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COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

Division of Fisheries and Oceanography

REPORT 53

THE FRENCH - AUSTRALIAN SATELLITE - BUOY EXPERIMENT

By G. R. Cresswell

Marine Laboratory
Cronulla, Sydney
1973

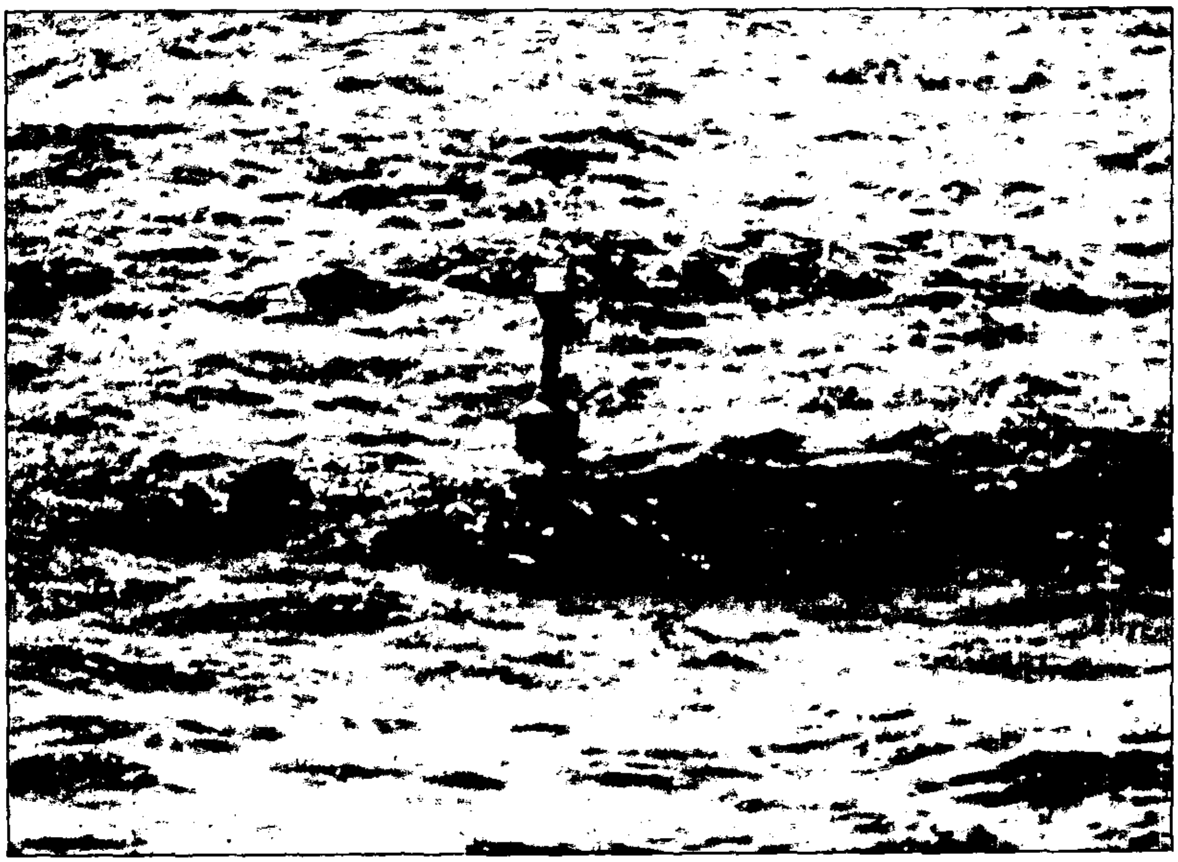

Plate 1. The buoy shortly after its release in the Tasman Sea.

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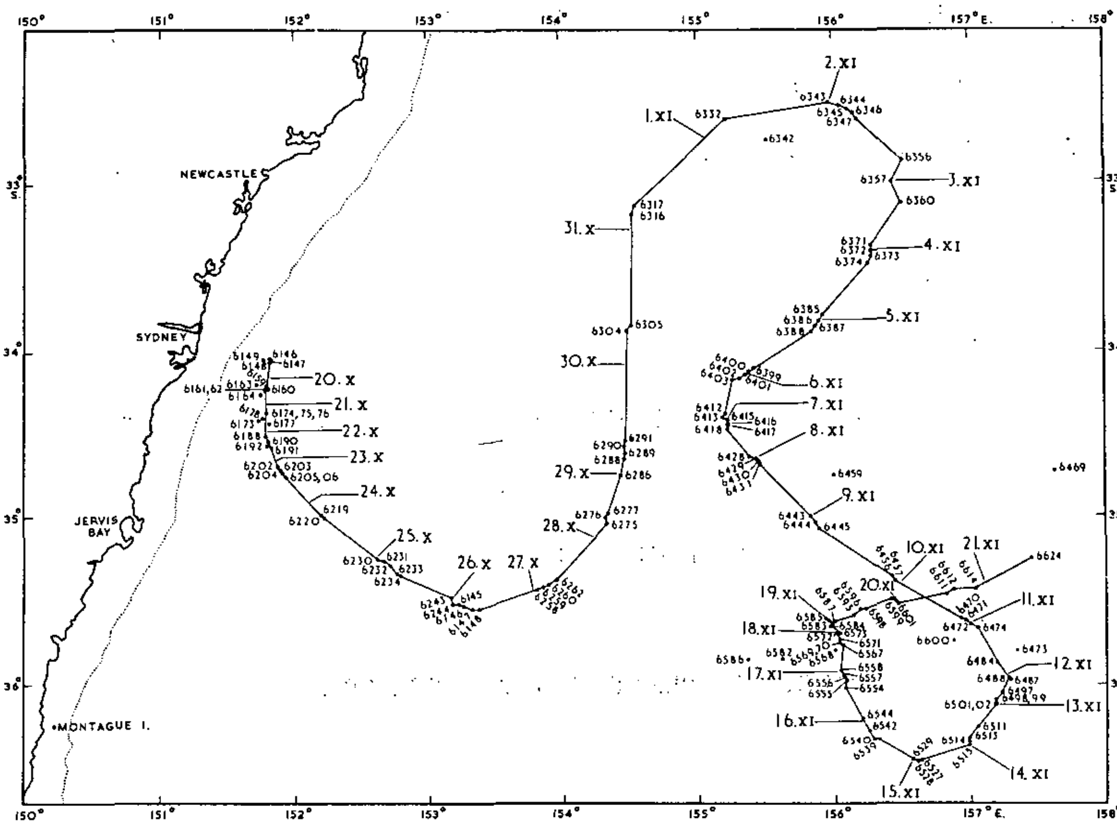

