Report

Long-Term Acidification of a

By R J Beamish, Pacific Biological Station, Fisheries and Marine Service, Department of the Environment, P O Box 100, Nanaimo, British Columbia, Canada, V9R 5K6; W L Lockhart, Fisheries and Marine Service, Freshwater Institute, 501 University Crescent, Winnipeg, Manitoba, Canada, R3T 2N6; J C Van Loon, Department of Geology, University of Toronto, Toronto, Ontario, Canada; and H H Harvey, Department of Zoology, University of Toronto, Toronto, Ontario, Canada.

In recent years the pH of George Lake has decreased at an estimated annual rate of approximately 0.13 pH units per year. Coincident with this, lake trout, walleye, burbot and smallmouth bass have disappeared and in 1973 northern pike, rock bass, pumpkinseed sunfish, brown bullhead and white suckers did not reproduce successfully. During the period 1967—1973 the average size of white suckers declined drastically. The population of white suckers also decreased from 934 mature fish in 1968 to 223 in 1973. The biomass of this species in 1973 was less than ten percent of that measured in 1968. Spinal deformities first appeared in the white sucker population in 1971 and increased to 11 percent in the spring of 1972 and 32 percent by the fall of 1972. It appeared that the increased percentage of deformities was related to a decrease in pH below 5.0. In 1972 and 1973 white suckers and some other species had abnormal concentrations of calcium in their serum during the period of ovarian maturation. While a direct causal relationship between the increased acid content of the lake and the disturbances in calcium metabolism was not demonstrated in this study, it was suggested that a change in normal calcium metabolism was induced by low pH values and the abnormal serum calcium values may be related to the failure of fishes to spawn.

Acidification of lakes due to acid precipitation is a well-known phenomenon in Sweden and Norway. Recognition has come only recently that this is also a problem in parts of North America (1, 2). The scope of the problem in North America has not been determined but in at least one area, the area of study in this report, the extent of acidification is as great or greater than any recorded elsewhere. The purpose of this report is to describe the effects of this acidification on fishes from one small lake.

George Lake (46°02'N; 81°24'W) is the lowermost lake in a drainage basin of approximately 5540 ha. Most of this drainage area is located within the series of small quartzite ridges in Ontario, Canada. Fish populations have disappeared from many of these lakes as a result of abnormally low pH values caused by atmospheric fallout of acid (1, 2). In George Lake, studies of the fish populations were initiated before the lake became critically acidic for most fishes. As the pH decreased it was possible to identify some of the physiological responses of certain species of fishes. These responses included: failure to spawn, low serum calcium in mature females, appearance of spinal deformities, changes in the average size of age-classes, reduction in the size of the population, and disappearance of species from the lake. Some of these changes were documented only for the white sucker, others for several species of fishes.

METHODS

Fish collected from 1966 to 1973 were weighed, measured for fork length and examined for condition, sex and maturity. Scale samples plus a portion of the pectoral or pelvic fin were used for determination of age (3). The size of the population of white suckers (*Catostomus commersoni*) was estimated using the Petersen method by a tag and recapture study in 1967 an again in 1973. Throughout the study, particular attention was paid to the success of spawning of this population. The pH was determined using a Radiometer PHM 53 specific ion meter on location in the field or in the laboratory with 12 hours of sampling. Hardness, alkalinity, total and suspended solids were determined according to procedures described in Standard Methods (4). Other major ions were determined by atomic absorption spectroscopy. Sulfate, chloride and the concentrations of nutrients were measured by methods in use at the Freshwater Institute (5). Procedures for heavy metal analysis have been described previously (2, 6). Standard reference solutions of metals (2) were analyzed in conjunction with all water samples. Blood was taken by syringe from the caudal blood vessels and allowed to clot at 0°C. Serum was withdrawn and stored frozen until analyzed. Total calcium was determined by atomic absorption spectroscopy on 25 µl serum samples using lanthanum to eliminate phosphate interference. Populations were sampled from George Lake, nearby Muriel Lake (pH 4.7), the less acidic nearby Kakakise Lake (pH 5.6) and the non-acidic waters (pH > 7.0) of Georgian Bay, Lake Manitoba and Roddy Lake. Roddy Lake has a calcium concentration (2.2 mg/l) similar to George Lake.

