Bulletin of the Institute of Marine Biology and Oceanography

Special Edition

Edited by

I.O.W. Findlay
J.M. Vakily

1993

Institute of Marine Biology and Oceanography
Fourah Bay College, University of Sierra Leone
Freetown, Sierra Leone

ICLARM

International Center for Living Aquatic
Resources Management
Manila, Philippines

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Preface

When the Bulletin of the Institute of Marine Biology and Oceanography was initiated in 1976, it aimed at providing an outlet for the presentation of the activities at the Institute. It has served this purpose well in the following four years, coming out with one issue every year except for the year 1979. Financial constraints forced the Institute to abandon the project in 1981. Since then, the Institute was left without a "voice", without a way to document its usefulness and the necessity of its existence in a country that profits in many ways from the exploitation of its marine resources.

The consequences are bitter: many interesting results from research work are either never properly published, or published in some foreign journals not available in Sierra Leone. Thus, they are "lost" to Sierra Leone, a very unsatisfactory situation, given that most research of the Institute is financed through public funds.

In 1991 IMBO started a research cooperation project with the International Center for Living Aquatic Resources Management (ICLARM), Manila, Philippines. This project is financed by the Commission of the European Communities.

One of the major objectives of this project is to preserve existing data and make them effectively available to interested researchers. While this refers in the first place to research data and involves the design of appropriate database systems, it is well understood that reports, articles, etc., are also "data" in a broad sense, which should be widely available. The project, therefore, considers it another important task to improve the access to literature available in Sierra Leone. To this end, the existing library facilities of the Department of Fisheries are being refurbished and the Bulletin of the Institute revived.

Given that over the years most of the copies of the first four issues have been distributed and that there has been a gap of more than ten years in the publication of the Bulletin, it was decided, based on a suggestion of Dr. D. Pauly, ICLARM, to start a new series of the Bulletin with a special edition that contains all the articles of the former issues, with the exception of a few articles not related to marine research.

The articles are presented in their original form, in the same order as they appeared in the Bulletin No. 1.1, 2.1, 3.1, and 4.2. (No. 4.1 was never issued). However, figures have been re-drawn and re-arranged and table layouts improved for better readability. In a few cases, inconsistencies are noted without attempting to interpret the author's intention. Major changes to the text usually relate to species names, which changed over the years. Whenever old synonyms were found in the text they were converted to their presently valid names. All references were checked and then compiled at the end of this volume to avoid duplication.

Dedication

This special edition of the Bulletin of the Institute of Marine Biology and Oceanography is dedicated to Professor Daniel Emanuel Babatunji Chaytor who has been Director of this Institute for two decades before he was appointed Vice Chancellor of the University of Sierra Leone in March 1993.

Professor Chaytor graduated from the University of Aberdeen, Scotland in 1958 with a B.Sc. in Zoology after winning the Nicol Prize in 1957 and the McGreggor Prize in 1958 - both academic awards reserved for the best students in Zoology. He continued his studies at University College, London, working on the growth of chick embryos for which he was awarded a Ph. D in 1961.

Upon his return to Sierra Leone he was appointed Lecturer in Zoology at Fourah Bay College. From 1965 to 1969 he successively served first as Senior Lecturer and Acting Dean of Basic Sciences, and later as Associate Professor and Dean of Basic Sciences at Njala University College. In 1969, he left Sierra Leone again to become Visiting Professor at the Massachusetts Institute of Technology, U.S.A.

He returned to Fourah Bay College in 1971 as Professor of Zoology and two years later in 1973 was appointed Professor and Director of the Institute of Marine Biology and Oceanography (IMBO).

During his directorship, Professor Chaytor placed great emphasis on the development of research and teaching programs at IMBO. He was very actively involved in teaching and thesis supervision. He has seen a total number of 44 students successfully completing their studies at IMBO either obtaining a Diploma in Aquatic Biology & Fisheries, or graduating with degrees, such as B.Sc. General (Zoology & Oceanography), B.Sc. (Joint Honours) and B.Sc. (Honours) in Marine Science. and - more recently - M.Sc. in Fisheries Biology.

Professor Chaytor has always shown a keen interest in establishing professional links with scientific institutions outside Sierra Leone. These included the Universities of Kiel, (Germany) and Rhode Island, Kingston, (U.S.A.), the University College of Swansea, University of Wales (U.K.) and the International Center for Living Aquatic Resources Management, (ICLARM) in Manila (Philippines). These links proved very valuable to the Institute as they became the basis for assistance that lead to the strenghtening and expanding of undergraduate and graduate studies. Assistance was obtained e.g. in the form of workshops or training courses. The course on tropical fish stock assessment conducted by Dr. D. Pauly (ICLARM) in early 1993 is but one example of this kind of international cooperation.