Fig. 1. The positions of the buoy for the period October 19 to November 21, 1972. The large numbers give estimated positions at 0000 hrs GMT daily, while the small four-figure numbers are "EOLE" satellite orbit numbers.

Abstract

The design, testing, and deployment of a prototype fibreglass spar buoy to carry an EOLE satellite transponder for ocean current and environmental measurements is described. The buoy with a drogue at 30 m depth was released in the East Australian Current and transponded to the satellite for 33 days, travelling 1400 km in a meandering path that took it 600 km eastward. The path of the buoy, in general, agrees with qualitative current estimates from aircraft I-R data, ship expendable bathythermograph data, and ship sea surface temperature data. The buoy, minus its drogue, drifted ashore after 4 months.

INTRODUCTION

In November, 1971, it was proposed to the Centre National d'Études Spatiales (CNES) of France that one of their "EOLE" satellite transponders (Morel, 1972) be used aboard a CSIRO instrumented free-drifting buoy. This followed their announcement that transponders could be made available to non-French researchers. It was planned to release the buoy in November, 1972 in the Eastern Indian Ocean to study surface currents to determine the role that these play in the prodigious migration of rock lobster larvae; the larvae can be found hundreds of kilometres out to sea. Estimates of seasonal wind-driven surface currents (Chittleborough and Thomas, 1969, Cresswell, 1972) have shown that these currents could carry the larvae seaward each summer when they hatch in the nearshore reefs of Western Australia.

In April, 1972, two transponders - one being a spare - and one antenna reached us from CNES. A transponder/antenna combination was laboratory and buoy tested from this time while battery supplies were tried, temperature sensor circuits were prepared and calibrated, and a prototype PVC/fibreglass spar buoy was built and tested.

In order to give the buoy a test in conditions perhaps more severe than it would encounter while free-drifting, it was moored in 15 metres of water about 1 km from Cronulla in the open ocean. It survived a great storm for a day, during which it was battered and immersed by breaking 3-6 m waves. It then broke at the junction directly beneath its flotation collar and the top section washed ashore.

A new bottom section was fitted and two strengthening cones were added above and below the flotation collar. The buoy was moored again, first for three weeks with a recording anemometer on the top, and then for two weeks with the transponder running. It was then brought ashore and checked and the sensors (which had been inside the buoy) were mounted externally.

At this juncture, because of notification that the "EOLE" experiment would finish on 31 December, 1972, it was decided to conduct an experiment in the East Australian Current. The relatively early finish to the experiment would have reduced the value to the lobster larval migration study in Western Australia and also there was more likelihood of obtaining supplementary data (airborne I.R. maps, XBT drops and sea surface thermograph records) for an eastern Australian experiment.

On 19 October, 1972, the buoy was released 50 km east of Cronulla. The launching was accomplished by four people sliding it over the stern of a 16 m fishing boat. The buoy carried thermistors for sea surface and air temperature, a radio beacon (27.195 mHz) and a red flashing light. Directly beneath the buoy was 4 m of 12 mm galvanized chain, then a swivel, and then 27 m of 37 mm circumference polyethylene line, to which was attached a "window blind" drogue 5.3 m x 4.2 m made of vinyl-covered nylon. The buoy communicated with the satellite until 21 November, 1972, and its track is shown in Figure 1; all fixes are shown, but the plotted track neglects doubtful fixes.

2. BUOY CONSTRUCTION

A local plastics firm constructed the spar buoy (Figure 2). The backbone of the buoy was 4.9 m of PVC pipe (outside diameter, O.D., 14 cm, I.D. 12.7 cm). To it was welded shaped PVC sheet for the bottom disc, the flotation collar, and the antenna receptacle. Two 2.5 cm holes were cut in the PVC of the flotation collar and chemicals for plastic foam were poured in. When the excess had foamed through and set it was trimmed off and PVC plugs were welded into the holes.

Layers of fibreglass mat were applied to the buoy and later 7.5 cm wide woven fibreglass "bandage" was wrapped around the tube section. After two finishing coats of resin had been applied the total fibreglass/resin thickness was about 5 mm. Following the moored destruction test it was felt that the inclusion of the extra cones would distribute stresses more evenly. Also, the thickness of the fibreglass and resin was increased to 10 mm at the junctions.

The transponder, supported by sponge plastic annuli, and its batteries (100 alkaline D cells in parallel sets of 10, expected to last well over one year), and the batteries for the radio beacon and light, were packed into 11.5 cm O.D./10 cm I.D. PVC tubes having PVC end caps with "O" rings. The tubes were held mechanically to each other by 11.5 cm O.D./10.8 cm I.D. PVC tube "clamp" sections 60 cm long that had a 2 cm slot cut along them; cables were taken up the slots. This gave an instrument package with an O.D. of about 12.4 cm, taking into account the distortion of the clamp sections. It fitted firmly into the buoy. Underwater connectors were used so that the transponder would operate even if the central tube of the buoy became full of water; the individual tubes contained silica gel packs. Cables for the radio beacon, the light, and test terminals were brought through holes in a 5 cm diameter, 2.5 cm thick PVC gland in the top of the buoy. Epoxy was used to plug the holes and anchor the cables.

