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ONCHOCERCIASIS CONTROL PROGRAMME IN WEST AFRICA:

TEN YEARS MONITORING OF FISH POPULATIONS

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ABSTRACT

Commencing in 1975, under the auspices of W.H.O., weekly applications of insecticides have been employed to control the blackfly which transmits human river blindness in West Africa. The results provided in this paper do not show, as a whole, any clear impact of OCP-applied pesticides on fish populations. The total catch, the number of species caught in each sample and coefficient of condition, appeared to fluctuate around a mean value, and no long-term drop was observed over the period investigated. The seasonal pattern is generally clear. In some cases longer term declines occur, generally being followed by a rise correlating with changing hydrological conditions.

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INTRODUCTION

Human Onchocerciasis is a dermal filariasis particularly serious in Guinean and Sudanian African savannas where it causes irreversible blindness among exposed populations. The filaria Onchocerca volvulus is transmitted to man by female blackfly of the Simulium damnosum complex (Philippon, 1977). The larvae of these flies are aquatic and occur only in fast-flowing parts of rivers. Thus the disease is most prevalent near water courses.

In the absence of any effective cure suitable for large-scale use, vector control was the most effective way to prevent the spread of this disease. Adult control being difficult, chemical treatment of larval stages in the rivers was considered the only feasible method (Anon., 1985).

The Onchocerciasis Control Programme (OCP) commenced in December 1974 under the auspices of the World Health Organisation (WHO) and was planned for a twenty year intensive implementation (Davies et al., 1978). The initial control area of 764,000 km^2 included Burkina Faso and parts of Ivory Coast, Ghana, Togo, Benin, Niger and Mali (Figure 1). The first routine insecticide treatments were in February 1975 in the central part of the OCP area, and have been progressively extended. Up to 18,000 km of rivers have been monitored, and treated when necessary in the weekly spraying programme.

Prolonged and extensive use of insecticides could have important environmental risks, and therefore it was necessary to evaluate the possible short-, medium- and long-term effects of insecticides on the non-target fauna (Leveque et al., 1979).

The aquatic monitoring programme is performed by national teams of scientists in the countries in the OCP area, aided by outside specialists. This support was essential because little information on the aquatic fauna was available. The surveillance has been primarily concerned with two major categories of organisms: the fish, by virtue of their economic importance, and the benthic invertebrates, which may more quickly respond to insecticides. An important consideration for OCP is the demonstration to the local human population that care is being taken in reducing the risks of pollution.

An independent Ecological Group, consisting of experts of international repute, meets every year and is in charge of the evaluation of the collected data which has been analysed by outside specialists (Cummins, 1985). The group advises OCP on safe insecticide use and new monitoring procedures.

AIMS AND PROTOCOL

All insecticides used by OCP have to follow an intensive screening procedure in order to prove their high toxicity against the S. damnosum larvae, and their low toxicity for non-target fauna (Leveque, 1987). The criteria are that the pesticides should have neither any direct impact on fish nor any effect on their life cycles. Among hundreds of insecticide formulations tested by OCP, few are selected after operational field trials.

The fish monitoring programme was based on two fundamental ideas:-

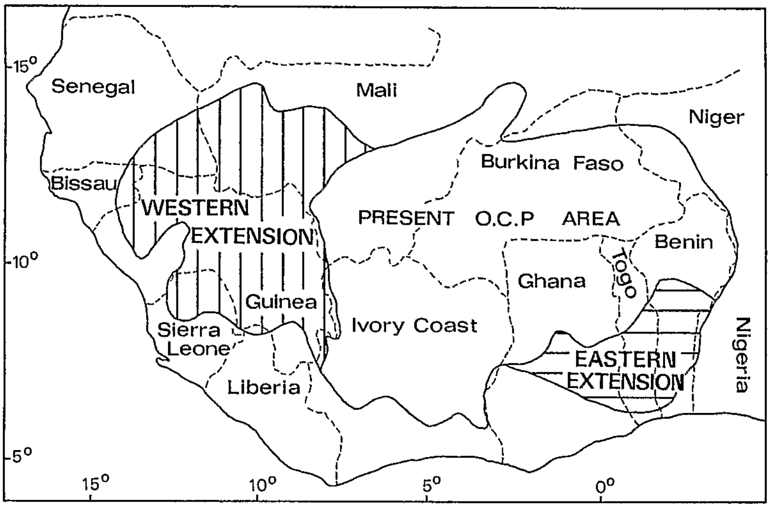


FIGURE 1 - Map of OCP area.

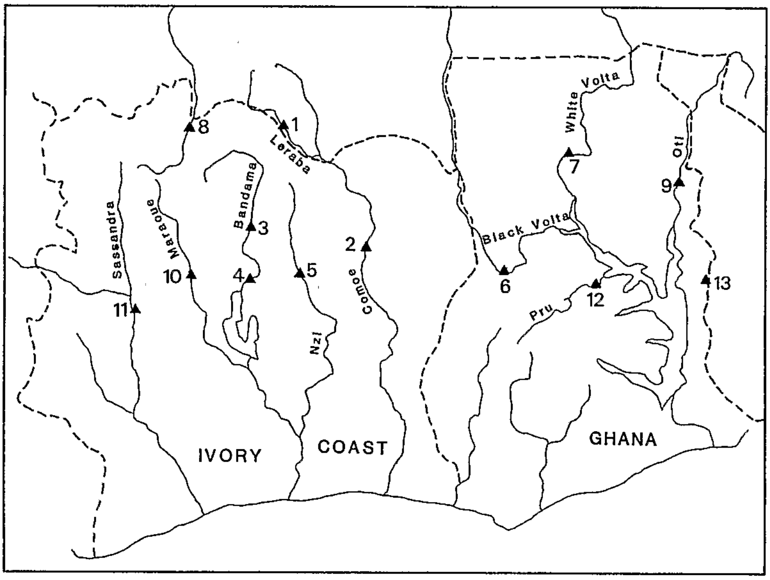


FIGURE 2 - Location of Major Fish Monitoring Stations in Ivory Coast and Ghana.

