Seasonal Interchange of High and Low Salinity Surface Waters off South-west Australia

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THE SEASONAL INTERCHANGE OF HIGH AND LOW SALINITY SURFACE WATERS OFF SOUTH-WEST AUSTRALIA

By D. J. ROCHFORD*

Summary

Hydrological records (1947–67) off the south-west coast of Australia (latitudes 25–35°S.) show that in most years surface salinities varied from highest values in summer to lowest in late autumn and winter. The magnitude of this annual salinity variation increased markedly towards the coast. Evaporation-precipitation changes in the salinity of a 50 m column of coastal waters can account for only *c.* 40% of this variation. Drift bottle returns have confirmed that in coastal waters at least this annual change in salinity is largely the result of reversal from a southward flow of tropical waters in autumn-winter to a northward flow of subtropical waters in summer.

I. INTRODUCTION

Rochford (1962) has shown that surface salinity of the south-east Indian Ocean decreases markedly from south to north. Subtropical waters south of 25°S., for example, have salinities greater than 35·80‰ whilst tropical waters north of 20°S. have salinities less than 35·00‰. Seasonal changes in surface salinity along 110°E. have shown (Rochford 1969) a southward drift of low salinity waters in late autumn and winter and a northward drift of high salinity waters in summer. Evidence for a similar reversal of flow in coastal waters is examined in this paper using 1951–57 salinity records off Rottnest I., drift bottle results in 1956–57, and cruise data of 1947–67.

II. CHANGES IN SALINITY OF COASTAL WATERS WEST OF ROTTNEST I.

In general, high salinity water (35·70–90‰) occurred during the summer (December–March) and low salinity (less than 35·30‰) during winter (June–September) (Fig. 1). However, there have been striking differences from year to year in this time-table. In 1954 lowest salinities occurred in March and highest in May and no value was below 35·40‰. In 1956 the winter low-salinity water first occurred in May, at least one month ahead of normal, and persisted until December and early January 1957.

The mean highest salinity at 50 m during the period 1951–57 was 35·70‰ and the mean lowest was 35·25‰ (Fig. 1). The rise in salinity from 35·25 to 35·70‰ could be caused by evaporation but this would require an annual E–P of at least 126 cm within a mixed layer of 50 m. The E–P value for the region off

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Fremantle is around 50 cm (Dietrich 1957). The advective contribution to this annual salinity change must therefore be greater than the climatological.

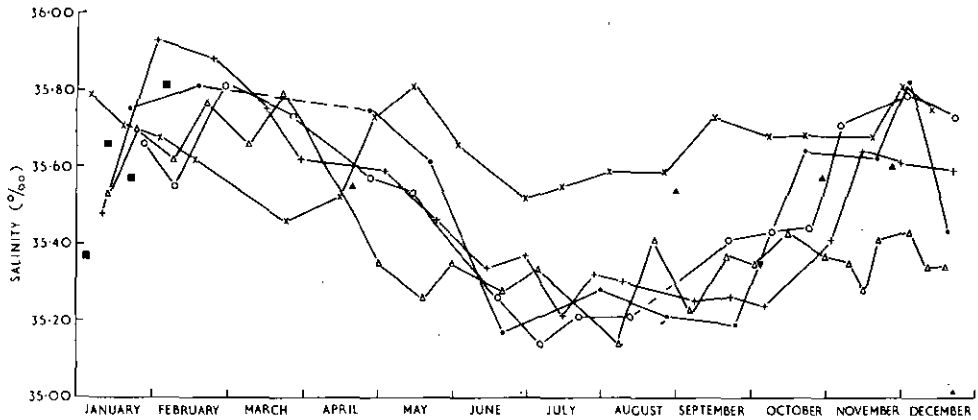

Fig. 1.– Variations in salinity at 50 m at the Rottnest I. 50 m station (32°S., 115°25′E.) during 1951–57. ▲ 1951. ● 1952. ○ 1953. X 1954. + 1955. △ 1956. ■ 1957. Data from CSIRO Oceanographical Station List Volume Nos. 14, 17, 18, 24, 27, 30, and 33.