A 30 x 1.2 cm steel disc having a "U" rod welded to it was attached to the buoy with four bolts. Two drilled halves of a steel annulus 30 x 5 x 0.3 cm were used on top of the fibreglass disc, rather than washers. The 18 bolts in the transponder antenna were used to attach it to the top of the buoy. Air-curing "Mastik" formed the gasket.

Some of the component masses of the buoy are given in Table 1.

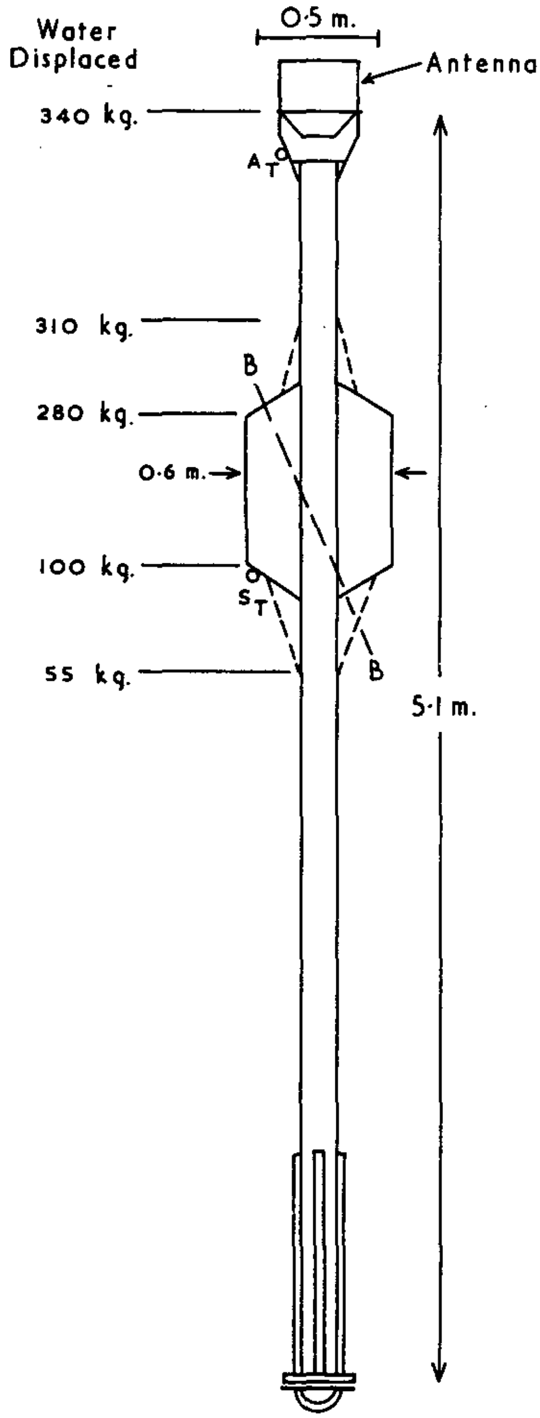

Fig. 2. A diagram of the buoy. The dashed lines show the modifications made to the prototype. A_T shows the position of a sun-shielded air temperature thermistor; S_T the position of a sea surface temperature thermistor. The line B-B shows the barnacle line evident when the buoy was recovered (Appendix A).

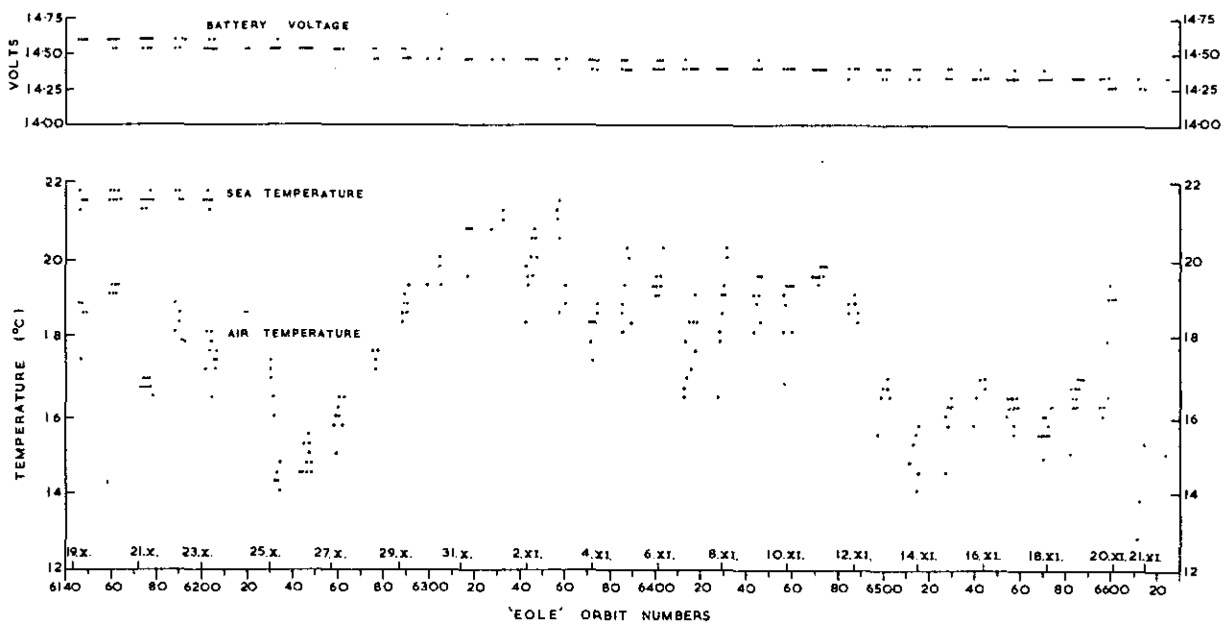

Fig. 3. Data received from the buoy via "EOLE". The dates given mark 0000 GMT for those days.