1. Leraba - Pont Frontiere
2. Comoe - Ganse
3. Bandama - Niakaramandougou
4. Bandama - Marabadiassa
5. Nzi - bridge of Dabakala Road
6. Black Volta - Bamboi
7. White Volta - Daboya
8. Bagoe - Kouto
9. Oti - Sabari
10. Maraoue - Mankono
11. Sassandra - Semien
12. Pru - Asubende
13. Wawa - Dodo Papasse

a) repeated long-term treatments could change the reproductive cycle of fishes, either by affecting the physiology or by direct effect on eggs or juveniles. If so, there could be changes in fish recruitment and, on a long-term basis, a decrease in fish abundance. This would apply to the fish community as a whole, or to particular species which could be more sensitive to insecticides.

b) Insecticides could affect the food chain leading to a serious reduction in diet.

It should be noted that such investigations could hardly be conducted in the laboratory because of the number and diversity of fish species involved, and the difficulties of maintaining most of the species in rearing conditions to complete their life cycle.

The monitoring stations (Figure 2) were chosen on the basis of accessibility at all seasons, suitability for sampling, availability of hydrological data and abundance of fish stocks.

In establishing the monitoring programme, the terms of reference included the introduction of simple standardized sampling techniques for use by different teams and under various environmental conditions (Leveque et al., 1979). Experimental fishing is therefore carried out using sets of gill nets 25 metres long and two metres deep with various mesh sizes (15,20,25,30 and 40 mm).

Usually each collection is the result of two sets of gill nets fishing on two consecutive nights, but some protocol variations have taken place, particularly in the early years of the programme. Data sheets for each sample record the number and total weight of individual species caught in the different mesh sizes. For comparison and standardization, results are expressed as catch per unit effort (CPUE) which is the number or weight of fish caught in 100 m^2 of net per night. Most of the monitoring stations were investigated every three months, but again there were some protocol variations during the ten years, mainly due to the accessibility of stations and availability of teams.

From the results obtained in sampling the different stations, it was therefore possible to follow long-term changes in:-

a) total catch for the set of gill nets with different mesh sizes or combinations of mesh sizes.
b) the number of species caught.
c) the quantity of each species caught.
d) the structure of the fish catch i.e. relative abundance of species in each mesh size.

Coefficient of condition, is a standard expression of the health of fishes which provides an assessment of feeding and ecological conditions. Fish were individually measured and weighed, to estimate the coefficient of condition (K) derived from the formula:- $K = W \times 10^5 / L^3$. where W is the weight in grammes and L is the standard length in mm.

Before the monitoring programme there were very few detailed studies on the biology and ecology of West African fishes. It was soon apparent that additional research was essential if the results of the monitoring programme were to be correctly interpreted. Various studies have since provided a better knowledge of the biology of the main species: Alestes baremoze, Brycinus nurse, B. imberi, B. macrolepidotus, B. longipinnis (Paugy, 1978, 1980a, 1980b, 1982a, 1982b), Petrocephalus bovei (Merona, 1980), Schilbe mystus and Eutropius mentalis (Leveque & Herbinet, 1980, 1982).

A study of the Bandama basin (Merona, 1981) provided information on the ecology of the fish species and confirmed the representative nature of monitoring stations. Electro-fishing has also been carried out in the rapids of some rivers to give a better understanding of fish populations of these habitats which cannot be sampled by gill nets, and of their changes over time. In order to help the different teams in identification of species, a catalogue of fishes was produced (Leveque & Paugy, 1984). All this information will be developed further in other publications.

INSECTICIDE TREATMENTS

Temephos ("Abate") is an organophosphorus larvicide which was used exclusively from 1975 to 1980. A 20% emulsion concentrate was applied at a dosage of 0.05 mgl^{-1} per 10 mn during the wet season, and at 0.1 mgl^{-1} per 10 mn in dry seasons.

In December 1979 temephos resistance developed in larvae of some cytospecies of the S. damnosum complex (Guillet et al., 1980; Kurtak, 1986) and spread rapidly to the southern forest zone and part of the humid savanna zone. This situation led to a large-scale application of Bacillus thuringiensis H14 ("Teknar") during the dry season (dose rate 1.2 mgl^{-1} per 10 mn) in these areas of resistance, together with "Chlorphoxim", another organophosphate, during the wet season (0.025 mgl^{-1} per 10 mn). However, a resistance to Chlorphoxim was discovered in July 1981 in the forest species already resistant to temephos (Kurtak et al., 1982). This necessitated an acceleration of screening of other alternative insecticides, and "Permethrin" and "Carbosulfan" appeared to be promising. These had only been used in the field during the rainy season (0.015 mgl^{-1} per 10 mn) where resistance to organophosphates was observed. No direct effect on fishes was apparent.

By the end of 1985 the treatment situation could be summarised as follows. Temephos was still used in those regions of the OCP area where no resistance had developed among Simulium populations; in the south-west, where strains resistant to this larvicide had appeared, Teknar was used where river discharge was below 75 m^3s^{-1}. Above this level, the strategy was to alternate other larvicides such as temephos, Chlorphoxim and, when necessary, Permethrin (WHO, 1986). As a result, insecticide treatment varied between rivers. Figure 3 illustrates the treatment regime for the main fish monitoring stations since the start of observations. More details of insecticides and treatment strategies will be found in Anon (1985).

It must be remembered that other insecticides may also affect the rivers in Ghana and Ivory Coast. Large amounts of agricultural pesticides, which are difficult to evaluate, may reach the water courses. According to Calamari (1985), 300 t of DDT, 600 t of Lindane, 100 t of methylparathion and 30 t of other compounds were used in 1976 in Ivory Coast. Since 1979 DDT has been replaced by organophosphates, carbamates and pyrethroids. Similar values are given for Ivory Coast by Balk and Koeman (1984) and are expected to increase two to three fold by the end of the century.

