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THE FEASIBILITY OF AND RECOMMENDATIONS FOR ANTI-LARVAL MEASURES AGAINST VECTOR ANOPHELINES IN ZAIRE

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EXECUTIVE SUMMARY

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Consultant services were provided to the United States Agency for International Development (USAID) project "Endemic and Communicable Disease Control (Malaria Component)" by two American Public Health Association (APHA) consultants from June 20 to July 10, 1980. The objective of the assigned task was to assess the feasibility of and recommend anti-larval methods useful for the control of anopheline species affecting the project areas. The team consisted of a medical entomologist and water management specialist. Its efforts were first directed to a search for malariometric and entomological information on the project areas. Field visits were made to determine the technical feasibilty of anti-larval measures under the three ecological settings--urban, rural, and marsh--which were identified as immediate concerns in the project's operational program.

The team encountered both administrative and technical problems. There appears to have been a communication breakdown from the United States backstop in Washington to the USAID mission in Zaire which created problems for the consultants in travel and lodging and which affected the ability of the mission to properly respond to the consultants' needs. Detail on these problems are presented in each consultant's evaluation of the assignment.

The consultants went to Zaire during the dry season, and thus were able to analyze the use of anti-larval methods under mosquito breeding conditions which exist in the project area for less than four months of the year. Although this timing facilitated greatly transportation around the project areas, only maintenance levels of the vector populations were observable. For this reason, the consultants recommend that a similar assessment of requirements for anti-larval measures be made during the wet season.

Other problems encountered during the assignment were associated with indigenous constraints on working in this political entity.

In assessing the potential for applying anti-larval measures in the areas around Kinshasa and Ngidinga, the consultants found that selected application of biological and environmental control methodologies was fairly feasible. Geophysical features (soil types, contour, etc.) of the land in the Kinshasa area are particularly suitable for the application of habitat manipulation, and extensive fish culturing and wet rice cultivation are favorable situations for use of larvivorous fishes. Chemical control methods are not recommended because of recurrent costs and the potential for creating technical problems in the future.

The following are recommended as prerequisites to implementation of anti-larval activities in the USAID project:

1. Recruitment of an advisor in source reduction for Zaire for a period of not less than 18 months. Long-range planning should be the keynote in the objectives of the position, and specific emphasis should be placed on training staff, setting up public demonstrations, and selecting, purchasing, and demonstrating the proper equipment to be used in a comprehensive source reduction program for the country.

2. Establishment of a basic malariometric surveillance program, against which the effectiveness of anti-larval measures on transmission of the disease can be evaluated.

3. Pursuit of the use of Peace Corps Volunteers to carry out retrospective studies for baseline malariometric data in the project areas.

4. Development of a system for recording and analyzing climatic data within the project areas for operational use in anti-larval activities.

5. Commissioning of studies to delineate special target habitats based on sound knowledge of the biology of the target vector species in the operational areas.

For the initiation of specific anti-larval measures in the USAID demonstration project, the following activities are recommended:

1. Initiation of geographical reconnaissance to identify all vector anopheline breeding areas.

2. Establishment of a larval inspectional system to monitor anopheline breeding levels in and adjacent to each of the project areas.

3. Formation of teams to conduct simple habitat manipulation within the pilot study areas.

4. Creation of an educational program to enlist the assistance of the community in the reduction of larval breeding areas through removal of breeding habitats from small plot farms and fish culture ponds.

5. Arrangements for or importation of indigenous larvivorous fish which have been used in anti-larval programs in tropical Africa.

6. Development of a distributional system to ensure the effective delivery of fish to individual anopheline breeding sites (i.e., rice fields, fish ponds, and artificial impoundments).

Of major concern to the implementation of an anti-larval program in the USAID project is the brevity of the time period remaining in the life to the project. The feasibility of superimposing an additional technology on an already understaffed project is questionable.

I. INTRODUCTION

I. INTRODUCTION

Background

In 1975 the United States Agency for International Development in cooperation with the Government of Zaire (GOZ) established an anti-malarial demonstration project designed to test the feasibility of various malaria control methodologies and to train personnel; the ultimate aim of the project was to select appropriate control methodologies applicable to the malaria control effort in Zaire.(1) (2)

Recognizing that Zaire is the third largest developing country in Africa (see Figure 1), and that the constraints discussed by the Strategy Advisory Group are particularly applicable,(3) it is anticipated that the organization and implementation of a nationwide malaria control effort will require an extended period of time (i.e., be commensurate with the development of administrative capabilities and available resources). To achieve specific goals the project must begin with focal programs designed to protect larger concentrations of susceptible populations and develop an organizational structure to support future expansion throughout the entire nation. The status of malaria in Zaire has recently been reviewed by a study team formed to assess the overall strategy for anti-malarial support for tropical Africa.(4) Much of the current information on malaria in Zaire has been included in the report of this group. Additional background information on the country may be found in Syncrisis: The Dynamics of Health, Number XIV: Zaire (5) and the Malaria Eradication/Control Programs in the Sub-Sahara Africa;(2) these documents will not be reviewed in this report.

The complicating role of the human host in the dynamics of malaria maintenance and amplification in Zaire is obvious and can be observed in daily living patterns and seasonal migrations. These elements, as in other tropical areas, are conducive to high levels of man-vector contact. It is also evident that modification of sociological patterns must be considered as integral to the initiation of a total anti-malaria program. The same point must be recognized in developing administrative feasibility. Such modifications are made slowly; therefore, time will be required to set the stage for a national anti-malaria effort.

