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SOFTWARE FOR TROPICAL FISHERIES RESEARCH: The needs and response by FAO and ICLARM[1]

by

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ABSTRACT

The introduction and spread of microcomputers in the 1980s with prices well within the reach of the majority offered an opportunity to develop new tools for the analysis and modelling of fisheries to improve fisheries management, especially for the developing tropics. The paper describes the efforts deployed by FAO and ICLARM for the adaptation, development and distribution of software packages. It provides an annotated list of the software currently available in FAO and ICLARM, a brief analysis of the distribution of requests received, and discussion on some of the future needs and concerns which require concerted effort of institutions involved in software development.

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INTRODUCTION

The rate of change in computer technology, which is increasing exponentially, with processing power of a room-size computer of the 1960s now on book-size microcomputers, has had an immense inverse effect on their cost, allowing all disciplines of science to take advantage of their capabilities and power. This development also improved the accessibility of computers especially to researchers from the developing world.

The current fisheries computer toolbox includes programs with functions ranging from simple data storage and retrieval to conceptualization and simulation. FAO (Food and Agriculture Organization of the United Nations) and ICLARM (International Center for Living Aquatic Resources Management), as international organizations concerned with improving fisheries management in the developing tropics have played a significant role in the development, adaptation and diffusion of much needed research tools and are expected to be even more active in this endeavour in future.

THE EFFORTS

In the late 1960s to mid-1970s, computational difficulties in stock assessment and fishery modelling were circumvented through approximation (e.g., linearization of non-linear functions, use of tables, etc.) and the statistical power of the methods was limited. As fisheries institutions in the developed world increased their access to mainframe computers, the emphasis moved to non-linear procedures, more systematic estimation of variances, sensitivity analysis, fisheries games, multispecies and bioeconomic simulations. In the early 1970s, FAO in its effort to disseminate methodologies and reduce the gap between developed and developing countries, published a compilation of programs in a common programming language, FORTRAN (Abramson 1971). This compilation contributed to the significant development of a common methodology and a world set of comparable population parameters.

As fishery research institutions in the developed world increased their access to mainframe computers a number of computer programs were developed. The need arose for a compilation of these programs in a common language (FORTRAN) and for their dissemination and FAO produced a compilation prepared by Abramson (1971). For the following two decades, this compilation was used by a very large number of research institutions worldwide, in developed and developing countries and contributed significantly to the development of a common methodology and a world set of comparable population parameters.

Responding to continuing demands for programs and for Abramson's compilation received at FAO (long after the document was out-of-print), FAO decided to examine the possibility to update the document which served its purpose, however outdated. FAO undertook a project to compile a world list of available programs on stock assessment which include, among others, the addresses of the originating institutions, the specifications of the software and the

hardware requirements. This was also aimed at catalizing dialogues and methodology transfer between developed and developing countries. Twenty one research institutions cooperated, from thirteen countries (10 developed and 3 developing). A catalogue of 170 programs was produced and distributed (Caddy 1982).

However, it became apparent that this valuable attempt was insufficient to resolve most of the problems largely associated with technical difficulties, given the differences in computing environment, insufficient documentation of the software and in the absence of support from experienced programmers. In both the developed and developing world these efforts produced at least as much frustration as benefits.

Decisions were made to produce a new compilation of programs to replace Abramson's compilation. Such programs would be compiled under FAO's responsibility, and standardized in presentation and functionality. These new compilations of routines (Sims 1985; 1988) included examples and sample data sets which have greatly enriched the quality of the presentation and facilitated learning and testing of the programs. However, new trends were emerging. Fisheries laboratories in the developing world were faced with increasing difficulties to use FORTRAN programs on mainframes as they lacked access to mainframe machines and support by competent system analysts and programmers to help them tailor the programs to their needs.

The late 1970s was an era when programmable calculators were beginning to put into the hands of fisheries scientists some of the computing power, previously exclusive to those who had access to large and sophisticated mainframe computers. FAO and ICLARM (ICLARM was incorporated in Manila in early 1977) took advantage of these developments and the early results were the publication of integrated packages incorporating most of the stock-assessment models then available for programmable calculators (Pauly 1981a; 1981b; 1984; Vakily et al 1986; Palomares and Pauly 1987).

The early 1980s saw the introduction of low-price microcomputers. It was anticipated that microcomputer technology would follow the trend set by electronic calculators where computing power of the machine improved and prices eventually dropped. This was the period when software products for tropical fisheries research in BASIC started to appear, notably the ELEFAN (Electronic LEngth Frequency ANalysis) suite of routines (Pauly and David 1980a; 1980b; 1981, Gaschütz et al 1980, David et al 1982). It included routines from data entry and manipulation, to estimation of growth parameters, recruitment patterns, mortalities and other related parameters. Most of the routines were based on models made for temperate fisheries more or less adapted for tropical fisheries. These were implemented on a 'steam-engined' TRS-80 Radioshack microcomputer which was fed via a cassette tape and with only 16K of RAM.

The FAO software production strategy was based on cooperation with other institutions since the objective was not to generate new methodologies, duplicating the work of national institutions, but to promote wider (international) use of

programs originally conceived to satisfy specific national needs. The idea was to start from available routines, and providing scientists with a modest financial support to upgrade them in terms of structure, user-friendliness, explicit theoretical support and multilingual user-guides. For FAO and its member countries the benefit was in availability of inexpensive and reliable software. For the cooperating institution, the benefit was the upgrading of the programs and their promotion in the international literature[5]. The only exception to that stategy was the production of the BEAM series for the promotion of bio-economics which was developed directly at FAO because there was nothing else available at that time.

The strategy of ICLARM, facilitated by the low cost of competent manpower in Manila, on the contrary was to undertake directly the development and adaptation work at ICLARM. As a matter of fact as part of its effort to serve their clients and in anticipation of even bigger demand for computer services, ICLARM's organizational chart now includes a Computer Services Unit (CSU) to deal primarily with software programming and database development in cooperation with FAO and other institutions.