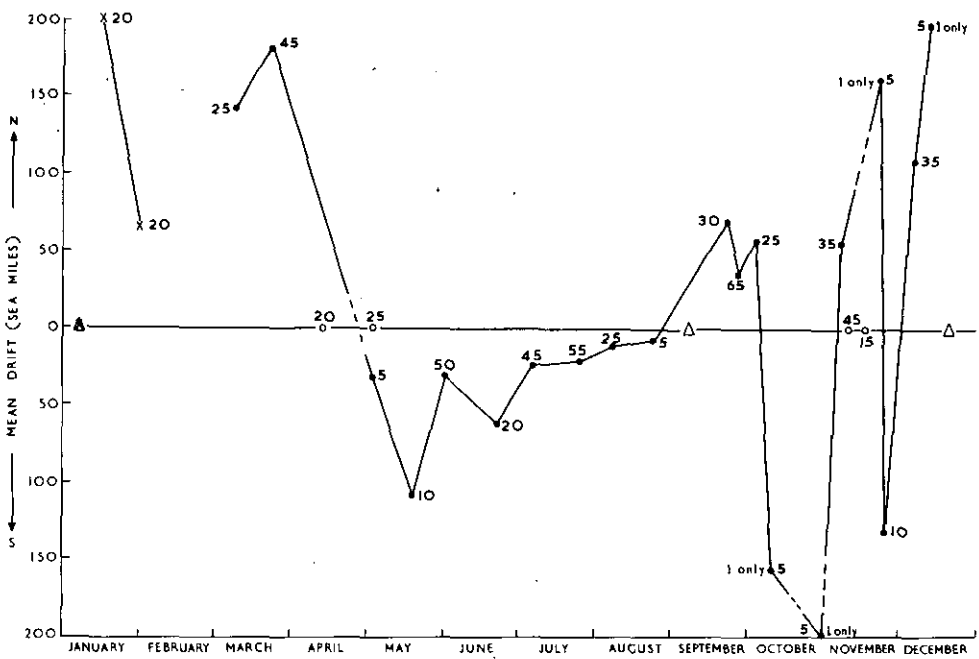

Fig. 2.– Mean drift in sea miles to the north or south of batches of drift bottles released at Bathurst Pt. Light (31°59′S., 115°32′E.) during 1956 (●) and 1957 (X). ○ All returns directly onshore. △ No returns from a batch of bottles. Numbers on the figure indicate percentage returns. Data from CSIRO Oceanographical Station List Volume No. 79.

The return of drift bottles from a release point off Rottnest I. (7 miles NW. of Bathurst Light) during most of 1956 and early 1957 confirms the marked change in direction of drift between March and May 1956 (Fig. 2). The drift to the north occurred in bursts from about September 1956 onwards but only after about November did the drifts to the north become stronger than those to the south, and only after January did drifts to the south cease altogether. From May onwards the drift was always to the south but the mean travel of a drift bottle became less and less until by August no significant travel occurred. The agreement between the changes in salinity (Fig. 1) and direction of drift (Fig. 2) off Rottnest I. between March and June 1956 confirms the usefulness of salinity as an indication of water origin and direction of movement along the West Australian coast.

III. Changes in Salinity of Oceanic Waters West of Rottnest I.

At SCOR–Unesco Reference Station I some 150 miles west of Rottnest I. the seasonal change in surface salinity followed the same pattern (Fig. 3), but with the amplitude of the annual variation much reduced. On two occasions in the summer of 1963 salinities were as low as those found in coastal waters in winter. This must have been caused by some exceptional drift of tropical waters in that particular year.