Professor Chaytor allocated much of his time and energy to what he considered crucial in a scientist's career: practical field work. He did not only assist in organizing the fisheries research cruises jointly carried out by Sierra Leone and the then USSR , but actively participated as a zealous marine biologist in some of the bi-annual cruises that took place during the years 1976 to 1990. Many other research projects, often carried out in cooperation with the Department of Fisheries, notably the oyster culture project, saw his eager involvement. These many years of practical research resulted in quite a number of articles that were published in well known international journals. A list of his publications related to Biological Sciences is given below. It is worthwhile to note that these represent just a small selection of his publications, with other articles covering fields such as education and science development.

However, Professor Chaytor's activities were not limited only to Sierra Leone. Beside being a member of several international scientific societies, such as the Association of Tropical Biology, the American Association for the Advancement of Science and the Society for Economic Anthropology, he also served in various capacities in international bodies. In 1980 he chaired the UNECA/UNESCO Workshop on Marine Science and Technology Development in Africa with subsequent missions to Ethiopia, Nigeria, Ghana, Liberia, Sierra Leone and the Gambia. Two years later he again became the Team Leader of a UNECA Mission to several African countries investigating their Marine Science and Technology Capabilities with reference to the UN Convention on the Law of the Sea (UNCLOS III).

In later years, his international involvement focused on environmental issues when he became a Consultant to UNEP on Environmental Education and Training, and the Project Leader for the UN-Sponsored Marine Pollution Research Project in Sierra Leone. In 1990 he attended the Third Session of the UN Environment Programme in Geneva as a member of the *Ad Hoc* Working Group of Experts on Biological Diversity.

Professor Chaytor also served as external examiner for the B.Sc., M.Sc. and Ph.D. degrees of the Universities of Ghana and Cape Coast in Ghana and for the M.Sc. and Ph.D degrees of the Universities of Lagos and Ibadan in Nigeria.

Last, but not least, it was Professor Chaytor who initiated the Bulletin of the Institute of Marine Biology and Oceanography in 1976. He had recognized the importance of providing a means of presenting the activities of IMBO and the results from the various ongoing research projects to a wider audience. The ultimate goal was, as he stated it in the preface to the first issue of the Bulletin, to help "focus the attention and support of both national and international bodies on the potential usefulness of the Institute's works in the scientific studies of the Atlantic seas bordering Sierra Leone, with particular reference to the rational development and conservation of the marine resources".

Professor Chaytor vacated his post as Director of the Institute of Marine Biology and Oceanography in February 1993, to assume his new position as Vice-Chancellor of the University of Sierra Leone. Students and staff of IMBO extend their heartiest congratulations to him, and wish him the very best, knowing that his friendly determination will make him a successful Vice-Chancellor, as it made him a successful and respected Director of IMBO.

Selected List of Publications of Professor D.E.B. Chaytor

McKenzie J. and D.E.B. Chaytor 1958. Alternations in the vascular pattern in chick embryos following the injection of insulin (Abstract). *J. Anat. 912*:664.

Chaytor D.E.B. 1958. Self-regulation in insulin-injected embryos. *J. Anat. 912*:664.

Chaytor D.E.B. 1962. Mitotic index in vitro of embryo heart fibroblasts of different donor ages. *Exp. Cell Res. 28*: 212-213 .

Chaytor D.E.B. 1963. The Control of growth of the chick embryo liver studied by the method of Parabiosis. *J. Embryol. exp. Morph. 11(4)*: 667-672 .

Vrba M. and D.E.B. Chaytor 1964. An attempt to detect and titrate Rous Sarcoma virus producing cells of rat tumour XC on the chorioallantoic membrane of the chick embryo. *Folio Biologica 10*:50-53 .

Williams M.O. and D.E.B. Chaytor 1966. Some helminth parasites of freshwater fishes of the Freetown Peninsula, Sierra Leone. *Bull. IFAN 28 Ser. A (No.2)*: 563-575.

Williams M.O. and D.E.B. Chaytor 1966. The freshwater fishes of the Freetown Peninsula. *Bull. IFAN 28 Ser. A (No.3)*: 1041-1063.