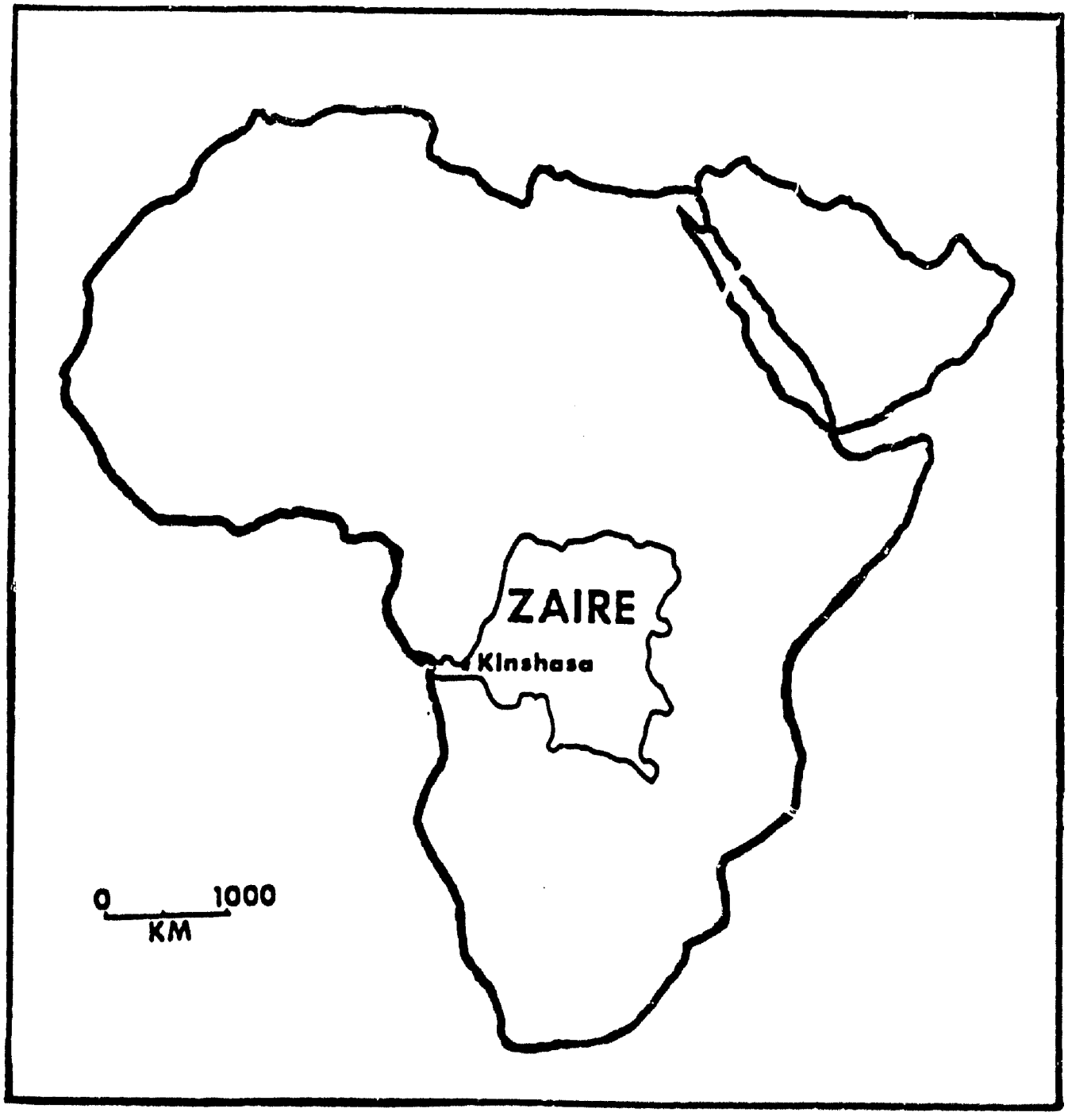
Scope of Work

The following report is a discussion of the feasibility of using anti-larval methods in an integrated malaria control program. As viewed by the authors, integrated control is defined as "any series of activities which leads to a significant reduction in morbidity and mortality from the disease". Included in this definition are all activities, including administrative procedures, measures to alter sociological factors, and the technical aspects of the program specifically directed at the interruption of the life cycle of the etiologic agent in either the intermediate or final host.

The authors perceived that the objective of their work was to assess the feasibility of anti-larval methods to control malaria in the USAID demonstration project; therefore, their specific activities were directed to the potential for

Figure 1

MAP OF AFRICA



demonstrating use of anti-larval measures under conditions observed at the project sites. It should be made clear that the authors did not assess the feasibility of classical anti-larval methods in mosquito control, because by definition, the latter is directed at control of any species of mosquito that constitutes a public nuisance. This unselective control philosophy would not meet the objectives of a disease control program. All observations were made during the dry season; for a complete evaluation of the applicability of anti-larval methodologies, similar observations should be made during the wet season (see Figure 2). The approach used to assess the feasibility and applicability of anti-larval methodology included:

--a review of obtainable malariometric and entomological data;

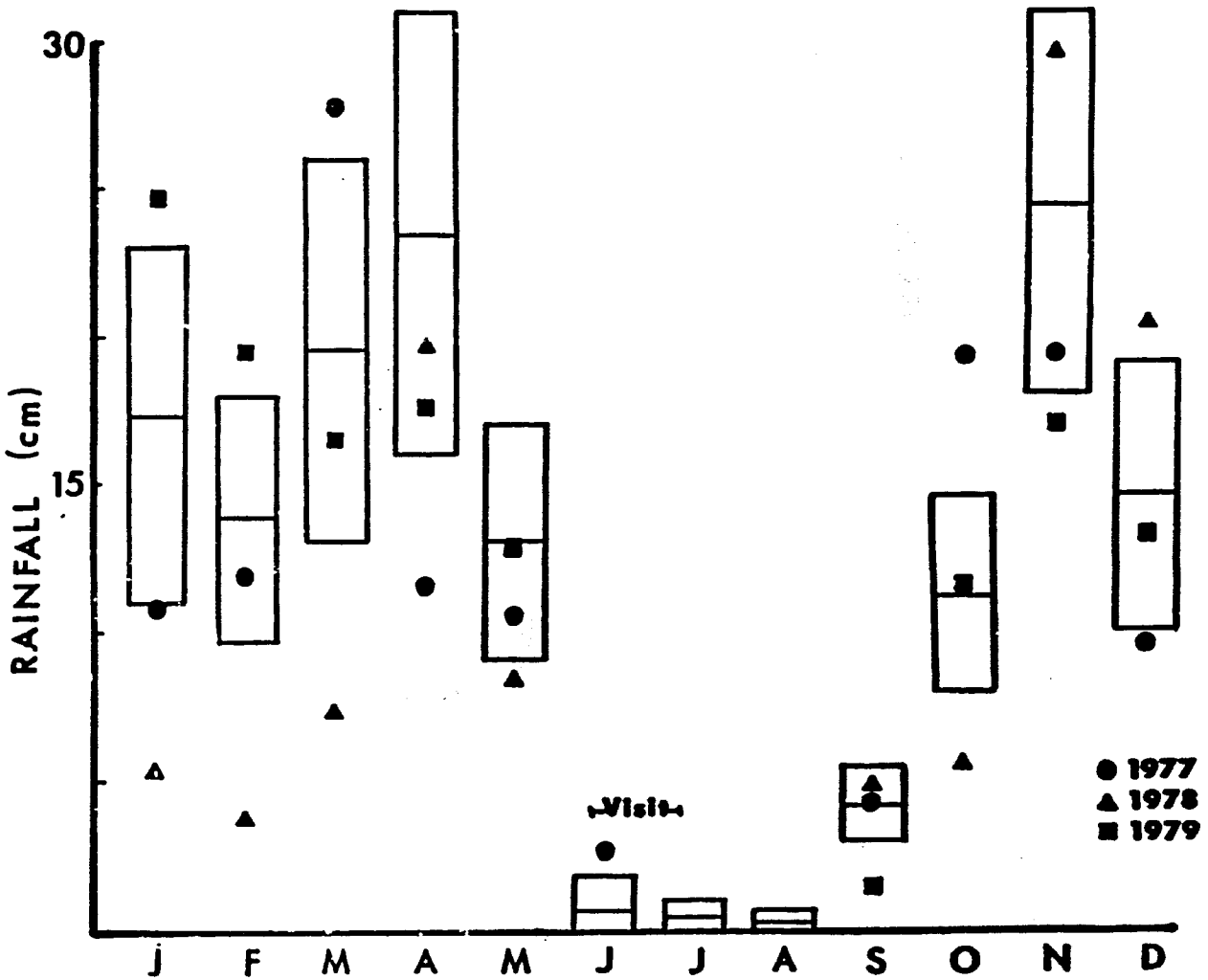
--discussions with national and international personnel about administrative and technical problems and constraints to implementation of new technology;

--field observations of the various ecological habitats affecting the project areas; and,

--an analysis of the observations and the preparation of recommendations on the use of anti-larval methods in the program.

Figure 2

MONTHLY RAINFALL RECORDED AT NDGILI AIRPORT
(In cm)



Note: Blocks represent 20-year mean ± 20 percent of the mean.

