PART I: Fish communities of Ivory Coast rivers treated by temephos
(C. Lévéque, D. Paugy & J.-M. Jestin)

PART II: Observations on fish populations in Abate-treated rivers in Northern Ghana (E. K. Abban, C. P. Fairhurst & M. S. Curtis)

PART III: Fish monitoring in West African rivers - problem and perspectives
(E. K. Abban, C. P. Fairhurst, C. Lévéque & D. Paugy)

February 1982
REPORT OF FISH POPULATIONS IN RIVERS OF IVORY COAST AND GHANA

PART I: Fish communities of Ivory Coast rivers treated by temephos (C. Léveque, D. Paugy & J.-M. Jestin)

PART II: Observations on fish populations in Abate-treated rivers in Northern Ghana (E. K. Abban, C. P. Fairhurst & M. S. Curtis)


February 1982
# PART I: FISH COMMUNITIES OF IVORY COAST RIVERS TREATED BY TEMEPHOS

## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1. ICHTHYOLOGICAL MONITORING PROGRAMME - CONDITIONS AND AIMS</td>
<td>1</td>
</tr>
<tr>
<td>2. CHANGES IN THE FISH POPULATIONS</td>
<td>5</td>
</tr>
<tr>
<td>2.1 Experimental fishing by gill net</td>
<td>5</td>
</tr>
<tr>
<td>2.1.1 Processing of experimental fishing data</td>
<td>5</td>
</tr>
<tr>
<td>2.1.2 Comoé-Léraba Basin</td>
<td>5</td>
</tr>
<tr>
<td>2.1.3 Sassandra Basin</td>
<td>8</td>
</tr>
<tr>
<td>2.1.4 Bandama Basin</td>
<td>14</td>
</tr>
<tr>
<td>2.2 Electrofishing</td>
<td>18</td>
</tr>
<tr>
<td>2.3 Conclusions</td>
<td>19</td>
</tr>
<tr>
<td>3. BIOLOGY OF THE MAIN SPECIES</td>
<td>19</td>
</tr>
<tr>
<td>3.1 Reproductive cycle</td>
<td>19</td>
</tr>
<tr>
<td>3.2 Coefficient of condition</td>
<td>21</td>
</tr>
<tr>
<td>3.3 Diet</td>
<td>22</td>
</tr>
<tr>
<td>4. CONCLUSIONS</td>
<td>25</td>
</tr>
<tr>
<td>5. BIBLIOGRAPHY</td>
<td>28</td>
</tr>
</tbody>
</table>
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1. ICHTHYOLOGICAL MONITORING PROGRAMME - CONDITIONS AND AIMS</td>
<td>1</td>
</tr>
<tr>
<td>2. CHANGES IN THE FISH POPULATIONS</td>
<td>5</td>
</tr>
<tr>
<td>2.1 Experimental fishing by gill net</td>
<td>5</td>
</tr>
<tr>
<td>2.1.1 Processing of experimental fishing data</td>
<td>5</td>
</tr>
<tr>
<td>2.1.2 Comoé-Léraba Basin</td>
<td>5</td>
</tr>
<tr>
<td>2.1.3 Sassandra Basin</td>
<td>8</td>
</tr>
<tr>
<td>2.1.4 Bandama Basin</td>
<td>14</td>
</tr>
<tr>
<td>2.2 Electrofishing</td>
<td>18</td>
</tr>
<tr>
<td>2.3 Conclusions</td>
<td>19</td>
</tr>
<tr>
<td>3. BIOLOGY OF THE MAIN SPECIES</td>
<td>19</td>
</tr>
<tr>
<td>3.1 Reproductive cycle</td>
<td>19</td>
</tr>
<tr>
<td>3.2 Coefficient of condition</td>
<td>21</td>
</tr>
<tr>
<td>3.3 Diet</td>
<td>22</td>
</tr>
<tr>
<td>4. CONCLUSIONS</td>
<td>25</td>
</tr>
<tr>
<td>5. BIBLIOGRAPHY</td>
<td>28</td>
</tr>
</tbody>
</table>
INTRODUCTION

An extensive Onchocerciasis Control Programme in West Africa was launched in 1974, under the aegis of WHO. Since that time there have been weekly applicates of insecticides in all rivers over an area of more than two million km² covering Upper Volta, Ivory Coast, Ghana, the north of Benin, Niger and Mali; it is planned to continue treatment for 20 years.

Toxaphos, which was the only insecticide used until 1980, was adopted after a number of tests, because of its effectiveness against the larvae of Simulium damnosum (the vector of onchocerciasis), which inhabit running water, and its apparent slight toxicity for the non-target fauna. Nevertheless, since its prolonged and intensive use could have risks, it was necessary to evaluate the possible medium-term and long-term effects of applicates on the organisms of the treated watercourses. Consequently, an aquatic environmental monitoring programme was prepared at the commencement of the larval eradication programme, so as to be sure that the insecticide released did not excessively disturb the functioning of the treated environments, and to provide warning to those carrying out treatment, should toxic effects be noted.

What has been done has been primarily concerned with two major categories of organisms: the invertebrates that abound in the watercourses and that are directly threatened by the insecticide in the same way as Simulium damnosum larvae; fishes, by virtue of their economic interest for the people living along the rivers. There has also been other research of shorter duration on water quality, plankton, etc.

The monitoring programme has been jointly carried out by several teams working in different zones but following the same established procedures (Levêque et al., 1979). The results on ichthyology obtained in Ivory Coast by the ORSTOM Hydrobiological Laboratory at Bouaké are set out here.

1. ICHTHYLOGICAL MONITORING PROGRAMME - CONDITIONS AND AIMS

Given that preliminary trials had shown that toxaphos apparently had no direct effect on fishes when employed at the recommended treatment rates, the monitoring programme was set up with the aim of studying the possible medium-term and long-term effects in the natural environment. The terms of reference also included the introduction of simple techniques capable of being used by the teams responsible for monitoring in the various zones of the programme, and under environmental conditions that are sometimes dissimilar.

In this context, and having regard to the difficulties of access to and work in many watercourses, as well as to the extent of the habitats for investigation, we therefore chose to give preferential treatment to a number of topics:

- study of changes in the catch composition of experimental fishing carried out at regular intervals with a standardized set of gill nets at selected monitoring station on treated and untreated rivers;

- study of the development of some of the biological parameters, more especially the coefficient of condition, which is a measure of the health of fishes. This parameter may consequently be used to assess whether fishes are still able to find the food that they require in the treated environments, and whether ecological conditions remain favourable to them. It also reflects any possible adverse effect of toxaphos on the metabolism of fishes.

Before we undertook this programme, our knowledge of the West African rivers was very limited. In particular, there were very few detailed studies of the biology and ecology of their fishes. It therefore very rapidly became apparent that additional research was essential if the results of the monitoring programme were to be correctly interpreted in the absence of adequate knowledge of the environment. Various studies were therefore carried out to provide a better knowledge of the biology of the main species: Alestes baremoze (Paugy, 1978); Alestes nurse (Paugy, 1980), Alestes imberi (Paugy, 1980), Alestes macrolepidotus (Paugy, 1982), Alestes longipinnis (Paugy, 1982), Petrocephalus bovei...
INTRODUCTION

An extensive Onchocerciasis Control Programme in West Africa was launched in 1974, under the aegis of WHO. Since that time there have been weekly applications of insecticides in all rivers over an area of more than two million km² covering Upper Volta, Ivory Coast, Ghana, the north of Benin, Niger and Mali; it is planned to continue treatment for 20 years.

Temephos, which was the only insecticide used until 1980, was adopted after a number of tests, because of its effectiveness against the larvae of Simulium damnosum (the vector of onchocerciasis), which inhabit running water, and its apparent slight toxicity for the non-target fauna. Nevertheless, since its prolonged and intensive use could have risks, it was necessary to evaluate the possible medium-term and long-term effects of applications on the organisms of the treated watercourses. Consequently, an aquatic environmental monitoring programme was prepared at the commencement of the larval eradication programme, so as to be sure that the insecticide released did not excessively disturb the functioning of the treated environments, and to provide warning to those carrying out treatment, should toxic effects be noted.

What has been done has been primarily concerned with two major categories of organisms: the invertebrates that abound in the watercourses and that are directly threatened by the insecticide in the same way as Simulium damnosum larvae; fishes, by virtue of their economic interest for the people living along the rivers. There has also been other research of shorter duration on water quality, plankton, etc.

The monitoring programme has been jointly carried out by several teams working in different zones but following the same established procedures (Lévéque et al., 1979). The results on ichthyology obtained in Ivory Coast by the ORSTOM Hydrobiological Laboratory at Bouaké are set out here.

1. ICHTHYOLOGICAL MONITORING PROGRAMME - CONDITIONS AND AIMS

Given that preliminary trials had shown that temephos apparently had no direct effect on fishes when employed at the recommended treatment rates, the monitoring programme was set up with the aim of studying the possible medium-term and long-term effects in the natural environment. The terms of reference also included the introduction of simple techniques capable of being used by the teams responsible for monitoring in the various zones of the programme, and under environmental conditions that are sometimes dissimilar.

In this context, and having regard to the difficulties of access to and work in many watercourses, as well as to the extent of the habitats for investigation, we therefore chose to give preferential treatment to a number of topics:

- study of changes in the catch composition of experimental fishing carried out at regular intervals with a standardized set of gill nets at selected monitoring station on treated and untreated rivers;

- study of the development of some of the biological parameters, more especially the coefficient of condition, which is a measure of the health of fishes. This parameter may consequently be used to assess whether fishes are still able to find the food that they require in the treated environments, and whether ecological conditions remain favourable to them. It also reflects any possible adverse effect of Abate on the metabolism of fishes.

Before we undertook this programme, our knowledge of the West African rivers was very limited. In particular, there were very few detailed studies of the biology and ecology of their fishes. It therefore very rapidly became apparent that additional research was essential if the results of the monitoring programme were to be correctly interpreted in the absence of adequate knowledge of the environment. Various studies were therefore carried out to provide a better knowledge of the biology of the main species: Alestes baremoze (Paugy, 1978); Alestes nurse (Paugy, 1980); Alestes imberi (Paugy, 1980); Alestes macrolepidotus (Paugy, 1982); Alestes longipinnis (Paugy, 1982); Petrocephalus bovei...
(de Merona, 1980), Schilbe mystus (Lévêque & Herbinet, 1980), Eutropius mentalis (Lévêque & Herbinet, 1982). An ichthyological study of the Bandama Basin (de Merona, 1980) has provided up-to-date information on the ecology of the fish species and a check on the representative nature of the monitoring stations. Electrofishing has also been carried out in the rapids to give us a better understanding of the fish populations of these biotopes, which cannot be sampled by gill net, and of their changes over time.

Lastly, stomach-content studies have established that the diet of the main species has not undergone significant changes (Vidy, 1976) and fecundity studies have demonstrated that temephos does not appear adversely to have affected reproduction (Albaret, 1982).

Monitoring technique

Observations were carried out at eight stations located in several drainage basins (Fig. 1):

- Bandama Basin: the Marabadiassa and Niakaramandougou stations on the Bandama itself, the Dabakala station on the N'zi, and the Mankono station on the Maroué. Except for Mankono, for which records date only from 1977, all these stations have been investigated since 1974;

- Comoé Basin: Gansé station on the Comoé and Pont Frontière station on the Léraba, records for both of which date from 1974;

- Sassandra Basin: Semien station, for which records date from 1975, treatment starting in 1978;

- Bagoé Basin (a tributary of the Niger): Kouto station, for which records exist from 1975, treated since 1977.

In general, the monitoring stations are located on rivers of tropical type having their highest water level in September and a lengthy low-water period from January to June (Fig. 2). There is a special account of the hydrological and physico-chemical characteristics of these watercourses (Itis & Lévêque, 1982).

Experimental fishing was carried out using a set of gill nets 25 m long and 2 m deep, with various mesh sizes: 15, 20, 25, 30 and 40 mm for the monitoring set. We made additional use of 12.5, 17.5 and 22.5 mm meshes, which will be taken into consideration in the results here set out. These nets, which were of multifilament nylon (12 500), were set up at 50%.

The monitoring stations were sampled every three months at the start of the programme. Having regard to the slight apparent impact of the insecticides, it was decided from 1979 onwards to make only two annual observations, one at the end of the high-water period, the other at the end of the low-water period.
(de Merona, 1980), Schilbe mystus (Lévêque & Herbinet, 1980), Eutropius mentalis (Lévêque & Herbinet, 1982). An ichthyological study of the Bandama Basin (de Merona, 1980) has provided up-to-date information on the ecology of the fish species and a check on the representative nature of the monitoring stations. Electrofishing has also been carried out in the rapids to give us a better understanding of the fish populations of these biotopes, which cannot be sampled by gill net, and of their changes over time.

Lastly, stomach-content studies have established that the diet of the main species has not undergone significant changes (Vidy, 1976) and fecundity studies have demonstrated that temephos does not appear adversely to have affected reproduction (Albaret, 1982).

**Monitoring technique**

Observations were carried out at eight stations located in several drainage basins (Fig. 1):

- **Bandama Basin**: the Marabadiassa and Niakaramandougou stations on the Bandama itself, the Dabakala station on the N'zi, and the Mankono station on the Maraoué. Except for Mankono, for which records date only from 1977, all these stations have been investigated since 1974;

- **Comoé Basin**: Gansé station on the Comoé and Pont Frontière station on the Léraba, records for both of which date from 1974;

- **Sassandra Basin**: Semien station, for which records date from 1975, treatment starting in 1978;

- **Bagoé Basin** (a tributary of the Niger): Kouto station, for which records exist from 1975, treated since 1977.

In general, the monitoring stations are located on rivers of tropical type having their highest water level in September and a lengthy low-water period from January to June (Fig. 2). There is a special account of the hydrological and physico-chemical characteristics of these watercourses (Iltis & Lévêque, 1982).

Experimental fishing was carried out using a set of gill nets 25 m long and 2 m deep, with various mesh sizes: 15, 20, 25, 30 and 40 mm for the monitoring set. We made additional use of 12.5, 17.5 and 22.5 mm meshes, which will be taken into consideration in the results here set out. These nets, which were of multifilament nylon (12 500), were set up at 50%.

The monitoring stations were sampled every three months at the start of the programme. Having regard to the slight apparent impact of the insecticides, it was decided from 1979 onwards to make only two annual observations, one at the end of the high-water period, the other at the end of the low-water period.
FIG. 1. LOCATION OF MONITORING STATIONS IN IVORY COAST
FIG. 1. LOCATION OF MONITORING STATIONS IN IVORY COAST
FIG. 2. RIVER DISCHARGES (MEAN MONTHLY VALUES), 1974-1978, AT THE STATIONS OF THE MONITORING PROGRAMME (DATA SUPPLIED BY THE HYDROLOGICAL SERVICE OF IVORY COAST)
FIG. 2. RIVER DISCHARGES (MEAN MONTHLY VALUES), 1974-1978, AT THE STATIONS OF THE MONITORING PROGRAMME (DATA SUPPLIED BY THE HYDROLOGICAL SERVICE OF IVORY COAST)
2. CHANGES IN THE FISH POPULATION

2.1 Experimental fishing by gill net

2.1.1 Processing of experimental fishing data

The experimental fishing results are expressed as the catch per unit of effort (c.p.u.e., the number or weight of fish caught per 100 m² of gill nets in the course of fishing for one night). In the processing of these data, we made use of correspondence analysis, the salient points of which have been amply described elsewhere (Benzécri, 1973; Hill, 1974; Lebart & Fenelon, 1973). This method is especially suitable for our type of data. One of its advantages is to permit simultaneous graphic representation of species and observations.

To facilitate the processing, the various types of nets employed were grouped into three categories: category 1 - nets with a mesh size of 12.5 and 15 mm; category 2 - nets with a mesh size of 17.5/20 and 22.5 mm; category 3 - nets with a mesh size of 25, 30 and 40 mm. The mean catch per unit of effort (c.p.u.e.) was calculated for each of these categories, and for all the gill nets in terms of the number of fish and the weight. These amalgamations into categories were made after a preliminary study had shown that there were strong affinities between the fish populations sampled by certain gill nets.

The processing was carried out on raw data (c.p.u.e. expressed as numbers or as weights) and on data coded by logarithmic transformation to base 5 for numbers and to base 10 for weights.

Correspondence analysis is frequently employed in ecology for the analysis of raw data. It gives preferential treatment to highly variable abundant elements, and consequently often brings out phenomena which seem obvious to the field ecologist. Coding, on the contrary, favours the characteristic species and observations, and here the analysis yields results somewhat different from the previous ones, bringing out different phenomena. The extreme case of coding is presence-absence.

At the present time the principle of coding has only an empirical basis born out by the experience of many specialists in data processing. It arose from the questions raised by biologists concerning the significance of raw data, especially data on numbers, when dealing with species of very different sizes. The biological significance of weight data appears to some biologists to be better.

We carried out our processing on raw results (numbers and weights) and also on coded data. Only some of the results of these analyses are given here, to the extent to which they seem to us to make a valuable contribution to the interpretation of the results.

