

VARIATION OF VERTICAL STABILITY PARAMETER IN THE SURFACE LAYERS OF THE ARABIAN SEA OFF COCHIN*

By C. P. RAMAMIRTHAM AND C. P. ARAVINDAKSHAN NAIR
Central Marine Fisheries Research Sub-Station, Ernakulam-6

INTRODUCTION

IN the ocean, the vertical stratification of a water column mainly depends on the vertical stability parameter. The latter has been found to be dependent upon the change of density (represented as Sigma-T) in the vertical direction. Potential temperature is to be used for accurate determination of Sigma-T when stability is to be computed. But the effect of compressibility on temperature need be taken into consideration below 100 m. only and in general the effect of changes in salinity is mostly small. Hence in the upper layers (mostly the ones constituting the mixed and top thermocline layers) the stability can be accurately represented by $E = 10^* \frac{-r}{az}$ according to Hesselberg and Sverdrup (1914-15). For positive values of E the stratification is stable and is not altered by vertical displacements of small quanta of water. For negative values of E the stratification is unstable and the slightest disturbance is sufficient to cause a readjustment in the stratification. Between layers with positive and negative stability there is always a surface with $E=0$. A small mass of water on displacement to the side where E is positive is always driven back to the surface, but a displacement to the side where E is negative removes it more and more from that surface. Thus the vertical stability, instability, or neutrality can be judged as $E = 0$.

DATA AND METHODS

The data presented in this report were collected during the years 1958 and 1959 from a normal section off Cochin. During the active monsoon and postmonsoon periods only shallow stations could be worked because of rough weather. In the other months deep stations have been included and the stability values for all the stations have been computed. The data for the upper layers are given in Tables 1 and 2. The hydrographic features existing in this region have already been discussed by Ramamirtham and Jayaraman (1960).

DISCUSSIONS

During August with low salinities near the coast in the surface layers the thermocline is found to be drawn up very near the surface resulting in intense vertical

* Published with the permission of the Director, Central Marine Fisheries Research Institute, Mandapam Camp.

SURFACE LAYERS OF THE ARABIAN SEA OFF COCHIN

203

thermal gradient between 0 and 10 m., with a remarkably high value of stability. Stations 306 and 308 were worked out during September and the high stability values are still maintained in the upper 10 m. layer. Mostly observations were

TABLE I

Variation of Vertical Stability Parameter (expressed as 10^3E) in the Arabian Sea off Cochin during Monsoon and Post-monsoon

Month Stn. No.	August 1958				September 1958				
	299	300	301	302	304	305	306	308	
Depth Interval									
0-10 m.	1,42,100	81,300	17,800	13,800	89,700	80,600	28,100	15,400	
10-20 m.			3000	12,900		-100	4,300	5,700	
20-30 m.	••		200	1,200			1,200	3,800	
30-50 m.	••			900				400	

Month Stn. No.	October 1958				November 1958				
	1335	336	340	34	356	355	354	353	352
Depth Interval									
0-10 m.	13800	18200	6900	5500	17500	3200	2000	1,1200	100
10-20 m.	2200		8000	7400	2300	2300	1600	700	900
20-30 m.	-800		0	2500		2100	100	1500	600
30-50 m.	••			384	••		19	1950	1600
50-75 m.								2800	3120

extended to very near the bottom and below 10 m. stability is found to decrease with depth instead of increasing, indicating unstable conditions. The thermal gradients below 10 m. are relatively weak. However, the decrease in stability is continuous, and not alternately becoming positive and negative as shown by Sastry in the 'Swatch of no ground' (1957), where extreme turbulence is indicated. In the present case upwelling and vertical turbulence during the monsoon and post-monsoon seasons may cause some kind of regular vertical mixing and produce vertical accelerations.

During October, the vertical distribution pattern of Sigma-T in two inshore stations shows very light surface water (Sigma-T 20.5) overlying denser water (Sigma-T 23.44) at 10 m. and below. Stations 340 and 341 were slightly deeper, stability values being high in the upper 20 m. layer and these values increase from surface downwards upto 20 m. Below 20 m. there is a sharp decrease in the stability values showing unstable conditions persisting below this layer. Near the bottom the negative values indicate good vertical mixing (station 335).

November is considered to be the month when a transition is taking place in the hydrographic conditions and the distribution of stability parameter for this month seems interesting. In the stations beyond the continental shelf (stations 352 and 353) the upper 30 m. column indicates more or less turbulent conditions. Between 30 and 50 m. levels there is present a water which has nearly the same value of stability in all the stations. Over the shelf the stability values show a decrease depthwise indicating the presence of convection processes, over the shelf. But in the offshore stations the tendency is for the stability values to increase from 10 m. depth down to the thermocline near which very high values are observed. In general in the offshore stations (352 & 353) the picture is more or less of a stable water column, down to the thermocline. Near the edge of the shelf, between 20 and 30 m. a rather low value is observed, which may be explained as being due to turbulence of a transient type, or eddy mixing. The temperature structure as well as the dissolved oxygen distribution shows the presence of a more or less well mixed water upto this level.

