5. Simulating fishermen society

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5.1 The study of fisheries

The management of the natural environments exploited by man, we speak here mainly of the aquatic environments, has been directed for a long time mainly towards the resource from an ecological point of view. It came to well understanding the natural environment in order to suggest afterwards an adequate exploitation by imposing catches which would be balanced with the resource dynamics. Little by little, social sciences through economists have been involved in the study of these optimum catches. Finally, researchers in sociology and anthropology have been studying recently how societies adapt themselves to the resource exploited through social structures which define the access to space and to the resource. Concerning small-scale fishing, a new theme of study, namely society, has been imposed; for instance, the TURF concept (Territorial Use Rights in Fisheries) seems currently to be a theme of research (Berkes, 1989) on fishing like the dynamics of the fish populations which are subjected to catches.

The current implications linked to the studies on fishing consist in going beyond this bipolar approach in order to suggest a research on the relations between society and environment. Therefore, it comes nowadays less to studying the resource dynamics but rather to analysing the relation between the types of exploitation observed and the resource dynamics.

Moreover, this interaction between man and resource is subjected to the environmental variability which originates from the space heterogeneity— there are different sites with different characteristics among which fish can move—and from the temporal fluctuations, for the environmental conditions (climate, hydrology ...) vary with the cycles, which leads to various behaviours in fish. Therefore, on the one hand, the resource is faced with a space-time variability and on the other hand, the processes endogenous to the resource dynamics (growth, reproduction, mortality) are subjected to a considerable variability between individuals. These space-time and biological variabilities lead the resource subsystem to follow specific courses.

Fishermen are subjected to this variabilty and therefore they adopt different strategies in order to adapt to it. This variability is considered both individually by each fisherman but also collectively by the fishermen's society: its structure must often adapt to this environment and its dynamics. Various adjustments to this variability are possible. In the group, they lead to an organization of the activities and to a division of space between the different users of the same resource. The space resource contributes, among other things, to build society.

The descriptions are given in terms of variability: variability of the environment, variability of the people subjected to this environment, for there is a big diversity in fishermen. At the higher level, we describe a society through a variability and a diversity in space occupation. Simulation is interesting in order to study the transition between the individual behaviour of the fishermen's households and the general behaviour of the group of households, in order to see whether the variability of the individuals and the variability of the environment where they are involved can be linked to the variability which is characteristic of the society observed.

5.2 Case study: the central delta of Niger

The central delta of Niger situated in Mali covers several thousands of km^2 in the Sahelian zone (Figure 5.1). The river whose water level varies considerably in the course of the year flows into a very flat zone. At the flood period, water is rising in the flooded plains, the channels ; at the recession period, ponds remain until the nearly complete drying. This hydrological situation gives rise to a highly productive ecosystem for the fish populations which ascend streams to reproduce in the easily flooded plains during the flood and descend from streams during the recession. This territory is inhabited by various ethnic groups including fishermen, farmers and stock breeders. This zone which yields nearly 100 000 t of fish/year has been severely affected by various phenomena such as the great Sahelian drought which led to the decrease of fish catches. A multidisciplinary ORSTOM and IER (Institute of Rural Economy, Mali) research team tries to identify the causes of this crisis (Quensiere, 1990). This team includes demographers, anthropologists, micro and macro- economists, biologists, fishing biologists and ecologists.

Researchers in ecology and biology study the responses and the adaptation of the fish populations to the space heterogeneity and to the hydrological variations. They also make investigations on the interactions between man and resource:

- on a local level (studying fish catches in such and such a place, at such and such a moment, with such and such an equipment),
- but also on a general level, namely in the village and in the fishermen's group (studying the time and space distribution of the activities of the fishermen's households).

On the other hand, researchers in anthropology and micro-economy study the social structures and their history. Therefore, they show (Fay, 1990)(Kassibo,1990) how since the 1940's, this area went from a highly organized type of exploitation including the access to water and land distribution between ethnic groups or families to a crisis due to new principles of exploitation resulting from the State (free access, fishing licence) and more productive equipment from Europe and Asia which gave rise to economically rational individual behaviours. The crisis which currently affects this area would result from conflicts between fishermen who claim different rights and from a severe drought which shrinks the resource. The decision