2.1.2 Comoë-Léraba Basin

Two stations were regularly sampled in this Basin: Gansé on the Comoë and the station known as Pont Frontière on the Léraba. If we consider the numbers of the species caught, it may be noted that the fish populations of the two stations are qualitatively quite similar, but differ in the relative abundance of some species: *S. mystus* is more abundant in the Léraba than at the station on the Comoë, as are *P. guentheri*, *H. fasciatus*, and *B. senegalensis* to a lesser degree. Conversely, the Mormyridae (*P. bovei* in particular, *M. furcidens*, *M. rume*) and *L. coubie* are better represented at Gansé. These characteristics are illustratd in Fig. 3, in which *P. bovei* and *S. mystus* make a strong contribution to the first axis dividing the observations at the two stations.

There is also a difference in the composition of the observations of the high-water period and the low-water period at each of the two stations (Fig. 4). There are two essential causes for this phenomenon: sampling is not carried out under precisely the same conditions in the course of these periods, and some species migrate upstream to reproduce during the high-water period. *E. mentalis* would appear to correspond to this latter case, since the abundance peaks in the catches occurred during the low-water period in the Comoë an-
2. CHANGES IN THE FISH POPULATION

2.1 Experimental fishing by gill net

2.1.1 Processing of experimental fishing data

The experimental fishing results are expressed as the catch per unit of effort (c.p.u.e. the number or weight of fish caught per 100 m² of gill nets in the course of fishing for one night). In the processing of these data, we made use of correspondence analysis, the salient points of which have been amply described elsewhere (Benzécri, 1973; Hill, 1974; Lebart & Fenelon, 1973). This method is especially suitable for our type of data. One of its advantages is to permit simultaneous graphic representation of species and observations.

To facilitate the processing, the various types of nets employed were grouped into three categories: category 1 - nets with a mesh size of 12.5 and 15 mm; category 2 - nets with a mesh size of 17.5/20 and 22.5 mm; category 3 - nets with a mesh size of 25, 30 and 40 cm.

The mean catch per unit of effort (c.p.u.e.) was calculated for each of these categories, and for all the gill nets in terms of the number of fish and the weight. These amalgamations into categories were made after a preliminary study had shown that there were strong affinities between the fish populations sampled by certain gill nets.

The processing was carried out on raw data (c.p.u.e. expressed as numbers or as weights) and on data coded by logarithmic transformation to base 5 for numbers and to base 10 for weights.

Correspondence analysis is frequently employed in ecology for the analysis of raw data. It gives preferential treatment to highly variable abundant elements, and consequently often brings out phenomena which seem obvious to the field ecologist. Coding, on the contrary, favours the characteristic species and observations, and here the analysis yields results somewhat different from the previous ones, bringing out different phenomena. The extreme case of coding is presence-absence.

At the present time the principle of coding has only an empirical basis born out by the experience of many specialists in data processing. It arose from the questions raised by biologists concerning the significance of raw data, especially data on numbers, when dealing with species of very different sizes. The biological significance of weight data appears to some biologists to be better.

We carried out our processing on raw results (numbers and weights) and also on coded data. Only some of the results of these analyses are given here, to the extent to which they seem to us to make a valuable contribution to the interpretation of the results.

2.1.2 Comoé-Léraba Basin

Two stations were regularly sampled in this Basin: Gansé on the Comoé and the station known as Pont Frontière on the Léraba. If we consider the numbers of the species caught, it may be noted that the fish populations of the two stations are qualitatively quite similar, but differ in the relative abundance of some species: S. mystus is more abundant in the Léraba than at the station on the Comoé, as are P. guentheri, H. fasciatus and B. senegalensi to a lesser degree. Conversely, the Mormyridae (P. bovei in particular, M. furcident, M. runge) and L. coubie are better represented at Gansé. These characteristics are illustrat in Fig. 3, in which P. bovei and S. mystus make a strong contribution to the first axis dividing the observations at the two stations.

There is also a difference in the composition of the observations of the high-water period and the low-water period at each of the two stations (Fig. 4). There are two essential causes for this phenomenon: sampling is not carried out under precisely the same conditions in the course of these periods, and some species migrate upstream to reproduce during the high-water period. E. mentalis would appear to correspond to this latter case, since the abundance peaks in the catches occurred during the low-water period in the Comoé an-
FIG. 3. COMOE-LERABA - FACTOR ANALYSIS IS CARRIED OUT ON NUMBERS OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, RAW DATA)
FIG. 3. COMO-LEMAHA - FACTOR ANALYSIS CARRIED OUT ON NUMBERS OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, RAW DATA)
FIG. 4. COMOÉ-LERABA - FACTOR ANALYSIS CARRIED OUT ON THE NUMBERS OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, CODED DATA)

<table>
<thead>
<tr>
<th>Category</th>
<th>Léraba</th>
<th>Comoé</th>
</tr>
</thead>
<tbody>
<tr>
<td>high-water</td>
<td>12-79</td>
<td>4-77</td>
</tr>
<tr>
<td>period</td>
<td>11-75</td>
<td></td>
</tr>
<tr>
<td>low-water</td>
<td>6-78</td>
<td></td>
</tr>
<tr>
<td>period</td>
<td>1-78</td>
<td></td>
</tr>
<tr>
<td>high-water</td>
<td>7-77</td>
<td>5-77</td>
</tr>
<tr>
<td>period</td>
<td>3-75</td>
<td></td>
</tr>
<tr>
<td>low-water</td>
<td>1-76</td>
<td></td>
</tr>
<tr>
<td>period</td>
<td>7-76</td>
<td></td>
</tr>
</tbody>
</table>

- 7 -
FIG. 4. COMOE-LÉRABA - FACTOR ANALYSIS CARRIED OUT ON THE NUMBERS OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, CODED DATA)
during the high-water period in the Léraba (Fig. 5). In general, no change ascribable to insecticidal treatment can be established in the composition of catches in the Comoé between 1975 and 1979. The specific structures of the observations for the different years are in fact fairly similar (Fig. 3). On the other hand, greater dispersion of the observations is to be noted in the Léraba. One of the main causes is the special development of *S. mystus* populations (Fig. 5). This species, which was plentiful in late 1974 and early 1975, subsequently became scarce (although there were abundance maxima in the catches at the end of the high-water period), practically disappeared in 1978, and reappeared in 1979. It was also well represented in samples taken in 1980 (Traoré, personal communication). A largely identical phenomenon was observed for *S. schall* (Fig. 5). Although the reasons for these long-term developments escape us, they are probably partly connected with hydrology, since high-water periods in which the level remains fairly low are not conducive to the reproduction of the species. The high-water periods of 1976 and 1978 were particularly poor in the Léraba (Iltis & Lévéque, 1982).

The same conclusions as before are reached when the observations considered are expressed as weights rather than numbers (Fig. 6). Some species are obviously caught preferentially during the high-water period (*P. endlicheri*), others during the low-water period (*L. coubie, C. velifer*) (Fig. 5).

The changes in total catches reveal a seasonal cycle with a reduction in the number of fish caught during the high-water period, but it is noticeable that there was no appreciable change between 1975 and 1979 in the c.p.u.e. (Figs. 7 and 8) for the station on the Comoé. The late 1976 to early 1975 catches in the Léraba are larger owing to the abundance of *S. mystus*, but they subsequently remain at a roughly equal level, although lower than the preceding level. This decline in the catches in 1975 would not appear to be ascribable to the action of the insecticide, but to natural variations in *S. mystus* populations that have also been observed in other rivers (Lévéque & Herbinet, 1980).

Nor can any appreciable reduction in the catch by categories of net be established over the five-year period, especially for the fine-mesh nets (category 1), which would appear to indicate that the recruitment was normal and that the insecticide had no appreciable effect on fecundity and on the survival of the young fish.

2.1.3 Sassandra Basin

The Semien station, which may be regarded as representative of the fish populations of the middle reach of the Sassandra (Paugy et al., 1979), is the only station to have been regularly fished since 1975. As treatment was not commenced until June 1978, we have data for three-and-a-half years prior to treatment. The changes in the c.p.u.e. (Fig. 9) show that treatment would not appear to have had any effect on the size of the catches during the period under investigation. The results are of the same order of magnitude before and after treatment, although a quite appreciable reduction is to be noted for fine-mesh nets between late 1976 and late 1978.

Nor does analysis of the raw data on the numbers of fish caught reveal any development in the populations before and after treatment (Fig. 10). The species *Alestesbaremoze, Alestes imberi* and *Petrocephalus bovei* make a strong contribution to the first two axes, which explain 60% of the variance. The variations in the catches of these species (Fig. 11) in fact explain the dispersion of the representative points of the observations, in accordance with their relative abundance. We do not know the reasons for these non-cyclic variations.

The processing of the coded data does not add anything to the interpretation in as far as only the species caught on several occasions make a significant contribution to the axes.
during the high-water period in the Léraba (Fig. 5). In general, no change ascribable to insecticidal treatment can be established in the composition of catches in the Comoé between 1975 and 1979. The specific structures of the observations for the different years are in fact fairly similar (Fig. 3). On the other hand, greater dispersion of the observations is to be noted in the Léraba. One of the main causes is the special development of *S. mystus* populations (Fig. 5). This species, which was plentiful in late 1974 and early 1975, subsequently became scarce (although there were abundance maxima in the catches at the end of the high-water period), practically disappeared in 1978, and reappeared in 1979. It was also well represented in samples taken in 1980 (Traore, personal communication). A largely identical phenomenon was observed for *S. schall* (Fig. 5). Although the reasons for these long-term developments escape us, they are probably partly connected with hydrology, since high-water periods in which the level remains fairly low are not conducive to the reproduction of the species. The high-water periods of 1976 and 1978 were particularly poor in the Léraba (Iltis & Lévéque, 1982).

The same conclusions as before are reached when the observations considered are expressed as weights rather than numbers (Fig. 6). Some species are obviously caught preferentially during the high-water period (*P. endlicheri*), others during the low-water period (*L. coubie, C. velifer*) (Fig. 5).

The changes in total catches reveal a seasonal cycle with a reduction in the number of fish caught during the high-water period, but it is noticeable that there was no appreciable change between 1975 and 1979 in the c.p.u.e. (Figs. 7 and 8) for the station on the Comoé. The late 1974 to early 1975 catches in the Léraba are larger owing to the abundance of *S. mystus*, but they subsequently remain at a roughly equal level, although lower than the preceding level. This decline in the catches in 1975 would not appear to be ascribable to the action of the insecticide, but to natural variations in *S. mystus* populations that have also been observed in other rivers (Lévéque & Herbinet, 1980).

Nor can any appreciable reduction in the catch by categories of net be established over the five-year period, especially for the fine-mesh nets (category 1), which would appear to indicate that the recruitment was normal and that the insecticide had no appreciable effect on fecundity and on the survival of the young fish.

2.1.3 Sassandra Basin

The Semien station, which may be regarded as representative of the fish populations of the middle reach of the Sassandra (Paugy et al., 1979), is the only station to have been regularly fished since 1975. As treatment was not commenced until June 1978, we have data for three-and-a-half years prior to treatment. The changes in the c.p.u.e. (Fig. 9) show that treatment would not appear to have had any effect on the size of the catches during the period under investigation. The results are of the same order of magnitude before and after treatment, although a quite appreciable reduction is to be noted for fine-mesh nets between late 1976 and late 1978.

Nor does analysis of the raw data on the numbers of fish caught reveal any development in the populations before and after treatment (Fig. 10). The species *Alestes baremoze*, *Alestes imberi* and *Petrocephalus bovei* make a strong contribution to the first two axes, which explain 60% of the variance. The variations in the catches of these species (Fig. 11) in fact explain the dispersion of the representative points of the observations, in accordance with their relative abundance. We do not know the reasons for these non-cyclic variations.

The processing of the coded data does not add anything to the interpretation in as far as only the species caught on several occasions make a significant contribution to the axes.
FIG. 5. CHANGES IN c.p.u.e. BETWEEN 1975 AND 1979 FOR THE MAIN SPECIES TAKEN AT THE MONITORING STATIONS ON THE COMOE AND THE LERABA

- S. mystus
- S. schall
- Labeo spp
- H. forskalii
- C. velifer

- E. mentalis
- A. baremoze
- P. bovei
FIG. 5. CHANGES IN C.P.U.E. BETWEEN 1975 AND 1979 FOR THE MAIN SPECIES TAKEN AT THE MONITORING STATIONS ON THE COMOE AND THE LERABA
FIG. 6. COMOE-LERABA - FACTOR ANALYSIS CARRIED OUT ON THE WEIGHT OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, RAW DATA)
FIG. 6. COMOE-LERABA - FACTOR ANALYSIS CARRIED OUT ON THE WEIGHT OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, RAW DATA)
FIG. 7. THE COMOR AT CANSSE - DEVELOPMENT OF CATCHES PER UNIT OF EFFORT BETWEEN 1975 AND 1979. 1, 2, 3 - NETS IN CATEGORIES 1, 2 AND 3. M - MEAN FOR THE WHOLE SET OF NETS

FIG. 8. THE LERABA AT PONT FRONTIERE - CHANGES IN CATCHES PER UNIT OF EFFORT BETWEEN 1975 AND 1979. 1, 2, 3 - NETS IN CATEGORIES 1, 2 AND 3. M - MEAN FOR THE WHOLE SET OF NETS
FIG. 7. THE GOMOE AT GANSE - DEVELOPMENT OF CATCHES PER UNIT OF EFFORT BETWEEN 1975 AND 1979. 1, 2, 3 - NETS IN CATEGORIES 1, 2 AND 3. M - MEAN FOR THE WHOLE SET OF NETS

FIG. 8. THE LERABA AT PONT FRONTIERE - CHANGES IN CATCHES PER UNIT OF EFFORT BETWEEN 1975 AND 1979. 1, 2, 3 - NETS IN CATEGORIES 1, 2 AND 3. M - MEAN FOR THE WHOLE SET OF NETS
FIG. 9. THE SASSANDRA (SEMIEN) - CHANGES IN MEAN c.p.u.e. FOR THE WHOLE SET OF NETS EMPLOYED (M) AND BY CATEGORIES OF NETS (1, 2, 3).

FIG. 10. SEMIEN (SASSANDRA) - CORRESPONDENCE ANALYSIS CARRIED OUT ON THE NUMBERS OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, RAW DATA).
FIG. 9. THE SASSANDRA (SEMIEN) - CHANGES IN MEAN c.p.u.e. FOR THE WHOLE SET OF NETS EMPLOYED (M) AND BY CATEGORIES OF NETS (1, 2, 3)

FIG. 10. SEMIEN (SASSANDRA) - CORRESPONDENCE ANALYSIS CARRIED OUT ON THE NUMBERS OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, RAW DATA)
FIG. 11. CHANGES IN c.p.u.e. BETWEEN 1975 AND 1979 FOR THE MAIN SPECIES CAUGHT AT THE SEMIEN STATION (SASSANDRA) (NUMBER OF FISH MEAN FOR THE WHOLE SET OF GILL NETS EMPLOYED)

A. baremoze

P. bovei

A. imberi

<table>
<thead>
<tr>
<th>Year</th>
<th>c.p.u.e. nb ind./100m³/night</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>10</td>
</tr>
<tr>
<td>76</td>
<td>20</td>
</tr>
<tr>
<td>77</td>
<td>30</td>
</tr>
<tr>
<td>78</td>
<td>10</td>
</tr>
<tr>
<td>79</td>
<td>30</td>
</tr>
</tbody>
</table>
FIG. 11. CHANGES IN c.p.u.e. BETWEEN 1975 AND 1979 FOR THE MAIN SPECIES CAUGHT AT THE SEMIEN STATION (SASSANDRA) (NUMBER OF FISH MEAN FOR THE WHOLE SET OF GILL NETS EMPLOYED)

- A. baremoze
- P. bovei
- A. imberi
2.1.4 Bandama Basin

Four stations were sampled in the Bandama Basin: two on the main river from which the basin takes its name (at Marabadiassa and Niska Ramandouguon), one on the N'Zi, a left-bank tributary (Dabakala) and one (Mankono) on the Marooue, which enters the Bandama on its right bank. Sampling at Mankono was not begun until June 1977, almost one year before the first insecticidal treatment of this river (April 1978).

In the area investigated the N'Zi is a narrow river, the hydrological regime of which is directly influenced by local rainfall. Because this results in appreciable fluctuations of water level, which may alter the catch results, we shall give separate consideration to the results obtained in this river. Apart from the Dabakala station, three other stations downstream (Mafa, M'Bahikro and Bocanda) were also investigated over a period of one year to test the effect of another insecticide (chlorphoxim) for blackfly control. We would recall that, whereas this new pesticide is proving to be far more toxic than Abate to the invertebrate fauna (Dejoux & Troubat, 1976), no harmful effect on the existing fish populations has been detected in the short term (Léveque et al., 1977; Maslin-Lény & Mérona, 1978).

There was no significant reduction of total catches at Dabakala during the period covered by the investigation (Fig. 12). However, it will be noted that the samplings carried out during the high-water period generally yield very low results, particularly because of the difficulty of using gill nets properly during this period. It should also be recalled that the high-water periods in 1976 and 1977 were particularly poor in the N'Zi and affected the recruitment to the fish stocks; nevertheless, despite these poor conditions, a certain number of young fish did manage to survive, as is shown by the catches in fine-mesh nets (category 1).

