Summary of Tees Estuary Investigations.

With 7 Figures in the Text

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Survey of the River Tees. Part II. The Estuary, Chemical and Biological.

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IN 1929 the Marine Biological Association began a survey of the River Tees Estuary, to study the various physical and chemical conditions and the types and distribution of animal and plant life. At the same time a tidal stream survey was carried out by the Hydrographic Department of the Admiralty. Later, for purposes of comparison, the scope of the enquiry was extended to a survey of the River Tay, but on a less extensive scale.

The investigation was made for the Department of Scientific and Industrial Research and occupied four years. Many facts of general interest to marine biologists emerged. The following is a brief account of some of the main findings and does not purport to summarise the results of the survey, for which the original report should be consulted.

The estuary of the Tees is deep and runs far into the country. For 11 miles, from the sea to Stockton, the channel is dredged to a depth of 18 feet below low water. The incoming tide is free to flow with less turbulence and vertical mixing of the water than in tidal estuaries with an uneven bed. In this respect the Tees falls into a distinctive, but not uncommon, class. Above Stockton the incoming tide flows over an uneven bottom having only a few inches of water over it at low water, and fairly complete vertical mixing is the rule. Salt water extends upstream to Stockton at low water, and penetrates a further 3 to 4 miles at high water, while the rise and fall of the tide has been observed some 9 miles beyond this, the fresh water being banked up by the tide.

Animals or plants living at any particular position in the estuary are regularly subjected to a considerable range of salinity every tidal period.

After heavy rains the fresh water tends to run seaward on the surface above the salter water below, and even under normal condition the net movement of the surface waters over a complete period of ebb and flood is seaward. This surface water picks up salt water from below, with the result that the net movement of the deeper layers is upstream. As a result of this circulatory system, which occurs in this class of estuary where the upper layers are less salt than the deeper layers, the effect of a moderate flood of fresh water from the river is to decrease the salinity in the surface layers and increase the salinity near the bottom.

Water entering the tidal reaches moves relatively slowly seawards, especially if the volume of fresh water coming in from the upper river is

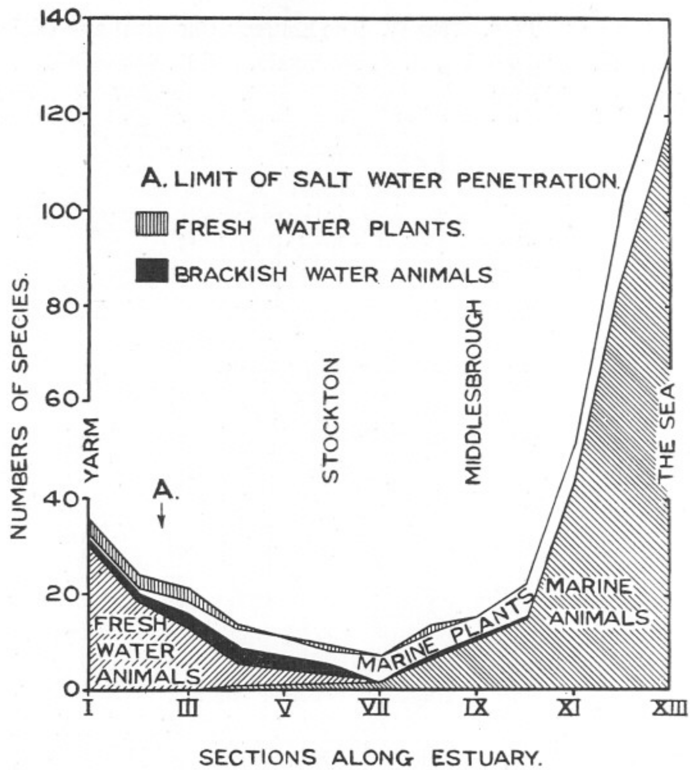

FIG. 1.—Composition of the Flora and Fauna along the Tees Estuary.

small. The mean time taken for all layers of a body of water to travel through the estuary has been estimated to vary from about 6 days under dry weather conditions to about $2\frac{1}{2}$ days under average weather conditions. Substances carried in the upper layers will reach the sea more rapidly and substances in the deeper layers less rapidly than the calculated mean time.