II. OBSERVATIONS AND FINDINGS

II. OBSERVATIONS AND FINDINGS

Review of Existing Data

With few exceptions, the authors were unable to locate sound epidemiological information on the transmission of malaria in Zaire. Their initial search was stimulated by the desire to evaluate the validity of the system which would be used to evaluate the effectiveness of the application of anti-larval measures to control the transmission of malaria. It was disturbing to find that the data that were available were of a point survey nature, and thus did not reflect seasonality (if present) of transmission. Even more disappointing was the knowledge obtained from a review of the program agreement[1] that WHO had initial responsibility for gathering baseline malariometric and entomological data and that such data had not been collected. The project advisor also indicated that this commitment had not been satisfied. Hopefully, this will not be the case with the remainder of the commitment outlined in the program agreement (i.e., long-term assistance of a malariologist, entomologist, and environmental specialist). A conspicuous void in the working material of the USAID advisor was the lack of historical information on malaria in this part of Africa. Given the long history of work on mosquito fauna in central Africa, surely there is a repository of this data which could be made available through either the WHO or other interested international organizations.

There is interest in Zaire in control of malaria; the authors observed that government officials had positive attitudes toward any actions to alleviate health problems, especially malaria. Keen interest was also shown by people in the field. Within the government, positive action has taken the form of support of the AID demonstration project.

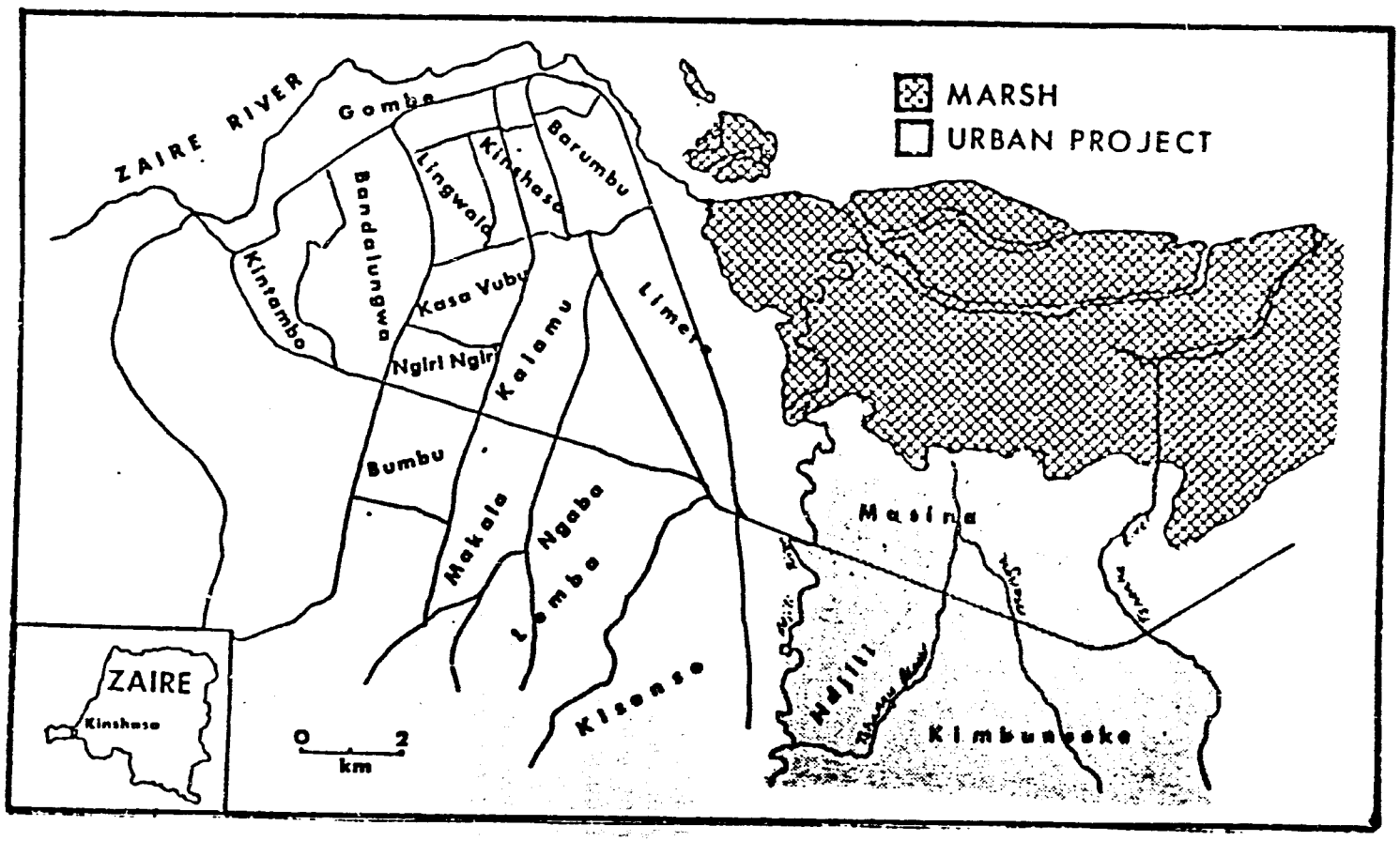
The implementation of this pilot project also indicates a consciousness of the role of malaria as a deterrent to the developmental process in Zaire. Unfortunately, this has not served as the genesis for drafting an overall plan which will expand the initial effort to a program of sufficient magnitude to reduce the disease in any sizable population of the country. Nor is there any evidence of the development of an overall plan that uses the country's resources.

Definitions of Assessment

As part of the description of the USAID project, two specific demonstrations were outlined. First, a malaria control pilot study was to be set up in the urban area of Kinshasa; second, a similar project was to be initiated in a nearby rural area. Malaria control in the urban project is complicated in that the selected physical setting is adjacent to an extensive marsh north of the project area (see Figure 3). This marsh poses a special problem associated with vector production and has a potential for intensifying malaria transmission in the area. The assessment of the feasibility of anti-larval methods was, therefore, approached as an evaluation of control methodologies applicable to three ecological settings: urban, rural, and marsh.

Figure 3

THE URBAN ANTI-MALARIA PROJECT AREA IN THE EASTERN SECTION OF KINSHASA, ZAIRE



The authors have used the following definitions to categorize the anti-larval methods that can be used:

- Chemical Control

  The mechanical application (i.e., with hand, ground, or aerial equipment) of any toxic compound to the habitat to control immature stages of the anopheline mosquito.

- Biological Control

  The use of a living agent (predator or parasite) to control the immature stages of the anopheline mosquito.

- Environmental Control

  The manipulation of larval habitats, including source reduction (habitat elimination) and water management (manipulation of water flow), which would render the habitat unsuitable for the production of anopheline mosquitoes.

To determine the applicability of each control measure, the following factors were considered:

1. Magnitude of the potential breeding problem. This factor will vary seasonally with rainfall, runoff, and flooding. (Considerations were, necessarily, based on only an educated guess.)

2. Accessibility of problem areas for application of each method (i.e., factors such as stability of the soil, substrate adjacent to the breeding habitats, vegetative growth, road access, etc.).

3. Cost of application (i.e., requirements for personnel, equipment, material, and frequency of inspections and applications).

4. Complexity of equipment requirements for the application of each method (including initial cost, technology required for maintenance, and training required for proper use).

5. Required personnel training in theory of application of method (for each category of control).

6. Requirements for supervision and evaluation of effectiveness of control method.

7. Environmental impact of each method (i.e., adverse effects on non-target organisms, potential for environmental degradation, effects on wildlife use, and consideration of beneficial effects on environment).

8. Potential for effecting biological changes in target species (enhancement of resistance to insecticides, forced behavioral modifications, such as induced changes in habitat section, etc.).