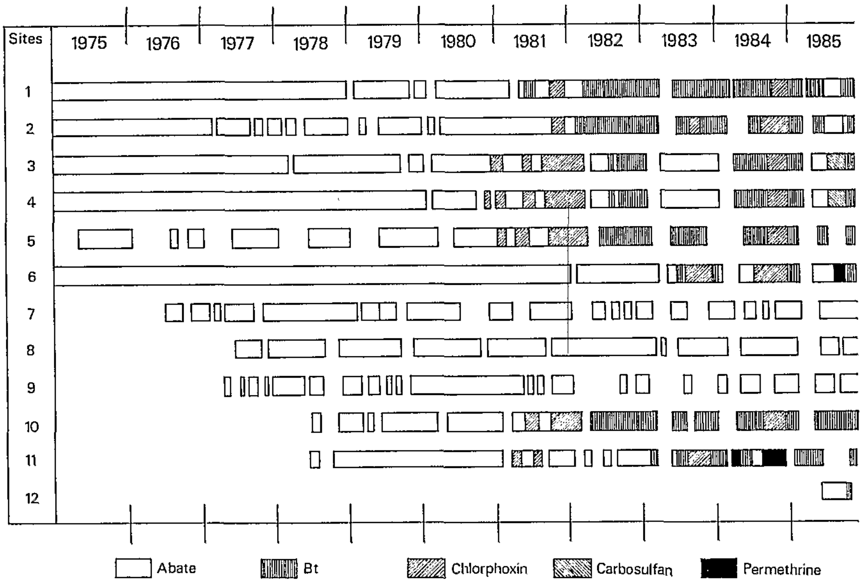


FIGURE 3 - Insecticide Treatment at the Major Aquatic Monitoring Stations

The areas surrounding some West African rivers are also treated with insecticides to control tsetse flies. The side effects of helicopter applications of dieldrin, endosulfan, permethrin and azamethiphos were monitored (Everts et al., 1983a, 1983b: Takken et al., 1978). No acute fish mortality was observed, except in Nigeria where a mass mortality of fish occurred following endosulfan spraying (Koeman et al., 1978) as well as in Ivory Coast (Everts et al., 1983b).

Another source of pollution is the sugar and fruit factories often situated along the rivers. The residues from this organic pollution could cause fish mortalities, such as those reported from the Sassandra upstream of the Semien monitoring station in 1985-1986.

RIVER HYDROLOGY AND BIOLOGICAL SIGNIFICANCE

The OCP area covers major river systems in West Africa, such as the Volta basin, part of the Niger basin, the northern parts of the Sassandra, Bandama, Comoe, Mono and Oueme basins. Most of these rivers are savanna type, with a water regime characterised by a flood period from July to November, with a peak in September and a lengthy low water period from January to June. For Ivory Coast, hydrological and physicochemical characteristics for the main water courses are summarised in Iltis and Leveque (1982). For the Volta basin, Moniod et al (1977) gave a synthesis of hydrological data.

Many of the rivers in the central part of the OCP area are intermittent and may dry up completely. For permanent rivers discharge is very low during the dry season, and the upper course is sometimes reduced to a series of pools. There are therefore several seasonal changes in flow which result in major ecological changes for the fish species. However, the importance of the flood period is also directly related to the abundance of seasonal rains and as a result of climatic fluctuations, the water discharge of rivers exhibits large changes from year to year (Figure 4). There may be differences between basins, but it is clear that a poor hydrological situation prevailed in the whole OCP area from 1982 to 1984.

In tropical rivers fish biologists recognise that hydrology plays a major role in fish behaviour. Fish reproduction tends to be highly seasonal and correlated primarily with flow (Welcomme, 1985). This is the case for many West African species which spawn during the earlier part of the flood: Alestes baremoze, Brycinus nurse, Petrocephalus bovei, Marcusenius furcidens, M. ussheri, Labeo senegalensis, L. coubie, Schilbe mystus, Eutropius mandibularis etc. (Albaret, 1982; Leveque & Herbinet, 1980, 1982; Paugy, 1978, 1980). However, some species are known to breed throughout the year: B. imberi, B. macrolepidotus, Hydrocynus forskalii, Tilapia zillii, Hemichromis fasciatus (Albaret, 1982; Paugy, 1980 , 1982).

It is also assumed that breeding success and survival of fry of many species could be related to the duration and water level of the flood period (for review see Welcomme, 1979, 1985). In years when there is insufficient water, the young fish have fewer refuges, are more vulnerable to predators and have fewer sources of food. Dansoko et al (1976) have shown that the reduction in commercial catches of Hydrocynus brevis and H. forskalii in 1972 and 1973 was a consequence of inadequate levels during the flood periods, and resulted in a poor condition factor, limited growth and weak recruitment to the fish stocks.

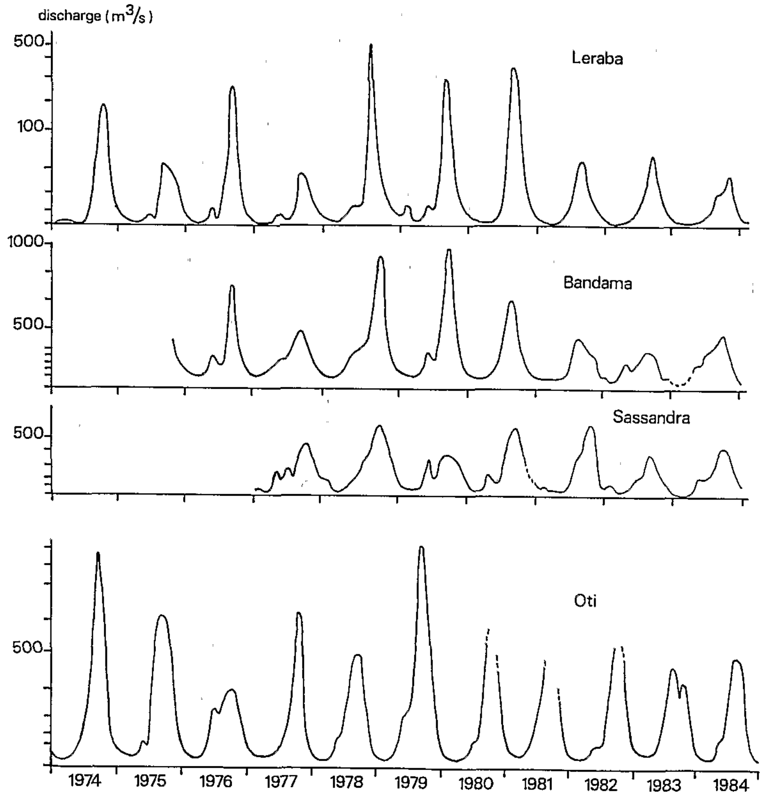


FIGURE 4 - Discharge (m^3 s^{-1}) per month for Some Monitoring Stations in the OCP area.

