COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

DIVISION of FISHERIES and OCEANOGRAPHY

Report No. 59

DISTRIBUTION OF OCEANIC WATER TYPES OFF SOUTH - EASTERN TASMANIA, 1973

By B. S. Newell

Marine Laboratory
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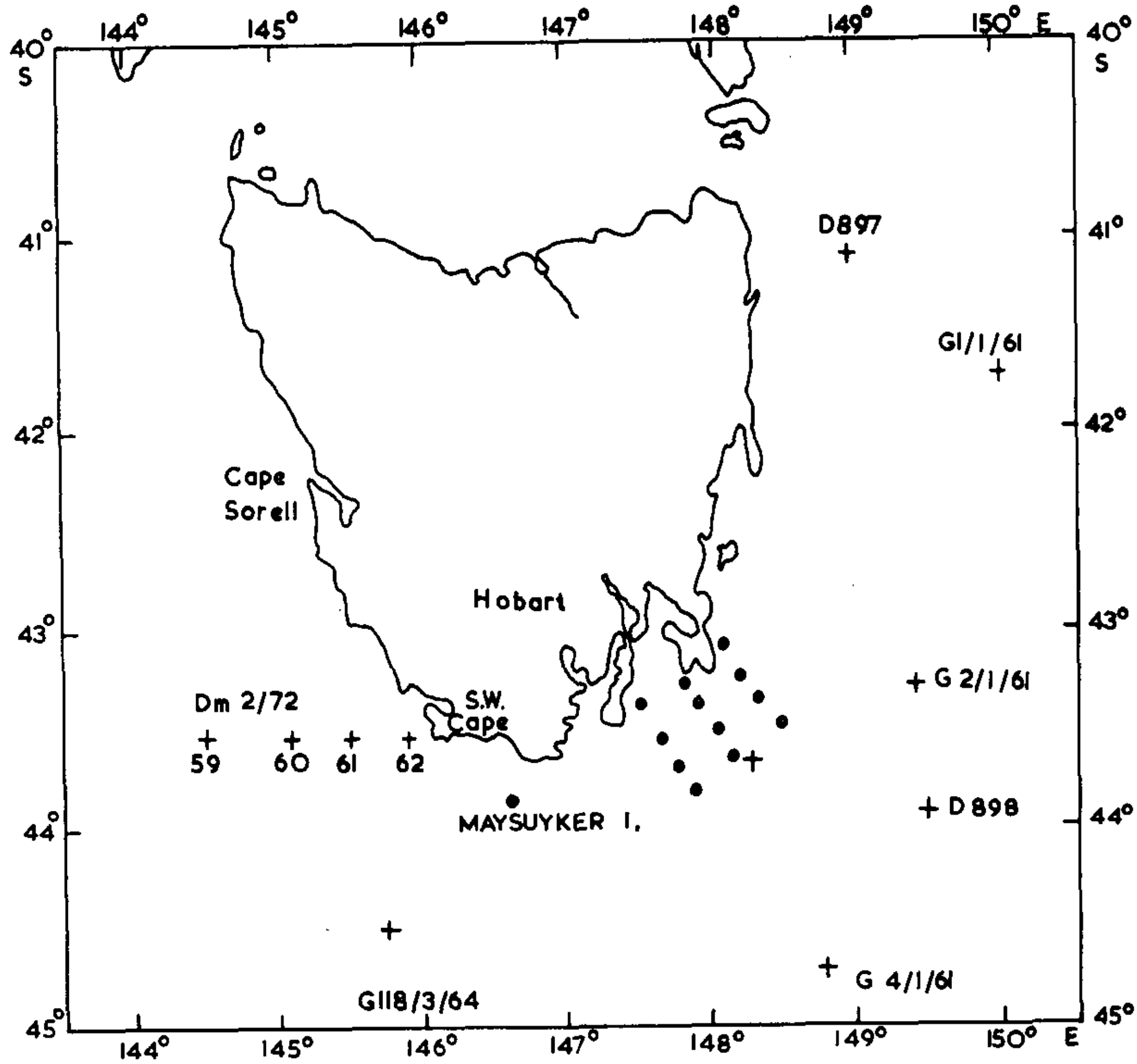

Fig. 1 Positions of stations on surveys conducted in February 1973 (K1/73) and September 1973 (Dm4/73). Also positions of stations 1, 2 and 4 on Cruise G1/61, stations 897 and 898 on Discovery II. 1932, station 118 on Cruise G3/64, stations 59 to 62 on Cruise Dm2/72, and the jarosite dumping site.

DISTRIBUTION OF OCEANIC WATER TYPES OFF SOUTH-EASTERN TASMANIA, 1973

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INTRODUCTION

During 1973, the Australian Government Inter-Departmental Committee on Ocean Dumping considered an application by Electrolytic Zinc Pty Ltd of Risdon, Tasmania, for permission to dump zinc processing wastes in the ocean off Tasmania. A provisional permit was issued to dump these wastes (known by the term "jarosite") at the rate of about 1,000 tons per day, within 5 miles radius of position 43°38'S, 148°18'E. At the same time, it was resolved to conduct oceanographic surveys adjacent to the dumping zone before and after dumping; the conduct of these surveys was undertaken by this Division.

The first survey cruise was carried out in February 1973 using H.M.A.S. *Kimbla*, whilst the second took place in September 1973 from H.M.A.S. *Diamantina*. The customary oceanographic properties (temperature, salinity, dissolved oxygen, nitrate and silicate) were measured at standard depths over a grid of 12 stations on both cruises, and this report discusses the results obtained.

On both cruises, samples were also obtained of the bottom sediment, zooplankton (from surface to 100 m depth) and water and suspended matter at selected depths. These samples are currently being analysed for their content of zinc, lead, mercury and cadmium. A full description of the results obtained, will be published in due course.

Dumping of jarosite commenced on December 6, 1973, so that the two survey cruises carried out should give not only the summer and winter distribution of oceanographic properties, but also the baseline levels of the four pertinent metals in the marine environment prior to dumping.