LIMNOLOGY AND CHEMISTRY

George Lake has an elevation of 190 m (meters above sea level) and has been isolated as a lake for about 3000 years. This oligotrophic lake has a maximum depth of 39.7 m, a mean depth of 18.3 m, a surface area of 182 ha, a volume of 33.3×10^6 m^3 and a September secci reading of 9 m. The irregular shoreline is marked by bare quartzite rock and talus slopes. There is very little littoral zone and in many areas vertical cliffs rise out of the deep water. Water drains from George Lake for several km before entering Georgian Bay, a part of Lake Huron.

George Lake waters are dilute and extremely soft (Table 1). Sulfate accounts for approximately 90 percent of the anions and the high sulfate and hydrogen ion concentrations are indicative that the low pH is a result of additions of sulfuric acid. Concentrations of manganese, zinc and nickel were higher than in other Canadian Shield lakes (2), but manganese and zinc were similar to concentrations found in acidified Swedish lakes (7). The elevated nickel concentrations appear to result from emissions from nickel smelters in Sudbury, Ontario, located 65 km upwind of George Lake. The high manganese values appear to result primarily from increased solubility or weathering or both at the lower pH values since the concentrations in precipitation are low (< 2 µg/l).

Lake and Resulting Effects on Fishes

The earliest known measurement of pH for George Lake (6.5) was determined in the summer of 1961, using a dye indicator method. Using this value and the pH values determined in this study, it was estimated from the slope of the regression curve that the mean annual decline in pH was 0.13 units (Figure 1). If the 1961 value is not used the estimated annual decline is unchanged but the function is less strongly linear, with the correlation coefficient (r) being reduced from 0.85 to 0.65. As pH is the negative logarithm of the hydrogen ion concentration, a constant decline in pH with time, as in Figure 1, represents an accelerating increase in the hydrogen ion content of George Lake. This accelerated increase in acidity probably results from the exhaustion of buffers in the lake. The reported loss of sport fisheries from lakes upstream of George Lake, a decade before the same species disappeared from George Lake, indicated that the acidification of George Lake is a culmination of the progressive acidification of the drainage area that commenced with the headwater lakes.

CHANGES IN THE POPULATION STRUCTURE OF WHITE SUCKERS AND OTHER SPECIES

A sufficient number of white suckers were sampled in 1967, 1968 and 1972 to produce growth curves for the population (Figure 2). In 1967 George Lake white suckers were fast-growing, large individuals that attained maximum ages of 16 years. In 1972, few fish older than age 6 were sampled, thus complete growth curves for 1967 and 1968 have not been included in this report. A "t" test of the mean size of individuals sampled from June to September in 1967 and 1972 showed that age 1, 2, 3 and 6 fish in 1972 were significantly smaller ($P \leqslant 0.05$) than fish of similar age in 1967. In 1973 few white suckers of age 1 to 4 were captured. Age 5, 6 and 7 fish in 1973 averaged 380, 405 and 425 mm and were similar to mean sizes of fish of similar age in 1972. Age 6 and 7 fish in 1973 were significantly smaller ($P \leqslant 0.05$) than white suckers of similar age in 1967. Some white suckers that had been weighed and tagged in years previous to 1972 were found to have lost weight when recaptured in 1972 and 1973. In 1973, all fish tagged at the start of the growing season and recovered at the end of the growing season in late November averaged less than one-half of the length increase achieved by fish of similar size in the 1967 growing season.