TABLE 1

Component masses of the buoy

Fibreglass hull and steel bottom plate	:	84 kg
Transponder tube (includes sensor circuit batteries)	:	15 kg
Transponder battery pack	:	26 kg
Radio beacon battery pack	:	4.5 kg
Flashing light battery pack	:	3 kg
Antenna and light	:	6.5 kg
		139 kg
Approximately 4 m of 12 mm chain	:	16 kg

3. DATA RECEIVED FROM THE BUOY VIA "EOLE"

Computer printouts forwarded by CNES contained the following information for each transponder response: orbit number, date and time, latitude and longitude, and four data channels of which three were usefully employed, viz. battery condition, sea surface temperature and air temperature. All this information was transferred to punched cards, but with the limited data from the experiment it was found adequate to do hand-drawn plots. Values from the three data channels are plotted against satellite orbit number in Figure 3. On many orbits there was more than one response, and therefore sometimes more than one datum value per channel.

The sea surface temperature channel, potentially the most useful in the experiment, unfortunately ceased working after five days, possibly because haste had dictated that the cable to the thermistor be only taped to the buoy (see also Appendix A). During the five days the sea temperature remained essentially constant - thereby agreeing with the buoy track in relation to the aircraft infra-red radiometer measured isotherms (see section 4).

The air temperature channel, identical to the sea surface temperature channel apart from the placement of the thermistor, functioned for the duration of the experiment. The temperature variation showed a reasonable agreement with the latitude of the buoy, being 15°C on October 25-27 and increasing rapidly to 21°C as the buoy moved north to November 1.

The channel for battery condition showed a linear decrease which amounted to about 0.3 volt. There was not a sudden decrease at the end which might have given a clue as to the fate of the buoy.

4. DATA FROM OTHER SOURCES

These took three forms: aircraft infra-red radiometer measurements of sea surface temperature made by CSIRO to locate schools of tuna; expendable bathythermograph (XBT) measurements made from the merchant ship *"Maheno"* and ships of the New Zealand and Australian Navies; sea surface temperatures recorded by merchant ships.

Aircraft isotherm maps were obtained for 9/10 October, 25 October, and 2 November, 1972. The buoy was within the mapped area on only one of these occasions, 25 October, and its track, the isotherms, and the aircraft flight path are shown in Figure 4. From the isotherm there was an indication of a meander across the northeast section of the mapped area. The track of the buoy lends credence to this suggestion. By 2 November the lower part of the meander, as indicated by the 22° isotherm, appeared to have moved 100 km to the southwest. The buoy during the interim had moved up the east side of the meander.

The *"Maheno"* XBT drops (Fig. 5) enable the current structure orthogonal to the section between Sydney and Wellington to be estimated. These data were provided prior to publication by Mr F.M. Boland, who has found (Boland, 1973) that the core of the East Australian Current occurs at the longitude where the 15°C isotherm crosses 250 m depth. This follows Hamon's (1968) finding that there is a very close relation between dynamic height and temperature at 240 m depth in the East Australian Current area.

When the buoy was released on 19 October at 34°S, 151°50'E the isotherm pattern showed few changes from that obtained fifteen days earlier: the southward-going core was at 152°45'E, or 100 km east of the buoy release point. This probably accounted for the slow initial drift (20 cm/sec) of the buoy. A northward-going current core at this time was at 155°15'E, but the current, judging by the moderate slope of the isotherms, was comparatively small.

On 2 November the southward-going core had moved westward by 50 km to 152°15'E, thereby agreeing, albeit zonally, with the aircraft finding that the lower part of the meander moved 100 km to the southwest during roughly the same period. Also on 2 November, the XBT data showed the northward-going core to have moved 100 km westward to 154°15'E and to have increased in strength. The buoy, by this time, was at its northernmost excursion, but on its fast northward run (average speed: 90 cm/sec between 29 and 31 October) it had travelled along the 154°30'E meridian, very near the core of the current. After reaching the northernmost point the buoy turned to travel southward in a current that was evident in the 2 November isotherm plot at 156°15'E (at 35°S).

By 17 November the southward-going current nearer the coast had moved - possibly south - away from the *"Maheno"* section; the northward current was weaker and had moved 50 km westward to 153°45'E and there was no evidence for the outer southward current. The buoy was south of the ship's path and was moving slowly northwards at 30 cm/sec prior to a rather sudden turn to the east on 19 November. Between 18 and 19 November its speed dropped to 7 cm/sec while once it had turned to the east its speed increased to 55 cm/sec. It was speculated at the time that the buoy had perhaps lost its drogue and was being driven by the wind.

The XBT drops made by HMNZS *"Otago"*, HMAS *"Swan"*, and HMAS *"Stuart"* showed that there was no evidence for noticeable currents between 157° and 159°E.