Taylor-Smith R. and D.E.B. Chaytor 1966. Investigations on West African plants. III. Toxicity studies of three West African medicinal plants. *Bull. IFAN. 28 Ser. A (.3)*: 895-898.

Chaytor D.E.B. 1969. The hydrology and chemistry of the River Jong in Sierra Leone. *Rev. Zool. Bot. Afr. 80 (3-4)*: 325-339 .

Chaytor D.E.B. and A. A. Aleem 1976. Further observations on the marine mollusca of Sierra Leone (Synopsis). *Bull. Inst. Mar. Biol. Oceanogr. 1 (No.1)*: 22-23.

Okera W. and D.E.B. Chaytor 1977. Survey of the shrimp stocks of the Sierra Leone inshore shelf. *Bull. Inst. Mar. Biol. Oceanogr. Vol. 2 (No.1)*: 10-14.

Okera W. and D.E.B. Chaytor 1978. Synopes of research on shrimps. 1. The common shrimp species of Sierra Leone's coastal waters: their distributon, abundance and size compositon. *Bull. Inst. Mar. Biol. Oceanogr. 3(1)*: 34-40

Aleem A. A. and D.E.B. Chaytor 1980. Further observations on the marine mollusca of Sierra Leone. *Bull. IFAN T 42 Ser. A. (3)*: 571-585.

Okera W. and D.E.B. Chaytor 1981. Observations on the environment, distribution relative abundance and size composition of four penaeid shrimp species off Sierra Leone (West Africa). *Meeresforsch. 29(1)*:30-42.

Domanevsky L., D.E.B. Chaytor, A. Ivanov, A. Kozhemyakin, V. Mokrousov, S. Overko and Yu. Sazcnov 1982. A preliminary estimate of the biomass of coastal pelagic fishes in the waters of the Republic of Sierra Leone. Report of Ad Hoc Working Group on Pelagic Stocks of the Sherbro Statistical Division (34.3.3) held at Freetown Sierra Leone, 18-23 October 1982. *CECAF/TECH/82/43. UN FAO/UNDP* Darkar June 1983. pp. 40-59 Appendix. 7.

Kamara A.B. and D.E.B. Chaytor 1992. Policy issues in fisheries and other marine resources development in Sierra Leone. Paper presented at the National Conference of the Agricultural Society of Society of Sierra Leone. Freetown. 25-29 November 1992.

Vakily J.M. and D.E.B. Chaytor 1992. L'evaluation et la gestion des resources halieutiques marine du Sierra Leone, Afrique Occidentale. *Bull. C.E. Cooperation Peche 5(2)*: 25-26.

Chaytor D.E. B. and E.T. Ndomahina (in press). The small pelagic and demersal fish stocks of Sierra Leone. Paper presented at the National Seminar on Fishery Industries Development. 25-29 November 1991.

DEVELOPMENT OF THE INSTITUTE

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FINDLAY, I.W.O. 1976. Development of the Institute. Bull. Inst. Mar. Biol. Oceanogr. 1(1):7-21.

The Institute of Marine Biology and Oceanography is situated at Kissy Dockyard some eight miles from Fourah Bay College and almost on the southern bank of the Sierra Leone River estuary. The Fisheries Division, Ministry of Agriculture and Natural Resources and the Institute share the same building and enjoy close co-operation and collaboration in the use of available facilities for field work and teaching as well as in the planning and execution of research projects. This situation has developed as a consequence of the joint inheritance of the West African Fisheries Research Institute (WAFRI) facilities.

The West African Fisheries Research Institute was established in 1952 as an inter-territorial unit for the then four British Colonial territories in West Africa - Gambia, Sierra Leone, Gold Coast (Ghana) and Nigeria - and financed under the Colonial Development and Welfare Fund. WAFRI was closed down in March 1957 because of financial and political reasons - the Gold Coast became the independent state of Ghana and withdrew its support. In its stead was established almost immediately the Fisheries Development and Research Unit (F.D. & R. Unit) jointly financed by the United Kingdom and Sierra Leone Governments. However, this Unit was closed down in 1961 when Sierra Leone became independent. The closure of the F.D. & R. Unit marked the complete break-up of WAFRI and the establishment of the Fisheries Division, MANR and the Fourah Bay College Marine Biology Laboratory. The Sierra Leone Government handed over the research section and available equipment of the F.D. & R. Unit to Fourah Bay College for the continuation of the Fisheries research work. Hence the present co-existence of the Institute and Fisheries Division in the same building.

