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Report of the

PILOT WORKSHOP ON THE APPLICATION OF BIOTELEMETRY TO FISH STUDIES FOR THE MANAGEMENT OF INLAND FISHERIES IN WEST AFRICA

Sélingué, Mali, 29 January – 10 February 2001

Institute of Research for Development

Office for Rural Development of Sélingué

Institute of Rural Economy of Mali

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organized by the
Institute of Research for Development (IRD)
Institute of Rural Economy of Mali (IER) and the
Office for Rural Development of Sélingué (ODRS)
with the support of the University of Liège and FAO

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PREPARATION OF THIS DOCUMENT

This is the report of the Pilot Workshop on the Application of Biotelemetry to Fish Studies for the Management of Inland Fisheries in West Africa which took place in Sélingué, Mali, from 29 January to 10 February 2001. Etienne Baras, Research Associate of the Belgian FNRS at the University of Liège, Vincent Bénech, Researcher in ichthyology with IRD in Bamako, and Gerd Marmulla, Fishery Resources Officer in the Fisheries Department of FAO in Rome collaborated in the production of this report.

We wish to thank the Institute of Rural Economy of Mali (IER) and the Office for Rural Development of Sélingué (ODRS) for organizing and hosting this workshop. We also wish to thank ATS Advanced Telemetry Systems Inc., AVM Instrument Company Ltd., and Star-Oddi for their much appreciated support, which included the donation of some equipment.

Distribution:

All members and associated members of FAO
Participants at the Pilot workshop
Other interested countries and national and international organizations
FAO Fisheries Department
Fisheries experts in FAO regional offices

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ABSTRACT

The pilot workshop on the application of biotelemetry to fish studies for the management of inland fisheries in West Africa was held on the premises of the Office for Rural Development of Sélingué (ODRS) in Sélingué, Mali, from 29 January to 10 February 2001. The workshop was organized by the Institute of Research for Development (IRD, France), and particularly by its Bamako-based centre, in cooperation with the Institute of Rural Economy of Mali (IER) and the Office for Rural Development of Sélingué (ODRS), with the support of the University of Liège (Belgium) and the Food and Agriculture Organization of the United Nations (FAO). The participants came from Benin, Burkina Faso, Côte d'Ivoire, Guinea and Mali. The aim of the workshop was to improve understanding of, and disseminate, biotelemetry, which is a very useful tool for the collection of the more precise information essential for improved sustainable management of aquatic resources.

The theoretical aspects studied included the operation of transmitters, antennae and active physical tags (biotelemetry transmitters and data storage tags), fish anaesthesia, tag attachment, effects of tagging on behaviour and physiology, transmitter retention, basic principles of radio and acoustic signal propagation, positioning of transmitters, as well as cartography and related mathematical principles.

Practical and group work concentrated on anaesthesia and tagging, operating receiving stations and transmitter search, and using biotelemetry transmitters. A test study was undertaken to familiarise participants with the different methods of positioning, area marking and cartography, as well as using data storage tags.

Prior to project definition by participants, a seminar was held to review the various methods that can be used to study the behaviour of fish in their natural environment, emphasizing their particularities and complementarity to biotelemetry.

All participants presented and improved the project proposal that they had prepared before the workshop and which was a vital element in the process of selecting candidates.

CONTENTS

PREFACE

1. Biotelemetry - remote measurement of biological variables - is a vital tool in order to quickly obtain information on the biology of fish in the natural environment, as shown by the growing number of studies which being undertaken using this technique in Europe and North America. It has been applied much less to tropical freshwater fish species, mainly because its potential is poorly known and there is a lack of specialized training in this field. The idea of diffusing information on biotelemetry to ichthyologists and fisheries managers in tropical areas arose as soon as discussions between Vincent Bénech (IRD) and Gerd Marmulla (FAO) began in 1997. This idea was presented to the European biotelemetrist community in a paper given at the third Fish Telemetry Conference in Norwich in June 1999, which was followed by a mini-workshop attended by E. Baras (ULg, Belgium), V. Bénech (IRD, France), M. Gerlier (Rhine Salmon Association, France), T.G. Heggberget (NINA – Trondheim), G. Marmulla (FAO) and V. Thorsteinsson (HAFRO, Iceland). This mini-workshop identified the need to disseminate information on biotelemetry in a more detailed and concrete way, linking theory to practice within a more structured training framework.

2. In this way, the idea of this pilot workshop on aquatic biotelemetry applied to fisheries management in tropical areas was born. The importance of inland fisheries in Western Africa, together with IRD experience in tropical ichthyology and fish radio-tracking in this region, provided the fishery interest and the logistics which were essential for the organization of this pilot workshop. The River Niger basin, and especially the Malian part of the basin, was an ideal host. The idea was given further shape when, through IRD-ODRS-IER contacts, the site of Sélingué was proposed as a venue for the workshop. Sélingué is one of the main reservoir lakes and fishery sites in Mali and the choice appeared all the more judicious in that it offered all the facilities required for conference organization, experimentation on cultured fish as well as the hosting of participants.

3. Following these contacts and during the visit of G. Marmulla to Mali in March 2000, the structure of the workshop became clearer. It was finalized in scientific, logistic and financial terms during a meeting between E. Baras, V. Bénech and G. Marmulla held on 19 April 2000 at IRD headquarters in Paris. During the following months, potential participants were contacted informally whilst each organizer carried out the tasks that they had been given. The final coordination meeting took place in the Aquaculture Station of Liège University in Tihange in November 2000. It was then that it was thought necessary for the participants to be able to access the information given during the workshop in a more structured and especially a more permanent way. A first draft of a handbook of aquatic biotelemetry followed, written in French for this first workshop. The three years of planning and ten months of intensive preparation necessary for this pilot workshop resonate throughout this report.