The most popular and, in some ways, the most controversial of the programs produced by ICLARM was ELEFAN I, a non-parametric program for the estimation of growth parameters from length-frequency data, readily available and under-used material. Inspite of the prevailing limitations, ELEFAN I proved itself as straightforward and easy to understand and better than the paper-and-pencil methods in use (Morgan 1983; Mathews 1987). The mid-1980s was the period when the methodology proliferated and resulted in the publication of several versions of ELEFAN[6] which developed progressively as an integrated package. During the 1980s the attention given to ELEFAN increased very rapidly as shown by the evolution of the citations analysis (Fig.1).

The time came to take stock of the progress made, to face the criticism addressed by part of the scientific community to the length-frequency analysis and to strengthen the dialogue with leading scientific institutions in the developed world. In February 1985, a workshop on the "Theory and Application of length-based methods in stock assessment" was held in Mazarra del Vallo, Italy, co-sponsored by ICLARM, Kuwait Institute for Scientific Research, FAO and the Italian Consiglo Nazionale delle Ricerche (Pauly and Morgan 1987).

During the same period and in relation with its training programme in stock assessment, FAO also took the initiative to develop an integrated software package for fish stock assessment (Length-base Fisheries Stock Assessment, LFSA), based on more parametric methods and developed for the Apple II microcomputer (Sparre

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[5]Such cooperation has involved IFREMER and ORSTOM (France), IMR (Norway), DIFMAR (Denmark) and University of Yucatan (Mexico).

[6]ELEFAN Kiel version (Brey et al 1988), HP-86/87 ELEFAN (Saeger and Gayanilo 1986), Apple ELEFAN (Chan and Liews 1986)

1987). However, the presence of two software packages resulted in some confusion among users trying to understand differences among largely overlapping packages.

In this period, trends were favouring IBM PCs as compared to other competing microcomputer trademarks. ICLARM embarked therefore on producing "The Compleat ELEFAN" (Gayanilo et al. 1987) for PCs, with graphic outputs whenever possible and incorporating the suggestions made at the Mazzara del Vallo workshop. FAO translated the LFSA package for use with IBM PCs. The use of menus and graphics made the methodologies even more acceptable and easy to understand. The manuals which were produced to support the software appeared to offer a much more efficient support to self-training than the conventional stock assessment manuals.

A large number of scientists from Asia, Africa, South America and Europe, were introduced to both LFSA and the Compleat ELEFAN (despite their large overlap) through the FAO/DANIDA training courses in Tropical Fish Stock Assessment (Venema et al. 1988). In 1989, a Letter of Agreement was signed between FAO and ICLARM to merge their respective packages into a new software called FiSAT (FAO-ICLARM Stock Assessment Tools; Pauly and Sparre 1990), incorporating new routines, modifying existing ones as required, reducing duplication of efforts and cooperating in the production of manuals.

The need for safer and more usuable tools lead both Organizations to agree informally to a few common guidelines based on experiences gained (see also Sparre and Garcia 1987) and notably:

- The products to be distributed in tropical developing countries should include methods used with data that are available or can readily be collected in these countries;

- The software must run on widely available, low-cost computing environments, and not on sophisticated workstations;

- The software must be as user-friendly as possible to improve the learning and concentrate user's attention on the method itself;

- Complex software should ideally be introduced to its users through training courses in order to shorten the error-prone learning phase;

- The product should be made available free-of-charge, or at a very low price and with no copy protection to ensure the largest possible access to methodology;

- The institution that produces the software must have a long-term commitment to maintain it and respond to user's inquiries and feedback;

- The documentation of the software should include the relevant theory, (referring to similar methods where relevant), the assumptions, and effects of their

violation, a section with practical advice and warnings, a program description and graphic view of its stucture, one or several sample data sets and outputs, a user's guide to running the program and specific routines and advice on validation.

During the 1980s the scope of the software production was broadened from stock assessment to bioeconomics, multispecies modelling, spatial analysis Geographic Information Systems applications and database development (Fig. 2).

THE PRODUCTS

The FAO Software Library

LFSA: Length Frequency Stock Assessment (Sparre 1987)

Originally developed in Apple BASIC, the package of programs has been translated to GWBasic and runs on standard IBM PCs. The routines incorporated in this package focus on the processing and analysis of time series of length-frequency samples. It includes routines for data handling and manipulation, estimation of growth and mortality parameters, yield-per-recruit analysis, and simple regression analysis. Its configuration and limited use of graphics capacity is the result of a voluntary choice to ensure that LFSA could be used on the simplest machines available. The evolution of this software was stopped (and its distribution limited) when the decision was taken in 1990 to merge it with the ICLARM package (The Compleat ELEFAN) to give birth to FiSAT (see below). This software is available only in English.

ANACO: Analysis of catch-at-age data (cohort analysis) (Mesnil 1989)

Written in FORTRAN, this set of programs aim at cohort analysis in its simplest form. It includes a simulation routine for training, which among others, enables users to gain insights into the mechanisms of cohort analysis (convergence, effects of changes in M and terminal F's etc.). A pseudo-cohort option (using only one year of catch-at-age data) is offered to examine the implication of the assumption of equilibrium. The manual contains few notes on how to modify the programs. This software is available in English and French.

ANALEN: Analysis of length-at-age data, multi-gear yield-per-recruit simulation and sensitivity analysis (Chevaillier and Laurec 1990)

Written in FORTRAN 77, this software, based on Jones' pseudo-cohort analysis, allowed for the analysis of multi-gear fisheries. It allows for the calculation of the potential effects of changes in fishing effort, mesh sizes and discarding practices. It aims at assessing the technological interactions between gear. Results are given in yield-per-recruit and fecundity-per-recruit for both long and short-term scenarios. The software also offers the possibility to calculate production in a deterministic way, based on the introduction of a stock-recruitment relationship. It calculates the variances of the parameters and allows for a powerful

sensitivity analysis of the different outputs. This software is available in French and will soon be available in English.

BEAM 1 and BEAM 2: Simple bioeconomic analytical simulation models for sequential fisheries on tropical shrimp (Coppola, Garcia and Willmann 1992)

Following numerous requests for advice on management of tropical shrimp fisheries with artisanal and commercial sequential fisheries implying complex socio-economic trade-offs, these two simple programs were prepared essentially as training tools to illustrate the basic implications of the introduction of bioeconomic considerations in standard stock assessment and conventional management. The BEAM 1 program, based on a Thompson and Bell modelization by age groups, was developed in 1982, computerized in 1985 and used, since then, in various training and assessment workshops. The BEAM 2 program is a variant of BEAM 1, based on a modelization by commercial categories. In both programs, the user is guided into a spread-sheet where the characteristics of the fishing regime can be modified and consequences are immediately estimated for artisanal and industrial capture and processing sectors. Used within the Organization for many years, the programs were published and distributed in 1992. The software is available only in English.

