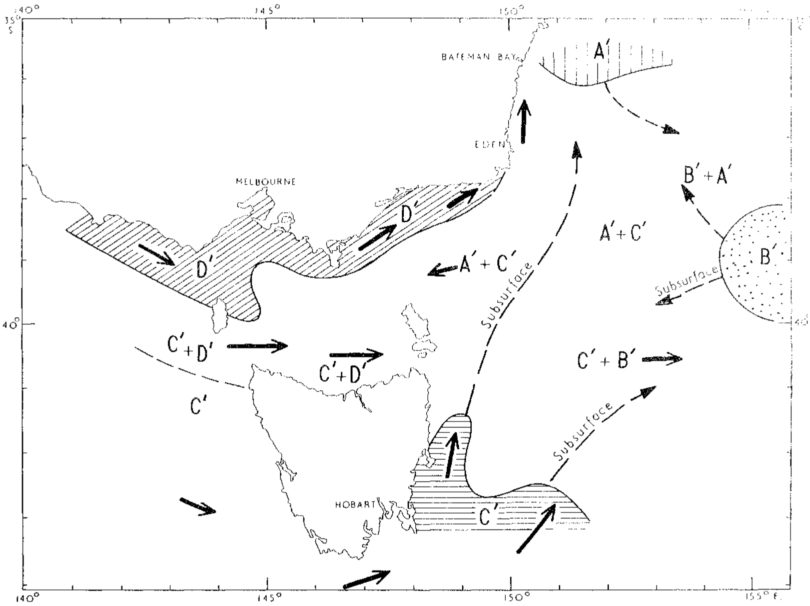

FIG. 9. - The surface water masses (fig. 8) and their mixtures in summer. Principal surface movements - solid, larger arrows. Principal subsurface drifts - smaller arrows and dashed lines.

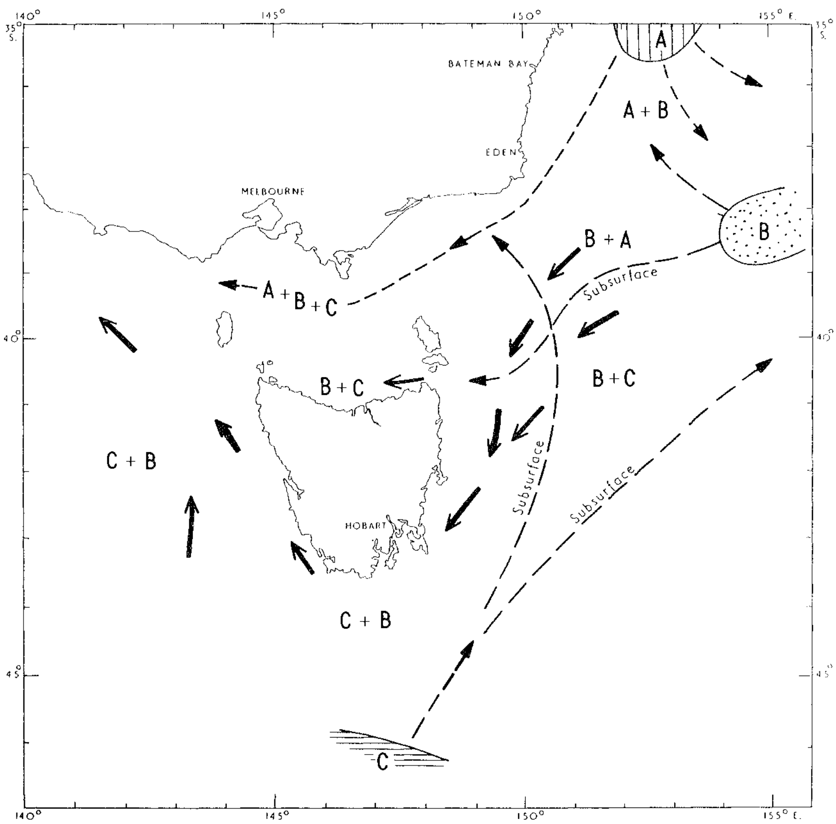

FIG. 10. - The surface water masses (fig. 8) and their mixtures in winter.

is still in doubt although all the evidence indicates its ultimate origin in the Gulfs of South Australia. Drift card results support this eastward drift (Vaux and Olsen 1961). The colder waters to the north of Tasmania in winter (fig. 3) are associated with mixtures of Sub-Antarctic and North Bass Strait water masses. However the content of the former is quite small judging by the insignificant effect upon phosphate concentrations (fig. 7). Perhaps the local contribution by cooling and riverine dilution of these waters is more important than advection in the maintenance of their winter characteristics.