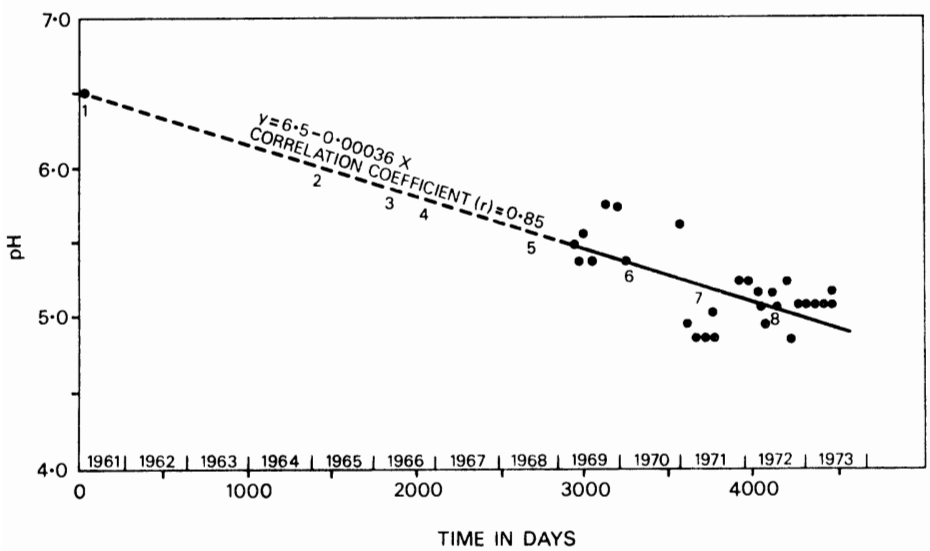
The decrease in growth confirms an earlier observation that growth of white suckers was adversely affected by decreasing pH (8). In this earlier study a reduced rate of growth was shown to be independent of the amount of food present and probably related to a reduction in food utilization or a change in feeding behavior or both. It is suggested that the reduced growth of George Lake white suckers in 1972 and 1973 was also independent of food supply and related directly to the decreasing pH in the lake.

The population of mature white suckers in 1967 numbered 930 (95 percent confidence interval of 830—1100) and a total biomass of 1.6×10^6 g (8). In the spring of 1973 there was an estimated number of 230 (95 percent confidence interval of 400—170) mature white suckers left in the lake. It was estimated from the mean weight of the 43 gillnetted fish that the biomass of mature white suckers was approximately 1.7×10^5 g. Thus from 1967 to 1972

Table 1. George Lake water chemistry, February 1972 to August 1973.

	Average concentration	Range	Number of determinations
pH	—	4.8—5.3	15
Conductivity, umho/cm²	40	35—45	15
Total dissolved solids, mg/l	28	10—49	15
Total suspended solids, mg/l	< 1	< 1—4	15
Hardness, mg/l as $CaCO_3$	12.3	7.92—16.38	15
Alkalinity, mg/l as $CaCO_3$	< 0.5	—	5
Sulfate, mg/l	14.3	12—16	15
Calcium, mg/l	3.21	1.76—4.01	15
Magnesium, mg/l	1.01	0.86—1.55	15
Chloride, mg/l	1.0	0.6—1.6	15
Sodium, mg/l	0.75	0.65—0.97	15
Potassium, mg/l	0.45	0.33—0.60	15
Total dissolved phosphorus, μg/l	8	5—13	5
Suspended phosphorus, μg/l	2	1—3	2
Total dissolved nitrogen, μg/l	350	200—300	2
Suspended nitrogen, μg/l	1	1	2
Manganese, μg/l	220	160—260	10
Iron, μg/l	27	7—45	13
Zinc, μg/l	24	8—45	13
Nickel, μg/l	10	5—15	13
Copper, μg/l	2	1—8	13
Lead, μg/l	< 2	< 2	13
Cadmium, μg/l	< 0.5	< 0.5	13
Arsenic, μg/l	< 5	—	1
Cobalt, μg/l	< 1	—	1
Chromium, μg/l	< 1	—	1