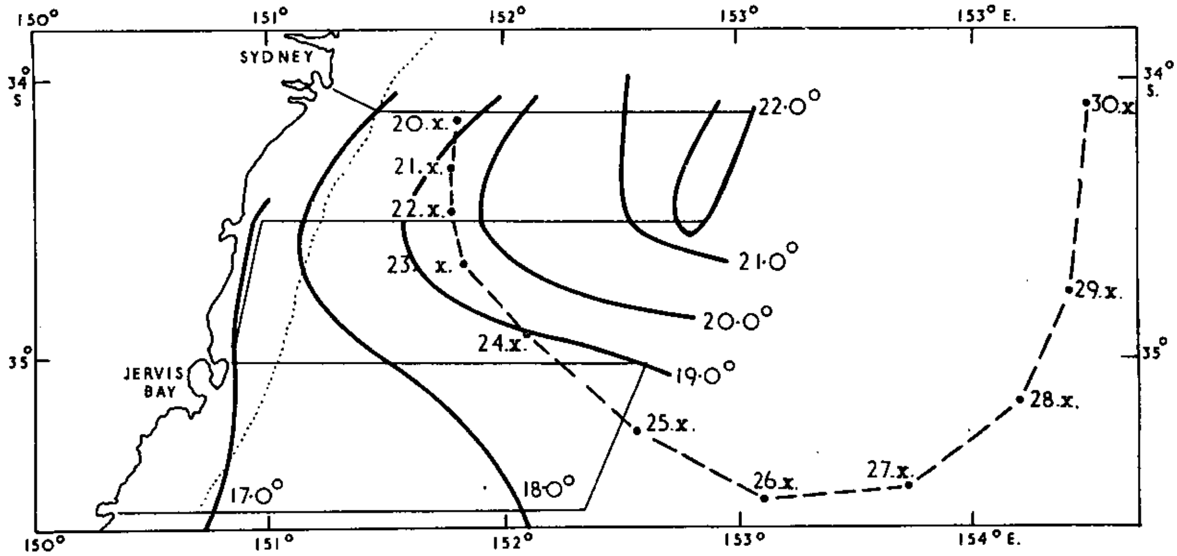

Fig. 4. The aircraft isotherm ($^{\circ}$C) map (═══) for 25 October, 1972, the flight path (——) and the buoy track (- - -).

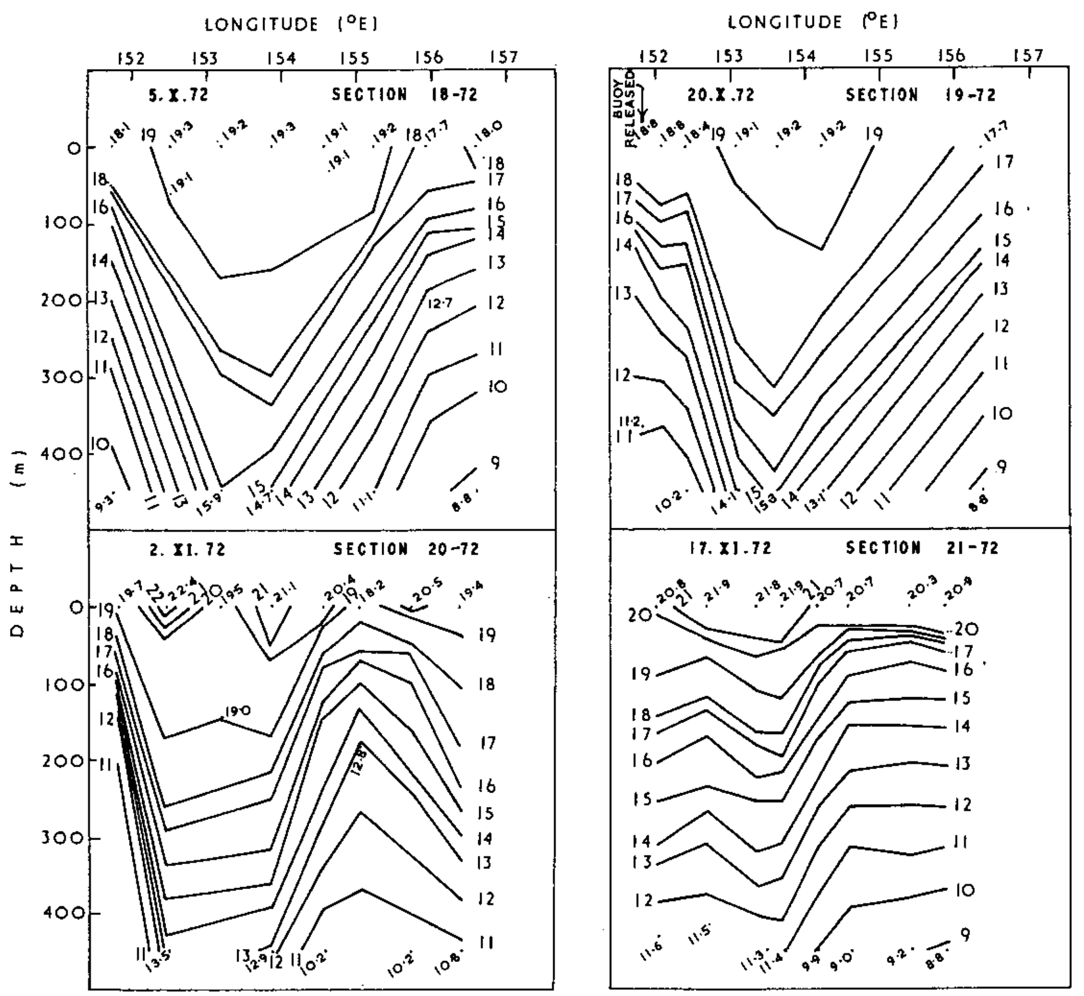

Fig. 5. The *Maheno* XBT sections for 5 October, 20 October, 2 November, and 17 November, 1972.