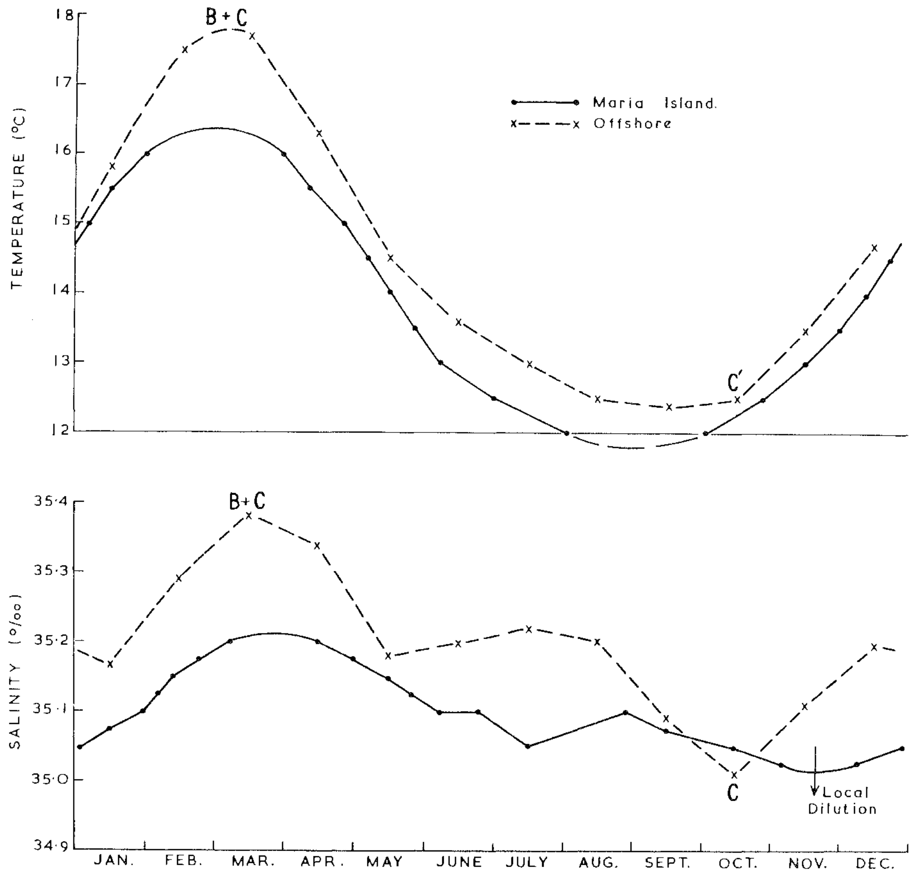

FIG. 11. - The mean annual curves of surface temperature and salinity off Maria Is. (42°36'S, 148°16'E) (1945-1972) and some 30 miles (48 km) off shore (1966-1973).

THE COASTAL ENVIRONMENT

Figure 11 shows that nearshore waters off Maria Is. have lower temperatures and salinities for most of the year than those some 30 miles further east. This is typical of most of the coastal water environment around Tasmania which is formed from the same water mass mixtures as offshore (figs. 9 and 10) but modified at all times by an accumulation of riverine waters which in general are colder than the open ocean water masses.

Nutrient contribution by these riverine waters does not appear to be important in the overall nutrient status of Tasmanian coastal waters.

