MARINE FISHERIES INFORMATION SERVICE

No. 53
SEPTEMBER, 1983

Technical and Extension Series

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

COCHIN, INDIA

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

THE MARINE FISHERIES INFORMATION SERVICE: Technical and Extension Series envisages the rapid dissemination of Information on marine and brackish water fishery resources and allied data available with the Fishery Data Centre and the Research Divisions of the Institute, results of proven researches for transfer of technology to the fish farmers and industry and of other relevant information needed for Research and Development efforts in the marine fisheries sector.

Abbreviation - *Mar. Fish. Infor. Serv. T & E Ser.*, No. 53 : 1983

ACIDITY IN VEMBANAD LAKE CAUSES FISH MORTALITY

V. K. Pillai, A. G. Ponniah, D. Vincent and I. David Raj

The sudden changes of variations in the environmental and climatic patterns in an area always cause certain undesirable and unforeseen events as well as problems. The severe drought conditions experienced in South India, especially in the state of Kerala during the summer of 1983 was such an unusual incident. Added to that the monsoon, this year, commenced late. Immediately after the first monsoon rains, in the third week of June, an instance of mass mortality of fishes and clams was reported from the Vembanad Lake. The report indicated that large scale mortality of several groups of aquatic organisms were occurring mainly in the southern half of the lake. Indications were that the phenomena started from the southernmost region and slowly spread to the north. Although, immediate reaction was to look for industrial pollution, the same was ruled out by undertaking immediate monitoring near the major industries situated in the vicinity. Personal discussions with several local farmers, and agricultural and soil scientists working in the region indicated that the unusual phenomena might have been caused by soil acidity. Hydrogen-ion concentration of the water showed that it was in acid range. However, the vast area of the lake affected as well as the quantity of acid required to effect such a lowering of pH (the pH showed a 50% reduction compared to the normal range) was rather a puzzle which prompted the scientists of CMFRI to undertake a detailed monitoring of the whole area extending from Aroor to Alleppey.

The environment

The Vembanad Lake, situated in the south-west coast of India, connected to the sea through the Cochin backwaters is well known for its fishery resource as well as for its role as a nursery ground for the commercially important crustacean fishery resources. The portion of the backwater system that extends from Cochin to Alleppey covering an area of about 80 sq.km. is generally known as the Vembanad Lake which is primarily connected with the Kuttanad region. The waters of the Vembanad lake is subjected to the flood waters emptied by the river systems and also to the sea water entering into the lake on account of the tidal action. The Vembanad Lake and the backwater system exert considerable influence on the ecology of the surrounding areas.

Four major river systems of Kerala, viz; Meenachil, Manimala, Pamba and Achancoil feed the region with an annual discharge of 11106 M m^3. The discharges of the river systems that enter into the Lake pass through Thanneermukkom barrage. During the S.W. monsoon, usually the discharge from the lake reaches a peak of 65 thousand cusecs (1840 m^3/sec).

Ecology

The ecology of the area with respect to the ability to sustain life, both on land and in water, is conditioned by salinity which in turn is controlled by the combination of flood waters and sea water entering the Lake. The wide spectrum of divergence in salinity, from sweet water to sea water, enables to sustain a wide variety of aquatic life, both plant and animal, in the water. An ecological balance has been struck over the period of its evolution with a combination of plant and animal life.

Geology

In the geologic past, it is believed that the entire area of Kuttanad was part of the shallow coastal area adjoining the Arabian sea. The silt carried by the rivers got deposited at the river mouths giving rise to the present coast and converting the shallow bay into an extensive lake-lagoon-backwater system. The lagoons and lakes gradually silted up and gave rise to sedimentary formations which were eventually converted into garden lands and wet lands by the gradual process of reclamation which now characterises Kuttanad. The deeper portions of the backwaters form the Vembanad Lake which extends from Alleppey in the south to Cochin in the north.