**FIG. 12. THE BANDAMA (DABAKALA AND MANKONO) - CHANGES IN MEAN C.P.U.E. FOR THE WHOLE SET OF GILL NETS EMPLOYED.**

![Graph showing changes in mean c.p.u.e. for the whole set of gill nets employed in Bandama Basin between 1976 and 1979.](image)

At the N'Zi-Maffa station, which is slightly downstream from the previous station, and which has been regularly sampled for two years, the c.p.u.e. values are of roughly the same order of magnitude, and an appreciable reduction of catches during the high-water period is also to be noted on account of the poor sampling conditions.

The other three monitoring stations in the Bandama Basin are representative of the area of the middle reach, which is in fact the major part of the river (de Mérona, 1981), and which is characterized by the presence of the species Aistes baremoze, A. macrolepidotus, Eutropius mentalis and Hydrocyonys forskali. However, the influence of the Kossou lake, filled in 1971, gradually made itself felt during the observation period.

Although the changes in c.p.u.e. (Figs. 12 and 13) at the monitoring stations are fairly uneven, there would not appear to be any tendency towards an appreciable reduction in catches, since the figures obtained in 1979 at stations on the Bandama are similar to those for 1975. On more detailed consideration, however, it is noted that the catches with fine-mesh nets at Niaka were poorer between the end of 1976 and the middle of 1979. The situation existing at the commencement of observation would appear to have been restored at the end of 1979.
2.1.4 Bandama Basin

Four stations were sampled in the Bandama Basin: two on the main river from which the basin takes its name (at Marahadiass and Niakaramandougon), one on the N'Zi, a left-bank tributary (Dabakala) and one (Mankono) on the Maroué, which enters the Bandama on its right bank. Sampling at Mankono was not begun until June 1977, almost one year before the first insecticidal treatment of this river (April 1978).

In the area investigated the N'Zi is a narrow river, the hydrological regime of which is directly influenced by local rainfall. Because this results in appreciable fluctuations of water level, which may alter the catch results, we shall give separate consideration to the results obtained in this river. Apart from the Dabakala station, three other stations downstream (Mafa, M'Bahiakro and Bocanda) were also investigated over a period of one year to test the effect of another insecticide (chlorphoxim) for blackfly control. We would recall that, whereas this new pesticide is proving to be far more toxic than Abate to the invertebrate fauna (Dejoux & Troubat, 1976), no harmful effect on the existing fish populations has been detected in the short term (Lévéque et al., 1977; Maslin-Lény & Mérona, 1978).

There was no significant reduction of total catches at Dabakala during the period covered by the investigation (Fig. 12). However, it will be noted that the samplings carried out during the high-water period generally yield very low results, particularly because of the difficulty of using gill nets properly during this period. It should also be recalled that the high-water periods in 1976 and 1977 were particularly poor in the N'Zi and affected the recruitment to the fish stocks; nevertheless, despite these poor conditions, a certain number of young fish did manage to survive, as is shown by the catches in fine-mesh nets (category 1).

FIG. 12. THE BANDAMA (DABAKALA AND MANKONO) - CHANGES IN MEAN C.P.U.E. FOR THE WHOLE SET OF GILL NETS EMPLOYED

At the N'Zi-Mafsa station, which is slightly downstream from the previous station, and which has been regularly sampled for two years, the c.p.u.e. values are of roughly the same order of magnitude, and an appreciable reduction of catches during the high-water period is also to be noted on account of the poor sampling conditions.

The other three monitoring stations in the Bandama Basin are representative of the area of the middle reach, which is in fact the major part of the river (de Mérona, 1981), and which is characterized by the presence of the species Aistes baremoze, A. macrolepidotus, Eutroplus mentalis and Hydrocynus forskalii. However, the influence of the Kossou lake, filled in 1971, gradually made itself felt during the observation period.

Although the changes in c.p.u.e. (Figs 12 and 13) at the monitoring stations are fairly uneven, there would not appear to be any tendency towards an appreciable reduction in catches, since the figures obtained in 1979 at stations on the Bandama are similar to those for 1975. On more detailed consideration, however, it is noted that the catches with fine-mesh nets at Niaka were poorer between the end of 1976 and the middle of 1979. The situation existing at the commencement of observation would appear to have been restored at the end of 1979.
FIG. 13. THE BANDAMA (MARABADIASSA AND NIAKA) - CHANGES IN MEAN c.p.u.e. FOR THE WHOLE SET OF NETS EMPLOYED AND BY CATEGORIES OF NET

Bandama: total weight of fish per 100 m² of net per night for the whole set of nets

Marabadiassa - weight of fish caught per 100 m² of nets per night for each of the three categories of net

Niakaramandougou: weight of fish caught per 100 m² of nets per night for each of the three categories of net
FIG. 13. THE BANDAMA (MARABADIASSA AND NIAKA) - CHANGES IN MEAN c.p.u.e. FOR THE WHOLE SET OF NETS EMPLOYED AND BY CATEGORIES OF NET

Bandama: total weight of fish per 100 m² of net per night for the whole set of nets

Marabadiassa - weight of fish caught per 100 m² of nets per night for each of the three categories of net

Niakaramandougou: weight of fish caught per 100 m² of nets per night for each of the three categories of net
It should also be mentioned that a clear reduction of the condition factor of some species was noted at the Niaka station in 1976 and 1977 (see below). On the other hand, the catches taken with nets in category 2 increased during this period. There was a change in the composition of the catches, namely a reduction in the weight and the numbers of *A. baremoze* taken, offset by increases for *E. mentalis* (Fig. 14).

From the end of 1979, however, the c.p.u.e. of *A. baremoze* recovered and remained stable in 1980 (Traore, personal communication). It seems most probable that this was a natural phenomenon connected in particular with the lack of water between 1976 and 1978. For *A. baremoze*, the absence of a high-water period is reflected in the main in the catches of the fine-mesh nets, but many adult fish did not reach sexual maturity during this period, which led to a poor recruitment in the following year. Consequently, this poor recruitment cannot be ascribed to temephos pollution.

In the Maroué, a sharp decline in the numbers of fish taken is to be noted at Mankono in 1977, well before the treatment begun in mid-1978, which would not appear to have had an appreciable effect on the size of catches (Fig. 12).

The analysis of the raw data for weight (Fig. 15) effects a fairly clear separation between the observations made at each of the three stations; this is due to a difference in the species composition of the fish populations. *A. baremoze* and *A. imberi* make a strong contribution to axis 1, which explains 32% of the variance, whereas on axis 2 (16% of the variance) the species playing this role are *L. senegalensis*, *A. nurse* and *H. forskalii*.

**FIG. 15. THE BANDAMA - FACTOR ANALYSIS CARRIED OUT ON THE WEIGHT OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, RAW DATA)**
It should also be mentioned that a clear reduction of the condition factor of some species was noted at the Niaka station in 1976 and 1977 (see below). On the other hand, the catches taken with nets in category 2 increased during this period. There was a change in the composition of the catches, namely a reduction in the weight and the numbers of A. baremoze taken, offset by increases for E. mentalis (Fig. 14).

From the end of 1979, however, the c.p.u.e. of A. baremoze recovered and remained stable in 1980 (Traore, personal communication). It seems most probable that this was a natural phenomenon connected in particular with the lack of water between 1976 and 1978. For A. baremoze, the absence of a high-water period is reflected in the main in the catches of the fine-mesh nets, but many adult fish did not reach sexual maturity during this period, which led to a poor recruitment in the following year. Consequently, this poor recruitment cannot be ascribed to temephos pollution.

In the Maraoué, a sharp decline in the numbers of fish taken is to be noted at Mankono in 1977, well before the treatment begun in mid-1978, which would not appear to have had an appreciable effect on the size of catches (Fig. 12).

The analysis of the raw data for weight (Fig. 15) effects a fairly clear separation between the observations made at each of the three stations; this is due to a difference in the species composition of the fish populations. A. baremoze and A. imberi make a strong contribution to axis 1, which explains 32% of the variance, whereas on axis 2 (16% of the variance) the species playing this role are L. senegalensis, A. nurse and H. forskali.

FIG. 15. THE BANDAMA - FACTOR ANALYSIS CARRIED OUT ON THE WEIGHT OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, RAW DATA)
Relative abundance of *L. senegalensis* and *A. imberi* is a feature of the Marabadiassa station; *A. baremoze* is the most plentiful at Niakaramandougou. The decline in the catches of this latter species in 1977-1978 (see above) had the effect of making the specific profile of fishing at Niakaramandougou relatively close to that of the Mankono station during this period. *H. forskali* was proportionally more plentiful at Mankono than at the other two stations, which explains why the points representing the observations are relatively grouped for this station. Analysis of coded c.p.u.e. shows that there is a contrast at Marabadiassa, as at Niakaramandougou, between the catches at the end of the high-water period and those at the end of the low-water period (Fig. 16), the former being characterized in particular by the presence of numerous *A. baremoze* on an anadromous spawning migration (Fig. 14).

**FIG. 16. THE BANDAMA - FACTOR ANALYSIS CARRIED OUT ON THE NUMBERS OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, CODED DATA)**

2.2 Electrofishing

The fishing, which was carried out in the main in areas of rapids where the river bed was rocky or stony, was complementary to the monitoring programme and is not therefore strictly within the terms of reference. Nevertheless, it did add some additional elements to our knowledge of the environment and to interpretation of the effects of the insecticide.

The populations sampled by electrofishing (de Mérona et al., 1977) are fairly different from those sampled by gill net, and the technique is one that is effective for use only in a relatively shallow area. Roughly speaking, three groups of species are distinguished:

- typical running-water species: *Amphilius atesuensis, Phractura clauseni, Chiloglanis occidentalis*, etc.
Relative abundance of *L. senegalensis* and *A. imberi* is a feature of the Marabadiassa station; *A. baremoze* is the most plentiful at Niakaramandougou. The decline in the catches of this latter species in 1977-1978 (see above) had the effect of making the specific profile of fishing at Niakaramandougou relatively close to that of the Mankono station during this period. *H. forskali* was proportionally more plentiful at Mankono than at the other two stations, which explains why the points representing the observations are relatively grouped for this station. Analysis of coded c.p.u.e. shows that there is a contrast at Marabadiassa, as at Niakaramandougou, between the catches at the end of the high-water period and those at the end of the low-water period (Fig. 16), the former being characterized in particular by the presence of numerous *A. baremoze* on an anadromous spawning migration (Fig. 14).

**FIG. 16. THE BANDAMA - FACTOR ANALYSIS CARRIED OUT ON THE NUMBERS OF FISH CAUGHT (TOTAL FOR THE THREE CATEGORIES OF NETS, CODED DATA)**

2.2 Electrofishing

The fishing, which was carried out in the main in areas of rapids where the river bed was rocky or stony, was complementary to the monitoring programme and is not therefore strictly within the terms of reference. Nevertheless, it did add some additional elements to our knowledge of the environment and to interpretation of the effects of the insecticide.

The populations sampled by electrofishing (de Mérona et al., 1977) are fairly different from those sampled by gill net, and the technique is one that is effective for use only in a relatively shallow area. Roughly speaking, three groups of species are distinguished:

- typical running-water species: *Amphilius atesuensis*, *Phractura clauseni*, *Chiloglanis occidentalis*, etc.
- the young of certain species, the adults of which live in pool reaches: *P. bovei*, *A. imberti*, *B. waldroni*, *C. velifer*, and *Tilapia* spp. in relatively shallow zones but not in rapids;

- species of the rocky zone: *Labeo parvus*, *Mastacembelus* spp., *Synodontis* spp. and Mormyridae, etc.

The species that feed in the rapids, several of which consume insect larvae, should, *a priori*, be the ones most directly affected by releases of insecticides, either through the direct action, or because they produce an appreciable reduction in the abundance of prey.

There was no appreciable change in the fish populations of the rapids on the Léraba and on the Bandama at Marabadiassa in 1976 and 1977. In the N'Zi, on the other hand, profound changes were noted, but these would appear rather to have been due to the unfavourable hydrological conditions, which resulted in the drying out of the rapids for several months in 1977.

2.3 Conclusions

Catches per unit of effort (c.p.u.e.) expressed in grams of fish caught per 100 m² of nets in one night of fishing, are an index of the relative abundance of fish in the environment sampled.

At the stations sampled, the mean c.p.u.e. for the whole set of nets employed here are around 2000 g/100 m²/night of fishing for the Bandama, 1500 g for the Comoé-Léraba, 800 g for the Sassandara. These results may be compared with those obtained by us, using the same mean of sampling, in other untreated rivers in West Africa (unpublished data), and Lévéque & Paugy 1981.

- Ivory Coast: Cavally (455-1500); Nipoue (1200-2400);
- Senegal: Gambie (860-3480, in general between 2000 and 3000);
- Guinea: Niphr (1400-1700); Tomine (1300); Koumba (1670); Kolente (3500); Makona (650); Diani (900).

It therefore seems that the c.p.u.e. of the treated rivers are quite comparable to what is observed in other rivers, and that temephos treatment does not have an adverse effect in this sphere.

3. BIOLOGY OF THE MAIN SPECIES

3.1 Reproductive cycle

Many species have a reproductive cycle related to the hydrological regime, and they spawn during the high-water period (Table 1). This phenomenon is well known in the Sahel zone; when it occurs the rivers spread out over the bottom land and the flood plains, which provide shelter and food for the young fishes. As regards the rivers investigated, the flooded zones are in general of small size, but nevertheless the waters of the high-water period do invade the biotopes most suited to the development of young fishes, especially in the woodlands along the bottom land.

Most of the Mormyridae and some of the Characidae have a reproductive period limited to a few months, during the high-water period, but slightly longer than that of the Siluridae. The reproduction of the Cyprinidae is protracted, with an interruption during the dry season.

Some of these species also undertake anadromous spawning migrations. At the Niakaramandougou station, for example, we have seen large quantities of *Alestes baremoze*, *Hutropius mentalis* and *Mormyrops longiceps* caught by local fishermen in August or thereabouts, whereas these species are less plentiful or relatively scarce in catches during the rest of the year.
- the young of certain species, the adults of which live in pool reaches: *P. bovei*, *A. imberi*, *B. waldroni*, *C. velifer*, and *Tilapia* spp. in relatively shallow zones but not in rapids;

- species of the rocky zone: *Labeo parvus*, *Mastacembelus* spp., *Synodontis* spp. and *Mormyridae*, etc.

The species that feed in the rapids, several of which consume insect larvae, should, a priori, be the ones most directly affected by releases of insecticides, either through direct action, or because they produce an appreciable reduction in the abundance of prey.

There was no appreciable change in the fish populations of the rapids on the Léraba and on the Bandama at Maruladiassa in 1976 and 1977. In the N'Zi, on the other hand, profound changes were noted, but these would appear rather to have been due to the unfavourable hydrological conditions, which resulted in the drying out of the rapids for several months in 1977.

2.3 Conclusions

Catches per unit of effort (c.p.u.e.) expressed in grams of fish caught per 100 m² of nets in one night of fishing, are an index of the relative abundance of fish in the environments sampled.

At the stations sampled, the mean c.p.u.e., for the whole set of nets employed here are around 2000 g/100 m²/night of fishing for the Bandama, 1500 g for the Comoé-Léraba, 800 g for the Sassandra. These results may be compared with those obtained by us, using the same mean of sampling, in other untreated rivers in West Africa (unpublished data), and Lévéque & Paugy 1981.

- Ivory Coast: Cavally (455-1500); Nipoue (1200-2400);
- Senegal: Gambie (860-3480, in general between 2000 and 3000);
- Guinea: Njër (1400-1700); Tomine (1300); Koumba (1670); Kolente (3500); Makona (450); Diani (900).

It therefore seems that the c.p.u.e. of the treated rivers are quite comparable to what is observed in other rivers, and that temephos treatment does not have an adverse effect in this sphere.

3. BIOLOGY OF THE MAIN SPECIES

3.1 Reproductive cycle

Many species have a reproductive cycle related to the hydrological regime, and they spawn during the high-water period (Table 1). This phenomenon is well known in the Sahel zone; when it occurs the rivers spread out over the bottom land and the flood plains, which provide shelter and food for the young fishes. As regards the rivers investigated, the flooded zones are in general of small size, but nevertheless the waters of the high-water period do invade the biotopes most suited to the development of young fishes, especially in the woodlands along the bottom land.

Most of the Mormyridae and some of the Characidae have a reproductive period limited to a few months, during the high-water period, but slightly longer than that of the Siluridae. The reproduction of the Cyprinidae is protracted, with an interruption during the dry season.

