Date: December 14, 1964

To: Members and collaborators, SCOR Working-Group #12 on "Abstracts and Bibliographies of Use in Marine Sciences"

From: S.B. Saila, Chairman
Aquatic Sciences Information Retrieval Center
University of Rhode Island
Kingston, Rhode Island, U.S.A.

I sincerely regret the delay in informing you of progress since my last communication in June, 1964. The following material is believed to be relevant to our activities and briefly indicates our current status.

(1) "Core journal" list.

Dr. Model has critically examined the first version of the core list and has presented some significant observations. Briefly, he found that the first list provided to him furnished about 18 percent of the material received by the Deutches Hydrographisches Institut. It was suggested by him that a list of more than 100 serials would be needed in order to be aware of about one-half of the hydrographic literature. According to him, a list of more than 1000 journals would be needed to reasonably cover all of marine sciences. Such a list would provide some indication of available literature but would not serve a specialist in some branch of marine science well.

Dr. Model has also emphasized the importance of "citation indexing" and pointed out the long use of this technique by his group.

Leslie Scattergood has kindly provided a list of journals cited in the U.S. Fish and Wildlife Service Fishery Bulletin--Vol. 57-62. A copy is enclosed as Appendix 1.

A minor revision of the tentative "core" list has been prepared. A copy is enclosed as Appendix 2.

Both Leslie Scattergood and I have been in contact with Dr. Eugene Garfield, Director, Institute for Scientific Information, 325 Chestnut Street, Philadelphia, Pennsylvania 19106, U.S.A. regarding a list of primary journals in marine sciences for coverage in the SCIENCE CITATION INDEX and probably CURRENT CONTENTS. Both the revised core list and the list compiled by L. Scattergood have been sent to him. The possibility of better coverage of marine sciences literature by the above-mentioned institute seems to be good. The value of this may be questioned.

It seems to me that the work done by Dr. Model and Leslie Scattergood clearly indicates (a) the diffuse nature of marine sciences literature (b) special interests and restricted literature coverage by mission oriented scientists. From this evidence I submit that the probability of generating a truly useful but limited "core journal" list for a CURRENT CONTENTS type of service is not high. Your comments and opinions on this matter would be appreciated. Perhaps several such core journal lists by divisions (i.e. physical, biological, chemical) of marine science might be a more desirable approach.

(2) Information Paper.

A copy of a paper which Sidney Holt's group was kind enough to reproduce is enclosed for your perusal and comments, Appendix 3.

(3) Progress and Comments on Other Matters.

a. Dr. Model reports that the first steps toward the provision of facilities for putting material from the Deutches Hydrographisches Institut into machine-readable form have been taken.

b. Sidney Holt has indicated further collaboration with marine scientific documentation activities in the U.S.S.R. VNIRO proceedings and The Bibliography of Soviet Fisheries Literature for the first half of 1964 have been received and will be incorporated into the Current

Bibliography for Aquatic Sciences and Fisheries (CBASF). In general, the cooperation in obtaining more comprehensive coverage of the literature from the U.S.S.R. has been very gratifying.

c. The new subject grouping of annotations in CBASF should significantly improve the acceptability of the publication. The delays in publishing are still great and ASIRC is currently exploring means for more rapidly and economically producing CBASF as well as exploring possibilities of producing permuted title and annotation indexes. Preliminary material on this work should be available soon and will be sent to you as soon as it is ready.

d. The chairman regrets that he has not been able to make suitable arrangements for the next meeting as yet. It was suggested (Dr. Model) that the next meeting be delayed until the recommendations of the preliminary meeting were acted upon. You may expect to hear about a proposed meeting date and location in the near future. It is my hope that this can take place during the early part of 1965. It has also been suggested by Dr. Model that the report of the next session be developed as the meeting proceeds.

Your chairman is satisfied with the progress which has been made and is grateful to all members and collaborators.

Saul B. Saila

Appendix 1.

The following material represents the efforts of Leslie W. Scattergood in compiling a serial list from author citations in The U.S.F.W.S. Fishery Bulletin Vol. 57-62. Comment--It is apparent that this list is highly specialized in contrast to the tentative "core" list we have made and generally agrees with the findings of Dr. Model which point out that a considerably expanded list is necessary in order to provide comprehensive coverage.

The serials are listed in order of the frequency to which they have been cited. No serial is listed that has been referred to less than four times in volumes 57-62.