OPENING OF THE WORKSHOP

4. The pilot workshop on the application of biotelemetry to fish studies for West African inland fisheries management was held in the buildings of the Office for Rural Development of Sélingué (ODRS) in Sélingué, Mali, from 29 January to 10 February 2001. The workshop was organized by the Institute of Research for Development (IRD, France) and in particular by its center in Bamako in cooperation with the Malian Institute of Rural Economy (IER) and the Office for Rural Development of Sélingué (ODRS). Also involved was the University of Liège in Belgium and the Food and Agriculture Organization of the United Nations (FAO).

The list of resource persons and participants from Benin, Burkina Faso, Côte d'Ivoire and Mali is included as Annex 1. The workshop prospectus and agenda are presented in Annexes 2 and 3.

5. The pilot workshop opening ceremony was held in the IRD center building in Bamako on 29 January 2001 in the presence of representatives from IER, ODRS, DNAER[1], the University of Liège and FAO. The president of the opening session, Professor J. Brunet-Jailly, IRD representative in Mali, welcomed partner organization representatives as well as IRD managers and participants from five countries in Western Africa. In his opening speech Professor Brunet-Jailly recalled the long tradition of IRD in Mali and reviewed the most important aspects of this scientific relationship. In particular, in the context of this workshop, he highlighted the importance of cooperation with Malian partners, especially with IER and ODRS, and also with international organizations such as FAO. He then wished the workshop all possible success.

6. The IER representative, Mr N'Diaye, also welcomed the participants and the distinguished guests present. Having described the restructuring of his Institute, Mr N'Diaye outlined the sixteen different IER research programmes and stressed the importance of the workshop for the IER which is involved in fishery management through its Fishery Research Programme.

7. Dr Vincent Bénech, researcher in ichthyology with IRD in Bamako, presented a summary of the studies undertaken collaboratively with IER on the migratory behaviour of catfish *Claria anguillaris* in the lower delta of the River Niger. This study, which was the first application of radiotelemetry in Mali, aimed at obtaining bio-ecological information that could not be obtained using standard investigative tools in the vast floodplain of the River Niger.

8. Mr Gerd Marmulla, a fish resource specialist in the Fisheries Department of FAO Rome, thanked the Institute of Rural Economy and the ODRS for hosting this workshop (Annex 4). He also thanked the Institute of Research for Development for organizing this workshop so efficiently and making available considerable human and material resources. Mr Marmulla stated that the aim of this workshop was to increase and diffuse knowledge on biotelemetry, a very useful tool in obtaining the more precise information which was essential for improved sustainable management of aquatic resources. He added that he was very pleased that Mali had welcomed this workshop as inland fishing was very important for this country where 80 to 130 000 tonnes of fish were caught every year. Moreover, Mali had already acquired some experience in radiotelemetry as was demonstrated by Dr Bénech in his presentation.

9. The general importance of biotelemetry, as well as the objective and agenda of the workshop, were presented by Dr Etienne Baras, research associate of the Belgian FNRS at the University of Liege. The efficient use of biotelemetry depends on mastering biological, physical and mathematical parameters central to the tagging of fish, to their behaviour, to the propagation of radio and acoustic waves in an aquatic environment and to the statistical data analysis underlying fishery management recommendations. Dr Baras mentioned that these key factors, the mastery of which determines the success of research projects, would be

[1] National Directorate of Rural Development and Equipment

analysed in detail during the workshop, in the context of seminars and practical sessions so that participants could develop projects involving the use of biotelemetry.

10. The opening of the workshop was followed by refreshments in the IRD garden. Photo 1 shows the trainees, the trainers and the distinguished guests who attended the opening ceremony of the pilot workshop in the IRD centre in Bamako. A minibus transferred the group to Sélingué in the afternoon. The same evening, a first round table provided an opportunity for the participants and the main resource people (Messrs Etienne Baras, Vincent Bénech, André Mahieux, Gerd Marmulla and Jean Raffray) to give a brief account of their background and the reasons for their interest in participating in the workshop.

FACILITIES IN SELINGUE

11. For the duration of the workshop, the Office for Rural Development of Sélingué offered the use of its conference room located in the administrative complex of Kangaré together with laboratories, ponds and reservoirs located on the fish farm at the base of the dam. The conference room was prepared by the training team so that it could be used for theoretical sessions and as a computer workshop. Four desktop and three laptop computers were available. Discussions on theoretical aspects and computer-based sessions were held in the conference room. The ODRS fish farm was the main center for all practical work concerning fish tagging, post-operative behaviour checks and use of biotelemetry equipment. The monitoring of the behaviour of transmitter-tagged fish in their natural environment was undertaken within the framework of a test study in the Sélinguéni pond, on the left bank of the river Sankarani, downstream from the Sélingué dam.

12. On the second day of the workshop, Mr Hinna Haïdara, Assistant Director General of the ODRS based in Sélingué, kindly presented the structure of the Office for Rural Development of Sélingué and its responsibilities in terms of lake management. He mentioned the multiple importance of the Sélingué lake for the regional economy, i.e. electricity production, irrigation, fishing and improving the navigability of the River Niger. He stressed that the lake, with about 4 000 tonnes of fish produced each year, was the second most productive area in Mali, after the Niger inland delta. The socio-economic figures presented highlighted the importance of fishing for the sustainable livelihoods of the rural population of Sélingué.