TABLE 2
Variation of Vertical Stability Parameter (expressed as $10^B E$) in the Arabian sea off Cochin during Winter and Summer

Month	December 1958					January 1959				
Stn. No.	358	359	361	362	363	374	375	376	377	378
Depth Interval										
0-10 m.	1200	-500	1700	2400	100	1700	400	-2100	2600	2100
10-20 m.		-300	700	2000	4800		800	3400	3700	..
20-30 m.		5000	600	200	3200			2000	1800	650
30-50 m.			900	4700	1650				4000	4100
50-75 m.				1120	2000					2920
75-100 m.					1560					2760

Month	April 1959					May 1959				
Stn. NO.	421	420	419	418	417	488	487	486	485	484
Depth Interval										
0-10 m.	-100	400	500	700	400	3200	2300	700	1100	200
10-20 m.		-200	4100	-300	-100		4900	600	3800	5600
20-30 m.		585	2000	400	1900		200	3300	4200	2200
30-50 m.	..		200	3200	2150				3500	2800
50-75 m.	..			1500	2680	1200	3080

During December, the temperature inversions found at the immediate surface layers constitute negative values of stability indicating highly unstable conditions.

In the deeper stations off the shelf, the stability values are different from those found during November, and there appears to be a fairly clear demarcation between the water at the shelf and that outside it. Ramamirtham and Jayaraman (1960) have indicated the characteristics associated with sinking during this period. Off the shelf, it can be seen that the stability values below 10 m. are alternately increasing and decreasing showing a certain amount of lateral mixing. The weak thermal gradients in the upper layers within the shelf constitute low values of E , and hence the mixed layer becomes more prominent during December. The cell-like structures in the temperature distribution often give rise to unstable water columns with a stability minimum in between (stations 362 and 363).

The negative values of stability within the shelf continue to persist during January and the demarcation between the inshore and offshore waters is becoming less prominent. A tendency for the stabilisation of the water column is seen in the offshore waters in January, and thus a stable column of water seems to have been established down to about 100 m. which is more or less the upper level of the discontinuity layer during this period, although the inshore stations still bear the mark of instability.

Data during the summer season consisted of observations during April and early May. During April in the layer 10-20 m. negative values are encountered within some stations. Except for these isolated unstable columns, below 20 m. the whole month shows positive high values of stability in the offshore region. During May, the section off Cochin shows uniformly positive values of stability, values increasing and decreasing depthwise. Lateral mixing is inferred and such conditions can be noted during the winter season as well. Vertical convections are highly restricted during May compared to April, when unstable conditions are predominant in the layer 10-20 m.

Cooper (1960), when studying the exchanges between the English and Bristol channels has stated that replenishment of the waters in the oceans by nutrients below, depends to a great extent on the stability of the water column. At stations where bottom turbulence is restricted (stability high) the replenishment will be restricted. In the present study it can be seen that during monsoon and post-monsoon seasons (August, September and October) the stability values near the bottom had been very low compared to the other seasons whereas in the surface layers they were quite high. As Sastry and Myrland (1960) have pointed out, during the monsoon and post-monsoon seasons, upwelling and divergence near the bottom produce vertical accelerations and this turbulence helps in the replenishment of the upper layers by nutrients from below. As a result, after the post-monsoon the waters are found to be more productive. During the other seasons, the comparatively higher values of stability near the bottom are sufficient to immobilize the reserves in the deeper waters especially those in the discontinuity layer. During the monsoon and post-monsoon seasons, stability is very high in the upper 20 m. column, whereas in the other seasons it is much lower. The upward migration of the thermocline during the former seasons contributes to the above. But during winter and summer seasons, good stability is noticed in the deeper layers within the shelf, and there is not as much difference in the values at upper and lower levels, as observed during monsoon and post-monsoon seasons. The waters get more and more mixed as can be deduced from an examination of the oxygen distribution in a vertical plane. Quite uniform and high values of oxygen exist within the shelf during the said seasons (Ramamirtham *et al.*, 1960),

SUMMARY

The variation of vertical stability parameter in the upper layers of the Arabian Sea off Cochin is presented and discussed. During monsoon and early post-monsoon seasons, the stabilities in the immediate surface layers are found to be high. But the waters over the shelf (near the bottom) are unstable. Vertical turbulence is inferred during these seasons and the effect of this on the productivity of the region is indicated. By the onset of winter, stable conditions are being restored and during summer good vertical stability is found in the region off Cochin. The effect of lateral mixing on the uneven distribution of stability is indicated. The high stability values over the bottom during the winter and summer seasons are found to be sufficient to immobilize the bottom nutrients during these seasons.

ACKNOWLEDGEMENTS

Our thanks are due to Dr. S. Jones, Director, Central Marine Fisheries Research Institute, Mandapam Camp, for his keen interest in these investigations. We are also indebted to Dr. R. Raghu Prasad, for his encouragement in the course of the work and especially to Sri R. Jayaraman, for the suggestions during the preparation of the paper.

REFERENCES

- COOPER, L. H. N. 1960. Exchanges of water between the English and Bristol channels. / *Mar. Biol. Ass. U.K.* (1960) 39: 637-658.
- RAMAMIRTHAM, C. P. and JAYARAMAN, R. 1960. Hydrographical features of the continental shelf waters off Cochin during the years 1958 and 1959. / *Mar. Biol. Ass. India*, 2(2): 199-207.
- SASTRY, A. A. R. 1957. Vertical stability of the upper layers in the Bay of Bengal. *Bull. Cent. Res. Inst. Univ. Kerala*, Trivandrum, 5(2): 1-7.
- SASTRY, A. A. R., and MYRLAND, P. 1960. Distribution of temperature, salinity and density in the Arabian Sea along the south Kerala Coast (South India) during the post-monsoon season. *Indian J. Fish.*, 6 :223-255.
- SVERDRUP, H. U., JOHNSON, M. W. and FLEMING, R. H. 1942. *Oceans, their Physics, Chemistry and General Biology*. Prentice Hall, New York-1 : 417-418.