BEAM 3: Bioeconomic analytical simulation of tropical shrimp fisheries with fixed or randomly variable recruitment (Cochet and Gilly 1990)

Written in QuickBASIC and conceived as an improvement of BEAM 1 and BEAM 2, BEAM 3 was developed to deal with more realistic fishery situations. The program can handle up to four species (or two sexes of two species) and a multitude of fleets operating sequentially or in parallel. It also allows recruitment to be either constant or variable with time. The model incorporated in the software aims at determining the optimum mesh size and the level of risk, in the long term. It calculates the probability density functions of the outputs and their distribution among fleets, allowing for the determination of the probabilities of occurrence of undesirable economic results. The model was tested on the shrimp fisheries of French Guiana.

BEAM 4: Bioeconomic analytical simulation of space structured, multispecies and multigear fisheries (Sparre and Willmann 1993)

Written in GWBasic, BEAM 4 is the last software of the bioeconomic series that FAO prepared to promote the use of bioeconomics in tropical fisheries analysis. It is the result of an attempt to provide a software able to deal with most of the situations encountered by FAO when providing advice on fisheries management and for which, the BEAM 1, 2 or 3 proved too simple. This generalized software remains deterministic but is able to handle several target and by-catch species and with several fleets which may be operating sequentially or simultaneously across several fishing grounds and landing sites, as well as, in several processing plants with different economic characteristics. It also accounts

for migration across spatial strata and for seasonally varying recruitment which is a necessary condition for optimizing seasonal closures in tropical fisheries. The software was tested on real fisheries first started in Madagascar (1989) and it has since been used in Morocco, Malaysia and China.

NAN-SIS: For logging and analysis of fishery survey data (Stromme 1992)

This software was developed progressively since 1986 in the Institute of Marine Research of Bergen, evolving from a mainframe version. It allows for logging, editing, and analysis of scientific fishery survey data, particularly length frequencies. It calculates catches, mean catch rates and variances on user-selected sub-sets of stations. It provides summaries by trawl station, species, genera, families or other user-selected groupings. It allows for swept-area calculation of fish densities. It allows the export of data to other packages such as STATGRAPHICS, ELEFAN, LFSA, CANOCO and the Cornell Ecology Program Series. The potential errors in dealing with a multitude of species, as characteristic of tropical situations, are limited by the use of a mnemonic species code system based on the FAO Species Identification Series. The package has been demonstrated in the FAO/DANIDA training programme and used in FAO fishery resources surveys in Oman (1989-90).

CLIMPROD: Experimental interactive software for choosing and fitting surplus production models including environmental variables (Freon and Mullon, 1993)

This software, written in PROLOG, was the response to a challenge: to develop an "intelligent" software to deal with the situations where too-small data sets of catch, effort and environment were to be used with highly parameterized models with acceptable (and in any case transparent) levels of reliability. The user is interactively guided, step by step, through a series of more and more complex analysis of its data set with conventional production models (Gulland, Fox Pella and Tomlinson) modified to take into account environmental effects on catchability, recruitment or both. The process leads to some conclusion or to the recognition that such modelization is impossible or statistically not recommended.

SPATIAL: Space-time dynamics in marine fisheries. A software package for non-migratory stocks (Seijo and Caddy 1993)

This is a simulation package developed to model the space-time distribution of fishing intensity using alternative approaches. Three models were built with different input data requirements and output possibilities. These fisheries simulation models can be very useful for training fisheries specialists and for conducting simulation experiments of a wide range of fisheries management strategies.

SPECIESDAB/POPDYN

SPECIESDAB is a database which contains FAO's standard authority of scientific nomenclature, FAO common names, almost 10,000 national and local

names, and ecological, biological, zoogeographical, bibliographic and basic fisheries information about some of the most important resource groups for fisheries. To date, the SPECIESDAB module covers on a global basis 21 resource groups, including shrimps, lobsters, cephalopods, sharks and seventeen families of bony fishes, for a total of more than 2,000 species. Additional groups for global coverage are to be added as new publications of the FAO Species Identification Programme on which other resource groups appear. SPECIESDAB also has a regional mode that builds a subset of the data for specific regional data management needs. The content of SPECIESDAB provides the taxonomic structure of FISHBASE (see below) and part of its other information.

SPECIESDAB is also designed to provide a modular interface with other fisheries databases using the scientific nomenclature as central reference. One such database, also developed in the FAO Marine Resources Service, is POPDYN. This module follows a standard format for stock and fishery data and can be used as a tool for collection and management of this type of information for working groups of FAO regional bodies or other organizations involved in recurrent stock assessments. POPDYN is an interactive database that allows data input by the user for stock information as it becomes available, whereas SPECIESDAB is a more static database containing basic biological information provided by specific experts.

FISHTAT PC

This is a software for the analysis of time series of fishery catches and aquaculture production. It is made of a user interface, a data base and a set of custom made routines to access the database, extract records of specific interest, process it as required, view it, undertake time series analysis, produce files, reports and graphs. Export facilities are available to Lotus 123, Dbase, Harvard Graphics, etc. The database contains the available datasets on world catches as reported in the FAO Fishery statistical yearbooks as well as more detailed data for the Mediterranean and West African regions and a separate set of data for aquaculture. It is envisaged that these will be distributed separately in the future. The beta version presently available is being distributed for testing and comments to a limited number of people. A public version should be distributed in 1994.