Soil characteristics

Soils of this region may be grouped into three categories viz. (1) Kayal soils (2) Karappadom soils and (3) Kari soils.

1. *Kayal soils:* These are found in the reclaimed lake bed in Kottayam and Alleppey Districts and they occupy an area of about 8,000 hectares. The land is situated 2 to 3 metres below the sea level. The soils are slightly acidic to neutral in reaction, very low in organic matter content, poor in total and available plant nutrients, but are fairly rich in Calcium. As they are seriously affected by salinity, crop failures are common in them.

2. *Karappadom soils:* These soils occur along the inland water ways and rivers and are spread over a large part in the upper Kuttanad covering an area of about 41,000 hectares. They are river borne alluvial soils. The fields lie in about 1–2 metres below sea level. The soils are characterised by high acidity, high salt content and a fair amount of decomposing organic matter. They are generally poor in available plant nutrients, particularly so in phosphorus. They are also highly deficient in lime. Infertility is the more serious problem in these soils.

3. *Kari soils:* These are peat soils found in large isolation patches in Alleppey and Kottayam Districts, covering an area of about 20,000 hectares. They exhibit characteristics of submerged forest area, but are not silted up. Deep black in colour, the soils are characterised by heavy texture, poor aeration, bad drainage and low content of available plant nutrients. They are affected by saline intrusion with consequent accumulation of soluble salts. They are also highly acidic in reaction. In these soils free sulphuric acid is formed by the oxidation of sulphur compounds present in the wood fossils found under the soil. Large amounts of woody matter at various stages of decomposition occur embedded in these soils.

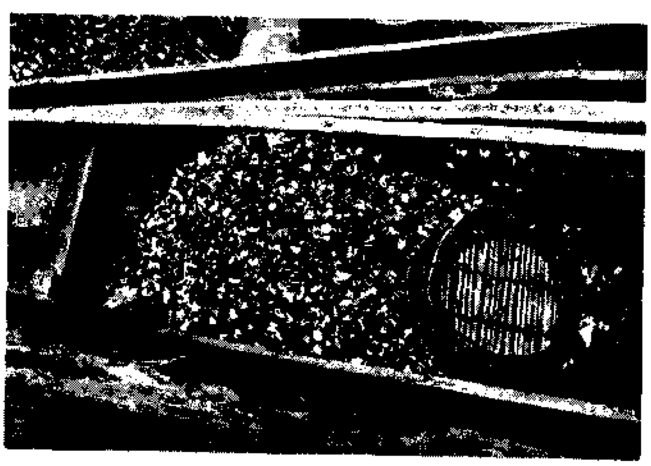
The Kari and Karappadom soils record pH below 5.0 under moist condition. The pH of these soils is found to decrease on air drying. The maximum pH

1

3

PLATE I. 1. *Collection of samples*
2. Dead clams collected by fishermen.
3. A typical kari soil field.
4. Close up of acid water leaching from the soil.
5. The water being pumped out from big paddy fields.

4



2

5

values of these soils are observed during September-October. On exposure of the soils during crop season the pH progressively decreases and reaches the minimum at post-harvest period, February–March. The seasonal variation is more marked in the Kari and Karappadom soils than in the Kayal soils. The Kari and Karappadom soils resemble the typical acid sulphate soils in several characters. Changes in oxidation reduction potential, oxidation of sulphur compounds under aerobic conditions and subsequent hydrolysis under anaerobic conditions of water logging with the production of mineral acids would all collectively contribute to a decrease in pH on drying (Money and Sukumaran, 1973). They also observed that either air-drying or sun-drying in the field drastically decrease the pH of the Kari and Karappadom soils. This aspect of the soil is significant in the context of cropping pattern, and water management.

