

PREFACE TO THE 1961 EDITION

The sea has always challenged the minds and imagination of men and even today it remains the last great frontier of Earth. It is a realm so vast and so difficult of access that with all our efforts we have explored only a small fraction of its area. Not even the mighty technological developments of this, the Atomic Age, have greatly changed this situation. The awakening of active interest in the exploration of the sea came during the Second World War, when it became clear that our knowledge of the ocean was dangerously inadequate. We had only the most rudimentary notions of the geography of that undersea world over which our ships sailed and through which submarines moved. We knew even less about the dynamics of the sea in motion, although the ability to predict the actions of tides and currents and waves might easily determine the success or failure of military undertakings. The practical need having been so clearly established, the governments of the United States and of other leading sea powers began to devote increasing effort to the scientific study of the sea. Instruments and equipment, most of which had been born of urgent necessity, gave oceanographers the means of tracing the contours of the ocean bottom, of studying the movements of deep waters, and even of sampling the sea floor itself.

These vastly accelerated studies soon began to show that many of the old conceptions of the sea were faulty, and by the mid-point of the century a new picture had begun to emerge. But it was still like a huge canvas on which the artist has indicated the general scheme of his grand design but on which large blank areas await the clarifying touch of his brush.

This was the state of our knowledge of the ocean world when *The Sea Around Us* was written in 1951. Since that time the filling in of many of the blank areas has proceeded and new discoveries have been made. In this second edition of the book I have described the most important of the new findings in a series of notes which will be found in the Appendix.*

The 1950's have comprised an exciting decade in the science of the sea. During this period a manned vehicle has descended to the deepest hole in the ocean floor. During the 'fifties, also, the crossing of the entire Arctic basin was accomplished by submarines traveling under the ice. Many new features of the unseen floor of the sea have been described, including new mountain ranges that now appear to be linked with others to form the longest and mightiest mountains of the earth—a continuous chain encircling the globe. Deep, hidden rivers in the sea, subsurface currents with the volume of a thousand Mississippis, have been found. During the International Geophysical Year, 60 ships from 40 nations, as well as hundreds of stations on islands and seacoasts, co-operated in an enormously fruitful study of the sea.

Yet the present achievements, exciting though they are, must be considered only a beginning to what is yet to be achieved by probing the vast depths of water that cover most of the surface of the earth. In 1959 a group of distinguished scientists comprising the Committee on Oceanography of the National Academy of Sciences declared that "Man's knowledge of the oceans is meager indeed compared with their importance to him" The Committee recommended at least a doubling of basic research on the sea by the United States in the 1960's; anything less would, in its opinion, "jeopardize the position of oceanography in the United States" compared with other nations and "place us at a disadvantage in the future use of the resources of the sea."

One of the most fascinating of the projects now planned for the future is an attempt to explore the interior of the earth by drilling a hole three or four miles deep in the bottom of the sea. This project, which is sponsored by the National Academy of Sciences, is designed to penetrate farther than instruments have ever

* For this special edition of *The Sea Around Us*, Rachel Carson's notes have been placed at their appropriate point of reference within the text.

before reached, to the boundary between the earth's crust and its mantle. This boundary is known to geologists as the Mohorovicic discontinuity (or more familiarly as the Moho) because it was discovered by a Yugoslavian of that name in 1912. The Moho is the point at which earthquake waves show a marked change in velocity, indicating a transition from one kind of material to something quite different. It lies much deeper under the continents than under the oceans, so, in spite of the obvious difficulties of drilling in deep water, an ocean site offers most promise. Above the Moho lies the crust of the earth, composed of relatively light rocks, below it the mantle, a layer some 1800 miles thick enclosing the hot core of the earth. The composition of the crust is not fully known and the nature of the mantle can be deduced only by the most indirect methods. To penetrate these regions and bring back actual samples would therefore be an enormous step forward in understanding the nature of our earth, and would even advance our knowledge of the universe, since the deep structure of the earth may be assumed to be like that of other planets.

As we learn more about the sea through the combined studies of many specialists a new concept that is gradually taking form will almost certainly be strengthened. Even a decade or so ago it was the fashion to speak of the abyss as a place of eternal calm, its black recesses undisturbed by any movement of water more active than a slowly creeping current, a place isolated from the surface and from the very different world of the shallow sea. This picture is rapidly being replaced by one that shows the deep sea as a place of movement and change, an idea that is far more exciting and that possesses deep significance for some of the most pressing problems of our time.

In the new and more dynamic concept, the floor of the deep sea is shaped by racing turbidity currents or mud flows that pour down the slopes of the ocean basins at high speed; it is visited by submarine landslides and stirred by internal tides. The crests and ridges of some of the undersea mountains are swept bare of sediments by currents whose action, in the words of geologist Bruce Heezen, is comparable to "snow avalanches in the Alps (which) sweep down and smother the relief of the lower slopes."

Far from being isolated from the continents and the shallow seas that surround them, the abyssal plains are now known to

receive sediments from the margins of the continents. The effect of the turbidity currents, over the vast stretches of geologic time, is to fill the trenches and the hollows of the abyssal floor with sediment. This concept helps us understand certain hitherto puzzling occurrences. Why, for example, have deposits of sand—surely a product of coastal erosion and the grinding of surf—appeared on the mid-ocean floor? Why have sediments at the mouths of submarine canyons, where they communicate with the abyss, been found to contain such reminders of the land as bits of wood and leaves, and why are there sands containing nuts, twigs, and the bark of trees even farther out on the plains of the abyss? In the powerful downrush of sediment-laden currents, triggered by storms or floods or earthquakes, we now have a mechanism that accounts for these once mysterious facts.