The Botany and Zoology Departments were put in charge of the laboratories and equipment at Kissy. Work in relation to marine biology only began early in 1963 by the Zoology Department and a year later by the Botany Department. In the period early 1963 to June 1965 when plans were afoot for the creation of the Institute, the Board of the Faculty of Pure and Applied Science of FBC had made grants of Le2,764 (£1,382) for the purchase of research equipment for the Institute.

In October 1965 the Fourah Bay College Senate adopted the proposals of the Dean of the Faculty of Pure and Applied Science for the creation of an Institute of Marine Biology and Oceanography and the appointment of a Director, and also the setting up of an Advisory

Committee to advise the Senate on the Institute's development. The Advisory Committee consisted of the representatives of the departments of Geography, Geology, Botany and Zoology and the Head of the Fisheries Division of the Ministry of Agriculture and Natural Resources. It was given powers to co-opt.

The Advisory Committee immediately began negotiations for a gift of an oceanographic vessel by the Federal Republic of Germany. The vessel should be of 45 ft in length with twin diesel engines, safe for long-range ocean-going, and fully fitted out for biological and oceanographic research work. In February, 1966 an official request was made through the Ministry of External Affairs to the Federal Republic of Germany under its Technical Assistance Programme. In June 1966 it became known that the Embassy felt that the request should not be processed before UNESCO's assistance had been definitely secured. The necessary assurance was communicated to the Embassy.

The Fourah Bay College Council also approved the allocation of Le10,000 (£5,000) of its Non-Recurrent Vote for 1965/66 to a reserve for the Institute. However, because of severe cuts in the grant made by the Government to the College, the allocated funds were reduced to Le1,500 (£750). Much of this fund was used up in the purchase of three air conditioners to replace worn out ones at the Institute.

In the summer of 1965 the Principal, Dr. Davidson Nicol, visited Paris and held discussions with UNESCO on the question of assistance to the Institute. As a result of these discussions UNESCO agreed to provide a Director and equipment for the Institute. However, in January 1966, the Director of the Office of Oceanography (UNESCO) informed the Principal that "the budget available to his department for 1966 had been severely cut, and it might not be possible to provide a Director for the Institute for more than a two-month period." He advised that the College put forward a request for a post under the Expanded Technical Assistance Programme of the U.N. Technical Assistance Board in Sierra Leone. The Principal immediately acted on this advice. In spite of this setback UNESCO at the beginning of 1966 had provided equipment for the Institute to the total value of $8,000.

In June 1966 the Dean of the Faculty of Pure and Applied Science put forward a strong plea for a larger grant to be made available to the Institute so as to provide a reasonable fund for its establishment in 1966/67 session. The College was able to rearrange funds within the Faculty and provided Le8,500 for the Institute. This fund was provided in September to set up the Institute financially independent of the Zoology Department to which it had hitherto been attached.

In July 1966 it was confirmed that the expert requested from UNESCO will be available in Sierra Leone for the academic year 1967/68 and also that a Dr. Hempel of the Office of Oceanography will visit the College in an advisory capacity.

In November, 1966, Senate approved the recommendations of the Advisory Committee and set up an interdisciplinary Committee - the Institute of Marine Biology and Oceanography Committee - to supervise the affairs of the Institute. The Committee became a Committee of Senate and was "composed of the Principal (ex-officio), the Heads of the departments (or their nominees) of Botany, Geography, Geology and Zoology, a nominee of Senate, the Permanent Secretary of the Ministry of Agriculture and Natural Resources, the Chief Fisheries Officer of the Fisheries Division of the Ministry of Agriculture and Natural Resources, and the Director of the Institute who shall be Secretary of the Committee." The Committee had powers to co-opt.

Dr. Hempel attended and addressed this meeting of Senate. He had arrived early in November and made a thorough investigation of the plans for the establishment of the Institute and examined the existing laboratories and equipment available to the Institute at Kissy. He held discussions with members of the Advisory Committee and visited the Embassy of the Federal Republic of Germany to see what the position was with regard to the Institute's request for a research vessel and to see what other aid could be obtained from the Federal Republic under its Technical Assistance Programme. He advised that,

i) the Director of the Institute should be a College appointment and that the actual running of the Institute should be his responsibility;

ii) UNESCO will provide an expert to advise both the Director and the College on the development of the Institute;

iii) UNESCO will not proceed to appoint an expert or provide further assistance until the college had made provision for the following initial establishment - a Director, a Chief Technician and two Research Fellows:

iv) the Fisheries Division vessel "Fulmar" needs to be modified for basic hydrographical and biological work if it should serve the needs of the Institute and the Fisheries Division for proper fisheries surveys;

v) the College should try to receive a research vessel of about 45 ft through bilateral assistance;

vi) the Federal Republic of Germany could not presently provide the Institute with a research vessel but could provide a sea water circulation unit plus accessories if approached as soon as the post of Director has been advertised.

