Length-based Fish Stock Assessment in Senegal

by

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Internship Report

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Introduction:

Global Graduates/Oregon International Internship Program offered an internship position working in Senegal with the Institut Sénégalais de Recherches Agricoles (ISRA) and the Natural Resource Based Agricultural Research (NRBAR). The author of this paper was accepted for this internship and lived and worked in Senegal from October 1 through December 15, 1996. I am a masters degree candidate in the Marine Resource Management program at Oregon State University, and I worked as an intern with the Centre de Recherches Océanagraphiques Dakar-Thiaroye (CRODT), which falls under the jurisdiction of ISRA. The original proposal for the internship outlined a plan to analyze catch per unit effort data for the Senegalese artisanal fisheries as well as to identify points of conflict between the artisanal and industrial fisheries.

Upon arrival in Senegal and after preliminary meetings with CRODT researchers, the internship goals were adjusted to be more in line with the needs of the CRODT. The revised proposal for the internship specified that I would develop a method for making the large amounts of length frequency data from the artisanal fishery that the CRODT has collected over the last 20 years amenable to analysis by the software package FiSAT (FAO-ICLARM Stock Assessment Tools), developed jointly by the FAO (Food and Agriculture Organization of the United Nations) and ICLARM (International Center for Living Aquatic Resources Management). In addition, acting upon a suggestion from the symposium "L'EVALUATION DES RESSOURCES EXPLOITABLES PAR LA PECHE ARTISANALE", henceforth referred to as the 1993 Dakar symposium, a second internship goal was the organization of a workshop on the use and application of FiSAT.

This report descibes the marine fisheries in Senegal. It includes a brief description of the oceanic conditions as well as a general review of length-based stock assessment. It concludes with observations that I made while an intern at the CRODT, as well as recommendations for rectifying the problems that were observed. The methodology that was developed for transforming the CRODT's length data into a format that can be imported into FiSAT is included as an appendix.

Background:

THE OCEANOGRAPHIC CONDITIONS OF SENEGAL:

Senegal is a west African nation with a population of approximately ten million, of which almost two million live in the Dakar metropolitan area. The waters off the west coast of Africa are dominated by the Canary Current. The Canary Current is one of the four most important upwelling zones in the world (Koranteng et al. 1996) and is formed by the eastern edge of the very broad southern flow of the North Atlantic Gyre (Rand McNally Atlas of the Oceans 1977). At the southern end of the Canary Current, off the coast of Senegal, upwelling lasts from December to June (Deme-Gningue and Touré 1993). The intensity of the Canary Current is very strong close to the continental coast and weakens progressively further offshore (Bas 1993). The system is similar to that off the Oregon coast (Huyer 1976), however, the continental shelf off of western Africa is wider than that off of Oregon, and is characterized by a sharper shelf break. The continental plateau north of Cape Verde runs north--north-east and is never more than ten miles in width (Deme-Gningue and Touré 1993). South of Cape Verde, the plateau widens to almost 30 miles in the Casamance region. The shape and size of the shelf area coupled with intense upwelling makes the Canary Current system a highly productive area (Koranteng et al. 1996).

Six nations have maritime claims to the Canary Current, with Morocco, Mauritania and Senegal having control of most of the zone. The Canary Islands (Spain), Madeira (Portugal) and the Cape Verde Islands have access to small parts of the area. The claims of Morocco, Mauritania and Senegal are the most important because (i) the narrow continental shelf where most of the production occurs is along their coasts, (ii) Cape Verde has claim to a very small portion of the area in relatively deep water and (iii) Spain and Portugal, before and after their entry into the European Economic Community (EEC), had negotiated fishing access to the national waters of Morocco and Senegal (Prescott 1993). The three continental states could most likely propose management of this maritime area without obstruction by the offshore territories. However, national friction between Senegal and Mauritania, and between Morocco and the former Western Sahara (Spain) currently impede the development of a comprehensive management plan for the Canary Current system.

FISHERIES IN SENEGAL:

In Senegal, fisheries resources are important economically and socially. In fact, over the last few years the fishery sector has become Senegal's primary economic sector, ahead of both peanuts and phosphate (Cormier-Salem 1994). The annual mean fisheries production in the 1980's was on the order of 250,000 mt, but reached 350,000 mt as of 1993 (Kébé 1994, Figure 1). Most of this production is done by the artisanal fishery (Diallo 1995, Figure 2). Artisanal fisheries are defined as small-scale enterprises utilizing labor intensive practices (Muth 1996). Also, there is generally a dependence upon the harvested fish products for household consumption. The artisanal fishery in Senegal is made up of a large fleet of around 4,000 pirogues (plank canoes) with outboard motors, and fishing operations are extremely labor intensive (Figure 3). Industrial fishing is characterized by less labor intensive practices with greater capital investment, and the harvest is completely targeted for sale rather than household consumption. The Senegalese trawler fleet has deteriorated, and by 1988 all 135 vessels were over 20 years old and second- or third-hand (Prescott 1993). Attempts are being made to renovate the trawler fleet through aid from European countries. In conjunction with this, artisanal fishermen are being encouraged to fish further away from the main fishing centers that are the most overfished.

There were sharp increases in catches from 1972 to 1991 (Samba 1994), primarily because of an increase in the motorization of vessels and the introduction of the purse seine. The exploitation of the Senegalese resources by both artisanal and commercial fleets are very important economically and socially. The fishery sector directly employs 57,000 fishermen, of which 47,000 are in the artisanal sector. The fishery sector also creates more than 150,000 jobs indirectly. In all, it is estimated that 15% of Senegal's labor force is linked to the fishery sector.

The major portion of the artisanal fishery catch, around 80%, consists of pelagic species, of which clupeids account for 77% (Samba 1994). Demersal species (sparids, serranids, ariids) and cephalopods, represent the other 20% of the artisanal fishery catch. Inshore pelagic species dominate the artisanal fishery by weight.

In Senegal, fish and other aquatic resources are the principal source of animal protein (Cormier-Salem 1994). In fact, Senegal is the fourth largest consumer of fish per capita in the world. Fish consumption has increased regularly, while milk and meat consumption remain very low. This is due to the development of production and trade in the fish market as well the massive growth and urbanization of Dakar. Much of this, in turn, is due to the persistence of the Sahel drought, which has greatly hampered agriculture, thus putting an even greater pressure on fisheries to increase production.

FISHERIES MANAGEMENT IN SENEGAL:

Due to the continued increase of fisheries production in Senegal, as well as the fact that almost all of the marine species caught in Senegalese waters are believed to be overfished (Diouf 1993, Koranteng et al. 1996), management of the marine fisheries is extremely important. The current management regime in Senegal includes both domestic and international aspects.