Some of these species also undertake anadromous spawning migrations. At the Niakaramandougou station, for example, we have seen large quantities of *Alestes baremoze*, *Eutroplus mentalis* and *Mormyrops longiceps* caught by local fishermen in August or thereabouts, whereas these species are less plentiful or relatively scarce in catches during the rest of the year.
### Table 1. Length on First Reaching Sexual Maturity, Reproductive Period and Fecundity of the Main Species Caught by Gill Nets in the Rivers of the Ivory Coast

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>FIRST MATURATION</th>
<th>REPRODUCTIVE PERIOD</th>
<th>RELATIVE FECUNDITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. bovei</td>
<td>55 mm 1st year</td>
<td></td>
<td>90 000</td>
</tr>
<tr>
<td>M. bruyerei</td>
<td>130 mm</td>
<td></td>
<td>52 000</td>
</tr>
<tr>
<td>A. arctocephalus</td>
<td>175 mm end of 2nd year</td>
<td></td>
<td>236 000</td>
</tr>
<tr>
<td>A. macrolopidotus</td>
<td>185 mm 2nd year?</td>
<td></td>
<td>180 000</td>
</tr>
<tr>
<td>A. imberi</td>
<td>55 mm 1st year?</td>
<td></td>
<td>191 000</td>
</tr>
<tr>
<td>A. nurse</td>
<td>80 mm end of 1st year</td>
<td></td>
<td>368 000</td>
</tr>
<tr>
<td>L. senegalensis</td>
<td>195 mm</td>
<td></td>
<td>182 000</td>
</tr>
<tr>
<td>P. parvus</td>
<td>105 mm</td>
<td></td>
<td>347 000</td>
</tr>
<tr>
<td>C. velifer</td>
<td>110 mm</td>
<td></td>
<td>20 000</td>
</tr>
<tr>
<td>S. mystus</td>
<td>110 mm end of 1st year</td>
<td></td>
<td>228 000</td>
</tr>
<tr>
<td>E. mentalis</td>
<td>200 mm</td>
<td></td>
<td>217 000</td>
</tr>
<tr>
<td>S. schall</td>
<td>160 mm</td>
<td></td>
<td>157 000</td>
</tr>
</tbody>
</table>
TABLE 1. LENGTH ON FIRST REACHING SEXUAL MATURITY, REPRODUCTIVE PERIOD AND FECUNDITY OF THE MAIN SPECIES CAUGHT BY GILL NETS IN THE RIVERS OF THE IVORY COAST

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>FIRST MATURATION</th>
<th>REPRODUCTIVE PERIOD</th>
<th>RELATIVE FECUNDITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>J F M A N J J A S O N D</td>
<td>No. of eggs/kg</td>
</tr>
<tr>
<td>P. bovei</td>
<td>55 mm 1st year</td>
<td>xx</td>
<td>90 000</td>
</tr>
<tr>
<td>M. bruyerei</td>
<td>130 mm</td>
<td>xx</td>
<td>52 000</td>
</tr>
<tr>
<td>A. baromoe</td>
<td>175 mm end of 2nd year</td>
<td>xx xx xx xx xx xx xx xx xx xx xx xx</td>
<td>236 000</td>
</tr>
<tr>
<td>A. macrolopidotus</td>
<td>185 mm 2nd year?</td>
<td>xx</td>
<td>180 000</td>
</tr>
<tr>
<td>A. imberi</td>
<td>55 mm 1st year?</td>
<td>xx</td>
<td>191 000</td>
</tr>
<tr>
<td>A. nurse</td>
<td>80 mm end of 1st year</td>
<td>xx</td>
<td>360 000</td>
</tr>
<tr>
<td>L. senegalensis</td>
<td>195 mm</td>
<td>xx</td>
<td>182 000</td>
</tr>
<tr>
<td>L. parvus</td>
<td>105 mm</td>
<td>xx</td>
<td>347 000</td>
</tr>
<tr>
<td>C. veller</td>
<td>110 mm</td>
<td>xx</td>
<td>20 000</td>
</tr>
<tr>
<td>S. mystus</td>
<td>110 mm end of 1st year</td>
<td>xx xx xx xx xx xx xx xx xx xx xx xx xx xx xx xx xx xx xx xx xx xx</td>
<td>228 000</td>
</tr>
<tr>
<td>E. mentalis</td>
<td>200 mm</td>
<td>xx</td>
<td>217 000</td>
</tr>
<tr>
<td>S. schall</td>
<td>160 mm</td>
<td>xx</td>
<td>157 000</td>
</tr>
</tbody>
</table>
The levels reached during the high-water period appear to have a direct influence on the success of the reproduction of species with an annual cycle. Dansoko et al. (1976) have shown that the reduction in commercial catches of Hydrocynus brevis and Hydrocynus forshalli in the central delta of the Niger in 1972 and 1973 was a consequence of inadequate levels during the high-water periods and was accounted for by a poor condition factor, limited growth and weak recruitment to the fish stocks during this period. The survival of young fishes is threatened in years when there is insufficient water: the young fishes have fewer refuges and are more vulnerable to predators; and there are fewer available sources of food.

In our opinion, this influence of the high-water periods explains the changes in the numbers of some species during the five years of observation. We have stressed this, in particular, for Schilbe mystax, the reduction of whose numbers in experimental fishing in the Comor-Leraba Basin could be explained by the inadequate levels of the high-water periods in 1976 and 1978, which were, moreover, general for all of the basins investigated here. It therefore seems that this phenomenon is not ascribable to temephos, as could have been thought from a hasty interpretation, but to the action of natural phenomena. Furthermore, confirmation for this hypothesis is provided by the improvement of catches in 1979. It is plausible that other species could have been affected by the high-water periods, although not as spectacularly as in the previous example.

However, some species reproduce throughout the year (Alestes macrolepidotus, Alestes imberi and some of the Cichlidae), and it has not been possible to establish any especially favourable period. These species are apparently more sedentary and better adapted than the preceding species to low-water periods for the survival of their young.

Albaret (1982) has studied the fecundity of many species. The fecundity of Cyprinidae, Characidae and Schilbeidae is very high (more than 150,000 eggs per kg of the female), and their eggs are of small diameter. These eggs, which in general contain little yolk, are released in large numbers into the natural environment and mortality is high; the eggs of Mormyridae, Claridae and some individual species (Barilius, Polypterus senegalus), are large and their fecundity is in the middle range (25,000-90,000 eggs per kg of the female). Las Bagridae, Cichlidae and certain species such as Mastacembelus nigromarginatus, Polypterus endlicheri and Papyrocramus afer, have eggs ranging from large to very large, and their fecundity ranges from a few thousand to 25 or 30,000. It is generally recognized that the species take more care with their eggs, which are laid in sheltered places.

These differences in fecundity and in the survival potential of the eggs ("r" and "k" strategy) may probably play a role in the dynamics of fish populations subjected to release of insecticides. The survival of the young fishes is, in effect, better a priori in the case of species whose eggs are large and few in number, which are generally benthic species than in the case of other species whose pelagic young, which are small and without nutrient reserves, would be more susceptible to insecticide waves. However, it has not been possible to make any study of this matter, particularly because of the difficulties of sampling.

The fact that we have been unable in various observations to establish differences in the fecundity of species inhabiting treated and untreated rivers could indicate that temephos has no marked effect on the reproductive physiology of fishes.

### 3.2 Coefficient of condition

The changes over time in the coefficient of condition \( K = \frac{10^5 W}{L^3} \), which is a simplified expression of the health of fishes, are dependent on several factors. First and foremost, these are natural factors, principally the availability of food, which is in general more plentiful during the high-water period than during the low-water period, and the sexual cycle for annually reproducing species. Spawning involves a reduction of short duration in condition following the release of ripe oocytes. Because the oocytes are generally formed from reserve substances, there is no appreciable weight gain during the maturation period (Durand & Loubens, 1970).
The levels reached during the high-water period appear to have a direct influence on the success of the reproduction of species with an annual cycle. Dansoko et al. (1976) have shown that the reduction in commercial catches of Hydrocynus brevis and Hydrocynus forskali in the central delta of the Niger in 1972 and 1973 was a consequence of inadequate levels during the high-water periods and was accounted for by a poor condition factor, limited growth and weak recruitment to the fish stocks during this period. The survival of young fishes is threatened in years when there is insufficient water: the young fishes have fewer refugia and are more vulnerable to predators; and there are fewer available sources of food.

In our opinion, this influence of the high-water periods explains the changes in the numbers of some species during the five years of observation. We have stressed this, in particular, for Schilbe mystus, the reduction of whose numbers in experimental fishing in the Comoé-Léraba Basin could be explained by the inadequate levels of the high-water periods in 1976 and 1978, which were, moreover, general for all of the basins investigated here. It therefore seems that this phenomenon is not ascribable to temephos, as could have been thought from a hasty interpretation, but to the action of natural phenomena. Furthermore, confirmation for this hypothesis is provided by the improvement of catches in 1979. It is plausible that other species could have been affected by the high-water periods, although not as spectacularly as in the previous example.

However, some species reproduce throughout the year (Alestes macrolepidotus, Alestes imberi and some of the Cichlidae), and it has not been possible to establish any especially favourable period. These species are apparently more sedentary and better adapted than the preceding species to low-water periods for the survival of their young.

Albaret (1982) has studied the fecundity of many species. The fecundity of Cyprinidae, Characidae and Schilbeidae is very high (more than 150,000 eggs per kg of the female), and their eggs are of small diameter. These eggs, which in general contain little yoke, are released in large numbers into the natural environment and mortality is high: the eggs of Mormyridae, Claridae and some individual species (Barilus, Polypterus senegalus), are large, and their fecundity is in the middle range (25,000-90,000 eggs per kg of the female). Las Bagridae, Cichlidae and certain species such as Mastacembelus nigromarginatus, Polypterus endlicheri and Papyrocrampus afer, have eggs ranging from large to very large, and their fecundity ranges from a few thousand to 25 or 30,000. It is generally recognized that the species take more care with their eggs, which are laid in sheltered places.

These differences in fecundity and in the survival potential of the eggs ("r" and "k" strategy) may probably play a role in the dynamics of fish populations subjected to release of insecticides. The survival of the young fishes is, in effect, better a priori in the case of species whose eggs are large and few in number, which are generally benthic species than in the case of other species whose pelagic young, which are small and without nutrient reserves, would be more susceptible to insecticide waves. However, it has not been possible to make any study of this matter, particularly because of the difficulties of sampling.

The fact that we have been unable in various observations to establish differences in the fecundity of species inhabiting treated and untreated rivers could indicate that temephos has no marked effect on the reproductive physiology of fishes.

3.2 Coefficient of condition

The changes over time in the coefficient of condition \( K = \frac{10^5 W}{L^3} \), which is a simplified expression of the health of fishes, are dependent on several factors. First and foremost, these are natural factors, principally the availability of food, which is in general more plentiful during the high-water period than during the low-water period, and the sexual cycle for annually reproducing species. Spawning involves a reduction of short duration in condition following the release of ripe oocytes. Because the oocytes are generally formed from reserve substances, there is no appreciable weight gain during the maturation period (Durand & Loubens, 1970).
Extrinsic factors may also alter the condition of fishes. By killing off the organisms on which fishes feed, various toxic substances reduce the amount of available food to the point of complete disappearance in extreme cases. The accumulation of pesticides in the tissues (Quelennec et al., 1977) may also modify the metabolism of fishes.

One of the difficulties encountered in the use of the coefficient of condition is that it is subject to variation in relation to the size of individual fish within the same species. We have demonstrated this, in particular, in Schilbe mystus (Lévéque & Herbinet, 1980). In general, the values become stable on reaching maturity. Consequently, the length of the fish on reaching sexual maturity must be determined if one wishes to trace the long-term development of this factor, and all values other than those observed in adult fish, or in a length range preselected for each species must be discarded, as has been done in this study.

For continuously-reproducing species, the results obtained in the various basins (Fig. 17) show that values of the coefficient of condition are relatively random, fluctuating around a mean which does not seem appreciably altered at the end of five years of monitoring. However, a tendency toward reduction is to be noted in 1977 and 1978; this tendency affected both the populations of treated basins and those of the Sassandra Basin, which was not treated until June 1978.

Annually-reproducing species were similarly affected; an annual cycle in which there is a reductor during the low-water period and a maximum at the end of the high-water period is to be noted in some instances. This is particularly the case for S. mystus in the Léraba. Nevertheless, there is generally speaking no very clear cycle. Nor is there any catastrophic reduction in the mean values to justify the conclusion that temephos has a direct or indirect effect.

Going into greater detail, it will be noted that many species have a coefficient of condition that is in general higher in the Sassandra than in the Bandama. These differences between basins are common and are probably due to more favourable or less favourable ecological conditions or to the presence of different genetic populations. Moreover, the same phenomenon has been observed in the Bandama, where the values recorded at Marabadiassa were higher than those at Niakaramandougou for some species (proximity to the Kossou lake?). Between 1976 and 1977 a very significant decline in the condition factor of Alestes baremoze, and a lesser decline in that of Eutropius mentalis, was noted in the part of the Bandama between the Kossou and Perkessedougou dams (Paupy, 1978). Subsequently, the coefficient of condition recovered at the two stations, although it did not reach the 1974-1975 values.

Inquiries carried out in 1976 revealed that this phenomenon was confined to this region of the Bandama and that it was probably connected with the sealing of the two dams, which impeded migration (Daget et al., 1973) and with a very low flood. This was not entirely negative in its effect, since Labeo senegalensis, on the other hand, developed well under these new conditions (Kouassi, 1979) and its coefficient of condition was increased.

3.3 Diet

A qualitative study of diet was undertaken on fishes that consume at least a proportion of aquatic invertebrates. Some, such as Petrocephalus bovei, feed entirely on aquatic invertebrates. Others (Alestes macrolepidotus, A. nurse and Eutropius mentalis) draw extensively on exogenous inputs (insects, plants, etc.). Yet others (A. baremoze and A. imberi) consume both, although with a pronounced tendency towards the indigenous fauna. The analysis of stomach contents carried out in 1975 on these species in treated and untreated rivers does not provide clear evidence of an influence exerted by the insecticide, since the diet was appreciably the same in composition whatever the provenance of the fishes (Vidy, 1976). Nevertheless, going into greater detail, it appears that Ephemeroptera, which are especially sensitive to temephos (Dejoux & Troubat, 1976), are less plentiful in the stomachs of fishes from treated rivers. However, the adaptive capacity of fishes in relation to nutrition has been demonstrated repeatedly in West Africa (Daget, 1952, 1956; Blache, 1964; Whitehead, 1969; Reynolds, 1973; Lauzanne, 1976). Consequently, it does not seem as if temephos has had any appreciable influence on the fishes by lowering food stocks to a critical level.
Extrinsic factors may also alter the condition of fishes. By killing off the organisms on which fishes feed, various toxic substances reduce the amount of available food to the point of complete disappearance in extreme cases. The accumulation of pesticides in the tissues (Quelennec et al., 1977) may also modify the metabolism of fishes.

One of the difficulties encountered in the use of the coefficient of condition is that it is subject to variation in relation to the size of individual fish within the same species. We have demonstrated this, in particular, in Schilbe mystus (Leveque & Herbinet, 1980). In general, the values become stable on reaching maturity. Consequently, the length of the fish on reaching sexual maturity must be determined if one wishes to trace the long-term development of this factor, and all values other than those observed in adult fish, or in a length range preselected for each species must be discarded, as has been done in this study.

For continuously-reproducing species, the results obtained in the various basins (Fig. 17) show that values of the coefficient of condition are relatively random, fluctuating around a mean which does not seem appreciably altered at the end of five years of monitoring. However, a tendency toward reduction is to be noted in 1977 and 1978; this tendency affected both the populations of treated basins and those of the Sassandra Basin, which was not treated until June 1978.

Annually-reproducing species were similarly affected; an annual cycle in which there is a reductor during the low-water period and a maximum at the end of the high-water period is to be noted in some instances. This is particularly the case for S. mystus in the Léraba. Nevertheless, there is generally speaking no very clear cycle. Nor is there any catastrophic reduction in the mean values to justify the conclusion that temephos has a direct or indirect effect.

Going into greater detail, it will be noted that many species have a coefficient of condition that is in general higher in the Sassandra than in the Bandama. These differences between basins are common and are probably due to more favourable or less favourable ecological conditions or to the presence of different genetic populations. Moreover, the same phenomenon has been observed in the Bandama, where the values recorded at Marabadiassa were higher than those at Niakaramandougou for some species (proximity to the Kossou lake?). Between 1976 and 1977 a very significant decline in the condition factor of Alistes baremoze, and a lesser decline in that of Eutropius mentalis, was noted in the part of the Bandama between the Kossou and Perkessedougou dams (Paugy, 1978). Subsequently, the coefficient of condition recovered at the two stations, although it did not reach the 1974-1975 values. Inquiries carried out in 1976 revealed that this phenomenon was confined to this region of the Bandama and that it was probably connected with the sealing of the two dams, which impeded migration (Daget et al., 1973) and with a very low flood. This was not entirely negative in its effect, since Labeo senegalensis, on the other hand, developed well under these new conditions (Kouassi, 1979) and its coefficient of condition was increased.