THEORETICAL ASPECTS OF BIOTELEMETRY

13. The topics covered in theory included the operation of transmitters, antennae and active physical tags (biotelemetry transmitters and data storage tags), fish anaesthesia, tag attachment, effects of tagging on behaviour and physiology, transmitter retention, basic principles of radio and acoustic signal propagation, positioning of transmitters, as well as cartography and related mathematical principles. Only the broad outline of each of these aspects is presented in this report. A more exhaustive description is available in a manual of some 160 pages developed during the preparatory phase of the workshop (E. Baras, V. Bénech and G. Marmulla) and distributed to all participants at the start. The syllabus contents can be found in Annex 5 of this report.

Fish tagging

14. The first seminar focused on procedures for attaching telemetry transmitters or data storage tags to fish. Telemetry transmitters contain an energy source and transmit, on a precise wavelength, a signal which can inform the observer of the position of the animal. When a sensor is coupled to the transmitter, information on the measured variable (depth, temperature, activity) can be deduced from variations in the signal pulse rate. Data storage tags, on the other hand, do not transmit a signal, but record data in an internal memory. These data are only available for reading and decoding after the animal has been recaptured. Photo 2 shows telemetry tags.

15. Telemetry transmitters and data storage tags can be fixed externally, inserted inside the stomach or inserted into the peritoneal cavity either by surgical operation or via the gonoduct. Each method has its intrinsic, environmental or specific advantages and disadvantages, and these must be taken into account when a study is established. Intragastric insertion is the least invasive method but can affect feeding behaviour. External attachment is usually adequate in the short term but causes problems in the longer term especially in running water. Intraperitoneal implantation is more invasive, as it generally requires surgery, but once the abdominal wall is healed, it is the safest method in terms of both the study success and fish health. Insertion into the peritoneal cavity through the gonoduct is only possible in some species. Because of the increased lifespan of telemetry transmitters and data storage tags, intraperitoneal insertion has become the most popular attachment method. The success or failure of this method often depends directly on the adoption of appropriate prophylactic and therapeutic measures, the choice of the incision site determined on the basis of histopathologic criteria and the method used to close the wound (suture, adhesives, cyanocrylates, clips) taking into account healing dynamics in the particular species. These different aspects have been tested on a wide range of fish species from temperate and tropical regions. Photos 4 and 5 show a tagged tilapia.

16. The second seminar reviewed biases associated with tagging, including tag shedding. In the case of external fixing, an early and non-intentional loss may be the result of loose knots, skin erosion or cuts in the dorsal muscles made by the attachment threads, especially in fast-flowing rivers. In fish with intragastric tags, peristalsis or (mainly) regurgitation can cause rejection. The frequency of regurgitation, and the delay between tagging and tag loss, both vary considerably depending on the species and the relative tag size. Tag expulsion can also occur for tags implanted into the peritoneal cavity, either through the incision, through an intact area in the abdominal wall, or, in some species, through the intestine. The different techniques and procedures which allow rejection probability to be minimized were analysed.

17. In discussing the impact of tags on fish physiology and behaviour, stress was laid on the fact that it was indispensable to take into account the characteristics of the species being studied, especially the characteristics of the swim-bladder (physostomatous and physoclistic species). Biases specific to external, intragastric and intraperitoneal attachment methods were also discussed. The risk of transposing conclusions from one species to another was stressed together with the need for feasibility studies in the case of species for which no information is available.

Detecting biotelemetry signals

18. Two seminars focused on the propagation of radio and acoustic waves in the aquatic environment. Their main objective was for participants to be able to undertake the calculations required to define study feasibility and the best strategy to adopt.

19. Radio signals (30-170 MHz) have omnidirectional propagation in the aquatic environment, but only wave vectors at an angle less than 6° to the perpendicular at the water-air interface can cross this interface and disperse in the air where they can be detected by an aerial antenna connected to a receiving station. The signal can only be detected if the accumulated damping during signal propagation has not reduced the signal/noise ratio below the receiver's threshold sensitivity level. The various damping factors (related to propagation in the water, at the water-air interface, in the air, in the receiving antenna and in the cabling) were reviewed. This review included equations which can be used to model damping as a function of environmental characteristics (such as depth, conductivity, transmission frequency, etc.). The main restrictions on the propagation of radio waves are the depth of transmission and increasing water conductivity. Thanks to these mathematical foundations, it became possible for participants to calculate the minimum energy required by transmitters in order to set up a study in different environments or else to adapt their tracking strategy to particular transmitters and to environmental conditions. Participants were able, in a practical session, to apply their theoretical knowledge of radio wavelength propagation in the definition of research projects.

20. When considering the choice of frequency bands in planning a project using radiotelemetry, it is strongly recommended to study carefully the existing possibilities. Of course, first it will be necessary to find out what bands are legally available in the country or countries of the project.

21. The second seminar on propagation dealt with acoustic wavelengths (30-80kHz). In acoustic telemetry, the transmission frequency is inversely proportional to the diameter of the piezo-electric transducer, so that tagging of small fish can only be done with high frequency transmitters and these suffer more damping in their propagation in an aquatic environment. The speed with which sound is propagated varies according to salinity and temperature. Any interface between environments with different propagation speeds gives rise to reflection and refraction of the signals so that thermoclines, haloclines and immersed macrophytes are major barriers to the propagation of acoustic waves. It is also for this reason that acoustic signals absolutely must be detected by an immersed hydrophone. As with radio waves, the damping factors of acoustic waves were reviewed and modeled as a function of environmental conditions. In a practical session, participants used these mathematical models to decide whether studies using acoustic biotelemetry were feasible in particular environments.