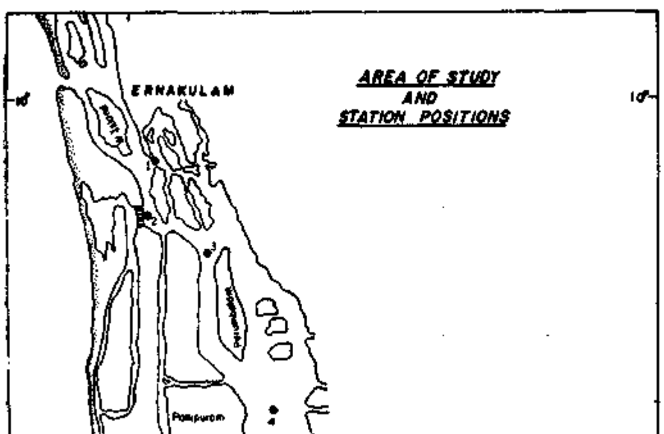


Fig. 1. Map showing the station position.

Observations

This report contains the results of investigations conducted by the Institute on the causes, effects and problems of this unusal phenomena. The details regarding the station positions from which samples were collected and analysed are given in Fig. 1. In order to identify the cause of the phenomena, water samples were collected at different transects covering an area of about 65 km from Aroor to Alleppey. In addition, samples were also collected from the paddy fields bordering the southern tip of the lake and also from the Muvatupuzha river where a major newsprint factory is located. Water temperature and pH were recorded from all the stations. Samples were also analysed for salinity, dissolved oxygen and ammonia.

The team investigating the phenomena monitored the water characteristics over the lake surface and adjacent waters to determine the causative factor and also to record the recovery in the situation during the course of a months time. It was found that in the middle region of the lake where the mortality occurred, lower salinity values were recorded (Table 2) indicating that the area was under freshwater regime. The recorded dissolved oxygen values were within the normal range that could support aquatic life. Very high values of ammonia were recorded in the area where extensive mortality had occurred (Table 3). The source of this high ammonia could be due to the pumping of water from the paddy fields where fertilizers had been used during the last season. But this high levels of ammonia could not have been a causative factor for the mortality of fishes since at low pH the ionization of ammonia will be considerably reduced thereby reducing the lethality of ammonia.

Among the parameters studied, pH showed low values on the acidic range. Most of the pH values recorded were in the range of 3.0 to 7.0 against the normal range of 7 to 8. Details are given in Table 1. On the first day of observation (28–6–'83) at Thaneermukkom the pH recorded was 3.65 and 2 km away (towards south) the same was 4.85. It was significant to note that during the initial sampling time the pH of the water collected from the paddy fields as well as from the open waters at the southern end of the Vembanad Lake recorded very low pH (4.0), especially the water pumped out of the paddy fields (pH 3.8). The paddy fields of Kuttanad are 1 to 2 m below the lake water level. Hence for preparing the fields for cultivation as well as for regulating the water flow during the cultivation, pumping of water is regularly practiced. The size of the pump and the quantity of water pumped out naturally depends on the size of the field, invariably extending to several thousand hectares. All these

Table 1. *Variation in pH in space and time*

Dates of collection	30.6.83 & 1.7.83		4.7.83		16.7.83		1.8.83		6.8.83	
Stations Location	S	B	S	B	S	B	S	B	S	B
1. Thevara	7.59	—	—	—	5.88	—	6.95	—	6.55	—
2. Aroor	4.80	6.44	—	—	5.18	5.70	5.55	—	6.22	—
3. Arookutty	6.22	6.44	—	—	5.88	6.10	6.55	6.40	5.88	6.07
4. Manalpuram	3.68	4.09	—	—	4.21	4.35	—	—	5.60	5.40
Thanneermukkam bund										
5. Western end	3.84	3.85	4.34	—	4.35	—	5.78	—	5.48	—
6. Middle	3.81	3.92	—	—	5.55	—	5.55	—	4.68	—
7. Eastern	3.99	4.06	4.03	—	4.25	—	5.77	—	4.30	—
8. Kaypuram	4.00	4.30	—	—	5.30	5.41	6.00	6.15	5.48	5.50
Muhamma										
9. Near shore 1	3.97	4.38	3.88	—	4.08	3.94	5.69	5.46	5.23	—
10. Near shore 2	—	—	—	—	3.85	3.83	5.92	5.50	—	—
11. Middle	3.97	4.11	—	—	3.85	4.00	5.78	5.65	—	—
Punnamada										
12. Cultivated fields	—	—	3.90	—	4.78	—	5.50	—	4.90	—
13. Canal connecting fields	3.90	—	3.80	—	3.70	—	5.40	—	4.80	—
14. Backwaters 1	4.00	—	3.90	—	4.30	—	5.40	—	5.33	—
15. Backwaters 2	4.00	4.20	—	—	—	—	—	—	5.47	5.45
East of Punnamada										
16. Backwaters	3.18	—	—	—	—	—	—	—	4.24	3.93
17. Cultivated fields	3.80	—	—	—	—	—	—	—	3.90	—
18. Fallow fields	—	—	4.41	—	—	—	—	—	4.83	—