At the mouth of the estuary the marine fauna is varied and abundant; above the limit of salt water, fresh water animals and plants are very numerous; in the central portion of the estuary where the greatest

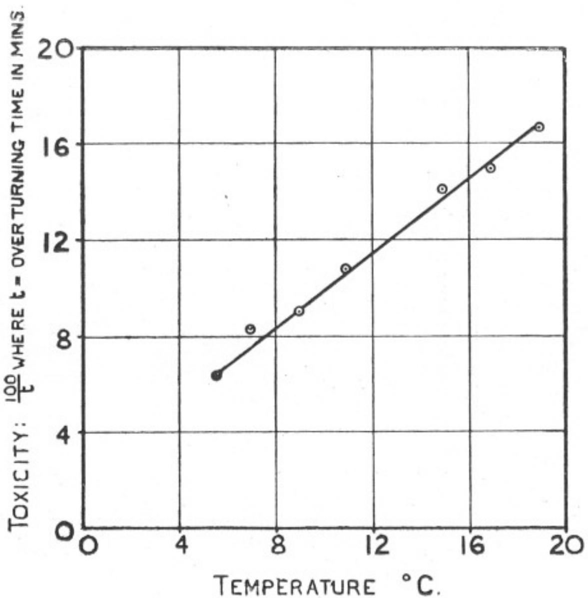

FIG. 2.—Relation between toxicity to trout of a solution of KCN (0·3 gm. CN per litre) and the temperature.

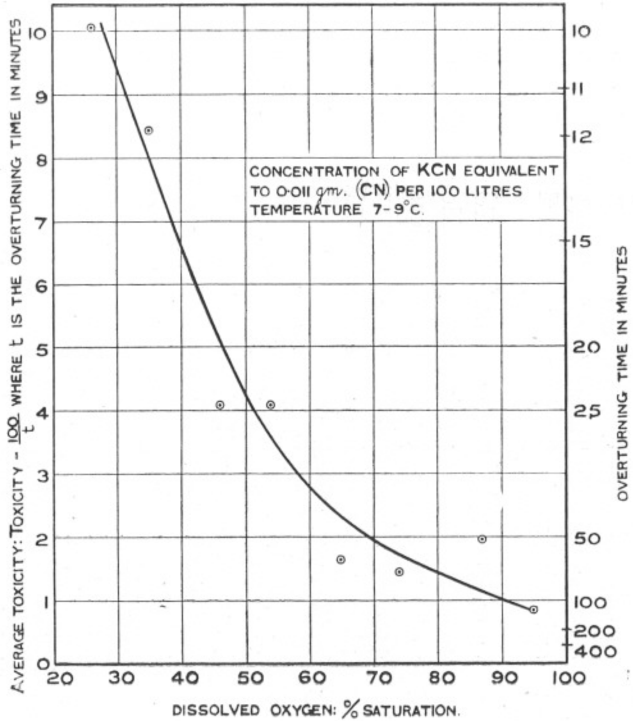

FIG. 3.—Toxicity to Rainbow trout of cyanide in solutions of different dissolved oxygen concentrations.

changes in salinity occur there is little variety or abundance of either marine or fresh water organisms. A similar general distribution had been found in the estuary of the Tamar (Percival) and in Randers Fjord (Johansen), and a similar distribution was found in the sandy estuary of the Tay.

From the extensive salinity data collected in the Tees Estuary, and less extensive data in the Tay, it was possible to divide both into thirteen sections between sea and fresh water. The sections in each case were roughly comparable in having similar ranges of salinity. Collections of animals and plants were made in each section and the numbers and kinds of each species found compared.