3.3 Diet

A qualitative study of diet was undertaken on fishes that consume at least a proportion of aquatic invertebrates. Some, such as Petrocephalus bovei, feed entirely on aquatic invertebrates. Others (Alistes macrolepidotus, A. nurse and Eutropius mentalis) draw extensively on exogenous inputs (insects, plants, etc.). Yet others (A. baremoze and A. imberti) consume both, although with a pronounced tendency towards the indigenous fauna. The analysis of stomach contents carried out in 1975 on these species in treated and untreated rivers does not provide clear evidence of an influence exerted by the insecticide, since the diet was appreciably the same in composition whatever the provenance of the fishes (Vidy, 1976). Nevertheless, going into greater detail, it appears that Ephemeroptera, which are especially sensitive to temephos (Dejoux & Troubat, 1976), are less plentiful in the stomachs of fishes from treated rivers. However, the adaptive capacity of fishes in relation to nutrition has been demonstrated repeatedly in West Africa (Daget, 1952, 1956; Blache, 1964; Whitehead, 1969; Reynolds, 1973; Lauzanne, 1976). Consequently, it does not seem as if temephos has had any appreciable influence on the fishes by lowering food stocks to a critical
FIG. 17. DEVELOPMENT OF THE COEFFICIENT OF CONDITION ($\bar{K}$) OF THE MAIN SPECIES AT THE VARIOUS MONITORING STATIONS. ANNUALLY-REPRODUCING SPECIES

- $A$. baremoze
- $E$. mentalis
- $S$. mystus

Legend:
- MARABALLARES
- NIAKARANYANDRAOU
- SASSANZRA
- CORM
- LIRABA
FIG. 17. DEVELOPMENT OF THE COEFFICIENT OF CONDITION ($\bar{K}$) OF THE MAIN SPECIES AT THE VARIOUS MONITORING STATIONS. ANNUALLY-REPRODUCING SPECIES

- A. baremoze

- A. nurse

- E. mentalis

- S. mystus
FIG. 17 (continued)

DEVELOPMENT OF THE COEFFICIENT OF CONDITION (K) OF THE MAIN SPECIES AT THE VARIOUS MONITORING STATIONS. CONTINUOUSLY-REPRODUCING SPECIES

H. forsalii

A. macrolepidotus

A. imberi

L. senegalensis

--- : Marabadiassa  --- : Sassandra  ------ : Comod
FIG. 17 (continued)
DEVELOPMENT OF THE COEFFICIENT OF CONDITION (K) OF THE MAIN SPECIES AT THE VARIOUS MONITORING STATIONS. CONTINUOUSLY-REPRODUCING SPECIES

H. forskalii

A. macrolepidotus

A. imberi

L. senegalensis

- - - - - Marabadiassa  - - - - - Sassandra  - - - - - Comod
threshold. Moreover, it has been noted that, overall, insecticidal treatments with temephos result in a temporary reduction of only 30-40% in the stock of aquatic insects (Dejoux et al., 1979). Nor did analyses carried out in 1976 and 1977 reveal appreciable changes in the composition of the stomach contents relative to 1975. A remark may be made here concerning Amphilius atenuensis. Half the diet of this species, which is associated with running water in which the flow rate is very high, consists of Simulium larvae (Merona, personal communication). Despite the almost total disappearance of this target species in treated waters, we have not noted any special effect on Amphilius populations, which remain plentiful in the rapids.

CONCLUSIONS

We are led to conclude, from the results obtained over a period of five years in the course of monitoring rivers treated with insecticides in the Ivor Coast, that releases of temephos have had no detectable effect on the fish populations. We have not been able to establish any changes ascribable to the effects of the insecticide in the composition of the populations or in the size of the catches in test fishing. Furthermore, nor would there seem to have been any appreciable alteration in the biology of the species or in their feeding habits during the period covered by the investigation. In studies of the effects of DDT in the "Victoria Nile", Corbet (1956) reached somewhat different conclusions, and noted a change in the diet of some fishes (Mormyridae in particular). Some species with a specialized diet, such as Mastacembelus, 95% of whose consumption consists of lithophilous insect larvae, even suffered from malnutrition or migrated.

Taken overall, the results reveal the very important role played by hydrology in the biology and dynamics of many species. Most of the rivers investigated have a tropical regime typified by a well-defined annual high-water period. Many species reproduce during this period, and their young enjoy conditions more favourable to their survival, finding food and shelter on the bottom land or flood plains, where the latter exist. Flooding is also beneficial to the adult fishes, which find that food is more plentiful at this time, principally food of terrestrial origin (insects, the fruits of certain trees, vegetation, etc.). When the levels attained during the high-water period are low, as was particularly the case in 1976 (Fig. 2), the survival of the young is threatened and the recruitment is in general poor, with the consequence that fishes are less abundant in the following year. Obviously, in some cases there may be confusion between the effect of the failure of water levels to rise sufficiently during the high-water period and the possible role of a pollutant. No simpl-spot analysis can be made of such a situation; what are needed are long-term studies which will establish whether the effects noted are merely transitory and the result of the low volume of water in the high-water period, or whether they are, on the contrary, lasting and due to the insecticide. The phenomenon is still further complicated by the existence of long-term fluctuations in some populations, the precise causes of which are not always well known. Schilbe mystus in the Léabra is a particularly clear example in these respects. This species, which was plentiful at the commencement of the observations in 1974, subsequently declined and disappeared almost completely after the high-water period of 1976, in which the rise in level was slight, only to reappear in abundance at the end of 1979. This example is a good illustration of the difficulty of interpreting results, of the need to be cautious and to avoid any hasty interpretation concerning the possible effect of insecticides, and of the value of long-term studies in ichthyological research.

Hydrology also has other consequences for sampling. Thus, some fishes make spawning migrations to the upper reach of rivers at the start of the high-water period and may disappear from some stations at this time. On the other hand, sampling by gill net in rivers is not carried out under the same conditions in the low-water and high-water periods. In the first case, the nets are set up in pools of still water, and the catches provide a general idea of the population. During the high-water period, the flow rate and the debris (branches, dead leaves) transported by the water restrict the sampling sites to a few calmer localities and the catches are less plentiful, equally due to the fact that the same number of fish are occupying a far larger volume of water.
threshold. Moreover, it has been noted that, overall, insectical treatments with temephos result in a temporary reduction of only 30-40% in the stock of aquatic insects (Dejoux et al., 1979). Nor did analyses carried out in 1976 and 1977 reveal appreciable changes in the composition of the stomach contents relative to 1975. A remark may be made here concerning *Amphilius atenuensis*. Half the diet of this species, which is associated with running water in which the flow rate is very high, consists of *Simulium* larvae (Merona, personal communication). Despite the almost total disappearance of this target species in treated waters, we have not noted any special effect on *Amphilius* populations, which remain plentiful in the rapids.

CONCLUSIONS

We are led to conclude, from the results obtained over a period of five years in the course of monitoring rivers treated with insecticides in the Ivory Coast, that releases of temephos have had no detectable effect on the fish populations. We have not been able to establish any changes ascribable to the effects of the insecticide in the composition of the populations or in the size of the catches in test fishing. Furthermore, nor would there seem to have been any appreciable alteration in the biology of the species or in their feeding habits during the period covered by the investigation. In studies of the effects of DDT in the "Victoria Nile", Corbet (1956) reached somewhat different conclusions, and noted a change in the diet of some fishes (Mormyridae in particular). Some species with a specialized diet, such as *Mastacembelus*, 95% of whose consumption consists of lichophilous insect larvae, even suffered from malnutrition or migrated.

Taken overall, the results reveal the very important role played by hydrology in the biology and dynamics of many species. Most of the rivers investigated have a tropical regime typified by a well-defined annual high-water period. Many species reproduce during this period, and their young enjoy conditions more favourable to their survival, finding food and shelter on the bottom land or flood plains, where the latter exist. Flooding is also beneficial to the adult fishes, which find that food is more plentiful at this time, principally food of terrestrial origin (insects, the fruits of certain trees, vegetation, etc.). When the levels attained during the high-water period are low, as was particularly the case in 1976 (Fig. 2), the survival of the young is threatened and the recruitment is in general poor, with the consequence that fishes are less abundant in the following year. Obviously, in some cases there may be confusion between the effect of the failure of water levels to rise sufficiently during the high-water period and the possible role of a pollutant. No simple spot analysis can be made of such a situation; what are needed are long-term studies which will establish whether the effects noted are merely transitory and the result of the low volume of water in the high-water period, or whether they are, on the contrary, lasting and due to the insecticide. The phenomenon is still further complicated by the existence of long-term fluctuations in some populations, the precise causes of which are not always well known. *Schilbe mystus* in the Léraba is a particularly clear example in these respects. This species, which was plentiful at the commencement of the observations in 1974, subsequently declined and disappeared almost completely after the high-water period of 1976, in which the rise in level was slight, only to reappear in abundance at the end of 1979. This example is a good illustration of the difficulty of interpreting results, of the need to be cautious and to avoid any hasty interpretation concerning the possible effect of insecticides, and of the value of long-term studies in ichthyological research.

Hydrology also has other consequences for sampling. Thus, some fishes make spawning migrations to the upper reach of rivers at the start of the high-water period and may disappear from some stations at this time. On the other hand, sampling by gill net in rivers is not carried out under the same conditions in the low-water and high-water periods. In the first case, the nets are set up in pools of still water, and the catches provide a general idea of the population. During the high-water period, the flow rate and the debris (branches, dead leaves) transported by the water restrict the sampling sites to a few calmer localities and the catches are less plentiful, equally due to the fact that the same number of fish are occupying a far larger volume of water.
We are able to arrive at some conclusions on the methodology employed from our experience of these five years of field work, and to make some proposals for future fish monitoring programmes in West Africa. First and foremost, we shall stress the value of long-term studies. Insecticides may be selected before their field use in relation to their effectiveness against the target fauna and to their low immediate toxicity against the non-target fauna. Such was the case for temephos. The point of monitoring is then to verify whether repeated releases over a long period may or may not have effects on the fish fauna not detectable when tests are carried out (accumulation in tissues and physiological consequences, for example). In other cases, when insecticides are known to be not without danger, it can be seen from long-term studies whether the consequences of use in the natural environment are compatible with the overall ecological balance.

Interpretation of monitoring results also requires a good knowledge of the biology and ecology of the species. Even if we now have adequate results in some basins, they must nevertheless be verified on proceeding to examine another river network, and it is most often necessary to supplement them. Consequently, a special programme should be put in hand at the start of observations.

It is also essential to ask for observations at reference stations two years before the foreseeable commencement of treatment. This is done for several purposes: to have time to verify the representative nature of these stations, and to acquire preliminary data on the biology of the species and the seasonal dynamics of the populations.

We therefore propose the following methodology for subsequent monitoring programmes.

(a) Sampling techniques

The use of fishing gear in the context of a fish monitoring programme should satisfy certain requirements: particularly a good representation of the indigenous fish populations, quantification of the data, standardization, and ease of use and installation under various hydrological and morphological conditions.

We do not currently have any fishing gear that is capable of exhaustive sampling and that satisfies all the conditions. All such gear catches only certain species and can be used only in certain types of environment. Thus, the drag seine, which is perhaps the least selective fishing gear, can be used only on uniform bottoms (generally sandy) and in relatively calm water. Its use was completely ruled out in the Ivory Coast, where the rivers have rocky and stony bottoms cluttered with the trunks of dead trees. We have used and recommend the use of a set of gill nets with different types of mesh. Although this gear, which is often found in West Africa, is selective, it can be used in various types of environment, except for rather shallow rivers and very fast-running waters.

Complementary information may be obtained using different fishing gear. The cast-net is the easiest to use, and it yields good results, although these are difficult to quantify. Electrofishing is also a promising technique for sampling shallow zones of running water inhabited by certain, generally small species, but its use is limited and difficult and the quantification of the results is uncertain.

(b) Site selection

The monitoring sites selected must be accessible in all seasons, and as close as possible to main roads. These sites must also be representative of the environments under investigation, and every operation should begin with a zonal research programme to establish whether or not the fish populations of the selected station are well represented in a large part of the river. It is less worthwhile to take a reach inhabited by a particular population as a reference.
We are able to arrive at some conclusions on the methodology employed from our experience of these five years of field work, and to make some proposals for future fish monitoring programmes in West Africa. First and foremost, we shall stress the value of long-term studies. Insecticides may be selected before their field use in relation to their effectiveness against the target fauna and to their low immediate toxicity against the non-target fauna. Such was the case for temephos. The point of monitoring is then to verify whether repeated releases over a long period may or may not have effects on the fish fauna not detectable when tests are carried out (accumulation in tissues and physiological consequences, for example). In other cases, when insecticides are known to be not without danger, it can be seen from long-term studies whether the consequences of use in the natural environment are compatible with the overall ecological balance.

Interpretation of monitoring results also requires a good knowledge of the biology and ecology of the species. Even if we now have adequate results in some basins, they must nevertheless be verified on proceeding to examine another river network, and it is most often necessary to supplement them. Consequently, a special programme should be put in hand at the start of observations.

It is also essential to ask for observations at reference stations two years before the foreseeable commencement of treatment. This is done for several purposes: to have time to verify the representative nature of these stations, and to acquire preliminary data on the biology of the species and the seasonal dynamics of the populations.

We therefore propose the following methodology for subsequent monitoring programmes.

(a) **Sampling techniques**

The use of fishing gear in the context of a fish monitoring programme should satisfy certain requirements: particularly a good representation of the indigenous fish populations, quantification of the data, standardization, and ease of use and installation under various hydrological and morphological conditions.

We do not currently have any fishing gear that is capable of exhaustive sampling and that satisfies all the conditions. All such gear catches only certain species and can be used only in certain types of environment. Thus, the drag seine, which is perhaps the least selective fishing gear, can be used only on uniform bottoms (generally sandy) and in relatively calm water. Its use was completely ruled out in the Ivory Coast, where the rivers have rocky and stony bottoms cluttered with the trunks of dead trees. We have used and recommend the use of a set of gill nets with different types of mesh. Although this gear, which is often found in West Africa, is selective, it can be used in various types of environment, except for rather shallow rivers and very fast-running waters.

Complementary information may be obtained using different fishing gear. The cast-net is the easiest to use, and it yields good results, although these are difficult to quantify. Electrofishing is also a promising technique for sampling shallow zones of running water inhabited by certain, generally small species, but its use is limited and difficult and the quantification of the results is uncertain.

(b) **Site selection**

The monitoring sites selected must be accessible in all seasons, and as close as possible to main roads. These sites must also be representative of the environments under investigation, and every operation should begin with a zonal research programme to establish whether or not the fish populations of the selected station are well represented in a large part of the river. It is less worthwhile to take a reach inhabited by a particular population as a reference.
(c) **Frequency of observations**

We would recall that we regard a preliminary two-year study as essential before the commencement of treatment. Having regard to the considerable life span of fishes and to the existence of an annual cycle, sampling should be carried out every two or three months during the initial years of monitoring, with the object of arriving at a better understanding of possible changes in catches as a function of the seasonal cycle, and of achieving clarity on the biology of the main species.

Subsequently, we recommend sampling at the end of the low-water period, which provides a status report on the populations after the dry season, and sampling at the end of the high-water period. The latter is the most interesting, because of the possibility of sampling the young of annually-reproducing species and of verifying whether the recruitment is proceeding normally.

Our experience leads us to propose that several other stations should also be sampled once a year, at the end of the high-water period, from the commencement of programmes. These stations should preferably be located on either side of reference stations in the same catchment, and could be used to verify, in long-term research, that the results obtained at these reference stations were well representative of the river as a whole. They would also have the advantage of enabling the reference station to be replaced, should it be altered as a consequence of road works or hydraulic engineering works.

(d) **Complementary research**

It would be worthwhile making a deeper study of the effect of pollutants on the physiology of fishes. In particular, it would be of interest to be able to recognize the concentration rates and the organs in which the insecticide is liable to accumulate.

In conclusion, if an ichthyological monitoring programme is to be carried out seriously it calls for the establishment of a permanent team for a period of several years. Proper interpretation of the results also requires a deep knowledge of the environment and of the species involved, and is unobtainable from occasional missions.

Consequently, this type of programme cannot be tackled in a superficial manner, and concentration of effort seems far preferable to geographical dispersion. The need for in-depth studies has also been emphasized as regards invertebrates.
(c) Frequency of observations

We would recall that we regard a preliminary two-year study as essential before the commencement of treatment. Having regard to the considerable life span of fishes and to the existence of an annual cycle, sampling should be carried out every two or three months during the initial years of monitoring, with the object of arriving at a better understanding of possible changes in catches as a function of the seasonal cycle, and of achieving clarity on the biology of the main species.

Subsequently, we recommend sampling at the end of the low-water period, which provides a status report on the populations after the dry season, and sampling at the end of the high-water period. The latter is the most interesting, because of the possibility of sampling the young of annually-reproducing species and of verifying whether the recruitment is proceeding normally.

Our experience leads us to propose that several other stations should also be sampled once a year, at the end of the high-water period, from the commencement of programmes. These stations should preferably be located on either side of reference stations in the same catchment, and could be used to verify, in long-term research, that the results obtained at these reference stations were well representative of the river as a whole. They would also have the advantage of enabling the reference station to be replaced, should it be altered as a consequence of road works or hydraulic engineering works.

(d) Complementary research

It would be worthwhile making a deeper study of the effect of pollutants on the physiology of fishes. In particular, it would be of interest to be able to recognize the concentration rates and the organs in which the insecticide is liable to accumulate.