Localizing transmitters, positioning fish in their habitat

22. The next seminar concerned the problem of the positioning of the signal-transmitting source by an operator. To this end, reception diagrams of directional and omnidirectional antennae or hydrophones were reviewed and compared with associated receiving strengths. The intrinsic performance of directional systems, in terms of opening angle and reception gain, was analysed according to the context of the biotelemetric study, in the case of both

automatic passive monitoring stations and active tracking by boat or vehicle. The participants were then able to determine objectively several key elements of the study strategy in a practical session, in particular: the type of antenna (dipole, loop, H-Adcock, Yagi) best adapted to the environment; the number of frequencies that could be scanned by a receiving station and the speed at which a motorized team could progress without running the risk of not detecting the signal. Should environmental conditions become too restrictive for one of the variables concerned, technical alternatives were considered, particularly receiving stations linked to antenna multiplexors (or switch boxes) and the use of coded transmitters operating on a similar carrier frequency.

23. The accuracy of positioning by triangulation is a matter of distance between the receiver and the transmitter, and of angle between the different bearings that serve to localize the transmitter by triangulation. Depending on the study context, positioning can be worked out from landmarks whose coordinates are known (e.g. area markers) or precise points whose coordinates are determined *in situ* (e.g. GPS). Some software utilities, specifically developed for radio-tracking applications, were presented and their mathematical principles set out so that they could be used in the practical sessions. Other alternatives were considered for the positioning of mixed (radio and acoustic) transmitters, and for the automatic positioning of acoustic transmitters by an array of omnidirectional hydrophones. In the latter case, positioning is achieved by an algorithm which deduces the position of the transmitter from the respective times of arrival of the signal at the hydrophones of the array (the inverse principle of hyperbolic navigation). With the combination of angular, metric and temporal information, the observer can determine the dimensions of the error polygon around the true position of the transmitter, this element being crucial to determine the collection strategy for cartographic and habitat data.

24. Fish locations are later positioned on habitat maps, using Cartesian coordinates. The home range or daily activity area can thus be calculated by one of the following methods: minimum convex polygon, bivariate statistics (i.e. ellipses with an N% confidence interval) or squares on gridded maps. The precision of the localization and the structure of the database (binormality constraint for ellipses) dictate the choice of method. It is also crucial, within the framework of this analysis, that each location of fish by telemetry is equally representative in time and therefore the data must be collected at regular intervals. The choice of this interval depends on the biology of the species being studied and the study logistics. In practice, it is recommended to use daily localization as a basis, complemented by 24-hour cycles wherein fish activity is described as often as possible, but still on a regular basis. Once this database is available, it is possible, via subsampling, to determine the importance of information loss through the increase in time intervals between successive observations. This loss can be compared with the budgets needed to undertake studies with different localization frequencies and hence a project rationale can be determined. This procedure can also be applied to data collection during a daily cycle. It is also very useful when it comes to programming data storage tags, programmable telemetry transmitters and automatic listening stations as it is a good way to optimize the tag lifespan with regard to the useful frequency of data collection. Photos 6 and 7 show trainee teams detecting signals.

CHOICE OF ALTERNATIVE AND COMPLEMENTARY STUDY METHODS, PROJECT DEFINITION

25. During the preceding seminars, participants were able to grasp the advantages, performance levels and limitations of biotelemetric tools within the framework of inland fisheries management. In several cases, mainly when the fish size was too small, biotelemetry could not be applied. In other cases, it cannot, on its own, answer all the questions arising in a study project but it greatly facilitates the application of other study and measurement tools. The objective of this seminar, which preceded project definition by participants, was to review the various methods that can be applied to study the behaviour of fish in their natural environment, whilst insisting on their specificity and complementarity with regard to biotelemetry:

- Hydroacoustics, resistivity counters
- Intrinsic genetic and chemical tags (body hard parts)
- External passive tags
- Internal passive tags
- Transponders

26. This inventory was rounded off with a list of standard questions which should allow participants to make a judicious choice of method to apply to different types of project and was illustrated through some case-studies of projects where biotelemetry had been used, as the main or secondary method, in studying the biology of fish and their relationship with the environment. Experimental procedures and criteria for choosing methods of tagging and monitoring were reiterated in the presentation of these projects.

PRACTICAL AND GROUP SESSIONS

27. The organization of these sessions during the workshop is described sequentially. In practice, sessions were repeated several times so that participants could improve their know-how in the fields that required more practice. The chronological list of the various tasks can be found in the agenda (Annex 3).

Anaesthesia and tagging

28. In the first practical session, participants learnt how to stitch on a polystyrene plate (photo 8) in order to understand the procedure to close an incision. They then practiced anaesthetics and abdominal surgery on cichlids (tilapias) and clariids (sharptooth catfish *Clarias gariepinus*) stocked at the ODRS fish-farm. These two groups of species were chosen as they are representative of West African fisheries. This operation was repeated during the workshop so that participants could master implanting telemetry transmitters and could test various fish size and tagging equipment (suture threads, needles of different types). Tagged fish were released into a pond through which there is a continuous flow of water from the Sélingué dam.

29. Fish (*Tilapia, Clarias and Auchenoglanis* sp.) tagged by training staff and equipped with data storage tags and telemetry transmitters were also released in the pond, their signals being recorded by a passive listening station set up within the boundaries of the fish-farm. Data loggers recorded the water temperature at the surface and at depth as well as the light

intensity at the water surface every five minutes for a week. The first objective of this operation was for participants to be able to compare different methods of biotelemetric measurements (radio transmitters vs. data storage tags) and to compare biological and environmental information during group sessions (cf. section "use of telemetry transmitters").

30. During the second week of the workshop, the pond was drained and tagged fish were checked and participants could evaluate objectively the quality of the tagging and any improvement they needed to make before applying the technique in a project.

