551·46·018·3 (267)

On the pattern of Surface Circulation in the Indian Ocean as deduced from drift bottle recoveries*

T. S. SATYANARAYANA RAO

Department of Zoology, Andhra University, Waltair

(Received 28 September 1961)

1. Introduction

Among the methods available for direct observation of the surface currents in the ocean none is more simple and least expensive than the use of drift bottles. Bernardin de Saint-Pierre was one of the first to suggest (Rouch 1954) the use of floating bottles with labels attached to them for studying the currents. Since then there have been many studies of lake and ocean currents by the use of drift bottles (Carruthers 1930, Hachey 1935, Johnson 1958, Miller 1952 and Rouch 1954).

As for the Indian Ocean, drift bottle studies are rare and the only paper that has come to the notice of the author is the one by Malpas (1930) who studied the surface currents in the Gulf of Mannar near Ceylon. In the present paper drift bottle data, made available to the author through the courtsey of Mr. Dean F. Bumpus of the Woods Hole Oceanographic Institution and Rear Admiral H. C. Daniel, United States Navy Hydrographer, are analysed to explain the pattern of surface circulation in the Indian Ocean.

The interpretation of the drift bottle data presents certain difficulties. The bottles might not have followed a straight course between the points of release and recovery. It would be difficult to know as to how long a bottle has been lying on the beach before being picked up. Besides, in large ocean areas such as the Antarctic, it is possible that the floating bottle might have gone round that continent once or twice before reaching land. Therefore, the problem of charting the trajectories of the bottles and the interpretation of their data require in most cases assumptions and careful reasoning. The one conclusion that could safely be accepted in this connection is that the movement of the surface waters of the sea or lake in question is in the general direction of the location where the drift bottle was picked up, no matter which way the bottle has been drifting between the points of release and recovery.

As is conventional in the study of the drift bottles, in this paper also the following are assumed. A trajectory of the drift bottle is assumed to follow the shortest course between places of release and recovery and is shown as a straight line wherever possible. The average drift, wherever it is possible to assert with some certainty has been calculated and indicated as numbers within brackets in Figs. 1 and 2.

2. Surface currents in the Indian Ocean

Sverdrup *et al.* (1942) have summarised what is known about the current in the Indian Ocean. There is reported to occur a great anticyclonic circulation in the South Indian Ocean, very similar to the existing circulations in the South Pacific and South Atlantic. A well-marked current prevails between the south latitudes of 40° and 50° carrying the surface waters eastward. This current is part of the great circum-Antartic circulation namely the West Wind Drift. To the north of 20° south latitude there is present a well developed South Equatorial Current carrying

*Contribution No. 1279 from the Woods Hole Oceanographic Institution and from the Department of Zoology, Andhra University, Waltair