In conclusion, if an ichthyological monitoring programme is to be carried out seriously it calls for the establishment of a permanent team for a period of several years. Proper interpretation of the results also requires a deep knowledge of the environment and of the species involved, and is unobtainable from occasional missions.

Consequently, this type of programme cannot be tackled in a superficial manner, and concentration of effort seems far preferable to geographical dispersion. The need for in-depth studies has also been emphasized as regards invertebrates.
5. BIBLIOGRAPHY


5. BIBLIOGRAPHY


QUELENNEC, G., MILES, J. W., DEJOUX, C. & MERONA, B. de (1977) Chemical monitoring for temephos in mud oysters and fish from a river within the onchocerciasis control programme in the Volta river basin area. WHO/VBC/77.683: 6p


QUELENNEC, G., MILES, J. W., DEJOUX, C. & MERONA, B. de (1977) Chemical monitoring for temephos in mud oysters and fish from a river within the onchocerciasis control programme in the Volta river basin area. WHO/VBC/77.683: 6p


PART II: OBSERVATIONS ON FISH POPULATIONS IN ABATE TREATED RIVERS IN NORTHERN GHANA

CONTENTS

1. INTRODUCTION ................................................. 32

2. METHODS .......................................................... 32

3. DATA ANALYSIS .................................................. 33

4. RESULTS AND DISCUSSIONS ...................................... 33

5. CATCH PER UNIT EFFORT OF FISHING ............................. 34
   (a) Schilbe mystus .............................................. 34
   (b) Entropius niloticus and E. mentalis ......................... 34
   (c) Alestes species ............................................. 35
   (d) Synodontis species .......................................... 35

6. FLUCTUATIONS IN COEFFICIENT OF CONDITION ................. 36

7. CONCLUSIONS ..................................................... 36
# PART II: OBSERVATIONS ON FISH POPULATIONS IN ABATE TREATED RIVERS IN NORTHERN GHANA

## CONTENTS

1. INTRODUCTION ................................................. 32
2. METHODS ...................................................... 32
3. DATA ANALYSIS .................................................. 33
4. RESULTS AND DISCUSSIONS .................................... 33
5. CATCH PER UNIT EFFORT OF FISHING ......................... 34
   (a) *Schilbe mystus* .......................................... 34
   (b) *Entropius niloticus* and *E. mentalis* ................. 34
   (c) *Alestes* species .......................................... 35
   (d) *Synodontis* species ...................................... 35
6. FLUCTUATIONS IN COEFFICIENT OF CONDITION .............. 36
7. CONCLUSIONS .................................................. 36
1. INTRODUCTION

The World Health Organization is currently carrying out a programme of controlling populations of the blackfly, Simulium damnosum, vector of onchocerciasis or river blindness. The project, officially designated the Onchocerciasis Control Programme (OCP), has mainly used a larvicide, Abate, to attack the aquatic developmental stages of the fly. The OCP has other sections including epidemiology and redevelopment (Davies et al., 1979).

The weekly use of chemicals over 18 000 kms of river make it imperative that some surveillance must be kept on the non-target fauna, particularly the invertebrates and fish. In this report, we present results of the fish surveillance work in Ghana.

Monitoring started in August 1976 on the rivers Oti and White Volta, and January 1977 on the Black Volta. The last two rivers were already being treated with insecticide and the Oti followed in March 1977. These rivers are wide savanna systems in northern Ghana and flow into the Volta Lake. Their ecology has been studied by Hopson (1964) and Abban (1976). The sites, as indicated on Fig.1, were selected because of (a) the existence of Simulium breeding sites, (b) access at all times of year, and (c) being the nearest riverine portions of the main rivers to the Volta Lake. It was anticipated that data collected at these points would serve as indications of possible effects of insecticide on the lake itself, resulting from upstream application of Abate. The fact that these sites were also situated near villages with large commercial fisheries has led to certain problems and may go a long way to explain the low catches as compared to the stations monitored in the Ivory Coast. More recently, stations have been established on the Pru (September 1978) and on the Wawa (December 1980) to gain information prior to the extension of the OCP control area.

2. METHODS

Lévêque et al. (1978) standardized the protocol of fish monitoring with the OCP area. There have been two methods commonly used. Firstly, the Catch Per Unit Effort (CPUE) was estimated regularly by the use of a battery of gill nets of five different mesh sizes (15, 20, 25, 30 and 40 mm.). The results were expressed as catch in term of numbers and weight per 100 m² surface area of net per night. For the results in Ghana, it must be mentioned that variations in protocol occurred at the start of sampling. Until March 1977, a half set of nets was used (i.e. 50 m² surface area of each mesh size) and the recorded CPUE obtained by extrapolation. From then until October 1979, the half set was used for two nights. Since then, a full set has been used for one or two nights.

Secondly, a condition factor was estimated by the formula coefficient of condition \( K = \frac{\text{Weight} \times 10^3}{\text{Length}^3} \). An attempt was also made to estimate the fish fry population from catches made by a pair of "fish-drift" nets. These were 3m long with a mesh size of 1.5 and a rectangular opening at one end of a 40 x 70 cm frame.
1. INTRODUCTION

The World Health Organization is currently carrying out a programme of controlling populations of the blackfly, Simulium damnosum, vector of onchocerciasis or river blindness. The project, officially designated the Onchocerciasis Control Programme (OCP), has mainly used a larvicide, Abate, to attack the aquatic developmental stages of the fly. The OCP has other sections including epidemiology and redevelopment (Davies et al., 1979).

The weekly use of chemicals over 18,000 kms of river make it imperative that some surveillance must be kept on the non-target fauna, particularly the invertebrates and fish. In this report, we present results of the fish surveillance work in Ghana.

Monitoring started in August 1976 on the rivers Oti and White Volta, and January 1977 on the Black Volta. The last two rivers were already being treated with insecticide and the Oti followed in March 1977. These rivers are wide savanna systems in northern Ghana and flow into the Volta Lake. Their ecology has been studied by Hopson (1964) and Abban (1976). The sites, as indicated on Fig.1, were selected because of (a) the existence of Simulium breeding sites, (b) access at all times of year, and (c) being the nearest riverine portions of the main rivers to the Volta Lake. It was anticipated that data collected at these points would serve as indications of possible effects of insecticide on the lake itself, resulting from upstream application of Abate. The fact that these sites were also situated near villages with large commercial fisheries has led to certain problems and may go a long way to explain the low catches as compared to the stations monitored in the Ivory Coast. More recently, stations have been established on the Pru (September 1978) and on the Wawa (December 1980) to gain information prior to the extension of the OCP control area.

2. METHODS

Lévéque et al. (1978) standardized the protocol of fish monitoring with the OCP area. There have been two methods commonly used. Firstly, the Catch Per Unit Effort (CPUE) was estimated regularly by the use of a battery of gill nets of five different mesh sizes (15, 20, 25, 30 and 40 mm.). The results were expressed as catch in terms of numbers and weight per 100 m² surface area of net per night. For the results in Ghana, it must be mentioned that variations in protocol occurred at the start of sampling. Until March 1977, a half set of nets was used (i.e. 50 m² surface area of each mesh size) and the recorded CPUE obtained by extrapolation. From then until October 1979, the half set was used for two nights. Since then, a full set has been used for one or two nights.

Secondly, a condition factor was estimated by the formula coefficient of condition \( K = \frac{\text{Weight} \times 10^3}{\text{Length}^3} \). An attempt was also made to estimate the fish fry population from catches made by a pair of "fish-drift" nets. These were 3m long with a mesh size of 1.5 and a rectangular opening at one end of a 40 x 70 cm frame.
In addition to the routine monitoring, some specific studies have been undertaken concerning the estimation of the possible impact of Abate on the fish of the rivers of Ghana. For example, a 48-hour study to estimate the immediate effect of Abate on fish catches was carried out on the Oti with the first treatment of the river (Abban and Samman 1981).

The effect of the flood regime of the Oti and White Volta on fish catches was reported by Abban (1979). A further study of the effect of Abate treatment on the fish catches, especially during the dry season is given in Abban and Samman (in press). Laboratory studies of the reaction of fish to Abate was reported to the OCP in 1981 (Abban and Samman, unpublished) and the aspects of the biology of a major species Butropius mentalis was discussed by Abban (1978).

An ichthyologist was appointed with the responsibility of OCP monitoring in March 1977. The introduction of this expertise is clear in the analysis of results, and in some of the multivariate statistics it is necessary to exclude data prior to this time.

3. DATA ANALYSIS

Standardized coding forms were used for monitoring throughout the OCP area, and facilitated the transfer of information for data handling using computers. Apart from the analyses carried out by the monitoring teams, the Salford University data handling team was contracted to assist in the handling and interpretation of the information. The type of statistics used, has been the subject of a series of reports to OCP (1979, 1980, 1981). In view of the variability of the results, the main analyses used have involved graphical presentations for ease of visual interpretation. The Shannon-Weiner diversity index and its component parts, species richness and evenness (Odum 1974) aided estimation of community change as did the technique of correspondence analysis (also known as reciprocal averaging) (Renzecri, 1973). This latter technique, whilst not being the most statistically sophisticated method and not including overall abundance, has a high visual information content and simultaneous portrayal of site/months and species allows indicator species to be recognized.

4. RESULTS AND DISCUSSION

Surveys of the northern Ghana rivers have identified some 107 species of fish with the Pru containing 69 species alone. Each river was considered rich in fish fauna and most species were widely distributed. These observations were attributed to the fact that all the rivers were directly connected to the Volta lake which has many species. Also the lake contains many fishes which are legacies of many small rivers which became partly or completely absorbed in the formation of the lake. Since the lake is relatively young (about 18 years) most of the fishes have not become completely adapted to the lacustrine condition of the lake. Thus many species migrate up into the rivers under observation, to spawn during the wet season. Lastly, being tropical rivers, the Volta basin rivers have a wide range of habitats within a relatively short distance and thus there is provision for various ecological groups of fishes to be widely distributed. Butropius mentalis, E. niloticus, Alestes leuciscus, Schilbe mystus, Synodontis sorex and S.gambiensis are perhaps the most dominant and widely distributed species with S.oceiiffcr also common in the Oti.
In addition to the routine monitoring, some specific studies have been undertaken concerning the estimation of the possible impact of Abate on the fish of the rivers of Ghana. For example, a 48-hour study to estimate the immediate effect of Abate on fish catches was carried out on the Oti with the first treatment of the river (Abban and Samman 1981).

The effect of the flood regime of the Oti and White Volta on fish catches was reported by Abban (1979). A further study of the effect of Abate treatment on the fish catches, especially during the dry season is given in Abban and Samman (in press). Laboratory studies of the reaction of fish to Abate was reported to the OCP in 1981 (Abban and Samman, unpublished) and the aspects of the biology of a major species Butropius mentalis was discussed by Abban (1978).

An ichthyologist was appointed with the responsibility of OCP monitoring in March 1977. The introduction of this expertise is clear in the analysis of results, and in some of the multivariate statistics it is necessary to exclude data prior to this time.

3. DATA ANALYSIS

Standardized coding forms were used for monitoring throughout the OCP area, and facilitated the transfer of information for data handling using computers. Apart from the analyses carried out by the monitoring teams, the Salford University data handling team was contracted to assist in the handling and interpretation of the information. The type of statistics used, has been the subject of a series of reports to OCP (1979, 1980, 1981). In view of the variability of the results, the main analyses used have involved graphical presentations for ease of visual interpretation. The Shannon-Weiner diversity index and its component parts, species richness and evenness (Odum 1974) aided estimation of community change as did the technique of correspondence analysis (also known as reciprocal averaging) (Renzecri, 1973). This latter technique, whilst not being the most statistically sophisticated method and not including overall abundance, has a high visual information content and simultaneous portrayal of site/months and species allows indicator species to be recognized.

4. RESULTS AND DISCUSSION

Surveys of the northern Ghana rivers have identified some 107 species of fish with the Pru containing 69 species alone. Each river was considered rich in fish fauna and most species were widely distributed. These observations were attributed to the fact that all the rivers were directly connected to the Volta lake which has many species. Also the lake contains many fishes which are legacies of many small rivers which became partly or completely absorbed in the formation of the lake. Since the lake is relatively young (about 18 years) most of the fishes have not become completely adapted to the lacustrine condition of the lake. Thus many species migrate up into the rivers under observation, to spawn during the wet season. Lastly, being tropical rivers, the Volta basin rivers have a wide range of habitats within a relatively short distance and thus there is provision for various ecological groups of fishes to be widely distributed. Butropius mentalis, E. niloticus, Alestes leuciscus, Schilbe mystus, Synodontis sorex and S. gambiensis are perhaps the most dominant and widely distributed species with S. ocellifer also common in the Oti.
Sampling of these main rivers was carried out approximately every month on the Oti and every two months on the White Volta, Black Volta and Pru. Numbers of fish caught during sampling were low in comparison to the Ivory Coast records and the intensive local fishing and differences in the character of rivers in the two countries must be borne in mind.

The correspondence analysis in Fig. 3 demonstrates some separation into wet and dry season on the White Volta with the late start of the rains in 1977 and the dominance of Alestes baremose in November 1978, being notable. A decrease in the number of species with increasing river height is noticeable with various Synodontis spp. being characteristic of the flood periods. For the Oti (Fig. 4) there is a clear separation into wet and dry seasons. 1977 is again abnormal with a very high catch of Eutropius mentalis in July and Alestes macrolepidotus in November. Changes in community structure indices reflect the start of the flood. There is a clear rise in numbers of species recorded, corresponding to changes in personnel and therefore pre-treatment collections cannot be easily compared.

The Black Volta at Ramboi again shows a drop in numbers and species at times of maximum flood, and the other seasonal influences are clear.

5. CATCH PER UNIT EFFORT OF FISHING

It is important to comment on (see Figs. 5, 6 and 7) catches recorded for the more dominant species in the basin:

(a) Schilbe mystax: This fish from Fig. 5 appears to be in the rivers all through the year. However, the CPUE was related to the river height. Generally the CPUE of the species increased immediately after the start of the wet season with rains in May/June and also during the receding period of flood usually about November/December. The initial increase in CPUE was attributed to the migration of the species into the rivers in response to increased flow rate of water with the start of rains. The low CPUE recorded during the flood period was only due to the fact that gill nets can not be as effectively deployed in high current rivers. The apparently abnormal shift of peaks during 1979/80 was mainly due to a corresponding shift in the flooding period of the rivers (Fig. 2).

(b) Eutropius niloticus and E. mentalis:

These two species generally appear and disappear from the rivers at the same periods in relation to the flood regime of the rivers (except for 1977 when E. mentalis dominated), the relationship being similar to that of Schilbe mystax. It is also apparent that E. niloticus commences its migration from the lake prior to E. mentalis. Based on the CPUE recorded for the two species, E. mentalis seem to migrate in larger schools than E. niloticus. A study of the seasonal abundance of adults and juveniles of E. mentalis in the White Volta showed that at the peak of the floods when the adults are apparently not available (attributed to influence of flood on effective deployment of gill nets) the fry were most abundant.
Sampling of these main rivers was carried out approximately every month on the Oti and every two months on the White Volta, Black Volta and Pru. Numbers of fish caught during sampling were low in comparison to the Ivory Coast records and the intensive local fishing and differences in the character of rivers in the two countries must be borne in mind.

The correspondence analysis in Fig.3 demonstrates some separation into wet and dry season on the White Volta with the late start of the rains in 1977 and the dominance of Alestes baremose in November 1978, being notable. A decrease in the number of species with increasing river height is noticeable with various Synodontis spp. being characteristic of the flood periods. For the Oti (Fig.4) there is a clear separation into wet and dry seasons. 1977 is again abnormal with a very high catch of Eutropius mentalis in July and Alestes macrolepidotus in November. Changes in community structure indices reflect the start of the flood. There is a clear rise in numbers of species recorded, corresponding to changes in personnel and therefore pre-treatment collections cannot be easily compared.

The Black Volta at Ramboi again shows a drop in numbers and species at times of maximum flood, and the other seasonal influences are clear.

5. CATCH PER UNIT EFFORT OF FISHING

It is important to comment on (see Figs. 5, 6 and 7) catches recorded for the more dominant species in the basin:

(a) Schilbe mystax: This fish from Fig.5 appears to be in the rivers all through the year. However, the CPUE was related to the river height. Generally the CPUE of the species increased immediately after the start of the wet season with rains in May/June and also during the receding period of flood usually about November/December. The initial increase in CPUE was attributed to the migration of the species into the rivers in response to increased flow rate of water with the start of rains. The low CPUE recorded during the flood period was only due to the fact that gill nets can not be as effectively deployed in high current rivers. The apparently abnormal shift of peaks during 1979/80 was mainly due to a corresponding shift in the flooding period of the rivers (Fig.2).

(b) Eutropius niloticus and E. mentalis:

These two species generally appear and disappear from the rivers at the same periods in relation to the flood regime of the rivers (except for 1977 when E. mentalis dominated), the relationship being similar to that of Schilbe mystax. It is also apparent that E. niloticus commences its migration from the lakes prior to E. mentalis. Based on the CPUE recorded for the two species, E. mentalis seem to migrate in larger schools than E. niloticus. A study of the seasonal abundance of adults and juveniles of E. mentalis in the White Volta showed that at the peak of the floods when the adults are apparently not available (attributed to influence of flood on effective deployment of gill nets) the fry were most abundant.
(c) Alestes species:

A. nurse and A. macrolepidotus: The species occur most in catches during the receding period of the flood, when river height is below 5 ft, with the peak catches of A. macrolepidotus following that of A. nurse in time. The data also suggest that high catches of A. nurse may be occurring in alternate years.