Operating receiving stations and transmitter search

31. The operation and use of receiving stations was summarized and illustrated with various types of receivers and antennae (loop, Yagi, M-Yagi) operating on different carrier frequencies (49 and 151 MHz). In order to familiarize participants with transmitter search at both long and very short distance, two sessions of "fox hunting" (i.e. searching for scattered transmitters; photo 9) were organized around the lake of Sélingué and within the ODRS fish-farm. Participants were thus able to assess their progress from one session to the next and were confronted with the different practical situations that they are likely to come across during projects, whether localizing live fish or recovering transmitters from fish caught by fishermen or predators.

Use of biotelemetry transmitters

32. Participants were able to use three main types of telemetry transmitter, measuring temperature, depth and fish activity. For each type of transmitter, they undertook a calibration which consisted of determining the variations in the interpulse interval in connection with the measured variable. Depth calibration was done in the lake of the Sélingué dam (0-18m) and the temperature calibration from a mixture of waters of different temperatures (15-32°C). In the case of activity transmitters, the calibration was established from static and active transmitters in order to determine the minimum and maximum pulse rates and complementary measurements were made on fish which had been tagged and were held captive in the aquarium so as to identify the minimum movements necessary to trigger a fast pulse rate. Calibration curves were then analysed on a computer in order to determine linear regressions to be used to interpret results collected by an automatic passive listening station.

33. An automatic signal recording station, consisting of an ATS Challenger 2100 receiver, a DCC II computer and a loop antenna (photo 10), was programmed to record signals from fish stocked in the ODRS pond during a 24 hour-cycle, for uninterrupted recording periods of 30 seconds per fish every five minutes. At the end of the recording, participants had the opportunity to download the station, to test if initial settings were adequate regarding reception gain and noise rejection, and finally to analyse the data collected by data storage tags and data loggers which measured the surface and depth temperatures.

34. These different stages gave the participants a better idea of the high level of performance of automatic passive listening stations but also of the need to program meticulously the reception gain in order to avoid biased information in their databases, which could modify the interpretation of the biological data.

Test study

35. A full-scale exercise, involving all the training staff and participants, was organized in the Sélinguéni pond. It aimed to familiarize participants with the different methods of positioning, area marking and cartography, this study consisted in:

- Tagging three fish of different species (*Bagrus bajad, Clarias gariepinus* and *Tilapia zillii*) with biotelemetry transmitters of the activity/inactivity type and releasing them in the pond at the start of the workshop.
- Mapping the pond by using wooden marks and three alternative methods for determining their respective positions (theodolite, GPS and successive polar coordinates combining compass and pentadecameter; polygon of Sélinguéni pond in Annex 6).
- Undertaking bathymetric transects.
- Comparing on the computer the accuracy of the three mapping methods.
- Positioning fish and measuring their activity rate during a six-hour observation period, on the basis of one localization per fish and one 30-second activity measurement every 10 minutes.
- Uninterrupted measurement (i.e. 30-second recording every minute) of the activity rate of one of the three fish (*Clarias*) by an automatic listening station.
- Determination of tracked fish positions on the computer
- Comparison between information collected by the automatic station and by the operators to determine how representative are the samples collected every 10 minutes compared to uninterrupted measurements

36. By combining these different operations, participants were able to put into practice various important aspects of the theoretical teaching and to integrate them into a logical sequence essential to undertaking a structured program.

Use of data storage tags: DST

37. At the outset of the workshop, three fish (*Tilapia, Clarias* and *Auchenoglanis* sp.) were fitted with data storage tags (DST 200 and DST 300, Star-Oddi). These tags were attached dorsally and the fish were released into the ODRS pond. All the tags measured, at one-minute interval, the depth and ambient temperature of the habitat occupied by the fish. The tag on the catfish *Clarias gariepus* also measured the orientation of the fish compared to the horizontal, the difference between successive measurements providing an index of activity.

38. When the pond was drained, participants were able to compare the effects of external attachment (for DSTs; photo 11) to those of surgery (for telemetry transmitters of similar weight; photo 12) on fish health. Participants were then involved in the different stages of the procedure for downloading the data storage tags (cutting of the tags [photo 13], withdrawal of the internal memory, downloading to the computer [photo 14]) and they began to analyse the biological data in comparison with environmental information provided by data loggers and biotelemetric data collected by the automatic station.

39. From the analysis of the data collected by different telemetric systems, participants were able to compare their respective levels of performance in terms of accuracy, safety and recovery guarantee, which are essential factors in defining the structure of a project.

ANNEX 1

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ANNEX 2

Prospectus

Application of biotelemetry to fish studies for inland fishery management in West Africa

Pilot workshop in Sélingué (Mali), 28 January - 10 February 2001

Marine and freshwater aquatic resources, especially fish, have been exploited for hundreds of years by inland fisheries, especially in tropical regions where fish consumption may reach 500 g per inhabitant per day. The spectacular increase in the human population of the intertropical regions has been accompanied by a growing intensification of fishing and increasingly obvious environment changes in terms of chemical or organic_pollution, or hydrological changes following the building of dams used essentially to produce hydroelectric energy. These changes are understandable and contribute to the economic development of intertropical regions, but they have interfered with ecological processes, especially with fish requirements in terms of habitat and migration. They have had or are going to have an impact on inland fisheries and on food security, not to mention the consequences for the biodiversity of non-exploited species. This objective assessment shows that there is an urgent need to collect accurate data on ecology and fish behaviour, in natural as well as in modified environments. Such data are essential for the integrated management of natural resources, combining biodiversity preservation, efficient fishery management and sustainable activities and livelihoods.