FWS Fishery Bulletin[1/]
FWS Special Scientific Report--Fisheries
Copeia
Transactions of American Fisheries Society
Journal of Fisheries Research Board of Canada[2/]
Journal of Parasitology
California Fish and Game
Report of U.S. Fish Commission[3/]
Commercial Fisheries Review
Proc. U.S. Nat. Museum
Journal of Marine Biological Association U.K.
Progressive Fish-Culturist
Biological Bulletin
Proceeding Academy of Natural Sciences-Philadelphia
Journal of Marine Research
Pacific Science
Transactions of Wisconsin Academy of Science
Publications of Seto Biological Laboratory
Bulletin of U.S. National Museum
Journal of Wildlife Management
California Fish and Game Bulletin Fish Bulletin
Zoologica
Bulletin of Bingham Oceanographic Collection
Report of Danish Oceanographic Expedition
Bulletin of American Museum of Natural History
Bulletin of Japanese Society of Scientific Fisheries
Ecology
Science
Great Britain Ministry of Agriculture and Fisheries, Fish. Invest.
Progress Reports of Pacific Coast Stations (FRB)
Transactions of American Microscopical Soc.
Marine Coast Fisherman
FWS Research Reports
FWS Fishery Leaflets
Ann. del Institute Biologia, Mexico
Nature
ICES Annales Biologique
Journal of Biological Chemistry
American Museum Novitates

Bulletin of Marine Science, Gulf and Caribbean
Publications of Ontario Fisheries Research Laboratory
Smithsonian Miscellaneous Collection
Bulletin of Fisheries Research Board of Canada[4/]
Journal du Conseil
Bulletin of Illinois State Natural History Survey
Limnology and Oceanography
Transactions of North American Wildlife Conference
Annals and Magazine of Natural History
Deep-sea Research
Ecological Monographs
Japanese Journal of Zoology
Journal of Morphology
Papers of Michigan Academy of Science, Arts, and Letters
University of California Publications in Zoology
Report of Reelfoot Lake Biological Station
Tellus
Bulletin of International Pacific Salmon Commission
FWS Circular

1/Includes Bulletin of U.S. Fish Commission and Bulletin of Bureau of Fisheries.
2/Includes contributions to Canadian Biology, contributions to Canadian Biology and Fisheries and Journal of Biological Board of Canada.
3/Includes Report of U.S. Commissioner of Fisheries.
4/Includes Bulletin of Biological Board of Canada.

Appendix 2

SCOR Working-Group #12

Tentative "Core" List (revised)

Advances in Marine Biology
Archiv. F. Fischereiwissenschaft
Archivio Oceanographia e Limnologia
Australian Journal of Marine and Freshwater Research
Bericht der Deutschen Wissenschaftlichen Kommission fur Meeresforschung
Beitrage zur Meerskunde
Biological Bull. Woods Hole
Bolletino Pesco Piscioltura e Idrobiologia
Botanica Marina
Bull. Bingham Oceanogr. Coll.
Bull. Mar. Sci. Gulf & Carribbean
Bull. Jap. Soc. Sci. Fisheries
Bull. Polar Research Institute of Fisheries and Oceanography (USSR)
Cahiers de Biologie Marine
Cahiers Oceanographiques
Contr. Scripps Instu. Oceanography
Deep Sea Res.
Deutsche Hydrographische Zeitschrift
Geochimica et Cosmochimica Acta
Helgolander Wissenschaftliche Meeresuntersuchungen
Hydrobiologia
Indian Journal of Fisheries
International Hydrographic Review
Investigacion Pesquera (Barcelona)
Journal du Conseil Int. Explor. Mer.
J. Fish. Res. Bd. Canada
J. Geophysical Research
Journal Marine Biological Association of India
J. Mar. Biol. Assoc., U.K.
J. Mar. Res.
Kieler Meeresforsch.
Limnol. Oceanogr.
Journal of Oceanography, Kobe, Japan
Marine Geology
Marine Sciences Instrumentation
Medd. Fra. Dann. Fiskeriog Havunders
Meteorologia i Gidrologia, Moscow
Netherlands Journal of Marine Research
New Zealand Journal of Geology and Geophysics
Oceanographical Magazine (The) Japanese Meteorological agency, Tokyo.
Oceanography and Meteorology, Nagasaki
Okeanologia
Pacific Science
Progress in Oceanography
Pubs. Institut. Mar. Sci. Texas
Pubblicazion Stazione Zoologica Napoli
Rapports et Proces-Verbaux Commission International pour l'Exploration Scientifique de la Mu Mediterraneo
Records of Oceanographic Works in Japan
Revue Algologique

