COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

DIVISION of FISHERIES and OCEANOGRAPHY

Report No. 57

A CRITICAL DESCRIPTION OF THE CSIRO SEA SURFACE TEMPERATURE AND SALINITY SAMPLING PROGRAM FROM MERCHANT SHIPS

By Ants Piip

Marine Laboratory
Cronulla, Sydney
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1. INTRODUCTION

Since 1966, The Fisheries and Oceanography Division of CSIRO has had a sea surface sampling program in operation in the waters adjoining eastern Australia. In this program, surface temperatures and salinities are regularly sampled by a number of merchant vessels on their cruises in an area bounded roughly by 0^{o} to 50^{o} South latitude, 140^{o} to 180^{o} East longitude.

The program is really a cooperative effort between CSIRO and the various shipping lines covering the area: CSIRO providing equipment for the program, the ships' personnel doing the observations in addition to their normal duties in running the vessels, at no cost to CSIRO. CSIRO collects the observed data from the ships, analyses and evaluates the data, and prepares monthly average surface isotherm and isohaline charts for every month of the year. These charts are of considerable interest and value to the scientific community as a record of the long term variability in the Tasman and adjoining seas; and to some extent even to the shipping companies.

In 1970 the program was extended to cover the south-eastern quadrant of the seas, extending to 135^{o}E.

2. SHIPS

About 20 ships take part in the surface water sampling program. Plying reasonably fixed routes, the ships range from 800 to 40,000 tons in size. A list of ships active in 1973 is given in Appendix I.

At times, there have been 30 ships in the program. The present decline in numbers is attributable to the generally unsettled state of worldwide and Australian shipping.

2.1 Data Collection - seawater intake

The participating ships normally read the water temperature every two hours while underway, and obtain water samples at the same time for later salinity analysis. A narrow range circular chart thermograph provides a continuous record of water temperature. The thermograph and thermometers serve as a mutual check for gross reading or instrument errors.

2.1.1 Installation (Fig. 1)

Water temperatures are measured, and samples obtained not from the actual sea surface but from a point a few metres below. For the purposes of a large-scale sampling program these sub-surface waters are sufficiently representative of conditions at and near the sea surface - the sampling point is within the

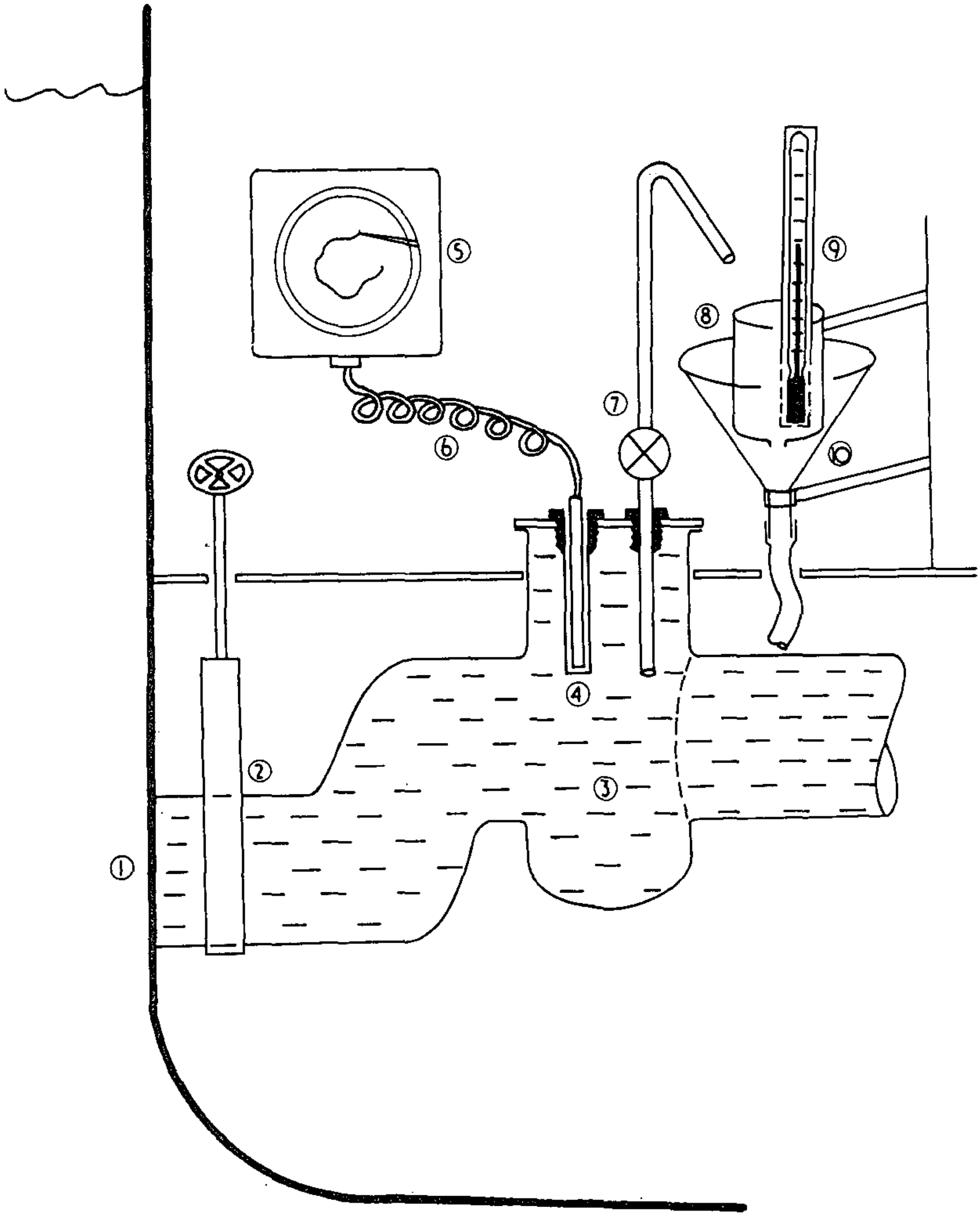

Fig. 1. Typical sampling point installation.

surface mixed layer. Its depth is also sufficient to be unaffected by the formation of a thin, very warm surface layer in the sea which can occur during calm weather in summertime - the daily thermocline.

All measurements on the participating ships are done in the engine room, the sampling point being installed in the raw seawater intake duct as close to the hull as deemed suitable by the ship's engineers. Intake depths depend on the size and design of the ship, and vary between 2 and 6 metres below surface.

Sampling point locations and installations are not uniform among the ships. Since the sampling points are usually installed (by outside contractors) with the ship afloat in port, most of them are located inboard of the seawater shutoff valve at varying distances from the hull (3 to 15 metres), nearly always in flat strainer box cover plates.

CSIRO, unfortunately, has very little control over the details of installation and selection of the best possible point: the location is dictated by the ship's layout, underwriters' rules, and limited time available for doing the installation.

2.1.2 Instrumentation

The sampling point has the sensor bulb of the mechanical mercury-in-steel thermograph mounted into the seawater intake duct, to a depth of 25 cm. The 24-hour circular chart recorder is fastened at a convenient, accessible spot nearby. The 5-metre steel capillary connecting the sensor bulb to the recorder is usually left free hanging, not fastened anywhere in its run. The majority of the thermographs supplied to the ships are made by Negretti and Zambra; a few Cambridge instruments also are used.

Adjacent to the thermograph bulb, a device is installed for withdrawing water samples from the intake duct. It is simply a stopcock, provided with a gooseneck, which directs the water stream into a cylindrical brass container used to support a 12-inch 50°C (0.1°C divided) laboratory type mercury thermometer at sufficient immersion depth in the flowing water. The thermometer itself is protected by a surrounding sheath. Water sample bottles are conveniently filled by deflecting the gooseneck a little bit, directing the flow into the sample bottle. Any overflow is caught by a large funnel leading into the bilges.

In some cases, the thermograph and thermometer-sampling fittings are not installed adjacent to each other, but in different positions on the seawater pipe separated by several metres (e.g., M.V. *MAHENO*).

Special 130 ml Pyrex bottles, closed by a lever-actuated ceramic stopper and rubber sealing gasket, are provided by CSIRO for storage of the water samples. The bottles are individually, permanently numbered.

2.1.3. Sampling procedure, logs

The procedure in the engine room is best described by quoting from the instruction sheet supplied by CSIRO to the ship's engineers:

"General Procedure:

1. Normally, sampling is done every two hours.
2. When placing a chart in the thermograph (every 24 hours), set the pen on the correct time and write date on the chart.
3. Open seawater tap to drain for at least 2 minutes - let the water run over the inserted thermometer.
4. In the meantime, press the time marking button on the thermograph to indicate the sampling time on the chart.
5. Make a tick in the thermograph temperature column to indicate that the pen button has been activated.
6. Read the thermometer whilst it is still immersed in the running seawater and record the temperature in the bottle log together with the date, time and bottle number.
7. To take a sample, rinse the bottle with seawater first, and then fill it leaving 1 inch space below the seal.

Remarks:

Whenever possible, record the date and time in GMT. If not convenient, please note on the logsheet that ship time is being used and note in the remarks column the time changes or clock adjustments.

Please remember that these samples are taken in coordination with the weather report and positions supplied by the Bridge. Therefore inform the Bridge when first and last samples are collected on each leg of the voyage.

Under no circumstances should the thermograph be adjusted.

If malfunctioning is suspected, please contact CSIRO, Cronulla."

The engineroom log sheets, Fig. 2, are ruled to provide space for the following entries:

Ship and cruise

Date

Time

Bottle number

Water temperature: thermograph and lab. thermometer

Remarks.

The engineers are not supposed to enter thermograph readings in the log: these values are filled in as the thermograms, Fig. 3, are read at CSIRO. They do have to change thermograph charts daily, label them correctly as to ship, cruise and date; and indicate the starting point on the circular chart.