In the sandy estuary of the Tay, and also in the muddy estuary of the Tamar, the marine species whilst progressively reduced as the head of the estuary is approached do not die out quite so quickly as in the Tees. In all three estuaries it is evident that the scarcity of marine and fresh water organisms in the central stretch is due mainly to unsuitable tidal and salinity conditions.

Tidal sand and mud banks at the mouths of the Tees and the Tay contain roughly the same number of organisms per unit area. The height above low water of the intertidal areas of mud in the central part of the Tees estuary varies considerably owing to the presence of wharves and retaining walls. Since the abundance of burrowing animals depends largely on the level of the available habitat in the tidal stretch it is difficult to determine the true causes of local fluctuations in their numbers. On the whole the fauna of the Tees estuary is similar both in variety and abundance to that of unpolluted estuaries, except that in the Tees there are few, if any, fish living permanently in the central reaches and the numbers of certain shrimps are much smaller.

The plankton or free floating organisms of the estuary consist of fresh water species, mainly diatoms, washed down from the upper river and marine organisms carried into the estuary mainly in the sub-surface current. In addition *Eurytemora hirundoides*, a brackish water variety of a small crustacean, is found. During the summer this copepod occurs in abundance and is distributed over the greater part of the estuary; in the winter it is not nearly so abundant and its range is restricted to a short stretch in the central portion (Fig. 4).

In the Tees estuary death of migratory fish is common. Salmon are often seen floundering near the surface or floating dead, while salmon and sea-trout smolts die in great numbers during their passage to the sea in the spring.

Various industrial effluents, many of them containing substances highly toxic to fish, are discharged into the estuary—approximately 4400 lb. of tar acids and 1800 lb. of cyanide were discharged daily. In addition, the

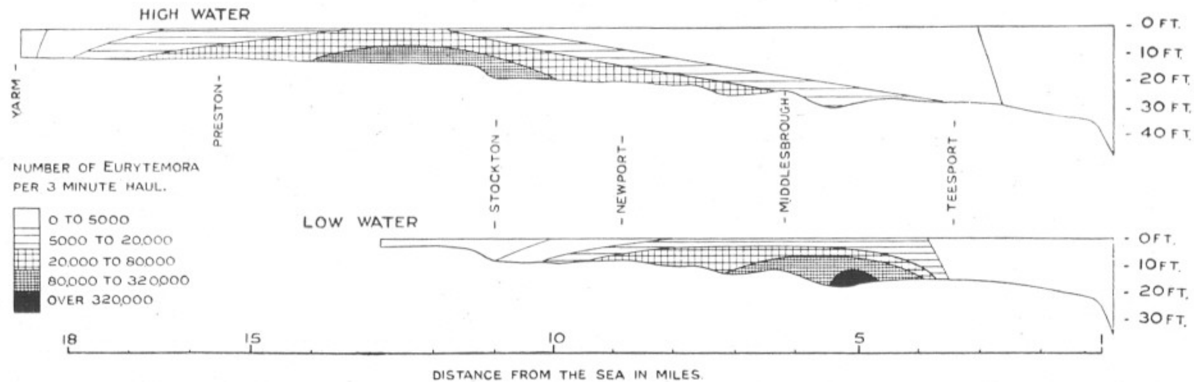

FIG. 4.—Average distribution of Eurytemora at high and low water in the Tees Estuary.

