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FIRST REPORTED INCIDENCE OF GAS-BUBBLE DISEASE IN THE HEATED EFFLUENT OF A STEAM GENERATING STATION [1]

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ABSTRACT

During the winter of 1970-71, thirteen species of warm-water fishes exhibited external symptoms of gas-bubble disease (mostly "pop-eye") in the discharge canal and cove of a steam generating station. Peak monthly incidences were 70.8, 33.3, and 23.5 percent for white bass, threadfin shad, and bluegill, respectively.

Forty-nine percent of the bluegill in excess of 4 inches were afflicted, whereas only 4.4 percent of those under 4 inches exhibited symptoms. Among the bluegill, the right eye only symptoms were more prevalent than were the left eye only symptoms at the 97.5 percent confidence level.

Dead fish, principally black crappie, observed in the discharge in February, 1971 did not exhibit external symptoms of gas-bubble disease. However, autopsies of dying black crappie revealed gas emboli in the larger vessels of the gill fragments.

INTRODUCTION

Gas-bubble disease (GBD) can occur when the blood of a fish becomes supersaturated with gases. This condition may result when a fish at equilibrium with air-saturated water is subjected to an increase in temperature, a decrease in pressure, or both. More commonly GBD develops when a fish is exposed to an environment that is supersaturated with dissolved gases.

Water can become supersaturated with gases when leaks allow the introduction of air into pumped water supplies for aquaria (Marsh and Gorham, 1905) or into gravity-fed water supplies for fish hatcheries (Harvey and Smith, 1961). Natural waters may also become supersaturated with gases. This condition, usually involving nitrogen, has been reported from springs (Marsh and Gorham, 1905; Rucker and Hodgeboom, 1953), wells (Rucker and Tuttle, 1948), streams (Harvey and Cooper, 1962) and lakes (Harvey, 1967).

If the degree of supersaturation is great enough, fishes generally exhibit external GBD symptoms which include bubbles in the integument (commonly on the head or fins) and exophthalmos ("pop-eye") caused by bubbles in the tissues behind or within the eye (Marsh and Gorham,

1 Contribution from Federal Aid to Fish Restoration Funds under Dingell-Johnson Project F-19, State of North Carolina.

1905). Internal histopathological changes also take place in the early stages of the disease (Pauley and Nakatani, 1967).

GBD symptoms are often accompanied by mortalities (Marsh and Gorham, 1905; Westgard, 1964; Beiningen and Ebel, 1970). Natural mortalities of fishes caused by oxygen supersaturation have been reported from both freshwater (Woodbury, 1941) and saltwater (Renfro, 1963). Traditionally, GBD has caused its greatest problem in fish hatcheries where the offending gas is most often nitrogen (Rucker and Tuttle, 1948; Rucker and Hodgeboom, 1953; Harvey and Smith, 1961). Recently, concern over gas-bubble disease has been focused upon salmon mortalities in the Columbia River (Westgard, 1964; Ebel, 1969). Ebel (1969) demonstrated that large portions of the Columbia River become supersaturated with nitrogen during periods of high flow. Neither nitrogen supersaturation nor gas-bubble disease has previously been reported from the heated effluent of a steam generating station, although the threat of this possibility was recognized by personnel of the Great Lakes Fishery Laboratory (1970).

The North Carolina Wildlife Resources Commission, in cooperation with Duke Power Company, and The Johns Hopkins University has been studying the effects of the heated effluent from the Marshall Steam Station upon the fishes of Lake Norman, North Carolina since July, 1968. During the winter of 1969-70, classical symptoms of gas-bubble disease appeared in the monthly fish samples taken from the discharge area. This report deals with observations on GBD made during that period and especially those made during the subsequent winter, 1970-71.

STUDY AREA

Lake Norman, a 32,500 surface-acre hydroelectric impoundment, is located on the Catawba River in Piedmont North Carolina. The lake was created in 1963 by the completion of Cowan's Ford Dam. The Duke Power Company Marshall Steam Station is located on the west shore of Lake Norman near highway NC 150, approximately midway between the dam and the headwaters of the reservoir (Figure 1). The station employs four coal-fueled generating units and has a nameplate generating capacity of 2.1 million kw. Cooling water for the plant is drawn from the main reservoir under an inverted "skimmer wall" which allows the use of cold hypolimnetic water for cooling.