Figure 1. The pH of George Lake at 3 m. Range in pH found from a vertical pH profile was less than ±0.2 pH units of this 3 m value. Thus no appreciable vertical stratification was found. A summary of the changes in fish is indicated as follows: 1. Last successful reproduction of walleye as calculated from age of fish captured in 1967 to 1968. 2. Last reported capture of smallmouth bass. 3. Study commenced. 4. Last successful reproduction of lake trout as calculated from age of fish captured from 1967 to 1973. 5. Last walleye captured. 6. Last burbot captured. 65 percent of white suckers examined did not spawn. 7. All brown bullheads examined after normal spawning period had not spawned. 8. Many of all the following fishes had not spawned when examined after the normal spawning period; brown bullhead, northern pike, white sucker, rockbass, pumpkinseed. Laketrout, northern pike, whitefish catches rare.



the population had decreased in number by 75 percent and in biomass by 90 percent. While some of the fish loss resulted from netting activities, the major cause of fish disappearance appeared to result from the declining pH.

Only the growth of white suckers has been studied in detail. However, it was observed that yellow perch (*Perca flavescens*) increased in individual size and perhaps numbers. Anglers reported only rare catches of large yellow perch prior to the 1960s. In 1968, yellow perch were extremely abundant in trapnet catches. More than 13 000 fish were captured using small-mesh trapnets (9) and a random sample of 300 individuals averaged 120 mm in fork length. By 1972 and 1973 the mean length of a random trapnet sample of more than 600 individuals each year was 139 and 148 mm respectively. In 1972 and 1973 trapnet effort was almost identical and equivalent to about one-half the effort in 1968. Catches in 1972 and 1973 were 2500 and 2600 fish, suggesting that the yellow perch were less abundant than in 1968. It appeared that the numbers of yellow perch increased dramatically in the mid-1960s as major predators declined and that the numbers declined by the early 1970s as the individual size increased.

REPRODUCTIVE FAILURES

In 1972 and 1973 about 65—75 percent of the population of female white suckers failed to release their ova to be fertilized. The age composition of the population indicated that major reproductive failures had not occurred in the past. In 1972, brown bullheads (*Ictalurus nebulosus*) were observed not to spawn and in 1973 most brown bullheads, rock bass (*Ambloplites rupestris*), pumpkinseed sunfish (*Lepomis gibbosus*) and northern pike (*Esox lucius*) had not spawned when examined after their normal spawning period. The failure of fishes to spawn has also been observed in other nearby acidified lakes (1, 2). Failure of fishes to reproduce in acidified waters has been reported in Sweden and Norway (10, 11). It has been suggested that in acidified waters the failure of reproduction results from increased egg and fry mortalities (10, 11, 12, 13). The study of the reproduction of fishes from George and nearby lakes indicated that while some increase in the mortality of eggs and fry may occur, the failure of female fish to spawn is an important cause of the reproductive failures. Therefore, when determining levels of pH that are harmful to fishes it is important not only to identify concentrations that cause egg and fry mortalities, but also to determine the levels that prevent females from spawning. Although it is unwise to conclude that other toxicants may behave in a similar manner, it is worth considering the possible inhibition of spawning when testing the effect of a particular toxicant on a fish population.