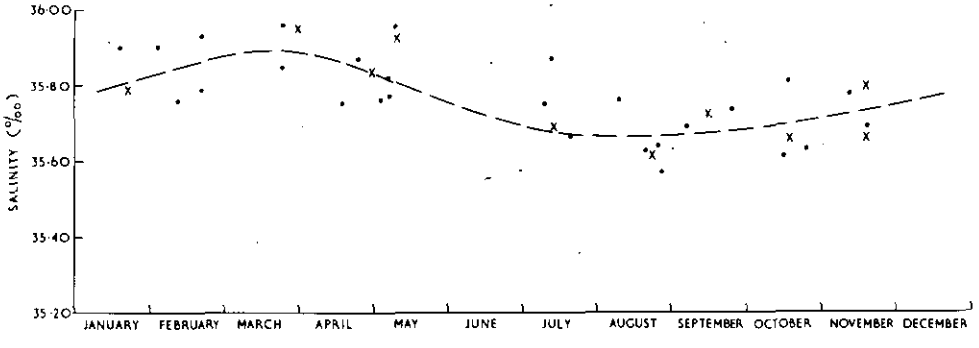

Fig. 3.– Variations in salinity at 0 m at SCOR–Unesco Reference Station at 32°S., 110°50′E. during 1960–65 (●) and the southernmost station at 32°S. on the 110°E. section during 1962–63 (X). Data from CSIRO Oceanographical Cruise Report Nos. 1, 2, 3, 4, 7, 9, 11, 14, 15, 17, 18, 20, 21, 23, 24, 25, 28, 36, 37, 40, 47, 49, 51, 56, 79.

At the southernmost station of the series of cruises along 110°E. in 1962–63, the seasonal changes in salinity were much the same as those at the reference station some 90 miles to the east. The diminution in the amplitude of the annual salinity change towards the west (cf. Figs. 1 and 3) shows that the tropical–subtropical interchange of waters off Rottnest I. is greater in the coastal region than further offshore.

IV. Salinity Changes along a Section West of Rottnest I.

Along this section extending some 100 miles west the low salinity water occurred for longer periods in the shoreward half and was more extensively distributed seaward at the surface (Fig. 4). In 1948 this low salinity water occurred only in winter (May–August), but in 1949 principally in autumn–winter (March–June) and early summer (November), and in 1950 in winter (June) and spring (October).