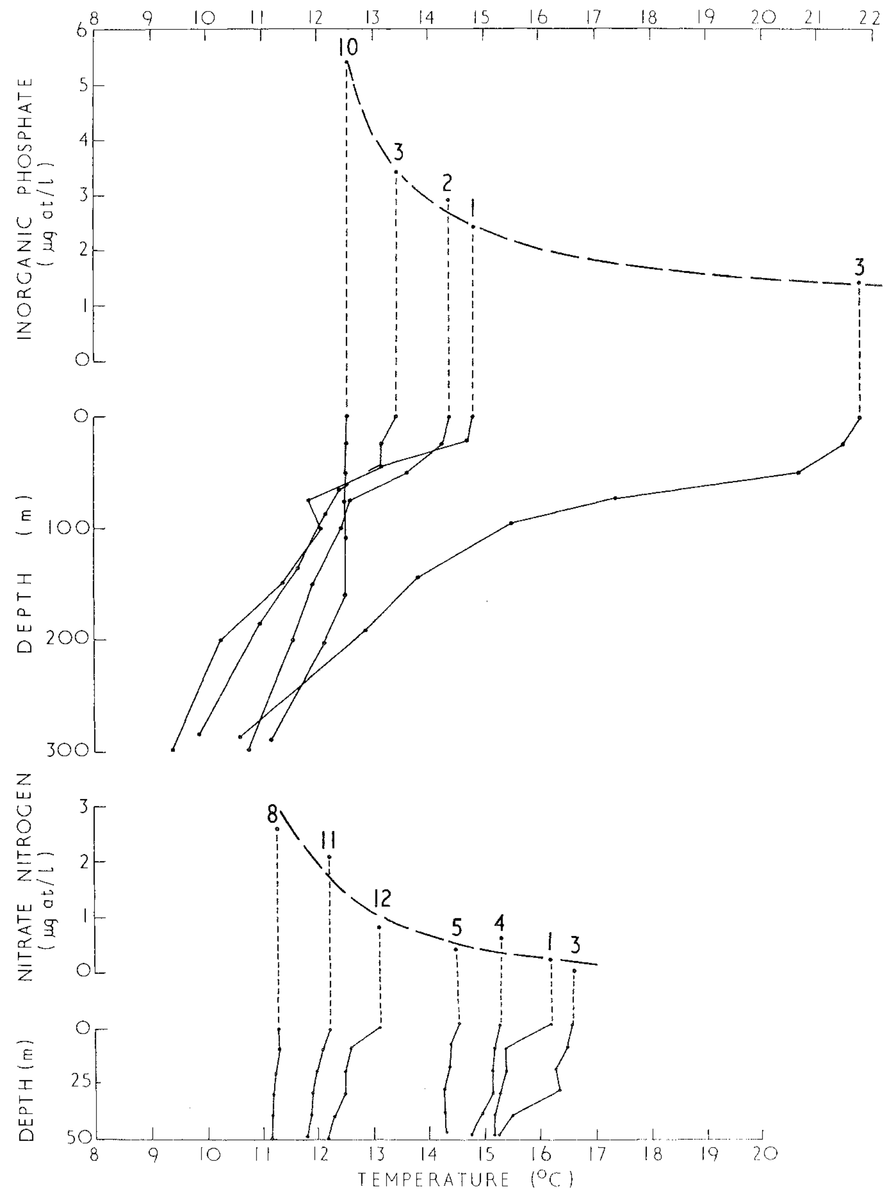

FIG. 12. - Vertical profiles of temperature (side scale for depth, top scale for temperature) in relation to phosphate and nitrate surface values (upper side scale) at Maria Is. station (bottom) and a deep station offshore (top).

ENRICHMENT PROCESSES

There is no evidence that upwelling or even large scale bottom intrusion of nutrient rich water, into the coastal region occurs around Tasmania. In coastal and deep offshore waters east of Maria Is. a spring increase in nutrients is largely a function of the extent of deep mixing, brought about by convective overturn (fig. 12). Offshore the surface nutrient increase is greater because of the much deeper mixing without the constraint of limited depth onshore. The maximum surface nutrient enrichment of Tasmanian surface waters, however is associated with the dynamic uplift of deep nutrient rich water within the core structure of cyclonic eddies (fig. 5). In winter also there is less penetration southward of the nutrient impoverished East Australian Current water and more introduction of the nutrient rich Sub-Antarctic water, increasing the surface phosphates generally.