In a detailed study of fish populations from the Logone flood plain, Benech and Quensiere (1983) were also able to demonstrate over ten years the existence of a positive correlation between fish production and flood volume, as well as changes in species composition and community structure related to drought periods. Many fish species migrate long distances upstream at the beginning of the flood in order to spawn and find good conditions favouring the development of fry. This is the case in the rivers considered here for A. baremose, B. leuciscus, Mormyrus rume, Mormyrops deliciosus, Distichodus rostratus, Eutropius niloticus, E. mandibularis, Labeo senegalensis, etc. These migration patterns could be modified as a result of water management schemes such as dams and impoundments, whose numbers and surface area are expected to increase greatly by the end of the century (Clay, 1984). These dams could act as barriers interrupting upstream migrations, but could also favour species which develop in the lakes where they find good ecological conditions and migrate upstream during flood (See Bernaczek, 1984, for review). Such examples are the Volta and Kainji lakes (Kapetsky & Petr, 1984) as well as the Kossou lake on the Bandama. Since the beginning of the monitoring programme other dams have been built, such as the Taabo on the Bandama, Buyo on the Sassandra and numerous smaller irrigation reservoirs on the upper reaches of the rivers. Other projects are planned for the future in Ivory Coast and Ghana. As a result of this management, changes in fish community structures are expected in many rivers both upstream and downstream of the dams (Bernaczek, 1984).

In conclusion, the composition of experimental fish catches could be subject to: a) seasonal changes as a result of migrations; b) year to year changes as a result of climatic fluctuations; c) long-term changes following effects of impoundments; d) possible larvicide impacts.

ECOTOXICOLOGICAL STUDIES

The effects of organophosphates (temephos and Chlorphoxim) in laboratory experiments showed that fish were able to accumulate temephos (Miles et al., 1976; Matthiessen & Johnson, 1978), but this accumulation seems to be limited and does not increase indefinitely, as was observed with DDT for instance. As an example, Sarotherodon mossambicus exposed weekly to operational doses (0.05 mg l^{-1} for 10 minutes) accumulated 3-4 mg kg^{-1} by direct absorption. They could also accumulate residues by eating contaminated food. An affinity of temephos for fatty tissues has been observed, but in contrast to organochlorides there is no accumulation in the liver.

According to results obtained in field conditions (Quelennec et al, 1977) fish captured during the dry season just below the spraying point exhibited traces of temephos (between 1.3 and 14.3 mg l^{-1} according to species) one day after treatment. Six days later contamination was lower (between 1 and 7 mg l^{-1}). At a distance of 1 km below the spraying point, fish were weakly contaminated (between 0 and 0.25 mg l^{-1}). In the rainy season, accumulation of temephos is much lower; 0-0.4 mg l^{-1} five hours after spraying, just below the spraying point, and 0-0.03 mg l^{-1} five days later. It should be mentioned that DDT residues were also found (0.01-0.35 mg l^{-1}) in the fish studied, probably as a result of the use of this pesticide in agriculture.

The inhibition of acetylcholinesterase activity due to organophosphates was also studied in laboratory and field conditions. In the laboratory (Gras et al., 1982; Pelissier et al., 1982, 1983), where operational doses were tested (0.05 mg l^{-1} for 10 minutes) inhibition by temephos was about 25% for Tilapia guineensis, but no fish intoxication was noted after repeated weekly exposures. When fish were exposed to the operational dose for 24 hours, the inhibitory effect is much higher; 38% after one exposure ad 69% after three weekly exposures. In the latter case the fish did not survive. The inhibition of acetylcholinesterase activity appears more important with Chlorphoxim.

In field conditions, the acetycholinesterase activity in the fish brain does not seem to be significantly different in rivers treated with temephos or untreated (Antwi, 1983, 1984; Scheringa et al, 1981). When Chlorphoxim is used, fish captured below spraying points exhibited a 20% reduction in enzymatic activity, but this inhibition was shown to be reversible (Antwi, 1983, 1985).