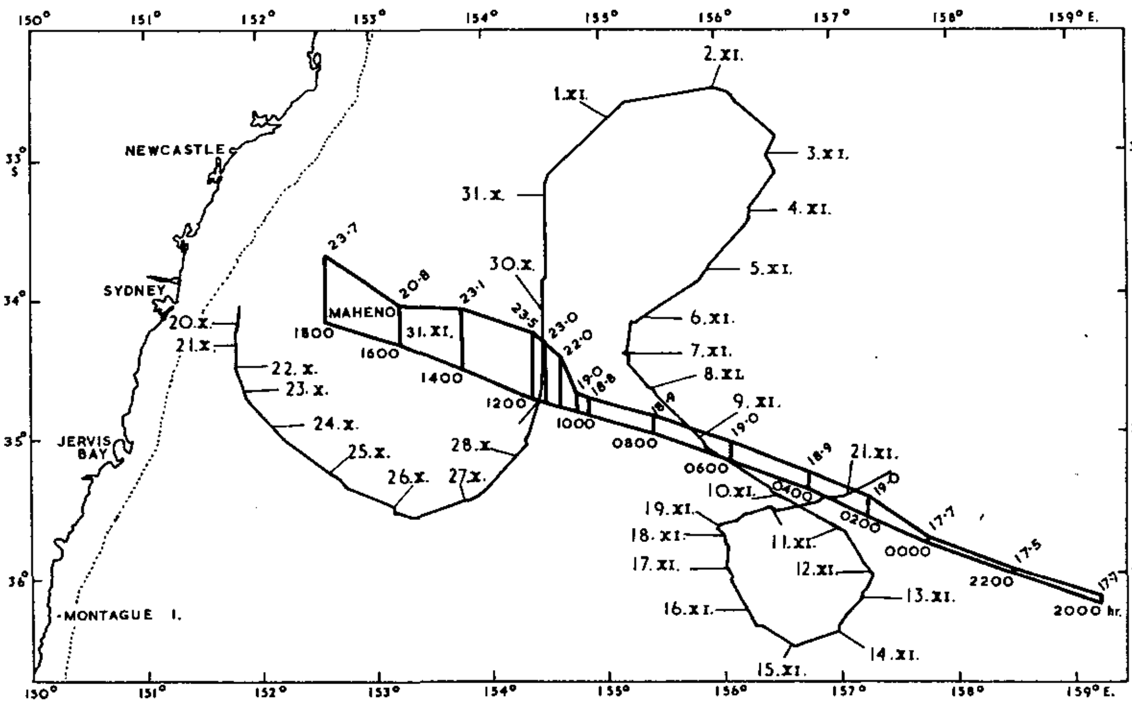

Fig. 6. The buoy track and sea surface temperature measured by *Maheno* 30/31 October. The ship's track also serves as a 17^{O}C baseline in this diagram.

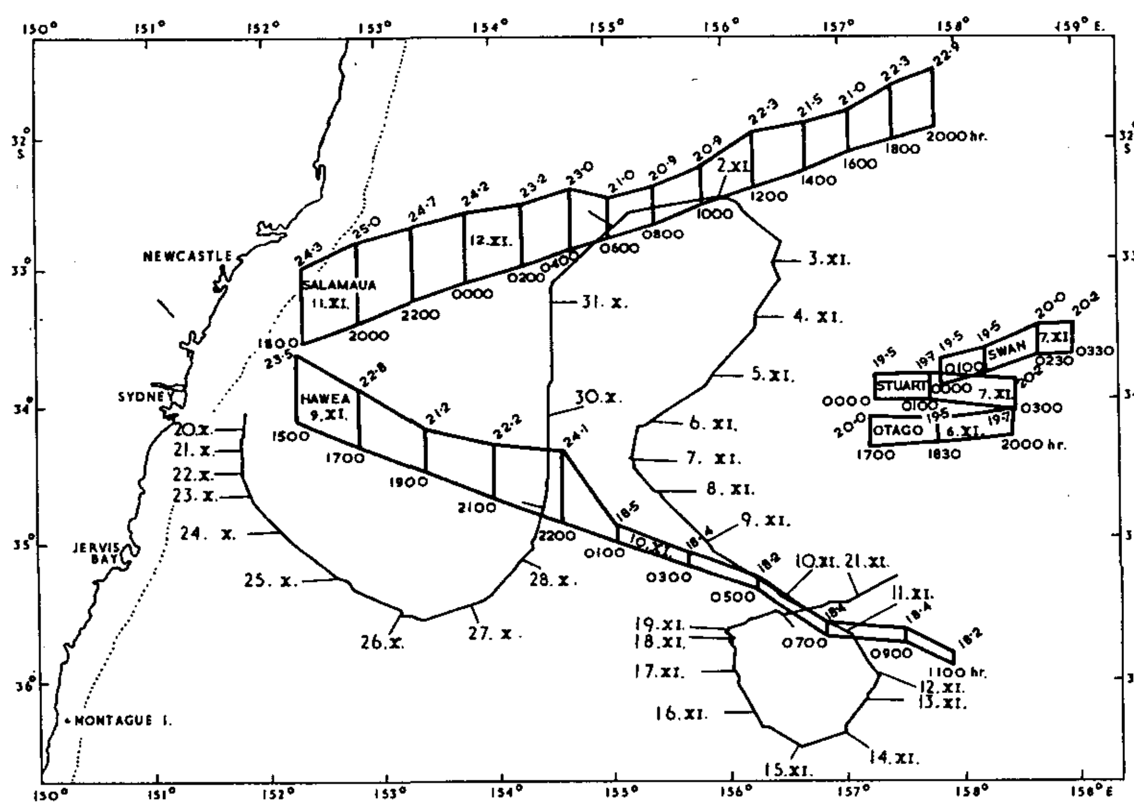

Fig. 7. The buoy track and the tracks and sea surface temperatures for the ships and times shown. The ship tracks also serve as 17^{O}C baselines in the diagram.

<u>Sea surface temperature measurements</u> are made by merchant ships operating in the Tasman and Coral Seas as part of a CSIRO research programme (CSIRO, 1972). During the drifting buoy experiment the ships *"Maheno"*, *"Hawea"*, and *"Salamaua"* traversed the area of interest.

Figure 6 shows the 30/31 October track of the *"Maheno"* and the sea surface temperatures, which are plotted for a 17°C baseline. In keeping with the aircraft I-R measurements, there appears to be an intrusion of northern warm water west of 154°30'E. The temperature gradient encountered on entering this water from the east amounted to 4.5°C in 35 km. This exceeds the usual maximum increase of 3.5°C reported by Hamon (1965). East of this temperature increase the temperature structure is featureless.