Sarsia
Sedimentology
Tellus
Trans. Amer. Fish. Soc.
Transactions Institute Marine Fisheries and Oceanography U.S.S.R.
Trudy Instituta
Trudy Morskogo Geofisicheskogo Instituta, Moscow/sevastopol
Travaux Centre Oceanographique de Pointe Noire (Republi Congo)
Veroffentlichungen des Instituts fur Meeresforschung in Bremerhaven
Zeitschrift f. Fischerei

Appendix 3

FAO Fisheries Technical Paper No. 42 . FIb/T42
(Distribution restricted) General - Computer Applications

ELECTRONIC DATA PROCESSING
INFORMATION RETRIEVAL AND TRANSLATION IN FISHERY SCIENCE

by

S. B. SAILA and R. A. SHAPPY

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1964

DOCUMENTS OF THE BIOLOGY BRANCH OF FAO FISHERIES DIVISION

Documents which are not official FAO publications are issued in several series. They are given a restricted distribution and this fact should be indicated if they are cited. Most of them are prepared as working papers for meetings, or are summaries of information for use of member governments, organizations, and specialists concerned.

DOCUMENTS DE LA SOUS-DIVISION DE LA BIOLOGIE DE LA DIVISION DES PECHES DE LA FAO

Des documents qui ne figurent pas parmi les publications officielles de la FAO sont publiés dans diverses séries. Ils font seulement l'objet d'une distribution restreinte, aussi convient-il de le préciser lorsque ces documents sont cités. Il s'agit le plus souvent de documents de travail préparés pour des réunions, ou de résumés d'information à l'intention des gouvernements des pays membres, ainsi que des organisations et spécialistes intéressés. Ces séries sont les suivantes:

DOCUMENTOS DE LA SUBDIRECCION DE BIOLOGIA DE LA DIRECCION DE PESCA DE LA FAO

Esta Subdirección publica varias series de documentos que no pueden considerarse como publicaciones oficiales de la FAO. Todos ellos tienen distribución limitada, circunstancia que debe indicarse en el caso de ser citados. La mayoría de los títulos que figuran en dichas series son documentos de trabajo preparados para reuniones o resúmenes de información destinados a los estados miembros, organizaciones y especialistas interesados.

FAO Fisheries Report **Flb/R (No.)**
FAO Fisheries Circular **Flb/C (No.)**
FAO Fisheries Synopsis **Flb/S (No.)**

Special groups of synopses are identified by symbols followed by classification numbers based on indexed code of "Current Bibliography":

SAST Data concerning certain species and fish stocks.

MAST Information on methods and subjects.

OT Oceanographic data.

IT Limnological data.

and

CART Information concerning fisheries and resources of certain countries and regions (FID/S).

Des catégories spéciales de synopses sont identifiées à l'aide de symboles suivis des chiffres de classification basés sur le code d'indexation de la "Current Bibliography":

SAST Données sur certaines espèces et populations de poissons.

MAST Renseignements sur des méthodes et des sujets.

OT Données océanographiques.

IT Données limnologiques.

et

CART Renseignements sur les pêcheries et les ressources de certains pays et régions (FID/S).

Grupos especiales de sinopsis se distinguen con las siglas siguientes, seguidas por números de clasificación que se basan en las claves de los índices de la "Current Bibliography":

SAST Datos relativos a ciertas especies y poblaciones.

MAST Sinopsis sobre métodos y materias.

OT Sinopsis sobre oceanografía.

IT Sinopsis sobre limnología.

y

CART Información sobre los recursos acuáticos vivos de algunos países y regiones (FID/S).

FAO Fisheries Technical Paper **Flb/T (No.)**

Special groups of Technical Papers are identified by:

RE Indexed lists of experts and institutions drawn from Registers maintained by Biology Branch

CB Lists of Periodicals, special sections of "Current Bibliography for Aquatic Sciences and Fisheries", special bibliographies and papers concerning documentation problems.

MFS Provisional editions of "FAO Manuals in Fisheries Science".

Some documents also have another identification, if, for example, they have been contributed to a meeting for which papers have been numbered according to another system.

Des catégories spéciales de documents techniques sont identifiées à l'aide des symboles suivants:

RE Listes indexées d'experts et institutions tirées des registres tenus à jour par la Sous-division de la Biologie.

CB Listes de périodiques, des sections spéciales de la "Current Bibliography for Aquatic Sciences and Fisheries", des bibliographies particulières et des articles sur les problèmes de documentation.

MFS Editions provisoires des "Manuels FAO de la science des pêches".