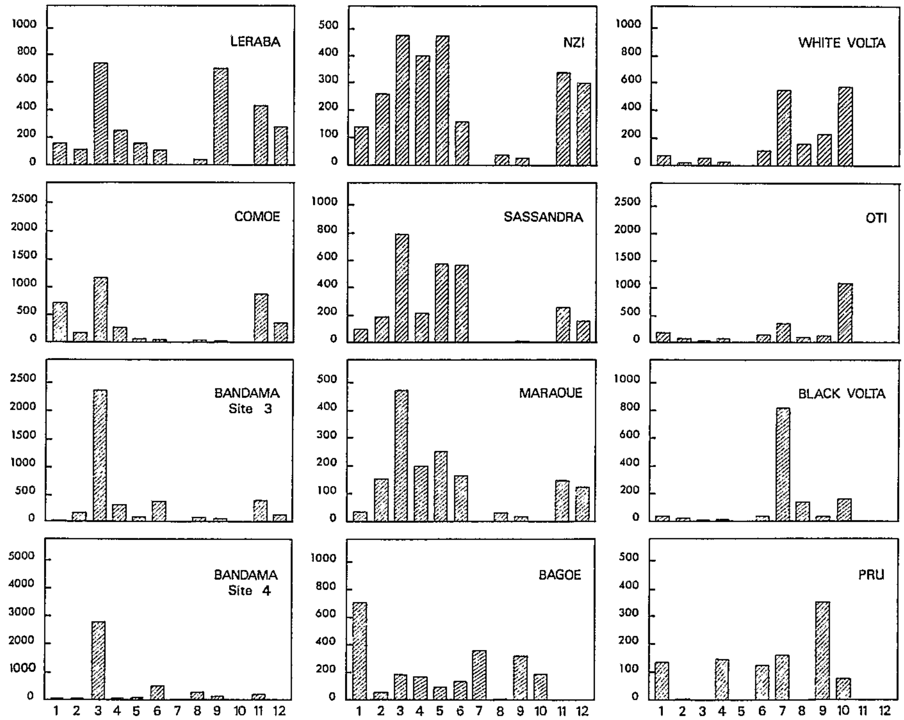


FIGURE 5 - Total Numbers of the Most Common Fish Caught in Gill Nets per Unit Effort at the Major Aquatic Monitoring Stations.

1. Petrocephalus bovei
2. Hydrocynus forskalii
3. Alestes baremoze
4. Brycinus macrolepidotus
5. Brycinus imberi
6. Brycinus nurse
7. Brycinus leuciscus
8. Labeo senegalensis
9. Schilbe mystus
10. Eutropius niloticus
11. Eutropius mandibularis
12. Chrysichthys velifer

RESULTS OF ECOLOGICAL MONITORING

1. Species Composition

The monitoring stations are situated in different river basins and at different levels of the water course. It is therefore not surprising to observe differences between stations in the relative abundance between species (Figure 5). Alestes baremoze is the dominant species in the south-flowing Ivory Coast rivers except in the Leraba-Comoe basin where Schilbe mystus is co-dominant. The Sassandra demonstrates a spectrum similar to the Maraoue. The Bagoe (Niger basin) and Volta exhibit a somewhat different fish fauna: Alestes leuciscus, Eutropius niloticus and Chrysichthys auratus instead of Brycinus imberi, Eutropius mandibularis and Chrysichthys velifer respectively.

2. Number of Fish Species

The number of fish species caught at selected stations (Figure 6) exhibits a seasonal change with a maximum at low water. This represents the greatest efficiency of the gill nets. There are different long-term trends in each river, but overall there is no evidence of a reduction in species richness over the ten year period. For Ivory Coast, there is a decrease in the number of fish species between 1981 and 1984 which could be related to the poor river discharges during that period (Figure 4). The recovery observed in 1985 follows a season of particularly heavy rain.

The total number of species could mask changes in species composition, some species being replaced. However, the results did not show evidence of disappearance of fish species in the experimental catches.

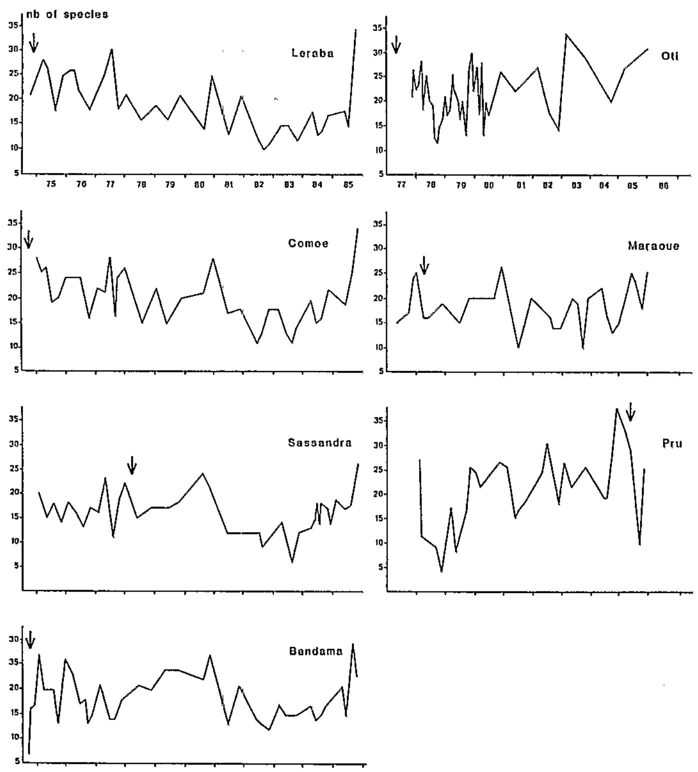


FIGURE 6 - Changes in Number of Fish Species per Sample at Various Stations Based on expectation of 2 sets of Gills nets on 2 consecutive nights.