water ultimately reaches the lake. However, during thr peak of the summer this year, the level of water in the lake and canals were reportedly lower than in the fields beforc the on set of the rains.

During the initial samplings it was observed that to reduce the acidity of soil which was damaging the crops, continuous flushing was carried out by allowing the lake water into the paddy fields and then pumping it out. This process added to the water acidity caused from the natural run-off from the dry fields and canals through the rivers to the lake. In certain very large paddy fields (blocks) the water remained stagnant during the summer due to non-cultivation for the last one or two seasons. It was noticed that in these fields pH was rather low (3.8 ± 0.53). Even one month after the reported fish mortality in the lake, a few fishes were found dead and floating in these fields.

From the present study it can be conclusively said that the high mortality was only due to the low pH in the water. This low pH was mainly due to the leaching out of acid waters from the paddy fields and adjacent canals.

The data revealed that the effect of pH reduction seemingly influenced the eco-system only upto the middle of the lake and coming towards the mouth of the estuary the effect appeared to have got neutralized, probably due to the regular tidal action. However, even after a month or so from the period of initial impact, there was not much change in the situation in the affected area. The fact that, though during the latter field trips the acidity was found reducing slowly, still low pH persisting in the southern area even after a months time indicated beyond doubt that the real causative factor for the low pH originated from the soil acidity. It is also reported that mineral acids were usually responsible for excessively low pH. The common mineral acid in natural water is sulphuric acid which results from the oxidation of iron pyrite (Boyd, 1982). The reason for the persisting low pH could be that the river water input into the

Table 2. *Variations in Salinity in space and time (‰)*

Dates of collection		30.6.83 & 1.7.83		4.7.83		16.7.83		1.8.83		6.8.83	
Stations	Location	S	B	S	B	S	B	S	B	S	B
1.	Thevara	7.38	—	—	—	0.21	—	3.88	—	1.36	—
2.	Aroor	6.48	9.83	—	—	1.10	0.28	1.19	—	1.40	—
3.	Arookutty	10.76	11.28	—	—	2.95	3.95	1.89	2.71	0.87	1.00
4.	Manalpuram	5.10	5.11	—	—	1.17	1.15	—	—	0.44	0.35
	Thanneermukkam bund										
5.	Western end	3.80	3.28	2.26	—	1.05	—	0.30	—	0.42	—
6.	Middle	4.27	5.11	—	—	0.94	—	0.35	—	0.42	—
7.	Eastern	3.54	3.35	—	—	0.63	—	0.35	—	0.37	—
8.	Kaypuram	3.37	4.70	—	—	0.49	0.47	0.21	0.17	0.25	0.30
	Muhamma										
9.	Near shore 1	4.24	5.00	—	—	0.51	0.51	0.34	0.18	0.26	0.28
10.	Near shore 2	—	—	—	—	0.47	0.47	0.21	0.19	—	—
11.	Middle	0.81	0.32	—	—	0.49	0.50	0.21	0.19	—	—
	Punnamada										
12.	Cultivated fields	0.98	—	0.99	—	0.50	—	0.29	—	0.50	—
13.	Canal connecting fields	1.82	—	1.16	—	0.66	—	0.35	—	0.54	—
14.	Backwaters 1	0.71	—	0.64	—	0.29	—	0.21	0.19	0.19	—
15.	Backwaters 2	0.48	0.50	—	—	—	—	—	—	0.12	0.12
	East of Punnamada										
16.	Backwaters	2.54	—	—	—	—	—	—	—	0.49	0.49
17.	Cultivated fields	5.09	—	—	—	—	—	—	—	0.67	—
18.	Fallow fields	—	—	—	—	—	—	—	—	0.49	—