Description and Observation of Ecological Settings

A. Urban Project

The project area is located on the eastern fringe of the city of Kinshasa and covers approximately 40 square kilometers. (See Figure 3.) The area is bounded on the east and west by the Mangu and Ndjili rivers, respectively, and on the north by an extensive marsh. Included in the area are the subpolitical districts of Masina, Ndjili, and Kimbanseke. The area is also transected south to north by the Tshangu and Mangu rivers.

Most of the population resides on high ground between the two boundary rivers. The total population is estimated at 200,000. The people reside in permanent brick and concrete houses with tin roofs. Soils in the area, especially in the high sections, are sandy and cover clay strata. The margins of the rivers are heavily enriched with organic materials deposited each wet season and they are bordered by individually owned small plot farms. A rudimentary irrigation system, introduced into the area during the colonial period, is present.

The Ndjili River flows through a clearly defined river bed approximately 1.0 kilometers in width. There is a narrow flood plane which consists of a series of oxbows, typical of a meandering river system. These old oxbows provide low areas in which water accumulates throughout the year, thus creating marshy areas favorable for continuous mosquito breeding. Both the Tshangu and Mangu rivers flow through relatively narrow basins (less than 0.5 kilometers) which are void of the typical oxbow characteristics of the Ndjili River. These rivers have a relatively shallow water depth (less than 0.5 meters) during the dry season. One artificial lake is located within the study area adjacent to the Ndjili River. The major water collection areas which form the mosquito breeding sites in the dry season are associated exclusively with the rivers and irrigated farm areas. Anopheline larvae collected from this project area are shown in Table 1.

1. Description of Microhabitats

a. Inactive Irrigation Canals Where the Water is Temporarily Quiescent

Most of the distribution system flows along the escarpment of the Ndjili River valley, under semi-shaded conditions created by a tree canopy. The channels, for the most part, contain marginal vegetation and, in some locations, support emergent vegetation.

Table 1

ANOPHELINES COLLECTED FOR VERIFICATION OF SPECIES/HABITAT ASSOCIATIONS IN THE URBAN PROJECT AREA OF KINSHASA, ZAIRE
(June-July 1980)

Larval Collections

Microhabitats Sampled	Present	Species
Irrigation Canals (inactive)	+	*An. gambiae*
Seepage Pools in Oxbows of River Beds	+	*An. gambiae*
River Water Collection in Oxbows with Hyacynth Cover	+	*An. coustani/paludis*
Tail Water from Small Plot Farms	+	*An. gambiae*
Still Water Eddies Along Margins of Shallow Rivers	+	*An. gambiae*
Sand Pits	+	*An. gambiae*
Fish Culture Ponds	-	

Adult Collections

Type of Collection	Number/Unit	Species
Interdomiciliary capture	*	*An. gambiae* *An. nili* *An. funestus*

* Collections were made by the national staff. The number of houses searched and the hours expended in collection were not recorded.

b. Seepage Water Collection Areas in Oxbows

These areas range in size from less than one meter to several hundred square meters. In some cases, these oxbows are heavily vegetated with emergent grasses and covered with floating vegetation.

c. Tail Water Collections from Irrigation and Leaks in Water Distribution Systems

Water accumulates and stands in small pools in low areas of the garden plots.

d. Still Water Eddies Along Margins

Numerous such sites are found in both the Mangu and Tshangu rivers. These microhabitats are formed either by dense emergent vegetation or by sand bars which interrupt the normal flow of marginal seepages into the river. The Tshangu River flow measured approximately 0.5 meters per second near the Boulevard Lumumba at the time of these observations.

e. Sand Pits

Small quantities of sand are mined from the river margins for use in home construction. The pits that are created fill with water from seepage and when fresh are favorable for anopheline mosquito production.

f. Fish Culture Ponds

These ponds are constructed adjacent to the Mangu River. Aerial reconnaissance of the project area revealed that the entire course of all the rivers transecting the project area is lined with ponds approximately 100 square meters in surface area.

2. Analysis of Potential for Application of Various Control Methods

a. Chemical Control

Initiation of a chemical control program in the urban project area would require a sizable increase in staff. No less than one assistant supervisor, two inspectors, and 10 spraymen would be needed to adequately cover the present area. To organize the staff and their activities an inspection system to identify positive breeding sites, a delivery system to apply the larvicide, and a system of reinspection to evaluate the effectiveness of the treatment

would have to be developed. Detailed geographical reconnaissance also would be needed to identify all offending habitats. In addition, a system of continuous monitoring and documentation of changes in habitats would be necessary. Inspections thereafter would be continuous but not necessarily routine. The maintenance of detailed rainfull data at key points in the project area would be required to direct inspections to areas known to be changed by additional rainfall.

Initiation of this type of program would require the intensive training of both supervisors and inspectors. Such training would include development of proficiency in field identification of target anopheline species and recognition of their associated habitats, calculation of insecticide requirements, dosage rates, and application techniques. Training of spraymen would require specific emphasis on the proper application of the selected insecticide to avoid adverse effects on the ecosystem.

Equipment support would require additional larval sampling devices, transportation, insecticides, and supplies of cone spray nozzles for use with existing sprayers.

The cost of this feasible control methodology is recurrent, and the treatment is of questionable value. An additional danger in the use of chemical anti-larval measures is the potential for enhancing vector populations' resistance to insecticides. This is of particular concern if the larvicides that are used fall within the same chemical grouping as the adulticides used in the residual spray program (i.e., chlorinated hydrocarbons, organophosphates, or carbamates). The costs of chemical anti-larval methods are recurrent and are increasing at inflationary rates.[6] The decision to use this control methodology would, therefore, be a question of both technical and administrative feasibility.

b. Biological Control

In the absence of field-testing of bacterial, fungal, viral, and other biological agents against anopheline vectors in Africa, the only feasible biological approach is use of larvivorous fish. In the pilot project area, four sites appear to be favorable for use of this method: fish culture ponds, the artificial lake, isolated rice fields, and permanent channels of the irrigation system. The first three lend themselves well to immediate introduction of larvivorous fish populations. The use of this technique in the fourth instance is moot, because of seasonal changes in water levels and management of water flow through the systems. Application of predatory fish to other habitats (e.g., rivers, oxbow areas, and farm plots) is counterindicated for such reasons as fluctuating water flow, which tends to disperse fish populations; floating vegetation, which in some cases completely masks the water surface, making it impossible for fish to penetrate the vegetation; and the temporary nature of some breeding sites.

c. Environmental Control

Environmental control through habitat manipulation appears to be the most promising method of anti-larval control in the project area. Many of the breeding sites can be eliminated through the combined efforts of the small farmer and trained project personnel. This program of collaborative habitat elimination is envisioned not as a classical health education program for the farmer, but as a "hands-on" demonstration by the project staff of simple methods of water management of numerous small habitats. The microhabitats in farming areas and along stream systems lend themselves to elimination through minor alterations, which might be made with simple equipment. For example, the breeding in tail waters from fields, irrigation canals, and water collections along the river courses could be corrected easily by properly leveling the farm plots and providing for proper runoff, by maintaining irrigation ditches, and by removing periodically infringing and floating vegetation from habitats along the watershed.

The fish culturing activities in the project area constitute a special situation which will require a more extensive educational program directed towards the proper construction and maintenance of culturing facilities. The thrust of this activity should be directed at the manipulation of seepages and drain-off from ponds to ensure that no vector breeding habitats are created adjacent to the pond or in the drainage system to the principal water courses. In addition, emphasis needs to be placed on keeping the pond free of emergent and floating vegetation.