METHODS

The locations of stations and the dumping site are shown in Fig. 1. Temperatures were measured with standard deep-sea reversing thermometers mounted in Nansen reversing bottles. Salinities were measured with an inductive salinometer (Brown and Hamon 1961).

Dissolved oxygen, nitrate and silicate were measured in samples taken from the Nansen bottles using the methods described in Major *et al.* (1973). Water samples for metals analysis were collected separately in 6-litre plastic canisters (Jitts 1964).

Density (sigma-t) values were calculated from the equations of Knudsen (La Fond 1951).

Depth calculations were made thermometrically by the method of Pollak (1950).

All data used in this report are available as listings from C.S.I.R.O. Cronulla, or the World Oceanographic Data Centres (Washington and Moscow). The February survey is identified as Kimbla Cruise 1/73 and the September survey as Diamantina Cruise 4/73.

RESULTS

(a) Summer (K1/73). The T/S relationships of all samples collected in February are shown in Fig. 2A. Below 200 m depth, the distribution of properties followed the classical sequence for these latitudes of Upper Oxygen Maximum, Antarctic Intermediate Water, Deep Oxygen Minimum and Deep Salinity Maximum. Superimposed on the Kimbla results in Fig. 2A are those from "Discovery" Stations 897 and 898 (o) worked in June 1932 (Discovery Committee 1941) and "Gascoyne" Stations 1, 2 and 4(+) worked in January 1961 (C.S.I.R.O. Aust. 1963). See Fig. 1 for positions. The agreement in distribution of properties with depth is very close.

Above 200 m depth, the distribution of properties was more complex. Some four water types could be detected by T/S characteristics and confirmed by oxygen/nitrate characteristics (see inset in Fig. 2A). These were, firstly, a coastal water of high temperature, high oxygen, low salinity and low nitrate, extending from surface to approximately 100 m depth and outwards to the second station in each section. Seaward of the second station, the water column contained, from surface to about 75 m depth, sub-tropical water of high temperature, high salinity, moderate oxygen and low nitrate content. This water was mixing horizontally with the coastal type giving a fairly even gradient of properties proceeding offshore. Beneath both these water types the stratum from about 100 to 175 m was occupied by subtropical lower water (or the upper oxygen minimum), having the characteristics of high salinity, low temperature, low oxygen and high nitrate. Fig. 2A shows that water of similar properties was present at similar depths at "Discovery" Stations 897 and 898, and also at "Gascoyne" Stations 1, 2 and 4.

Around 100 m depth at the offshore stations, a small intrusion of low salinity, low temperature, high oxygen and high nitrate water appeared. This water type has been called "Sub-Antarctic" since it appeared to have properties akin to those of the near-surface waters south of the Subtropical Convergence, i.e. in the region of the West Wind Drift between latitudes 43^{o} and 50^{o}S. Deacon (1937) gives the T/S characteristics of Sub-Antarctic Water at the Subtropical Convergence as salinity 35.00‰ and temperature 11^{o}C. The water appearing in the *Kimbla* sections does have salinities of 35.00‰ or less but is of higher temperature (ca 13^{o}C). However, Deacon's definition was based on winter values, so that 13^{o}C is not an unduly high temperature