lake after several spells of monsoons showers has not been sufficient to flush the acids produced at the water-soil interface continuing for several weeks as the monsoon this season had been weak and halting in the initial period.

Though there are fishes that are exceptionally tolerant to low pH of upto 3.5 (Dunson *et al.*, 1977), many other investigators have found pH 5 as the lowest tolerant limit for freshwater fishes (Jones, 1964; Cooper and Wagner, 1973). For crustaceans, the lowest tolerant limit has been found ranging from 4.5 (Havas and Hutchinson, 1982) to 5.5 (Leivestad *et al.*, 1976). The present observation revealed that it took nearly 30 days for the pH to reach 5 in the affected region south of Thanneermukkom barrage. Irritation to the eyes reported by the divers doing clam fishing and redness of the eyes of fishes caught, indicated the continuous effect or acidity.

From the literature, it is apparent that many aquatic organisms are physiologically unable to tolerate conditions of high acidity (Havas, 1981). By experimental studies it has been established that at least four major physiological functions are altered at low pH. This includes calcium and sodium regulation,respiration and acid base balance. Several studies have revealed that anoxia and sodium depletion result when fishes are exposed to acid waters. (Packer and Dunson, 1972; Dunson *et al.*, 1977; Leivstad and Muniz, 1976; Ultsch and Gros, 1979. During our observations from the middle of July onwards dead as well as dying young ones of cat fish *Keletius* sp. (total length 63–83 mm)

Table 3. *Spacial and temporal distribution of ammonia (ppm)*

Dates of collection		30.6.83 & 1.7.83		4.7.83		16.7.83		1.8.83		6.8.83	
Stations	Locations	S	B	S	B	S	B	S	B	S	B
1.	Thevara	6.07	—	—	—	0.88	—	0.32	—	1.63	—
2.	Aroor	1.07	1.02	—	—	0.60	0.47	0.31	—	0.49	—
3.	Arookutty	0.54	0.40	—	—	0.96	1.06	0.24	0.31	0.49	0.30
4.	Manalpuram	1.28	1.28	—	—	0.75	0.73	—	—	0.29	0.28
	Thaneermukkam bund										
5.	Western end	1.26	1.25	0.84	—	0.89	—	0.32	—	0.30	—
6.	Middle	0.65	1.02	—	—	0.78	—	0.32	—	0.33	—
7.	Eastern	0.91	1.04	0.84	—	0.51	—	0.33	—	0.34	—
8.	Kaypuram	1.05	1.64	—	—	0.86	1.11	0.33	0.28	0.26	0.26
	Muhamma										
9.	Near shore 1	1.53	1.65	—	—	0.89	1.11	0.32	0.35	0.26	0.28
10.	Near shore 2	—	—	—	—	0.95	0.98	0.26	0.26	—	—
11.	Middle	0.09	1.53	—	—	1.88	1.11	0.24	0.24	—	—
	Punnamada										
12.	Cultivated fields	0.51	—	0.59	—	0.66	—	0.49	—	0.19	—
13.	Canal connecting fields	1.32	—	0.42	—	0.95	—	0.65	—	0.74	—
14.	Backwaters 1	0.51	—	0.52	—	0.60	—	0.24	0.30	0.10	—
15.	Backwaters 2	0.36	0.33	—	—	—	—	—	—	0.07	0.05
	East of Punnamada										
16.	Backwaters	0.54	—	—	—	—	—	—	—	0.31	0.49
17.	Cultivated fields	0.42	—	—	—	—	—	—	—	0.67	—
18.	Fallow fields	—	—	1.51	—	—	—	—	—	0.32	—

were observed. The dying fishes were found gasping and struggling at the surface indicating anoxia.