A second, positional log, Fig. 4, is kept by the ship's bridge, with room for

Ship and cruise,

Ship's Draft

Date

Time (preferably GMT)

Time zone

Latitude

Longitude

Air temperature, wind

Sea state

Other meteorological data

Remarks.

Bridge log entries are to be made to correspond to the samplings in the engine room, at two-hour intervals.

C.S.I.R.O. DIVISION OF FISHERIES & OCEANOGRAPHY
TEMPERATURE RECORD & HYDROLOGY BOTTLE LOG

VESSEL M.V. MAHENO (I 7)

CRUISE (SECTION) LYTTELTON - SYDNEY

REMARKS

SHEET No. 1

DATE			G.M.T.		BOTTLE	WATER TEMPERATURE		REMARKS	
YEAR	MTH	DAY	HOUR	MIN	NUMBER	THERMOGRAPH	LAB. THERMO		
72	12	23	19	00	5511	158	159		0.1
		23	21	00	5571	152	152		0
		23	23	00	0566	165	167		0.2
72	12	24	01	00	1837	167	170		0.3
		24	03	00	2365	166	170		0.4
		24	05	00	3317	169	170		0.1
		24	07	00	5486	170	170		0
		24	09	00	2497	174	174		0
		24	11	00	0546	174	172		-0.2
		24	13	00	5536	177	177		0
		24	15	00	3137	173	175		0.2
		24	17	00	3441	175	179		0.4
		24	19	00	5198	178	181		0.3
		24	21	00	0553	177	178		0.1
		24	23	00	5252	180	182		0.2
72	12	25	01	00	2930	183	184		0.1
		25	03	20	4394	196	197		0.1
		25	03	20	0693	194	193		-0.1
		25	07	00	0219	193	192		-0.1
		25	09	00	3777	189	189		0

FO 20.9/71

Fig. 2. Engine room logsheet.

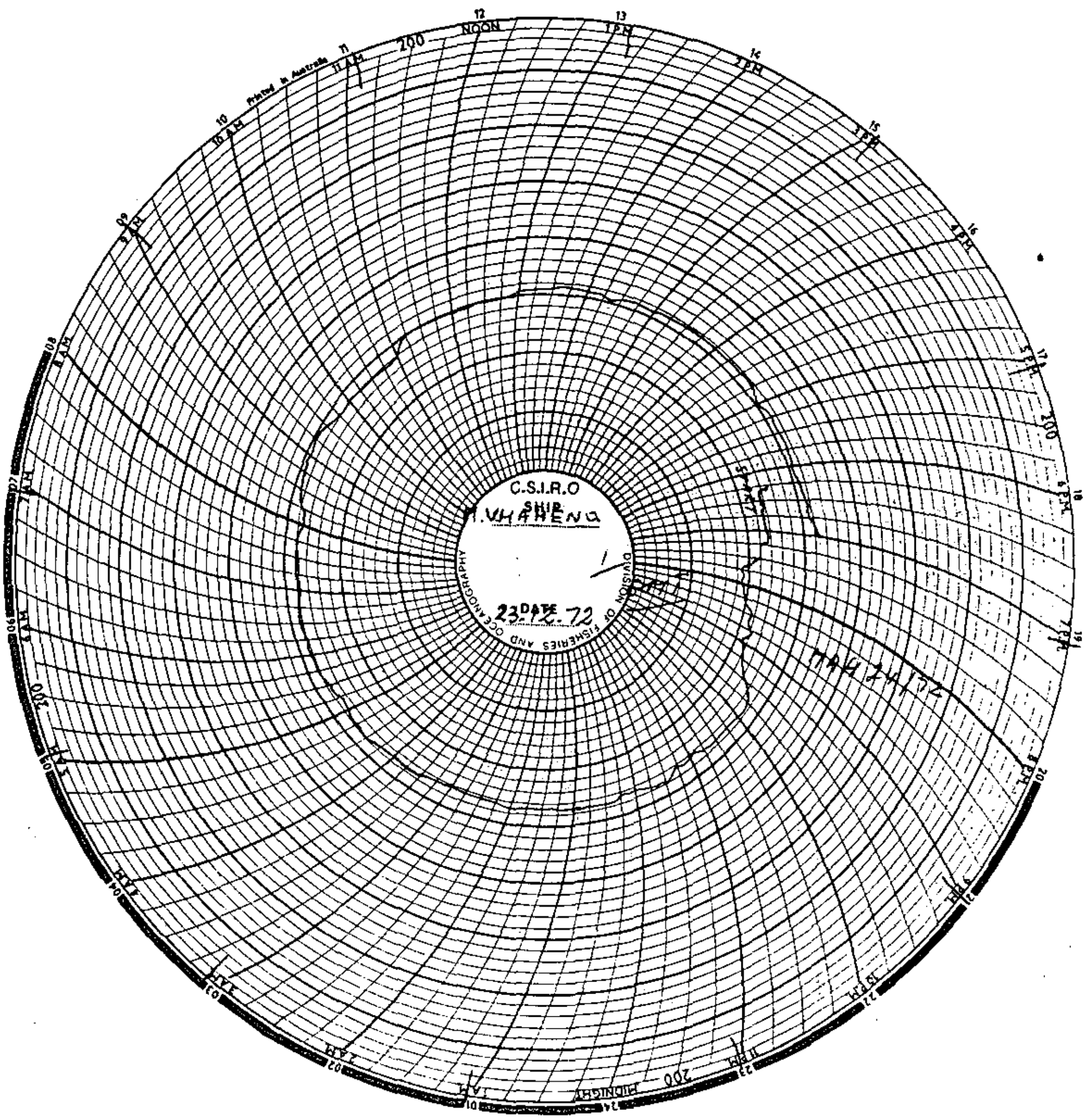

Fig. 3. Thermograph record.

CSIRO DIVISION OF FISHERIES AND OCEANOGRAPHY

POSITION AND MET. LOG.

VESSEL (I 7) M V MAHENO	FROM LYTTELTON	TO SYDNEY	DRAFT 16'03 18'01	SHEET No. 1

SHIPTIME GMT = SHIPTIME – ZONE

DATE			TIME		TIME ZONE		LATITUDE S		LONGITUDE E		AIR	WIND		UNUSUAL FEATURES OBSERVED ON WATER
YEAR	MONTH	DAY	HOURS	MINS.	HOURS	MINS.	DEG.	MINS.	DEG.	MINS.	TEMP. °C	DIRECT	FORCE	Current, colour, slicks etc
72	12	24	07	00	12	00	40	23	173	16	16·0	35	07	
72	12	24	09	00	12	00	40	15	172	37	16·6	30	07	
72	12	24	11	00	12	00	40	01	172	00	17·0	28	07	
72	12	24	13	00	12	00	39	40	171	41	17·0	27	06	
72	12	24	15	00	12	00	39	38	170	42	16·5	25	05	
72	12	24	17	00	12	00	39	26	170	04	16·4	25	05	
72	12	24	19	00	12	00	39	15	169	26	16·0	25	04	
72	12	24	21	00	12	00	39	04	168	47	16·3	32	04	
72	12	24	22	30	11	30	38	52	168	09	16·5	32	05	
72	12	25	00	30	11	30	38	40	167	30	17·2	29	05	
72	12	25	02	00	11	00	38	29	166	52	14·0	28	05	
72	12	25	04	00	11	00	38	17	166	14	14·0	28	05	
72	12	25	06	00	11	00	38	05	165	35	14·0	27	04	
72	12	25	08	00	11	00	37	53	164	56	14·2	27	04	
72	12	25	10	00	11	00	37	31	163	46	17·8	27	05	
72	12	25	12	00	11	00	37	24	163	12	18·2	27	06	
72	12	25	14	00	11	00	37	13	162	35	18·0	27	06	
72	12	25	16	00	11	00	37	02	161	58	17·0	26	07	
72	12	25	18	00	11	00	36	51	161	20	17·2	25	07	
72	12	25	20	00	11	00	36	33	160	44	17·5	25	08	
9	—	14	15 —	18	21 —	24	27		—	37	56 – 58	62-63	65-66	

FO.24.7/72

WIND DIRECTION CODE

00	Calm	
01	5° to 14°	
02	15° to 24°	NNE
03	25° to 34°	
04	35° to 44°	
05	45° to 54°	NE
06	55° to 64°	
07	65° to 74°	ENE
08	75° to 84°	
09	85° to 94°	E
10	95° to 104°	
11	105° to 114°	ESE
12	115° to 124°	
13	125° to 134°	
14	135° to 144°	SE
15	145° to 154°	
16	155° to 164°	SSE
17	165° to 174°	
18	175° to 184°	S
19	185° to 194°	
20	195° to 204°	SSW
21	205° to 214°	
22	215° to 224°	
23	225° to 234°	SW
24	235° to 244°	
25	245° to 254°	WSW
26	255° to 264°	
27	265° to 274°	W
28	275° to 284°	
29	285° to 294°	WNW
30	295° to 304°	
31	305° to 314°	
32	315° to 324°	NW
33	325° to 334°	
34	335° to 344°	NNW
35	345° to 354°	
36	355° to 4°	N
99	Variable or unknown	

WIND FORCE CODE		KNOTS
00	Calm	0 - 1
01	Light air	1 - 3
02	Light breeze	4 - 6
03	Gentle breeze	7 -10
04	Moderate breeze	11-16
05	Fresh breeze	17-21
06	Strong breeze	22-27
07	Moderate gale	28-33
08	Fresh gale	34-40
09	Strong gale	41-47
10	Whole gale	48-55

Fig. 4. Bridge logsheet.