A. leuciscus and A. luteus: These are two small and almost identical species and are caught almost exclusively by the smallest mesh of the battery of gill nets (i.e. 15mm.). The peak catches of these occur between January and March (dry season). The high catches recorded during October and November 1979 was because the duration of the flood during that year was so short that by November/December the rivers were in their dry season state.

(d) Synodontis species

Synodontis sorex, S. occellifer and S. gambiensis all migrate from the lake into the rivers to spawn after the Schilbeidae and their peak catches occur when the rivers are high (above 5.5 ft). The ability of the gill nets to catch the Synodontis when most species were apparently unavailable has been attributed in part to the spiny nature of the species.

River Pru

In the Pru, which is yet to be treated, Alestes macrolepidotus and Schilbe mystus have been considered the most important fishes in terms of regularity in catch and numbers of individuals caught. The Pru has a slightly delayed flooding period compared to the rivers in northern Ghana. The periods of high catches of various fishes correspond with similar hydrological states in the other rivers. During 1979 when the flooding of Pru lasted longer than in 1978 and 1980, the peak catches of S. mystus occurred in January and February of 1980. Fig. 8 again shows separation of wet and dry seasons although quantification of discharge was impossible, due to the absence of a water gauge. S. mystus is seen to be characteristic of high water levels (November, December) and Alestes macrolepidotus of low water (February). An example of the working of correspondence analysis, is in November 1978 when only Synodontis gambiensis was found.

In conclusion, it could be said that in addition to natural fluctuations, which can not be fully explained, the flooding regime of the rivers was the most important variable to be considered in relation to changes in CPUE. Since the flooding regime of rivers is flexible in time, slight changes in peak catch periods over a number of years must be expected.
(c) Alestes species:

A. nurse and A. macrolepidotus: The species occur most in catches during the receding period of the flood, when river height is below 5 ft, with the peak catches of A. macrolepidotus following that of A. nurse in time. The data also suggest that high catches of A. nurse may be occurring in alternate years.

A. leuciscus and A. luteus: These are two small and almost identical species and are caught almost exclusively by the smallest mesh of the battery of gill nets (i.e. 15mm.). The peak catches of these occur between January and March (dry season). The high catches recorded during October and November 1979 was because the duration of the flood during that year was so short that by November/December the rivers were in their dry season state.

(d) Synodontis species

Synodontis sox, S. ocellifer and S. gambiensis all migrate from the lake into the rivers to spawn after the Schilbeidae and their peak catches occur when the rivers are high (above 5.5 ft). The ability of the gill nets to catch the Synodontis when most species were apparently unavailable has been attributed in part to the spiny nature of the species.

River Pru

In the Pru, which is yet to be treated, Alestes macrolepidotus and Schilbe mystus have been considered the most important fishes in terms of regularity in catch and numbers of individuals caught. The Pru has a slightly delayed flooding period compared to the rivers in northern Ghana. The periods of high catches of various fishes correspond with similar hydrological states in the other rivers. During 1979 when the flooding of Pru lasted longer than in 1978 and 1980, the peak catches of S. mystus occurred in January and February of 1980. Fig. 8 again shows separation of wet and dry seasons although quantification of discharge was impossible, due to the absence of a water gauge. S. mystus is seen to be characteristic of high water levels (November, December) and Alestes macrolepidotus of low water (February). An example of the working of correspondence analysis, is in November 1978 when only Synodontis gambiensis was found.

In conclusion, it could be said that in addition to natural fluctuations, which can not be fully explained, the flooding regime of the rivers was the most important variable to be considered in relation to changes in CPUE. Since the flooding regime of rivers is flexible in time, slight changes in peak catch periods over a number of years must be expected.
6. FLUCTUATIONS IN COEFFICIENT OF CONDITION

The coefficient of condition of fish (K), generally thought of as a constant for a species is used to express the state of health of a species in numerical terms. Some variations in the condition of a fish is, however, expected in connexion with the reproductive cycle of fish. This is because the process of gonad development, especially in the females, is usually associated with the accumulation of fats in the muscle and around the viscera. Also, periods of abundance or otherwise of preferred food materials could contribute to slight fluctuations in the condition of fish. In the present work the condition of fishes has been estimated to give indications of deviation or evolution, which might be attributed to the use of Abate in the rivers. The fluctuations in K which appear in the accompanying diagrams (Fig.9) were attributed to natural parameters. There appeared to be little variation in K with length of fish except where numbers were low. The type of analysis used, involved a logarithmic transformation of the data, to stabilize the variance, enabling a greater size range to be included (Salford report 1979). Examples of fluctuations of K in different fish groups as shown in Fig.9 is explained as follows:

**Synodontis gambiensis** on the White Volta (9) shows the effect of spawning on the condition of the species. This fish spawns during the middle of the flood (i.e. July to mid-August) and has lower coefficient from about September until about February the following year, when the fish starts developing for the next spawning season.

**Alestes macroepidotus** which spawns during the later part of the flood period shows an increasing condition from about the peak of the flood (July/August) till spawning period (November/December) and the coefficient is lower until July/August again. **P. mentalis** spawns about the middle of the flood season - as shown by a study of the seasonal abundance of the adults and juveniles in the White Volta - (Abban, IAB report 1978). Thus the condition of the fish apparently increases during the early part of the flood period when fat is being accumulated for spawning.

7. CONCLUSIONS

The effect of any chemical used as Abate is applied in the rivers of the Volta basin could affect fish and fish populations in one of, or a combination of, the following ways. Firstly, the chemicals could affect the survival of both adults and juvenile fishes. Secondly, the distribution of fish populations could be affected, which in the long term also alters the fish population structure of entire rivers (Abban and Samman, in press). Thirdly, the continuous application of a chemical in a river system could cause changes in the coefficient of condition of the fishes. This could happen if the chemical adversely affects fish food materials in the water or puts the fish in a state which will divert the attention of fish from food. Lastly, the possibility of the accumulation of the chemical or its breakdown products in various tissues could affect the general physiology and in particular the reproductive activities of the fish.
6. FLUCTUATIONS IN COEFFICIENT OF CONDITION

The coefficient of condition of fish (K), generally thought of as a constant for a species is used to express the state of health of a species in numerical terms. Some variations in the condition of a fish is, however, expected in connexion with the reproductive cycle of fish. This is because the process of gonad development, especially in the females, is usually associated with the accumulation of fats in the muscle and around the viscera. Also, periods of abundance or otherwise of preferred food materials could contribute to slight fluctuations in the condition of fish. In the present work the condition of fishes has been estimated to give indications of deviation or evolution, which might be attributed to the use of Abate in the rivers. The fluctuations in K which appear in the accompanying diagrams (Fig.9) were attributed to natural parameters. There appeared to be little variation in K with length of fish except where numbers were low. The type of analysis used, involved a logarithmic transformation of the data, to stabilize the variance, enabling a greater size range to be included (Salford report 1979). Examples of fluctuations of K in different fish groups as shown in Fig.9 is explained as follows:

*Synodontis gambiae* on the White Volta shows the effect of spawning on the condition of the species. This fish spawns during the middle of the flood (i.e. July to mid-August) and has lower coefficient from about September until about February the following year, when the fish starts developing for the next spawning season.

*Alestes macroepidotus* which spawns during the later part of the flood period shows an increasing condition from about the middle of the flood (July/August) till spawning period (November/December) and the coefficient is lower until July/August again. *Catoprion mentalis* spawns about the middle of the flood season - as shown by a study of the seasonal abundance of the adults and juveniles in the White Volta - (Abban, IAB report 1978). Thus the condition of the fish apparently increases during the early part of the flood period when fat is being accumulated for spawning.

7. CONCLUSIONS

The effect of any chemical used as Abate is applied in the rivers of the Volta basin could affect fish and fish populations in one of, or a combination of, the following ways. Firstly, the chemicals could affect the survival of both adults and juvenile fishes. Secondly, the distribution of fish populations could be affected, which in the long term also alters the fish population structure of entire rivers (Abban and Samman, in press). Thirdly, the continuous application of a chemical in a river system could cause changes in the coefficient of condition of the fishes. This could happen if the chemical adversely affects fish food materials in the water or puts the fish in a state which will divert the attention of fish from food. Lastly, the possibility of the accumulation of the chemical or its breakdown products in various tissues could affect the general physiology and in particular the reproductive activities of the fish.
In the routine monitoring attempts were made to collect samples at given intervals from treatment days. However, in practice treatment schedules varied and some samples were taken on treatment days. This could explain some of the variations in Catch Per Unit Effort although no clear pattern emerges because the hydrological conditions were varied.

Secondly, no long term changes in the condition of fish emerges from the interpretation of data. Indeed, if there was a trend it would be difficult to separate the role of Abate from continued evolution resulting from the development of the Volta lake and its numerous influences on the fisheries of the tributary rivers.

The temporary changes in the catch composition at the sampling sites can not be said to have been due to the application of Abate, and no species could be said to have been eliminated or otherwise. However, a regular study on representative rivers to monitor fish distribution may have to be undertaken - perhaps once every two or three years.

The dominant pattern is seasonal, dependant on the hydrological regime and the presence of many species migrating from the lake. Differences between years may often be great although explanations can often be found in annual variations in river depth and the timing of the collections.
In the routine monitoring attempts were made to collect samples at given intervals from treatment days. However, in practice treatment schedules varied and some samples were taken on treatment days. This could explain some of the variations in Catch Per Unit Effort although no clear pattern emerges because the hydrological conditions were varied.

Secondly, no long term changes in the condition of fish emerges from the interpretation of data. Indeed, if there was a trend it would be difficult to separate the role of Abate from continued evolution resulting from the development of the Volta lake and its numerous influences on the fisheries of the tributary rivers.

The temporary changes in the catch composition at the sampling sites can not be said to have been due to the application of Abate, and no species could be said to have been eliminated or otherwise. However, a regular study on representative rivers to monitor fish distribution may have to be undertaken - perhaps once every two or three years.

The dominant pattern is seasonal, dependant on the hydrological regime and the presence of many species migrating from the lake. Differences between years may often be great although explanations can often be found in annual variations in river depth and the timing of the collections.
FIG. 1 - LOCATION OF MONITORING STATIONS IN GHANA
FIG. 1 - LOCATION OF MONITORING STATIONS IN GHANA
FIG. 2 - RIVER HEIGHT REGIME IN THE WHITE VOLTA AND OTI

WHITE VOLTA

OTI
FIG. 2 - RIVER HEIGHT REGIME IN THE WHITE VOLTA AND OTI
FIG. 3 - CORRESPONDENCE ANALYSIS ON WHITE VOLTA

WATER LEVEL - H - high
D - decreasing
L - low
I - increasing
FIG. 3 - CORRESPONDENCE ANALYSIS ON WHITE VOLTA

- H: high
- D: decreasing
- L: low
- I: increasing
FIG. 4 - CORRESPONDENCE ANALYSIS ON OTI

- HIGH WATER
- LOW WATER
FIG. 4 - CORRESPONDENCE ANALYSIS ON OTI

△ - HIGH WATER
△ - LOW WATER
FIG. 5 - C.P.U.E. (wt-g) OF MAJOR FISHES ON THE WHITE VOLTA
FIG. 5 - C.P.U.E. (wt-g) OF MAJOR FISHES ON THE WHITE VOLTA
FIG. 6 - C.P.U.E. of Alestes Leuciscus on White Volta, ITI
FIG. 6 - C.P.U.E. OF ALFSTES LEUCISCUS

ON

WHITE VOLTA

UTI
FIG. 7 - C.F.U.E. OF MAJOR FISHES IN THE BLACK VOLTA AND PRU

Eutropius mentalis (Black Volta)

Alestes macrolepidotus (Pru)

A. leuciscus

Schilbe mystus (Pru)
FIG. 9 - FLUCTUATIONS IN COEFFICIENT OF CONDITION

Alestes macrolephtorus

Svamonia gambiaensis

Eutropius mentalis
FIG. 9 - FLUCTUATIONS IN COEFFICIENT OF CONDITION

Alestes macrolepidotus

Svaodon t

Eutropius mentalis

White Volta
Oti
Svaodon gambiensis

PART III: FISH MONITORING IN WEST AFRICAN RIVERS - PROBLEMS AND PERSPECTIVES

CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 The effects of insecticides on fish in West Africa</td>
<td>48</td>
</tr>
<tr>
<td>1.2 Problems in the interpretation of results</td>
<td>49</td>
</tr>
<tr>
<td>1.3 Continuity</td>
<td>49</td>
</tr>
<tr>
<td>1.4 Collaboration</td>
<td>50</td>
</tr>
<tr>
<td>2. RECOMMENDATIONS FOR FUTURE PROGRAMMES</td>
<td>50</td>
</tr>
<tr>
<td>2.1 Monitoring sites</td>
<td>50</td>
</tr>
<tr>
<td>2.2 Methodology</td>
<td>50</td>
</tr>
<tr>
<td>2.3 Calendar of Operations</td>
<td>51</td>
</tr>
<tr>
<td>3. CONCLUSIONS</td>
<td>51</td>
</tr>
</tbody>
</table>
PART III: FISH MONITORING IN WEST AFRICAN RIVERS - PROBLEMS AND PERSPECTIVES

CONTENTS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>The effects of insecticides on fish in West Africa</td>
<td>48</td>
</tr>
<tr>
<td>1.2</td>
<td>Problems in the interpretation of results</td>
<td>49</td>
</tr>
<tr>
<td>1.3</td>
<td>Continuity</td>
<td>49</td>
</tr>
<tr>
<td>1.4</td>
<td>Collaboration</td>
<td>50</td>
</tr>
<tr>
<td>2.</td>
<td>RECOMMENDATIONS FOR FUTURE PROGRAMMES</td>
<td>50</td>
</tr>
<tr>
<td>2.1</td>
<td>Monitoring sites</td>
<td>50</td>
</tr>
<tr>
<td>2.2</td>
<td>Methodology</td>
<td>50</td>
</tr>
<tr>
<td>2.3</td>
<td>Calendar of Operations</td>
<td>51</td>
</tr>
<tr>
<td>3.</td>
<td>CONCLUSIONS</td>
<td>51</td>
</tr>
</tbody>
</table>
For reasons of economic importance, fish populations have been the object of particular study within the framework of aquatic surveillance. It is also important for psychological reasons to show the villagers mainly occupied in fishing, that care is being taken about the risks of pollution.

During work carried out since 1974 by teams based in Ivory Coast and Ghana, the conclusion is that Temephos as an anti-Simulium larvicide, has no detectable effect, in the long-term, on the composition and stocks of fish. This is, of course, based on the methods used and does not include chemical analysis. Furthermore, effects have not been seen in studies on the biology of principal species, notably fecundity and reproduction. It is obvious that dietary regimes will be affected to some extent, but the insectivorous species appear to have not been affected by the destruction of part of the entomological populations.

The scientific results obtained in the course of monitoring fish populations are presented in reports from the different teams.

The experience acquired and the knowledge we now have of the problems of acquisition and treatment of the data, enable us to present constructive recommendations for future programmes of fish monitoring. These could be continuation of existing programmes, extension of OCP areas or where new insecticides are introduced.

1.1 The effects of insecticides on fish in West Africa

Insecticides may have rapid, medium or long-term effects. The monitoring methods, therefore, must be adapted to the different possibilities.

In the case of a rapid effect of insecticide on the fish, a drop in catch per unit effort will be noticed in a short space of time. Such observations may be confirmed by fish mortality following treatment. This eventuality ought not to occur if tests are carried out in vitro followed by field testing prior to utilization in a programme. Such preliminary experiences are very important, were carried out in the case of Abate, and should be carried out for new insecticides.

For medium- and long-term effects, the impact of an insecticide may be low and indirect. Accumulation of toxic products may modify the metabolism of the fish (respiration, assimilation, nutrition and reproduction). In the last case diminution of fecundity will be detected by regular estimation during periods of reproduction. However, it is important to execute in vitro tests on local species before regular field use, in order to know which organs are affected and what quantity of insecticide accumulates. Furthermore, it is necessary to make the same observation on natural populations at the start of the campaign to see if there is any difference from laboratory results. It must be underlined that different species will react in different ways, according to their behaviour. Such studies have only been partially carried out for Abate. The toxicity of the insecticide will be most pronounced in juveniles and pelagic species with small and abundant eggs. This effect will be most clear in the catches of juveniles in the nets of the smallest mesh size and at the end of the flood season when most of the populations reproduce.

The insecticide may not affect the fish directly, but destroy an important part of their diet. Some species are able to modify their food choice if an alternative is available. In contrast, more specialized fish may suffer malnutrition. The coefficient of condition will act as an indicator of this.