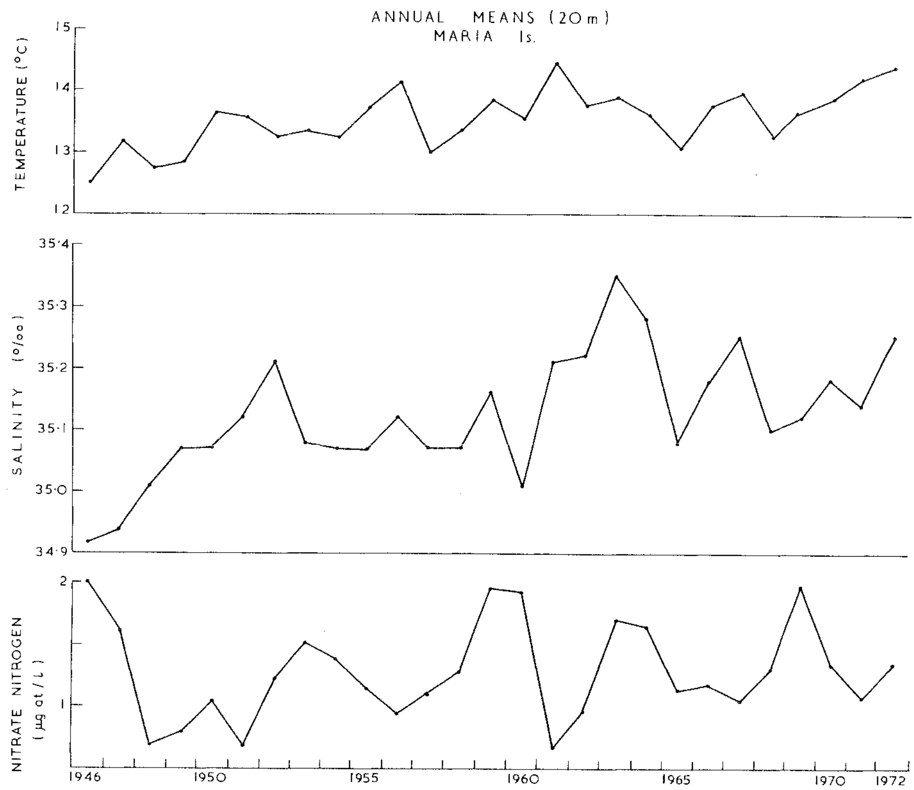

FIG. 13. - The long term trends in mean annual values of 20 m Temperature (°C) and Salinity (°/oo) at the Maria Is. station, 1946 to 1972.

DISCUSSION - CONCLUSIONS

The paucity of oceanographical data around Tasmania permits only very tentative and generalized conclusions about seasonal changes in circulation, water mass composition and chemical fertility of its marine waters. The data are inadequate for example, to examine time changes of the order of months to days. Moreover at the Maria Is. monitoring station (lat. 42°36'S long. 148°16'E), 27 year changes in mean annual temperature, salinity and nitrate nitrogen at 20 m (fig. 13) show that cycles of several years have been superimposed upon a long term trend of greater than a 27 year period. Temperatures and salinities have increased during this long term trend but nitrates exhibited only a slight trend towards higher values. The cause of such a trend could be complex, involving changes in weather patterns coupling with circulation of different water masses, thereby causing changes in the local Maria Is. rainfall, and air temperatures which accentuated or decreased the magnitude of the trend. It is unwise therefore to overgeneralize about the permanent features of the Tasmanian marine physical environment on the basis of presently available data.

However it is unlikely that vastly increased data in the future will negate the following conclusions:

(a) Tasmanian waters generally, especially in summer off East Tasmania, are of low chemical fertility status, and enrichment processes such as upwelling are not in evidence.
(b) The contribution of sub-Antarctic waters to the characteristics of surface waters around Tasmania is greater off the west coast than elsewhere. However even there the contribution of tropical sub-tropical water masses is still a predominant feature.
(c) The most promising regions for enhanced productivity are those within the core waters of the winter cyclonic eddies off S.E. Tasmania and perhaps also off S.W. Tasmania.

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