2.2 Data collection - bucket method

Two small ships, operating on the northern island routes, have enginerooms too small and cramped for installation of a thermograph or usual sampling device. Having low freeboard, they do their sampling by the traditional bucket method. Standard double-wall rubber buckets, etc., are provided by CSIRO. The operators on these ships are to follow these instructions:

> "To rinse the sampling bucket, make a lowering and discard the first lot. Place the thermometer in the second haul for at least one minute. Using a magnifying glass if necessary, read the temperature to 0.1°C while keeping the thermometer bulb well immersed. In the tropics, constant immersion of the thermomeeter and fast work is essential.
>
> Fill the sampling bottle from the bucket after the bottle number and the temperature of the sample is recorded in the log in the usual manner alongside the position, meteorological data, etc. Discard faulty bottles.
>
> For best results it is advisable to keep the sampling gear, i.e., the bucket and rope, immersed in seawater all the time. A pedal bin with lid, or a similar container, filled with seawater protects the gear against possible contamination by dust, soot, and against deposits of dry salt. The quality of samples is often decided by the cleanliness of the sampling gear."

2.3 Servicing of ships

Water samples and filled-out log sheets are collected from the ships during their turnover in port. At the same time, thermograph and sampler installations are inspected and malfunctions corrected if necessary, or thermographs replaced. If possible, a short discussion with the ship's officers or engineers is in order at this time.

Ships making port within reasonable distance from Sydney are serviced by personnel from the Fisheries and Oceanography Division. Ships not coming near Sydney are serviced at their calling ports by personnel from other Divisions of CSIRO, and various State Fisheries Departments. At some distant ports, arrangements have been made to have the samples and logs collected by the ships' agents, and shipped to Fisheries and Oceanography at Cronulla.

Servicing of the ships and keeping track of their arrival times at accessible ports takes up a large proportion of the time at CSIRO of personnel involved in the program. In general, the ships do not inform CSIRO of their movements - with their continuously changing schedules this would be difficult indeed. The problem is even more difficult with ships that have to be serviced far from Sydney, by people not directly assigned to the sampling program. Delays of several months are common in the case of these ships, from gathering data until its arrival at Fisheries and Oceanography in Cronulla.

3. QUALITY OF RAW DATA

All data for the program are collected by observationally untrained personnel, who do this task in addition to their normal shipboard duties, without any extra remuneration. Often the instructions they have received are only second- or third-hand, and consequently vague: this because of rapid turnover in ships' personnel. A new man aboard usually receives his instructions from his predecessor, who may have received his in the same way. Ships are provided with instructions for performing the required observations - a copy of engine room procedure is displayed near the thermograph recorder. Apparently details of the instructions are not too well absorbed by the observers, partly because they do not realize the importance of correct procedure; and lack of background information concerning the whole sampling program, its significance and requirements. Adherence to good procedure could be improved if clear instructions were constantly available to the observer for consultation: e.g., printed on the backside of each bridge and engineroom log sheet blank. Human errors, combined with nonuniformity and imperfections of the instrumentation, introduce uncertainties into all data.

Since the quality of the whole sampling program and its final results depend directly on the quality of the raw data, a critical evaluation of the major factors is in order.

3.1 Position

The ships involved in the program are all using classical navigation methods. Positions at sea are determined by celestial navigation at dawn and dusk, and at noon. A taffrail log records distance run. Between fixes, ships run on dead reckoning, steering a course corrected for estimated drift and set. A celestial fix gives the ship's position to within a few miles, between fixes the estimated position can easily be off by 15-20 miles.

The two-hourly positions entered in the sampling program bridge log sheets apparently are obtained from the estimated ship's track lines. Thus, the average position error in the log sheets can be estimated to be around ± 10-15 miles in any direction. For the purposes of the sampling program, describing the sea surface in terms of monthly averages over a 1 degree square, this uncertainty is negligible.

3.2 Time

Time appears in three places in the original data sheets: on the bridge position log, in the thermometer and sample number log kept in the engine room, and the 24-hour thermograph chart. It only serves as a correlating parameter in determining the geographical location of each sample, and to synchronize temperature log entries with the continuous thermograph record.

In practice, deciphering and synchronizing the three time entries is a major problem. Although the ship's instructions strongly recommend using 24-hour GMT in the logs (but permitting as an alternative ship's time and time zone information), more often than not the entries in the logs are kept in different systems: GMT; zone time; 12 and 24 hour ship's time, changed in 1 hour, 30 minute or 15 minute increments according to the individual ship's procedure - either log can follow any one of these systems without any regard to what is used in the other. In addition, the thermograph chart often follows its own time system, independently even of the engine room log. At times, zone corrections are made by moving the thermograph chart back and forth in time, adding further confusion. On the same cruise, relationships between the three time entries are apt to be different from day to day.

An inordinately large amount of time and effort at the Division goes to waste in sorting out the different sorts of time found in the ship's records. Strict instructions to use GMT exclusively, and a 24-hour clock showing GMT in the engine room would improve the situation.

3.3 Temperature

Temperature measurements in the seawater intake duct are quite sensitive to installation details and procedures. As will be described later, temperatures entering the program as data are really the readings from the mercury thermometer at the sampling point in the ship's intake duct, reconstructed from thermograph data and smoothed somewhat in the data reduction process, but not corrected for any errors due to non-ideal installations, etc.

3.3.1 Uncertainties due to installation

Since no comparative measurements of "true" surface temperature and indicated temperature at the sampling point in the ship's seawater intake duct have been made in any of the participating ships, one has to rely on results of other investigators in trying to assess the importance of each factor.

The World Meteorological Organization has published the results of such a survey, involving some 16,000 comparative measurements from various types of ships (James and Fox, 1972). Their findings give some insight to the probable errors and uncertainties of our operations: more qualitative than quantitative, since the data analyzed by James and Fox, and previous surveys of the same kind, show that the distribution of errors is erratic for any selection of variables, and does not follow any standard distribution. Standard deviation of the errors in all cases is many times higher than the mean error. A similar situation prevails in our own program. Thus, the significance of each variable is hard to assess, and optimum corrections cannot be determined.

All investigators have found bucket temperatures to be approximately 0.3°C lower than readings in the ship's seawater intake duct - as obtained from an installation of average quality. Installations with precision thermometers or thermistors close to the hull, or independent precision measurements of near-surface water give a temperature only 0.1°C warmer than the bucket. A plausible interpretation of these (mean) discrepancies is that the bucket does read 0.1°C lower than true surface temperature, because of bucket cooling due to wind and evaporation during the measurement process; the remaining 0.2°C difference being caused by imperfections in the average intake thermometering installation and/or technique. Intake water gradually warms up during its passage through the pipes: engine rooms are warmer than the surrounding sea; also some heat is generated through frictional losses by the water flow itself.

Thus, the distance inboard of the measuring point, i.e., the length of pipe between hull and measuring point, has an appreciable effect on thermometer readings. The error increases with increasing distance:

distance inboard	0-3 m:	no appreciable error
	3-6 m:	0.6°C higher than at hull
	6-9 m:	0.7°C higher than at hull.

The depth of the seawater intake port, at least in the range encountered in our ships (0-6 m), has only a negligible effect on thermometry errors. Likewise, the other factors analyzed by James and Fox can be ignored in our case.

There are strong indications that in several of our installations the sampling point suffers from a pocket of semi-stagnant water under the strainer box cover. An inspection of thermograph records from some ships (e.g., *ENNA G*, *NORTH ESK*), often shows a curious coincidence: the normally smooth temperature trace has regularly spaced dips at 2-hour intervals, centred around the tickmark on the record signifying sampling. The trace starts going down smoothly about 10-15 minutes before sampling, reaches a plateau in about 10 minutes where the trace is about 1/2-3/4^{o}C lower than before, and after some time starts creeping upwards again, reaching the original level in about half an hour. This phenomenon is more pronounced when the ships are in southern waters, where the temperature differential between engine room and seawater is higher. An explanation is simple: when the sampling stopcock is opened sometime before sampling, the semi-stagnant water starts draining off and is replaced by fresh water from the main flow. After sampling, the stopcock is closed and the stagnant part of the water in the strainer box starts warming up again, with a rather high thermal time constant. Provided that the stopcock is left open a sufficiently long time before actual sampling, errors from this particular source would be minor. If the stopcock is open for a minute or two only, indicated temperature can be too high by half a degree.

3.3.2 Thermometer uncertainties

Intrinsic thermometer errors are below 0.1^{o}C - although non-precision thermometers are used, they all are checked in the laboratory before delivery to the ships. Units showing errors above 0.1^{o}C within the seawater temperature range (10-30^{o}) are discarded.

The type of thermometer protective sheath used until late 1973 could have been a source of appreciable error: the bottom plug, protecting and supporting the thermometer's mercury reservoir, was not designed to allow free circulation of water around the bulb. Being made of plastic, a very bad heat conductor, the support had the effect of enclosing the mercury in a thermal insulator. Thermometers mounted in this sheath had a thermal time constant of one minute: after a step change in water temperature it took the thermometer a minute to reach 60% of the step, 3½ minutes for 90%. Consequently, thermometer readings in cases when the thermometers were immersed in running seawater at the sampling point only during observations, for an unknown and presumably insufficient time, can easily have been in error by considerable amounts: always too high because engine rooms always are warmer than the sea.

The thermometer support in the sheath has been redesigned to permit free water circulation around the thermometer bulb. These minor design changes have reduced the thermal time constant by a factor of three, 90% of a step change is indicated in less than a minute.

In all ships the sampling point is located at a height well below eye level, usually in a somewhat awkwardly accessible and not too well illuminated spot. The thermometers used at present are of the engraved stem type, the 0.1^{o}C gradations (about ½ mm apart) lying 2-3 mm in front of the mercury column. To read the thermometer at the sampling point, the observer practically has to squat down, but even then he is looking at the thermometer from above, at an angle, causing a parallax error of up to 0.2°C or so.

Also, the paint filler in the external gradations on the thermometer stem tends to wash away after some use. This makes the thermometer quite difficult to read accurately, particularly when it is wet. Unlike all previously described sources of uncertainty this does not tend to introduce a systematic error, biasing the readings towards the high side of true temperature - it just introduces unnecessarily high random reading errors.

Illuminated magnifiers, supplied to the ships, are of some help in reading thermometers, but their lifetime on board tends to be short.