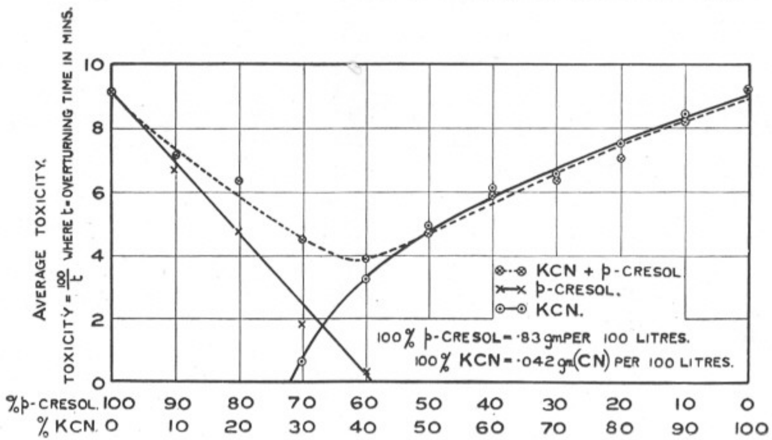

FIG. 5.—Toxicity of mixtures of potassium cyanide and p-Cresol to Rainbow trout.

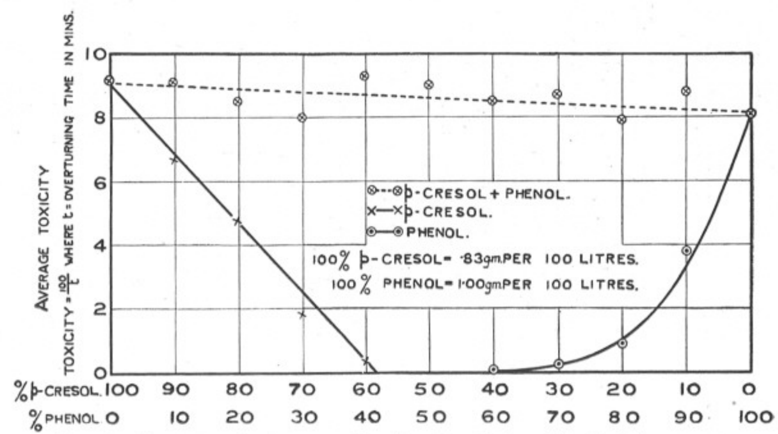

FIG. 6.—Toxicity of mixtures of p-Cresol and phenol to Rainbow trout.

untreated sewage from a considerable population flows into the central part of the estuary and its decay causes partial deoxidation of the water. The extent of this deoxidation is controlled mostly by the prevailing temperature.

Cyanide is very much more toxic than tar acids, concentrations of the order of 0·01 to 0·02 part per 100,000, calculated as (CN), being sufficient to kill fish in less than an hour. Laboratory experiments showed that the toxicity of a solution of cyanide increases with rise of temperature and as the concentration of dissolved oxygen is reduced (Figs. 2 and 3), but

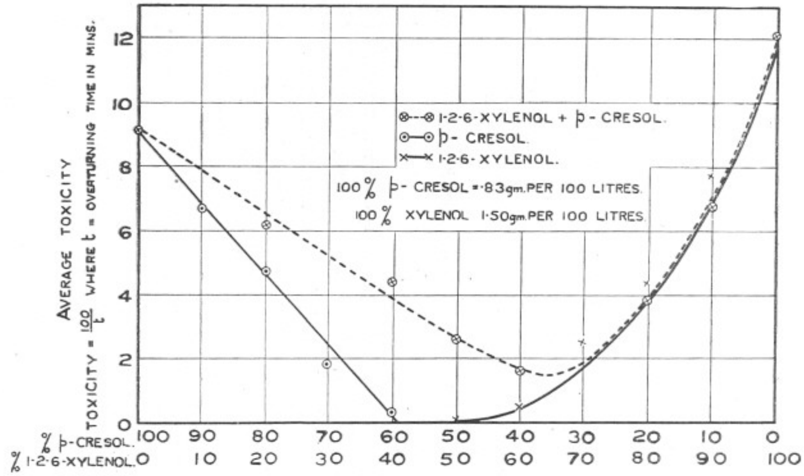

FIG. 7.—Toxicity of mixtures of p-Cresol and 1·2·6 Xylenol to Rainbow trout.

is little affected by additions of sub-lethal concentrations of tar acids. The toxicity of various mixtures of these poisons was tested with the results shown in Figures 5, 6 and 7.