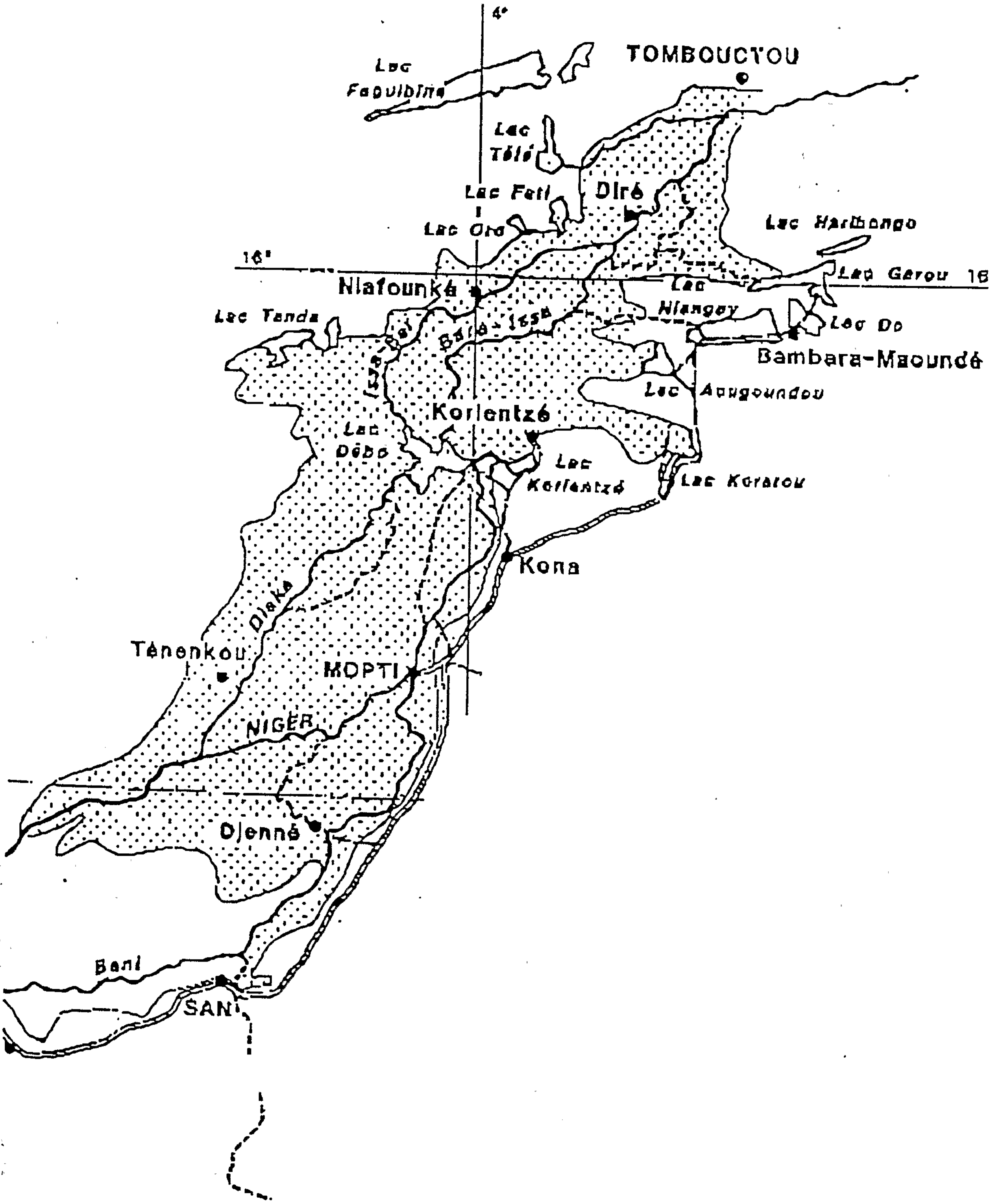

Figure 5.1: The central delta of Niger

making of the households which are living in this zone corresponds to several economic and social behaviours. The relation between the economic and social decision making is a study theme for the researchers in social sciences who consider reality from different points of view and with different models.

In short, we are faced with different households of fishermen (ethnic groups, number of people, origin...) which are subjected to a fluctuating hydrological and ecological environment. Different theories, points of view and models are available on the production strategies, on the fishermen's decisions and observations are available on the space occupation and the organization of the activities carried out by these groups of fishermen. Therefore, Figure 5.2 (Lae, 1990) gives some results observed in the field. We worked out a simulator in order to simulate the different types of individual behaviours and raise the following questions:

- By subjecting a population of fishermen to the hydro-ecological variability, is it possible to go from the individual behaviour to the distribution of the activities and the occupation of the space resource in the group?
- What is the interaction between the different types of decision making and the resource dynamics?

In the following chapters, a presentation is given of the structure of the simulator in order to answer these questions, then we give some examples of different simulations which show how this simulator is used.

5.3 Building up of a simulator

The simulator worked out refers to the decisions made by the households in a fluctuating environment. First, we describe the basic module which simulates the dynamics of the fish populations in an heterogeneous area and the process of decision making used by the fishermen's households. First, we give a presentation of the knowledge representation techniques used.

5.3.1 Representation of knowledge

The modelling of ecological processes makes use most often of mathematical representations (differential equation, matrix analysis) which modelize the relations between concepts and magnitudes (stocks, biomass, population density) for which general measurements are available. The modelling of knowledge suggested is based on the use and development of the principles of the Distributed Artificial Intelligence (Ferber,1989). A number of techniques and methods are used and developed (Bousquet et Cambier, 1990) as part of our application. First, we selected the object-oriented design (Pave, 1989) as the basic element of the building up of the model. The object-oriented design consists in modelizing the world by representing its different constituent objects. It comes only to transcribing the elements of the world observed (fish, fishermen, biotopes, etc.) into computer entities. A computer object includes both the description of the real object by defining its attributes (for instance, a fish object will have size, weight attributes, etc.) but also its own behaviours (for instance, growth, movement).

This design is well adapted to our study which is conducted on a multidisciplinary basis. Thus, researchers make use of different concepts (biomass, price, migration flows) but they observe the same objects. The object-oriented design and the related inheritance properties allow to describe the different points of view on the same object. For instance, the anthropologist will consider the Household object through its ethnic group, household size and origin