Figure 7 shows the tracks and temperatures of *"Salamaua"* on 11 November; *"Swan"*, *"Stuart"*, and *"Otago"* on 6/7 November; and *"Hawea"* on 9/10 November. Once again the temperature structure at 35°S, 154°30'E (*"Hawea"*) shows a steep gradient from east to west which amounts to 5°C; a *"Maheno"* pass through this area several days later showed the same structure. The *"Swan"*, *"Stuart"*, and *"Otago"* temperature structures were featureless. The *"Salamaua"* measurements gave some evidence (0600, 0800, and 1000) that the clockwise loop taken by the buoy contained cool surface water right up to its apex.

5. DISCUSSION AND CONCLUSIONS

From the available data it would appear that, during the experiment, there was an intrusion of warm water from the north near the coast, and an intrusion of cool water from the south at 155°-156°E. The buoy followed the current that separated these two water masses. Its track, at least to the northernmost point reached, agrees with the finding (Hamon, 1965) that the East Australian Current frequently leaves the coast in latitude 33°S-34°S and then swings to the north or northeast. Although sea surface temperature is not always a good indicator of current structure (Hamon, 1965), it appears that in the present experiment it was reasonably reliable until the buoy reached its northernmost point. One valuable feature of the buoy experiment is the insight that it will give to the *"Maheno"* XBT section interpretation, because from a single section it is not possible to differentiate between eddies and meanders.

While the buoy was not used in the Indian Ocean as planned, it is felt that a successful, relatively inexpensive ($600), free-drifting buoy system has been developed; quite likely it will be used in the Indian Ocean in the future. At present, improvements which are being tested on later model buoys include a wind vane to orient the buoy for wind velocity measurements and the use of a car battery in a compartment in the base of the buoy.

It seems that the French "EOLE" satellite, along with the buoys that it tracked from France and other countries, has shown what might be expected in the future: satellite-tracked instrumented buoys being used for weather prediction and oceanography and being distributed in the same fashion as radiosonde balloons. Particularly for Australia, normal weather prediction is greatly handicapped by the lack of stations to the west and south of the continent. In the north the determination of the likely severity of tropical cyclones would benefit from moored or drifting buoys. For oceanography it would appear that a satellite-tracked buoy is able to give current measurements of unprecedented accuracy. If these are combined with the more conventional oceanographic techniques a powerful attack on oceanographic problems - such as the western rock lobster larval migration - could be mounted.

6. ACKNOWLEDGEMENTS

I am particularly grateful to the President and staff of Centre National d'Études Spatiales for making the experiment possible. The merchant ships *"Maheno"*, *"Hawea"*, and *"Salamaua"* and the navy ships HMNZS *"Otago"*, HMAS *"Swan"*, and HMAS *"Stuart"* are all thanked for their data contributions. R. Watts, the plastics manufacturer, is thanked for the important role that he played. At this Division D.R. Lockwood provided all electronics advice and R. Catlin handled circuit construction; J. Wood designed many of the fittings for the buoy and helped assemble it; S. Hynd provided the aircraft I-R data; D. Rochford provided the merchant ship data; F.M. Boland is thanked for the XBT analysis.

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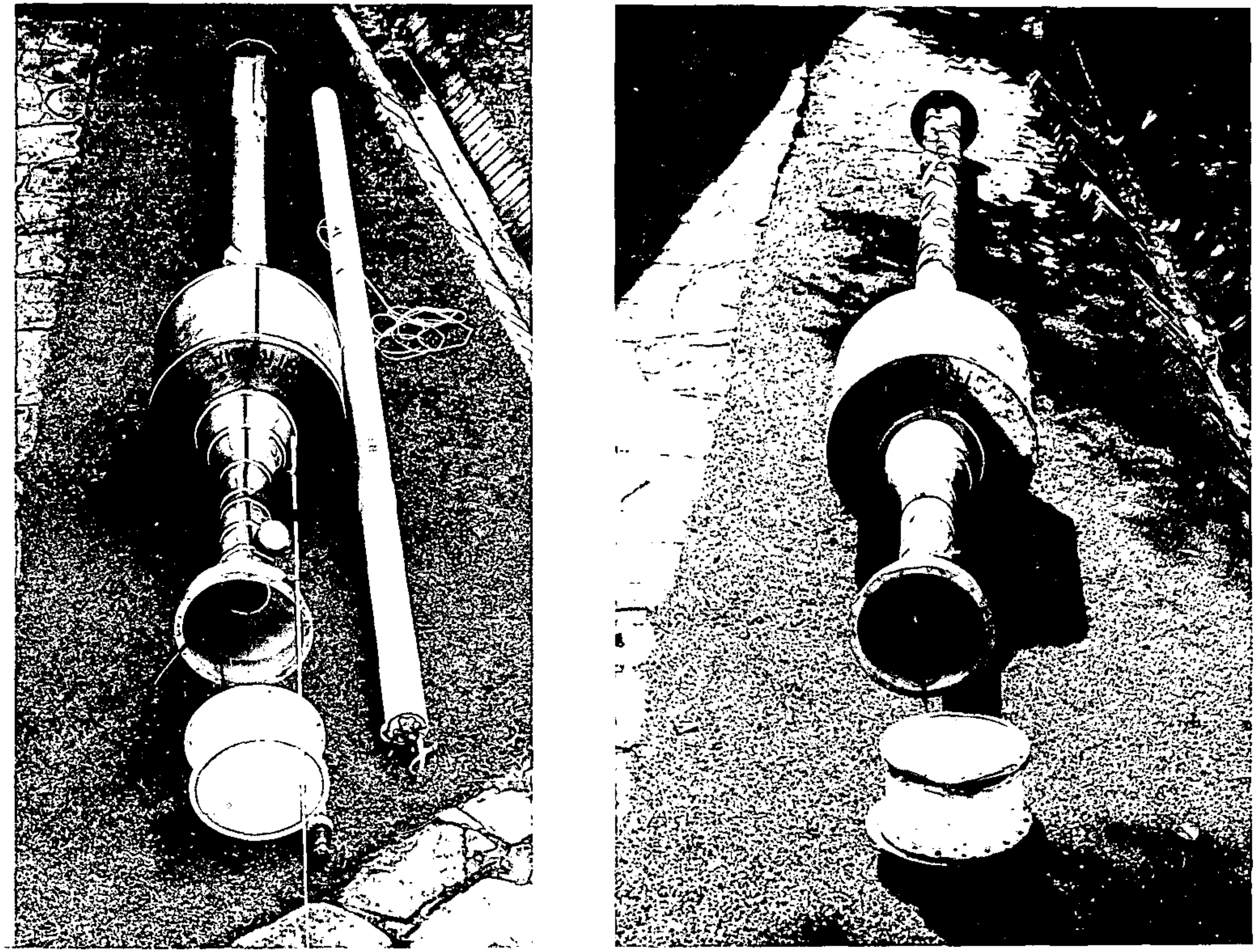


Plate 2. Photographs of the buoy before and after the experiment. The latter photograph does not show the instrument package.