METHODS AND MATERIALS

Gill nets, electrofishing equipment, and a midwater trawl were used monthly to sample the Lake Norman Fish population.

In the discharge cove, nylon gill nets measuring 120 feet by 6 feet were set on a point of land near the mouth of the cove, approximately 3,800 feet from the discharge structure (Figure 1). One 1-inch bar mesh net and two 2-inch bar mesh nets were set perpendicular to the shoreline and fished for two consecutive days each month.

A boat-mounted Smith-Root Mark V electrofishing unit with an output of 425 v pulsed DC at 60 Hertz was used to sample the entire shoreline of the discharge canal and cove monthly.

The midwater trawl consisted of a 25-foot long net mounted on a 3 by 9 foot rectangular frame. Mesh size used consisted of ¾ inch in the wings, ½ inch in the throat, and ¼ inch in the cod end. The trawl could be regulated to fish as a surface tow (between the surface and a depth of four feet), or as a deep tow (between depths of eight and twelve feet). In the discharge canal, two six-minute tows (one deep and one shallow) were made each month while matching four-minute tows were made in the discharge cove.

Fishes collected by the above methods were identified, measured and weighed individually. Obvious injuries, deformities, disease symptoms, as well as "pop-eye" and other symptoms of gas-bubble disease were recorded as they were observed in the course of weighing and measuring the fishes.

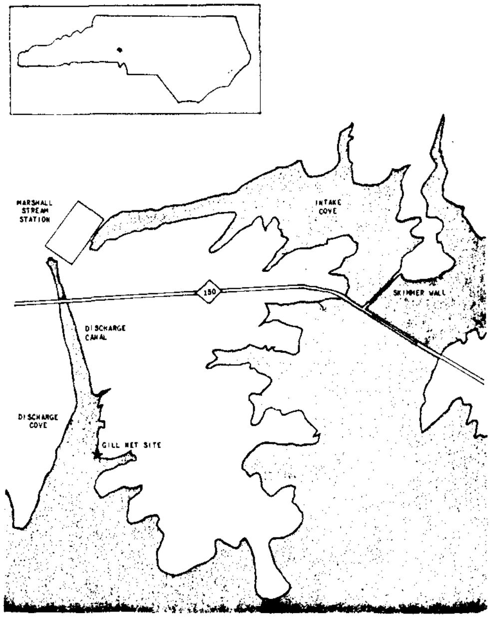

FIGURE 1. Location of Marshall Steam Station, Duke Power Company showing intake and discharge coves.

A weekly creel census was carried out each Saturday during the latter period of this report. "Pop-eyed" fishes encountered during the creel survey were indicated on the creel data forms along with length and weight information from March through May, 1971.

RESULTS AND DISCUSSION

Three species of fishes representing two families were found to be afflicted with gas-bubble disease during the winter of 1969-70, whereas thirteen species representing six families showed symptoms of this malady during the winter of 1970-71 (Table 1). "Pope-eye" was the major diagnostic feature and was the single observed symptom in the great majority of cases (Figure 2). Relatively few fishes were diagnosed on the basis of bubbles on the head, fins, in the mouth, or in the vicera.

The observed incidences in Table 1 may have been influenced by increased susceptibility of afflicted specimens to sampling gear. Also, it is sometimes possible to misdiagnose capture-connected injuries as GBD symptoms. On the other hand, the necessarily rapid and cursory examination of fishes may have resulted in overlooked symptoms. It is possible also, for fishes to suffer from GBD without exhibiting external symptoms (Marsh and Gorham, 1905; Ebel, 1969). It is believed that these influences tend to counterbalance one another and that the observed incidences in most cases are reasonable estimates of actual GBD frequencies.

Increased surveillance during the winter of 1970-71 may account for some of the increase in GBD incidence during that period, but the majority of the increase was undoubtedly due to a change in the physical conditions of the heated effluent. Cooling water temperature increases ($\triangle$T) during the two periods were similar (Table 2). The 1970-71 increase in GBD incidence may have been due to unknown changes in the dissolved nitrogen regime.