The Institute was constituted in November 1966. The post of Director was advertised through the agency of the Inter-University Council but no applications were received. The first Research Fellow, in the person of Mr. Ivan W.O. Findlay was appointed for two years on contract terms. He was previously a Research Assistant in the Botany Department studying for a Ph.D. Professor D.F. Owen, Head of the Department of Zoology, was appointed Administrative Director as from 1 September 1967. The staff of the Institute now consisted of the Administrative Director, a Research Fellow, a Laboratory assistant, a messenger/cleaner and a watchman. A lecturer in the Zoology Department, Mr. D. Hanstschmann, also made use of the Institute's facilities. The Institute lacked a boat of its own but could make use of the Fisheries Division vessel, the "FULMAR" and "FN3".

In October 1967 a Plan of Operation for the Survey and Development of the Pelagic Fish Resources Project in Sierra Leone was signed by the Government and UNDP (Special Fund) and by FAO (the executing agency) in November 1967. The project was to last for five years from 1967 to 1972. The co-operating agency nominated by Government was the Fisheries Division, MANR. The Project (locally known as the *Sardinella* project) became operational as a unit within the Fisheries Division, MANR. FAO provided a research vessel "AWEFU", equipment and personnel. Close co-operation in research and use of facilities developed among the members of the staff of the Division, the Survey Unit and the Institute.

In May 1968 Dr. Walter Fischer was appointed UNESCO expert for a year to the Institute and he took up his appointment in August, 1968. Dr. Walter Fischer came from the University of Chile Marine Biology Station. He left the Institute in March, 1969.

In October, 1968 Mr. Ivan Findlay was re-appointed Research Fellow on obtaining his doctorate degree. In December he was invited to act as Director on the resignation of the Administrative Director. He acted in this position until March, 1973, when Professor D.E.B. Chaytor of the Zoology Department was appointed substantive Director.

In September 1969, Mr. E.A.M. Leigh became the first Research Assistant in the Institute and also worked for an M.Sc. degree which he obtained in 1973. He has since left for Britain on a Commonwealth Scholarship to study for a doctorate degree.

In January 1970 Dr. A.A. Aleem joined the Institute as UNESCO expert replacing Dr. W. Fischer. In July 1970 Dr. Aleem was awarded the degree of Doctor of Science by London University for his work in the field of Marine Biology. He was also accorded the status of Professor of the University by Fourah Bay College. He left the Institute in 1974 to join the Department of Oceanography, King Abdulaziz University, Jeddah, S. Arabia.

In March, 1970 proposals for a Diploma in Aquatic Biology & Fisheries were approved by the Faculty Board and recommended to the Academic Board of the College. In January Senate gave its approval for the Course to commence in the following session (i.e., 1971/72 session). The Diploma Course is intended to provide middle-level manpower training for the effective development of the country's fisheries.

In March 1973 another Research Fellow was appointed to the Institute, Dr. Wazir Okera, and he took up his appointment in June.

The affairs of the Institute were supervised by an interdisciplinary committee. The Institute's functions include teaching, training and research. Courses in marine and freshwater biology and ecology are given as part of the requirements for the general and honours degree in Science of the University to students in the Botany and Zoology Departments. Facilities also exist for the training of postgraduate students.

Staff

Director:	Professor D.E.B. Chaytor B.Sc. (Aberdeen); Ph.D. (London)
Senior Research Fellows:	Dr. I.W.O. Findlay B.A. (Keele); Ph.D. (Dunelm)
	Dr. W. Okera B.Sc. (London); Ph.D. (Dar es Salaam)
Research Assistants:	E.A.M. Leigh (on study leave) B.Sc. (Dunelm); M.Sc. (Sierra Leone) J.E.H. Wilson, B.Sc. (Sierra leone)
Special Research Assistants: (Oyster Culture Project of the Government Fisheries Division)	E.T. Ndomahina B.Sc. (Sierra Leone) Rebecca Thomas B.Sc. (Sierra Leone) Cho Wellesley-Cole B.Sc. (Sierra Leone)

Laboratory Technician:	C.V. Mustafa
Laboratory Assistant:	A. Fofana
Cleark/Typist:	Victoria Davis (Mrs.)
Messenger/Cleaner:	A.B. Kamara