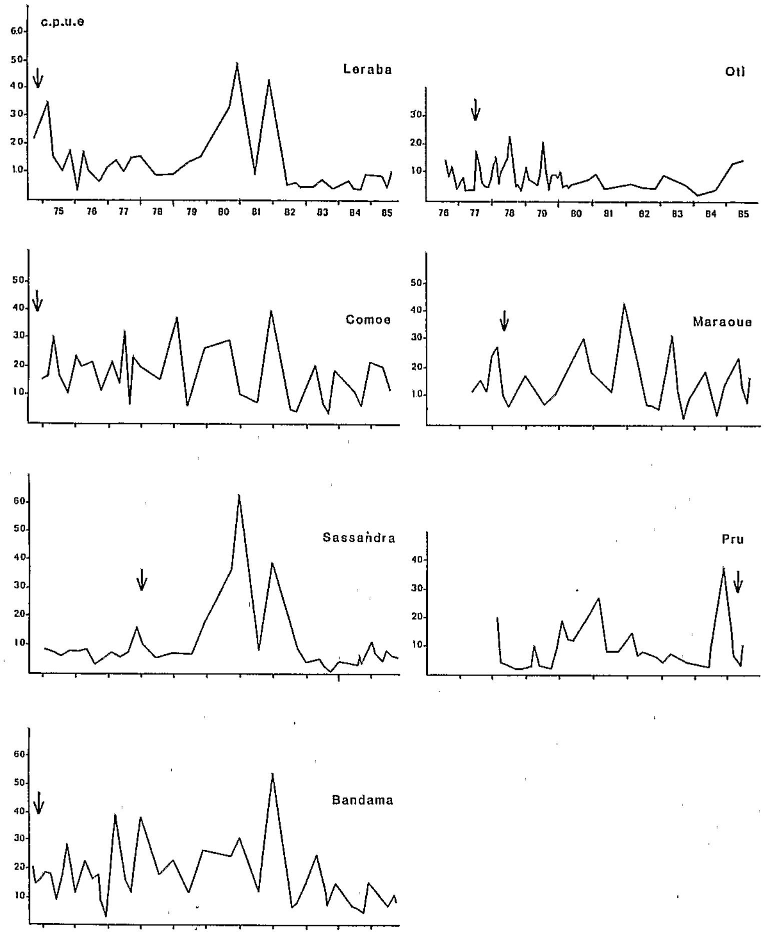


FIGURE 7 - Changes in Mean C.P.U.E. (Catch per $100m^2$ per night) for the Whole Set of Gill Nets in Various Stations

3. Changes in Total Experimental Catches

When considering changes in the fish catches, expressed as the mean CPUE for the standardized set of gill nets (Figure 7), a seasonal pattern is generally observed, with higher catches at the end of the high water period (November to January) and lower catches during the flood (August to September). Again this pattern is partly the result of the fishing gear being more efficient in low water conditions. The high CPUE values observed in the Sassandra in 1980 appear to be due to an increase in Alestes/Brycinus species (Alestes baremoze, Brycinus nurse, B. imberi). A similar phenomenon was observed in 1980-1981 in the Leraba due to increased catches of Alestes baremoze, Eutropius mandibularis, Schilbe mystus and Lates niloticus. Over the ten year period no long-term reductions in mean catch can be discerned.

When considering different mesh sizes (Figure 8), and particularly the smaller ones efficient for juveniles, there is a more obvious correlation with year-to-year changes in hydrology. At Niaka on the Bandama, for instance, catches in the 15 mm mesh size are lower in 1976-1977 and 1982-1984 which correspond to a poor flood (Figure 4). The catch was better with more favourable hydrology between 1979 and 1981. A similar situation occurred on the Leraba (Figure 8b).

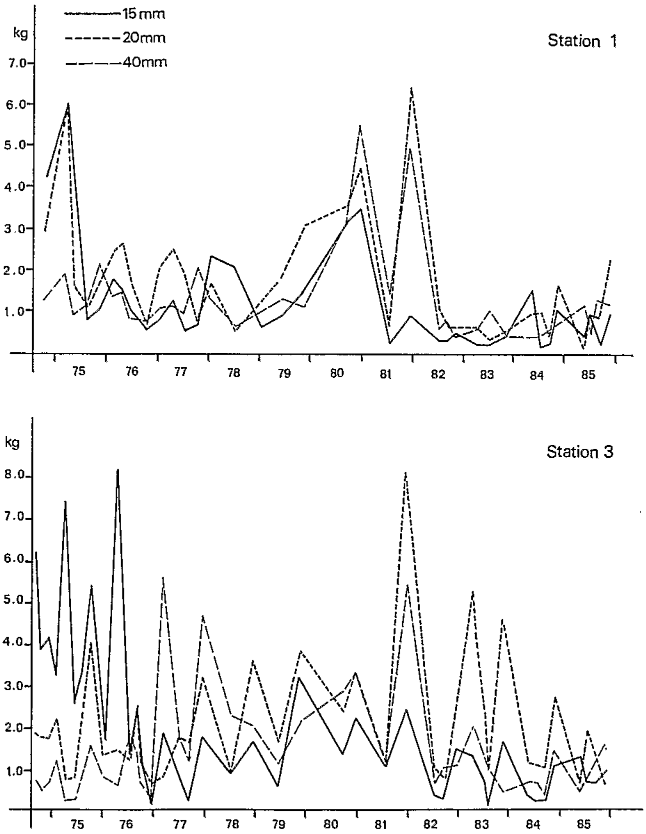


FIGURE 8 - Changes in Catch (C.P.U.E.) for Different Mesh Sizes at Two Monitoring Stations (Leraba and Bandama)

4. Changes in the Structure of the Fish catches

It is difficult to compare many graphs of species abundance against time and overlay these with abiotic factors. Therefore multivariate analyses are appropriate and the method used here is the factorial analysis of correspondence, the salient points of which are amply described elsewhere (Benzecri, 1973: Lebard & Fenelon, 1973: Hill, 1974). This method is particularly informative as it permits simultaneous graphical representation of species and samples.

Two examples are given here, the first being the river Oti at Sabari with only Abate treatment being applied. Although treatments have been less frequent in recent years, the river Mo has received heavy insecticide applications. This tributary joins the Oti before the Volta Lake so all migratory fish would be exposed to Abate at some time.

In the ordination presented in Figure 9a. the first axis separates the samples into low and high water periods. Dry period collections are characterised by Alestes, Labeo and Chrysichthys species, as well as Synodontis filamentosus and Schilbe mystus. The second axis has a group of high water samples in the middle, with rising and falling water periods being more diffuse. Comparison with Figure 10 gives some reasons for this pattern, as the Petrocephalus spp. are not common after 1979, while Eutropius niloticus continues to be abundant throughout the sampling period. Apparent reductions in abundance can also be correlated with a reduction in frequency of monitoring from monthly to quarterly. Therefore species such as E. niloticus may be under-represented as the main migration period is more likely to be missed.