Il arrive que certains documents portent d'autres numéros d'identification, comme c'est le cas s'ils ont été préparés pour une réunion dont les documents ont été marqués à l'aide d'un autre système.

Grupos especiales de documentos técnicos se identifican por las siglas siguientes:

RE Listas índices de expertos y de instituciones tomadas de los registros que se llevan en la Subdirección de Biología.

CB Listas de periódicos, secciones especiales de la "Current Bibliography for Aquatic Sciences and Fisheries", bibliografías especiales y trabajos relativos a los problemas de documentación.

MFS Ediciones provisionales de los "Manuales FAO de la Ciencia de la Pesca".

Algunos documentos tienen también otra identificación si, por ejemplo, son contribuciones a una reunión cuyos documentos han sido marcados con arreglo a otros sistemas.

ELECTRONIC DATA PROCESSING
INFORMATION RETRIEVAL AND TRANSLATION IN FISHERY SCIENCE

by

S. B. SAILA and R. A. SHAPPY
Aquatic Information Retrieval Center
Kingston, R.I., U.S.A.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1964

PREPARATION OF THIS PAPER

Contribution by the authors from the Aquatic Sciences Information Retrieval Centre to 93rd annual meeting of the American Fisheries Society, 11.9.1963. Reproduced in this series as an information paper for the FAO Advisory Committee for Marine Resources Research and the Scientific Committee for Oceanic Research Working Group on Marine Science Abstracts and Bibliographies. It should be read in conjunction with FAO Fisheries Circular (7), "Computer programs for fisheries problems".

PREPARATION DE CE DOCUMENT

Contributions des auteurs de l'Aquatic Sciences Information Retrieval Centre à la 93ème réunion annuelle de l'American Fisheries Society, 11.9.1963. Reproduites dans cette série à titre de documents d'information pour le Comité consultatif de la recherche sur les ressources de la mer et le Scientific Committee for Oceanic Research Working Group on Marine Science Abstracts and Bibliographies. Ce document devra être lu accompagné de FAO Fisheries Circular (7), "Computer programs for fisheries problems".

PREPARATION DE ESTE DOCUMENTO

Información proveniente del Aquatic Sciences Information Retrieval Centre recopilada por los autores como contribución al 93° Período de Sesiones de la American Fisheries Society celebrado el 11 de septiembre de 1963. Se reproduce en esta serie para información del Comité asesor sobre investigaciones de los recursos marinos de la FAO, y del Scientific Committee for Oceanic Research Working Group on Marine Science Abstracts and Bibliographies. Debe leerse junto con FAO Fisheries Circular (7). "Computer programs for fisheries problems."

Distribution:

FAO Fisheries Division
FAO Regional Fisheries Officers
Author
ACMRR Members
Selectors 2 and 5

"Current Bibliography" entry:

Saila, S.B. and R.A. Shappy (1964) MF
FAO Fish.tech.Pap., (42):9 p.
Electronic data processing, information retrieval and translation in fishery science. Fr Es

Describes current applications of computers to fisheries science and offers reasons for restricted current use. Discusses implications of computer technology for communications in fishery science.

ELECTRONIC DATA PROCESSING, INFORMATION RETRIEVAL AND TRANSLATION IN FISHERY SCIENCE

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Synopsis:

Some current applications of computers to fishery science are described and reasons for restricted current utilization are offered. Although future developments in computer science including time-sharing and problem oriented languages are expected to relieve this situation, education in computer applications is the real key to greater use. Information retrieval developments in aquatic sciences are progressing but will require strong support to keep pace with other disciplines. Machine translation is but one facet of the communication problem and its rôle is expected to be limited in fishery science.

Resumé: Emploi des calculateurs électroniques dans les sciences halieutiques: Traitement des données, sortie des résultants et traduction

Les auteurs décrivent certaines des applications récentes de l'emploi des calculateurs aux sciences halieutiques et étudient les facteurs qui en limitent actuellement l'utilisation. On espère que les progrès de la science des calculs électroniques, notamment en matière de "time sharing" et de langages conçus pour des problèmes donnés apporteront une solution partielle, mais la véritable condition préalable au développement de l'emploi des calculateurs réside dans la formation de personnel qualifié en matière d'application des calculateurs. Dans le domaine des sciences aquatiques la sortie des données se perfectionne mais il faudra deployer un effort énergique pour qu'elle se maintienne au niveau atteint dans les autres disciplines. La traduction automatique n'est qu'un aspect du problème des communications et elle ne semble promise qu'à un role limité dans le domaine de la science des pêches.

