No bottom samples have been collected on the shoal parts of Nantucket Shoals, but neighboring stations suggest 32 to 32.5 per mille as the probable values there at 20 to 40 meters for the summer, autumn, and winter—perhaps slightly lower in spring.

ALKALINITY

It has long been known that under normal circumstances sea water is invariably a very slightly alkaline solution. Within the last few years attention has been attracted to the seasonal and regional variations in the precise degree of alkalinity in the sea by the probability that this feature of the aquatic environment may be one of the controlling factors in the biology of marine organisms, especially of the unicellular planktonic forms. Seasonal changes in this respect also afford a possible measure of the activity of diatom and other plant flowerings, and thus of the intensity of life processes in general in the sea, because marine plants increase the alkalinity of the sea water as they draw carbon from the bicarbonates in solution.

This whole question is exceedingly technical; so much so that no convenient measure for alkalinity has yet been devised, the meaning of which would be obvious to any one who had not devoted some attention to the subject. Salinity, for example, is expressed in percentage or per thousand (the more usual terminology), temperature in degrees—expressions sufficiently familiar to be readily understood. The degree of alkalinity, however, usually is stated in terms of the concentration of the hydrogen-ion, which can hardly be expected to bring a concrete image to the mind of anyone not a trained chemist. Perhaps to the marine biologist or to the oceanographer who is not a trained chemist the following quotation in non-technical language may help to clarify the matter:

> The unit of hydrogen-ion concentration is 1 normal hydrogen-ion per liter of water, or about 1 gram of hydrogen-ion per liter. The finest distilled water contains only about 1 gram of hydrogen-ion in 10,000,000 liters of water at about 22° C., and thus its hydrogen-ion concentration is about 10^{-7}. Sea water, however, is alkaline and contains only about a tenth this concentration of hydrogenions. (Mayor, 1919, p. 157.)

The symbol "pH" was invented by Sörensen (1909) and has since been widely adopted to avoid the necessity of writing negative exponents, the notations added thereto being—stated in the baldest possible terms—the logarithm of the reciprocal of the true hydrogen-ion concentration.[20] Therefore, the larger the number of pH the less acid or more alkaline is the water, pH 7 being about neutrality, anything below that acid, and anything above that alkaline.

Determinations of the alkalinity of the sea water can be carried out with little difficulty at sea by the colorimetric method.[21]

The colorimetric tubes used on the *Albatross* in 1920 and on the *Halcyon* were prepared especially for us by Dr. A. G. Mayor and used as prescribed by him (Mayor, 1922, p. 63). These give correct readings for pH if the salinity be 32 to 33 per mille, but for higher salinities every additional 1 per mille of salinity requires a

[20] For a fuller explanation of the reason for expressing the hydrogen-ion concentration by the term pH, rather than directly, see Mayor (1919 and 1922), Clark (1920), and Atkins (1922).

[21] McClendon, Gault, and Mulholland (1917) and Mayor (1919) give details as to the preparation and use of the comparator tubes for rough and ready use at sea.

correction of −0.01 of pH, and a correction of +0.01 for every 1 per mille by which the salinity falls below 32 per mille, thus:

Salinity, per mille	Correction to pH
29	+0.03
30	+0.02
31	+0.01
32–33	0
34	−0.01
35	−0.02

For use on shipboard, where conditions of light and shade are not always of the best, and where the lurching of the vessel may make it difficult to handle delicate apparatus, a dark comparator box, in which three tubes can be inserted—the sea water to be tested and a standard on either side of it—much facilitates the comparison of slight differences of color. We have made the following series of determinations from the *Albatross* and *Halcyon*. Accuracy can be expected to ±0.05 of pH, my experience corroborating Mayor's (1922, p. 65) statement that differences as small as 0.03 pH can be detected with the particular colorimetric tubes employed.