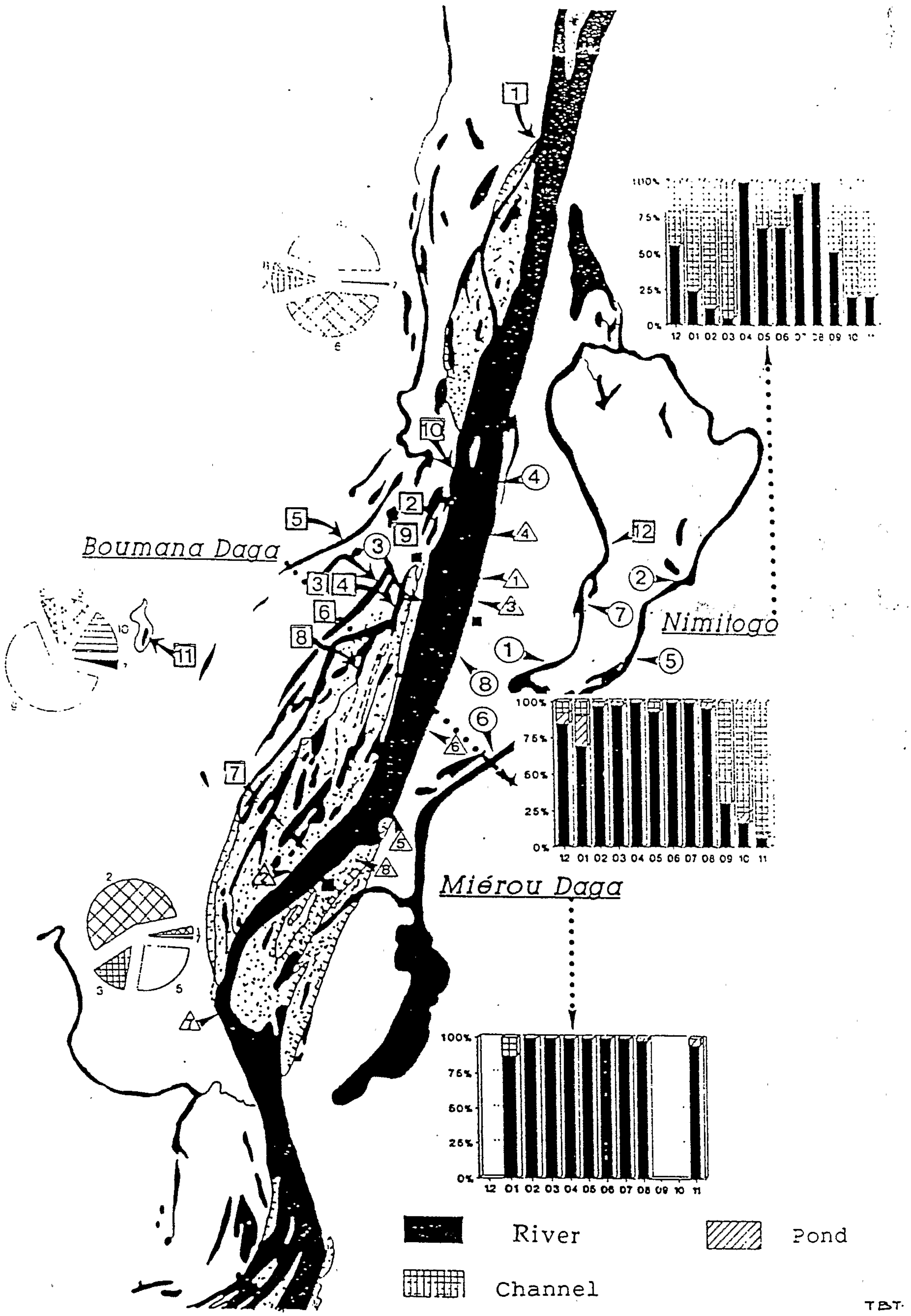

Figure 5.2: Results of a survey

attributes, while the fishing specialist will consider it through the various types of equipment and his technical ability.

Although one can focus on the description of objects, researchers get different types of knowledge on the dynamics of these objects and on their interactions. This knowledge can refer to complementary subjects (for instance, there are, on the one hand, rules on the dynamics of the fish populations and on the other hand, rules on the social relations between fishermen) or even opposed ones (for instance, a researcher in economy will not describe the dynamics of the fishermen's decision through the same rules as the researcher in anthropology). Each of these types of knowledge can be described in the form of a set of rules (knowledge source) which represent different evaluations on the dynamics of the world of objects.

We selected a blackboard system in order to organize this knowledge, to lead these different evaluations and points of view to cooperate. The blackboard controls the simulation dynamics and makes use of the different types of knowledge when they are necessary. Thus, the blackboard will call in the ecologist in order to specify the fish growth and in the fishing specialist in order to determine fish catches according to the environmental conditions, etc.

The simulator has been worked out from the Smalltalk language on SUN station. The simulator is divided into two great models: the ecological dynamics and the fishing dynamics. We give a simple description of the ecological dynamics and we will lay more emphasis on the simulation of the activities carried out by the fishermen's groups.

5.3.2 Hydro-ecological modelling

In the delta, four great types of different biotopes can be distinguished: the river which is supplied with water all the year round, channels or arms which are supplied with water at the time of the flood and flooded plains which are supplied with water at the height of the flood. At the recession period, plains and channels are no longer supplied with water and there are ponds which dry up little by little. These four great types of biotopes to which we will add the fields for agriculture represent the area common to fish and fishermen, the sites where they interact. We simulated the dynamics of fish populations within this area composed of biotope objects by defining objects of fish groups which reproduce, grow bigger, die, migrate and enter into competition through biotopes as related to their hydrological evolution.

This dynamical simulation by representing the variability linked to resource is used as a basis for the simulation on the fishermen's decisions and at the same time as a basis of comparison for the different strategies of production which will be tested. We will observe how these different activities change the characteristics of the fish populations (evolution of the biomass, weight and age structure...).

5.3.3 Modelling of the fishermen's decision making

As we built an hydro-ecological world, we create different household objects. These objects get different attributes which correspond to the ethnic group, to the numbers of individuals it contains, etc. The simulator allows to create fishermen's populations according to the distributions observed in the field (for instance, 80% of the households belong to the Bozo ethnic group, or the number of individuals per household complies with a normal law with a mean of 7 and a standard deviation of 2). Once these households have been entered into the simulation, they make decisions about their activities and act accordingly.

The decision making model formalized by us is divided into four phases: building up – perception – decision(selection) – action. Then we remain close to a classical decision making modelling (Allen, 1986) (Simon, 1977). Some decision making models which will be tested and are expressed in the stimulus-reaction form do not require these four phases, unlike other more cognitive models.

The **building phase** is used to record all the activities likely to be carried out in the environmental conditions. According to the works conducted by the different researchers of the team, the whole possible fishing activities are composed of the whole biotope-equipment couples (pond-cast net, river-cast net, river-gill net, etc.) which are also called "technotopes". Agriculture will be considered as another possible activity in order to study the relation between fishing and agriculture. Each fisherman defines for each of the possible activities an object called agenda on which he will store information in the course of the following phase, namely the perception phase. Therefore, there are so many agenda objects as there are possible activities.

The **perception phase** consists for the fisherman in getting information on each of the potential activities. The environmental conditions of the fisherman are interpreted by the different researchers who give information which are stored on the agenda objects. This information must be transcribed into a common syntax in order to be compared. We selected two types of representations in order to translate the information which result from the fisherman's environment through the researcher's knowledge. The first transcription is quantitative and the second one is qualitative.

- Quantitative transcription: a classical transcription into the economical decision making theory is the financial transcription. Given a possible activity, the available information are transcribed into profit or cost: the X information shows that the Y activity will yield (cost) 1 000 F.

  Given x Household
  Given y Flood
  If y height = high
  Then x fishing River: 1 000

  As mentioned before, the environment fluctuates and its fishermen must therefore foresee the future environmental conditions: fishermen get ideas on the results of the possible activities which include the variability of their environment. For instance, in order to calculate the receipts derived from an activity (a site-equipment couple), the resulting fish catch must be evaluated. The fisherman knows that this catch is included into a distribution composed of the fish caught in the past in this site with this equipment. Each of the fishermen can interpret this distribution as risky by considering that catches will be maximum, as discreet by considering that they will be minimum and as moderate. Therefore, the utility calculations include different attitude towards uncertainty about the results of the interaction with the resource.