B. Rural Project

The center of the rural project is located approximately 150 kilometers south of Kinshasa, at Ngidinga (see Figure 4). Approximately 2,500 square kilometers are proposed for coverage to protect an estimated population of 28,000. The area is bounded on the west and south by the Inkisi River and a hypothetical line drawn east, parallel to the Zaire border to a point of intersection with the eastern limits, and an imaginary line drawn from the headwaters of the Nsete River due south. The northern boundary is delineated by the villages of Kimpemba and Kiyengo on the highways.

The terrain is hilly, with elevations reaching to almost 1,000 meters. The area contains numerous valleys which form the headwaters of the streams in two major watersheds. The tops of the hills are covered with savanna-type vegetation which drops off sharply into the valleys where tropical vegetational types occur along the streams and rivers.

Scattered villages are located along dirt roads in the higher elevations throughout the area. Houses are constructed of either mud blocks or plastered wood thatch; both types of houses generally are roofed with indigenous grass thatch. Small plot farming is done in the valleys along the streams and up adjacent slopes. The land is cleared of tropical vegetation by slashing and burning. Also located in these valleys are numerous man-made fish ponds. The anopheline species collected in this area are shown in Table 2.

Figure 4

THE RURAL ANTI-MALARIA PROJECT AREA SOUTH OF KINSHASA, ZAIRE

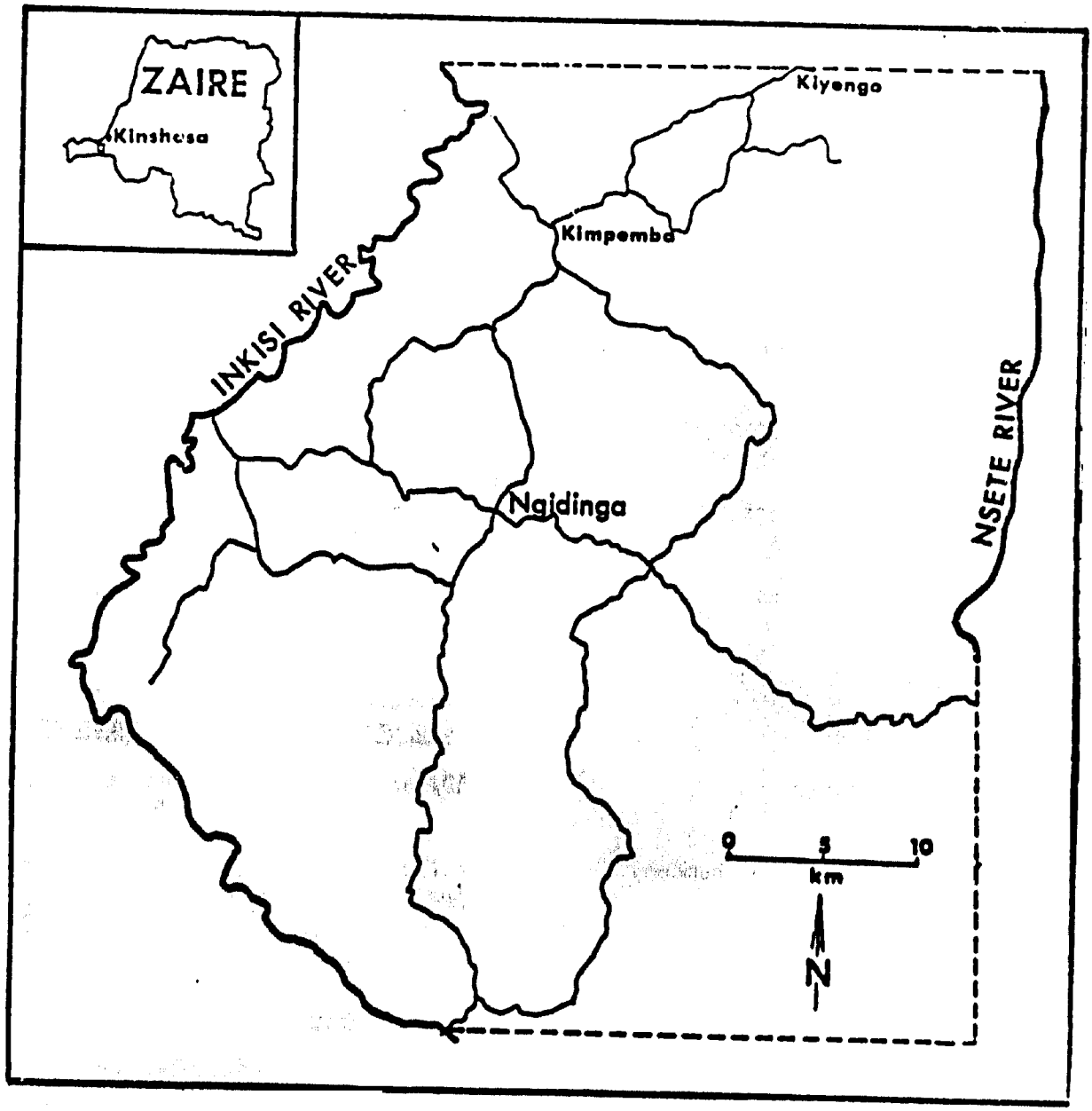


Table 2

ANOPHELINE SPECIES COLLECTED FOR VERIFICATION OF SPECIES/HABITAT ASSOCIATIONS IN THE RURAL PROJECT AREA OF NGIDINGA, ZAIRE
(June-July, 1980)

Larval Collections

Microhabitat Sampled	Present	Species
Slow-flowing Streams with Quiescent Pools, Semi-shaded under Forest Canopy	+	*An. coustani/paludis*
Seep Springs at Origin of Small Streams	-	
Swampy Areas Adjacent to Non-Confined Water Flows	-	
Channels and Runoff in Slash and Burn Farm Plots	-	
Fish Culture Ponds	-	

Adult Collections

Type of Collection	Average Cap/Unit	Species
Interdomiciliary	50/man/hr	*An. gambiae* *An. nili*
Night Capture (cebo humano)	2.2 bites per man/hr	*An. gambiae* *An. paludis* *An. coustini*

1. Description of Microhabitats

a. Slow-Flowing Streams

This habitat is made up of still water pools in a slow-flowing stream with a defined course. The streams flow usually under a dense forest canopy.

b. Seepage Springs

These springs form at the headwaters of small streams and rivers throughout the area. Many of the springs are void of tree cover.

c. Swampy Areas Adjacent to Non-Confined Water Flows

These are water soaked bogs rich in organic matter usually covered by a tree canopy.

d. Channels and Drains from Farm Plots

Slash-and-burn farm areas are generally used for small-crop cultivation. These plots are similar to those observed in the river basins of the Kinshasa project area. Trees are removed and the plots are usually exposed to direct sunlight.

e. Fish Ponds Constructed at Margins of Seepage Areas

Information gathered from an employee of the OXFAM organization indicated that such ponds have been constructed in a large number of the seepage areas in valleys throughout the project area. The number of ponds used for fish culturing in the area would be difficult to estimate without aerial reconnaissance. Heavy culicine breeding was found to be associated with improper drainage of water at the margins of the ponds.