Albatross stations

Station	Date	Depth	pH corrected	Salinity, per mille	Temperature °C.
42° 20′ N. by 70° 40′ W.	Mar. 10	Surface	7.9	32.00	------
42° 17′ N. by 70° 07′ W.	do	do	7.9	32.43	2.22
42° 12′ N. by 69° 06′ W.	do	do	7.9	32.65	2.22
20063	Mar. 11	do	7.9	32.61	3.61
	do	190 meters	7.88	34.61	4.63
20064	do	Surface	7.9	32.84	3.5
	do	330 meters	7.98	34.78	4.02
20065	do	Surface	7.9	32.63	3.61
	do	80 meters	7.9	32.69	2.73
20066	do	Surface	7.9	32.57	3.33
	do	70 meters	7.9	32.59	3.53
20067	Mar. 12	Surface	7.9	32.68	3.05
	do	90 meters	7.9	32.79	2.80
20068	do	Surface	7.9	32.65	3.33
	do	150 meters	7.9	33.86	4.40
	do	190 meters	7.89	34.23	4.92
20069	do	Surface	7.9	32.83	3.33
	do	1,000 meters	7.88	34.92	3.77
20073	Mar. 17	Surface	7.9	32.44	2.22
20074	Mar. 19	do	7.9	32.09	1.39
	do	150 meters	7.9	33.69	4.68
20075	do	Surface	8	31.80	.56
	do	90 meters	8	33.21	3.76
20078	Mar. 20	Surface	8	32.45	1.95
20079	Mar. 22	do	7.9	32.56	2.50
	do	200 meters	7.9	33.31	4.29
20082	Mar. 23	Surface	7.9	32.59	2.67
20083	do	do	7.9	32.17	1.95
20085	do	do	7.9	------	2.50
20087	Mar. 24	do	7.9	32.49	3.05
	do	250 meters	7.89	34.22	5.06
20089	Apr. 6	Surface	7.96	31.25	3.05
20090	Apr. 9	do	7.9	32.36	3.33
	do	120 meters	7.9	32.48	2.25
20091	do	Surface	8	31.97	3.33
20092	do	do	7.94	31.01	3.05
20095	Apr. 10	do	8.02	30.07	3.05
20096	do	do	8.02	29.94	2.78
20098	Apr. 11	do	7.95	32.39	3.05
20099	Apr. 12	do	7.99	31.46	3.61
20103	Apr. 15	do	7.9	32.74	3.89
20104	do	do	7.9	32.32	3.05
20107	Apr. 16	do	7.9	32.34	3.33
20108	do	do	7.9	32.58	4.17
	do	130 meters	7.9	33.05	3.75
20109	do	Surface	7.9	32.65	4.17
	do	150 meters	7.88	34.54	6.47

Albatross stations—Continued

Station	Date	Depth	pH corrected	Salinity, per mille	Temperature °C.
20112	Apr. 17	Surface	7.9	32.54	3.61
20113	do	do	7.9	32.50	3.33
20116	Apr. 18	do	8	32.14	3.61
	do	195 meters	7.9	33.91	4.25
20117	do	Surface	8	31.87	3.61
20118	Apr. 20	do	8.05	31.55	4.44
20121	May 4	do	8.18	29.08	5.56
	do	60 meters	8.15	32.24	2.39
20122	May 8	Surface	8.19	28.26	7.22
	do	85 meters	7.9	32.38	2.30
20123	May 16	Surface	8.02	29.94	8.89
	do	55 meters	7.9	32.18	2.35
20124	do	Surface	7.93	29.87	9.72
	do	100 meters	7.9	32.45	2.65
20125	do	Surface	7.92	30.25	9.17
	do	140 meters	7.9	32.21	4.04
20126	May 17	Surface	7.9	31.53	8.33
	do	160 meters	7.9	33.49	4.10
20127	do	Surface	7.9	31.89	7.22
	do	145 meters	7.9	32.98	3.80
20128	do	Surface	7.9	32.98	7.78
	do	70 meters	8	32.50	5.04
20129	do	Surface	7.9	32.61	7.78
	do	160 meters	7.88	34.72	8.28
20130	May 19	Surface	8	33.17	12.22