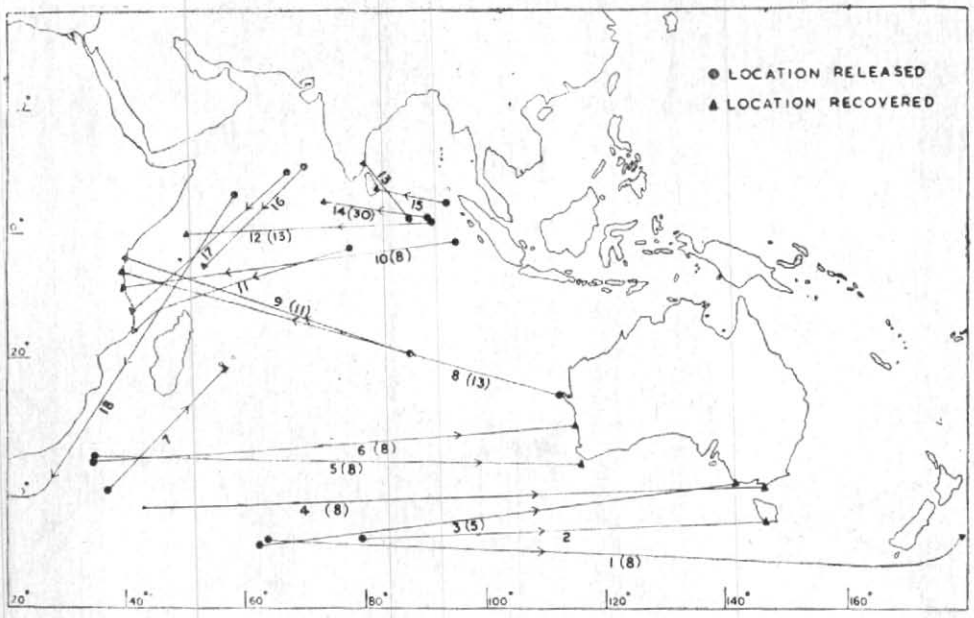

Fig. 1. Bottles 1—18

Numbers in brackets give approximate drift per day in miles

the waters from east to west. It is this current which feeds the strong Agulhas current flowing south. The anticyclonic system in the South Indian Ocean, therefore, consists of mainly 3 well developed currents, namely, the West Wind Drift, the South Equatorial and the Agulhas.

The current pattern in the Indian Ocean north of the equator is fluctuating and largely conforms to the prevailing monsoon winds. During the period of the northeast monsoon namely, December-April, the North Equatorial Current is well developed with a very strong component in the western sector. Besides, there is also a marked counter current between the latitudes 0° and 10° south.

When the southwest monsoon commences blowing over this region from May onwards, the surface pattern of the circulation changes. The North Equatorial Current almost disappears giving place to the east flowing monsoon current. A strong Somali current is developed along the coast of Somaliland and this carries waters to the north and becomes part of the great cyclonic eddy in the Arabian Sea. Similarly in the Bay of Bengal a strong northerly current skirting the east coast of India is formed late in December and this also is ultimately absorbed as part of a cyclonic circulation there.

3. Drift bottle trajectories

The minimum trajectories of 31 drift bottles are indicated in Figs. 1 and 2. These bottles can be studied under 3 groups based on the area of release and recovery.

Group I : (Fig. 1)—Bottles No. 1 to No. 7 released and recovered between the latitudes of 20° and 50° south are included in this group. All of them with the exception of No. 7 have travelled eastward, thousands of miles before they are stranded and recovered on or off the coast of Southern Australia. In these latitudes the surface current has a greater frequency towards the east and is shown as such in most of the current atlases. The drift of the above

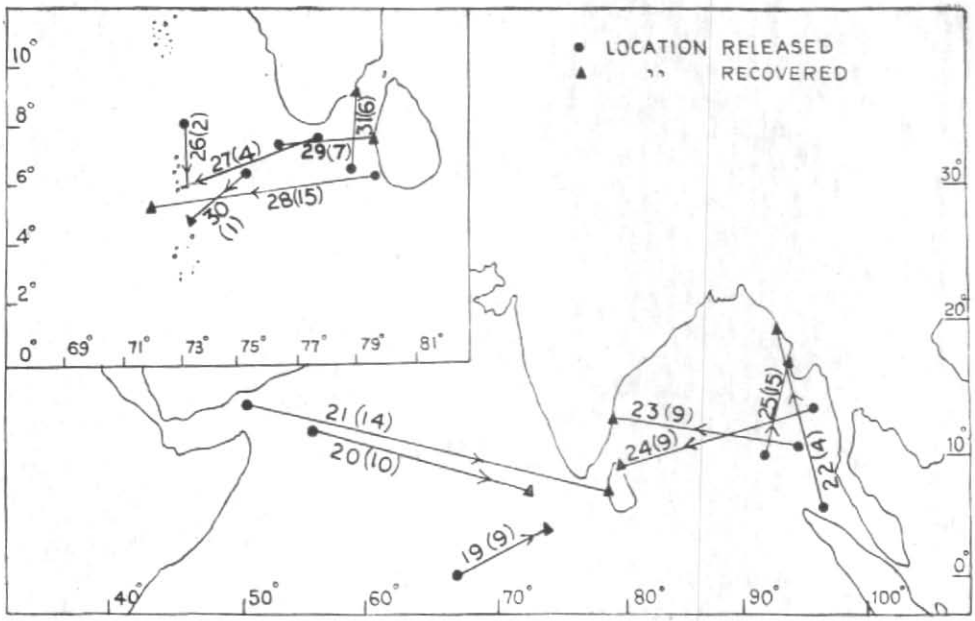

Fig. 2. Bottles 19—31

Numbers in brackets give approximate drift per day in miles

bottles clearly substantiates the prevalence of an easterly drift in this part of the South Indian Ocean.