The majority of fish caught off West Africa are taken by foreign fishing fleets, with Russia as the leading harvester (Goffinett 1992). This is not the case in Senegal, however, where foreign fleets supply only a small amount of the catch. The management problems of Senegal are atypical for West Africa due to the lack of a foreign fishing presence and the fact that the country's management capabilities are well developed for the area. Starting in 1967, the entire West African region received fisheries aid in the form of research assistance and monetary aid from the FAO Committee for the Central Atlantic Fisheries (CECAF). The research included both social, biological and economic aspects (Kwiatkowska 1993). CECAF funding from the United Nations was withdrawn in 1985 but the United States donated a bridging grant that carried the program through 1987 (Goffinett 1992). Although it appears that the United Nations will resume funding for CECAF, the 1989 Rabat Ministerial Conference was convened, which led to the conclusion in 1991 of the Dakar Convention on Fisheries Cooperation Among African States Bordering the Atlantic Ocean (Kwiatkowska 1993). The Dakar convention expressly follows the Law of the Sea Convention and existing agreements between the 22 West African states.

> A wide range of measures aimed to promote 'an active and organized cooperation' in fisheries include, under the Dakar Convention, those pertaining to conservation and rational management of single and shared fish stocks, exchange of scientific information and statistics, harmonization of conservation and utilization policies, assessment and conservation of highly migratory species, monitoring, surveillance and control of fishing vessels, development of fishery production, marketing of fishery products, fishery planning and financing, social conditions of fishermen, and harmonization of fisheries policies and legislation (Kwiatkowska 1993).

In most developing countries, one of the most difficult aspects of a management regime is enforcement. In Senegal, this is complicated because there are several agencies employed in fisheries monitoring and enforcement, including the Ministry of Fisheries, police, customs and the navy (FAO 1983). Canada has supplied large amounts of funding to Senegal for the management and enforcement of its fisheries (Goffinett 1992). There are numerous laws in Senegalese legislation pertaining to fisheries, such as a prohibition on bottom dragging within six miles of the coast and a requirement that all foreign vessels fishing within Senegalese waters register with the Senegalese Ministry of Fisheries. However, the fact that most of Senegal's fish harvest is by the artisanal sector, management options aimed at reaching a sustainable harvest are limited and difficult to implement (Deme 1993) because it is politically and socially unacceptable to impose hardships upon the artisanal fishermen when much of the harvest is for subsistence. This is doubly difficult due to the persistence of the Sahel drought, which severely limits alternative employment possibilities for fishermen. One avenue that is being pursued is to relocate some of the artisanal fleet from the Dakar region. The fish stocks in the southern Casamance region are underutilized and represent a means to lower the fishing pressure on the over-fished northern stocks (Cormier-Salem 1994; Deme 1993).

STOCK ASSESSMENT:

For a management regime to be effective, there needs to scientific advice based on stock assessment. The primary purpose of stock assessment is to provide descriptive information on the status of the exploited stocks and recommendations on future harvests. Often this involves estimating the sustainable exploitation levels that give the maximum yield. The general procedure for a stock assessment is detailed in Figure 4.

Assessment analyses of fisheries are dependent upon some measure of age and changes in abundance of age composition over time (Rosenberg and Beddington 1988). Aging fish is most often done by counting rings on hard parts such as otoliths (ear bones) and scales. The addition of the annual rings to hard parts is due to growth, which is in turn determined by food availability. The seasonality in temperate waters, which affects food availability, causes the formation of distinct annual rings and thus makes aging of the fish possible. In tropical waters, seasonality is much less pronounced, thus making age determination using hard parts more difficult. Another problem with aging fish in tropical waters is the pattern of recruitment. Temperate fish stocks are usually dominated by a single pulse of recruitment every year. In tropical waters, fish often spawn over extended periods of time and often more than once per year (Sparre and Venema 1992). A third difficulty with aging fish in the tropics is that it is relatively expensive, and most developing countries are severely cash limited. In general, traditional age-based methods of stock assessment cannot be directly applied to tropical fish stocks. Length based stock assessment is often seen as a last resort approach to stock assessment but it is often the only practical method available in tropical waters for the reasons mentioned above (Rosenberg and Beddington 1988).

There are a great variety of methods for conducting a stock assessment. One simple approach is known as yield per recruit analysis. With this method, estimates of yield from a recruiting fish are related to different levels of fishing effort and length at first capture. With this, it is possible to determine whether the fishery is being growth overfished. Growth overfishing occurs when the amount of fishing effort is so high that yield per recruiting fish decreases with increasing effort. The fish are being caught so rapidly that growth potential is wasted. Recruitment overfishing occurs when the population size is reduced so low that the production of recruiting fish is severely diminished or even fails. With the information available from a yield per recruit analysis or from methods such as Virtual Population Analysis, the likely consequences of fishing at different exploitation rates can be explored. For a more in-depth analysis of stock assessment methods see Sparre and Venema 1992.

LENGTH-FREQUENCY ANALYSIS:

Length is an alternative non-linear measure of time that can be used as a proxy for age (Gallucci et al. 1996). Although there are many stock assessment methods that use lengths, in general these methods are still age-based and work by transforming length to age. Fish grow throughout their lives, thus making it possible to determine growth rate from length. The process is somewhat complicated by the fact that fish growth is usually asymptotic, with growth continually slowing. Using observations of fish length frequency and equations for growth and survival, it is possible to determine values for the stock parameters. The growth of fish is usually described by the von Bertalanffy growth formula, which is expressed in its simplest form as

$$L(t) = L_\infty\left[1 - e^{-K(t-t_0)}\right],$$

where L(t) is the length of a fish at age t, L_∞ is the average maximum of a fish, K is a growth coefficient that controls how rapidly fish grow to L_∞, and t_0 is the theoretical age at which length is zero. In length frequency analysis, a model for growth in length is combined with an equation that describes the decline in numbers of fish in a cohort. Most commonly, the following exponential decay model is used,

$$N(t) = N(0)e^{-Zt},$$

where N(t) is the number of fish at time or age t, and Z is the instantaneous mortality coefficient. With this equation, the coefficient Z determines how fast the numbers of fish will decline, with larger values of Z producing quicker decreases. The instantaneous total mortality coefficient can be broken into two factors, an instantaneous fishing mortality coefficient (F) and an instantaneous natural mortality coefficient (M), such that Z=F+M. The instantaneous fishing mortality coefficient is the portion of total instantaneous mortality due to fishing (the catch), while the instantaneous natural mortality coefficient is the portion that die due to natural causes such as predation, disease and old age.

Length frequency analysis is a general term for a variety of methods that have been developed to determine the values for the stock parameters when only length information is available. The analysis can be applied to two forms of length frequency data: data from a single aggregated sample or from a time series of samples. For the first method, a histogram is made of the lengths from a sample of the catch and the modes of the smaller lengths are assumed to represent different age groups (Figure 5). The difference in length between the modes is the amount of growth between those age groups. With the second method, there are a sequence of samples and two types of information are available. First is the growth averaged over a year, and second is growth during the sampling intervals (Figure 6). One of the difficulties with any type of length frequency analysis is differentiating the older age classes. Because growth decreases as fish age, the lengths of fish in the older age classes smear together and there are no distinct modes (Figure 5).