APPENDIX A.

The Condition of the Buoy upon Recovery

The buoy was sighted and recovered by two fishermen on 12 February, 1973, at 30°15'S. on the N.S.W. coast, some 400 km north of Sydney. It had lost its drogue and the antenna was knocking against rocks due to wave action. Our inspection revealed the following:

(i) The buoy hull was, at first sight, apparently undamaged but a later water test showed the bottom fibreglass/PVC disc to be partly cracked away from the main spar and that water could leak into the buoy. A new bottom disc with supporting flanges will be fitted for later tests.

(ii) All exterior fittings - the air temperature thermistor housing, radio beacon, transponder test leads, and flashing light - had been cut off and/or undone, by whom and when it is not known, but, according to the finders, before it reached the Australian coast.

(iii) The puzzle about the failure of the sea surface temperature thermistor is not solved: the leads to it were missing and it was broken off.

(iv) The shackle beneath the buoy to the drogue line had come undone. It was wired, but apparently should have been welded. Since a large part of the ballast was beneath the buoy this meant that the buoy ceased to float vertically. In fact, barnacles on it showed that it floated at 65° from the vertical, with the side carrying the exterior fittings facing downwards. Therefore these fittings were in place for some considerable time after the buoy lost its drogue.

(v) Within the buoy hull there was noticeable dampness which was at first attributed to condensation (see however (i) above). The antenna contained some water due to its canister seal being distorted by the encounter with the rocks.

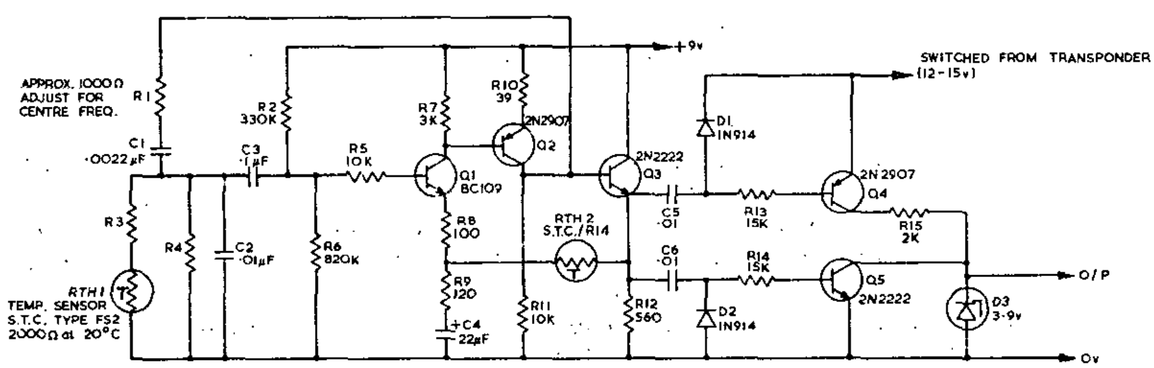
(vi) A major fault that most likely caused the transponder to fail was the shorting of the battery supply. The tiers of alkaline D cells were firmly attached to a 2.5 cm diameter central support tube, but the entire assembly had rotated within the PVC tube containing it. The two leads from the top of the batteries to the tube end cap had inexorably twisted until parts of the insulation were stripped away. Within the battery container were several cc's of liquid thought to be the result of the batteries shorting. Future battery packs will be internally anchored by means of a keyway.

(vii) The transponder was dry and intact within its PVC container. When tested at the laboratory it did not operate correctly and it has been forwarded to CNES for checking.

APPENDIX B.

The Thermistor Circuit

This was adapted for the transponder by D.R. Lockwood from a modular bathysonde that he has developed. There were no problems with the circuit. When the buoy was recovered the air and sea temperature circuits were tested with a new thermistor, since the buoy mounted ones were missing, and they operated correctly. The circuit diagram appears in Figure 8.



NOTE: R1, R3, R4 & C1, C2 ARE COMPUTED BY PROGRAMME AEB XXC/BRIDGE.

Fig. 8. The thermistor circuit diagram.

APPENDIX C.

Attempts to Prepare a Second Transponder

The spare transponder and an "EOLE" balloon-type antenna that had cut down over Victoria were combined in an attempt to have a second buoy release in November, 1972. Unfortunately, when the transponder was put in the buoy for a vertical on-shore test, the heating effect of the November sun damaged the UHF section. The UHF sections from two cut-down balloon transponders regrettably met the same fate: the first even though the buoy top section was painted white and the lower section shaded; the second when the buoy was floating in a swimming pool. It is of interest that these ex-balloon units did work in the laboratory prior to being put into the buoy; with one, some of the circuitry had a noticeable coating of mud - this was removed by spraying with "CRC".

It would appear that extreme caution needs to be exercised in warm sunny areas. We will have future buoys made from white, rather than red, fibreglass and will make a white canvas sleeve for the top half of the buoy. This will, we feel, remain wet and cool the buoy by evaporation. Apart from this, the normal precautions of shading the buoy on boat decks, spraying it with water and having an external on/off switch will be followed.

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