Group II : (Fig. 1)—In this group are included bottles No. 8 to No. 18. Most of these bottles show a westward drift. Bottles No. 8 to No. 12 are in the zone of the Equatorial Current and all of them have made a beeline for the East African coasts of Kenya and Tanganyika. The drift of the bottles released and recovered between the latitudes of 0° and 20° S clearly reflects the movement and direction of the South Equatorial Current. Except for the bottle No. 11, the rest of them have taken less than a year to travel their respective distances and show an average drift of nearly 11 miles per day. Bottle No. 12 which was released and recovered in the equatorial region showed a fast movement of 13 miles per day.

Bottles No. 13 to No. 15 are in the belt of the North Equatorial Current, of these No. 14 alone was recovered in the sea. Its velocity of drift was indeed very great and worked out to about 30 miles per day. According to the atlas of the surface currents for the Indian Ocean published by the United States Navy Hydrographic Office (1950 edition) the surface currents in the region of the bottle No. 14 are strong in the months of November to December and flow west or northwest with an average speed of 20—30 miles per day. Perhaps this would explain the fast drift of the bottle No. 14.

Bottles No. 16 to No. 18, released in different parts of the Arabian Sea have all drifted in the southwestern direction. No. 18 has gone straight down along the east coast of Africa and rounding the Cape of Good Hope it proceeded further north on the west coast of Africa. It was recovered near 6° north latitude, after travelling nearly a distance of 6000 miles in about 400 days, at the speed of about 15 miles per day.

Group III : (Fig. 2)—The trajectories of the bottles No. 19 to No. 31 are given in

Fig. 2. From a study of these it is sufficient to state here that the trajectories of the bottles in this region more or less correspond with the direction of the currents reported in the areas concerned (United States Atlas 1950), under the different monsoons.

4. Conclusion

In the South Indian Ocean the trajectories of the drift bottles indicate the occurrence of two well defined surface currents; one of them being the West Wind Drift carrying waters from Africa towards Australia. The other current is the South Equatorial Current. There is no evidence from the available drift bottles data for the occurrence of the west Australian current flowing north, neither there is evidence for the occurrence of the Equatorial counter current.

In the Indian Ocean, north of the equator, the drift of each bottle depends on the period in which it was released and recovered. During the period of the northeast monsoon (December—April) the bottles have drifted westward; in the southwest monsoon period the bottles show an eastward movement. This is in conformity with the available data as given in the United States Navy Atlas on the surface currents of the Indian Ocean (1950).

5. Scope for the future

During the forthcoming International Indian Ocean Expedition it would be very useful if the participating ships could undertake to release and recover drift bottles for studying the surface currents in the Indian Ocean.

6. Acknowledgement

The author wishes to thank Mr. Dean F. Bumpus of the Woods Hole Oceanogaphic Institution and Rear Admiral H. C. Daniel of the U. S. Navy for kindly supplying drift bottle data for my use. The analysis of the data was partly carried out while the author was working at the Woods Hole Oceanographic Institution, Woods Hole, Mass., U. S. A. and to the authorities of the Institution, the author is very grateful for providing excellent facilities for research. He is grateful to Prof. P. N. Ganapati, Head of the Department of Zoology, Andhra University for kindly going through the manuscript and offering useful suggestions.

REFERENCES

Anon.	1950	*Atlas of surface currents, Indian Ocean*, U.S. Navy Hydrogr. Off., H.O. Pub. No. 556, pp. 12.
Carruthers, J. N.	1930	*J. Mar. biol. Ass. U.K.*, **17**, pp. 241-275.
Hachey, H. B.	1935	*Science*, **82**, pp. 275-276.
Johnson, J. H.	1958	*U.S. Fish and Wild Live Service, Special Sci. Rep., Fish.*, 267, pp. 1-30.
Malpas, A. H.	1930	*Ceylon J. Sci. (C), Fish.*, **4**, pp. 1-95
Miller, A. R.	1952	*Tech. Rep. W.H.O.I.*, Ref. No. 52-28, pp. 1-15.
Rouch, J.	1954	*Bull. Inst. Oceanogr.*, No. 1046, p. 5.
Schott, Gerhard	1935	*Hamburg Verlag von C. Boysen*, p. 413.
Sverdrup, H. U., Martin, W. Johnson and Fleming, R. H.	1942	*The Ocean. Their physics, chemistry and general biology*, Prentice-Hall pp. x-1087.