During the 1993 Dakar symposium, recommendations were made to carry out a more in-depth analysis of Senegal's fisheries using the large quantity of length frequency data that had been collected by the CRODT. These data had not been analyzed due to "the priority placed on understanding and analyzing the dynamics of the harvesting system" (Pauly 1993) and because of the overwhelming quantity of the data and the lack of data processing capability.

Major progress has been made in recent years in the area of information processing using computers. Since the advent of microprocessors, the ELEFAN (Electronic Length Frequency ANalysis) software package has been extensively used to conduct length frequency analyses throughout the world (Gayanilo 1993). Another widely used program is LFSA (Length Frequency Stock Assessment). These two programs have been recently combined into one software package, FiSAT (FAO-ICLARM Stock Assessment Tools, Pauly and Garcia 1994). The FiSAT software, developed jointly by FAO and ICLARM, can easily manipulate large quantities of data (Gayanilo et al. 1996). It was suggested as a tool for analyzing the CRODT's length data.

It must be stressed that length frequency analysis should not be the only tool used to assess the status of Senegal's fisheries. As with any scientific approach, there are numerous possible sources of error. Thus the results of this type of fishery analysis should always be carefully examined and evaluated. This is especially important with fish stocks in tropical and sub-tropical waters, for which the performance of these methods remains somewhat unclear (Pauly and Morgan 1987). The stock monitoring system for Senegal should include length frequency analysis, but only as one part of an assessment program. For example, tagging studies to determine growth and catch per unit effort studies to monitor mortality and abundance should be carried out in conjunction with the length frequency analysis.

With the FiSAT software package, CRODT researchers will have a tool with which they can estimate values of the various stock assessment parameters (L_∞, K, Z, F, and M) using the available length data that have been collected over the last twenty years (Figure 7). These parameters will provide insight into whether or not the fisheries are being exploited at sustainable levels, and will allow CRODT researchers to assess the strength of the fish stocks, thus providing managers and policy makers with better information on which to base fisheries decisions.

Results:

INTERNSHIP ACTIVITIES:

The CRODT's data are stored in a format that cannot be imported directly into the FiSAT program. Thus, there was a need for the development of a methodology for interfacing the CRODT's length data with FiSAT.

As one task of my internship, I developed a method for making amenable to analysis by FiSAT the large amounts of previously unanalyzed length frequency data that the CRODT has collected over the last 20 years (Appendix 1). Four FORTRAN programs were written that transform the

the data into a format that can be imported into FiSAT. The first two programs determine the minimum and maximum lengths for the chosen data and the second two programs reformat the data and save it as an ASCII file on a floppy disk. With this methodology, two years of length data for any species in the database can be analysed using the FiSAT software package. Also, during the internship FiSAT was installed on CRODT's computers and I verified that my programs and FiSAT were fully operational.

The CRODT does not posses the technical expertise to conduct a workshop on the use of FiSAT or length-frequency analysis. However, the CRODT is interested in organizing a workshop that would be given by experts who are qualified in these two areas. As a second task of my internship I discussed with fisheries researchers at the CRODT the organization of such a workshop. They are very interested in attending the workshop in order to gain proficiency in using the FiSAT software for length-frequency analysis. I developed a plan and preliminary budget for the workshop, which I gave to the CRODT researchers upon my departure from Senegal.

Discussion:

Using the preliminary methodology presented in this paper (Appendix 1), it is very easy to quickly transform the CRODT's artisanal fisheries length data into a format that can be imported into the FiSAT software. This methodology is applicable to all species as long as (1) there is a species code and (2) there are data for the chosen year. The complete usefulness of this methodology will not be fully known until analyses have been conducted with the FiSAT software using the transformed data. However, based on the interest shown by the CRODT's artisanal fisheries researchers, this methodology will be a useful tool. This methodology could also be adapted for use in transforming the industrial fisheries data to make it compatible with FiSAT. The FORTRAN programs would have to be modified, however, because the industrial fisheries length data are stored in a different format than the artisanal data. The industrial fishery length data base is filed by boat and includes data for each species caught by the boat. Also, the FORTRAN programs are specific to the row and column format of the artisanal fisheries data files. The changes that would be necessary include changing the section of code that determines which rows the programs read.

The FORTRAN programs, as they currently stand, need to be edited before the artisanal data can be used. The lengths in the database are chosen from different size classes, and thus they cannot be combined into a single group without statistical manipulation. This would include using the mass for each catch to estimate a weighted length frequency. If the different catches from which the lengths are measured have different length distributions, then the catches have to be adjusted for the relative size of each catch. For example, five lengths from a catch of one hundred fish should not be given the same weight as five lengths from a catch of one thousand fish. The latter lengths should be amplified at a 10:1 ratio compared to the first set.

Also, before the data are analyzed using FiSAT, the quality of the data needs to be assessed. This would include determining if the data were collected using acceptable methods. The manner in which the fish are selected for length measurement can be vital to the integrity of the stock assessment. Once this data verification is done there needs to be a course at the CRODT on size-frequency analysis, which then needs to be followed by a workshop at the CRODT in which detailed analysis would be carried out on the length data for the important fish stocks of Senegal. As the final internship requirement, I wrote a draft proposal for this workshop.

As part of the internship requirements, I conducted a sample analysis using the FORTRAN programs and the FiSAT software. The result of the analysis was that the *Pomadasys incisus* appears to be over-exploited. The instantaneous rate of fishing mortality was estimated to be greater than the rate of natural mortality and sustainable yields could be increased by a reduction in fishing pressure. However, numerous simplifications were involved in the analysis including

(1) using the FiSAT program defaults whenever possible, (2) ignoring seasonality in the data, (3) assuming that there was no need to separate the lengths by port or gear type, and (4) that the quality of the data was acceptable. The existence of so many assumptions illustrated, however, the need for the above mentioned workshop. At the workshop, experts in the field of length-frequency analysis would instruct the researchers at the CRODT how to answer the problems implicit in the assumptions.

Observations:

While completing this internship, I observed several problems that will impede the successful analysis of the Senegalese fishery data using FiSAT. However, it should be possible to correct these problems, at which time it should be possible to proceed with the analysis of the CRODT's vast amount of length frequency data.