SIPAL/SIPAM: Information systems for the promotion of aquaculture in Latin America and the Mediterranean regions

SIPAL and SIPAM are two complex information systems developed through two important regional projects for aquaculture development in Latin America (AQUILA project) and the Mediterranean (MEDRAP project). These systems aim at providing the project countries with a rapid and targeted access to information useful for aquaculture managers and planners, producers and services. The system is interactive and is developed through a network of institutions in the region. It can be used at national level and data can then be combined at regional level. The system contains data on taxonomy (derived from SPECIESDAB), aquaculture companies, dealers, market prices (derived from GLOBEFISH), research institutions, aquaculture production and methods, nutrition, socio-economic data (derived from FIPDAT, an FAO database), etc. The system has a user interface through which

various databases and facilities can be accessed as well as commercial packages such as WordPerfect, Lotus 123, Harvard Graphics, Statgraphics, MS Project, etc. SIPAL is in operation. SIPAM is deing tested.

RMDB: Regional Maritime Database. An integrated information system for the management of fisheries and coastal areas in West Africa.

This product is mentioned here despite of the fact that it is still only in project because it represents a milestone in the use of computers in fisheries research. The RMDB which will be developed in cooperation with FAO.

The ICLARM software library

The Compleat ELEFAN: An integrated system for the estimation of growth, mortalities and other related parameters from length-frequency data (Gayanilo, Soriano and Pauly 1987).

This 12-disk software package includes routines for: (i) data handling and management; (ii) estimation of growth parameters using the ELEFAN I approach; (iii) estimation of mortality parameters and recruitment pulses; (iv) age-structured, length-structured and length/age version of the virtual population analysis model; (v) estimation of growth parameters from other data types (e.g., growth increments); (vi) routines for model class progression analysis, and (vii) other utilities for system maintenance. Results are presented in graphic form when possible. The software can be installed on a standard IBM PC/XT/AT or its compatibles with at least a CGA or HERCULES graphic adapter.

ECOPATH II: A software for balancing steady-state ecosystem models and calculating network characteristics (Christensen and Pauly 1992).

ECOPATH II presents an approach for balancing ecosystem models. It includes: (i) routines for balancing the flow in a steady-state ecosystem from estimation of a missing parameter for all groups in the system; (ii) routines for estimating network flow indices, and (iii) miscellaneous routines for deriving additional indices such as food selection indices and omnivory indices. The software is distributed in one disk and the manual is available in English and French, and soon will be made available in Spanish and Portuguese.

A spreadsheet solution for the estimation and comparison of fish growth parameters from pond experiments (Vakily 1988)

This package presents a method to estimate and compare the growth of fish in pond experiments using a Gulland/Holt plot. The method is implemented on a LOTUS 1-2-3 spreadsheet, allowing easy data handling and analysis. An example is provided along with a 5-1/4" disk for use with an IBM PC/XT/AT or compatible microcomputers.

MAXIMS: A computer program for estimating the food consumption of fishes from diel stomach contents data and population parameters (Jarre et al 1990).

A two-disk software package for IBM PC (and its compatibles) which estimates the size specific daily food consumption of fishes from a 24-hour cycle of stomach contents data for either one or two feeding periods per day, as well as population food consumption and related parameters. The ingestion and evacuation, as incorporated in the model used, can be expressed by rates proportional to different powers of the stomach contents. Results are presented in graphic form (e.g., 24-hour cycle of stomach content, gross conversion efficiency or ration vs weight).

CDS Assistant: A program to facilitate and expand the capabilities of the CDS/ISIS bibliographic software released by UNESCO (Gayanilo 1990)

An intermediary software which facilitates (i) creation of a print/display format for use with the UNESCO-sponsored CDS/ISIS software through a series of commands, and (ii) translation of text files generated by either SCIMATE (now called PRO-CITE) or PAPERBASE bibliographic software to a format (ISO 2709) that may be readily imported to CDS/ISIS.

B:RUN: A decision support system and teaching tool for managing the coastal resources of Brunei Darussalam (Gayanilo, Silvestre and Pauly (in prep.))

A one-disk spreadsheet-based low-level GIS originally designed to help formulate options for the development of Brunei Darrusalam's coastal fisheries under economical and ecological constraints. Four program modules are available to the user: (i) a low-resolution plot of values; (ii) high-resolution plot of fixed structures; (iii) cost-return analysis using a Sheafer-Fox surplus production model, and (iv) graphical representation of a simulation of an oil spill for the region.

In the late 1980s, software in other fields of interest to ICLARM staff began to emerge: OPUS, a socioeconomic software for solving linear programming models using simplex algorithm; GIFT, a program to analyze the vast amount of data in the Genetic Improvement of Farmed Tilapias; FIDAS, a data acquisition system for marine fisheries research; GOTCH.A, for the construction of catch curves (for estimation of total mortality) when growth is seasonal; AUXIM, auximetric grid analysis of population growth parameters; ClamBase, a database to genetically track, monitor and evaluate giant clams; RESTORE, a tool to monitor and evaluate natural resource systems; MAPPER, a low-level GIS which allows the plot (in part or in full) of the earth with facilities to superimpose on the map other values; and TRANSECT, which graphically plots and analyzes the components of a transect.

Developments in the pipeline include a multispecies virtual population analysis for tropical application; bioeconomic software utilizing yield-stock

prediction models coupled with OPUS and a database for information on reefs (ReefBase).

Joint FAO-ICLARM undertakings

FISAT: FAO-ICLARM Stock Assessment Tools (Gayanilo, Sparre and Pauly (in press))

This integrated software is a result of an FAO-ICLARM cooperation to merge two packages: LFSA (from FAO) and The Compleat ELEFAN (from ICLARM): The package contains all the functions of the two components and includes new routines and models. Using several programming languages (BASIC, C, PASCAL and FORTRAN) it can accept several types of data most commonly used for fish stock assessments (e.g., length or weight frequencies, growth increments, size-at-age, etc.). The routines are grouped into four which cover (i) data handling, (ii) estimation of population parameters and predicting yield and stock behaviours given present fishing regime, (iii) supplemental routines, and (iv) utilities (e.g., importing/exporting data, configuring outputs). In addition to all these, help messages are always available with a press of a key. This package will be distributed on six 3.5" disks and is available only in English.

FISHBASE: A biological database on fish (Froese, Palomares and Pauly 1992)

FishBase is a relational database containing key information on the biology of fishes. It includes nomenclature, distribution, ecology, reproduction, growth and mortality, etc. It is being developed in ICLARM through a cooperative project involving FAO (which provides tha data contained in its SPECIESDAB) and national institutions in France, Malawi, the Philippines, Ghana, Germany, Mexico and others, with funding from the Commission of the European Communities. It also includes a coloured picture display of fishes and distribution maps. The BETA-release (on 3.5" disks) covers 6,000 fish species, i.e., a quarter of all fish species in the world have been documented. The package is available in English and will soon be made available in French.