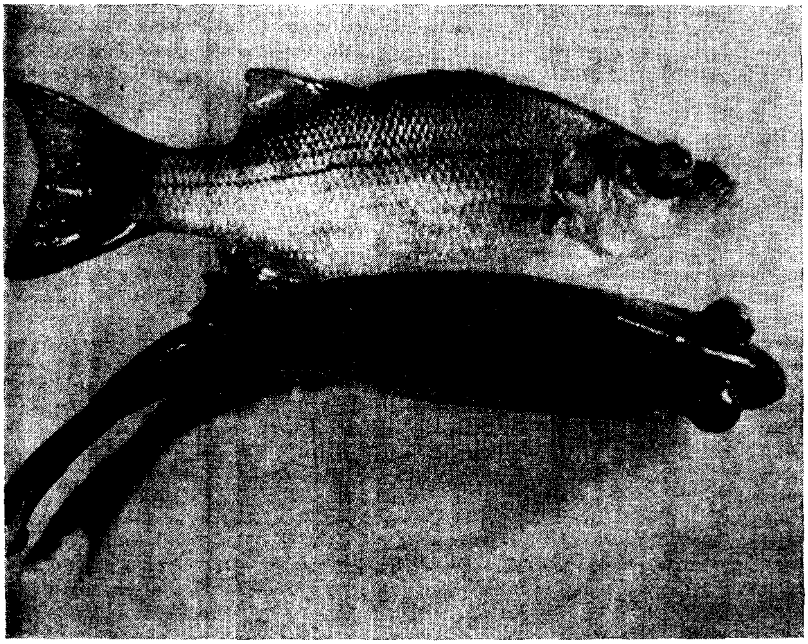

FIGURE 2. White bass exhibiting gas-bubble disease symptoms.

TABLE 1. Incidence of gas-bubble disease symptoms, mostly "pop-eye", found in the monthly sampling of the Marshall Steam Station discharge canal and cove, Lake Norman.

	Dec., 1969-May, 1970			Dec., 1970-May, 1971		
Species	No.	GBD	%	No.	GBD	%
Lepomis gulosus	9	1	11.1	3	1	33.0
Lepomis macrochirus	341	10	2.9	398	41	10.3
Dorosoma petenense	6,571	1	tr.	2,253	173	7.7
Ictalurus platycephalus	2	0	0	2	1	50.0
Morone chrysops	288	0	0	348	101	29.0
Micropterus salmoides	72	0	0	69	5	7.2
Notemigonus chrysoleucas	84	0	0	32	3	9.4
Notropis analostanus	74	0	0	90	5	5.6
Pomoxis annularis	2	0	0	14	1	7.1
Pomoxis nigromaculatus	14	0	0	49	1	2.0
Lepomis auritus	18	0	0	18	1	5.6
Cyprinus carpio	24	0	0	61	1	1.6
Perca flavescens	147	0	0	404	1	0.2

In 1970-71, GBD symptoms first appeared in bluegill *Lepomis macrochirus,* in December, in threadfin shad *Dorosoma petenense,* the following month, and in white bass *Morone chrysops,* in February (Figure 3). The incidence in these three species peaked in the same order during that winter and spring. All three species showed a peak incidence that was much higher than the average incidence for the entire winter and spring period. Of the 24 white bass collected in April, 1971, 17 (70.8%) were afflicted with "pop-eye". The incidences for threadfin shad and bluegill peaked at 33.3 and 23.5 percent, respectively. The temporal