Extracto: Elaboración electrónica de los datos, recolección de información y traducción en la ciencia de la pesca

Se describen algunas aplicaciones actuales de las máquinas calculadoras a la ciencia de la pesca y se establecen las razones de su limitada utilización en la actualidad. Aunque es de suponer que los posteriores avances en el sector de la ciencia del cálculo mecánico, entre ellos la subdivisión del tiempo y los vocabularios apropiados para los problemas de que se trate, contribuirán a mejorar tal situación, la enseñanza de las aplicaciones de las calculadoras es la verdadera

clave para su empleo en grado más amplio. Se va progresando en lo relativo a la recolección de información referente a las ciencias acuáticas pero este sector habrá menester de un firme apoyo para se mantenerse al compás de otras disciplinas. La traducción mecánica no representa más que un aspecto del problema de la comunicación y se espera que su funcion se limite a la ciencia pesquera.

INTRODUCTION

The background and conceptual development of electronic data processing extends back to the 17th century, although the design and fabrication of devices utilizing electronic switching circuits for computing did not occur until 1940. An interesting historical account of developments as well as an introduction to numerical methods is given by Stibitz and Larrivee (1957). There has been a virtually explosive growth in numbers, speed and sophistication of computers during the past two decades. Many sciences, especially the physical sciences and engineering have extensively adopted computers for routine applications and are now critically examining current practices and future trends. Waterman (1962) has pointed out that the emergence of electronic computer techniques holds considerable interest and promise for all the biological sciences. The importance of electronic data processing was recognized by the American Fisheries Society some time ago as indicated by a presentation on the role of computers in fisheries science at the 88th annual meeting, Philadelphia, Pennsylvania, September 8-13, 1958. The recent inclusion of computer program descriptions in the Transactions (Abramson, 1963) further attests to the significance of this tool to the profession.

Fishery science has evolved into a highly sophisticated discipline, particularly with reference to optimum yield theory and population dynamics in general (Beverton and Holt, 1957; Carlander, 1955; Le Cren and Holdgate, 1961; Ricker, 1958; Schaefer, 1957; and Watt, 1956, 1962). Extensive use of statistical methods has been made in fishery science as clearly indicated in a bibliography compiled by Schultz, 1961. Although it is difficult to assess completely their utilization by fishery scientists, it is evident from published literature that electronic data processing systems have not been extensively used as yet in the profession for any purpose. The reasons for this are not entirely clear, but it is suggested that problems of machine availability, usage based on whether programs are available which match a given problem situation, inertia on the part of fishery scientists to learn to communicate with a computer, and cost considerations have contributed to this state of affairs.

A key consideration limiting general computer usage as well as usage by fishery scientists is the need for precise communication totally devoid of ambiguity using one or another of the artificial computer languages. The degree of difference between these artificial languages and natural language with which we are all familiar is minimized when use is made of algorithmic languages like ALGOL or FORTRAN. Many of the imperative statements in these languages are comprehensible even to the non-programmer who merely understands English or is familiar with algebra. This is not true of machine languages because these are based on the internal instruction formats of each particular computer.

The impediment posed by this unusual form of communication can be most easily overcome by complete avoidance -- the non-programmer can obtain entirely satisfactory results from a computer by making use of pre-written, debugged programs for the desired application. Depending on the application area, many such programs exist in the large program libraries supported by the computer manufacturers as well as in the private holdings of most computer facilities. In order to make effective use of these prewritten programs, it must first be determined from the applicable documentation that the program does in fact provide the output computations required. If so, it remains only to prepare input data in a format and sequence acceptable to the program.

Another medium of communication which is intermediate in complexity between the use of prewritten programs and the use of some general purpose algorithmic language like FORTRAN is the use of problem oriented languages. These problem oriented languages are essentially composed of a variety of generalized subroutines each of which performs an elementary set of calculations which routinely occur in a particular application. For example, a language called COGO has been developed for aiding the highway design engineer. This language contains subroutines for solving the many problems of plane trigonometry which arise in this application. The user of a problem oriented language must select the appropriate subroutines available from the vocabulary of the

language, sequence these to provide for the designed logical flow of computation, and supply control parameters and input data values derived from the problem under study. To our knowledge, problem oriented languages have been developed for highway design, simulation of systems, and inventory management.

It seems to us that, among the variety of media described above, professional scientists can and should enlist the aid of computers in their quantitative work. Particularly important to the adoption of this new technology are those professionals in education. Whereas we don't believe computer programming for specific applications is worthy of college credit, the faculty member who uses computers as a fast, accurate and flexible tool in his own research can impart sufficient awareness of machines and their functions as an ancillary part of most quantitative courses.