In conclusion, we report the necessity of key preliminary studies in laboratory and field. This will lead to clarification of the direction of research and of the survey methodology.
For reasons of economic importance, fish populations have been the object of particular study within the framework of aquatic surveillance. It is also important for psychological reasons to show the villagers mainly occupied in fishing, that care is being taken about the risks of pollution.

During work carried out since 1974 by teams based in Ivory Coast and Ghana, the conclusion is that Temephos as an anti-Simulium larvicide, has no detectable effect, in the long-term, on the composition and stocks of fish. This is, of course, based on the methods used and does not include chemical analysis. Furthermore, effects have not been seen in studies on the biology of principal species, notably fecundity and reproduction. It is obvious that dietary regimes will be affected to some extent, but the insectivorous species appear to have not been affected by the destruction of part of the entomological populations.

The scientific results obtained in the course of monitoring fish populations are presented in reports from the different teams.

The experience acquired and the knowledge we now have of the problems of acquisition and treatment of the data, enable us to present constructive recommendations for future programmes of fish monitoring. These could be continuation of existing programmes, extension of OCP areas or where new insecticides are introduced.

1.1 The effects of insecticides on fish in West Africa

Insecticides may have rapid, medium or long-term effects. The monitoring methods, therefore, must be adapted to the different possibilities.

In the case of a rapid effect of insecticide on the fish, a drop in catch per unit effort will be noticed in a short space of time. Such observations may be confirmed by fish mortality following treatment. This eventuality ought not to occur if tests are carried out in vitro followed by field testing prior to utilization in a programme. Such preliminary experiences are very important, were carried out in the case of Abate, and should be carried out for new insecticides.

For medium- and long-term effects, the impact of an insecticide may be low and indirect. Accumulation of toxic products may modify the metabolism of the fish (respiration, assimilation, nutrition and reproduction). In the last case diminution of fecundity will be detected by regular estimation during periods of reproduction. However, it is important to execute in vitro tests on local species before regular field use, in order to know which organs are affected and what quantity of insecticide accumulates. Furthermore, it is necessary to make the same observation on natural populations at the start of the campaign to see if there is any difference from laboratory results. It must be underlined that different species will react in different ways, according to their behaviour. Such studies have only been partially carried out for Abate. The toxicity of the insecticide will be most pronounced in juveniles and pelagic species with small and abundant eggs. This effect will be most clear in the catches of juveniles in the nets of the smallest mesh size and at the end of the flood season when most of the populations reproduce.

The insecticide may not affect the fish directly, but destroy an important part of their diet. Some species are able to modify their food choice if an alternative is available. In contrast, more specialized fish may suffer malnutrition. The coefficient of condition will act as an indicator of this.

In conclusion, we report the necessity of key preliminary studies in laboratory and field. This will lead to clarification of the direction of research and of the survey methodology.
1.2 Problems in the interpretation of results

It is important to realize the length of the biological cycle of the fish. The majority of species reproduce each year and live for several years. Therefore, an insecticide having a medium- or long-term effect, would necessitate several years of observations on the population structure and abundance. The interpretation is complicated by natural variations in population abundance. Some of these are related to hydrological phenomena.

Such a situation could be exemplified by low survival ability of young fish during periods of low flood or short flood duration. There are also other unmeasurable natural phenomena which must be taken into account to avoid hasty interpretations. An example worth considering is given by catches of *Schilbe mystus*, which became very low in the Leraba just after treatment started and in the Bagoué before treatment. In both rivers, however, the catches of *S. mystus* increased considerably in 1979, by which time both rivers were under treatment.

Consideration should also be given to variations due to spawning migrations in the interpretation of results (consequently the need for biological studies in the Programme area). Finally, to compare results obtained over long periods, it is necessary to ensure uniformity in methodology and experience of scientists and technicians in the field. This makes it necessary to have qualified and experienced staff capable of replacing existing personnel.

In conclusion, many years of observation are required to confirm that an insecticide is adversely or otherwise affecting fish populations or communities because of the many parameters that have to be considered before a satisfactory conclusion can be reached.

The recording and storage of field data in its raw form is important for accurate interpretation by the field teams, the coordinating hydrobiologist and/or outside bodies and provides a full historical record in case of staff changes.

In view of the variability of the data and the importance of biological knowledge in the interpretation, the analyses need to aid the construction of hypotheses, retaining the identity of each sample and preferably involve graphical representation.

Techniques such as correspondence analysis can detect major trends and disturbances and may identify indicator species. Statistical improvements may be made, but the natural population variability at any one place, renders precise analyses unnecessary.

Field workers should be able to interpret the diagrams, but not necessarily to perform the statistical task. However, most analyses could be carried out by the coordinating hydrobiologist using a pre-programmed micro-computer. Copies of the data should be held in HQ, Geneva, and external statistical work is only necessary in case of problems, development and independent assessment.

1.3 Continuity

If conclusions are to be made from data collected over many years, then the information must be gathered in the same way. Obviously, the method of collection must be standard. Changes in protocol are only permissible if some conversion factor may be employed without loss of statistical value. It is evident from the present work that the abundance, species composition and condition factors vary with the hydrological season. Collections made even at monthly intervals show considerable variation. The idea is to sample at the same hydrological season of each year. This is still not ideal because of differences in water level between years, but would be better than a calendar date. Other commitments on the part of monitoring personnel would, however, cause complications. It is also essential to be aware, from sector offices, or hydrological stations, of the development of the water regime and notes should be taken, and included on the forms, concerning possible influences from factors such as fishing activity, algal blooms, and other evidence of disturbance including the date of the last treatment. Such comments are invaluable to the interpretation of data, e.g. the
1.2 Problems in the interpretation of results

It is important to realize the length of the biological cycle of the fish. The majority of species reproduce each year and live for several years. Therefore, an insecticide having a medium- or long-term effect, would necessitate several years of observations on the population structure and abundance. The interpretation is complicated by natural variations in population abundance. Some of these are related to hydrological phenomena.

Such a situation could be exemplified by low survival ability of young fish during periods of low flood or short flood duration. There are also other unmeasurable natural phenomena which must be taken into account to avoid hasty interpretations. An example worth considering is given by catches of Schilbe mystus, which became very low in the Leraba just after treatment started and in the Bagoué before treatment. In both rivers, however, the catches of S. mystus increased considerably in 1979, by which time both rivers were under treatment.

Consideration should also be given to variations due to spawning migrations in the interpretation of results (consequently the need for biological studies in the Programme area). Finally, to compare results obtained over long periods, it is necessary to ensure uniformity in methodology and experience of scientists and technicians in the field. This makes it necessary to have qualified and experienced staff capable of replacing existing personnel.

In conclusion, many years of observation are required to confirm that an insecticide is adversely or otherwise affecting fish populations or communities because of the many parameters that have to be considered before a satisfactory conclusion can be reached.

The recording and storage of field data in its raw form is important for accurate interpretation by the field teams, the coordinating hydrobiologist and/or outside bodies and provides a full historical record in case of staff changes.

In view of the variability of the data and the importance of biological knowledge in the interpretation, the analyses need to aid the construction of hypotheses, retaining the identity of each sample and preferably involve graphical representation.

Techniques such as correspondence analysis can detect major trends and disturbances and may identify indicator species. Statistical improvements may be made, but the natural population variability at any one place, renders precise analyses unnecessary.

Field workers should be able to interpret the diagrams, but not necessarily to perform the statistical task. However, most analyses could be carried out by the coordinating hydrobiologist using a pre-programmed micro-computer. Copies of the data should be held in HQ, Geneva, and external statistical work is only necessary in case of problems, development and independent assessment.

1.3 Continuity

If conclusions are to be made from data collected over many years, then the information must be gathered in the same way. Obviously, the method of collection must be standard. Changes in protocol are only permissible if some conversion factor may be employed without loss of statistical value. It is evident from the present work that the abundance, species composition and condition factors vary with the hydrological season. Collections made even at monthly intervals show considerable variation. The idea is to sample at the same hydrological season of each year. This is still not ideal because of differences in water level between years, but would be better than a calendar date. Other commitments on the part of monitoring personnel would, however, cause complications. It is also essential to be aware, from sector offices, or hydrological stations, of the development of the water regime and notes should be taken, and included on the forms, concerning possible influences from factors such as fishing activity, algal blooms, and other evidence of disturbance including the date of the last treatment. Such comments are invaluable to the interpretation of data, e.g. the
water flow may step at certain times of the flood in almost all the rivers and nets may not be in the same place for a series of collections.

It is also clear that changes in personnel and expertise inevitably affect the results. Minor differences in scientific methodology and taxonomy knowledge will be reflected in difficulties in interpretation. A long-term commitment on the part of staff is required, with collaborative field meetings as well as table discussions. Unfortunately, yearly monitoring contracts and the routine nature of most of the work, are not always compatible with this aim.

Long-term planning is important with respect to staff. The development of expertise is not a short-term task. If staff changes occur, sufficient time must be allocated to the training of new personnel to ensure compatibility and continuity of data.

1.4 Collaboration

In any large-scale monitoring exercise with several teams, a coordinating biologist is essential. His office must be considered as headquarters and information bank. Field staff will be required to report progress and any specific comments or problems, and to answer queries and carry out specific exercises as required. The hydrobiologist in return would be responsible for the continued standardization of methodology and for the supply of information on e.g. hydrology and treatment dates, if not locally available. It is also important that the hydrobiologist visit the field teams to discuss progress and view the sampling sites during a study period, particularly when new personnel are involved.

Visits of experts to the field teams is good for the programme in general and all monitoring personnel can recognize areas requiring outside help. The hydrobiologist would also be able to inform all the teams of the objectives of such visits and ensure that relevant subsequent reports are distributed.

2. RECOMMENDATIONS FOR FUTURE PROGRAMMES

2.1 Monitoring sites

The choice of sampling station is firstly a function of access throughout the year. The sites also need to be representative of important parts of the treated river and a previous study is indispensable for the selection.

An expert with experience of the sampling problems and, preferably of the region, is needed for counselling the local team.

It is not recommended to choose stations in the immediate proximity of villages and camps having substantial fisheries. This is not conducive to optimum study because of pollution, overfishing and disturbance to both parties. It is also important to know the level of fishing activity in the river basin, if such knowledge is available, and the hydrological regime.

It also is saving time at the start of the programme if a systematic inventory is carried out by an expert.

2.2 Methodology

Until the present time the monitoring protocol assessed the variation in CPUE and K by a battery of 5 gill nets with different mesh sizes. The experience of five years lead is to propose certain modifications, namely the addition of three more mesh sizes. The standard battery should contain the following mesh sizes: 12.5, 15, 17.5, 20, 22.5, 25, 30 and 40 mm.
water flow may stop at certain times of the flood in almost all the rivers and nets may not be in the same place for a series of collections.

It is also clear that changes in personnel and expertise inevitably affect the results. Minor differences in scientific methodology and taxonomy knowledge will be reflected in difficulties in interpretation. A long-term commitment on the part of staff is required, with collaborative field meetings as well as table discussions. Unfortunately, yearly monitoring contracts and the routine nature of most of the work, are not always compatible with this aim.

Long-term planning is important with respect to staff. The development of expertise is not a short-term task. If staff changes occur, sufficient time must be allocated to the training of new personnel to ensure compatibility and continuity of data.

1.4 Collaboration

In any large-scale monitoring exercise with several teams, a coordinating biologist is essential. His office must be considered as headquarters and information bank. Field staff will be required to report progress and any specific comments or problems, and to answer queries and carry out specific exercises as required. The hydrobiologist in return would be responsible for the continued standardization of methodology and for the supply of information on e.g. hydrology and treatment dates, if not locally available. It is also important that the hydrobiologist visit the field teams to discuss progress and view the sampling sites during a study period, particularly when new personnel are involved.

Visits of experts to the field teams is good for the programme in general and all monitoring personnel can recognize areas requiring outside help. The hydro-biologist would also be able to inform all the teams of the objectives of such visits and ensure that relevant subsequent reports are distributed.

2. RECOMMENDATIONS FOR FUTURE PROGRAMMES

2.1 Monitoring sites

The choice of sampling station is firstly a function of access throughout the year. The sites also need to be representative of important parts of the treated river and a previous study is indispensible for the selection.

An expert with experience of the sampling problems and, preferably of the region, is needed for counselling the local team.

It is not recommended to choose stations in the immediate proximity of villages and camps having substantial fisheries. This is not conducive to optimum study because of pollution, overfishing and disturbance to both parties. It is also important to know the level of fishing activity in the river basin, if such knowledge is available, and the hydrological regime.

It also is saving time at the start of the programme if a systematic inventory is carried out by an expert.

2.2 Methodology

Until the present time the monitoring protocol assessed the variation in CPUE and K by a battery of 5 gill nets with different mesh sizes. The experience of five years lead is to propose certain modifications, namely the addition of three more mesh sizes. The standard battery should contain the following mesh sizes: 12.5, 15, 17.5, 20, 22.5, 25, 30 and 40 mm.
length of one side. The 12.5 and 15 mm allows better estimation of the annual recruitment of fish. Moreover, a good sample of juveniles and small species is beneficial as these are a priori more susceptible to insecticide. We also recommend a wider survey, each year, in some river basins at the end of the flood. These studies will permit an improvement of the knowledge of the fish communities. For this it is necessary to use other fishing techniques, such as cast nets and electric fishing and fisheries investigation.

It is also recommended that for the pre-treatment and 2-years post-treatment period, an investigation of the diet and fecundity be carried out for the main species. After this period, these investigations could be carried out every two years. Chemical monitoring for the accumulation of insecticides can be carried out at the same time.

2.3 Calendar of operations

We propose the time schedule in the accompanying diagram. After the installation of the team and choice of station, an intensive surveillance should be carried out two years before and two years after the start of treatment. The frequency of visits should be every three months to the principal station. After this period the station should be sampled twice a year, before and after the flood. If there is any doubt about the action of the insecticide this frequency is maintained. On the other hand, if an effect is not detected after two years, the surveillance may be reduced to once per year after the flood.

Finally, if a new insecticide is used the intensive monitoring is re-established.

3. CONCLUSIONS

Because of the economic and ecological importance of fish populations, it is necessary to carry out surveillance in areas where insecticides are being used to ascertain any important effects on non-target fauna. Any meaningful programme must take account of delayed effects, the longevity of the species and long-term natural variations.

In the design and execution of such a monitoring scheme it is important to create a balance between scientific desirability and practical necessity. A minimum programme of observation includes studies on population size, structure and key work on the biology of the important species. The logistic problems are great but we consider that the enclosed recommendations represent this minimum effort required to assess any changes.
length of one side. The 12.5 and 15 mm allows better estimation of the annual recruitment of fish. Moreover, a good sample of juveniles and small species is beneficial as these are a priori more susceptible to insecticide. We also recommend a wider survey, each year, in some river basins at the end of the flood. These studies will permit an improvement of the knowledge of the fish communities. For this it is necessary to use other fishing techniques such as cast nets and electric fishing and fisheries investigation.

It is also recommended that for the pre-treatment and 2-years post-treatment period, an investigation of the diet and fecundity be carried out for the main species. After this period, these investigations could be carried out every two years. Chemical monitoring for the accumulation of insecticides can be carried out at the same time.

2.3 Calendar of operations

We propose the time schedule in the accompanying diagram. After the installation of the team and choice of station, an intensive surveillance should be carried out two years before and two years after the start of treatment. The frequency of visits should be every three months to the principal station. After this period the station should be sampled twice a year, before and after the flood. If there is any doubt about the action of the insecticide this frequency is maintained. On the other hand, if an effect is not detected after two years, the surveillance may be reduced to once per year after the flood.

Finally, if a new insecticide is used the intensive monitoring is re-established.

3. CONCLUSIONS

Because of the economic and ecological importance of fish populations, it is necessary to carry out surveillance in areas where insecticides are being used to ascertain any important effects on non-target fauna. Any meaningful programme must take account of delayed effects, the longevity of the species and long-term natural variations.

In the design and execution of such a monitoring scheme it is important to create a balance between scientific desirability and practical necessity. A minimum programme of observation includes studies on population size, structure and key work on the biology of the important species. The logistic problems are great but we consider that the enclosed recommendations represent this minimum effort required to assess any changes.
REPORT OF FISH POPULATIONS IN RIVERS OF
IVORY COAST AND GHANA

PART I:
Fish communities of Ivory Coast rivers treated by temephos
(C. Lévêque, D. Paugy & J.-M. Jestin)

PART II:
Observations on fish populations in Abate-treated rivers in Northern
Ghana (E. K. Abban, C. P. Fairhurst & M. S. Curtis)

PART III:
Fish monitoring in West African rivers - problem and perspectives
(E. K. Abban, C. P. Fairhurst, C. Lévêque & D. Paugy)

February 1982
REPORT OF FISH POPULATIONS IN RIVERS OF
IVORY COAST AND GHANA

PART I: Fish communities of Ivory Coast rivers treated by temephos
(C. Lévêque, D. Paugy & J.-M. Jestin)

PART II: Observations on fish populations in Abate-treated rivers in Northern
Ghana (E. K. Abban, C. P. Fairhurst & M. S. Curtis)

PART III: Fish monitoring in West African rivers - problem and perspectives
(E. K. Abban, C. P. Fairhurst, C. Lévêque & D. Paugy)

February 1982