- Qualitative transcription. When analysing the knowledge produced by the researchers of the team, one observes that there are information which cannot be transcribed in this quantitative form. Therefore, we also foresaw a more qualitative representation derived from the poll theory. The X information shows that the Y activity is favourable, unfavourable, impossible, compulsory. Therefore, each researcher, each knowledge can express a view on the possible activities according to these four modalities.

The **selection phase** consists in making a choice among the various possibilities offered. For this purpose, different models are available. Some of them impose the decision, there is no choice. For others, like that of the economical decision, it comes to comparing the potential activities among them. Again, several processes are possible: selection of the most profitable activity, selection of the activity which got the most favourable opinions, the least unfavourable opinions, etc.

When making a decision, the fishermen's household is involved into an ecological but also a social environment. The study of these social relations is the first objective of this simulator. The social situation in which the fisherman is involved can be considered according to two approaches. The top-down approach consists in involving the fishermen's household into a constraining structure. The anthropologists supply the team with a knowledge who describe the structure of the fishermen's society and the distribution of the activities as follows:

Given x Household
If x ethnic group = bozo
Then A compulsory activity (forbidden, favourable, etc.).

The bottom-up approach, on the contrary, consists in giving to the fisherman relations, other households with which he can have interactions and principles which govern these interactions. For instance, it is considered that each household gets 10 neighbours and that he gets a mimetic behaviour towards the best one or towards the activity most represented within the group or on the contrary the least represented. These simulations which are submitted to the environmental variability can lead to different organizations of the society. Simulation is interesting in that it can test these different models in the same artificial universe in order to compare and observe how they are adequate to reality.

The action phase After determinining its activity, the household acts on its environment by going to fish. In relation to the activity selected (the site-equipment couple), it selects an equipment and goes to a site, the biotope. There, his fish capture depends on the amount of fish observed in the biotope and which can be characterized by a certain variability. The fisherman does not catch exactly the same amount of fish in the same biotope with the same equipment. He stores this fishing and adds it to his experience. The belief attribute records all the fishings practised by the fishermen's household for different sites, equipment and seasons. Thus, he acquires an experience which can be a source of new interrogation on his decision. The construction-perception-selection-action cycle is completed. For each fishing, the corresponding amount of fish is removed from the biotope.

Therefore, this simulator allows to test different models of decision making for the households living in a variable environment. We described the principles of the simulator, the computer techniques selected or worked out and the simulation structure. Now, we will give examples of simulations based on different decision making models in order to give a general outline of the use of this equipment.

5.4 Simulations

We already presented the data we are working with:

- input data on the original distributions which allow to create fishermen's populations, data on the environmental variability and on the variability of catches. It describes our artificial universe and its variability.
- output data on the fishermen's activities, on their space occupation. That comes to making descriptions at the level of the fishermen's group.

Among these original data about the agents of the artificial world and their whole space occupation, there are models of decision making which can be tested and discussed through their tendency to represent the variability observed. Data refer to 36 different villages in different areas and environments. Simulations of this situation require that the data gathered which are currently raw should be analysed. This analysis is being made and therefore we cannot give simulations which are directly compared to the reality observed. Moreover, the decision making models must be discussed and specified with each researcher.

The analysis presented shows through various examples the potentialities of the simulator and simulations show its subsequent use. Theoretically, we built an artificial world on which we tested different decision making models. The results of these different simulations will be compared by analysing how, according to different individual behaviours, the fishermen's groups occupy their area throughout the year.

5.4.1 The different proposed models

We tested several different decision making models which show the possibilities of the simulator. The first simulation presented supplies the fisherman with a rational behaviour from an economical point of view, he tries to maximize his profits, then we compare this rationality to the environmental variability. The households could get different behaviours towards the risk (risky, discreet, mean). Moreover, anthropologists studied the behaviour of the fishermen's society and described the relations between the fishermen's groups. We will give a schematic representation of this organization in order to observe its consequences. Finally, various theoretical models on the interaction between fishermen such as phenomena of mimetism and repulsion will be tested.

The resource without catches of fish

The first simulation presented concerns the evolution of the resource without catches of fish. We worked out a universe composed of a river biotope, a channel biotope, an flooded plain biotope and a pond biotope. The hydrological cycle is as follows: at the beginning of the flood, water rises from the river to the channel and from the channel to the easily flooded plain. The three biotopes are connected, which allows fish to migrate from the river to the plain. At the recession period, water withdraws progressively from the plain and the channel and fish gather in the river. The pond is a specific biotope for it is isolated from the others. Schematically, the resource cycle is as follows. At the flood period, fish reproduce, ascend the channels or the plains, find conditions which are very favourable to growth and at the recession period, they descend the river where fish are too numerous. This overcrowding slows down their growth. These results are represented schematically in Figure 5.3 where the time evolution of the biomass is represented. The dynamical modelling of the resource allows to supply the fishing model with a basis sensitive to the fishermen's captures.

Model of economic rationality

We defined an original population of fishermen which will be identical for all the simulations presented. We present results for 2 years long simulations. The fishermen's population includes 50 fishermen, 50% of whom are Bozo and 50% are Somono. The number of individuals in a family complies with a normal law whose mean is 7 and standard deviation is 2. The fish populations are defined.