Internal scale thermometers, where the scale lies much closer to the mercury column and is protected from outside influences, would certainly reduce parallax and other reading errors - at a very slight increase in thermometer cost.

3.3.3 Thermographs

Although the thermograph is the most conspicuous (and expensive) component of the shipboard installation, its role in measuring temperatures for the program is minor. Basically, it serves as a monitor of surface temperature fluctuations, and a check for the thermometer readings, independent of the operator.

The thermographs used at present are variants of normally wide-range (say 100°C) instruments, factory modified to give a narrow (20-30°C) recording range. These thermographs never were designed to be precision instruments, being more in the nature of an indicator, at best with an accuracy of one per cent of the range covered. It can be suspected that making their range narrower has increased the susceptibility to ambient temperature changes, and decreased their long-time stability. Also, the extremely hostile environment of a ship's engine room takes its toll in long-time reliability: vibration; ship's roll and pitch; humid, oily, hot atmosphere and rough handling, all tend to increase wear and tear in the pen actuating mechanism (essentially a bourdon tube deformed by changes in the volume of mercury enclosed in the large sensor bulb and 5-m thin steel connecting capillary). Vibration effects ("grass", or undue widening of the pen trace) are hardly ever seen on the recorded trace. On the other hand, vibration might even be considered beneficial for easy motion of the pen arm, by reducing bearing and pen-chart striction.

Before being installed on the ships, the thermographs are checked out and aligned at the Division's laboratory in Cronulla, and their error curves determined. Nonlinearities, amounting to ± 1/3^{o}C from a best straight line fit, are common in the thermograph's calibrations. Since very little can be done about this in Cronulla, they usually are ignored, and the instrument calibrated to minimize mean error. Since the temperature used in the program is obtained from the thermograph reading by adding a linear correction corresponding to the difference in thermometer and thermograph readings, these remaining thermograph nonlinearities can cause an error in the final data.

After having been in use for some time, the thermograph calibration usually has shifted somewhat, with very little change in the nonlinear part. The shift, for all practical purposes, affects only the mean error, which usually shows considerable variation from cruise to cruise, half a degree shifts being quite common. Therefore, the thermograph-thermometer correction is calculated anew for each cruise, or batch of data from each ship. Attempts to use the previous cruises' correction result in apparently increased mean and standard errors in the data collected on a later cruise.

Used alone, the present thermographs would yield data of very questionable value. In conjunction with thermometers they increase the reliability of data collected, and only can introduce an error equal to their nonlinearities, plus part of the calibration shift during a cruise. If necessary, these errors could be reduced by more sophisticated procedures in the subsequent processing by computer: e.g., polynomial or sectionally linear error description, and making the thermograph shift points breakpoints in generating new error descriptions - even if they occur in the middle of a cruise.

3.4 Salinity

Salinity, being a conservative property of the seawater, is not affected by thermal conditions in the ship's engineroom. Contamination in the intake duct is unlikely, or if it occurs, it should not affect the salinity of the water sample. Collection and storage methods of the samples are adequate to ensure arrival of the samples at Cronulla, where they are analyzed, without any significant change of their salinity.

4. LABORATORY PROCEDURES

4.1 General

The data and samples gathered by a merchantman, i.e. completed bridge and engineroom logsheets, thermograph charts and water samples, are collected during the ship's turnover in a suitable port and brought to the Division at Cronulla, where the data are processed and records archived.

Upon arrival at Cronulla, the data are checked for completeness. Time entries in the two logs and thermograph charts are inspected and differences in time system entries adjusted to reduce all three documents to GMT.

Station positions are inspected for obvious errors, and adjusted by linear interpolation if the sampling in the engineroom has been done at times different from position entries in the bridge log. Differences less than ¼ hour are ignored.

4.2 Temperature

Thermograph records are read with the help of transparent templates. For each different thermograph range a different template is available, carrying appropriate scales (the thermograph chart blanks only carry a numbered hours scale; the temperature scale is left without numbers). Thermograms are read at times corresponding to the logged samplings and thermometer readings, and the reading is entered in the thermograph column of the engineroom log - which has been left blank by the sample-taker. With care, thermogram reading errors can be kept down to $\pm$ 0.1-0.2°C.

Differences of thermometer and thermograph readings are determined for each station, and pencilled on the margin of the log sheet. These should be reasonably uniform, or follow a reasonably linear dependence on the indicated temperature. An abnormally large, or different, difference at a particular station is indicative of a reading error in one of the two instruments. In a case of this sort the thermograph chart reading is checked, and either the thermometer or thermograph entry in the log corrected, depending on which was in error. Sudden changes of the mean thermometer-thermograph difference indicate changes in thermograph calibration. At present, they are ignored in later computation of mean errors.

4.3 Salinity

Salinity of the collected seawater samples is measured with a Hamon salinometer (Hamon, 1956). This is a compensating type temperature-conductivity bridge, calibrated in chlorinity. With careful operating technique, and frequent calibration checks, it can give measurements good to within ±0.02‰ Cl = 0.035‰ S (S = 0.03 + 1.805 Cl; S and Cl in ‰).

Before measurement, seawater samples are stored in the same room with the salinometer and secondary salinity standard for at least half a day to minimize temperature differences, which can affect quality of the measurement. The salinometer electrodes are cleaned daily in a 0.1N HCl bath. Before each series of measurements, the salinometer is calibrated against the standard; likewise at the beginning of each new salinity logsheet (about 25 samples, or an hours's work). Small calibration errors are entered in the heading of the logsheet, and all measurements of this sheet are corrected accordingly until the next calibration check. When the errors become excessive, over ±0.03% Cl, or change erratically from check to check, the electrodes are replatinized.

The measured salinity, expressed as chorinity of each sample is entered in the salinity logsheet, together with its bottle number and salinometer correction.

Empty sample bottles are washed and dried thoroughly and sealed, ready for next use.

5. DATA PROCESSING

5.1 Punchcards

From the edited ship's data and salinity measurements in the laboratory, three different kinds of computer punchcards are prepared, one of each kind for each station:

(a) from the bridge log:

date and time
position
meteorological data

(b) from engineroom log:

date and time
sample bottle number
thermograph reading
thermometer reading

(c) from salinity log:

bottle number
chlorinity.

From here onwards, data processing proceeds by computer. We shall only describe the operations on the data in brief outline, without going into programming details - these depend largely on the machine available, and change whenever machines change.

5.2 First pass: cruise summary

Batches of the three kinds of data input cards, covering the whole of a ship's cruise, are fed into the computer which combines the data for each station on a single printout line. This cruise summary contains the following information (Fig. 5):

Fig. 5 Computer Printout - Cruise summary

VESSEL *MAHENO* (17) CRUISE 24 YEAR 72 ALL TIMES GMT

STAT NUMB	DATE MT DA	TIME	POSITION LAT	LON	TEMPS. GPH	THER	SALIN	AIR TEMP DRY	WIND DN	FC	WE V	SEA DN A	SWEL DN A	SPEED	THER-GPH
762	12 23	19 0	4023S	17316E	15.8	15.9	35.07	16.0	35	07				0.0	.1
763	12 23	21 0	4015S	17237E	15.2	15.2	34.99	16.6	30	07				19.9	0.0
764	12 23	23 0	40 1S	172 0E	16.5	16.7	34.94	17.0	28	07				19.8	.2
765	12 24	1 0	3940S	~~17441E~~ 17121	16.7	17.0	35.17	17.0	27	06				81.2	.3
766	12 24	3 0	3938S	17042E	16.6	17.0	35.23	16.5	25	05				*9.5	.4
767	12 24	5 0	3926S	170 4E	16.9	17.0	35.32	16.4	25	05				19.9	.1
768	12 24	7 0	3915S	16926E	17.0	17.0	34.96	16.0	25	04				19.8	0.0
769	12 24	9 0	39 4S	16847E	17.4	17.4	35.41	16.3	32	04				20.3	0.0
770	12 24	11 0	3852S	168 9E	17.4	17.2	35.44	16.5	32	05				19.9	-.2
771	12 24	13 0	3840S	16730E	17.7	17.7	35.43	17.2	29	05				20.4	0.0
772	12 24	15 0	3829S	16652E	17.3	17.5	35.39	14.0	28	05				19.8	.2
773	12 24	17 0	3817S	16614E	17.5	17.9	35.39	14.0	28	05				19.9	.4
774	12 24	19 0	38 5S	16535E	17.8	18.1	35.41	14.0	27	04				20.4	.3
775	12 24	21 0	3753S	16456E	17.7	17.8	35.21	14.2	27	04				20.4	.1
776	12 24	23 0	3731S	~~16346E~~ 16406	18.0	18.2	35.32	17.8	27	05				36.7	.2
777	12 25	1 0	3724S	16312E	18.3	18.4	35.41	18.2	27	06				17.4	.1
778	12 25	320	3711S	16229E	19.6	19.7	35.52	18.0	27	06				19.3	.1
779	12 25	520	37 0S	16152E	19.4	19.3	35.44	17.0	27	07				19.3	-.1
780	12 25	7 0	3651S	16120E	19.3	19.2	35.43	17.2	25	07				19.9	-.1
781	12 25	9 0	3633S	16044E	18.9	18.9	35.44	17.5	25	08				20.1	0.0

36 ATYPE CARDS READ 36 CTYPE CARDS READ 36 SALINITY CARDS READ
FIRST STAT 762 LAST STAT 797
SLOPE = -.037 CONSTANT = .759
MEAN THERMOGRAPH CORRECTION = .02 STANDARD ERROR = .21

Fig. 5. Computer Printout - Cruise summary.

Station Number: chronological, by ship and year. Assigned by the computer.

Month and date

Time

Position: latitude and longitude, in degrees and minutes.

Water Temperature: thermograph and thermometer readings.

Salinity: chlorinity is converted to salinity, and the sample assigned to its proper station by means of bottle numbers in bridge and salinity logs.

Meteorological data: air temperature, wind, sea state. This data is for reference only, no use being made of it in the program.