In the spring of 1931 an extensive survey was carried out during the period when salmon and sea-trout smolts were migrating through the estuary to the sea. As in the two previous years, large numbers of fish were killed in the polluted region. With the low prevailing water temperature, the concentration of dissolved oxygen remained at a moderately high level and was more than 50 per cent of the saturation value until the end of the migration period when it fell to between 40 and 50 per cent. In a laboratory experiment Rainbow trout lived comfortably for 35 days in a stream of running water, the oxygen concentration of which varied between 37 and 58 per cent with a mean value of 48 per cent of the saturation value. Over short periods of a few days the minimum oxygen requirements of trout were found to be considerably lower than these concentrations. During the migration tar acids were present in the estuary in concentrations of 0·01 to 0·03, and more rarely in amounts exceeding 0·05 part per 100,000; these are considerably lower than the minimum concentration required to kill fish. On the other hand, cyanides were present on most days during the migration in concentrations as high as, and sometimes exceeding, 0·02 part (CN) per 100,000, which is sufficient to kill fish in a short period. Samples of estuary water taken from the mortality stretch and found to be toxic to trout were rendered innocuous by the removal of cyanide. This was done by adding formaldehyde. Moreover the colour of the gills of smolts found dying in the estuary was brighter than that of normal fish, a characteristic symptom of poisoning by cyanide. All the evidence collected points to the fact that cyanide, discharged as a constituent of effluents from coke-oven gas coolers, was the main cause of the mortality in 1931. It is also possible that in exceptionally warm spring weather the dissolved oxygen content of the water might fall so low as to be insufficient to support fish life.

Smolts were systematically netted, marked and released during the migration in 1931. Some of these marked fish were later recovered and were found to have remained in the estuary for periods up to 9 days. No relationship was found between the numbers netted on any day and the volume of water coming down from the upper river. The dead smolts collected provided information on the size, age, sex and food of the migrating fish. The collection was composed mainly of two-year-old fish, and migration appeared to be dependent on their reaching a size above a certain minimum. Fish which did not grow to this length in two years migrated in the following season.

In view of the mortality of fish brought about in the Tees estuary by cyanide, some experiments were carried out to determine the effect of cyanide on invertebrate animals. Of four crustaceans, the ranges of which are particularly restricted in the Tees, two were apparently unaffected by the maximum concentration normally found in the estuary, while two, the common shrimp and the chameleon shrimp, were susceptible to this concentration. It seems probable that the ranges of these latter animals are restricted by the presence of cyanides.

Both cyanides and tar acids undergo decomposition when diluted with water, and it is probable that a considerable loss of these substances occurs during the period in which they are carried to and fro in the estuary. While the rate of decomposition of tar acids is markedly accelerated by the presence of sewage, that of cyanides is apparently unaffected. The breakdown of cyanides is, however, increased when they are diluted with estuarine water, and it is possible that this water contains a specific bacterial flora capable of bringing about their decomposition.

An examination was made of the methods by which the oxygen demand of the different types of polluting material entering the estuary might be assessed and compared. In determining the rate at which dissolved oxygen is absorbed from solution by sterile industrial effluents it is essential that they should be diluted with water containing an appropriate bacterial flora ; the diluent used was aerated estuary water of a constant salinity. The total oxygen demand of the sewage was estimated from the population served by the sewerage systems, the demand due to spent pickle liquors was calculated from the weight of ferrous iron discharged, and the oxygen demands of other industrial effluents were determined experimentally. It has been estimated that, of the total oxygen demand, nearly 60 per cent is due to sewage, about 3 per cent to spent pickle liquors and nearly 40 per cent to other industrial effluents. The experimental data are given fully in Tables in the Report.

H. W. H.