The first simulation presented is based on a model of economical rationality without considering the fishing variability. Any fisherman who goes to the same site with the same equipment catches the same fishes. At each time interval, at each selection, the fishermen's household selects the most profitable activity which will yield the biggest profit. The results presented in Figure 5.4 show that all the fishermen make the same choice at the same moment. The only period when the fishermen occupy simultaneously several different areas

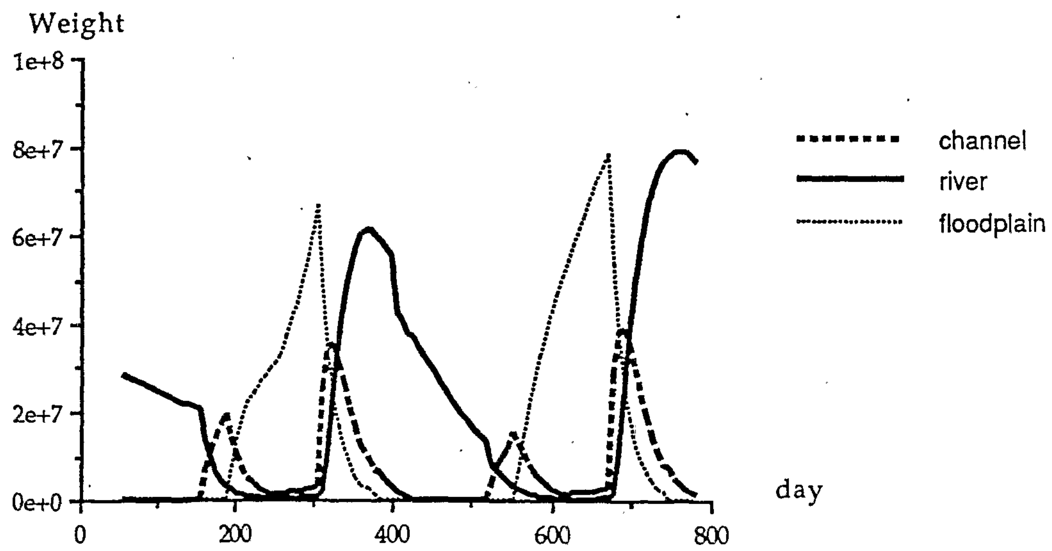

Figure 5.3: Dynamic of resource without capture

is the low water period for catches are similar in the pond and in the river. Rapid changes in the space occupation are observed: all the fishermen change their activity together at the same moment. Due to this type of result, this model of economical rationality which was considered as too much simple and did not include the variability of the ecological environment and of the human behaviour was dismissed.

Several economical studies turn towards the study of the model of economical rationality in relation to this variability. Therefore, the second simulation included the catch variability. A fishing activity is hazardous and the results are submitted to a considerable variability. Thus, we considered that a fishing activity was represented by a normal law whose mean and standard deviation are defined. In each biotope, a fishing is selected randomly in a normal law with a mu mean and a sigma standard deviation as related to the equipment and the existing amount of fish. Results are shown in Figure 5.5. There is a big homogeneity and again all the fishermen tend to do the same thing at the same moment. Activities begin to diversify and the changes in phase are less immediate than the previous simulation, but conclusions are nearly identical. Thirdly and in our simulation of economical calculation in variable conditions, we supplied the fishermen's households with different behaviours towards the risk. We simulated a population including:

- 1/3 of the households which select an activity by averaging their experiences,
- 1/3 of the households which select an activity by taking the risk to consider their highest achievement in the course of the two previous weeks,
- 1/3 of the households which select an activity by considering their lowest achievement in the course of the two previous weeks.

Results are shown in Figure 5.6. A even more important diversity is observed in the space occupation. Fishermen select different activities and the changes in the space occupation are more spread over time. Therefore, the simulation shows, in our theoretical world, that different behaviours towards the risk may change the model of space occupation.