The failure of many species to reproduce occurred after a drop in pH in the summer of 1971 to 4.7, a brief winter rise to 5.2 and a fall again to 4.8 in the summer of 1972. Since the spawning of three of the five species was successful prior to 1973, the pH that initiated the reproductive failures must have been within the range of 5.2 to 4.7. Four other species had disappeared from the lake before 1973 (Figure 1). Approximate date of the last successful reproduction of walleye (*Stizostedion vitreum vitreum*) and lake trout (*Salvelinus namaycush*) was estimated from the age of the youngest fish captured in the study. Smallmouth bass (*Micropterus dolomieui*) disappeared before the study commenced in 1966 and burbot (*Lota lota*) disappeared about 1970. Gillnet catches of lake trout were rare in 1972 and in 1973 only one lake trout was captured. The few lake trout captured were emaciated and in poor condition. If the estimated time of disappearance is representative of the species intolerance to pH, then the order of loss would be smallmouth bass at pH > 5.5, followed by walleye, burbot and probably lake trout at pH ranging from 5.8 to 5.2. Northern pike, white sucker, brown bullhead, pumpkinseed sunfish and rock bass would be of intermediate tolerance of pH 5.2 to 4.7. Yellow perch, lake herring (*Coregonus artedii*), and some cyprinids appear more resistant and are still spawning in George Lake.

It has been assumed that the observed spawning difficulties were primarily related to low pH and not the result of elevated heavy metal concentrations such as zinc. In other publications (2) arguments are presented that indicated that while concentrations of zinc may be high, the concentrations probably are not in the range that is harmful to fishes.

Figure 2. Growth curves for the George Lake white sucker population for the years 1967, 1968 and 1972. Curves fitted by eye. Numbers refer to sample size.

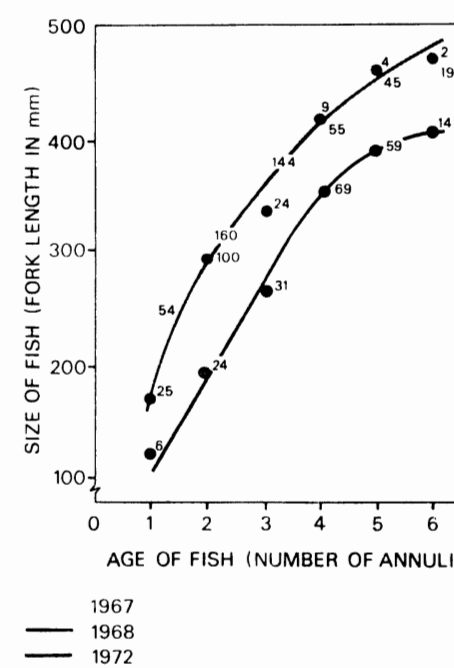


Table 2. Mean serum calcium concentrations (mg/dl) from mature fishes in George and other lakes. Sample number in parentheses.

Species	Lake	Sample Data	Serum calcium in		Female: Male Ratio
			Females	Males	
White sucker	George	September 1972	11.4 (9)	12.5 (13)	0.92
		May 1973	14.4 (16)	11.3 (10)	1.28
		November 1973	15.0 (7)	11.1 (7)	1.35
	Georgian Bay	September 1972	17.2 (7)	11.1 (3)	1.54
	Manitoba	December 1972	23.0 (11)	11.6 (17)	1.99
	Roddy	September 1973	12.9 (18)	11.0 (10)	1.18
		January 1974	14.7 (10)	8.6 (4)	1.71
	Kakakise	November 1973	15.2 (6)	10.0 (3)	1.52
Brown bullhead	George	May 1973	10.7 (4)	9.0 (6)	1.20
		August 1973	12.4 (4)	12.7 (10)	0.97
		November 1973	13.2 (11)	10.2 (7)	1.29
	Georgian Bay	May 1973	23.0 (2)	9.7 (4)	2.37
		August 1973	20.6 (10)	14.4 (9)	1.43
Yellow perch	George	May 1973	22.6 (10)	12.8 (4)	1.76
	Georgian Bay	May 1973	32.1 (4)	9.9 (1)	3.24
	Muriel[1]	May 1973	30.3 (8)	11.4 (8)	2.67
Lake herring	George	November 1973	20.6 (5)	11.5 (6)	1.80
	Kakakise	November 1973	19.7 (12)	11.8 (6)	1.67
Northern pike	George	November 1973	25.5 (1)	19.2 (8)	1.33

[1] Muriel Lake has an average annual pH of approximately 4.7 and yellow perch is the only species that is reproducing successfully.