ANALYSIS OF SOFTWARE DISTRIBUTION

To best examine if the computer tools are reaching the expected 'clients', a software distribution analysis was conducted by examining archives on diskettes of requests and correspondence. The analysis does not consider the number of copies distributed by other authorized organizations or informally duplicated.

An analysis was made of the requests received by FAO for ANACO, ANALEN, LFSA and BEAM3. The number of records examined for each program represents a significant proportion of the total number of packages distributed (see below).

Records analysed	ANACO	ANALEN	LFSA*	BEAM 3
Number	146	41	424	35
% of total distributed	97.3	58.5	>50.0	42.7

* The total number of copies of LFSA distributed is unknown

The distribution of two ICLARM products were also examined: The Compleat ELEFAN, distributed since 1988 and ECOPATH II, published in 1991. The analyses included from 80 to 90% of the total number of copies distributed.

FAO records indicate that roughly 50% of the requests received came from industrialized countries and half from developing countries (Fig. 3). Western Europe was responsible for more than a third of all requests (34.4%) followed North America. Italy, France, USA and India together accounted for one quarter of all requests. Similarly, about 50% of the copies of the Compleat ELEFAN were distributed to Europe and North America and the other half to developing countries. This shows that the impact of the FAO and ICLARM software projects were equally distributed in the developed and developing world.

In order to analyse the impact of the language of publication on the software diffusion, requests for FAO software[7] were sorted out according to the first language of the country from which the requests were made: Arabic, Chinese, English, French, Spanish and "other" (Fig. 4). Most requests came from "other" countries (43.1%) followed by English (20.9%), Spanish (15%), French (12.4%), Arabic (7.2%) and Chinese (1.3%). Software produced only in French (ANALEN, BEAM3) had a much higher proportion of requests from French speaking and Arabic speaking countries (45.1%). Software produced only in English (LFSA) had a much higher proportion of requests from English and Spanish speaking countries. Software produced in both English and French (ANACO) was equally well requested by both groups of countries. This suggests that a multilingual strategy enhances software distribution worldwide and transfer of methodologies to clients.

The analysis of a sample of 177 LFSA records indicated (Fig. 5) that requests came essentially from universities and government agencies (essentially fishery research agencies). Similarly, the analysis of the distribution of The Compleat ELEFAN and ECOPATH II (Fig. 6A and 7A) showed that about 50-60% of the packages were requested by organizations dealing mainly with fishery research and about 40% by academic institutions. This shows that the software are equally well distributed between academic and research institutions.

CONCLUSIONS AND DISCUSSION

With the generalized use of PCs in the developed laboratories, a growing number of PC-based packages have been and are being produced by various

[7]ICLARM is also producing several language-versions of the ECOPATH II and FISHBASE but it is still too early for an assessment on language impact.

organizations. Many of them are still produced for "local" use, are not user-friendly and lack appropriate documentation. The efforts of FAO and ICLARM towards methodology transfer were not the only ones and a few other packages have been developed by universities, national research agencies and private companies. There are obvious limitations in what FAO as a development agency and ICLARM as an international center dedicated to strategic research can do in terms of methodology development and transfer. A concerted effort is therefore required not only between FAO and ICLARM but also with the advanced research agencies in the developed world in order to:

- reduce duplications;
- ensure transfer of the latest methodologies;
- benefit from cross-fecundation;
- improve peer-reviewing of the software and its documentation, and
- provide better (more equitable) language coverage.

In addition, cooperation is needed to ensure minimum compatibility in terms of platforms (DOS, Windows) and import-export facilities to facilitate transfer of data from one package to another. There is also a need to further the efforts to cover new areas. There is still a demand for:

- better production models combining global and analytical approaches;
- bio/socio-economic models to study fishery interactions;
- multispecies and ecosystem models;
- spatial interaction models (e.g. in the coastal areas);
- interfaces with Geographic Information Systems;
- better approach to data and system uncertainty;
- sensitivity and risk analysis;
- integration of non-parametric statistical methods;
- testing of management strategies by simulation, and
- fisheries games for training purposes.

Some important questions remain to be answered. Is there still room for spreadsheet-based programs? Is there a need to develop expert systems for fisheries analysis? How can we facilitate effective access to the number and diversity of packages that are and will soon be available? How can we better put them in perspective to enlighten the users' choice? How can we reduce the price of some good but too expensive packages to make them accessible to developing countries' laboratories? Would it be useful and could we have an international library of public domain computer routines for fishery purposes? How best can we use the competence available in the developing world and the low cost of manpower to improve programmes originating from the developed world? Could an institution like ICES cooperate formally in the efforts for methodology transfer?

It may be useful to put in perspective the efforts made by FAO and ICLARM for the development, adaptation and transfer of fishery software. Originally, programs concerned single species and single methods (e.g. ANACO or ELEPHAN I). Very rapidly, the need arose to develop integrated packages combining many methods based on the same type of data, particularly but not only length frequency

(e.g. LFSA, ELEFAN, FISAT). In the process, dynamic pool (analytical) methods were privileged although FAO produced a package for surplus production analysis (CLIMPROD). The need to take into account various forms of interactions led to the production of ANALEN (where fleet interactions are modelled) and ECOPATH II (where species interactions are taken into account) and, more recently to the adoption of MSVPA in ICLARM. The necessity to study fisheries interaction in bio-economic terms for more relevant and realistic analysis of management and development options led FAO and, more recently ICLARM to produce bio-economic analytical simulation models (e.g. BEAM) including space-structured ones (SPATIAL).

In parallel with this increased complexity, substantial efforts have been made to develop databases for general distribution and as a means to promote comparative stock assessments and fisheries analysis (e.g. SPECIESDAB, FISHBASE, REEFBASE, FISHSTAT PC, etc.). Some of these are based on interactive networks of users which cooperate with the data input. They are modular in the sense that national or regional versions are available as well as a global one.