In spite of limited past applications of computers in fishery science their diversity is not only interesting but also suggestive of future trends. Examples of computer usage include a classic study of population productivity of smallmouth bass by Watt (1957), an iterative solution of an equation for growth in length by Parker and Larkin (1957), construction of tables of polynomials as an aid in the solution of the von Bertalanffy growth equation (Tomlinson and Abramson, 1961) a von Bertalanffy growth curve program (Abramson, 1963) and mortality studies by Paloheimo, 1960. Other applications have been made in the form of a computer simulation of salmon migration (Saila and Shappy 1962, 1963), modelling a perch fishery (Menshutkin, 1964) and in the development of a mechanized information retrieval system for the aquatic sciences (O'Connor, and Saila, 1962, Saila, Shappy and O'Connor, 1962a, b).

It must be recognized that fishery science is advancing in a number of ways just as the approaches to all of biological science are entering a new era. In the past, both disciplines have frequently bogged down in a quagmire of data collection and ultimately, dust collection on the part of the collected data. The general approach outlined by Watt (1962) indicating the high desirability of continuous interaction between theory and experiment is a fundamental step in the advancement of fishery science and elimination of the above mentioned waste. The role of computers in this approach will become increasingly important as the transition from descriptive and classificatory literature to mathematical and quantitative work is made.

PRESENT AND FUTURE METHODS AND APPLICATIONS

A well established pattern of digital computer usage based on the concepts of a program and program library has evolved to date. Virtually all colleges and universities and many state and Canadian provincial agencies are now equipped with computers and libraries of programs capable of handling a variety of general statistical and mathematical problems, as well as many special problems. Programs, for the purposes at hand, are complete sets of instructions or commands to a computer to perform given sets of operations. These take a variety of forms since there are at present several programming languages, both symbolic assembly languages and algebraic compiler languages. The latter include FORTRAN and ALGOL which represent significant steps toward more effective communication between man and machine. Widespread use of FORTRAN and ALGOL has resulted in programming systems for many makes of computers. Informal exchange of programs among some fishery scientists is now in effect but the need for a centralized program exchange oriented toward aquatic scientists is already apparent and represents a challenge to the profession. Preliminary steps in establishing a formal mechanism for program exchange have already been made by the American Fisheries Society (Abramson, 1963). It is suggested that it be the policy of the fishery profession to channel actual mailings of programs and program write-ups through existing program libraries. The publication of program abstracts should be patterned after those developed by one of the user groups. These procedures will assure adequate screening and usable programs in the library as well as efficient exchange.

The classic current requirements to justify computer use for a given problem involve: a) complex computational effort which is difficult or prohibitive by manual methods, and b) the problem must be repetitive. The unfortunate artificial rigidity of the above as well as rigid input format requirements of most library programs have not been conducive to liberal attitudes by occasional users. It must be concluded however, that recent increases in computation speed, reduced costs, algebraic compilers, general availability of computers and numerous programs should have induced more utilization by the fishery scientist than is apparent at present.

Recent developments and trends in computer technology and conceptual scientific advances suggest major changes in future computer applications by our profession. A few of these are indicated. It is very likely that soon there will not only be more powerful computer languages but also languages designed for specific applications -- the so-called problem oriented languages. Such a language will probably be developed for ecology, if not for fishery science specifically. At least one data processing consulting firm has found it economical to develop a language oriented to its common applications (O'Hara, 1964). It is the feeling of these authors that the efforts of at least one graduate student (possibly working toward an interdisciplinary degree) could be profitably spent in studying the practicality of one or more computer programming languages for ecology; perhaps with particular emphasis on such areas as population dynamics, fisheries biology and fisheries hydrography. The more significant equipment advances will probably be made in input/output capabilities which will allow for more effective communication with the machine. Closely related to this is the technique of time-sharing -- the equipping of a single computer with a large number of separate consoles (input/output and control devices) which will allow a number of individuals to work at the machine simultaneously from several remote access points. Time-sharing should be especially attractive to fishery scientists for several reasons. Problems which are generated may be solved in a number of places and payment will be necessary for only the time and machine capacity used at a particular location. This concept obviously allows for availability of a large system to multiple users at relatively low cost. The machine is shared by the user not in the sense of having access to only a portion of the machine, but in the sense of direct access. It seems reasonable to predict that in spite of decreasing costs and increased numbers of computers, time-sharing will be the most rational approach toward increased usage by the fishery profession. The concept of time sharing is now only in its preliminary developmental stages at large computer installations. It also appears logical to anticipate relatively large data processing systems operated and maintained by a government agency such as the U.S. Fish and Wildlife Service on a regional basis with time sharing by state fisheries organizations in the region. This is conceived as becoming operational within the framework of the federal aid to fisheries program between the states and the federal government.