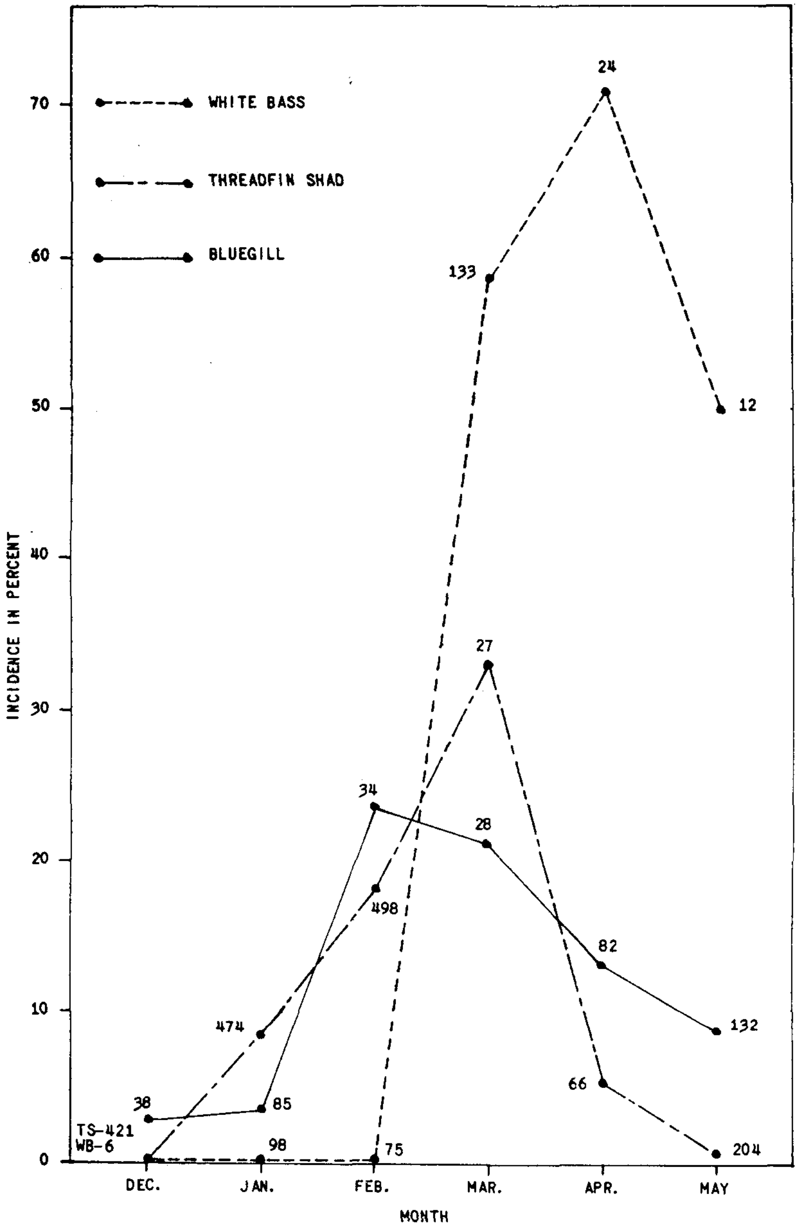

FIGURE. 3. The incidence of external symptoms of gas-bubble disease (mostly "pop-eye") for three species of fishes captured in the heated effluent from Marshall Steam Station, Duke Power Company, Lake Norman, 1970-71. Numbers of fish examined for G.B.D. are shown at each percentage point.

TABLE 2. Average monthly temperature increases ($\triangle$T's) in degrees F. of the cooling water passing through the Marshall Steam Station, Lake Norman, North Carolina.

	Month					
	Dec.	Jan.	Feb.	Mar.	April	May
Winter 1969-70	23.4	27.5	28.3	20.9	21.7	20.7
Winter 1970-71	21.5	24.6	28.6	27.0	25.5	21.8

separation of incidence peaks for the three species probably reflect specific differences in disease development.

Size Differences

Small bluegill exhibited symptoms of gas-bubble disease far less frequently than larger specimens. When the collected specimens were arbitrarily divided into two size categories, 27 (49.1%) of 55 bluegill four inches long or greater were found to exhibit GBD symptoms. The incidence among bluegill in the less-than-four-inch group was only 4.4 percent of the 344 specimens collected. These data parallel the findings of Egusa (1959) that young carp *Cyprinus carpio*, and goldfish *Carassius auratus*, were less susceptible to GBD than adults. Marsh and Gorham (1905) noted size differences in susceptibility and postulated that an increase in the body temperature of larger fishes above ambient temperatures could contribute to the liberation of gases in the blood stream. Egusa (1959) attributed size differences to the stronger muscular activity of larger fishes. Increased predation upon small bluegill afflicted with GBD could account for the wide divergence in incidence between size groups observed in the study.

Right Eye vs. Left Eye

Chi-square tests indicated that among bluegill, right eye only symptoms of gas-bubble disease were more prevalent than left eye only symptoms at the 97.5 percent level of confidence. There wer no significant differences between right eye only and left eye only symptoms in white bass and threadfin shad.

Creel Census

In the creel census, GBD was observed in white bass, largemouth bass *Micropterus salmoides*, black crappie *Pomoxis nigromaculatus*, white crappie *Pomoxis annularis*, and bluegill. Again, white bass were most often afflicted. Of the 396 white bass inspected during March through May, 1971, 68 or 17.2 percent exhibited "pop-eye". The highest incidence occurred in the last week of March when 8 of the 13 specimens (61.5%) were found to be afflicted.