This concept as well as the need to use more and more often data from various databases in a suite of assessment tools and models and the need to promote efficient representation and communication of data has led to the development of integrated information systems (SIPAL, SIPAM, RMDB) which offer to the user, through a user-friendly interface, the possibility to use packages and databases developed by FAO, ICLARM or others together with commercial packages (for text processing, Desktop mapping, statistical analysis, graphics etc.). In the field, this leads to the practical development of dedicated workstations. With the development of communication (electronic data transfer, E.mail) this leads to the possibility to improve the work efficiency at research center level through sharing of resources. This also offers an important opportunity and incentive for improved scientific collaboration at regional and international level.

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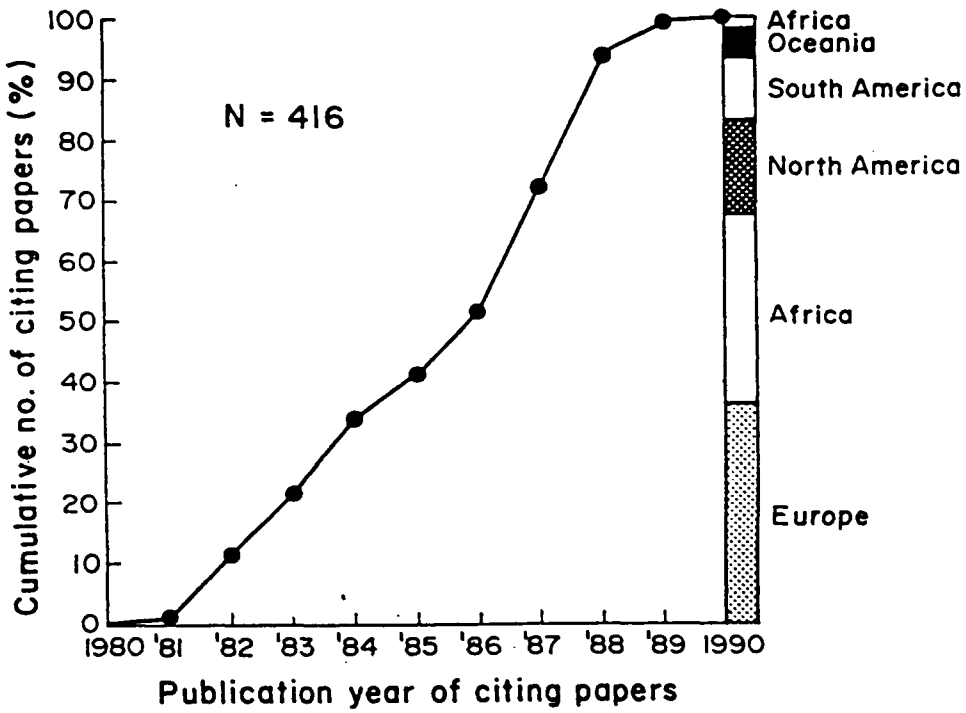

Fig. 1. Evolution of the rate of citation of ELEFAN in the scientific literature since 1980 and distribution of these citations by region (adapted from Pauly and Gayanilo 1990).

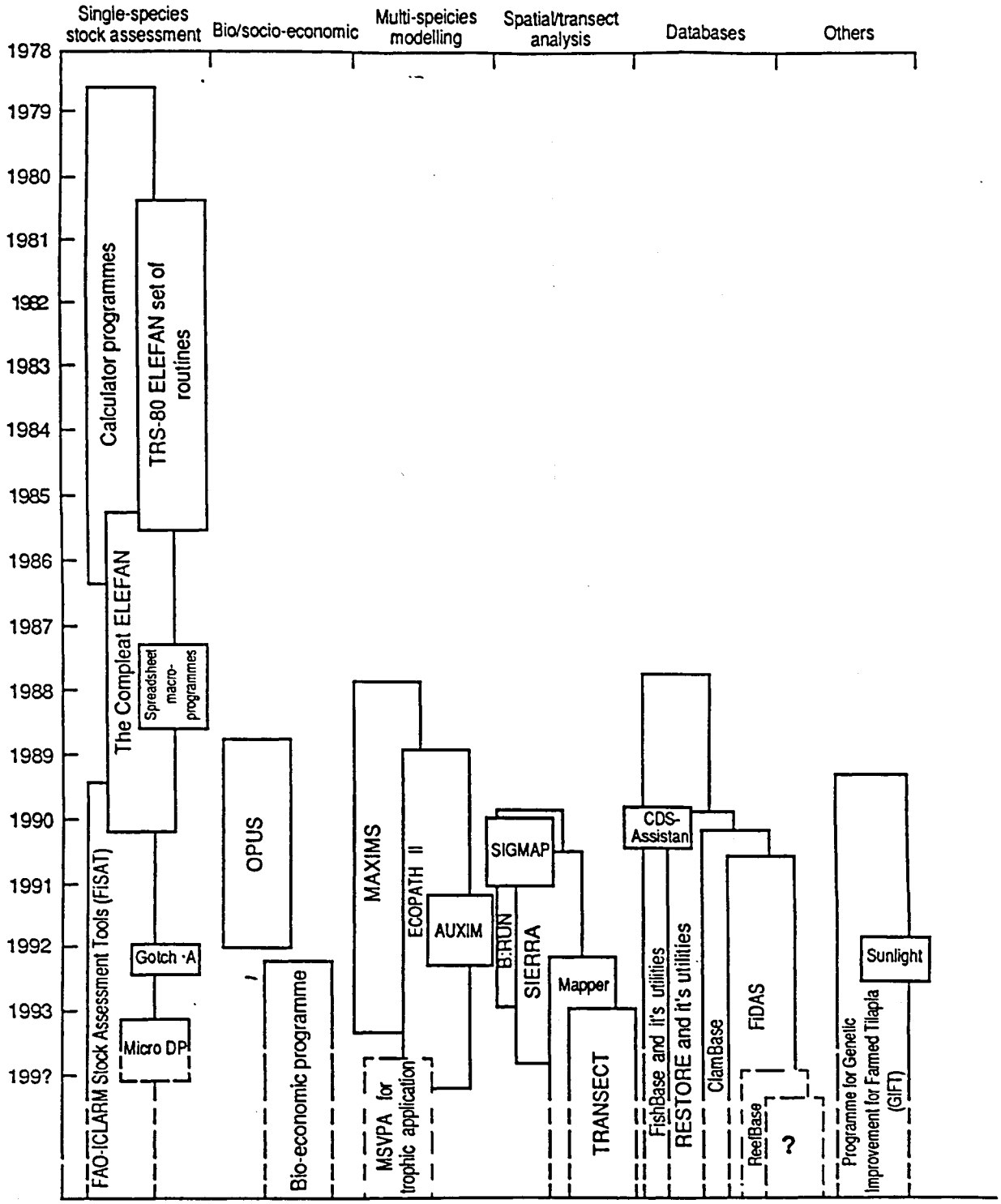

Fig. 2. Evolution of the ICLARM software projects.