2. Analysis of Potential for Application of Various Control Methods

a. Chemical Control

The use of chemical control methods in the rural setting would be governed by the same constraints outlined for the urban project area, as well as by the need for further elucidation of the vector species habitats and their

physical proximity to the human populations. Should distribution and accessibility of offending habitats be favorable for the villages, larviciding teams could cover the area more rapidly along the existing road network than in the urban setting. Selection of the larvicides would also be of utmost importance, and only larvicidal oils or hormonomimetic compounds would be recommended to avoid enhancing the resistance of the vector populations to the insecticides used in the residual spraying program. Given the potential for application of other anti-larval methods, however, repetitive application of chemical larvicides would be a very complex and expensive operation over the long term.

b. Biological Control

From the limited observation of fish culturing in the project area, the authors concluded that the configuration of the land would appear to lend itsel to further development of this industry. It would also appear that proper location and construction of the ponds would lead to the creation of fewer anopheline breeding habitats. Basic construction and maintenance procedures for this type of pond are the same as for ponds located in the valleys transecting the urban area. A program in which larvivorous fish are distributed would be beneficial in the rural area from the onset of spraying operations, ensuring that the ponds are not a significant vector-producing habitat. Because a number of ponds are located near the proposed operational base, geographical reconnaisance would be required to locate ponds suitable for breeding ponds for larvivorous fish. As in the urban area, a system of fish distribution would be required.

c. Environmental Control

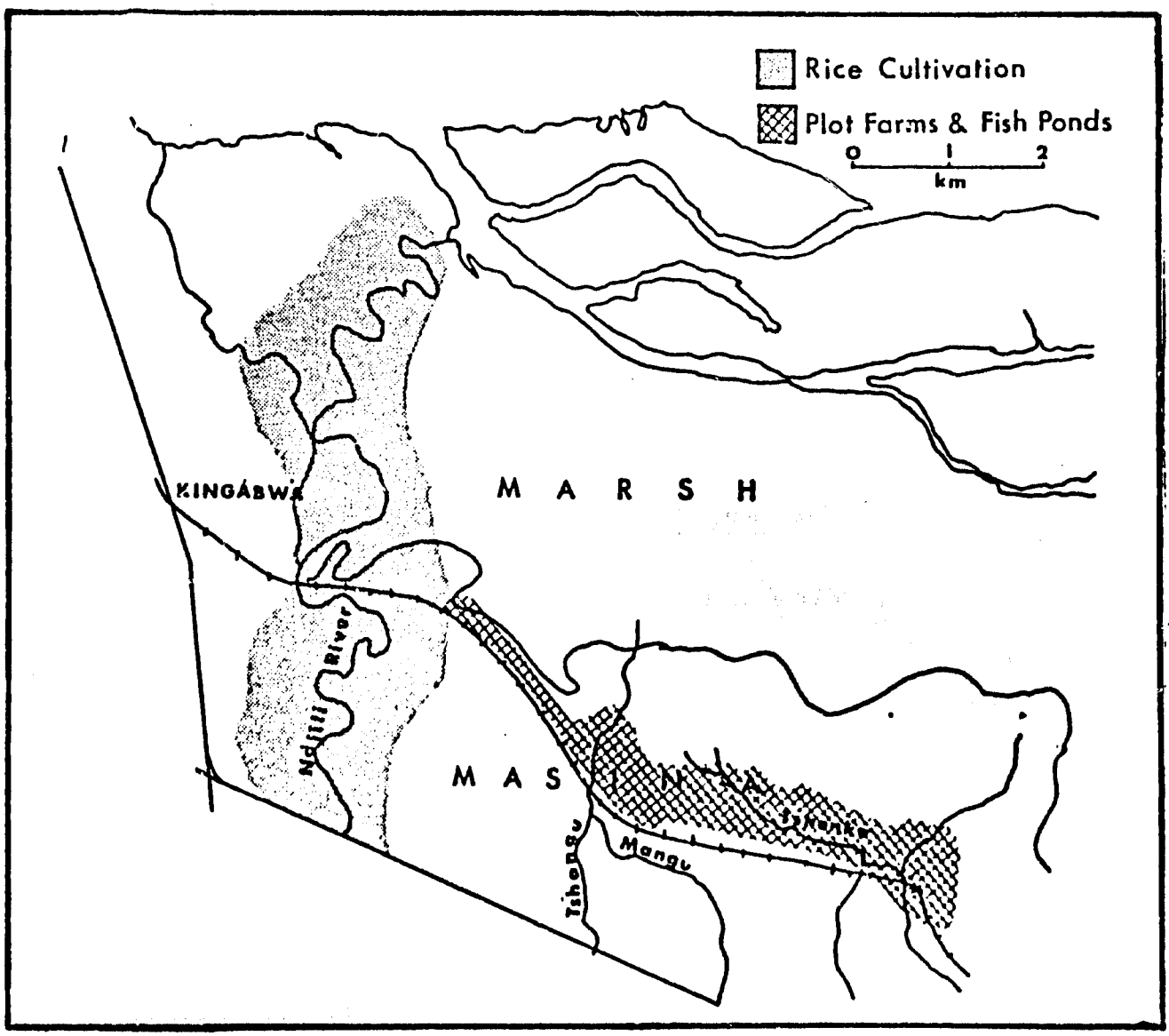
Observation of small-plot farming and fish culturing would indicate that an educational approach, including a cooperative effort with the local farmers, would facilitate the reduction or elimination of vector breeding habitats associated with farming practices. Because of the nature of the stream system and the practice of impounding the head water, this situation might lend itself to installation of automatic flushing systems to scour the breeding sites along the stream beds.(7) The feasibility of this system needs to be tested to ensure that the procedure does not increase rather than decrease the breeding sites of the vector anopheline species. It should be noted that this system of control is applicable only to streams with well defined water courses.

D. Marsh Problem

An extensive marsh is located east of Kinshasa and forms the northern boundary of the urban project area. The marsh forms the northern limits of the subpolitical district of Masina (see Figure 5). The total marsh covers an estimated area of 65 square kilometers along the south side of the Zaire River and is intersected by the well defined channel of the Ndjili River. The Tshangu and Mangu/Tshenke rivers flow out and across the marsh surface and have no definite boundaries during the dry season. At the mouths of these river systems and along

Figure 5

THE MARSH EAST OF THE CENTER OF THE CITY OF KINSHASA, ZAIRE



the escarpment, small-plot farming and fish culturing activities have developed. Extensive rice cultivation is practiced on both sides of the Ndjili River east of the mainland (Kingabwa) and north of the Boulevard Lumumba, which passes east to west through the project area.

During an aerial reconnaissance of the marsh, three major zones of natural vegetational associations were observed between the escarpment and the Zaire River. Where both the Tshangu and Tshenke rivers flow out and onto the marsh surface, a palm tree/shrub/fern habitat reaching a height of 10 meters has developed. This habitat seems to be located on a higher ground formed by alluvial deposits during the wet season. The second vegetational association was a tall grass (three meters in height) which forms a belt through the center of the marsh. The remaining vegetational association was a type of reed located outside the marsh area up to the mainstream of the Zaire River. All of these vegetational associations appear to be rooted in a water-logged and floating vegetational mat.

No large open surface ponds were observed on the marsh during this period of the year; they may, however, be present in the wet season, when the marsh is covered with two to three meters of water. The rice culture is located on the higher elevation gradients of the marsh where the vegetation has been burned and the land drained by a rudimentary irrigation system. Observations of the marsh during the dry season indicate that there is little breeding potential for anopheline species in the marsh as a whole. Anophelines were found in rice fields, fish ponds, plot farms, and sand pits. The species of anopheline larvae collected from the marsh are shown in Table 3.

1. Description of Microhabitats

a. Rice Paddies

The size of the rice paddies appears to be relatively uniform (20 x 50 m) and is contained by berms constructed of material from the soil and vegetation mat of the marsh. The berms are relatively porous and permit water to flow between the paddies. Floating vegetation is also thrown to the top of the berm, and there is much spillage into the edge of the paddie. The favorable microhabitat appears to be in the margin of the paddie in areas where the vegetation spills over.

b. Irrigation Ditches of Small Plot Farms

This microhabitat appears to be the same as that observed in both the urban and rural project areas.

c. Fish Culture Ponds with Floating Vegetation

Anopheline breeding in this habitat has always been associated with the vegetation at the margin of the pond and with floating vegetation.