Ship's speed: calculated from station positions and time between stations. Serves as a check for position errors.

Difference between thermometer and thermograph readings.

For the whole cruise, or batch of cards, the computer also determines and lists at the end of the printout:

Number of data cards of each type.

First and last station number in the batch.

Slope and constant of the best linear fit between thermograph reading and thermometer - thermograph difference.

Mean thermograph correction for this particular cruise.

Standard error of the differences between thermometer and thermograph readings.

It must be pointed out that these corrections, standard errors and best linear fit parameters pertain only to differences between thermometer and thermograph readings: they entirely ignore any errors caused by the installation of the sampling point and are in no way indicative of the measurement errors and uncertainties between actual and indicated seawater temperatures (cf. "Quality of raw data - temperature").

SURFACE SAMPLE LISTING FROM FILE   ALL TIMES GMT

VC	CR	STAT	YR	MT	DA	TIME	LAT.	LONG.	TEMP.	SALIN	V	SWEL DN	SWEL A	S.D.	AIR TEMPS DRY	WIND DN	WIND FC	WE	ATMOS. PRESS.	SEA DN	SEA A	T T
86	Ø8	Ø662	72	12	Ø8	14ØØ	381ØS	162Ø2E	19.1	35.55					15.7	21	Ø4					C
P6	Ø1	Ø127	72	12	Ø1	233Ø	38Ø2S	16457E	16.7	35.39					15.1	19	Ø3					C
P6	Ø1	Ø173	72	12	Ø7	213Ø	38Ø6S	16436E	16.5	35.3Ø					16.2	3Ø	Ø5					C
I7	24	Ø774	72	12	24	19ØØ	38Ø5S	16535E	17.9	35.41					14.Ø	27	Ø4					C
P6	Ø1	Ø126	72	12	Ø1	213Ø	381ØS	1653ØE	16.7	35.39					14.5	19	Ø4					C
P6	Ø1	Ø174	72	12	Ø7	233Ø	3818S	16513E	16.8	35.39					16.5	3Ø	Ø5					C
P6	Ø2	Ø273	72	12	3Ø	Ø13Ø	3818S	16542E	18.5	35.43												C
P6	Ø2	Ø274	72	12	3Ø	Ø33Ø	38Ø7S	165Ø6E	18.5	35.41												C
I7	23	Ø739	72	12	Ø9	23ØØ	3824S	16644E	17.4	35.44												C
I7	23	Ø74Ø	72	12	1Ø	Ø1ØØ	3812S	166Ø2E	16.7	35.35					16.7	36	Ø5					C
I7	24	Ø772	72	12	24	15ØØ	3829S	16652E	17.4	35.39					14.Ø	28	Ø5					C
I7	24	Ø773	72	12	24	17ØØ	3817S	16614E	17.6	35.39					14.Ø	28	Ø5					C
P6	Ø1	Ø124	72	12	Ø1	173Ø	3832S	16646E	15.9	35.3Ø					13.5	2Ø	Ø4					C
P6	Ø1	Ø125	72	12	Ø1	193Ø	382ØS	1661ØE	16.Ø	35.3Ø					15.Ø	19	Ø4					C
P6	Ø1	Ø175	72	12	Ø8	Ø155	3823S	166Ø7E	16.6	35.41												C
P6	Ø1	Ø176	72	12	Ø8	Ø33Ø	3831S	16636E	16.2	35.3Ø					15.2	24	Ø4					C
P6	Ø2	Ø272	72	12	29	233Ø	3828S	16618E	18.1	35.43												C
I7	23	Ø738	72	12	Ø9	21ØØ	3836S	16726E	16.4	35.41					15.Ø	Ø2	Ø3					C
I7	24	Ø771	72	12	24	13ØØ	384ØS	1673ØE	17.8	35.43					17.2	29	Ø5					C
P6	Ø1	Ø123	72	12	Ø1	153Ø	3849S	167Ø3E	16.Ø	35.39					14.Ø	2Ø	Ø5					C
P6	Ø1	Ø177	72	12	Ø8	Ø53Ø	3842S	16713E	16.7	35.39					15.5	21	Ø5					C
P6	Ø1	Ø178	72	12	Ø8	Ø73Ø	3853S	16754E	16.1	35.37					15.5	21	Ø4					C
P6	Ø2	Ø27Ø	72	12	29	19ØØ	3851S	16741E	17.Ø	35.39												C
P6	Ø2	Ø271	72	12	29	21ØØ	3841S	167Ø4E	17.5	35.43												C
I7	23	Ø737	72	12	Ø9	19ØØ	3849S	168Ø8E	16.6	35.39												C
I7	24	Ø77Ø	72	12	24	11ØØ	3852S	168Ø9E	17.5	35.44					16.5	32	Ø5					C
N9	12	Ø344	72	12	12	18ØØ	3952S	1445ØE	15.5	35.71					13.5	25	Ø3					C
N9	11	Ø326	72	12	Ø1	14ØØ	39Ø1S	145Ø2E	17.Ø	35.7Ø					19.4	Ø7	Ø3	Ø2			3	C
N9	11	Ø327	72	12	Ø1	16ØØ	3933S	14521E	15.7	35.62					19.Ø	Ø6	Ø3	Ø3			3	C
N9	12	Ø332	72	12	1Ø	14ØØ	3956S	14536E	15.2	35.52					16.1	3Ø	Ø6					C
N9	12	Ø333	72	12	1Ø	16ØØ	3924S	14516E	15.5	35.5Ø					16.Ø	26	Ø6					C

Fig. 6. Computer Printout - monthly station summary.

The first computer printout undergoes another proofreading and editing, where remaining undetected errors and inconsistencies are corrected. New cards are punched to replace those with erroneous entries, and the cruise data are ready for the next processing step in the machine.

5.3 Second pass: monthly summaries

For the second pass through the computer, all cruise summaries for all ships for one month are fed into the machine.

Operations performed on the month's data are twofold in this pass, and the output is printed out as two distinct listings:

1) a "surface sample listing from file" (Fig. 6).

In this listing, all stations have been sorted in sequence according to geographical latitude. Within each degree latitude, stations are grouped according to the observing ship.

This printout lists the following data:

Ship's name (coded)

Cruise number

Station number

Month and date

Time

Latitude

Longitude

Temperature = (1+s)Tg+C; where s-slope, C-constant, Tg-thermograph reading (slope and constant from cruise summary.)

Salinity

Meteorological data

2) Data from geographically sorted listings are averaged over each square degree for which entries are available, and listed in the "1 square degree summary" (Fig. 7):

Latitude (degrees and minutes. Mean of all stations within the square degree).

Longitude (degrees and minutes. Mean of all stations within the square degree).

SURFACE SAMPLE LISTING FROM FILE   ALL TIMES GMT

LAT	LONG	MEAN TEMP	NO. T	S.D. T	MEAN SAL	NO. S	S.D. S
37S	165E	16.9	1	Ø.ØØØ58..2Ø.	35.35	1	Ø.ØØØ58..2Ø.
38S	137E	16.6	1	Ø.ØØØ 3..29.	35.46	1	Ø.ØØØ 3..29.
38S	138E	17.1	4	.6Ø41Ø..26.	35.46	4	.Ø611Ø..26.
38S	139E	17.Ø	3	.3Ø921..33.	35.46	3	.Ø6121..33.
38S	14ØE	16.9	4	.52628..21.	35.4Ø	4	.Ø9628..21.
38S	141E	17.2	4	.58Ø35..23.	35.57	4	.Ø3535..23.
38S	142E	17.2	4	.5ØØ43..27.	35.62	4	Ø.ØØØ43..27.
38S	143E	18.1	1	Ø.ØØØ5Ø..2Ø.	35.71	1	Ø.ØØØ5Ø..2Ø.
38S	144E	16.4	1Ø	.42436..45.	35.64	1Ø	.Ø4636..45.
38S	145E	15.5	1	Ø.ØØØ57.. Ø,	35.55	1	Ø.ØØØ57.. Ø.
38S	147E	16.1	3	.2Ø45Ø..38.	35.54	3	.Ø595Ø..38.
38S	148E	17.7	7	1.ØØ444..29.	35.56	6	.Ø6142..33.
38S	149E	18.5	17	.54526..33.	35.56	17	.Ø4726..33.
38S	16ØE	18.8	1	Ø.ØØØ44..33.	35.46	1	Ø.ØØØ44..33.
38S	161E	19.Ø	2	Ø.ØØØ28..16.	35.48	2	Ø.ØØØ28..16.
38S	162E	19.1	1	Ø.ØØØ1Ø.. 2.	35.55	1	Ø.ØØØ1Ø.. 2.
38S	164E	16.6	2	.Ø94 4..46.	35.35	2	.Ø45 4..46.
38S	165E	17.7	5	.82112..25.	35.41	5	.Ø1512..25.
38S	166E	16.9	9	.74624..25.	35.37	9	.Ø5424..25.
38S	167E	16.8	7	.64Ø45..24.	35.4Ø	7	.Ø2145..24.
38S	168E	17.Ø	2	.4815Ø.. 9.	35.42	2	.Ø255Ø.. 9.
39S	144E	15.5	1	Ø.ØØØ52..5Ø.	35.71	1	Ø.ØØØ52..5Ø.
39S	145E	15.5	24	.46824..2Ø.	35.55	24	.Ø8824..2Ø.
39S	146E	15.5	4	.34Ø1Ø..36.	35.58	4	.1541Ø..36.
39S	147E	16.1	12	.52333..2Ø.	35.57	12	.1ØØ33..2Ø.
39S	148E	17.1	6	.75314..17.	35.54	6	.Ø6Ø14..17.
39S	149E	17.6	14	.51927..26.	35.58	12	.Ø6928..27.
39S	15ØE	17.2	4	.7Ø418..4Ø.	35.5Ø	4	.1Ø518..4Ø.
39S	151E	17.8	4	.35Ø2Ø..41.	35.63	4	.Ø492Ø..41.
39S	152E	17.3	3	.73525..25.	35.55	3	.Ø9425..25.
39S	153E	17.1	4	.64Ø29..33.	35.47	4	.Ø8829..33.
39S	154E	17.2	3	.Ø4237..32.	35.49	3	.11Ø37..32.
39S	155E	17.2	3	.Ø8434..23.	35.52	3	.Ø1234..23.
39S	156E	16.8	1	Ø.ØØØ25..22.	35.35	1	Ø.ØØØ25..22.
39S	157E	17.1	6	.72745..24.	35.52	6	.13445..24.
39S	158E	16.8	7	.85845..28.	35.35	6	.Ø7943..29.