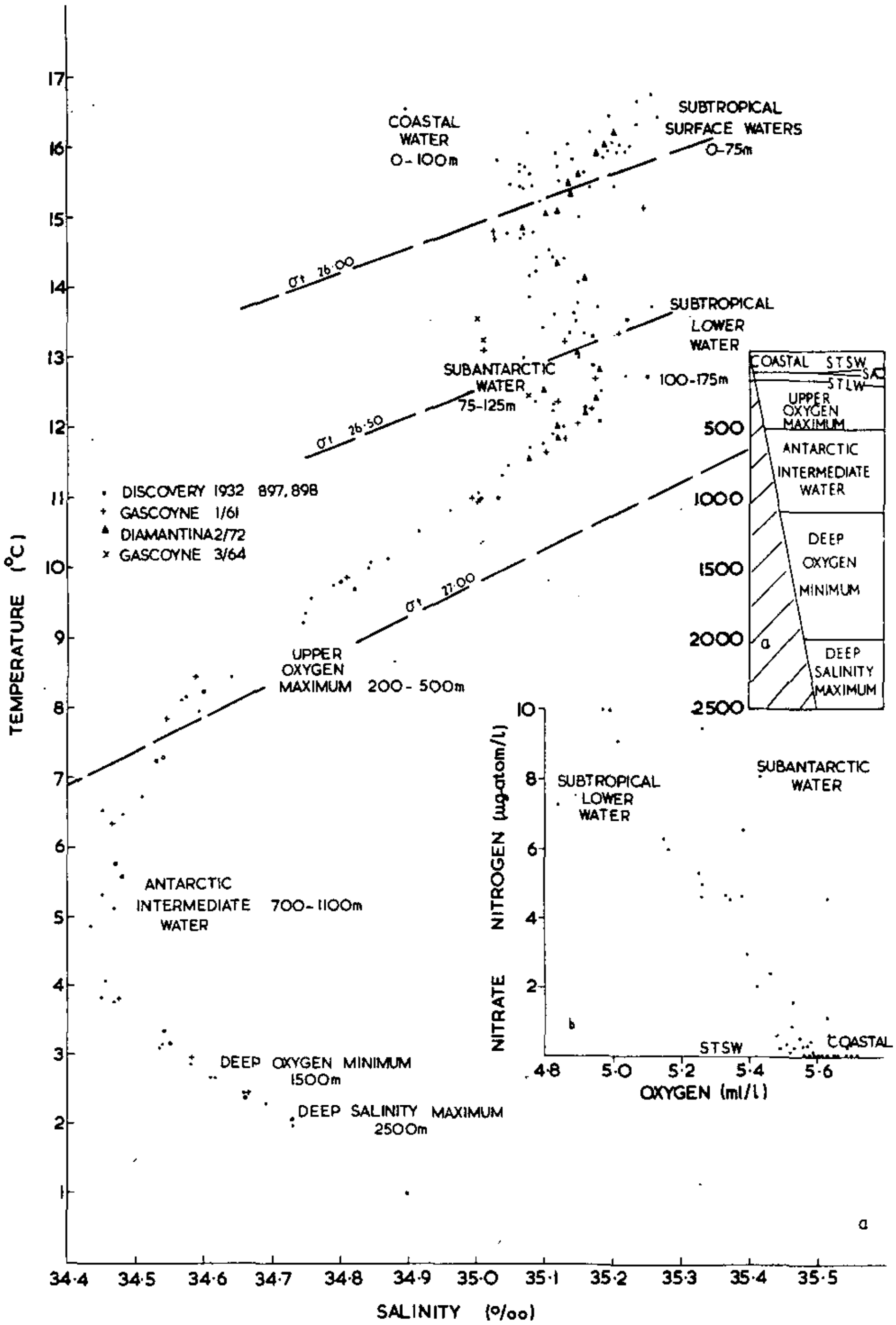

Fig. 2A T/S diagram of all samples from Cruise K1/73, together with some samples from Discovery II, 1932, Cruise G1/61, Cruise G3/64 and Cruise Dm2/72.

- ● Kimbla 1/73
- o Discovery II, 1932 (Stns. 897, 898)
- Δ Diamantina 2/72 (Stns. 58-62)
- \+ Gascoyne 1/61 (Stns. 1, 2 and 4)
- X Gascoyne 3/64 (Stn. 118).

Inset (a) Diagrammatic representation of depth distribution of water types encountered in February, 1973.

Inset (b) Oxygen and nitrate diagram for 0-200 m samples collected in February 1973.

for this water in February. Its dissolved oxygen content of 5.3 to 5.6 ml/l (inset Fig. 2A) is slightly lower than that to be expected of surface waters south of the Subtropical Convergence, judging from Deacon (1937), Sverdrup (1941) or the *Hakuho Maru* Cruise KH-68-4 (1970). However, the intrusion lies at 100 m under an overlying Subtropical water layer, so that the oxygen content would tend to decrease from surface values. It seems most likely that this intrusion of Sub-Antarctic surface water is one of the transient density effects common along the Subtropical Convergence. Certainly this water type cannot be equated with the Upper Antarctic Intermediate Water of Rochford (1960), the Sub-Antarctic Intermediate Water of Wyrtki (1962) or even the Sub-Antarctic Upper Water of Sverdrup (1941). All of these latter have origins further south. The T/S characteristics of the upper 100 m at Station 118 on "Gascoyne" Cruise 3/64 (C.S.I.R.O. Aust. 1967) in March 1964 (Fig. 1) have been entered on Fig. 2A (X) as representing surface waters south of the survey region. It would appear that the samples from K1/73 labelled "Sub-Antarctic" could have arisen from mixing of such surface waters with Subtropical Lower Water. The depth distribution of all 8 water types is shown diagrammatically on an inset in Fig. 2A, whilst their characteristic properties are listed in Table 1.

TABLE 1

Characteristic properties of the eight water types encountered on Cruise *Kimbla* 1/73 (February 1973).

WATER TYPE	DEPTH RANGE (m)	TEMP °C	SALINITY ‰	OXYGEN ml/l	NITRATE μg at./l	SILICATE μg at./l	SIGMA t
Coastal	0	15.0	<35.10	5.2	<2.0	<1.0	25.8
	100	16.5		5.6			26.2
Subtropical	0	15.0	35.10	5.5	<1.0	<0.4	25.8
Surface	75	16.8	35.26	5.7			26.2
Sub-Antarctic							
Subtropical	100	12.0	35.10	4.8	6.4	1.7	26.40
Lower	175	14.0	35.25	5.2	10.3	2.9	26.60
Upper oxygen	200	8.0	34.55	5.0	15.0	5.0	26.75
Maximum	500	10.0	34.75	5.2	20.0	10.0	27.00
Antarctic	700	4.0	34.40	4.0	30.0	20.0	27.10
Intermediate	1100	7.0	34.50	4.6	35.0	50.0	27.40
Deep oxygen	1100		34.60	3.6	38.0	75.0	27.60
Minimum	2000	3.0		3.8			
Deep salinity	2000	2.0	34.75	4.0	36.0	87.0	27.80
Maximum	3000						