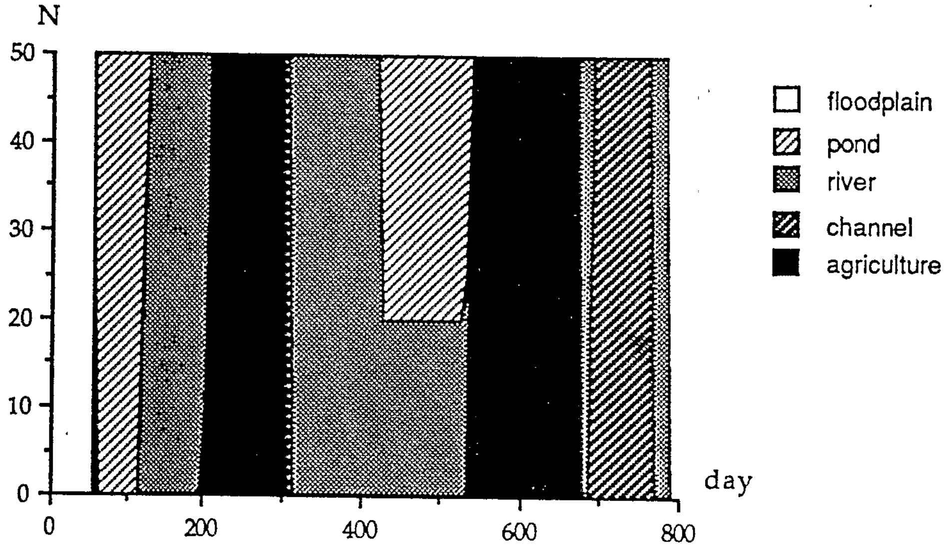

Figure 5.4: Economic rationality without catch variablility

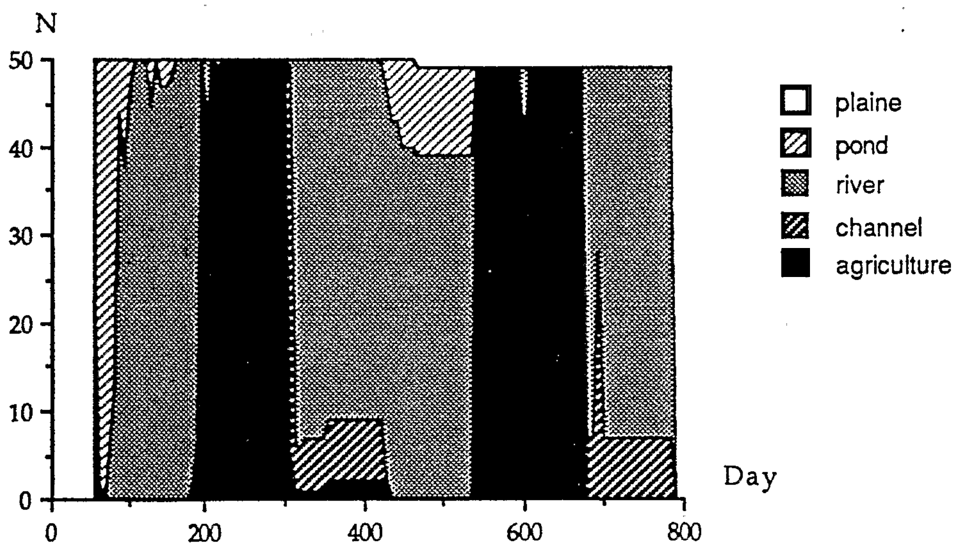

Figure 5.5: Economic rationality with catch variablity

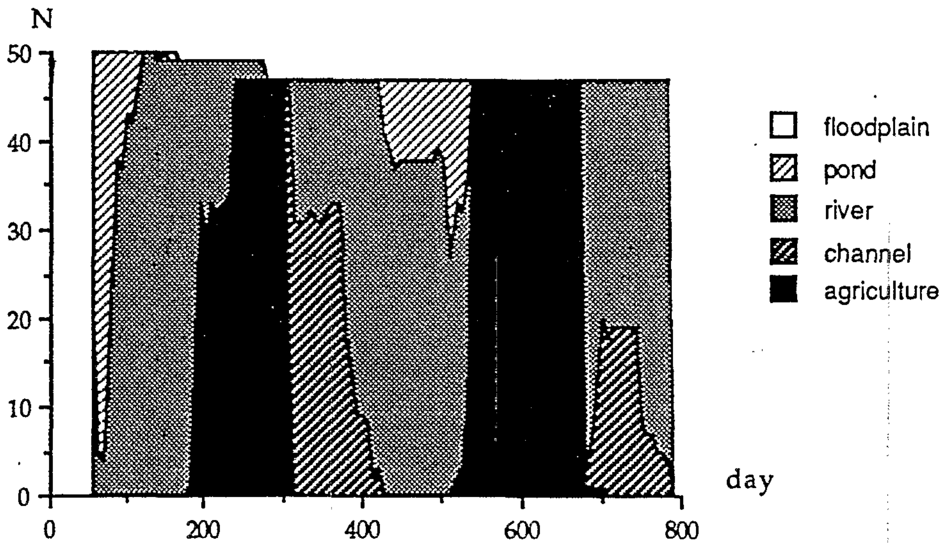

Figure 5.6: Different behaviours towards the risk

Social interaction

The economical rationality which is faced with an environmental variability or different behaviours towards the risk is an individual decision making model. The household is involved into an environment which is only ecological. The interaction with the other households is very indirect, it goes through the amount of fish observed in the biotope that depends on the exploitation of this biotope. It's an exploitative interaction. However, the micro-economists and the anthropologists show, by studying the history of populations and their relations with space that perception and decision making are not only individual but also collective. C. Fay (Fay, 1990) and B. Kassibo (Kassibo, 1990) describe how the different groups of fishermen shared the access to the resource and how society adapted to its environment and variability. The simulator presented must allow to represent different social relations. The representation of these interactions can be considered according to two approaches: the top-down approach and the bottom-up approach.

The **top-down approach.** As part of our simulations, the transcription of the anthropological knowledge corresponds to a top-down approach. The knowledge put forward by researchers describes organizations in the fishermen's group. In simulations, the social organization partly imposes the fishermen's activity: the social environment is considered as a constraint by the fishermen's household. The simulation worked out allows to represent easily this type of constraints. For instance, in the Delta, the fishermen belonging to the Somono and Bozo ethnic groups share the space and the ressource. As for the other simulations, the anthropological knowledge is very schematically represented, which shows that it is possible to represent social constraints in this simulator. Before the disorders observed in the last thirty years, and in some regions of the delta, the Bozo people occupied flooded plains and ponds, while Somono people concentrated on the river. We reproduced this situation by only entering the following rules:

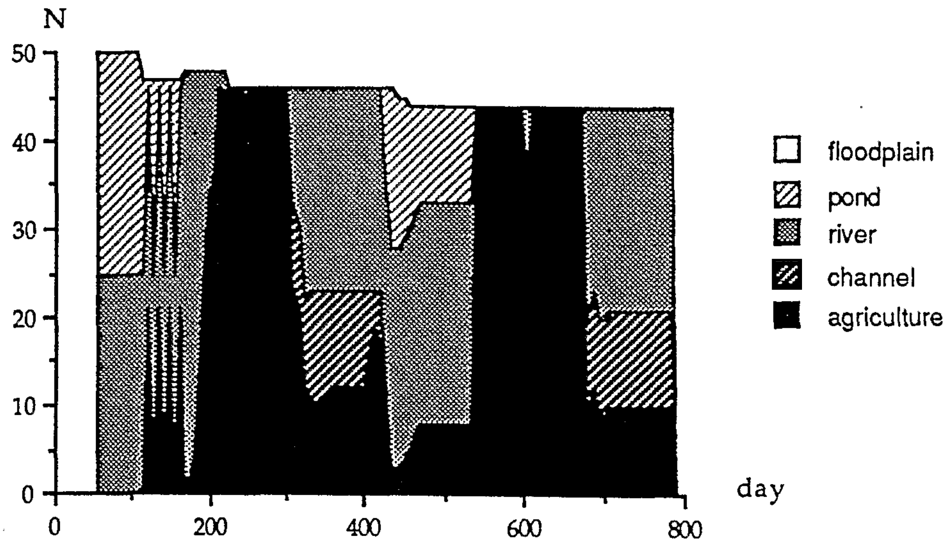

Figure 5.7: Transcription of anthropological knowledge

Given x Household
If x ethnic group = Somono
Then x fishingPond: veto.

Then the space occupation is predefined. The results observed in Figure 5.7 are not surprising. Bozo and Somono fishermen are distributed on an equal basis in the pond and in the river at the period of low waters. However, it is particularly interesting on the one hand, to compare these results with those obtained for the other models and on the other hand, to compare them with the field observation. Although the society was well organized before the 1940's, numerous critical phenomena (fishing licences which give free access to all the territories, highly profitable equipment, drought and population growth which led to reduced areas) have occurred since that period and led to individual behaviours. However, this relation is badly known. We suggest to apply these different simulations to the 36 villages for which data are available and to observe how these models account for the space occupation. To what extent does each of these models account for the reality, how are they opposed or complementary?