The first problem was the lack of communication between the artisanal and industrial fishery researchers. Although the same populations of fish are being harvested by both fisheries, the researchers do not, or at least very rarely, share data. The reason for this may be that funding for positions is very much related to research productivity, thus making researchers more likely to hoard data for future use. Also, length frequency data from the two fisheries are stored in different formats, making it more difficult to use data from both fisheries. The sharing of length data would be easier if it was stored in a single format, but there may be good the reasons for the existing storage formats. Lack of communication is prevalent throughout the CRODT and a similar lack of communication exists between the CRODT and LiInstitut Francais de Recherche Scientifique pour le Developpment en Cooperation (ORSTOM). The ORSTOM research facility is on the same grounds as the CRODT with the researchers from the two institutions sharing many resources such as the computer facility. Here is an example of the lack of communication. When we asked CRODT staff if any of the researchers had a copy of FiSAT, we were told no. We then procured a copy of the software from the FAO, only to learn that one of the ORSTOM researchers owned a copy and had used it in producing some in-house research reports. Besides a general lack of communication, there also seems to be some animosity by the CRODT staff directed towards ORSTOM, from a feeling that ORSTOM researchers show little respect for the CRODT. It seems that a simple system of communication, such as a seminar series or newsletter, would alleviate the problem by allowing the researchers to know what their fellow researchers are working on.

More broadly than Senegal, there seemed to be little interaction between the researchers of the numerous coastal West African countries. Cooperation among these countries is important because most of the exploited fish stocks range through the coastal waters of many countries. The workshop that I proposed would include researchers from neighboring countries, which would facilitate the development of a length frequency analysis system that was common throughout West Africa.

Another problem I observed was the manner in which the fish length data were collected from the artisanal fishery. At the beach, the catch from the pirogues was dumped into piles and separated by species (Figure 8). The technician would then estimate the mass of the catch and an assistant would select and measure five fish (Figure 9). The manner in which the fish are selected is not strictly random. The assistant picks five fish from the pile without using a predetermined sampling protocol. The assistant might tend to pick the largest fish or perhaps the most colorful. A method for randomly selecting fish needs to be implemented. Fully randomizing the collection of data, so that all units (the fish in a pile) have an equal chance of being selected, is the most important requirement of the sampling regime. Non-random selection of fish can be a major source of bias and must be avoided. Although sampling of the entire fish catch may not be done in a simple random manner, it should be possible to randomize the selection process on a smaller scale, such as by boat. The system for estimating the mass of each catch needs to be addressed as well and some accurate method needs to be implemented. Also, to aid in the statistical averaging of length samples from different size catches, the average fish weight of each sample should be measured and recorded.

The difficulty of aging fish in the tropics was discussed earlier. However, there are seasonal changes in the waters off of Senegal (Bas 1993), which should make it possible to determine the ages of Senegalese fish. Currently there is no aging of fish being done in Senegal. The use of age data in combination with length data would greatly increase the reliability of stock assessments.

In conclusion, I feel the internship was very successful, both for myself as well as the CRODT and I was able to develop and finish the internship in the three months available to me. As with most internships, the interns probably benefited more than the host institution. Personally, I learned a great deal about working in unusual conditions, in which resources were limited and the culture and languages were very different from my own. If there is any follow up to this project, such as the above mentioned workshop being hosted by the CRODT, the artisanal fishery researchers at the CRODT should gain another tool with which to tackle the problem of sustainably managing Senegal's myriad of fisheries.

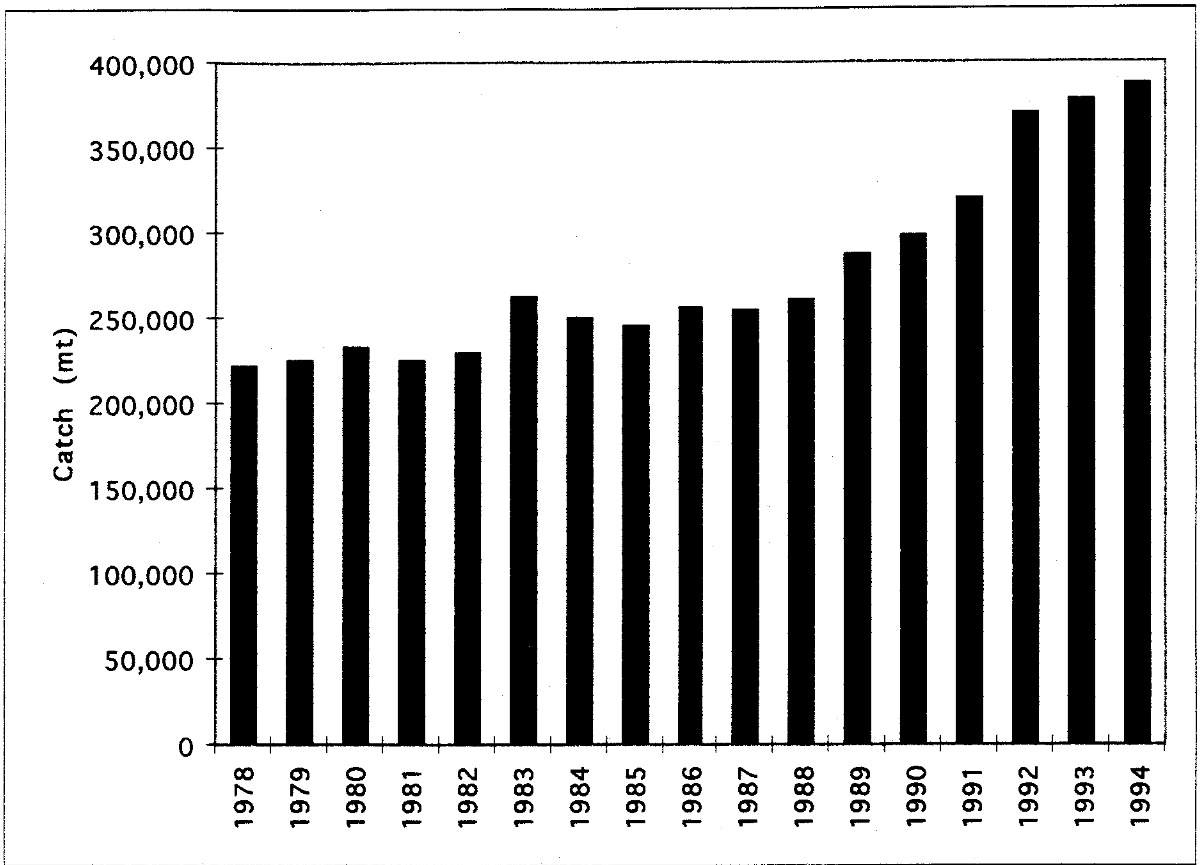

Figure 1. Total catch of Senegalese fisheries from 1978 - 1994 (Statistics from FAO yearbook).