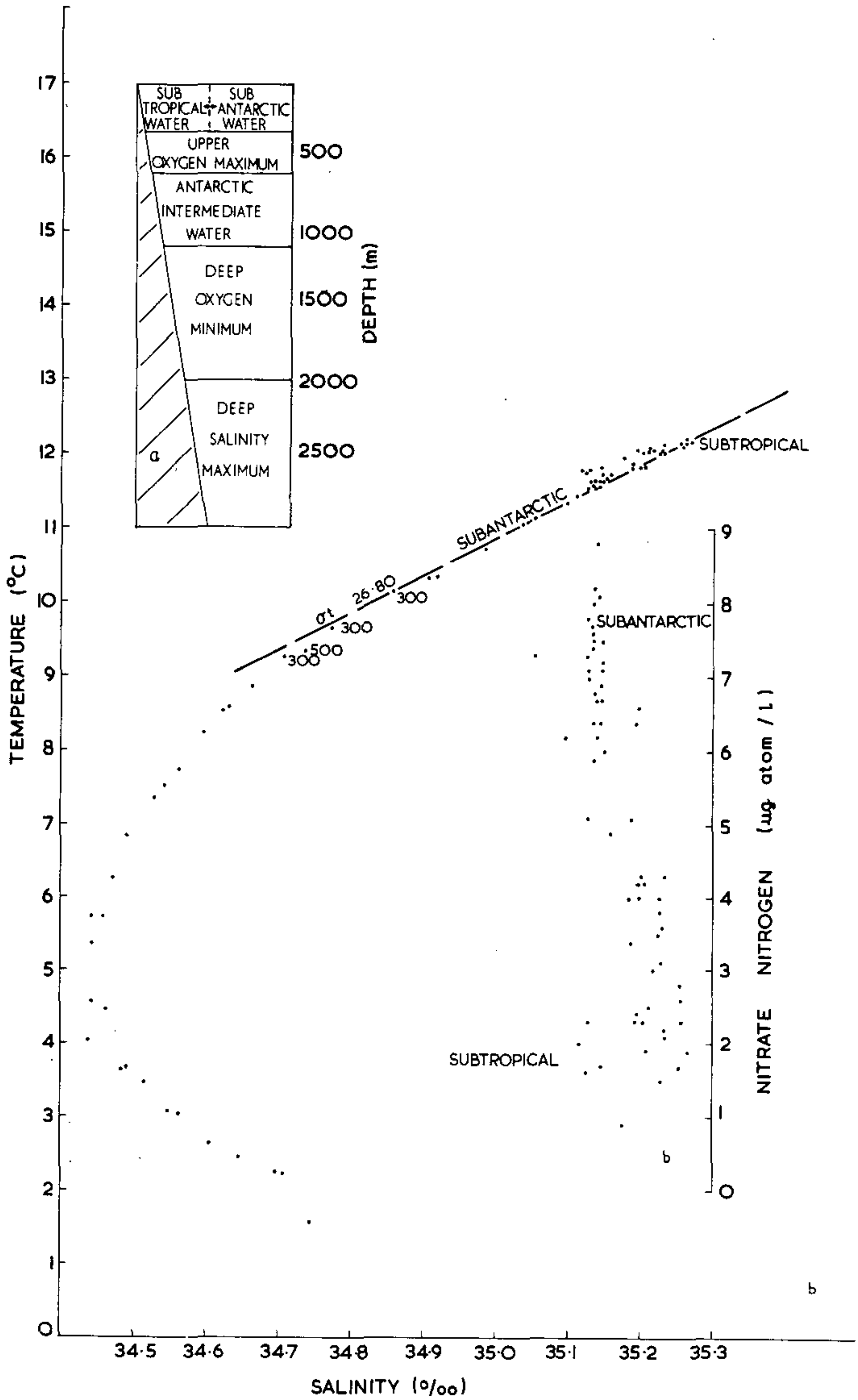

Fig. 2B T/S diagram of all samples from Cruise Dm4/73.
Inset (a) Diagrammatic representation of depth distribution of water types encountered in September, 1973.
Inset (b) Salinity and nitrate diagram for 0-300 m samples collected in September, 1973.

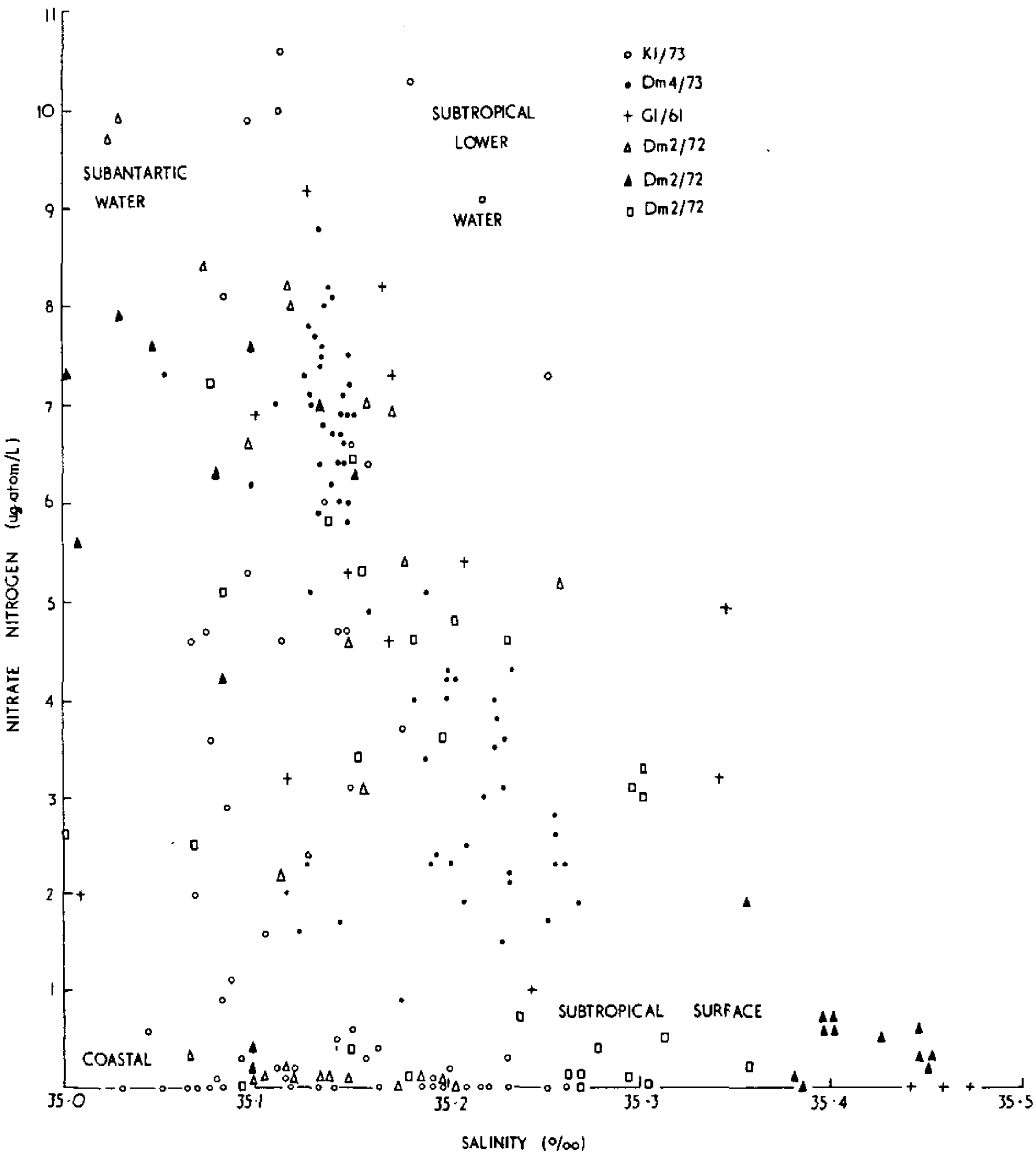

Fig. 3 Salinity and nitrate diagram for 0-200 m samples from Cruise K1/73, 0-300 m samples from Cruise Dm4/73 and near-surface samples from Cruise G1/61 and Cruise Dm2/72.