Research Facilities and Activities of the Institute

The terms of reference for the research and teaching activities of the Institute are scattered in several memos and it is therefore appropriate to summarise here the basis for the existence of the Institute. The research activities of the Institute are aimed at

1. pursuing studies related to the biological productivity and optimal exploitation of the fishery resources of Sierra Leone and eastern Atlantic waters;
2. finding scientific solutions to problems facing the fisheries Division (MANR) in its effort to manage, regulate and develop rationally the harvest of marine biological resources; and
3. undertake other researches in the biological, physical, chemical and geological oceanography relevant to the national and regional needs of West African maritime nations.

These aims are somewhat similar to those of the Institute's predecessor, the West African Marine Fisheries Research Institute but in the present day circumstances, the effective execution of the above objectives has been hampered by various factors.

The Institute lacks adequate working space and an offshore-going vessel. At present, the Institute is housed in an old building with the Fisheries Division and unless a new building is erected either on the present premises or on land adjacent to the present building, the functions of the Institute will continue to stifle. The Institute shares with the Fisheries Division a Library which has been receiving many good journals. This library however, needs attention, especially in updating its systems of cataloguing and lending; and a special effort made to get the journals bound. The library of Fourah Bay College also used to receive several other marine titles, but lately both the libraries have been unable to meet the costs of some of these journals.

For several years now, due to lack of a suitable boat, the Institute and the Fisheries Division have been unable to carry out offshore work on the continental shelf of Sierra Leone, where the bulk of the fish resources of the country is found and exploited. Thus a modest fisheries research vessel, probably a 20 m wooden or metal hull stern trawler/purse-seiner powered by 200-300 HP engine is very essential for the Institute and Fisheries Division to perform their functions effectively. This vessel can also be fitted for oceanographic work. The 34 ft wooden boat 'Pente' owned by the Fisheries Division and at times also used by the Institute staff, is suitable only for work in the sheltered Sierra Leone River Estuary. The Institute has three `Laros' rubber dinghies and two 15 HP outboard engines, suitable for ecological work in shallow inshore bays and estuaries. The Institute's VW van is in running order and is providing useful service. There is also a reasonable collection of laboratory glassware and chemicals but overseas scientists wishing to undertake work at the Institute are advised to write to the Director to check on items that they may require during the course of their work.

Sierra Leone is situated centrally on the eastern side of the tropical North Atlantic in a zone which is influenced by both the warm and cold surface currents of the Central Atlantic. The seas bordering Sierra Leone are known to be fairly rich in fish resources. There is a large natural harbour on the estuary of the Sierra Leone River. The coastline stretches for about 200 miles and it is irregularly indented, providing numerous near-shore ecological habitats such as estuaries, bays, lagoons and mangrove swamps. Most of these habitats are still unspoilt and provide many interesting ecological problems for investigations.

The present research activities of the Institute are centered on the three Senior Scientists: Professor D.E.B. Chaytor continues to participate and supervise the research projects on the biological problems associated with commercial oyster culture which include:

i) fouling of raft-cultured oysters

ii) oyster larval ecology and

iii) oyster reproductive biology.

His project on the mullets funded by the International Foundation for Science is also in progress.

Dr. I.W.O. Findlay has been monitoring several physico-chemical properties of some streams discharging into the Sierra Leone River Estuary for three years now and although short gaps occur in his sampling, the data accumulated so far should provide some useful baseline information for future pollution studies. His work on the algal ecology of one of the streams is still in progress.

Dr. W. Okera completed a project on the cockles *Senilia (Arca) senilis* and the first phase of the beach-seine inshore pelagic fisheries project. He will resume the latter project in due course; currently, he has started studies on the 4 species of penaeid shrimps.

Teaching Programmes

The senior staff of the Institute teach the following University Marine Science courses:

