

Marine Fish Cultivation

In their recent review in *Nature*¹ of the papers on an experiment in marine fish cultivation by my colleagues and me², Cooper and Steven express the view, "that encouragement of fish growth in arms of the open sea such as the North Sea or the English Channel by the addition of plant nutrients can never be a paying concern". This categorical statement, based on a previous paper by Cooper³, seems to bar once and for all any large-scale application of fertilizers to suitable parts of the sea. Leaving a fuller discussion to a forthcoming paper on fertilizer application in an open sea-loch, may I point out here that Cooper's arguments and figures do not, in my opinion, bear out his conclusion. For an assessment of the economics of fertilizing the sea we require figures showing: (a) the return in crop and stock per ton of fertilizer added to land, (b) the return in fish and shell-fish per ton of fertilizer added to the sea. The latter figures unfortunately do not exist. If our experiments have shown anything, it is the desirability of keeping an open mind to a rational approach to the whole problem of increasing the amount of human food growing in the sea, and pursuing research step by step along various lines, not excluding the fertilizing of suitable larger areas. As regards the threatening scarcity of phosphate, should it become necessary to recover it from the sea it may prove possible to extract it from water taken from greater depths of unproductive areas where the concentration of phosphate is high and its availability to plants low.

F. GROSS

Department of Zoology,
University of Edinburgh.

¹ Cooper, L. H. N., and Steven, G. A., *Nature*, **161**, 631 (1948).

² *Proc. Roy. Soc. Edinburgh*, **63** (1947). An Experiment in Marine Fish Cultivation. I. Introduction. By F. Gross. II. Some Physical and Chemical Conditions in a Fertilized Sea-Loch (Loch Craigin). By Dr. A. P. Orr. III. The Plankton of a Fertilized Sea-Loch. By Dr. S. M. Marshall. IV. The Bottom Fauna and the Food of Flatfishes in a Fertilized Sea-Loch (Loch Craigin). V. Fish Growth in a Fertilized Sea-Loch (Loch Craigin). By Dr. F. Gross.

³ Cooper, L. H. N., *J. Mar. Biol. Assoc.*, **27**, 326 (1948).

We do not agree that the expression of a view is a "categorical statement" barring any door to further research. Be that as it may, we still consider that no evidence has yet been produced in support of the belief that encouragement of fish-growth by artificial fertilization of arms of the open sea, such as the English Channel or North Sea, can be made a paying concern. On the other hand, there is no little evidence in support of the opposite view. Perhaps the most convincing is the failure of Dr. Gross and his colleagues to demonstrate that marine fish cultivation could be made to pay even in a very tiny and almost completely enclosed body of water.

A large-scale fertilization of the sea is continuously in progress, for our method in the most advanced countries of disposing of the sewage of coastal towns achieves just this. The discharge from Plymouth, which must be considerable, affects the nutrient content of Plymouth Sound but is soon dissipated in the open sea beyond the breakwater. Its effect on the English Channel has rarely been notable. The problem would be most easily studied in an area already nutrient-poor, such as the Mediterranean and its adjacent seas. Such studies by Bernard¹ off Monaco and off Banyuls near the Franco-Spanish

frontier, and by Ercegović² and Nümann³ in the shallow northern Adriatic, do not seem to have found any appreciable enrichment by sewage. A quantitative assessment of the effect of sewage from large coastal cities discharging into seas of low natural nutrient resources should provide the readiest means of testing Ritchie's thesis which Gross again propounds.

Though there is a continuing exchange of the waters of the English Channel or the North Sea with the Atlantic Ocean, it is not easy to place a measure on it; it would seem to be large. The work of Proudman⁴ suggests that the Irish Sea empties itself through the North Channel and is replaced through the St. George's Channel in a very few years, perhaps no more than two. The phosphate to be added to such arms of the sea, to do any good, would need to be measured in thousands of tons per annum. That part not quickly harvested as fish would vanish into the ocean in a year or two. Though it seems true that four-fifths of the phosphate added to arable land becomes tightly bound in the soil complex, some of it is still available to plants such as lupins which can get it out again; and given time enough, may not a saturation value be reached beyond which phosphate added to the soil remains freely available to plants? Be the answer to this what it may, there is a difference between immobilizing riches in a safe deposit and broadcasting them throughout the five oceans.

As to the last sentence of Dr. Gross's letter, it is always dangerous to try to foretell scientific development. Though the phosphate and nitrate resources of the deep ocean are enormous, the concentration rarely exceeds 90 $\mu\text{gm./l.}$ of phosphate-phosphorus, or 0.000003 *M*. In the near future, no engine devised by man is likely to harness this reserve better than the vast oceanic circulation and upwelling impelled by winds on a global scale, followed by production of plants and animals. Fisheries in the most favoured regions provide the best means yet known or foreseen of exploiting this natural asset. Our heritage of bird guano and rock phosphate, upon which we are so dependent, represents the final stages of this process of enrichment of surface ocean water by upwelling of deep water. This heritage is being replaced more slowly than it is being spent; we ought not to hasten the wastage.

We do not wish to bar any development once and for all. Economic justification of marine research can come only from the application of our increasing knowledge to problems of production from the sea. None the less, fervid advocacy of a very costly programme, followed by practical failure, could only bring the science of the sea into ill repute. Surely the right approach is through small-scale experiments to larger ones, establishing firm experience as we go. The Loch Craigin experiment on these lines was thoroughly sound and worthy of critical appreciation. This we attempted in our review.

L. H. N. COOPER
G. A. STEVEN

The Laboratory,
Citadel Hill,
Plymouth.

¹ Bernard, F., *Ann. Inst. Océan.*, Paris, **17**, 349 (1938).

² Ercegović, A., *Acta Adriatica* (Institutu Biologico-Oceanographici Split (Jugoslavia)), No. 5 (1934).

³ Nümann, W., *Thalassia* (Istituto italo-germanico di biologia marina di Rovigno d'Istria), **5**, Heft 2, 1 (1941).

⁴ Proudman, J., *Phil. Trans. Roy. Soc.*, B, **239**, No. 812, 579 (1946).