- o Kimbla 1/73
- ● Diamantina 4/73
- \+ Gascoyne 1/61 (Stns. 1, 2 and 4)
- Δ Diamantina 2/72 (Stns. 58-62)
- ▲ Diamantina 2/72 (Stns. 53-57)
- □ Diamantina 2/72 (Stns. 48-52).

The Subtropical Lower Water encountered on K1/73 occupied a sigma-t range of 26.70 to 26.80, a depth range of 100 to 175 m, had an oxygen content of 5.0 to 5.4 ml/l, and a salinity around 35.20‰ or higher. This water may therefore be equated with the Subtropical Water of western origin described by Rochford (1960).

However, the surface subtropical water is more difficult to identify. A previous description of winter and summer distribution of surface temperature and salinity around Tasmania has been published (Newell 1961). This was based on all data available up to 1959 and indicated that high temperature, high salinity surface waters penetrated further south along the east coast of Tasmania than along the west coast, especially in summer. Salinities (>35.20‰) and temperatures (>16^{o}C) like those of the subtropical surface water encountered on K1/73 did not occur further south than the Freycinet Peninsula - Maria Island region but of course the distribution represented six-month averages in half-degree squares. Such water could well be present further south in February.

On the other hand, there is great similarity between the subtropical surface water encountered on K1/73 and the near surface waters slightly further west. Values of salinity and temperature obtained at Stations 59 to 62 on *Diamantina* Cruise 2/72 (Fig. 1) in April 1972 have been entered on Fig. 2A (Δ) and show a distribution identical with those from K1/73. Values from "Gascoyne" Cruise 1/61 (+), although collected in January, do not coincide with those of K1/73. The same holds for salinity nitrate relationships (Fig. 3). Only 6 out of 12 G1/61 samples (+) fall on the broad mixing path of Sub-Antarctic/Subtropical Lower Water (high nitrate) to Coastal/ Subtropical Surface Water (low nitrate), whereas most samples from Dm2/72 Stations 59 to 62 (Δ) fall on this path.

If we consider direct evidence of water movement to explain the origin of the Subtropical Surface Water of K1/73, the pattern is at first not helpful. Drift bottles released off the north west coast of Tasmania between 1958 and 1960 moved south and east mainly in winter. In summer (and K1/73 was carried out in February) bottles moved generally north (Newell 1961, Vaux and Olsen, 1961). However, two drift bottles released off the west coast in November were stranded on South Bruny Island, indicating some southward movement in summer. Furthermore, the survivors of M.V. *Blythe Star* drifted east from South West Cape to the Tasman Peninsula in October 1973.

If wind direction and force be taken as an indirect indication of surface water movement, then it is probable that water moves east past the survey region for most of the year. Table 3 gives the direction and mean speed of winds for 0900 and 1500 hours at Cape Sorell and Maatsuyker Island (Fig. 1). Table 3 is reproduced from R.A.A.F. Publication No. 252, Vol. II, 1942, "Weather on the Australian Station". Whilst winds at Cape Sorell show a seasonal cycle, tending to blow from the north in winter and the south in summer, those at Maatsuyker Island blow from southwest to northwest all year round. Since the drift bottles previously mentioned were all released from

TABLE 2

Characteristic properties of the near-surface water types encountered on Cruise *Diamantina* 4/73 (September 1973).

WATER TYPE	DEPTH RANGE (m)	TEMP °C	SALINITY ‰	OXYGEN ml/l	NITRATE µg at./l	SILICATE µg at./l	SIGMA t
Subtropical	0	11.7	35.15	ca. 6.0	<4.0	<1.0	ca.26.80
	300	12.2	35.27				
Sub-Antarctic	0	11.0	35.05	ca. 6.0	>4.0	1.0	ca.26.80
	300	11.7	35.15		9.0	2.0	

sites north of Cape Sorell, their seasonal reversal in movement corresponds with the wind change. If the same relation holds further south, surface water probably moves eastwards all the year round.

The vertical density structure to 300 m depth in February is shown in Fig. 5. The tilt of the isopycnals in the western section (Stations 1 to 4) shows a slight downward trend offshore, suggesting a westward eddy movement in Storm Bay. In the central (Stations 5 to 8) and easternmost (Stations 9 to 12) section, however, the trend suggests an east-going current offshore, with lateral transport producing a convergence and downward flexure of isopycnals at the junction of the offshore subtropical water with the inshore coastal water. Such a current pattern concurs with the conclusion previously drawn.

(b) Winter (Dm4/73). The T/S relationships of all samples collected on *Diamantina* Cruise 4/73 are shown in Fig. 2B. It is apparent that the complex structure of the near-surface waters found in February had completely disappeared in September. Instead, the upper 300 m depth stratum was vertically mixed to a uniform density (sigma-t 26.80) and showed the presence of only 2 water types also mixing horizontally.

At the shoreward, or northern stations of the survey grid, water was present having subtropical properties. Its salinity was 35.20‰ or more, as in February, but its temperature had fallen from the 16-17°C range of February to a range of 11.8 to 12.2°C. At the southern stations, water of Sub-Antarctic properties occurred. Its salinity was again 35.10‰ or less, as in February, but its temperature had fallen from ca. 13°C to 11.0 to 11.8°C. These temperature decreases are almost certainly a climatic seasonal effect. The subtropical and Sub-Antarctic water types may again be separated by their nitrate content (inset in Fig. 2B) but the subtropical surface water, by horizontal mixing, has increased its nitrate content from near-zero to at least 1.0 µg at./l.

TABLE 3

Wind direction and mean speed (in knots) at Cape Sorell and Maatsuyker Island.