Table 3

ANOPHELINE SPECIES COLLECTED FOR VERIFICATION OF SPECIES/HABITAT ASSOCIATIONS IN THE MARSH PROBLEM AREA NEAR KINSHASA, ZAIRE
(June-July 1980)

Larval Collections

Microhabitats Sampled	Present	Species
Rice Paddie	+	*An. gambiae*
Irrigation Ditches of Small Plot Farms at Margin of Marsh	+	*An. gambiae*
Fish Culture Ponds with Floating Vegetation	+	*An. spp.*
Fish Culture Ponds without Emergent or Floating Vegetation	-	
Sand Pits	+	*An. gambiae*

2. Analysis of Potential for Application of Various Control Methods

a. Chemical Control

Inaccessiblity of the breeding habitats at the interface of the marsh and the farmed area and in areas under rice cultivation render the use of ground-applied control measures impractical. Although it is possible to achieve control through aerial dispersal of larvicides, the investment in aerial equipment and recurrent costs would be prohibitive for a long-term, routine control program. Should equipment become available, this method of treatment would undoubtedly control the breeding, but the wisdom of its use is questionable because of the staggered harvest and pesticide contamination of crops. Application, therefore, would have to be selective to prevent insecticide contamination of harvestable rice.

b. Biological Control

The application of biological control methods appears to be possible in two major situations associated with the marsh: in artificial impoundments for fish culturing and in rice paddies. Introduction of larvivorous fish into these habitats is, apparently, feasible if a restocking program is set up to reintroduce the fish after the annual flooding during the wet season. Maintenance of a sizable fish-rearing facility would not be an insurmountable problem in extensive fish-culturing ponds located above the flood line in the nearby river basins of the Ndjili, Mangu, and Tshangu rivers, where new stock would be available year round. Because no herbicides or pesticides are used on the rice fields, the fish, once planted, should be able to survive well when the paddies are not inundated (during the dry season). The fish culture ponds along the margin of the marsh also may be inundated and would require restocking as well.

c. Environmental Control

Ground-proofing of the rice paddie layouts indicated design deficiencies in the water management system. Inadequate provision for the control of the water flow within the impoundments has helped to create ideal breeding habitats. The development of a comprehensive irrigation system for impoundments and proper construction and maintenance of berms and dikes would help to reduce the magnitude of the problem.

Environmental Concerns

There are a number of concerns associated with any anti-larval control method that must be evaluated before a measure is selected. Some of these concerns have been identified by the authors and are listed below.

A. Chemical Control

Among the hazards associated with chemical control actitivies are:

--toxic effects of pesticides on non-target organisms;

--chemical contamination of potable water and food crops;

--destruction of beneficial insect life (i.e., insects in the food chain, predators of mosquito larvae, etc.);

--possible bio-amplification of insecticides in food chains; and,

--danger of intoxication associated with application and exposure of general human population.

B. Biological Control

To initiate biological control it will be necessary to identify indigenous larvivorous fish or to introduce a widely used species (e.g., Gambusia spp. and/or Poecilia spp.).[8] [9] Some concern has been expressed that these non-indigenous fish species may out-compete and subsequently replace indigenous fish populations. The authors have found no documentation that the introduction of either genus of fish has adverse effects on native fish.

C. Environmental Control

A remote environmental concern in a program of habitat manipulation would be the possible effects on groundwater levels. In the Kinshasa area, where the water table is shallow (approximately 2.5 meters), use of this method would not be likely to produce detectable changes.

Identification of Constraints

A review of the documents outlining the position of malaria control in the overall development of health projects would reveal budgetary constraints, lack of adequately trained personnel, lack of appropriate training programs for health personnel, insufficient experience in the use of materials requiring moderate to sophisticated mechanical technology, inadequate communications (i.e., rapid mail, telephones, telegraph, and radio), inadequate transport systems and facilities, and inadequate recordkeeping and data collection procedures.

Although each of these deters in some way the implementation of a countrywide anti-malaria effort, none should be an insurmountable block to the start of a program.

Each of the following factors is related to the initiation of countrywide anti-larval measures. One should not infer from the discussion that demonstration and training in the use of the methodology should not be carried out.

One of the major constraints to the initiation of anti-larval measures for control of malaria is cost, particularly when chemical or large-scale environmental control methods are considered. Because the health budget of Zaire is less than what is needed to support current ongoing health programs, one might question whether funds would be available to launch an extensive program. Budgetary constraints might be overcome if outside resources were made available through international donor agencies and if an acceptable, comprehensive plan, with realistic goals phased with the development of national resources, were proposed.

The training needed to implement an anti-malaria program in Zaire has been studied by a special consultant in training.(10) The consultant assessed health training facilities in Zaire for training lower-echelon personnel and addressed the problem of training technical personnel on a long-range basis. Since there are no personnel in Zaire trained in the use of anti-larval methods and since existing training programs for health personnel are not specialized, a complete training program in the application of anti-larval methodologies appropriate for Zaire would be needed.

A technological background is needed to implement a highly mechanized program. Without such a background, a person cannot properly maintain and operate sophisticated equipment. It may be possible to overcome such constraints by reverting to and using technologies appropriate for solving a particular problem. The recommended anti-larval measures alter minor habitats through judicious use of a shovel. A simplistic approach in which part of the estimated unemployed manpower of Kinshasa (reportedly between 25 percent and 50 percent) would be used would be most feasible.

Another major constraint to the efficient operation of any field program, especially an anti-larval program, is the lack of communication facilities to support rapid reporting of field data and subsequent rapid followup with appropriate larval control measures. Intercity, or even intracity, communication does not exist at this time in Zaire (i.e., there are no functioning telephones, radio, etc.).

It may be possible to resolve the problem of communication in the demonstration program area by installing of an internal radio system and by judiciously using couriers equipped with mopeds or similar equipment. Such a system would add considerably to the cost of an expanded anti-malaria control effort.

Transportation also is a major constraint to the operation of an anti-larval program. Rapidly escalating operating costs, inadequate maintenance of vehicles, and the lack of roads connecting remote areas make it difficult to reach some of the major larval habitats. Although little change in the national transportation system is envisioned, the USAID demonstration project should not be overly constrained by poor transportation because the sites involved are small.

To expand the anti-malarial effort nationwide, however, modes of transportation other than motorized ground vehicles (e.g., water-powered vehicles, animals, off-road mechanical vehicles, etc.), would be needed.

The absence of an overall health statistics system that can provide malariometric information for an evaluation of an anti-malaria control program is a constraint. Until basic surveillance and measurement of the disease become routine activities, it will not be possible to evaluate the effectiveness of any applied control methodology. Hospital and local clinic records, which if properly analyzed, can provide information on malaria in Zaire, are relatively evenly located in the program areas. Curative medical facilities might be able to provide background data and constitute a network throughout which a continuous surveillance and evaluation system could be established. Additional training would be required, but this might be provided by the project epidemiologist or in a series of short courses conducted by external consultants. Preliminary inquiry revealed that Peace Corps Volunteers might be made available for retrospective studies and to serve as possible resources for training in the field.

Associated with any goal-oriented program are constraints on resources and time. For the anti-malaria effort as a whole, both are of equal importance. For the time-limited USAID demonstration project, the key constraint is time. The short period remaining in the life of the project may cause the project to fall short of its goal of fully demonstrating many of the alternative methods of integrated malaria control.