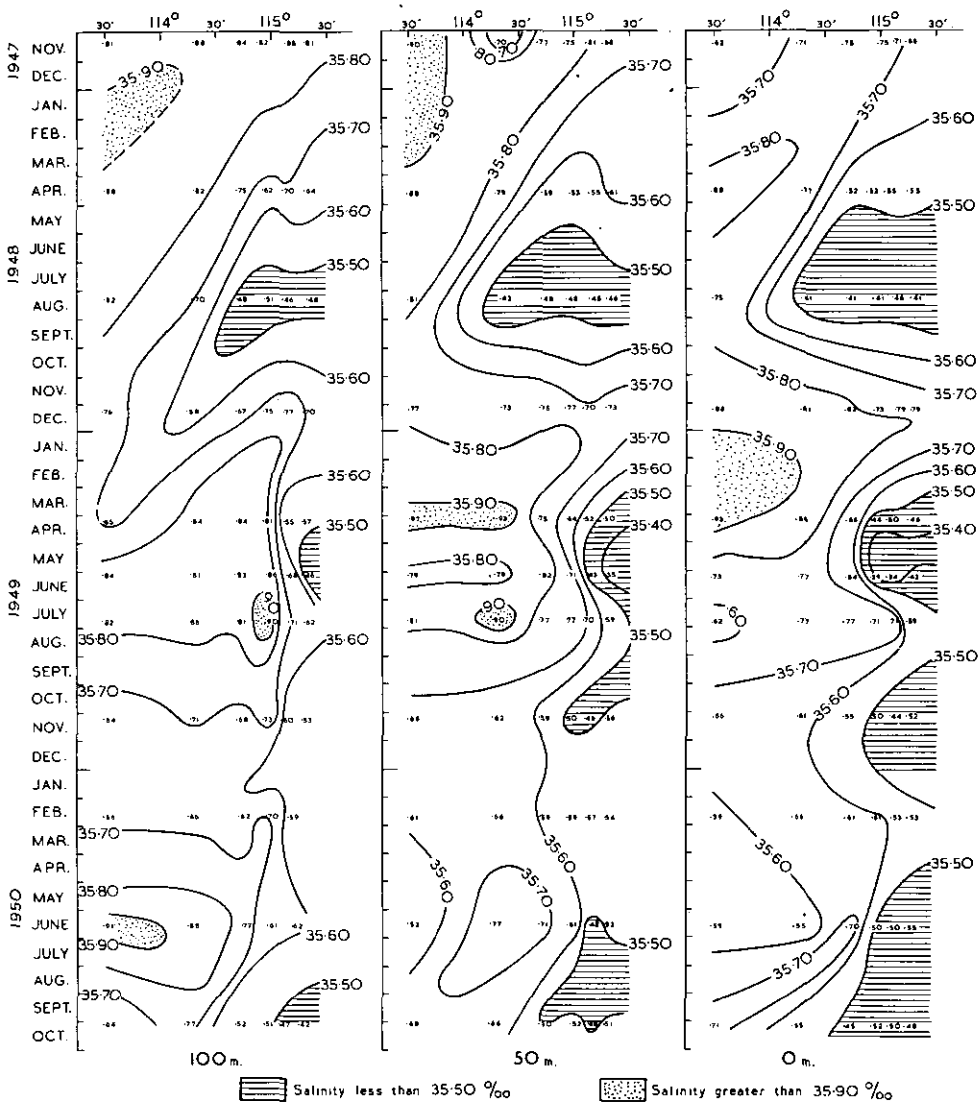

Fig. 4.– Changes in salinity (‰) at 0, 50, and 100 m along a section at latitude 32°S. during 1947–50. Data from CSIRO Oceanographical Station List Volume No. 3.

V. SEASONAL CHANGES IN THE OCEANIC DISTRIBUTION OF LOW SALINITY WATERS

The seasonal changes in the southward limit of surface waters less than 35·60‰ salinity (Fig. 5(*a*)) were much greater in the coastal waters south of Shark Bay than in the general offshore region. The seasonal pattern was similar to that off Rottnest I. (Fig. 1) with low salinity water predominating along the coast in the winter and high salinity in the summer. During 1963–64 cruises to the edge of the continental shelf showed very similar seasonal changes in the position of the 35·60‰ isohaline (Fig. 5(*b*)).

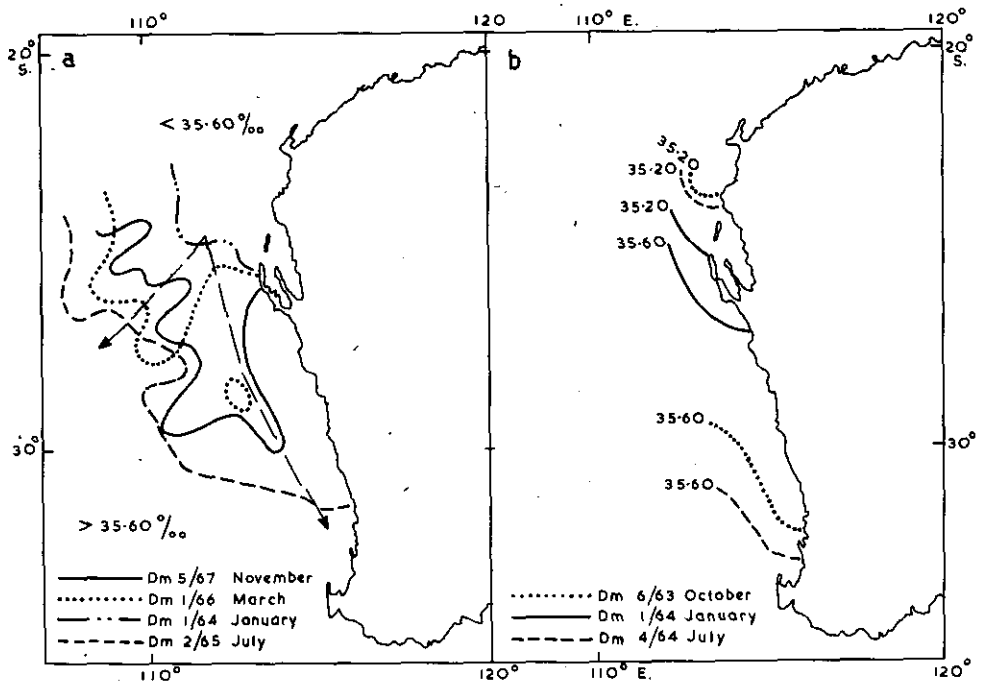

Fig. 5.– Seasonal changes in position of the 35·60‰ surface isohaline during cruises in the south-east Indian Ocean from 1963–67. Data from CSIRO Oceanographical Cruise Report Nos. 1, 2, 3, 4, 7, 9, 11, 14, 15, 17, 18, 20, 21, 23, 24, 25, 28, 36, 37, 40, 47, 49, 51, 56, 79.