Although the beginnings of our present concept of a dynamic sea go back perhaps several decades, it is only the superb instruments of the past ten years that have allowed us to glimpse the hidden movements of ocean waters. Now we suspect that all those dark regions between the surface and the bottom are stirred by currents. Even such mighty surface currents as the Gulf Stream are not quite what we supposed them to be. Instead of a broad and steadily flowing river of water, the Gulf Stream is now found to consist of narrow, racing tongues of warm water that curl back in swirls and eddies. And below the surface currents are others unlike them, running at their own speeds, in their own direction, with their own volume. And below these are still others. Photographs of the sea bottom taken at great depths formerly supposed to be eternally still show ripple marks, a sign that moving waters are sorting over sediments and carrying away the finer particles. Strong currents have denuded the crest of much of the vast range of undersea mountains known as the Atlantic Ridge, and every one of the sea mounts that has been photographed reveals the work of deep currents in ripple marks and scour marks.

Other photographs give fresh evidence of life at great depths. Tracks and trails cross the sea floor and the bottom is studded with small cones built by unknown forms of life or with holes inhabited by small burrowers. The Danish research vessel *Galathæa* brought up living animals in dredges operated at great depths, where only recently it was supposed life would be too scanty to

permit such sampling. These findings of the dynamic nature of the sea are not academic; they are not merely dramatic details of a story that has interest but no application. They have a direct and immediate bearing on what has become a major problem of our time.

Although man's record as a steward of the natural resources of the earth has been a discouraging one, there has long been a certain comfort in the belief that the sea, at least, was inviolate, beyond man's ability to change and to despoil. But this belief, unfortunately, has proved to be naïve. In unlocking the secrets of the atom, modern man has found himself confronted with a frightening problem—what to do with the most dangerous materials that have ever existed in all the earth's history, the by-products of atomic fission. The stark problem that faces him is whether he can dispose of these lethal substances without rendering the earth uninhabitable.

No account of the sea today is complete unless it takes note of this ominous problem. By its very vastness and its seeming remoteness, the sea has invited the attention of those who have the problem of disposal, and with very little discussion and almost no public notice, at least until the late 'fifties, the sea has been selected as a "natural" burying place for the contaminated rubbish and other "low-level wastes" of the Atomic Age. These wastes are placed in barrels lined with concrete and hauled out to sea, where they are dumped overboard at previously designated sites. Some have been taken out 100 miles or more; recently sites only 20 miles offshore have been suggested. In theory the containers are deposited at depths of about 1000 fathoms, but in practice they have at times been placed in much shallower waters. Supposedly the containers have a life of at least 10 years, after which whatever radioactive materials remain will be released to the sea. But again this is only in theory, and a representative of the Atomic Energy Commission, which either dumps the wastes or licenses others to do so, has publicly conceded that the containers are unlikely to maintain "their integrity" while sinking to the bottom. Indeed, in tests conducted in California, some have been found to rupture under pressure at only a few hundred fathoms.

But it is only a matter of time until the contents of all such containers already deposited at sea will be free in the ocean waters,

along with those yet to come as the applications of atomic science expand. To the packaged wastes so deposited there is now added the contaminated run-off from rivers that are serving as dumping grounds for atomic wastes, and the fallout from the testing of bombs, the greater part of which comes to rest on the vast surface of the sea.

The whole practice, despite protestations of safety by the regulatory agency, rests on the most insecure basis of fact. Oceanographers say they can make "only vague estimates" of the fate of radioactive elements introduced into the deep ocean. They declare that years of intensive study will be needed to provide understanding of what happens when such wastes are deposited in estuaries and coastal waters. As we have seen, all recent knowledge points to far greater activity at all levels of the sea than had ever been guessed at. The deep turbulence, the horizontal movements of vast rivers of ocean water streaming one above another in varying directions, the upwelling of water from the depths carrying with it minerals from the bottom, and the opposite downward sinking of great masses of surface water, all result in a gigantic mixing process that in time will bring about universal distribution of the radioactive contaminants.

And yet the actual transport of radioactive elements by the sea itself is only part of the problem. The concentration and distribution of radioisotopes by marine life may possibly have even greater importance from the standpoint of human hazard. It is known that plants and animals of the sea pick up and concentrate radiochemicals, but only vague information now exists as to details of the process. The minute life of the sea depends for its existence on the minerals in the water. If the normal supply of these is low, the organisms will utilize instead the radioisotope of the needed element if it is present, sometimes concentrating it as much as a million times beyond its abundance in sea water. What happens then to the careful calculation of a "maximum permissible level"? For the tiny organisms are eaten by larger ones and so on up the food chain to man. By such a process tuna over an area of a million square miles surrounding the Bikini bomb test developed a degree of radioactivity enormously higher than that of the sea water.

By their movements and migrations, marine creatures further

upset the convenient theory that radioactive wastes remain in the area where they are deposited. The smaller organisms regularly make extensive vertical movements upward toward the surface of the sea at night, downward to great depths by day. And with them goes whatever radioactivity may be adhering to them or may have become incorporated into their bodies. The larger fauna, like fishes, seals, and whales, may migrate over enormous distances, again aiding in spreading and distributing the radioactive elements deposited at sea.

The problem, then, is far more complex and far more hazardous than has been admitted. Even in the comparatively short time since disposal began, research has shown that some of the assumptions on which it was based were dangerously inaccurate. The truth is that disposal has proceeded far more rapidly than our knowledge justifies. To dispose first and investigate later is an invitation to disaster, for once radioactive elements have been deposited at sea they are irretrievable. The mistakes that are made now are made for all time.

It is a curious situation that the sea, from which life first arose, should now be threatened by the activities of one form of that life. But the sea, though changed in a sinister way, will continue to exist; the threat is rather to life itself.

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