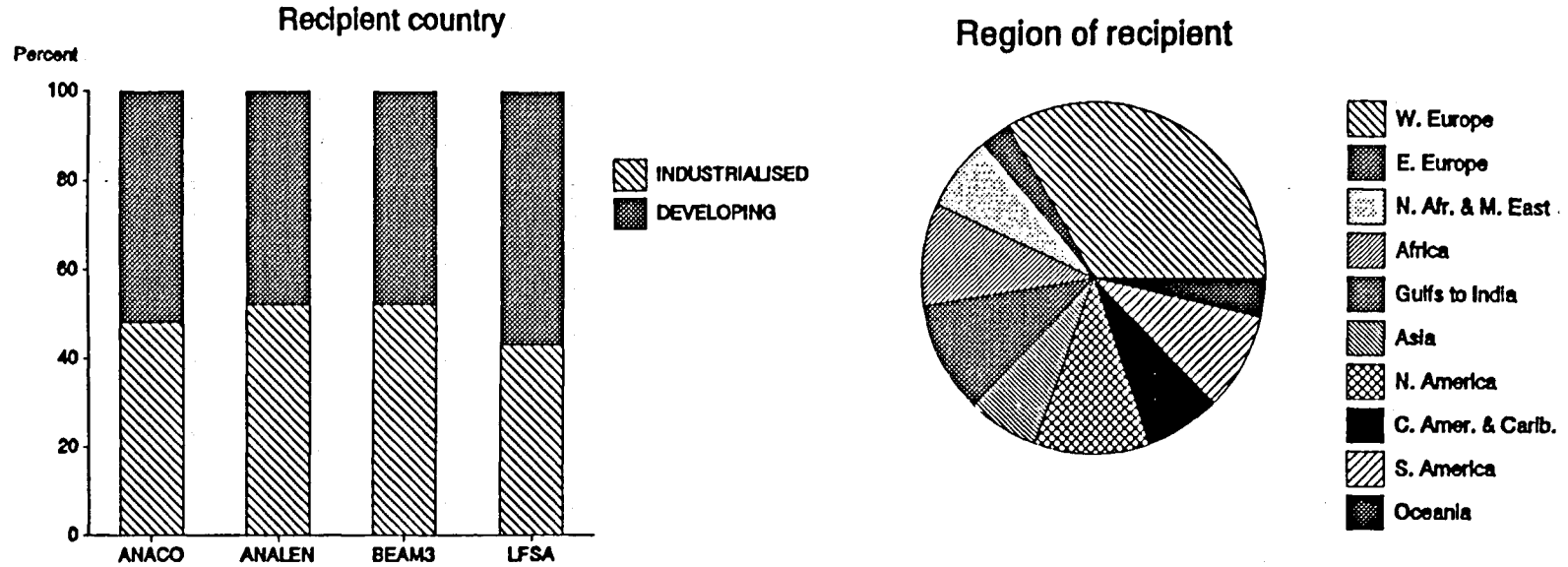

Fig. 3. Distribution of FAO Fisheries software by category of countries and by region.

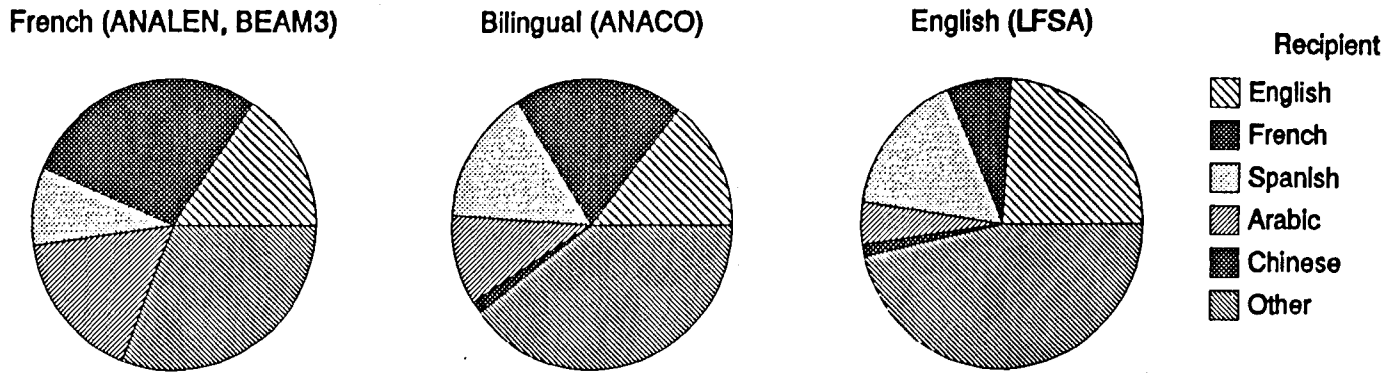

Fig. 4. Official languages in the requesting countries as a function of the language used for the FAO fishery software.