Fig. 7. Computer Printout - 1 square degree summary.

Mean temperature

Number of temperature observations

Standard deviation of temperatures

Mean salinity

Number of salinity observations

Standard deviation of salinities.

Very large standard deviations of temperatures can be found in this listing, amounting to over 1^{o}C. Part of these high values are caused by installational differences between ships, partly they are real: in computing mean temperatures, observations for the entire square degree are lumped together over the whole month. Observations averaged together can have been separated by 80 miles in space, and/or 30 days in time. In the ocean, surface temperature differences of a few degrees Celsius can occur over much shorter distances (e.g., fronts and patches); twice a year, in spring and fall, surface temperatures are subject to rapid change, a degree or more in a few weeks or even days is not unusual.

The listing of one degree mean values also is proofread and edited for obviously wrong entries, keeping in mind the probability of real temperature variations in the time and space covered.

(To facilitate this final editing, until recently a second sorting of the month's data was done at the same time: entries were identical in content to the monthly summary mentioned above, except that they were listed in order of descending temperature, not geographical latitude.

This information was also presented as a T-S diagram, done on the computer's line printer: the number of observations falling within each 0.1^{o}C x 0.1‰ S cell was printed out in the appropriate place in the grid. This made unlikely T-S combinations extremely conspicuous and gave guidance for correction of erroneous entries.)

5.4 Third pass: grid printout, contours

The third and final pass of the data through the computer positions the monthly 1 square degree average values on a square grid, each value being printed out inside its proper square degree. Mean position of the stations inside the square are indicated by a mark at the correct place.

Separate grids are printed for temperature and salinity. These printouts, done on a large plotter, are prepared in a scale matching available contour charts of the areas covered: 0^o-50^oS, 140^o-180^oE for the Tasman and Coral Seas; 29^o-45^oS, 133^o-156^oE for the south-eastern region.

(Until recently, a grid printout of temperature and salinity standard deviations also was prepared in the same format.)

Transparent chart overlays are positioned over the computer grid printouts, and isotherms for every degree C, isohalines for every 0.1% S, are pencilled in by the senior scientist in charge of the sampling program.

Data points are available only in square degrees in which observations have been made during the month under analysis. Large areas, between ships' tracks, are without data - normally, these areas are left blank. Realistic estimates of isotherm and isohaline configurations can only be made for areas where data is available, relying heavily on knowledge of the area and its past history, and consulting the various listings and printouts described earlier.

The sketches are then redrawn and tidied up by a draughtsman, and the month's surface isotherm and isohaline charts are ready for publication.

6. DATA PRESENTATION - CHARTS

The main output of the sea surface sampling program are the monthly surface temperature and salinity charts.

Four charts are issued for every month, the total area covered by the program being divided into two regions:

(1) Tasman and Coral Seas (Figs. 8, 9)
0^o-50^oS, 140^o-180^oE.

(2) Southeastern Region (Figs. 10, 11)
29^o-45^oS, 132^o-156^oE.

Separate charts of temperature and salinity are issued for each region. Samples of one month's charts are depicted in Figs 8-11.

The charts are basically Mercator contour charts of the particular region. They carry a one-degree grid, but no bathymetry.

Dots along ship's tracks indicate the mean position of all observations taken within the particular one-degree square during the month.

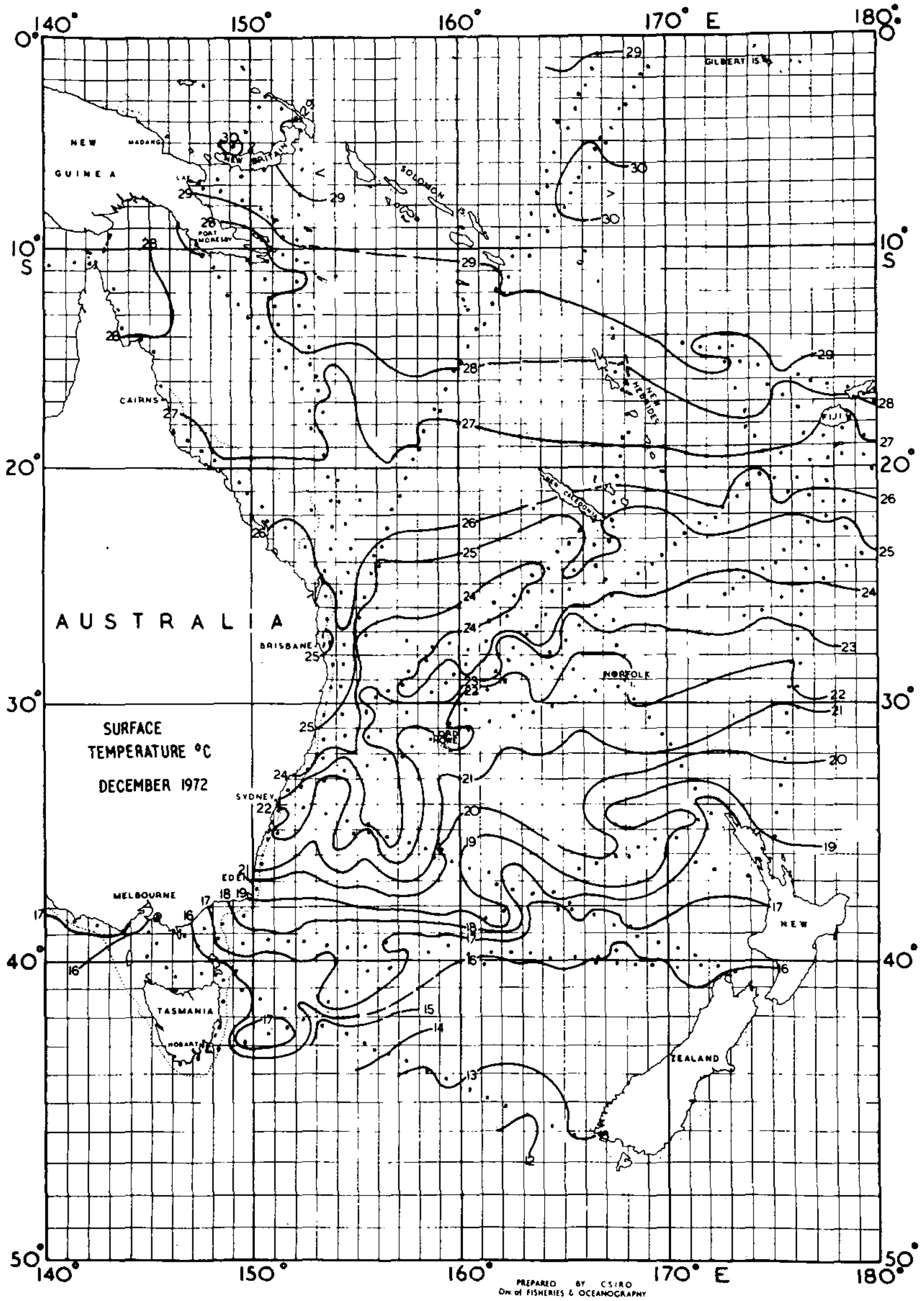

Fig. 8. Monthly temperature chart - Tasman and Coral Seas.