1. The Undergraduate Diploma in Aquatic Biology and Fisheries, now in its sixth year of operation, was formulated by the Institute with the aim of providing a practical aquatic sciences course for a *limited* number of Sierra Leoneans and other nationals who would become Fisheries Field Officers or Superintendents in the Fisheries Division of appropriate Government Ministries or for appointment in similar capacities in the fishery industries. The Diploma holder is also suitably qualified for laboratory work in the water industry and municipal functions of water pollution prevention. The course duration is three years and the *minimum* requirement for admission is a School Certificate with 4 Credits (or equivalent G.C.E. qualification) including Biology (or Additional General Science and General Science) and Mathematics, and at least a Pass in English Language. Applicants with G.C.E. "A" levels or other comparable qualifications are also considered for admission. In the Diploma course, the students learn the

elements and basic techniques of aquatic and fishery science studies. Although presently the Institute's facilities for practical training at sea, inland lakes, rivers and estuaries are limited, the teaching staff are doing their best to provide a training that will produce practical Extension Workers for the rational exploitation, development and management of the fisheries and other marine and freshwater resources of Sierra Leone. The senior staff of the Fisheries Division of the Ministry of Agriculture and Natural Resources also participate in the teaching programme of the Diploma, thereby ensuring that the relevance of the course to the practical needs of the country is maintained. This joint effort undertaken by a department of the Government Ministry and that of the University in the training programme will also enable the students to readily appreciate the relevance of University education in the service of a nation.

2. At the B.Sc. (General) and B.Sc. (Hons.) degree courses in the biological subjects, the senior staff of the Institute teach courses in algae, algal ecology and limnology in the Botany Department and marine ecology and fisheries science in the Zoology Department at Fourah Bay College. Zoology Honours students in their 4th and 5th years also carry out short research projects with senior members or staff of the Institute as part of the requirements for the Honours degree.

3. The Institute has drawn up syllabuses for a 5-years B.Sc. Honours degree in Marine Science (specialising either in the Biological, Physical, Chemical or Geological Oceanography). At its present stage of development, financial limitations and priorities, the Institute is only able to launch the Marine Science (Biological Oceanography) degree course; it is anticipated that entry into this course will be highly competitive and restricted to really promising future Marine Biologists. Courses leading to the Marine Science degree in physical, chemical and geological oceanography cannot be started unless the Institute's facilities in the teaching and research of these subjects both on shore as well as at sea are developed. It is hoped that the development of these subjects will receive the attention that they ought to be receiving as soon as the financial circumstances permit. For without the effective establishment of these disciplines, we shall not be able to provide an interdisciplinary course in Marine Science and neither are we fully justified in calling ourselves an Institute of Oceanography!

4. Facilities exist at the Institute for post-graduate work in Marine Biology and Fisheries Biology, leading to higher degrees of the University of Sierra Leone. Post-graduate research projects are oriented towards finding practical solutions of biological problems associated with the exploitation, development and conservation of the aquatic resources of Sierra Leone.

PROJECT SUMMARY: MARINE MOLLUSCA OF SIERRA LEONE

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Chaytor, D.E.B. and A.A. Aleem. 1976. Project Summary: Marine mollusca of Sierra Leone. Bull. Inst. Mar. Biol. Oceanogr. 1(1): 22-23.

A collection of the marine Mollusca has been assembled for reference purposes in the Institute of Marine Biology and Oceanography. It has been made over a period of five(5) years from several localities around the Sierra Leone River Estuary and the Freetown Peninsula. This is part of a bigger effort to build up a reference collection of the marine fauna and flora of Sierra Leone. Notes have been included on the occurrence and abundance as well as on general ecology of the species. So far the Cephalopoda and Polyplacophora have been excluded.

Sixty species of gastropods have been documented; fifty species of bivalves and one scaphopod complete the present list. The list is accompanied by a short note on the marine mollusca of economic importance in Sierra Leone, namely *Ostrea* (= *Crassostrea*) *tulipa* and *Arca* (= *Senilia*) *senilis*. *Cymbium neptuni*, *C. proboscidale* and *Tonna galea* are large edible molluscs inhabiting deep waters and frequently taken in trawl nets and beach-seines. Other bivalves sought for food are *Chama*, *Donax*, *Tellina* and *Tagelus angulatus*. The biology of these species, being so little known, should be fertile ground for studies in the future.

The general picture of rocky shore zonation shows the periwinkles dominant in the upper littoral zone, with *Littorina angulifera* occupying the more sheltered shores while *L. punctata* and *Tectarius granosus* occupy more exposed shores. *T. granosus* penetrates higher up the shore than the other two periwinkle species. The mid-tide zone is the site of the oysters and the barnacles, with *Brachyodontes puniceus* occupying the crevices among the barnacle and extending down to the lower littoral zone. The limpet *Siphonaria pectinata* abounds just below the barnacles zone along with the key-hole limpet *Fissurella*. This is also the zone of *Chama* and *Thais* which extend even to the infralittoral zone.

Tectarius, *Littorina* and *Nerita* display vertical migrations following the rise and fall of the tidal level.