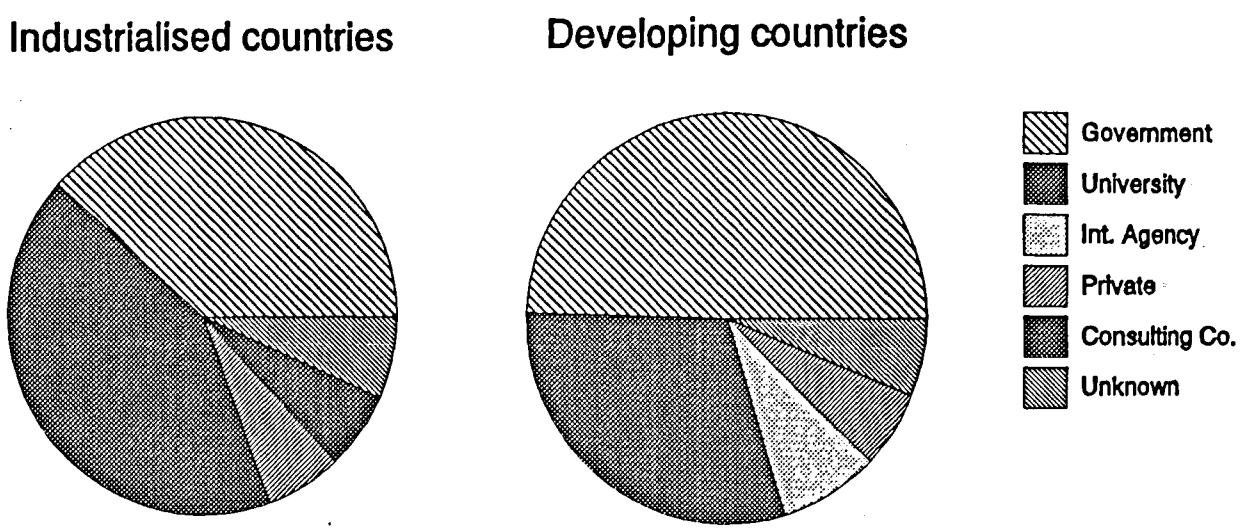

Fig. 5. Type of organizations requesting FAO fishery software.

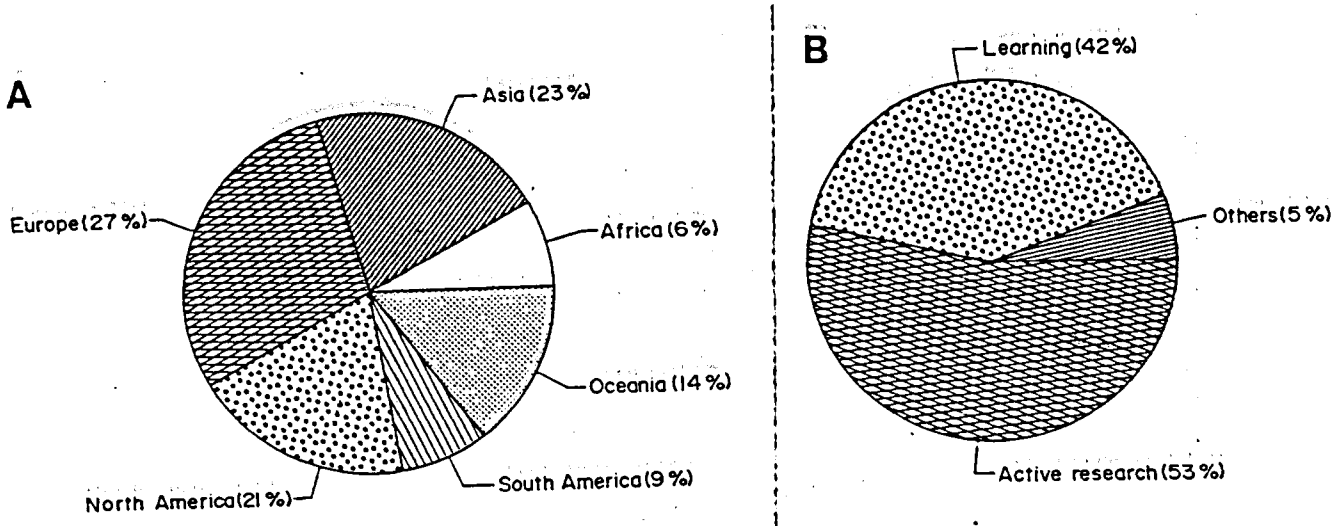

Fig. 6. Distribution of The Compleat ELEFAN by region (A) and type of requesting institution (B).

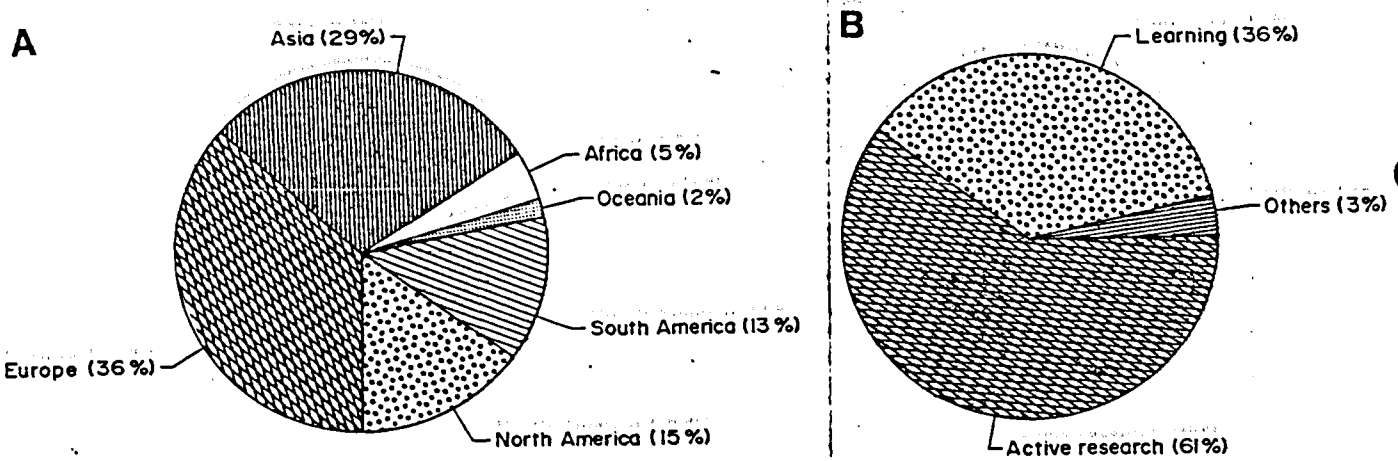

Fig. 7. Distribution of ECOPATH II by region (A) and type of requesting institution (B).