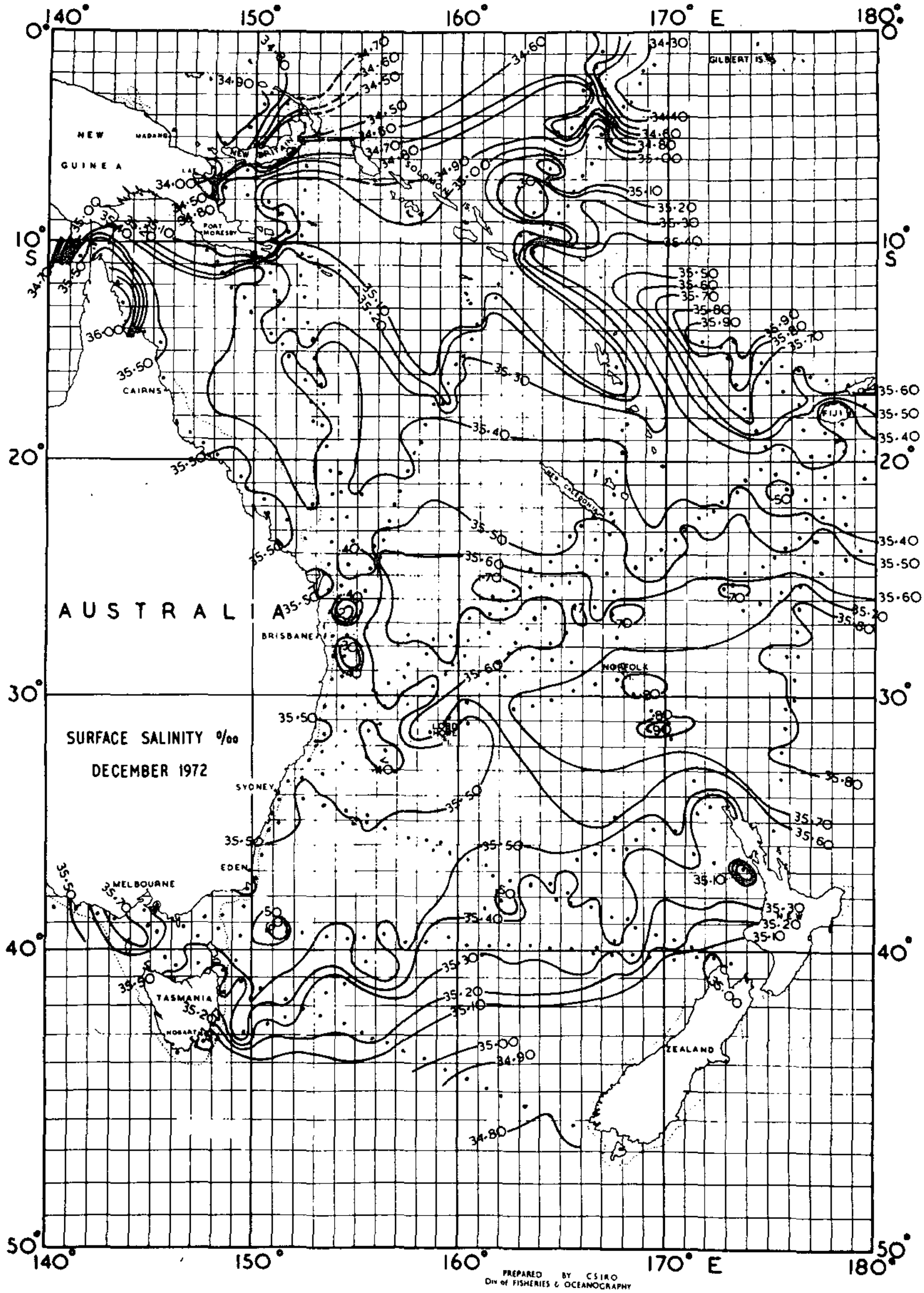

Fig. 9. Monthly salinity chart - Tasman and Coral Seas.

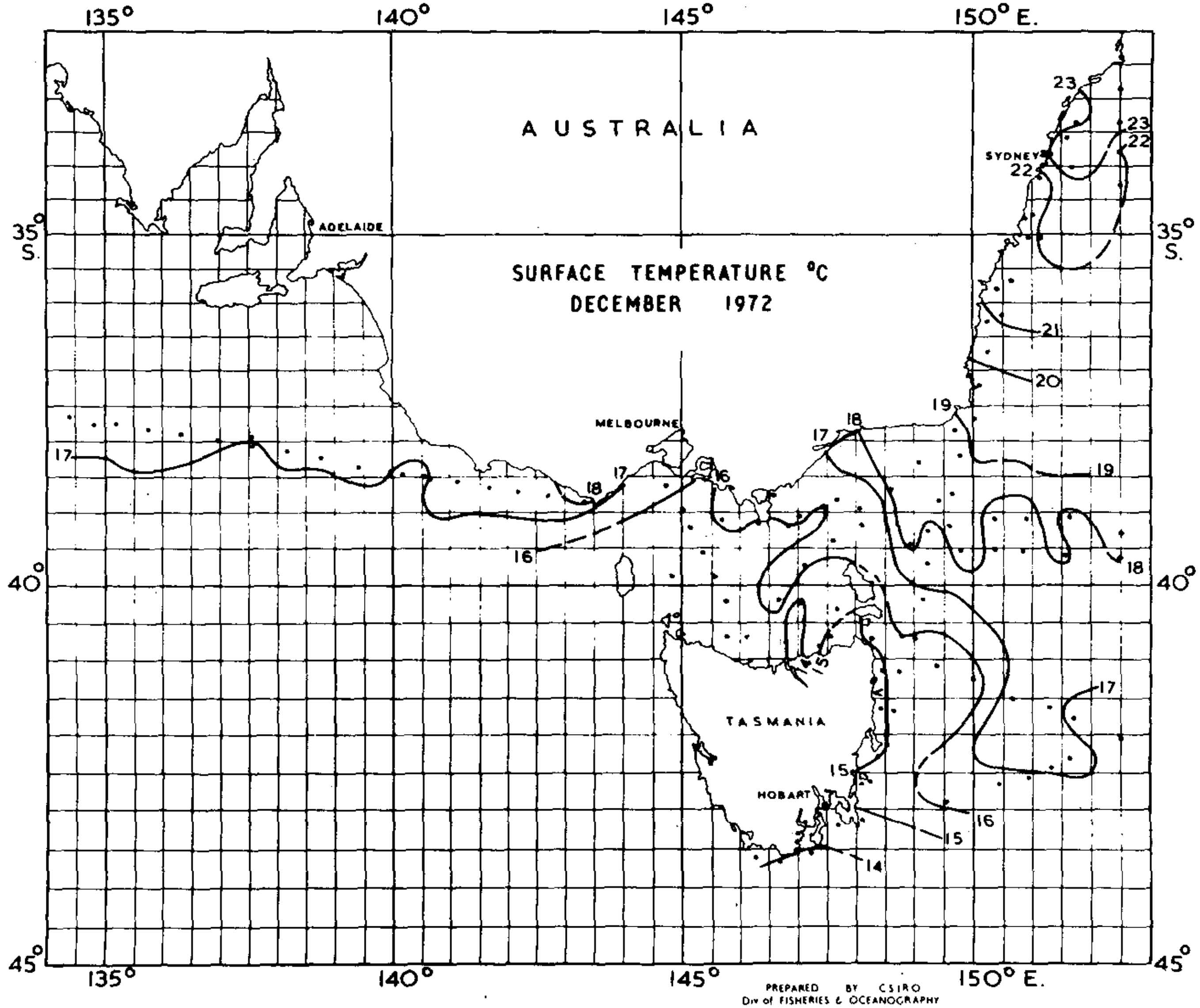

Fig. 10. Monthly temperature chart - Southeast Region.

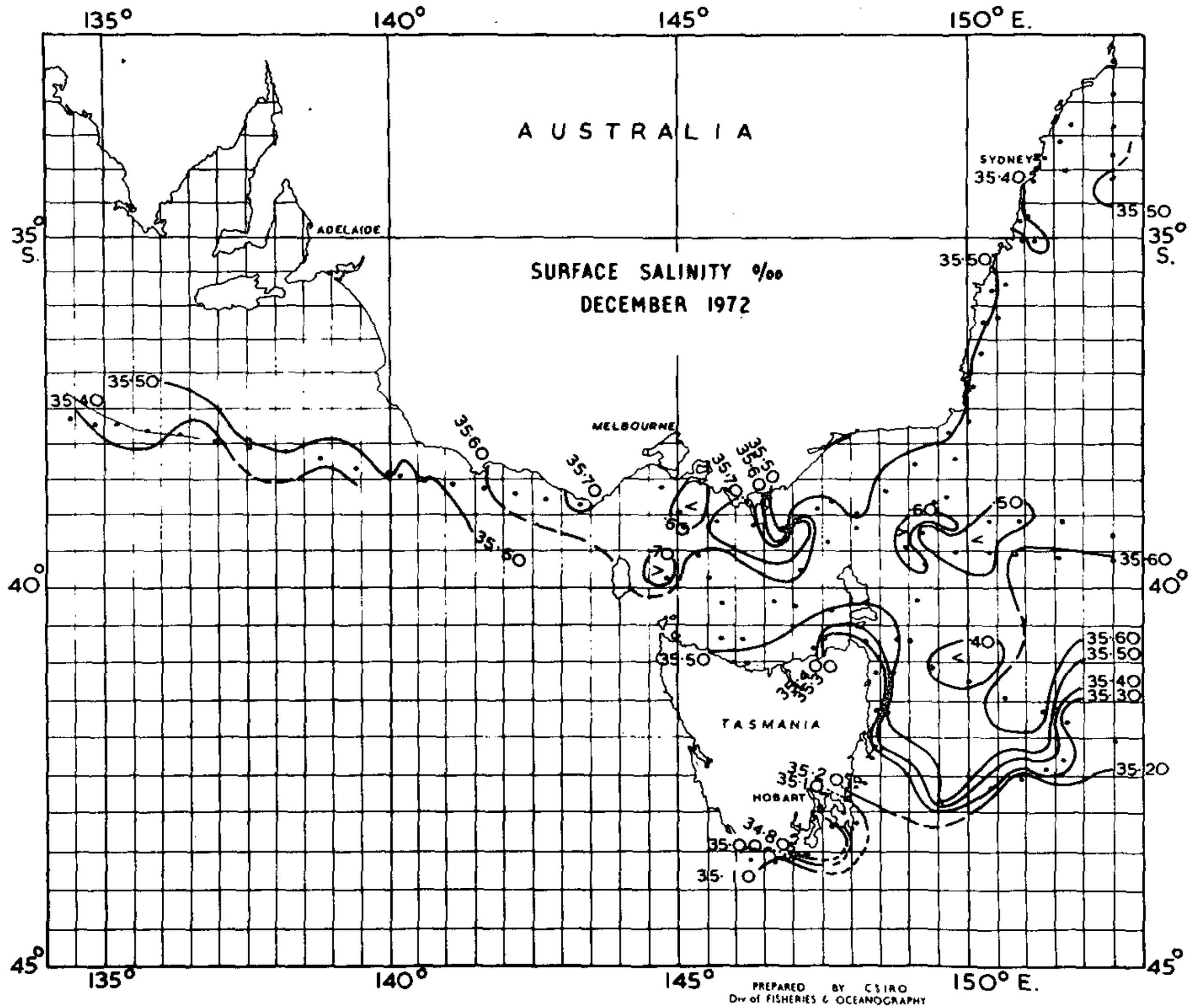

Fig. 11. Monthly salinity chart - Southeast Region.

The charts, 38 x 25.5 cm in size, are issued in sets covering a whole calendar year. At present, late 1973, publication of the charts has fallen behind - the latest Tasman and Coral Seas sets issued are for the year 1971.

About 50 copies of the chart sets are prepared of each issue. The present distribution includes about 25 addresses, mostly meteorological and fisheries research and administration groups in Australia, New Zealand and Japan.