DEVELOPMENT OF DEFORMITIES

Of all white suckers examined before 1970, less than 1 percent were deformed. These deformities had their origin in a misshapen spinal cord, resulting in sigmoid external appearance. In 1970, 100 white suckers and in 1971, 21 such fish were handled and one deformed fish was found in each sample. In the spring of 1972, 11 percent of 213 white suckers examined showed evidence of developing or well-developed deformities. An additional 79 white suckers were examined in September 1972, and 32 percent of both males and females had some degree of deformity. One individual that was not deformed when tagged in 1967 was deformed when captured in 1972.

Fathead minnows (*Pimephales promelas*) exposed for one generation to pH levels ranging from 7.5 to 4.5 were able to survive in all concentrations (14). However, at pH 5.2 and 4.5 these minnows were deformed and did not spawn. Young white suckers maintained in the laboratory for prolonged periods at pH 4.2 to 4.4 also developed deformities (15). This similar response of white suckers and fathead minnows to sublethal concentrations of acid in the laboratory is accepted as corroboration that the deformity of George Lake white suckers was due to acid stress.

One possible explanation for the development of deformities as a result of low pH would be that fish respond in a manner similar to mammals under conditions of acid stress. In humans, during prolonged acidosis, blood may be buffered by the substitution of Ca^{++} for Na^{+} in the urine (16). Calcium is obtained from tricalcium phosphate of bone which increases in solubility with decreasing pH. One mole of tricalcium phosphate permits the excretion of four equivalents of acid, thus allowing neutralization of acid without depletion of the alkali reserve. However, this process results in serious demineralization of the skeleton (16). In acid solutions, rainbow trout (*Salmo gairdneri*) died from a failure to maintain blood pH (17). The prolonged exposure of white suckers in George Lake to low pH may have resulted in demineralization of the bone, in an attempt to maintain blood pH, and thus caused the observed deformities.

X-rays of some deformed fish showed several vertebrae in the area of the deformity that had smaller, malformed centra apparently as a result of bone withdrawal. However, many x-rays of deformed fish did not show such obvious signs of abnormal vertebral formation, thus the deformities may also be the result of other structural alterations that are not apparent in x-rays.

SERUM CALCIUM CONCENTRATIONS

Serum calcium concentrations were first measured in mature George Lake male and female white suckers in September 1972. Serum calcium values were low and a "t" test indicated the females were not significantly different from males ($P \leqslant 0.05$, Table 2). At the same time female white suckers of similar maturation state from Georgian Bay had concentrations distinctly elevated over males ($P \leqslant 0.05$). A significant difference ($P \leqslant 0.05$) between males and females was also found in a group of white suckers that were sampled in December 1972 after being transported from Lake Manitoba and held in the laboratory for several months. All immature fish examined had serum calcium concentrations similar to males. Data for immature fish are not presented in this report.

The concentration of serum calcium in maturing female fish is related in part to the degree of ovarian maturation and is approximately double male values (18, 19, 20). None of the samples of female George Lake fish achieved this expected female to male ratio. The two species that had the greatest ratios, yellow perch (1.76) and lake herring (1.8), were the only two species of the six species sampled that were still reproducing successfully in the lake. White suckers sampled from the non-acidic Roddy Lake in September 1973 had a low ratio of female to male calcium concentrations (Table 2) that undoubtedly resulted from the very early stage of maturity. The January 1974 samples averaged 14.7 mg/dl for females and 8.6 mg/dl for males, and this ratio was much higher than those found in any of the George Lake samples. Thus the white suckers in this lake, of similar calcium content to George Lake but higher pH, had female to male calcium ratios that were in the range of the two successfully reproducing species in George Lake. It was concluded that the low calcium concentration in George Lake water was not *per se* the cause of the abnormally low serum calcium ratios. In general, a female to male serum calcium ratio of 1.4 appeared to separate the fishes experiencing reproductive failures in George Lake from successfully reproducing species remaining in the lake and from similar species that were reproducing successfully in other lakes (Table 2).