The specific areas of fishery science in which extensive use of computers will develop are difficult to predict because it is believed that the large proportion of potential users are still in our colleges and universities, many of which are presently training students in various aspects of computer science. However, there are already certain classes of problems which cannot be undertaken reasonably without resort to electronic computation. A few examples of these are indicated. Sneath and Sokal (1962) and Jahn (1962) have outlined a theoretical justification for and a summary of techniques used in the field of numerical taxonomy. They have clearly stated that advances in this area as well as current practices require electronic computers. It is suggested that fish taxonomists become familiar with this new area. Further, the common problem of classification of an individual into one of two or more populations (groups) can often be approached using the linear discriminant function (Fisher, 1936) and the generalized distance function of Rao, 1952. These techniques can be handled expeditiously with computers.

Significant conceptual and operational advances can be anticipated in optimum yield problems which will be approached by dynamic programming (Watt, 1963) because of the large number and complex nature of constraints imposed on such systems. Analysis of entire ecosystems have been formalized in a manner related to Leontiff's economic input-output analysis by Riffenburgh, 1962. Simulation of ecosystems has also been attempted utilizing a system of simultaneous first-order differential equations (Garfinkel, 1963). A general purpose systems simulator (GPSS1) has been developed by the IBM programming staff, and may serve as a prototype for some aquatic sciences simulation problems. The general purpose systems simulator seems especially appropriate for the study of the efficiency of various types of fish-ways. Without attempting to predict their relative merits, there seems to be no question but that most future models of fish population dynamics and systems approaches to ecological problems will require extensive use of large-scale data processing systems. In addition to simulation and modelling studies with the aid of digital computers, analog computers and modelling exemplified by the work of Doi (1958) in sardine availability studies and Odum (1960) in ecological analyses remain to be explored further.

Marine weather forecasting and fisheries hydrography will soon assume a more important role. At present computer programs are available which permit weather forecasting at various locations and some hydrographic predictions are also made. However, even the high speed of present computers is taxed with this kind of program. The pioneering efforts of Hela and Laevastu (1961) in fisheries hydrography deserve careful study and imaginative thinking as a foundation for progress in this area.

Linear programming will undoubtedly assume a greater significance in fisheries economics and has already been applied to a cost and planning study of fish ponds (Arroyo; 1961), to a study of optimum diversity structure of a plankton community (Patten, 1963), as well as to commercial fishery conservation (Zellner, 1962). Such models as Patten has described will undoubtedly have utility in studying fish communities. Information theoretic concepts (Margalef, 1958) are also a useful approach to new horizons in studies of succession and even phylogenetic evolution. Fish behaviorists may soon become involved with Markov processes as a means for better understanding of some aspects of behavior, and the diversity of computer applications in the behavioral sciences (Borko, 1962) will probably be utilized to some degree by fish behaviorists. Indeed, there hardly seems to be an area of fishery science in which the doors to further knowledge aren't opened wider with the aid of electronic computers. Some indication of computer applications in biology and medicine is evident in the bibliography of Empey (1962) and in a bibliography entitled "Data Processing in the Life Sciences: A Survey" prepared by North American Avaition, Inc., 1963, which includes 492 references. The book by Sterling and Pollack (1964) further emphasizes developments in biology and medicine. Wildlife biologists are also considering computer applications as exemplified by Benson (1964).

IMPLICATIONS OF COMPUTER TECHNOLOGY FOR COMMUNICATIONS IN FISHERY SCIENCE

Relatively recent interest and work in mechanical translation, information retrieval, permuted title indexes (e.g. BASIC indexes as are now prepared for Biological Abstracts) and other non-conventional documentation techniques are only specific illustrations of a more general concern that the existing mechanisms for scientific communications are inadequate. These inadequacies have been apparent for some time to portions of the scientific community (e.g. chemistry and metallurgy) and will become more apparent in fishery science and related disciplines for several reasons.

(1) First, and most obvious, is the continuing increase in the rate of research effort in fishery science and related disciplines. This increasing activity contributes to the now well known "flood of literature" which makes it impossible for many researchers to keep abreast of even the published literature which is relevant to their interests. To be comprehensively informed about related work in progress, before publication, is an impossibility for most workers. While individual workers are able to overcome the "literature problem" to some extent by becoming specialized in their reading habits (as has been interestingly pointed out by Bar-Hillel, 1963), specialization cannot be a completely acceptable solution. There are the remaining problems, for instance, of younger scientists without many years of experience, becoming familiar with the important aspects of a problem, and the application to fishery science of conceptual advances and techniques developed in other disciplines.