Among the techniques and methodologies that can be applied, biotelemetry is particularly interesting because of the accuracy of the data collected and the speed at which it can be done. The term biotelemetry covers a variety of tools and methodologies (radio and acoustic tracking) which allow the collection of data on fish bio-ecology (home range, habitat use, seasonal and daily migrations). Such data, which are crucial to understanding the biology of fish, to preserving their biodiversity and to managing inland fisheries, are more difficult to obtain with conventional observation and sampling techniques and methods whose efficiency depends on environmental conditions.

Some 1 500 studies, based on telemetry techniques, have been carried out in Europe, North America, Australia and Eastern Asia. In comparison, the total number of studies in tropical freshwaters remains very low, despite the importance of inland fisheries and the relatively favorable environmental conditions to undertake such studies. The relative scarcity of such studies, despite their obvious interest and the crucial information they can provide, originates from the poor knowledge of these technologies, and their reputation for being expensive and in particular complex - the more so because the scientific and technical training that would allow them to be demystified is rare or does not exist. In the context of sustainable development, it is thus imperative to put these techniques and this theoretical and practical knowledge at the disposal of researchers in tropical regions and in other interested developing countries, so that they can use them in an optimal way.

This pilot workshop, which is being organized in Sélingué, Mali from 28 January to 10 February 2001, focuses on areas such as education, and assistance to research, management and development. It will be attended by eight trainees from French-speaking African countries who are interested in developing short or medium term research programmes concerned with optimizing the management of inland aquatic resources and which cannot be undertaken without mastering "the telemetry tool".

In Mali, host country for this pilot workshop, the exploitation of fish resources is of great importance. Fish production exceeds 100 000 tonnes per year and represents one of the main income sources for the country. The Directorate of the Malian Institute of Rural Economy (IER) has agreed to co-host the workshop in collaboration with the Office for Rural Development of Sélingué (ODRS). The ODRS management offered the use of its infrastructure in Sélingué. IRD, ULg and FAO will contribute, in terms of financial and human resources, to the organization of this pilot workshop. The workshop will alternate between theoretical and practical aspects, from project development to data analysis and formulating recommendations for research programmes on resource management (cf. Agenda).

After the workshop, the projects developed by the trainees will be monitored by the organizers in order to disseminate these activities and to maintain a fruitful relationship between partners. The workshop and the activities that will directly or indirectly originate from it could lead on to a discussion workshop during the "*4th Conference on Fish Telemetry in Europe*" where the advantages of the approach adopted by, and any problems encountered in, the pilot workshop can be discussed. Finally, it may be possible to organize this type of workshop in other regions of the world that wish to benefit from this kind of training (Asia, Latin America, English speaking African countries, Eastern Europe).

ANNEX 3

Agenda

Sunday 28 January 2001
Participants arrive in Bamako

Monday 29 January 2001
Opening ceremony and welcoming of participants
Transfer to Sélingué
Round table: introductions and participants expectations

Tuesday 30 January 2001
Telemetry tags
Fish anaesthesia and tagging

Practical sessions on fish anaesthesia and tagging
Round-up of daily progress

Wednesday 31 January 2001
Effects of tags and tagging on fish biology
Basic principles on localizing telemetry transmitters

Practical sessions: transmitter search ("fox hunting")
Round-up of daily progress

Thursday 1 February 2001
Radio wave propagation in the aquatic environment
Calculation of reception range for radio transmitters

Practical sessions: fish tagging and transmitter localization (continued from Wednesday)
Round-up of daily progress

Friday 2 February 2001
Acoustic wave propagation in the aquatic environment
Calculation of reception range for acoustic transmitters

Practical sessions: area cartography and transmitter-equipped fish localization

Saturday 3 February 2001
Radio tracking strategy: choice of waves and frequencies
Use of automatic stations

Cartography and localization: mathematical foundations and application

Sunday 4 February 2001
Free

Monday 5 February 2001

Habitat use by fish: fundamental calculations
Accuracy of localization: calculation and implications for habitat mapping.

Practical sessions: revision
Round-up of daily progress

Tuesday 6 February 2001

Alternative methods to study fish behaviour in natural environment (hydro-acoustics, tagging and recapture, types of tags, selection criteria)
Presentation of a project proposal using the radio-tracking tool by K. DA COSTA

Tracking cycle of tagged fish in the natural environment

Wednesday 7 February 2001

Definition of study projects involving biotelemetry: criteria, structure and implementation
Presentation of a project proposal using the radio-tracking tool by T. KONE

Capture of tagged fish, tagging evaluation, data recovery from electronic recorders (data storage tags and data loggers)
Presentation of a project proposal using the radio-tracking tool by A . CHIKOU
Round-up of daily progress

Thursday 8 February 2001

Biotelemetric data recovery from data storage tags and a biotelemetric automatic recording station
Presentation of a project proposal using the radio-tracking tool of S. ALHOUSSEINI, M.E. DIOP and H. TRAORE
Round-up of daily progress

Friday 9 February 2001

Presentation of a project proposal using the radio-tracking tool of A. TOGUYENI
Presentation of a project proposal using the radio-tracking tool of S. BOUDA

Workshop general debriefing
Workshop official closing ceremony

Saturday 10 February 2001

Return journey to Bamako
View web sites of telemetry equipment manufacturers
Participants leave Bamako

ANNEX 4

Inaugural address: Application of Biotelemetry to Fish Studies for Inland Fisheries Management in West Africa (G. Marmulla, FAO)

Honourable Representative of the Institute of Rural Economy,
Honourable Director of the Office for Rural Development of Sélingué,
Honourable Director of the Institute of Research for Development in Mali,
Dear colleagues, ladies and gentlemen,

On behalf of FAO Director-General, Dr Diouf, and of the FAO Representative in Mali, Mr Ramos, it is my great pleasure and privilege to welcome you all to the opening of this workshop.