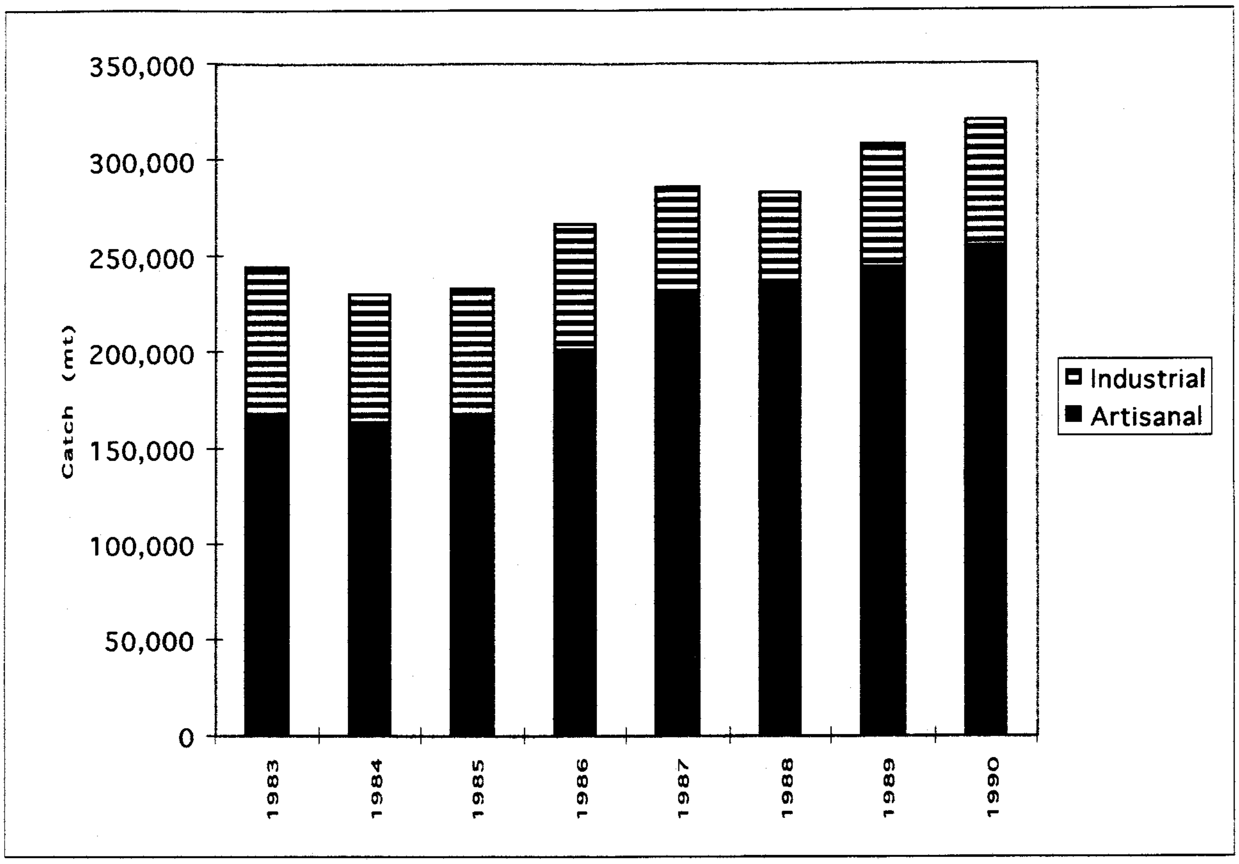

Figure 2. Catches (tonnes) by the artisanal and industrial fishing sectors in Senegal. The industrial catch does not include harvest by foreign ships, but in Senegalese waters the foreign catches are relatively small.

Figure 3. Artisanal fishing, including processing and marketing, is extremely labor intensive. The pirogue above is in the process of being unloaded manually. The two men with boxes full of fish on their heads will carry the entire catch onto shore (around 1-2 tonnes). Each box has a capacity of about 70 pounds. The men on and around the pirogue are the crew. A small outboard motor has been pulled into the pirogue.

INPUT:	Fisheries Data and Assumptions.
PROCESS:	Analyses of historical data.
OUTPUT:	Estimates of growth and mortality parameters.
PROCESS:	Predictions of yield for a range of alternative exploitation levels.
OUTPUT:	Optimum fishing level. Maximum sustainable yield.

Figure 4. Flow chart of the stock assessment process (From Sparre and Venema 1992).

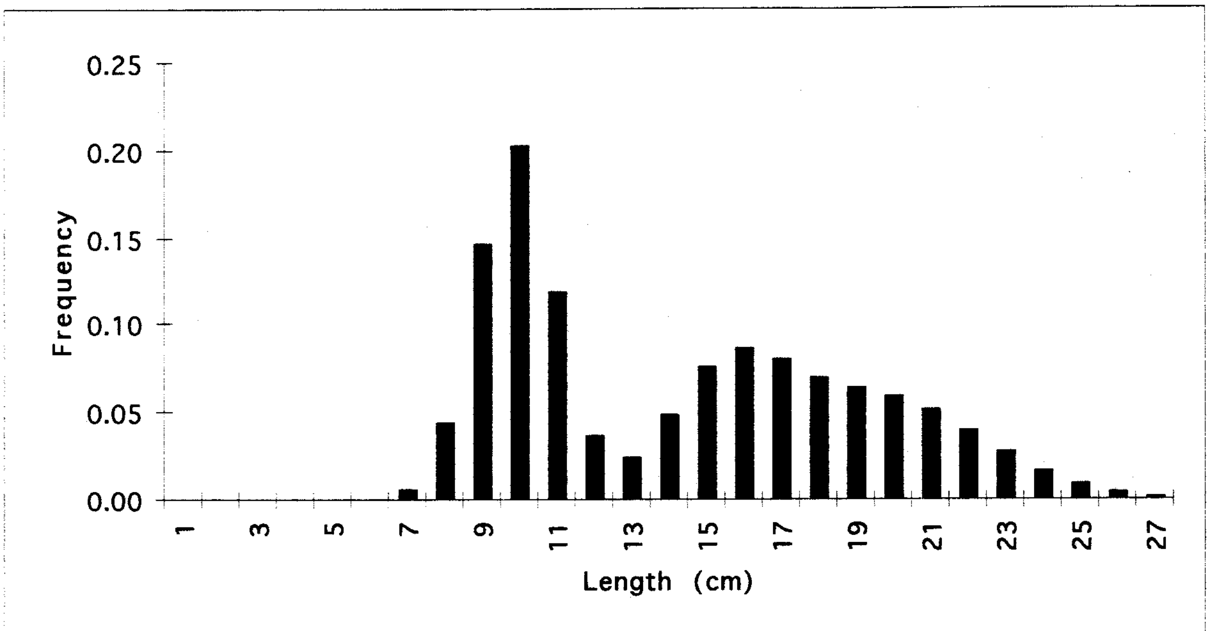

Figure 5. Hypothetical length-frequency sample. The first two age group modes are relatively easy to discern, with the first age group mode at 10 cm and the second age group mode at 16 cm. The difficulty of discerning age groups increases dramatically after the first few ages.