MAATSUYKER ISLAND, Tasmania

MONTH	WIND																			
	0900 Hours' Observation										1500 Hours' Observations									
	Percentage from-									Mean speed in knots	Percentage from-									Mean speed in knots
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm		N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	
January	1	3	9	9	4	6	48	14	6	20	0	3	10	8	7	8	54	8	2	22
February	3	3	8	3	4	10	46	17	6	18	1	4	11	4	3	13	46	14	4	21
March	3	3	12	5	4	10	38	17	8	17	1	5	14	3	3	10	47	11	6	18
April	5	3	6	6	3	5	39	20	13	6	4	5	9	8	4	10	42	16	2	17
May	3	3	5	2	3	8	46	25	5	20	1	3	10	4	3	12	47	17	3	20
June	7	2	5	3	5	7	40	30	1	20	3	3	6	3	6	8	49	17	5	17
July	7	2	7	6	2	6	35	32	3	18	6	5	8	6	6	8	41	15	5	17
August	3	4	5	8	4	7	39	29	1	20	3	3	9	7	10	12	40	14	2	17
September	3	1	4	3	2	7	47	32	1	23	1	1	7	4	1	13	51	21	1	22
October	3	1	5	4	1	14	41	26	5	18	1	5	6	6	6	13	49	14	0	21
November	0	2	10	4	3	10	49	17	5	18	0	3	11	5	2	14	51	12	2	20
December	3	1	5	5	3	8	54	15	6	22	1	0	7	9	4	11	53	14	1	23
Means	3	2	7	5	3	8	44	23	5	19	2	3	9	5	4	11	49	14	3	20
No of years of observation										5										

CAPE SORELL, Tasmania

MONTH	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Mean speed in knots	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Mean speed in knots
January	10	10	5	5	21	19	12	14	4	11	3	1	1	1	34	26	19	15	0	14
February	14	11	13	8	22	13	8	6	5	10	9	1	0	2	46	22	10	9	1	12
March	21	14	12	9	9	17	9	8	1	13	12	3	0	3	33	19	15	14	1	13
April	14	14	15	10	12	20	7	6	2	12	6	6	1	5	31	23	13	13	2	13
May	25	20	12	10	3	9	10	11	0	13	21	8	5	8	10	13	13	20	2	13
June	20	27	25	7	7	7	4	3	0	12	22	11	13	5	21	9	5	11	3	11
July	29	12	14	6	5	14	9	11	0	14	24	6	7	3	12	16	11	18	3	14
August	29	17	8	3	8	14	11	10	0	16	19	6	1	1	15	22	15	20	1	15
September	22	9	11	5	11	16	16	10	0	14	15	1	1	1	18	24	15	24	1	15
October	26	5	5	6	11	14	15	17	1	14	14	1	1	1	22	16	17	27	1	15
November	16	5	8	9	16	26	7	10	3	10	9	0	2	1	24	34	14	12	4	11
December	14	5	7	12	20	16	8	12	6	9	6	1	1	3	42	21	13	13	0	12
Means	20	12	11	8	12	15	10	10	2	12	14	4	3	3	25	20	13	16	2	13
No. of years of observation										5										