We would like to express our sincere gratitude towards all of our partners with whom we have been in close contact over several months in order to organize this workshop. First I wish to thank the directorate of the Malian Institute of Rural Economy who, in collaboration with the Office for Rural Development of Sélingué, agreed to host this workshop so that it could take place in an African country which already has some experience of biotelemetry. Also I would like to thank the directorate of the Institute of Research for Development in Mali as it has put considerable human and material resources at the disposal of this workshop and continues to do so. I also wish to say a special and warm word of thanks to my two colleagues, Dr Vincent Bénech from IRD and Dr Etienne Baras from the University of Liège - also partners in this activity - for their efficient and tireless cooperation over several months.

It is a great pleasure for me to be here today at the opening of this workshop on the application of biotelemetry to fish study in inland fisheries management in West Africa, this workshop being the first of its kind. It is a pilot workshop - and this has nothing to do with flying planes, but means that it is the first time that a workshop on the techniques and use of radio-tracking in Africa has been organized with the support of FAO. This workshop has been organized in order to improve and disseminate our knowledge of the tool of biotelemetry which can be used to generate the more accurate databases that are essential for improved sustainable management of aquatic resources.

The importance of inland fisheries should not be under-estimated and is even increasing in many West African countries, particularly in Mali where 80 to 130 000 tonnes of fish per year have been produced in recent years. Such fisheries thus play an important role in the protein supply to the mostly rural population. It is therefore essential that natural resource managers be able to protect the foundation of fishing, meaning the fish needed for stock renewal in order to ensure sustainable exploitation. Where the biological aspects of fishing are concerned, lack of knowledge about the biology or the behaviour of species that are very popular with fishermen can in some cases be a barrier to sustainability. In order to guarantee the role of fishing as an important source of protein, overexploitation of the resource must be avoided, through improved and appropriate management.

The usefulness of biotelemetry is no longer doubted, it is even taken for granted, especially in North America and in Europe. We are convinced that, in Africa too, biotelemetry can provide data leading to better decisions and therefore improved management. It is for this reason that we are here today. For this workshop, we have only invited participants from French speaking countries, in particular Benin, Burkina Faso, Côte d'Ivoire, Guinea and Mali, because it is really a first test. However, if considered useful, this type of activity, co-funded by FAO, could be repeated to train on the subject other African experts speaking French, English or other languages.

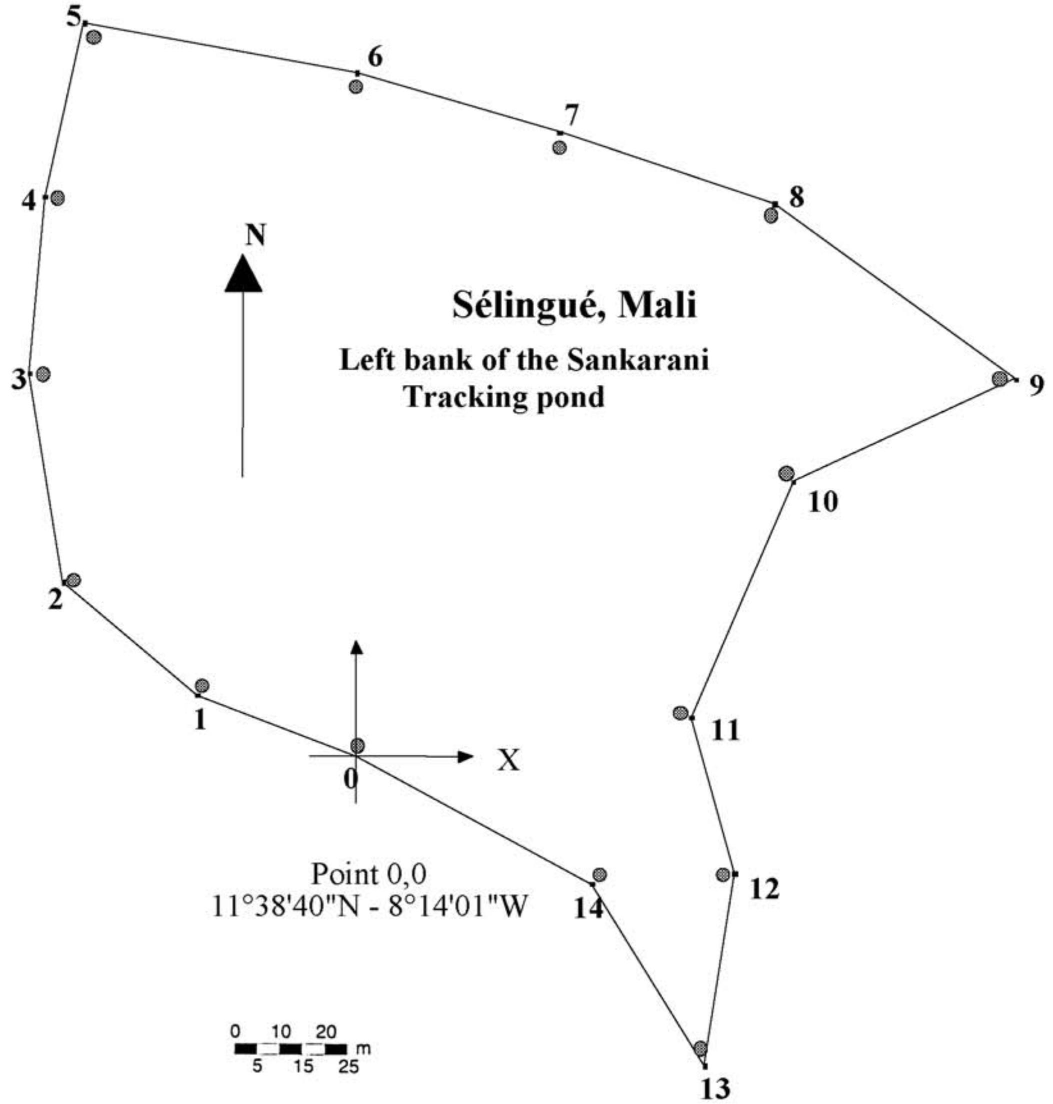
Having set out the objectives, we hope that all the theoretical and practical work to come during the next two weeks will be interesting and useful. My colleague Dr Baras will now explain to you in detail the work programme for the coming days.