VI. CONCLUSIONS

(1) Changes in surface salinity from around 35·80‰ in summer (December–February) to around 35·20‰ in winter (July–September) occurred in most years (1951–57) at a fixed coastal station off Rottnest I. The major exception was in 1954 when both winter and summer values of salinity were abnormal.

(2) Cruises during 1947–50 offshore of Rottnest I. show a similar pattern in the annual salinity changes, with the amplitude of the change diminishing westward.

(3) More widespread cruises during 1963–67 show that low salinity water spreads southward in winter and is replaced by high salinity water in summer.

(4) Drift bottle returns in 1956–57 confirm this southward drift in winter and northward drift in summer.

VII. REFERENCES

Dietrich, G. (1957).– "Allgemeine Meereskunde." (Gebrüder Borntraeger: Berlin–Nikolassee.)

Rochford, D.J. (1962).– Hydrology of the Indian Ocean. II. The surface waters of the south-east Indian Ocean and Arafura Sea in the spring and summer. *Aust. J. mar. Freshwat. Res.* **13**, 226–251.

Rochford, D.J. (1969).– Seasonal variations in the Indian Ocean along 110°E. I. Hydrological structure of the upper 500 m. *Aust. J. mar. Freshwat. Res.* **20**, 1–50.

DIVISION OF FISHERIES AND OCEANOGRAPHY
TECHNICAL PAPERS

1. BLACKBURN, M., and RAYNER, G. W. (1951).—Pelagic fishing experiments in Australian waters.
2. HOUSTON, T. W. (1954).—Commercial trawling tests in the Great Australian Bight, 1949–52.
3. BLACKBURN, M., and DOWNIE, R. J. (1955).—The occurrence of oily pilchards in New South Wales waters.
4. WEATHERLEY, A. H. (1958).—Tasmanian farm dams in relation to fish culture.
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6. JITTS, H. R. (1959).—Measurements of light penetration in the Tasman Sea, 1955–57.
7. ROCHFORD, D. J. (1959).—The primary external water masses of the Tasman and Coral seas.
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9. HUMPHREY, G. F. (1960).—The concentration of plankton pigments in Australian waters.
10. NEWELL, B. S. (1961).—Hydrology of south-east Australian waters: Bass Strait and New South Wales tuna fishing area.
11. HAMON, B. V. (1961).—The structure of the East Australian Current.
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13. THOMSON, J. M. (1962).—The tagging and marking of marine animals in Australia.
14. WOOD, E. J. F. (1963).—Dinoflagellates in the Australian region. II. Recent collections.
15. HAMON, B. V. (1963).—Australian tide recorders.
16. THOMSON, J. M. (1963).—A bibliography of systematic references to the grey mullets (Mugilidae).
17. WOOD, E. J. F. (1963).—Dinoflagellates in the Australian region. III. Further collections.
18. DYSON, N., JITTS, H. R., and SCOTT, B. D. (1965).—Techniques for measuring oceanic primary production using radioactive carbon.
19. TRANTER, D. J. (1966).—The Australian Clarke-Bumpus sampler and calibration tank.
20. WISELY, B. (1966).—Application details and sea-trial results of an antifouling and anticorrosion system.
21. CASTILLEJO, F. F. de (1966).—Non-seasonal variations in the hydrological environment off Port Hacking, Sydney.
22. HYND, J. S., and ROBINS, J. P. (1967).—Tasmanian tuna survey. Report of first operational period.
23. HIGHLEY, E. (1967).—Oceanic circulation patterns off the east coast of Australia.
24. KESTEVEN, G. L., and STARK, A. E. (1967).—Demersal fish stocks of the Great Australian Bight as estimated from the results of operations of F.V. *Southern Endeavour*.
25. KIRKWOOD, L. F. (1967).—Inorganic phosphate, organic phosphorus, and nitrate in Australian waters.
26. HYND, J. S. (1960).—Report on a survey for yellowfin tuna, *Thunnus albacares* (Bonnaterre), in Queensland waters.
27. HIGHLEY, E., and STARK, A. E. (1968).—The Great Australian Bight and trawling tests of F.V. *Southern Endeavour*.
28. HIGHLEY, E. (1968).—The International Indian Ocean Expedition: Australia's contribution.
29. ROCHFORD, D. J. (1969).—The seasonal interchange of high and low salinity surface waters off south-west Australia.