Halcyon stations

Station	Date	Depth, meters	pH corrected	Salinity, per mille	Temperature, °C.
10488	Dec. 29, 1920	Surface	7.9	31.82	3.89
10631	Aug. 22, 1922	do	8	31.29	17.80
10632	do	do	8	31.21	18.00
	do	73 meters	8	32.37	4.50
10636	Aug. 24, 1922	do	7.9	31.09	15.80

On March 25 and 26, 1919, Mayor (1922) found the alkalinity to be as follows at several stations between Cape Ann and Yarmouth, Nova Scotia:[22]

Locality	pH corrected	Salinity, per mille	Temperature, °C.
10 miles off Cape Ann	8.04	31.75	4.3
47 miles off Boston Harbor	8	32.54	4.2
Near Cashes Ledge	8	32.56	3.5
32 miles off Yarmouth	7.96	31.46	2.2
8 miles off Yarmouth	7.06	31.67	1.4

Henderson and Cohn (1916) found the alkalinity of several Gulf of Maine samples to vary from pH 8.031 to pH 8.102.

Off the Atlantic coast of the United States, between New York and the Tortugas, Mayor (1922) has reported a range of pH from 7.95 to 8.23, noting a characteristic difference between the gray-green coastal water, with a pH of about 8, and the deep blue gulf stream outside the edge of the continent, with a pH upward of 8.2.

The pH as tabulated above shows the Gulf of Maine to fall among the less

[22] For general summaries of the measurements of pH that have been made in various seas, see Clark (1920), Atkins (1922), and Palitzsch (1923).

alkaline seas, as might have been expected from its comparatively low-salinity and temperature. Within the gulf, however, the pH from station to station does not correspond to the differences in salinity or in temperature; neither have I been able find any definite parallelism between the pH and the abundance of diatoms—certainly no decided rise even at the times and stations when these pelagic plants are flowering most freely. In short, the volume of water is too large and its circulation too free for any given flowering to reflect its active photosynthesis by an appreciable local rise in pH.

The fact that in March the deeper of two samples was in several cases the more alkaline, but that in May the reverse was true, may be significant, the phytoplankton being most abundant in the well-illuminated strata near the surface. It is not improbable, also, that a larger number of observations carried out through the the year would reveal a seasonal fluctuation of pH, with the maximum in early spring and summer following the vernal flowerings of diatoms and the summer multiplication of peridinians, such as occurs in the Irish Sea[23] (Moore, Prideaux, and Herdman, 1915; Bruce, 1924).

VISUAL TRANSPARENCY

Measurements of the transparency of the water were taken at 18 stations durthe summer of 1912 with the ordinary "Secchi" disk—a metal plate 14 inches in diameter, painted white, and rigged with a bridle, so that it hangs horizontal. This is viewed through a water glass[24] while being lowered, and the depth at which it disappears from view is recorded.

In the clearest water the disk was visible to 8.2 fathoms, but at most of the stations it disappeared at 4 to 5 fathoms. Local variations in transparency did not parallel the variations in color (p. 823), for while the water was most transparent when bluest, it was not least so where greenest, but where the percentage of yellow was only 20 (station 10038).

The transparency does not measure the penetration of sunlight, for water cloudy with silt or with diatoms may still be translucent, like ground or opal glass, though transparent to only a small degree.

Transparency, in meters

Date, 1912	Station	Transparency	Date, 1912	Station	Transparency
July 11	10004	6.4	Aug. 15	10031	7.3
July 17	10011	11	Aug. 20	10036	7.3
July 23	10012b	11	Aug. 21	10037	7.3
July 24	10014	11	Aug. 22	10038	5.5
July 25	10015	8.2	Do	10039	11
July 26	10016	6.4	Aug. 24	10040	9.1
Aug. 7	10022	13	Aug. 29	10043	9.1
Do	10023	15	Aug. 31	10044	9.1
Aug. 8	10025	12			

[23] See Nelson (1924) for an account of rapid diurnal variations of pH in the estuarine waters of New Jersey.
[24] The use of the water glass is necessary to escape the effect of reflections from the surface.