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SUPERSATURATION OF ATMOSPHERIC GASES IN COASTAL WATER

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The sardine fishery on the coast of Maine is plagued by sporadic sequences of poor fishing seasons. The dearth of juvenile herring, which are the basis of this fishery, seems to be due in part to the failure of the schools to occupy the waters close to shore where they are most available to the conventionally used fishing gear. Studies are now being conducted by the U.S. Bureau of Commercial Fisheries to learn some of the reasons for this behavior. Of particular interest are the responses of juvenile herring to several components of their physical environment. These studies have led to the discovery that the upper layers of certain protected coastal waters were highly supersaturated with dissolved oxygen during that part of the year when herring normally inhabit these waters. This condition has prevailed for the past three years, in all three of which the herring fishery has been relatively unsuccessful in at least one major segment of the coast. Unfortunately, no prior data are available to show whether or not similar supersaturation occurred during normal herring seasons. To determine this, the annual trends of dissolved oxygen are being followed until at least one normal year for herring can be included in the study.

Although extreme supersaturation of oxygen has been shown in several instances to have detrimental physiological effects on fish, no information is available to show how sensitive herring might be in this respect, nor whether they are able to detect and avoid supersaturated water. Several laboratory experiments were therefore conducted to provide this information. Groups of 10 - 15 herring were held in an elongated tank (5.5 x 0.3 x 0.4 meters) and water supersaturated under pressure with either air or pure oxygen was added at one end of the tank. The distribution of herring in the tank was noted by counting them in the two ends of the tank every 15 minutes for 2 hours. After an interval of several hours, allowing time for the water in the tank to reach normal saturation, the treated water was added to the opposite end, and again the distribution of herring recorded. The procedure was repeated at least three times for every level of supersaturation used. A significant change in distribution occurred, away from the supersaturated end, in all experiments where the saturation of oxygen exceeded 130% and that of nitrogen exceeded 120%. When nitrogen was 100% or less, the herring avoided the oxygen supersaturated end only when the saturation exceeded 200%.

The highest supersaturation observed in the coastal water was 153% and occurred in June, 1964. This record was in water pumped to the laboratory from the harbor nearby and as a result of the supersaturated condition many fish in the laboratory aquaria showed symptoms of gas bubble disease. Oxygen measurements made of the harbor water directly showed that it, too, was highly supersaturated. No measurements of nitrogen were made at that time, but in retrospect it seems likely that nitrogen as well as oxygen was in excess. Subsequent measurements showed that, although nitrogen seldom exceeded 110% saturation, occasionally saturations of about 120% were observed, generally in the spring. Oxygen saturation of over 130% was common during the spring and early summer. When measurements of both gases were made, the ratio of their concentrations indicated that usually the excess oxygen was biologically produced, although physical causes such as warming contributed somewhat.

Although most of the measurements were made near Boothbay Harbor, a few other localities along the coast were also sampled. No observations were made that were as high as those at Boothbay Harbor, but values of over 120% saturation were common. Oxygen measurements made offshore in the Gulf of Maine by the Albatross IV during the same period were substantially lower: few were as high as 120%.

The seasonal trends of dissolved oxygen at Boothbay Harbor are shown in Figure 1. The monthly means are based on daily maximum values. Oxygen remained near or below 100% saturation during the late fall and winter, but both concentration and percent saturation increased markedly early in the spring, presumably due to early phytoplankton flowering. With increasing temperature the percent saturation continued to increase, reaching a maximum when the temperature rise was most rapid. The concentration was maximum when the water was cold, but lagged the temperature minimum somewhat because of the increasing photosynthesis which follows the coldest part of the year. When the water temperature was at a maximum, both concentration and saturation began to decline, although supersaturation prevailed throughout most of the summer.

According to the experimental evidence, the supersaturation of natural waters was not high enough to act as a barrier to herring. Unless the effects were too subtle to be demonstrated experimentally, oxygen supersaturation is probably not a significant agency in governing the movements of herring directly. This, however, does not negate indirect relationships between herring distribution and oxygen supersaturation, such as adverse effects from the phytoplankton which caused the supersaturation. Whether any relationship at all exists still remains to be demonstrated.

MONTHLY AVERAGES OF DAILY O_2 MAXIMA AND CORRESPONDING WATER TEMPERATURE