Simkiss (21) has reviewed the literature concerning calcium regulation in fishes and has pointed out that plasma calcium of all vertebrates consists of a diffusible or ionic form and a non-diffusible or protein-bound form. Female vertebrates with bony skeletons, that lay yolky eggs, synthesize yolk proteins in the liver and transport these proteins to the ovary as complexes of calcium with phosphoproteins (22). The abnormal serum calcium concentrations in George Lake white sucker females did not appear to result from a failure of the normal calcium-regulating mechanisms, since their calcium levels were similar to those of males. Rather it appears that the absence of substantial increases over male values

was related to additional regulating factors associated with ovarian muturation and the increase in the protein-bound fraction of serum calcium. It does appear that the alterations in normal calcium metabolism have resulted from the increased acid content of the lake and this disruption has affected the female reproductive physiology of some species.

References and Notes:

1. R J Beamish and H H Harvey, *Journal Fisheries Research Board Canada* **29**, 1131 (1972).
2. R J Beamish, *Water Research* **8**, 85 (1974).
3. R J Beamish, *Journal Fisheries Research Board Canada* **30**, 607 (1973).
4. *Standard Methods for the Examination of Water and Waste Water*, 13th ed (American Public Health Association, American Waterworks Association and Water Pollution Control Federation, New York, 1965) 874 pp.
5. M P Stainton, M J Capel and F A J Armstrong, *Fisheries Research Board of Canada, Miscellaneous Special Publication* No. 25, 125 pp (1974).
6. J C Van Loon, J Lichwa, D Ruttan and J Kinrade, *Water, Air and Soil Pollution* **1**, 19 (1973).
7. E Hörnstrom, C Ekström, U Miller and W Dickson, *Institute of Freshwater Research Drottningholm, Information*, No. 4, 97 pp (1973) (In Swedish with English summary).
8. R J Beamish, *Journal Fisheries Research Board Canada* **31**, 49 (1974).
9. R J Beamish, *Journal Fisheries Research Board Canada* **30**, 587 (1973).
10. B Almer, *Institute of Freshwater Research Drottningholm, Information*, No. 12, 45 pp (1972).
11. K W Jensen and E Snekvik, *Ambio* **1**, 223 (1972).
12. *EIFAC Technical Paper* 4, 24 pp (1968) and *Water Research* **3**, 593 (1969).
13. N Johansson, J E Kihlström and A Wahlberg, *Ambio* **2**, 42 (1973).
14. D I Mount, *Water Research* **7**, 987 (1973).
15. R J Beamish, *Transactions American Fisheries Society* **101**, 355 (1972).
16. A White, P Handler and E L Smith, *Principles of Biochemistry* (McGraw-Hill, New York, 1964) p 690.
17. R Lloyd and D H M Jordan, *International Journal of Air and Water Pollution* **8**, 393 (1964).
18. W R Fleming, J G Stanley and A H Meier, *General Comparative Endocrinology* **4**, 61 (1964).
19. M Oguri and N Takada, *Bulletin of the Japanese Society of Scientific Fisheries, Tokyo* **33**, 161 (1967).
20. M R Urist and K A Van de Putte, in *Sharks, Skates and Rays*, P W Gilbert, R F Mathewson and D P Rall, eds (Johns Hopkins Press, Baltimore, Maryland, 1967) pp 271—285.
21. K Simkiss, in *Proceedings of the Symposium on Ageing Fish*, T B Bagenal, ed (Unwin Brothers, England, 1974) pp 1—12.
22. M R Urist and A O Schjeide, *Journal of General Physiology* **44**, 743 (1961).