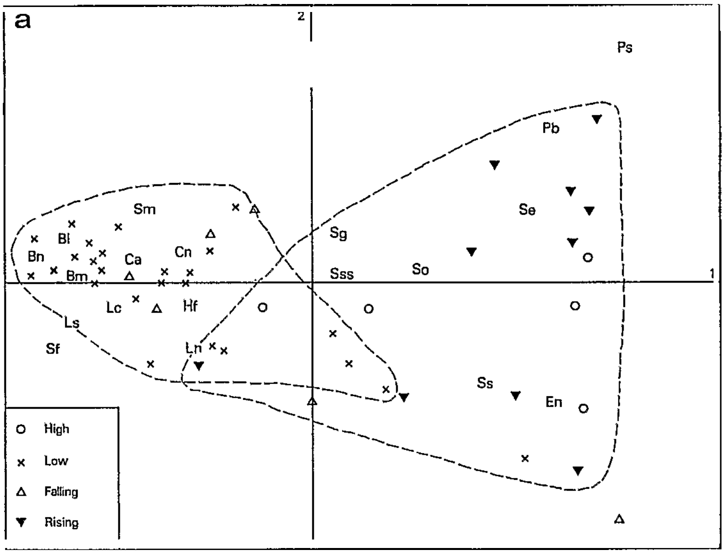
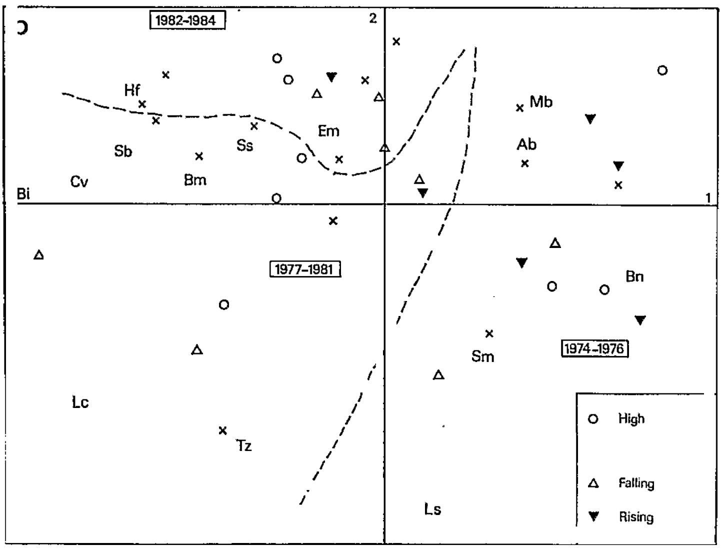


FIGURE 9 - Correspondence Analysis of experimental catches (in fish numbers) at:

a) Oti at Sabari
b) Bandama at Niakaramandougou

Pb	Petrocephalus bovei	Bm	Brycinus macrolepidotus
Ps	Petrocephalus simus	Bn	Brycinus nurse
Se	Synodontis eupterus	Bl	Brycinus leuciscus
So	Synodontis ocellifer	Bi	Brycinus imberi
Sss	Synodontis sorex	Ab	Alestes baremoze
	Synodontis gambiensis	Cv	Chrysichthys velifer
Ss	Synodontis schall	Ls	Labeo senegalensis
Sf	Synodontis filamentosus	Lc	Labeo coubie
Sb	Synodontis bastiani	Sm	Schilbe mystus
Em	Eutropius mandibularis	Ln	Lates niloticus
En	Eutropius niloticus	Tg	Tilapia galilea
Hf	Hydrocynus forskalii	Mb	Marcusenius bruyerei



In conclusion, the major patterns of community change reflect seasonal influences rather than year-to-year differences. Changes in abundance of individual species over time have a partial explanation in reduction of sampling frequency, but species such as Petrocephalus bovei and P. simus appear to become rarer, a trend which is more difficult to explain in terms of hydrology.

The second example is the river Bandama at Niakaramandougou. The river feeds into the Kossou Dam, and early treatments were with Abate, other insecticides being employed from the end of 1980. The ordination (Figure 9b) appears to separate Abate treatments from the rest, but closer examination reveals a distinct community change at the end of 1976, with A. nurse becoming more rare and species such as A. imberi, C. velifer and Hydrocynus forskalii increasing in abundance. The second axis is dominated by Labeo senegalensis, Schilbe mystus and Tilapia galilaea, indicative of another change at the beginning of 1982 when these species became a smaller proportion of the catch (Figure 16). In the centre of the ordination lies Eutropius mandibularis which has maintained a relatively constant proportion of the catch throughout the sampling period. The reason for the changes could lie in a combination of a lag effect of the filling of the Kossou Lake and the wet years of 1979 and 1980. Therefore, effects of treatment are again not obvious, and this conclusion is reached for other sampling stations.

5. Coefficient of Condition

Long-term changes in the mean coefficient of condition (K) were studied for the most abundant species at the different monitoring sites. Selected examples are given in Figure 10 for species whose food is primarily based on aquatic invertebrates. The values of the coefficient of condition are relatively random, fluctuating around a mean which does not seem appreciably altered over the ten year period of treatment. There is no evidence of a long-term decrease or irreversible modification in K. Nevertheless, when examined in detail, significant short-term decreases were observed for a few species. This is the case for Alestes baremoze and to a lesser extent for Eutropius mandibularis in the Bandama river in 1976-1977. A similar phenomenon occurred for Brycinus nurse in the Sassandra and Leraba rivers between 1981 and 1983. Such decreases, which apparently do not affect all species in the same river, or the same species at every site, seem difficult to explain. However, the drop in K for A. baremoze in 1976-1977 was restricted to the course of the Bandama between the Kossou and Ferkessedougou dams (Paugy, 1978) and coincided with a period of poor floods (Figure. 4). The fall in value of K for A. nurse between 1981-1983 coincided with severe drought in the Sassandra and Leraba. For some species, therefore, there should be a relationship between K and changes in hydrology. Minor fluctuations in K relate to the life cycle and the seasons (Paugy, 1978, 1980 ; Leveque & Herbinet, 1980). It was also observed that for the same species there could be differences in K for the different river basins.