7. OVERALL QUALITY OF RESULTS

Installation imperfections on board the participating ships are the main source of uncertainty and error in our data.

Temperature reading errors, more precisely differences between thermometer and thermograph readings, are reduced to a tolerable value by our various procedures: the mean standard temperature reading error (between thermometer and linearly adjusted thermograph readings) for all 1972 cruises is 0.3°C, peaking sharply in the interval 0.1-0.2°C.

Of course, reading error minimization leaves installational errors unaffected. As shown previously, these errors are systematic and introduce a bias into all engineroom temperature readings. We estimate the temperatures are too high by 0.5±0.5°C. Near the equator the bias can be expected to be near the low end of the range, increasing as one moves south towards colder surface waters.

Because of the bias, the average isotherms probably are distorted in shape, and located somewhat too far south, displaced towards colder water regions.

Inability to cope with patchiness of oceanic surface waters, in contrast to real fronts, introduces some additional unknown distortion into the shape of our isotherms. One should not try to read too much into the details of the charts - only the very large, broad features have any real significance.

Similar arguments apply to the isohalines, except that we have no reason to suspect the existence of a bias in our values. Salinities should be good to within ±0.03‰ Cl = ±0.05‰ S, limited by the maximum permissible salinometer shift between calibrations.

8. QUALITY AND SIGNIFICANCE OF RESULTS - A DISCUSSION

A quality assessment of a program which tries to describe average local conditions in a variable medium like the ocean, is largely a philosophical question.

Because of the very few and scattered observations for each final data point, the final product in our case temperature and salinity contour charts, is certainly an artifact that can describe the actual situation only approximately. At no time has the real distribution of variables been identical to the average, but we can be reasonably certain that the situation has been similar to our picture some time in the period of observations. Local values in an average model are tacitly assumed to lie between the observed values of the parameter - a somewhat debatable assumption since there is no guarantee that the few observed values really have described extremes of local conditions.

Although the near-surface oceanic waters are subject to quite efficient natural averaging processes by wind and weather from one side, the other being stabilized by the tremendous heat capacity of the seasonal thermocline, they are not uniform in space because of patches, distinct bodies of water differing in temperature from the mean, which travel around in the sea for long periods of time without losing their individuality by mixing. A sampling program like ours, where readings are taken at fixed intervals during a ship's passage through the area, does not correct for their influence on mean values (it could be done if thermogram readings were taken not at sampling times, but averaged over the interval between samples). A patch differing by half a degree in temperature from the spatial average in its vicinity - a common enough occurrence - can introduce large distortions in the course and shape of mean surface isotherms deduced from only a few observations in the area.

Also, real variability in time and space of surface temperatures is apt to deform the shape of deduced isotherms if observations are few and widely scattered - like ours.

For these reasons, one has to agree with James and Fox *(op. cit)* and others (e.g. Franceschini, 1955): ship's sea surface temperatures cannot be utilised to portray true synoptic conditions, or show fine details in anomalous cases.

The real value of large-scale, long-time sampling programs is historical, in documenting and describing conditions over long periods of time, years and decades. The influence of short-term or small scale imperfections filters out in averages over such long periods, and the results become very useful and usable for detection of long term changes in areas larger than the original cell size (ours: month x square degree): e.g., 6-year time series based on our charts indicate a gradual warming of the surface waters in the area of our operations. Both the summer and winter temperatures show a gradual increase over the years (Fig. 12).

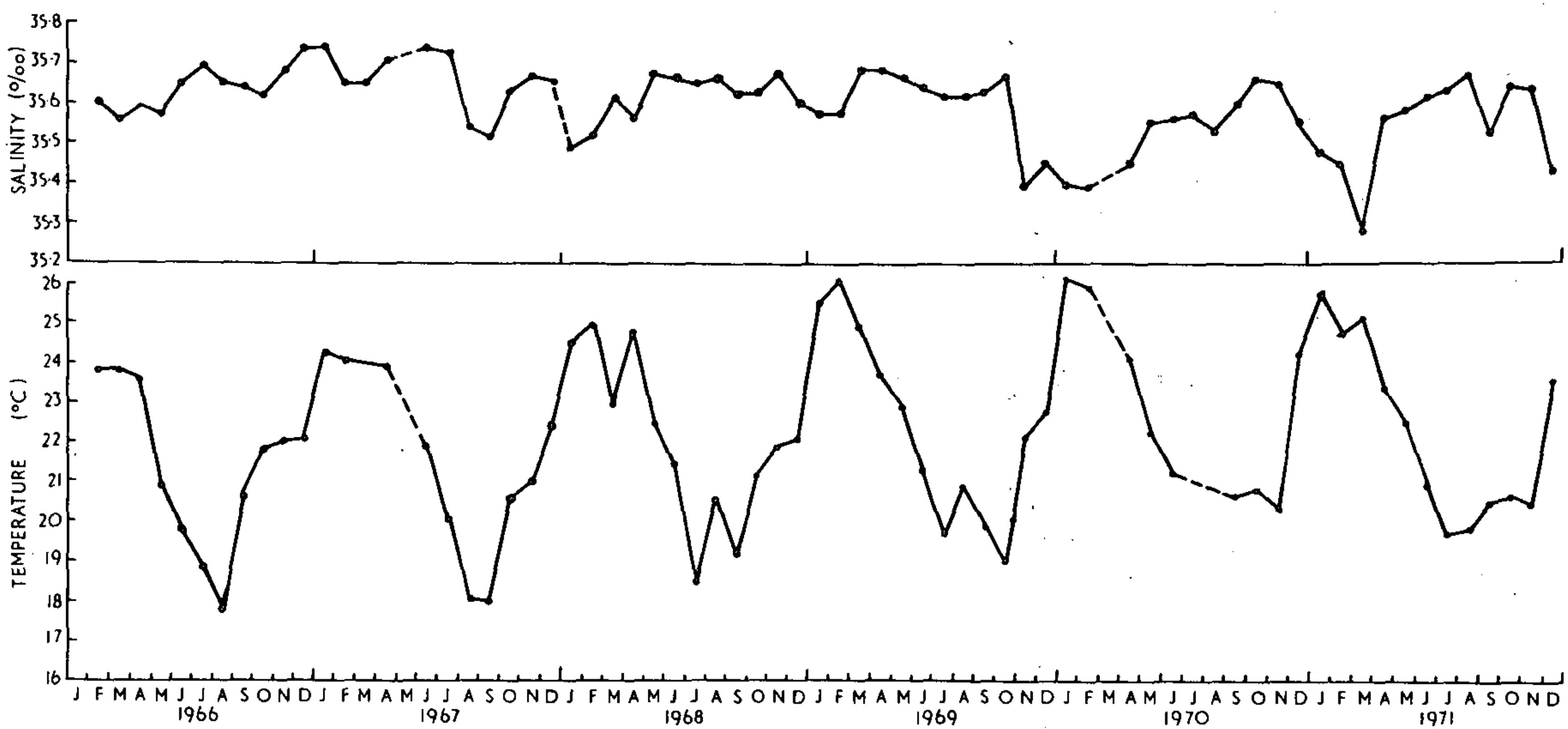

Fig. 12. Time series 1966-71, 32-33°S 154-155°E, Salinity and Temperature.

Systematic measurement errors play a minor role in long time series trend analyses - provided the errors have remained constant. If they have changed - because of a change or improvement in measuring methods - one has to know the magnitude of the change.

9. REFERENCES

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APPENDIX I.

Ships participating in program in 1973

NAME OF COMPANY	NAME OF SHIP	SIZE (Gross Tons)	SPEED (Knot)	ROUTE
Australian National Line	Australian Trader	7005	17½	Hobart-Sydney,Burnie(Tas.)-Sydney
	Empress of Australia	8196	18½	Melbourne-Devonport(Tas)-Melbourne
	North Esk	1603	10	Pt.Pirie(S.A.)-Hobart,Hobart-Geelong(Vic.)
	Darwin Trader	10802	15½	Brisbane(Qld)-Darwin(N.T.)
Broken Hill Proprietary Co Ltd	Iron Endeavour	40316	15	Kwinana(W.A.)-Pt.Kembla(NSW)
Department of Shipping and Transport (Commonwelath of Australia)	Cape Moreton	2106	15	Melbourne-Flinders Islands (Bass Strait)-St.Vincents Gulf(S.A.)
	Cape Pillar	2106	15	
Union Bulkships Pty Ltd (Aust)	Kooringa	5976	16	Melbourne-PerthW.A.)
Union Steam Ship Company of New Zealand Ltd (New Zealand)	Maheno	4510	18	Wellington(N.Z.)-Sydney
	Hawea	2926	16½	Sydney-Lyttleton(N.Z.)-Sydney Melbourne-Lyttleton-Melbourne
	Ngakuta	4576	12½	Sydney-Auckland(N.Z.)-Melbourne
	Seaway King	2961	16	Hobart(Tas.)-Sydney
New Guinea Australia Line	Coral Chief	3945	14½	Sydney-Lae-Rabaul(New Guinea)
	Island Chief	3925	14½	Sydney-Pt.Moresby(New Guinea)
Karlander Aust. Pty Ltd	Salamaua	4367	13½	Sydney-New Caledonia-Solomon Islands(Santo)
Pacific Navigation Co.	Tauloto 2.(ex-Safia)	4367	13½	Sydney-Fiji-Samoa-Tonga
Gilbert & Ellice Islands Development Authority	Ninikoria	800 approx	8	Nauru-Ocean Island-Gilbert & Ellice Islands-Fiji
	Moanaraoi	800 approx	8	Nauru- Ocean Island-Gilber & Ellice Islands-Fiji
Nauru Pacific Line	Enna G	9994	15	Melbourne-Nauru-Fiji-Sydney
	Rosie D	9994	15	Sydney-Nauru-Fiji-Sydney
Messageries Maritimes Cie.	Polynesie	1846	12	Sydney-New Caledonia-New Hebrides (Vila)