The incidence of "pop-eye" in white bass observed in the creel census was always less than that observed in the scheduled sampling during any given month. This may indicate the GBD causes a debilitating effect on white bass serious enough to affect feeding.

Mortalities

While electrofishing in the discharge cove on February 19, 1971, a few hundred dead black crappie were observed. Ten to twenty fish examined showed no signs of injuries or external symptoms of disease. Two dying black crappie were examined in the laboratory. The gills of both fish appeared bloodless and necrotic even though the fish were still alive. Microscopic examination of the gills revealed long cylindrical gas emboli lodged in and completely occluding the major blood vessels of many gill filaments. The emboli cosely resembled those described by Woodbury (1941). Protists were conspicuously absent.

An attempt was made to assess the extent of the mortality on the following day. There were fewer fish, but 87 freshly dead specimens were counted and examined for "pop-eye", hook wounds, etc. Sixtynine of the fishes examined were black crappie. Small numbers of bluegill, largemouth bass, and yellow perch *Perca flavescens* comprised the balance. In addition to the dead fish, 4 bluegill and 17 threadfin shad were found dying. Three of the dying bluegill exhibited "pop-eye". A six-inch bluegill that did not exhibit "pop-eye" and a three-inch specimen with double "pop-eye" were examined in the laboratory. Both contained gas emboli in the vessels of the gill filaments. Nine of the 17 dying threadfin shad exhibited "pop-eye". One "pop-eyed" specimen was examined in the laboratory and no emboli were found in the gills.

Surveillances carried out on February 22 and 23 revealed a total of 304 dead fish, predominantly crappie. These observations suggest that a relatively constant mortality took place during that week. The symptoms exhibited by dying fishes implicate gas-bubble disease as a principal factor in the mortalities.

Nitrogen Determinations

Complete diagnosis of gas-bubble disease generally includes demonstrating the existence of gas supersaturation. Attempts to determine nitrogen concentrations using the gasometric method devised by Post (1970) were unsuccessful during the winter, 1970-71. Water samples taken in April, 1971 were analyzed by gas chromatography in the laboratory of a private research firm. Even though the determinations were variable, they did indicate that some degree of nitrogen supersaturation existed in the discharge.

CONCLUSIONS

1. The heating of lentic waters by a steam generating station can result in levels of gas supersaturation high enough to cause gas-bubble disease.
2. Highest incidences of gas-bubble disease occurred during the winter months.
3. Monthly incidences of GBD were highest in white bass, threadfin shad, and bluegill.
4. Small bluegill exhibited symptoms of gas-bubble disease far less frequently than did larger specimens.
5. Among bluegill, right eye only symptoms of GBD were far more prevalent than left eye only symptoms.
6. Fish mortalities observed in the Marshall Steam Station discharge area in February, 1971 were apparently caused by GBD.

ACKNOWLEDGMENT

The authors wish to express appreciation to Duke Power Company for supplying data on nitrogen concentrations and the information in Table 2.

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STREAM DAMAGE FROM MANGANESE STRIP-MINING

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ABSTRACT

Abandoned manganese strip mines in Smyth County, Virginia have for many years contributed pollution to the streams draining them. Streams in the Cripple Creek drainage area were sampled during the summer of 1967 to determine the nature and extent of pollution in them, and to evaluate the reclamation work being done by the United States Forest Service. Affected streams were compared with control streams on the basis of physical, chemical and biological properties.

Manganese levels in all streams sampled were found to be below one part per million. A controlled experiment with $Mn(NO_3)_2$ showed that the median tolerance limit for rainbow trout fingerlings is about 16 ppm Mn, which, together with stream sampling data, indicates that manganese is not present in toxic concentrations in the study streams.

Killinger Creek, which drains a partially reclaimed area, was found to support fewer species of fish and benthic fauna than Crigger Creek, a comparable control stream. Siltation is probably the main contributing factor. Bedload was much greater in affected streams than in control streams. Although volume of bedload was high in Blue Spring Creek, which drains a reclaimed area, particle size distribution of the bedload indicates that much of the finest silt has been flushed from the upper portion of this stream. Blue Spring Creek supports an abundant population of aquatic insects and fish fauna, indicating that reclamation has been effective on this watershed. It was also found that rainbow trout are spawning successfully in this stream.

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