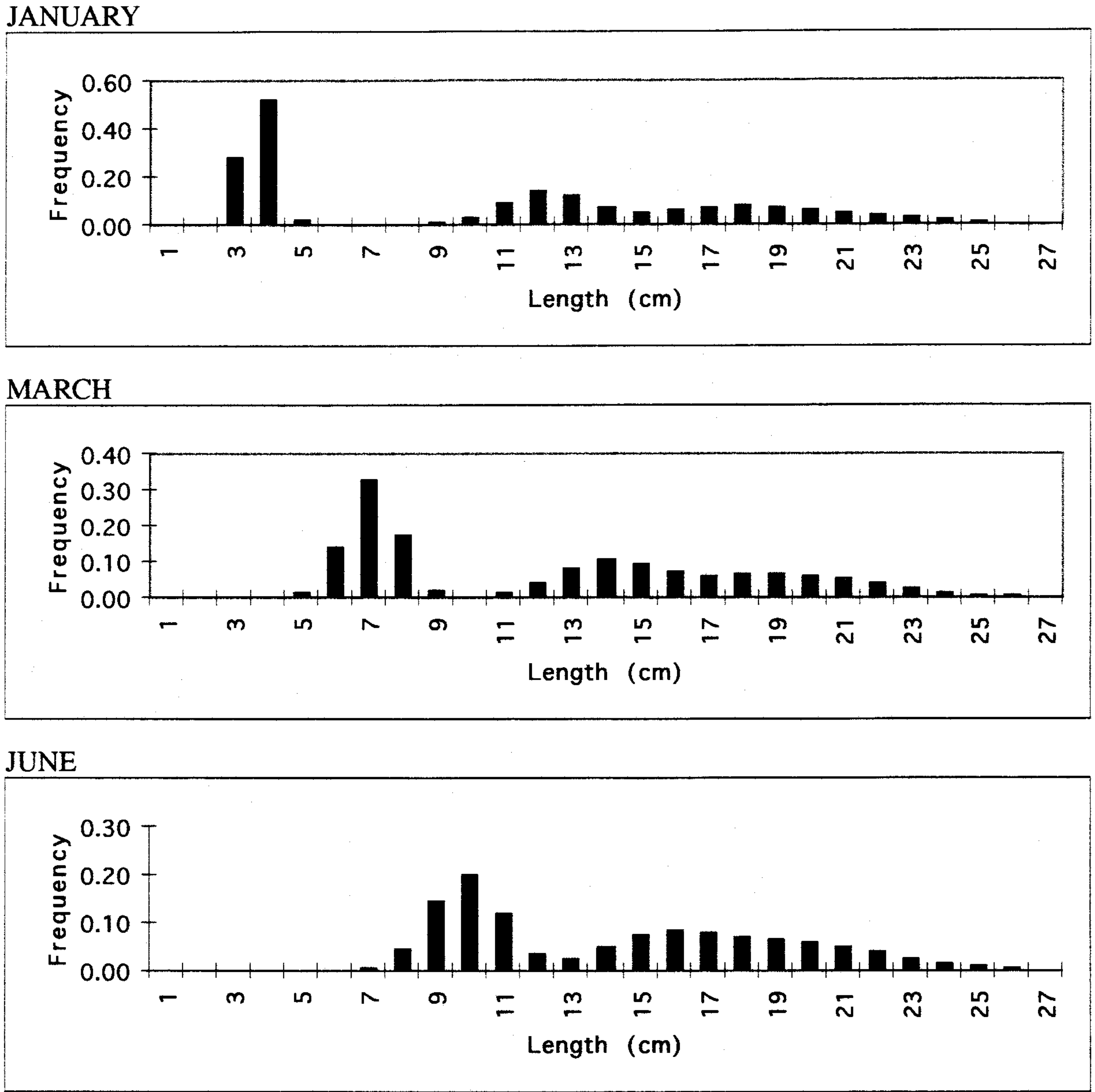

Figure 6. Hypothetical time series of length frequency samples. With multiple samples, cohorts can be followed through time. The first age group mode is 4 cm in January, 7 cm in March and 10 cm in June.

FILE

- About
- Create file
  - Length on weight frequencies
  - Growth increments
  - Length-at-age
  - Catch-at-age
  - Mean lengths and s.d.
  - Probabilities of capture
  - Values by size
  - Two-column regression
- Load file
  - Length on weight frequencies
  - Growth increments
  - Length-at-age
  - Catch-at-age
  - Mean lengths and s.d.
  - Probabilities of capture
  - Values by size
  - Two-column regression
- Save file
- Print file
- Sample manipulation
  - Merge files
  - Pool samples
  - Correct using probabilities
  - Adjust class interval
  - Smooth data
    - Running average by 5 classes
    - Running average by 3 classes
  - Convert
    - Length to length
    - Weight to length
  - Raise samples
    - Using C/f
    - Using catch/sample weight
    - Using a constant
    - % of sample total
    - Square root of sample total
- DOS Shell
- Return to DOS

ASSESS

- Parameter estimation
  - Direct fit of L/F data
    - ELEFAN I
      - Curve-fitting by eye
      - Response surface analysis
      - Scan of K-values
      - Automatic search routine
      - Output of results
    - Shepard's method
      - Resonse surface analysis
      - Scan of K-values
    - Powell-Wetherall's plot
  - Analysis of length-at-age
    - Non-seasonal growth
    - Seasonalized growth
  - Modal progression analysis
    - Bhattacharya's method
    - NORMSEP
    - Linking of means/C.V. of L_∞
  - Analysis of growth increment data
    - Gulland and Holt plot
    - Munro's method
    - Faben's method
    - Appledoorn's method
  - Mortalities
    - Z from steady-state sample
      - Length-converted catch curve
      - Jones/van Zalinge plot
      - From mean length
        - Beverton and Holt model
        - Ault and Ehrhardt method
      - Hoenig's model
    - Natural mortality
      - Rikhter and Etanov's method
      - Pauly's M equation
      - M from selection data
  - Recruitment patterns
  - Probabilities of capture
    - Trawl-type selection
    - Gillnet selection
  - Virtual population analysis
    - Age-structured VPA
    - Length-structured VPA
    - VPA with pseudocohorts
- Prediction
  - Relative Y/R and B/R analysis
    - Knife-edge
    - Selection ogives
  - Thompson and Bell models

SUPPORT

- Simulation of L/F samples
  - Closed habitat
  - Migratory stock
- Sample weight estimation
- Sample bar graph
  - 2D display
  - 3D display
- Maximum length
- Growth performance indices
- Regression analysis
  - $Y = a + b \bullet X$
  - $Y = a' + b' \bullet X$
  - $\log(Y) = a + b \bullet \log(X)$
  - $\ln(Y) = a + b \bullet X$
  - $Y = a + b \bullet \ln(X)$
  - $Y / X = a + b \bullet X$
  - $\ln((1 - Y) / C) = a + b \bullet X$
  - $Y^C = a + b \bullet X$
  - $Y = a + b \bullet X^C$

UTILITIES

- Copy data file
- Show file status
- Delete file
- Import file
  - ELEFAN
  - LFSA
  - LOTUS 1-2-3 (ver .01)
  - ASCII standard
- Export file
  - LOTUS 1-2-3 (ver 2.01)
  - ASCII standard
- Configure printer device
- Calculator

Figure 7. Systems available with the FiSAT software package. The four main components are FILE, ASSESS, SUPPORT and UTILITIES.