Except for the immediate mortality to fishes (like rays, *Etroplus* and *Mugil*), crustaceans (mainly crabs *Scylla serrata* and *Macrobrachium* sp.) and clams (*Villorita* sp.) the subsequent incidence of mortality were rather limited to the young ones of cat fishes (*Keletius* sp.). During the latter period of survey it was observed that there was limited fishing activity mainly for *Etroplus*. However, the destruction to the clam beds (*Villorita* sp.) is massive. Even after a month from first reports, there was not a single live clam specimen available in the southern half of the lake beyond Thanneermukkom. Subsequent monitoring of the water acidity showed that the effect is getting reduced, although the process is rather slow, it may take a few more months for the ecosystem to be back to maintain the normal balance of equilibrium between the environment and the living organisms.

ACKNOWLEDGEMENTS

The authors wish to record their deep sense of gratitude to Dr. E. G. Silas, Director for the constant encouragement and valuable suggestions. They are also thankful to Dr. P. V. Ramachandran Nair, Senior Scientist and Head of Division, Fishery Environment Management Division, for his constant help, encouragement and also for critically going through the text.

References

Boyd, E. C., 1982. Water Quality Management for Pond Fish Culture. Elsevier Scientific Publishing Co., New York, 1982.

Cooper, E. L. and C. C. Wagner, 1973. The effects of acid mine drainage on fish populations. *Ecol. Res. Ser. Env.* Prot. Agency, R3-73-032: 73-124.

Dunson, W. A., F. Swarts and M. Silvestri, 1977. Exceptional tolerance to low pH of some tropical backwater fish. *J. Experimental Zoology*, **202** (2): 157-162.

Havas, M., 1981. Physiological response of aquatic animals to low pH. p. 49-65. *In* R. Singer (Ed.) Effects of acidic precipitation on Benthos. *Proc. Symp. Acidic Precipitation* on *Benthos*, 1980, North American Benthological Society, Hamiton, N. Y.

———— and T. C. Hutchinson, 1982. Aquatic invertebrates from the smoking Hills, N.W.T: effect of pH and metals on mortality. *Can. J. Fish. Aquatic Sci.* **99** : 890:903

Jones, J. R. E., 1964. Fish and river pollution. Butterworths, London, pp. 107-116.

Leivestad, H. and I. P. Muniz, 1976. Fish kill at low pH in Norwegian rivers. *Nature* 259: 391-392.

————, G. Hendrey, L. P. Muniz and E. Sneknik, 1976. Effects of acid precipitation on freshwater organisms. p. 86-111. *In* F.H. Brackke (Ed.). Impact of acid precipitation on forest and freshwater ecosystems in Norway. Research Report 6/76, SNSF Project.

Money, N. S. and K. M. Sukumaran, 1973. Chemical, Microbiological and Agronomic aspects of the Acid Saline waterlogged soils of Kerala. Technical Bulletin No. 1; Kerala Agricultural University, Trichur, 1973; pp. 1-26.

Packer, R. K. and W. A. Denson, 1972. Anoxia and sodium loss associated with the death of Brook trout at low pH *Comp. Biochem. Physiol.*, **41A**, 17-26.

Ultsch, G. R. and G. Gross, 1979. Mucus as a diffusion barrier to oxygen: possible role in O_2 uptake at low pH in carp *(Cyprinus carpio)* gills. *Comp. Biochem. Physiol.* **62A**: 685-689.