ANNEX 5

Contents of the handbook on aquatic biotelemetry

ANNEX 6

Polygon of the Sélinguéni pond



Wooden marks were set on the shore of the pond, and their respective positions were determined using three alternative methods (theodolite, GPS and successive polar coordinates combining compass and pentadecameter).

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ANNEX 7

Material and equipment used during the workshop

Briefcase	
Information leaflets	IRD, IER, ODRS, FAO
Folders + badges	IRD
Photocopied radio-tracking handbook	ULg, IRD, FAO
Dissection case	IRD
1 / 50 000 and 1 / 2 000 000 maps of Sélingué	IRD
Note pad, pen and pencil	IRD
Leaflets on radio-tracking equipment suppliers	ATS, AVM, Star-Oddi
List of participants (address, tel, email…)	IRD
Invitation to the welcome reception at IRD	IRD
Radio-tracking equipment	
2 receivers 151 MHz AVM	IRD
2 receivers 49 MHz AVM	FAO
2 receivers 48-49.9 MHz ATS	IRD
1 ATS Data collection computer (DCC)	IRD
1 receiver 48-49.9 MHz ATS + headphones	FAO
3 Diamant antennae 48-49.9 MHz	IRD
2 M-Yagi antennae 49 MHz	FAO
2 Yagi antennae 151 MHz	IRD
4 headphones	IRD
1 depth option transmitter 48 MHz	IRD
1 active/inactive transmitter 151 MHz	IRD
1 transmitter with temperature option 151 MHz	IRD
1 position based transmitter 49 MHz	IRD
1 active/inactive transmitter 49 MHz	IRD
1 real time activity transmitter 49 MHz	IRD
1 transmitter with temperature option 49 MHz	IRD
2 AVM chargers	IRD
2 AVM Voltage and plug adapters	IRD
1 AVM cigar lighter adapter	IRD
Dummy transmitters (7small, 3 large, external antenna.)	IRD
3 DST 300 (temperature, depth, angle)	IRD
2 DST 300 (temperature, depth)	IRD
20 dummy DST	IRD
DST software for PC-DOS	IRD
Cutter, needles, steel wire	IRD
Teaching equipment	
Conference room	ODRS
Blackboard	ODRS
White and colour chalk	IRD
1 PC + printer	ISFRA
2 PC	IRD
1 Mac Performa 630	IRD
1 lap-top PC	IRD
1 lap-top PC	ULg
1 Powerbook 150	IRD
1 colour printer	IRD
Iomega ZIP for MAC	IRD
3 x 10 1,3 Mo PC disks	IRD
UPS 1000 + cable	IRD
Over Head Projector for acetates	IRD
Video recorder + TV	IRD
VHS cassettes	IRD, ULg

Slide projector	FAO
2 boxes of OHP acetates	IRD
Slides	ULg
Screen	ODRS
Fish stocked in the ODRS fishfarm in SELINGUE	IRD
Oreochromis niloticus (250 g produced by ODRS)	IRD
Clarias gariepinus (500 g to 2 000 g produced by ODRS and local fishing)	IRD, ODRS
Hemisynodontis membranaceus (caught in the lake)	IRD, ODRS
Tilapia and *Sarotherodon* (caught in the lake)	IRD, ODRS
Bagrus bayad (caught in the lake)	IRD, ODRS
Auchenoglanis occidentalis (caught in the lake)	IRD, ODRS
Gymnarchus niloticus (caught in the lake)	
Holding tanks	
3 concrete tanks of 3 m^3	ODRS
1 drainable pond	ODRS
Aquarium of 300 litres	IRD
Field laboratory of the ODRS fishfarm	
Aquarium 300 litres + support desk + accessories	IRD
Dissection tables (2)	ODRS
Small metallic desk	IRD
Electricity: multisocket extension leads	IRD
Desk lamp	IRD
Water: 10 m plastic hose	IRD
400 ml of phenoxy-ethanol + 10-ml syringe	IRD
Biseptine (disinfectant)	IRD
Super glue cyanoacrylate	ULg
Scales 1g to 6 000 g	IRD
2 basins, 1 net for anaesthetics and recovery	IRD
Operating slab	IRD
1 sponge, 2 tea towels, 2 towels	IRD
Nets	ODRS
Boats	
Zodiac	IRD
15 HP Outboard motor	IRD
Life jackets	IRD
Land-based transport	
1 Toyota Hi-Lux double cabin (5 seats)	IRD
1 Toyota plateau (3 seats)	IRD
1 Moped	IRD
Communication	
Satellite telephone + 12V car battery	IRD
Other equipment	
100 Petersen disk tags	IRD
100 Carlin dangling tags	IRD
4 portable batteries + 2 chargers	IRD
Stakes	IRD
Pentadecameter (2+1)	IRD,ODRS
Level	IRD
2 GPS	IRD
2 Walkie-talkies + 1 double charger + 4 spare batteries	IRD
Torch + batteries	IRD
Ice boxes (1+1)	IRD, ODRS