Figure 8. The fish are carried onto the shore and dumped into piles separated by species. The separation occurs on the pirogue. A representative of the pirogue then sells the catch to fish mongers (a role occupied solely by women).

Figure 9. The assistant to the CRODT technician measures a fish. The process by which the assistant selects the fish to measure needs to be randomized.

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APPENDIX: USERS GUIDE FOR IMPORTING ARTISANAL FISHERIES DATA FROM THE UNIX/SUN SYSTEM INTO FiSAT.

INTRODUCTION:

At the Centre de Recherches Océanagraphiques Dakar-Thiaroye (CRODT), length data collected for Senegal's artisanal fisheries are stored in Dbase 4 on a UNIX/SUN system. This UNIX/SUN format is unwieldy for conducting length frequency analysis and the data stored in the UNIX/SUN storage format cannot be imported directly into the FiSAT program. FiSAT is a software package for length freqency analysis developed jointly by the FAO and ICLARM. Manual re-entry of the large data files is far too time consuming to be efficient. Thus there was a need to develop a method of transforming the stored data into a format that could successfully interface with FiSAT (Appendix Figure 1). This prompted the development of the FiSAT-UNIX/SUN interface. Four FORTRAN programs were written that transform the artisanal fisheries length data into an ASCII format and allow the user to select species and years to be transformed.

The FiSAT software has an import feature that makes importing files straightforward. However, for this function to be successful, the file to be imported must be in one of four formats (Lotus 123, Compleat ELEFAN, LFSA or ASCII) as defined in the FiSAT User's Guide. Due to the format of the CRODT's data, it was decided that transformation of the data into ASCII format was simplest. Not only must the data be stored as ASCII characters, but they must be in a precise format, organized into specific columns and rows. The description of the ASCII data storage format is on pages 104-105 in the FiSAT User's Guide.

The development of the methodology for transforming the CRODT's length data was a three step process. The first step involved manipulating the data files in the UNIX/SUN system. The length frequency data were reorganized and stored in the /bidon/pa/taille directory. The reorganization included making a separate file for each data collection year. Previously, all of the data had been stored in a single massive file. The second step involved writing two FORTRAN programs that changed the data into an ASCII file that could be imported into FiSAT. Two shells were written that implement the two FORTRAN programs. Documentation was written that outlines the steps for (1) transforming the data from a UNIX/SUN format to ASCII and (2) saving the transformed data in FiSAT. The third step was a sample analysis to verify that the data had been transfered to FiSAT correctly.

The first shell routine is MINMAX, which simply implements the first FORTRAN program MINIMUM. At this stage the user must input codes for the target species and the program then determines the minimum and maximum lengths for the year and species specified. The second shell routine is DATAFISAT to which the user must input the year, species, the minimum and maximum lengths determined by the MINMAX shell, and a file name for the transformed data. The FORTRAN program EXTRACT then organizes the data for the year and species selected, saving it to a disk as an ASCII file that can be imported into FiSAT.

The following methodology defines 22 steps needed for transforming the CRODT's length data into an ASCII format that can be imported into FiSAT. Some sample test results are also included that can be used to verify that the FORTRAN programs and methodology are working correctly.

METHODOLOGY:

1. In the UNIX/SUN system, move to the **home/latdior/manne** directory.
    - This is where the FORTRAN programs and shells are stored.
2. Type MINMAX at the prompt.
    - This activates the MINMAX shell which in turn runs the program MINIMUM. This program searches for the minimum and maximum lengths for the entered species in the given year.
3. Enter species code number at the prompt. Refer to species code list (Ferraris et al. 1993).
    - This selects which species MINIMUM will search for.
4. Enter the year for which you want the data scanned.

- This restricts the search to the year entered.

5. Write down the species code, year, and minimum and maximum that are given as output by the MINMAX shell.
    - These data will be used with the DATAFISAT shell that reformats the data.
6. Type DATAFISAT at the prompt.
    - This activates the DATAFISAT shell which in turns runs the program EXTRACT.
7. Enter the species code used in step 3.
8. Enter the year used in step 4.
9. Enter the minimum size found by the MINMAX shell.
10. Enter the maximum size found by the MINMAX shell.
11. Enter the name you wish the file to be saved as. **Note:** The file name must be entered with an **asc** suffix.
    - This saves the reformatted data as an ASCII file with the given name.
12. Insert a diskette into the diskdrive. At the prompt type **doswrite -a** ***filename.asc filename.asc.*** Make sure to include the **asc** suffix on both filenames.
    - This saves the file to the diskette.
13. Switch to a PC that has FiSAT loaded on it.
14. Copy the file from the diskette to the **C:\FISAT\DATA** directory.
15. Change to the **C:\FISAT** directory and type **start**.
16. Go to the **Utilities** menu by typing **alt+u**.
17. Select the **Import** option.
18. Select the **ASCII** option in the IMPORT submenu.
19. Select the file that was just copied to the **C:\FISAT\DATA** directory.
    - This brings up the newly formatted data.
20. Go to the **File** menu by typing **alt+f**.
21. Select the **Save file** option.
22. Name the file the same as it was imported but **without** the **asc** suffix.

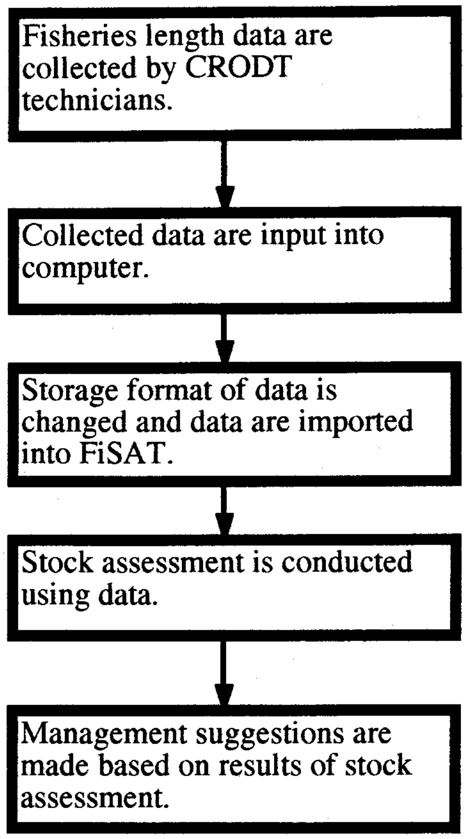
The data has now been reformatted and successfully imported into FiSAT. The data are now available for manipulation using the FiSAT software.