Moreover, the consequences of these different space occupations on the resource dynamics can be compared. Then, given all the simulations concerning the economical rationality, the same evolution of the fish populations was observed as related to their number and biomass (Figure 5.8). The resource did not depend on fishing. On the contrary, the resource dynamics has been modified by forcing fishermen to follow the collective model of exploitation (Figure 5.9). Given the same halieutic result, fishermen caught nearly the same general amount of fish in all the simulations, the evolutionary curves of the resource are different. This type of result obtained here on a highly simplified modelling shows how interesting simulation is.

The bottom-up approach. Although the simulation of a society based on the anthropological knowledge is particularly interesting to study the consequences of the social organization on the use of a renewable resource or to compare it to simulations concerning

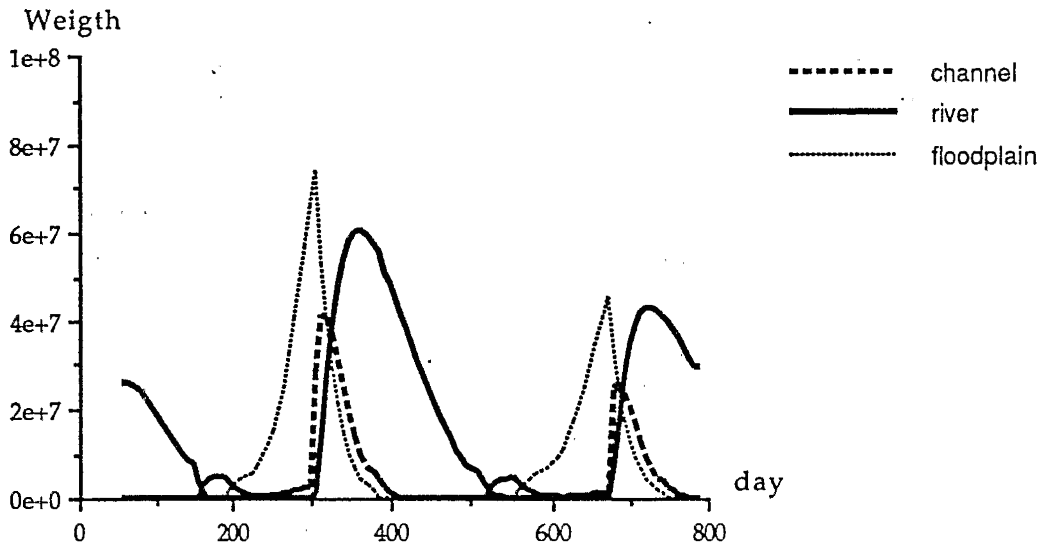

Figure 5.8: Resource dynamic with economic rationality simulation

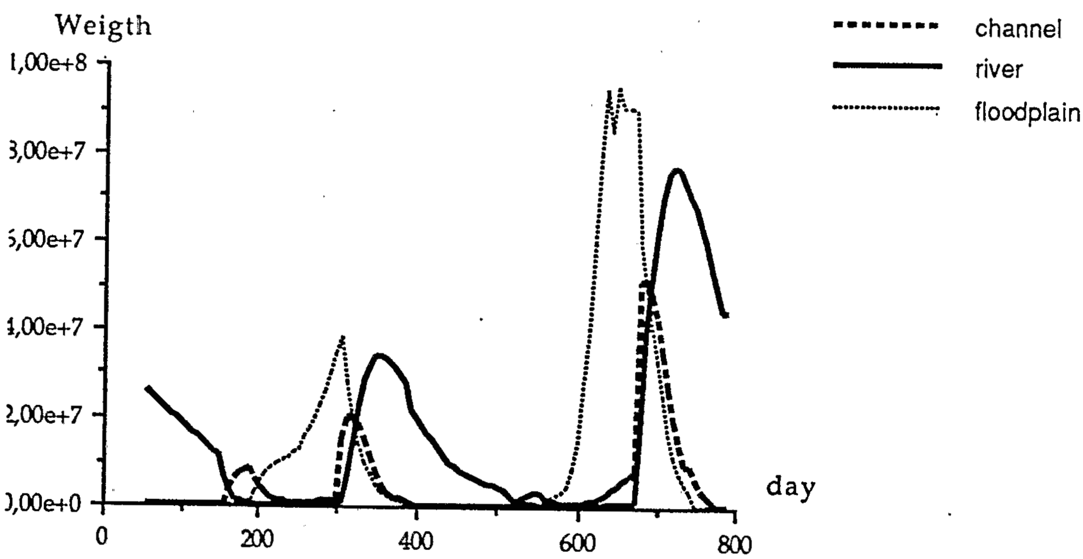

Figure 5.9: Resource dynamic with anthropological simulation

other theories of decision making, most of the current researches are more interested in the study of the structuration of a society based on the interactions between its constituent individuals. Thus, there are numerous researches in the literature concerning the macroscopical behaviours based on reactions at the microscopical level. Many works and particularly those using the genetic algorithms simulate the evolution of groups over long periods of time and are interested in the learning process of the agents by observing the society which survived or those which disappeared.

Within the team, we are working on the one hand, on shorter time intervals of about 1 to 5 years and on the other hand, as seen in the previous example, the rules of interaction between the agents involve an already organized society. For the moment, rules of interaction are not available at the micro level and they would account for the macroscopic organization. We are going to work on simulations in order to test the organization between several households which negociate the distribution of their activity in order to maximize a collective result. The formalization of this type of knowledge is proceeding: we are going to associate the simulator with representations of the negotiations conducted between the persons involved.

Otherwise, we tested the influence of communication, of information sharing in these societies of fishermen. In the economical simulations, we considered no sharing of information: the fisherman decides only in relation to his own experience. Fishermen are likely to get access at least to a part of the results obtained by the other fishermen. Therefore, we simulated the sharing of information between fishermen according to different methods. The amount of information shared can vary according to two points:

- the networks of information between fishermen. A fishermen's household can get a variable number of relations with the other households,
- the amount of information transmitted during a communication.

When a household has access to the experience of another, does he get access to all its achievements or only to a few fishing results? The simulator allows to test the influence of the amount of information between the fishermen's households.

For instance we present 2 simulations where households get successively 2 and 5 social relations. The results are shown in Figures 5.10 and 5.11. Comparing these results to those shown in figure 6 we conclude that the size of the communication network may change the space occupation.