23. The authors gratefully acknowledge the assistance of the following people: Drs W B Scott and E J Crossman; Messrs W Sherlock, J Wales, J Drolet, R Wickström, D Metner, A Lutz, G A McFarlane, A Bennett, D W Fallis, D Barnes, R Schmidt, C-L Landberg and L Milanese.
24. Received February 13, 1974.

AMBIO BRIEFS

An Economic Approach to Sweden's Waste Problems

The amount of solid waste from households rises with rising affluence. At present the average Swedish household produces 270 kg of waste per person which amounts to almost a doubling since 1960. A continued rise by about 2—3 percent per year is projected. The amount of industrial waste is about 700—800 kg per person and year.

At present, Swedish municipalities are charged with handling this waste. They have what amounts to a monopoly on waste disposal which in the future will be a valuable asset to the municipality where today it is often something of a problem. According to a recent proposal by a group of experts appointed by the Ministry of Agriculture, the economics of waste disposal will be made much more favorable by large scale recirculation programs run by the municipalities.

A large proportion of household wastes is paper. (About 50 percent by weight or 70 percent by volume.) The economics of recirculation of paper are good and expected to be even better in the future. Most of the reclaimed paper is used in Sweden, but there is also an important export to the continent. The potential for increasing the recirculation lies mainly in household wastes. The total amount of paper waste from households is about 780 000 metric tons per year. Of this, about 100 000 tons is non-reclaimable. 300 000 tons per year is newspapers and magazines which go to waste disposal compared with 25 000 tons which are already reclaimed. The potential for reclamation is thus great if households cooperate. Paper recirculation from other sources—shops, offices *etc*—is not as good, about 80 000 tons per year. This is largely due to the fact that many of these sources already reclaim most of their waste paper.

The group recommends that the municipalities get a monopoly on reclaiming paper and that they be empowered to issue regulations that households must cooperate by separating paper from other wastes. The reclaiming of paper by others will in principle be illegal but exemption should be granted to charities, organizations *etc* that finance their work by selling waste paper, and to shops, offices, industries *etc* which have satisfactory arrangements for recirculation of waste paper.

Scrapped cars. Old cars are a special waste disposal problem, both in the large urban areas and in rural areas. In 1970 the City of Stockholm had 2500 abandoned cars.

Getting rid of an old car is often a problem, particularly in rural areas where no firm is nearby and the transportation cost may be great. Small junk yards in rural areas are often badly managed, conspicuous eyesores. At present the number of yards in the country is estimated to 2000—3000. The cost of getting rid of a car with no useful components which can be sold by the junk yard is about Sw Kr 75—175, exclusive of transportation. To solve these and other problems, the report recommends a system of authorization for scrapping yards and a levy on new cars. This will be paid back to the last owner on presentation of a certificate from the authorized yard proving that the car has been delivered to that yard.

Authorization of scrapping firms would provide a control both on their location and management. The county governments which are proposed as authorizing agencies will be able to control that only firms with satisfactory arrangements for final disposal of those parts of a car that can not be sold as spare parts get licenses. Such arrangements may be either facilities for cutting up the wreck or arrangements with the car fragmentation plant in Halmstad on the Swedish west coast which now handles a large share of all scrapped cars.

Levy system. The proposal is that a levy of Sw Kr 400 be placed on every new car sold in the country after July 1, 1975. Beginning on January 1, 1976, a sum of Sw Kr 500 will be paid on presentation of a certificate proving that the car has been delivered to an authorized scrapping firm. Administration of the system will be possible through the existing national car register which will ensure that only the person registered as owner of the car can get the refund. Since the mean life of a Swedish car is something like nine years, the system will pay both for its own administration and provide subsidies to municipalities for clearing up old junkyards and taking care of abandoned wrecks.

To prevent speculation in the system, only cars which have passed the annual road safety control later than December 31, 1974 will get the refund.

Lars Emmelin