TEST DECK:

To test the above methodology, import the data for species code 3501 for the year 1982. Then under the assess menu of FiSAT, choose the 'Direct fit of L/F data'. At this point there are three options: ELEFAN I, Shepard's Method and Powell-Wetherall's plot. Select the 'Powell-Wetherall's plot' option. For type of analysis, select 'Percentage of sample total' and opt for 'Temporal weighting'. The results should match those shown below.

Analysis	Temporal weighting	L_∞	Z/K	r	midlength	frequency of midlength
Percentage of sample total	YES	34.130	6.857	-0.896	21	18634.86

Estimates of L_∞ and Z/K using Powell-Wetherall plot for species code 3501 and year 1982.



Appendix Figure 1. Overview of a process by which management decisions might be made. The process begins with data collection and ends with stock assessment results being used to generate management options. The UNIX-FiSAT data transformation program is concerned solely with the third step in the process.

PROGRAM LISTINGS:

MINMAX

```
# Shell Script
#--------------------------------------
clear
echo "Search for the min and max length for a species "
echo " "
echo -n " Year        : "
read AN
LEN=`echo $AN | wc -c`
if (( $LEN != 3 ))
  then
  echo " bad year, give two numbers "
  exit 1
fi
echo -n " Species code  : "
read specie
**********
NEW CODE FOR SELECTING INDIVIDUAL PORTS WOULD BE ADDED HERE
**********
FILE=/bidon/pa/taille/pa$AN.long
if test ! -f $FILE
then
  if test ! -f $FILE.Z
  then
    echo "le fichier n'existe pas "
  else
   echo "Decompression fichier "
    cd /bidon/pa/taille
    uncompress $FILE.Z
    cd -
  fi
fi
echo $FILE > minimum.par
echo $specie >> minimum.par
/home/latdior/manne/minimum
echo "Compression fichier "
cd /bidon/pa/taille
compress $FILE
cd -
echo "That's all folks  "
```

MINIMUM

```
      CHARACTER*1 AST_
      CHARACTER*2 FI_
      CHARACTER*80  LINE_
      CHARACTER*60 file1,file2
      DIMENSION ll(50)
C***********   DEBUT TRANSFORMATION *************************************
      OPEN(5,FILE='minimum.par')
```

```
      read(5,500)file1
      open(1,file=file1)
      read(5,510)ispecie
  500 format(A60)
  510 format(I4)
      min = 1
      max = 1
   10 read(1,100,end=999) iesp, n, (ll(i),i=1,50)
      if (ispecie.ne.iesp)goto 10
      min = ll(1)
      max = ll(1)
      backspace(1)
 1000 read(1,100,end=999) iesp, n, (ll(i),i=1,50)
      if (ispecie.ne.iesp)goto 1000
      if (n.le.0) goto 1000
      if (n.gt.50) N=50
  100 format(52X,2I5,50I4)
      DO 888 k=1,n
        if (ll(k).lt.min) min=ll(k)
        if (ll(k).gt.max) max=ll(k)
  888 CONTINUE
      goto 1000
  999 continue
      print*, " Length MIN : ",min
      print*, " Length MAX : ",max
      stop
      end
```

<u>DATAFISAT</u>

```
# Shell Script
#---------------------------------------
clear
echo "Create a data format for FISAT soft "
echo "  "
echo "   Before executING this program you must have the MIN and MAX length "
echo "   for species which you want to analyze "
echo "   Use program minmax for this "
echo "  "
echo -n " Year            : "
read AN
LEN=`echo $AN | wc -c`
if (( $LEN != 3 ))
  then
  echo " bad year, give two numbers "
  exit 1
fi
echo -n " Specie code      : "
read specie
echo -n " Min length       : "
read MIN
```

```
echo -n " Max length       : "
read MAX
**********
NEW CODE PORT SLECTED ABOVE WOULD BE ENTERED HERE
**********
echo -n " File output      : "
read FICOUT

FILE=/bidon/pa/taille/pa$AN.long
if test ! -f $FILE
then
  if test ! -f $FILE.Z
  then
    echo "le fichier n'existe pas "
  else
   echo "Decompression fichier "
    cd /bidon/pa/taille
    uncompress $FILE.Z
    cd -
  fi
fi
echo $FILE   > extract.par
echo $FICOUT >> extract.par
echo $specie >> extract.par
echo $AN   >> extract.par
echo $MIN    >> extract.par
echo $MAX    >> extract.par
# lancememnt du programme extract
/home/latdior/manne/extract
echo "That's all folks  "
```

EXTRACT

```
      CHARACTER*1 AST_
      CHARACTER*2 FI_
      CHARACTER*80  LINE_
      CHARACTER*60 file1,file2
      DIMENSION ll(50),mcount(1000,24),month(24), iday(24), iyear(24)
      data mcount/24000*0/
      data iday/1,15,1,15,1,15,1,15,1,15,1,15,1,15,1,15,1,15,1,15,1,15,
     +      1,15/
      data month/1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12/
C***********   DEBUT TRANSFORMATION ********************************
      OPEN(5,FILE='extract.par')
      read(5,500)file1
      open(1,file=file1)
      read(5,500)file2
      open(2,file=file2)
      read(5,510)ispecie
      read(5,510)ian
      read(5,510)min
      read(5,510)max
```

```
   write(2,510)ispecie
   write(2,*)
   write(2,521)
 500 format(A60)
 510 format(I4)
 521 format(" cm ")
1000 read(1,100,end=999) iqz,iesp, n, (ll(i),i=1,50)
   if (ispecie.ne.iesp)goto 1000
   if (n.le.0) goto 1000
   if (n.gt.50) N=50
 100 format(5X,I5,42X,2I5,50I4)
   DO 888 k=1,n
       long=ll(k)
       mcount(long,iqz)=mcount(long,iqz)+1
**********
NEW CODE TO INCORPORATE STATISTICAL WEIGHTING BASED UPON SAMPLE
SIZE WOULD GO HERE
**********
888 CONTINUE
   goto 1000
 999 continue
C* sortie resultat
   DO 668 K=1,24
     iyear(k)=ian
 668 Continue
   write(2,700) (iday(i),i=1,24)
   write(2,700) (month(i),i=1,24)
   write(2,700) (iyear(i),i=1,24)
 700 format(21X,24I9)
   DO 600 I=min,max
     F1 = I - 0.5
     F2 = I + 0.5
     write(2,200)F1,F2,Float(I) , (float(mcount(I,iqz)),iqz=1,24)
 600 CONTINUE
 200 format(F8.2,F9.2,F9.2, 24F9.2)
   stop
   end
```