5.5 Conclusion

The simulation study presented here fits into a synthesis conducted by a multidisciplinary research team. Therefore, we worked out a simulator which includes the different knowledge of researchers in order to simulate a society which is organized round the use of a renewable resource. There are several theories, several models in order to account for the activities selected by fishermen and we make use of the simulator in order to observe their influence on the resource dynamics, to compare between them and to compare them to the data observed in the field. We are particularly interested in links between the individual behaviour of fishermen and the organization of the fishermen's society, particularly in its space occupation which reflects the collective use of the resource. The techniques used which are derived from the Distributed Artificial Intelligence allowed to build a highly modulated simulator in order to test rapidly very different hypotheses on the functioning of the fishermen's households. These works aim, after having simulated these societies of fishermen, at going back to the

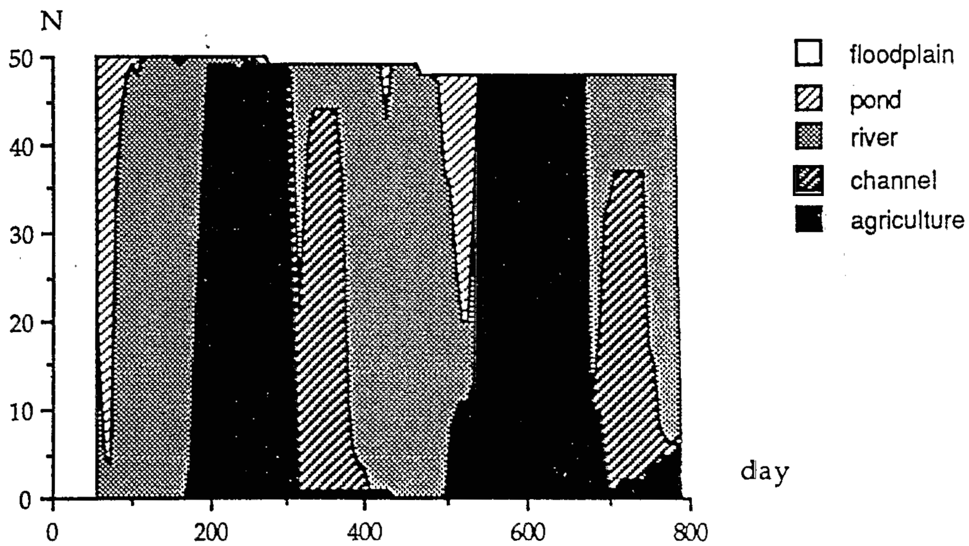

Figure 5.10: Economic rationality, communication with two households

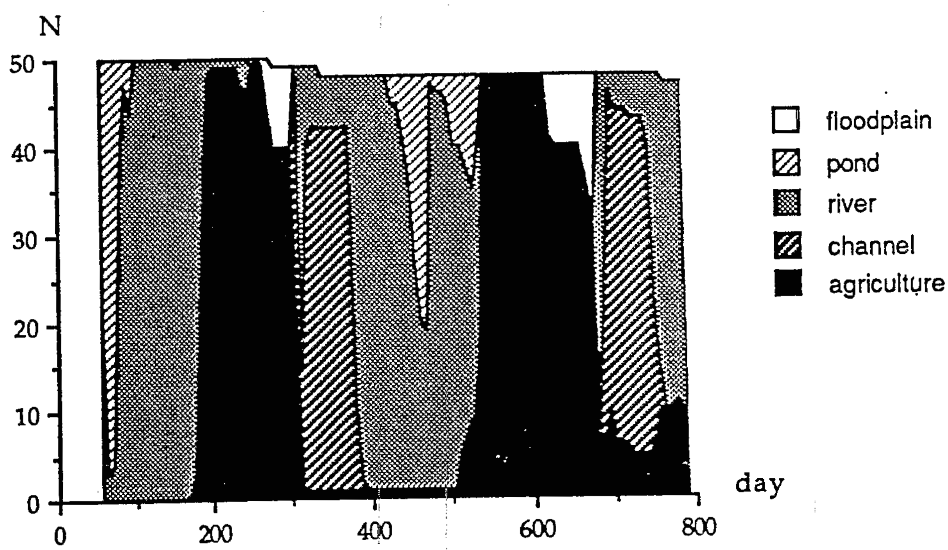

Figure 5.11: Economic rationality, communication with five households

researcher in order to show the dynamical consequences of their knowledge, to inform them of the dependance of their models on the environmental variability and to help them to relate their different models.

References

Allen, P.A. (1984) 'Vers une science nouvelle des sciences complexes', in IDATE-UNU eds, Science et pratique de la complexite, Actes du colloque de Montpellier, pp: 307-340.

Berkes, F. (1989) 'Community-based management and sustainable development: a framework for research, in J.R.Durand and Weber (eds) La recherche face a la peche artisannale, Proceedings of ORSTOM-IFREMER symposium.

Bousquet, F. Cambier, C. (1990): 'Transfert d'echelle et univers multi- agents: le cas du systeme de la peche du Delta Central du Niger', in C.Mullon ed., Seminfor ORSTOM 4

Fay, C. (1990) 'Systemes halieutiques et espaces de pouvoirs: transformation des droits et des pratiques de peche dans le Delta Central du Niger (Mali), 1920-1980, in Cahiers Sciences Humaines, 25 (1-2), pp. 213-221.

Ferber, J. (1989) 'Objets et agents: une etude des structures de representation et communication en Intelligence Artificielle' These d'etat, Paris 6.

Kassibo, B. (1990) 'L'organisation sociale de la peche dans le delta central du niger: genese et evolution des systemes de production halieutique', Actes de l'atelier IER-ORSTOM, Bamako, 34pp.

Lae, R. (1990) 'Les pecheries artisanales du secteur de Mopti: ressource, communautes de pecheurs et strategies d'exploitation'. Actes de l'atelier IER-ORSTOM, Bamako, 34pp.

Pave, A. (1989) 'Object Centered representation and problems related to living systems in nature, in Pave and Vansteenkiste eds, Artificial intelligence in numerical and symbolic simulation.

Quensiere, J. (1990) 'Systemique et pluridisciplinarite: l'exemple du programme d'etude de la peche dans le delta interieur du niger', in C.Mullon ed., Seminfor ORSTOM 4

Simon, H.A. (1981), 'The sciences of the Artificial', MIT