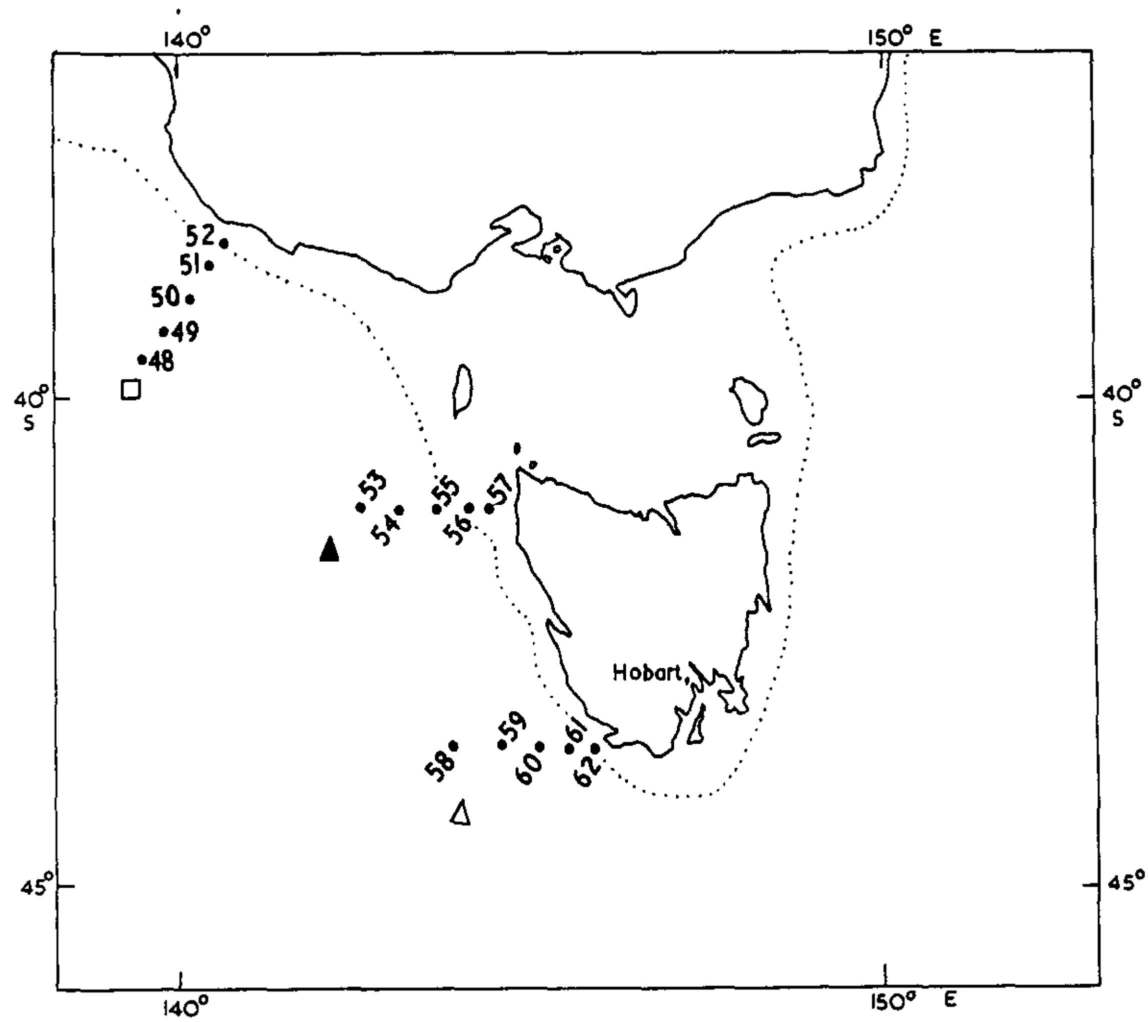

Fig. 4 Positions of Stns. 48 to 62 on Cruise Dm2/72.

The origin of the subtropical surface water found in September is easier to determine than that of February. No data are available from other cruises in the area at that time of year, but since salinity and nitrate values are less seasonally dependent than temperature or oxygen, the former 2 properties have been displayed in Fig. 3, not only for Dm4/73 (●) but also for all stations on Dm2/72. The positions of these latter stations are shown in Fig. 4 as are the symbols used for their nitrate-salinity relationships in Fig. 3.

Comparing nitrate-salinity relationships in Fig. 3, it is apparent that the results from Dm4/73 show a marked shift to higher salinities as well as to higher nitrate content (as already mentioned). Whilst high salinities were also encountered on G1/61 and at Stations 53 to 57 on Dm2/73 (Fig. 3) the best fit of the samples from Dm4/73 is with those from Stations 48 to 52 of Dm2/72 (Fig. 4). It seems, therefore, that the high salinity subtropical water found along the South Australian coast in summer, moves south and east past southern Tasmania in the winter. (The actual origins of this high salinity water is still uncertain. It could derive from the South Australian Gulfs, the Great Australian Bight, or the South Indian Gyre.) Such a pattern of movement fits well with the wind changes in the area and with the results of drift-bottle recoveries (Newell 1961, Vaux and Olsen, 1961).

The distribution of water types below 300 m in September follows the classical pattern described in the previous section.

Fig. 6 shows the distribution of isotherms in September, with intense vertical mixing, and a horizontal mixing gradient from warmer water onshore to colder water offshore. Such structure as exists tentatively suggests a strong east-flowing current offshore with lifting of colder water towards the south and accumulation of warmer water towards the coast.

CONCLUSIONS

The distribution of water types below 200 m depth in summer and 300 m depth in winter, follows the classical pattern and shows no seasonal change.

The distribution of water types in the upper layers, however, is complex and shows marked seasonal change. In summer, four water types could be recognised. These were, an onshore coastal water, an offshore subtropical surface water, an intermediate layer of subtropical lower water (or upper oxygen minimum) and a small intrusion at around 100 m depth of Sub-Antarctic surface water. In winter, only two water types could be recognised. These were, an onshore subtropical water and an offshore Sub-Antarctic water.