III. RECOMMENDATIONS

III. RECOMMENDATIONS

The use of selected anti-larval control methods can and should be made an integral part of the demonstration/pilot program presently in operation in Zaire. The methods considered by the authors to be appropriate are long-range methods and their use should be directed to the reduction of the number of breeding habitats of the vector anopheline species. In assessing the resources available at this time, the authors conclude that it would be appropriate to recommend a fundamental technology that employs the simplest of tools to achieve the desired results. For reasons stated elsewhere in this report, the authors do not consider repetitive use of chemical control measures to be practicable or desirable.

The recommendations which follow are divided into three parts. The first part includes general recommendations pertinent to the achievement of the stated goals of the USAID demonstration project; the second part includes those recommendations related to the initiation of any of three types of anti-larval measures; and in the third section are listed those recommendations applicable to specific ecological settings (i.e., urban, rural, or marsh).

General Recommendations

1. An advisor in source reduction should be recruited for a period of not less than 18 months to support the present project staff. This person would be responsible for training, long-range planning for environmental control, and demonstration of the use of anti-larval measures to interrupt the transmission of malaria.

2. A concerted effort should be made by the personnel backstopping the project to collect all pertinent records on malaria and the anopheline fauna of Zaire. These data would provide background information useful for the project and for planning future program expansion. The collection of data should be housed in the offices of the Zaire Malaria Control Service after that organization has been formally established.

3. A basic malaria surveillance system should be established to provide data for continuous monitoring of the disease. This is particularly important at this time, because the data are needed for an evaluation of the effectiveness of the control methods being tested. Specific studies should include:

    a. Retrospective studies using malariometric data available in clinics run by governmental agencies, donor organizations (Salvation Army, Catholic Church, etc.), and private practitioners.*

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* See Chapter II, "Identification of Constraints."

b. Prospective studies of malaria transmission using the above mentioned agencies and organizations. If feasible, similar studies involving medical facilities in other parts of the country could be initiated to obtain more comprehensive data on the prevalence of the disease throughout Zaire.

4. Entomological studies should be initiated to enumerate and identify all vector anopheline species in the project areas. Specific investigations should be carried out on the biology of these anopheline species; the identification of specific species/habitat relationships should be emphasized in particular.

Recommendations Pertinent to Application of All Anti-Larval Control Methods

1. A training program specifically directed to the application of anti-larval methods should be established. The program must include the identification of immature stages of the vectors and of vector breeding habitats; use of larval sampling methods and control technology (habitat manipulation, drainage, ponding); use of biological control techniques; calculation of fish culture stocking rates; chemical control; the mechanics of application; care of equipment; determination of dosage rates, etc.

2. Geographical reconnaissance should be started to identify active and potential breeding habitats. A record system should be developed which facilitates rapid identification of each breeding site and permits chronological recording of the breeding history of each site. These data should be used to set priorities in a long-term program of habitat elimination.

3. Rainfall stations should be established within the project areas. They should be located at distances sufficient to detect variations in rainfall, in time and amount, in the control areas. A system of daily collection and analysis should be developed so that these data can be used in making operational assignments of larval inspectors and control teams.

4. A program of larval inspection and control should be incorporated into the existing anti-malarial pilot project so that simple habitat manipulations in the urban project can begin.

5. An immediate effort should be made to procure those commodities (e.g., hand tools for habitat elimination--shovels, hoes, etc.) needed to initiate simple source reduction activities.

Recommendations for USAID Demonstration Project Applicable To Each Ecological Setting Identified in Report

If anti-larval measures are to be initiated in the project, the following activities should begin as soon as possible.

A. Control in Urban Project Area

1. A maintenance team responsible for channeling and cleaning natural water courses in the project area should be organized. The team's activities would include opening oxbow water collections, cleaning out emergent vegetation, and assisting farmers in the installation of proper drainage at the edge of rivers.

2. An education program in proper water management and use, including maintenance of irrigation systems, proper leveling of farm plots, and drainage of tail waters, should be developed.

3. An educational program in the proper construction and maintenance of fish ponds should be developed. The specific emphasis should be placed on the elimination of floating vegetation, the stocking of larvivorous fish, and the provision of peripheral drainage.

B. Control in Rural Project Area

1. The land area proposed for coverage in the rural project should be reduced by at least 50 percent. The elimination of southern and eastern-most villages would appear to be the most logical step. The logistics of the control operation may prove impossible during the wet season if the presently envisioned plan for spraying operations is implemented. If the human population is reduced to a non-statistically feasible level with the change, consideration should be given to areas north of the northern-most villages. The villages eliminated from the spraying program in the south could be used as controls to test the significance of the operation.

2. As in the urban setting, where small plot irrigation and fish culturing are practiced, a program to educate the farmer should be initiated. The program should focus on maintenance of irrigation channels, proper leveling of farm plots, drainage to tail waters and elimination of floating vegetation, stocking of larvivorous fish, and proper construction of peripheral drainage around fish culture ponds.

3. One form of habitat manipulation that might be feasible for the control of anopheline larvae in the small riverlets observed in Bas-Zaire would be the installation of automatic flushing systems (sluicing) at the headwaters of the streams.[7] It is recommended that a site be identified and a pilot system installed. The system's effectiveness in reducing specific anopheline vector populations should be evaluated.

C. Control in Marsh Area

1. As was recommended for both the urban and rural project areas, an educational program for the farmers using the margins of the

marsh should be initiated. The water management practices previously mentioned should be stressed.

2. A program of biological control using larvivorous fish is recommended for rice cultivation on the marsh. A system similar to that used in the rice growing areas of the United States would appear to be feasible.[11] The facilities where fish are cultured for annual restocking of the fields need be identified.

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REFERENCES

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* AID consultant to Kinshasa.

Appendix A

LIST OF PERSONS CONTACTED

Appendix A

LIST OF PERSONS CONTACTED

Ambassador Robert B. Oakley	U. S. Embassy

USAID and Technical Advisors to Zaire

Mr. Normal L. Sweet	Mission Director
Dr. Walter Boehm	Acting Director
Mr. Clifford Belcher	Chief of Public Health
Mr. Joseph W. Jacobs	Public Health Advisor
Mr. Robert L. Turner	Malaria Advisor
Mr. Richard L. Thornton	Population Officer
Mr. Ike Hatchimonji	Advisor, Food and Agriculture
Mr. Andrew Stancieff	Advisor, Etudes des Resources, Terretre par Satellite
Mr. Joseph Pessutti	Consultant, Etudes des Resources, Terretre par Satellite

Peace Corps

Mr. Baudouin de Marcken	Director
Mr. Daniel Smith	Special Projects (Fisheries)

Governmental Authorities

Capt. Luvangdio	Zairian Air Force
Capt. Lubiku Lusiense	Director-General, Institute Geographique
Cit. Bifuma bia Nganga	Director de Technique Institute Geographique
Cit. Kasbala Mabayabo	Director, Service de meteorologique
Cit. Pini	Chief Division of Meteorology, Service de meteorologique

Dr. Kalume Leishikwa Mulamba	Ministry, Department de lu Sante Publique
Cit. Kanku Nkashana	Secretaire Particulier, Departmente de lu Sante Publique
Zaireux Air Force Personnel	

Members of the Anti Malaria Project

Dr. Makengo Bigonsa	Medical Director
Citoyen Tscbipangu	Supervisor
Citoyen Mplumba	Assistant Supervisor for Field Operations
Citoyenere Ndudi-Ndudi	Secretary Interpiter