The relative stability of coefficient of condition indicates that fish are able to feed normally in treated rivers. In fact, stomach content analysis carried out in 1975, just after the start of treatment (Vidy, 1978), and in 1976-1977, did not reveal significant changes in the diet of fish species feeding entirely (Petrocephalus bovei) or partially (A. baremoze, B. imberi, B. nurse, E. mentalis) on the aquatic invertebrate fauna. It has been observed that temephos treatment resulted in a temporary reduction of aquatic insects by only 30-40% (Dejoux, 1983), and it does not seem that treatment could lower food stocks to a critical threshold. Moreover, the adaptability of many freshwater fishes to various types of food has been demonstrated a number of

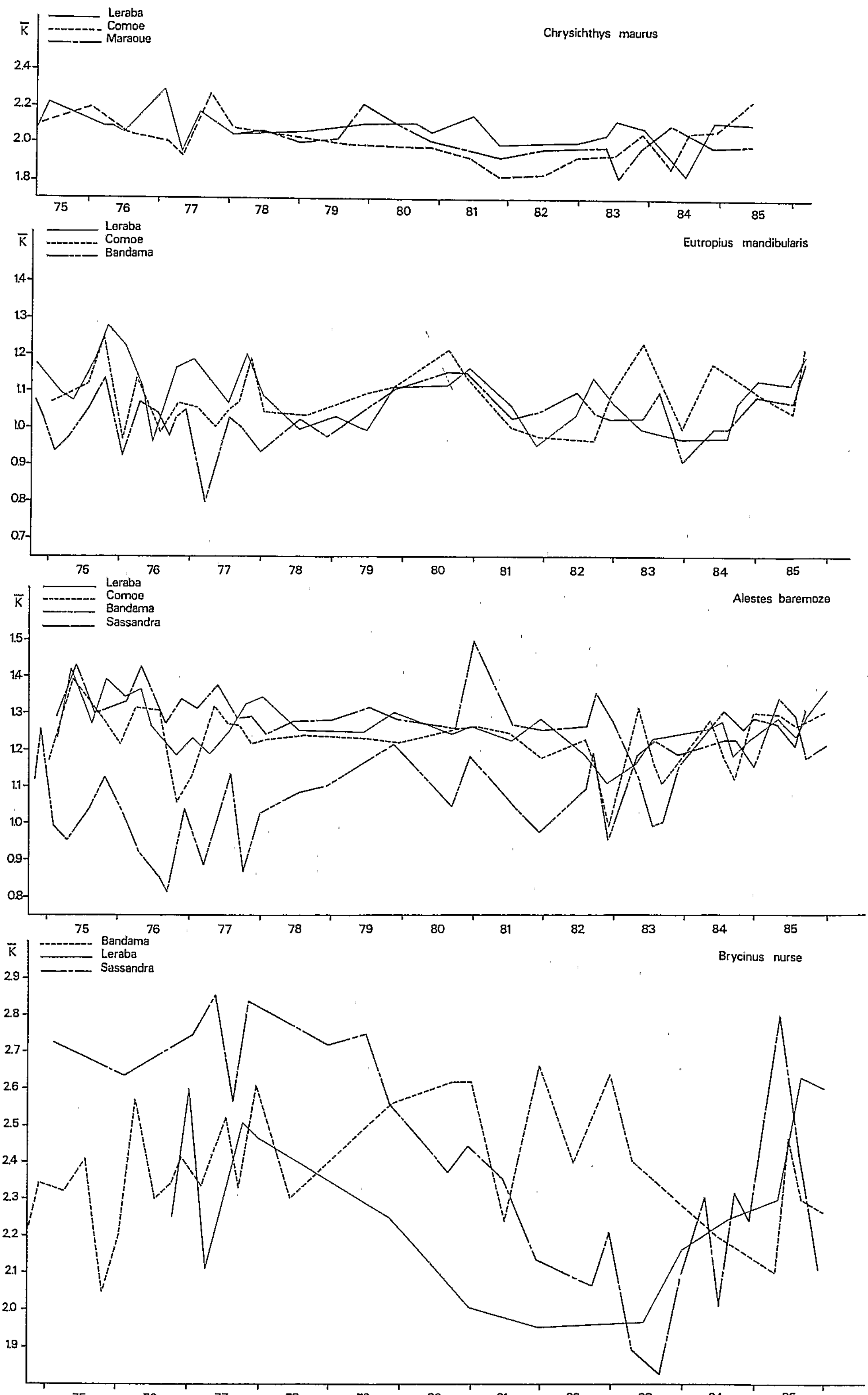


FIGURE 10 - Changes in coefficient of conditions for selected species

times (Lauzanne, 1976; Welcomme, 1985). Nevertheless, Corbet (1956) observed a change in the diet of some fish, particularly Mormyridae. Some species with a specialized diet, such as Mastacembelus victoriae apparently suffered from malnutrition or migrated.

CONCLUSIONS

Experimental fish sampling has been carried out for ten years in West African rivers treated weekly with insecticides by OCP using the standard protocol. The monitoring stations investigated differed in many ways, with:-

a) their location on different river basins
b) the relative abundance of fish species, despite many species being common to different basins
c) the insecticides used, some stations always being treated with temephos, others with temephos up to 1980 and later with an alternation of insecticides (Figure 3).

For the interpretation of data collected, we were faced with different sources of bias:-

a) the human factor, in that data were collected by different teams and there were changes in the personnel responsible for fish monitoring in Ivory Coast and Ghana. This could lead to some differences which on occasion could be recognised by detailed statistical analysis. This source of bias did not appear to change the overall picture.
b) lack of knowledge concerning the changes in fish community structure as the result of changes in natural environmental factors. This is the case for instance for river discharge, which could vary greatly between years, and is known to affect the reproductive success of fishes.
c) lack of knowledge concerning the uses and abuses of insecticides other than those applied by OCP. It is known (Calamari, 1985; Balk & Koeman, 1984) that large amounts of agricultural pesticides are used in the OCP area, but the questions are: what reaches the river beds, and what is the impact on the aquatic fauna? A few direct, observations also showed that insecticides are sometimes used as poison when fishing in rivers. However, the extent of this influence is not known.

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