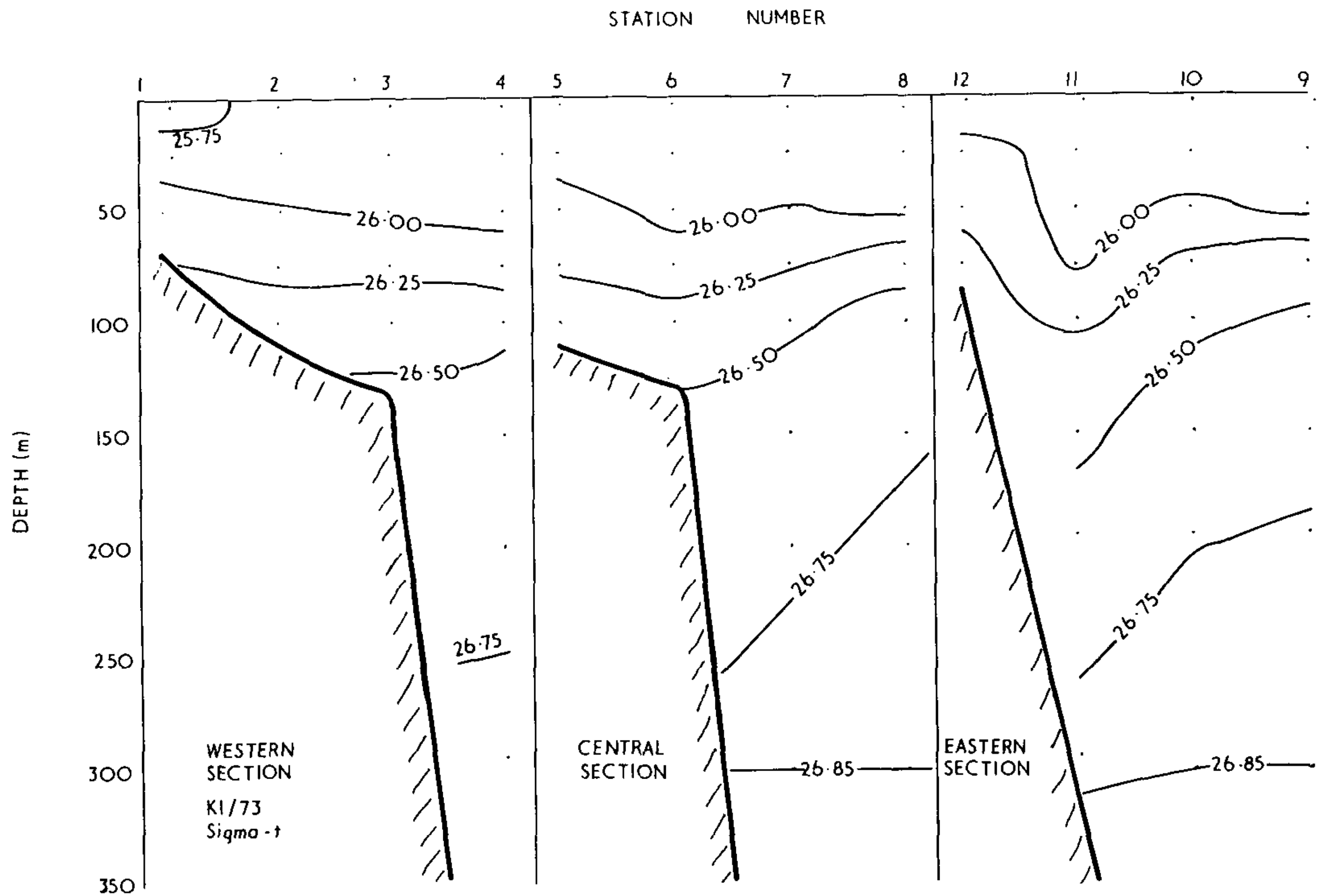

Fig. 5 Vertical distribution of density along the three survey sections in February, 1973. Western Stns. 1-4, Central Stns. 5-8 and Eastern Stns. 9-12. See Fig. 1.

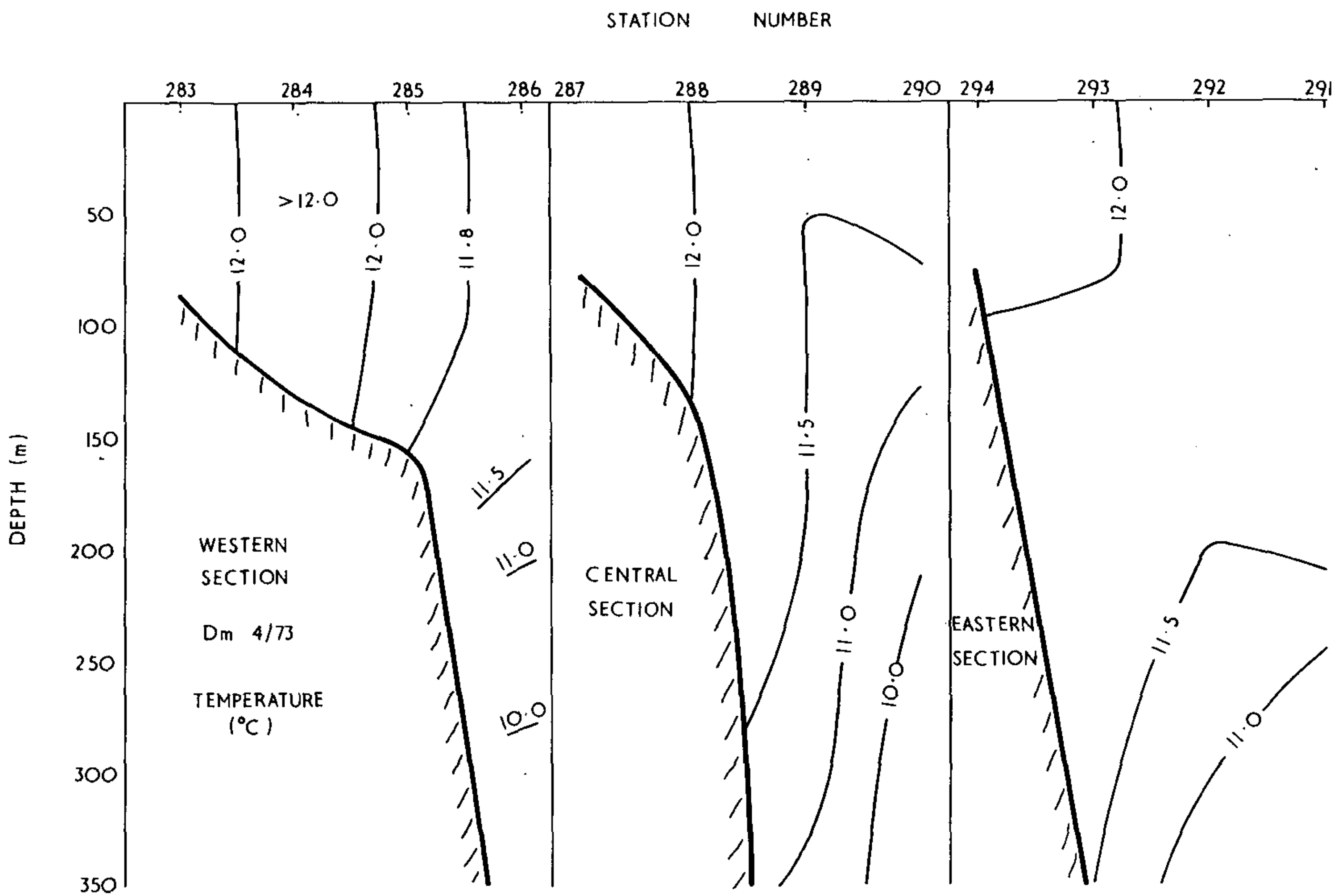

Fig. 6 Vertical distribution of temperature along the three survey sections in September, 1973. Western Stns. 283-286, Central Stns. 287-290 and Eastern Stns. 291-294. See Fig. 1.

In summer, the upper layers were well stratified. The density distribution suggested an easterly drift offshore with possibly a westerly counter-current in Storm Bay. In winter the upper waters were thoroughly mixed to a uniform density down to 300 m. Temperature distribution suggested a general easterly drift through the survey area.

It is fairly certain that the upper water types encountered in winter derived from west and northwest of Tasmania. The situation in summer is less clear. Whilst wind direction and water properties suggested an origin west of Tasmania, the general oceanic circulation pattern in the southwest Tasman Sea makes it possible that at least one water component (the subtropical surface water) derived from the East Australian Current System and moved south into the area.

Material introduced into the surface waters at the dumping site in winter is almost certain to be carried eastwards away from the area. Material introduced in summer may also be mainly carried eastward, but there is a possibility of some material moving onshore or westwards with subtropical surface waters.

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