(2) There are also severe economic constraints on most special libraries which attempt to procure fisheries literature and related publications which are becoming more numerous and expensive. Thus even very important journals and books are often difficult to procure.

(3) The problems of procuring and understanding foreign language publications are also important.

(4) The time lags in the publication of research results and abstract journals also hamper efficient communications.

The many other reasons for increasing concern over improved communications in fishery science are beyond the scope of this paper. However, it does seem clear that computers will be usefully used to help alleviate some of the problems as outlined below.

The use of computers to prepare key-word-in-context (permuted title indexes is already well known) through the BASIC indexes to Biological Abstracts. This technique has some clear limitations which are, in part, due to the difficulty of summarizing the content of documents in a short title. However, this form of index, particularly with modifications such as have been recently developed at Biological Abstracts and Chemical Abstracts, will have some application to the documentation of fisheries literature in the future. Indeed permuted title indexes to some specialized bibliographies related to fisheries work have already been prepared at the Aquatic Sciences Information Retrieval Center (ASIRC).

A major application of computers will be in the area of information (i.e. literature) storage and retrieval. The concept of coordinate indexing is, at present, one of the more effective means of preparing information from documents for mechanized retrieval. This concept is based on analysis and characterization of documents by descriptors or tags. These descriptors are designed to describe the content and other characteristics of documents. Documents carefully tagged in this way may be retrieved selectively by inquiries also phrased in the form of descriptors, and only those documents tagged with descriptors matching those of the inquiry are retrieved as being relevant. Progress in this sort of work has been described by O'Connor and Saila (1962) and Saila, O'Connor, and Shappy (1962b). Related work for physical oceanography is also being undertaken by Rigby and London at the National Oceanographic Data Center (NODC Newsletter, No. 3-03, March 31, 1963). It is clear that computers will be used in these information retrieval systems and others which are now being planned.

An extension of information storage and retrieval techniques is the selective dissemination of information (Luhn, 1959) matching user interests with current documents to automatically channel the proper information to the proper user. This technique is in various stages of development in all disciplines, but computers may be expected to play a greater role in this technique in the future.

The use of computers in citation indexing and bibliographic coupling should also be mentioned. Citation indexing involves listing references, in some form, together with citations of documents in which the references have been cited. A citation index therefore lists, under each reference, the documents which have cited it. Modified citation indexes have been used for some time in the FAO Current Bibliography for Aquatic Sciences and Fisheries and by Dr. Model at the Deutsches Hydrographisches Institute in Germany. An example of citation indexing is given by Garfield and Sher (1963). Citation indexing and the related technique of bibliographic coupling (Kessler, 1963) are handled very readily by computers, and such techniques will probably be usefully applied to fisheries literature in the future.

The National Oceanographic Data Center is also actively considering the problems of storing and retrieving certain types of biological data which are relevant to fishery science. This task clearly requires the use of computers.

The language barrier is a formidable obstacle to the free flow of scientific information. No easy solution nor even optimistic prediction is possible for the near future. There is a paucity of competent translators, especially in our country. Furthermore, many translations which are made do not become generally available through centralized services. Steps to more widely disseminate this information are being taken, and the Aquatic Sciences Information Retrieval Center is expected to contribute in this area. Computers are presently being utilized for translating from one language to another but such translations are still fairly crude. This appears to be the case primarily because translations of idiomatic expressions are difficult, and fundamental studies concerning the nature of language have not advanced sufficiently.

One interim approach to computer aided translation is exemplified by the work of J. A. Bachrach at the Communauté Européenne Charbon et Acier (CECA) in Luxembourg (Bachrach, 1964). In this system, human translators scan lengthy technical documents and merely underline terms and phrases with which they are unfamiliar. The physical document is then sent to clerical workers who keypunch the underlined terms. A digital computer then performs the normal dictionary look-up task and returns listings of definitions, sample usages in context, and source authority (for further perusal by the human translator if he thinks this is necessary). Terms for which the computer has no information are routed to a group of language research specialists who compile the missing information. This material is submitted to both the original enquirer and to the mechanized dictionary.

CONCLUSION

The future of fishery science will strongly depend on computer oriented people who have not yet made their contributions. In spite of serious obstacles, the probability of accelerated progress and dramatic new developments is virtually a certainty.

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