Fuller details of the biology and ecology are to be found in Aleem and Chaytor (1980).

PROJECT SUMMARY: THE COCKLE FISHERY OF SIERRA LEONE

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OKERA, W. 1976. Project Summary: The cockle fishery of Sierra Leone. Bull. Inst. Mar. Biol. Oceanogr. 1(1):24-25.

In Sierra Leone, several marine molluscan species are gathered for food by coastal inhabitants. The mangrove oyster *Crassostrea tulipa* which is also found growing on estuarine intertidal rocks and the brackish and estuarine intertidal cockle, *Senilia senilis*(L.) (=*Arca senilis* L. 1758) are the most important exploited species. Other molluscan species include the sublittoral rock oyster *Crassostrea denticulata*, the gastropod *Cymbium* spp. and the cuttlefish, probably *Sepia officinalis hierredda*. From estuaries and mangrove creeks, the bivalves *Iphigenia laevigatum*, *Tagelus angulatus*, *Tellina nymphalis* and the gastropods *Tympanotonus fuscatus* and *Semifusus morio* are also collected. While some work has been done on the oyster, biology and fishery of the remaining species are poorly known.

The cockle is frequently seen being gathered in the villages dotting the coastline of Sierra Leone River Estuary and the smaller estuaries of the Freetown Peninsula. Dried cockle meat is often on sale in Freetown markets. Shells, with their convex surfaces uppermost, are fixed in the soil around the village huts. This practice probably minimises the erosion of the soil caused by heavy rain-water runoff from the roofs. Cockle shells are also used in making handicrafts.

All the cockle collection sites examined were exploited and had cockle densities of about 9 large (> 10 mm) individuals per m^2. At River No. 2 estuary at peak spatfall, there were about 130 seed cockles per m^2. Spat settlement began in November-December after the rainy season, reached the peak in January-February and continued to early part of the following rainy season (May-June). Seed cockles were absent from August to October.

Rings on the cockle shells were formed once a year, during July to September (maximum rainfall). They were successfully used in ageing the cockles. The first ring was formed at a mean age of 7 months and the subsequent ones annually. The growth period of the inter-ring bands, considered to extend from August to following July (*Senilia senilis* growth year), may actually be of only 10 months duration. Sublittoral cockles from No. 2 estuary showed higher growth rate compared to those of beds exposed at low tide and subjected to greater exploitation. Those from the Sierra Leone River Estuary showed even greater growth. *Senilia senilis* grows slowly and lives long (up to 8-9 years) but heavy exploitation in many places reduces the stocks to young and few year-classes.

PROJECT SUMMARY:

PRELIMINARY INVESTIGATIONS ON THE FOULING ORGANISMS AFFECTING RAFT CULTURED OYSTER POPULATIONS IN SIERRA LEONE

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WELLESLEY-COLE, C. 1976. Project Summary: Preliminary investigations on the fouling organisms affecting raft cultured oyster populations in Sierra Leone. Bull. Inst. Mar. Biol. Oceanogr. 1(1):26-28.

Earlier work on oyster culture in Sierra Leone was done by E.T.A. Golley-Morgan during 1964 and 1965 at Bonthe. Further work was done in the Sierra Leone River Estuary in 1965 by two oyster culturists from Taiwan and by J.B. Hunter in 1969. These earlier studies led to systematic attempts at culturing oysters, beginning in February 1974. This present study is part of the Oyster Culture Project of the Fisheries Division, Ministry of Agriculture and Natural Resources. It deals with fouling organisms which are marine and estuarine organisms interfering with the growth of oysters on raft cultures. The preliminary investigations were carried out during December 1975 and January 1976.

Three stations to be studied were selected and visited on a weekly basis. These were,

1. Jui, situated on the east coast of the Freetown Peninsula off the Bunce River, a tributary of the Sierra Leone River;
2. Kissy Dockyard I, also situated on the east coast of the Freetown Peninsula on the Sierra Leone River Estuary and
3. Dare, 35 km north east of Freetown on the Sierra Leone River Estuary.

Tray, rack, beach and raft culture methods have been used in Sierra Leone; however, raft culture has been found to be most productive and therefore research was focused on foulers affecting raft-cultured oysters. Oyster shells, bamboo and asbestos panels measuring about 8 x 6 x 1 cm were punched through the middle and strung out 0.5 m apart on weighted nylon strings to a depth of 2 m. These strings bearing the panels are known as the cultch and they were hung on the rafts at the different stations and exposed for one month.

At Jui and Dare, *Crassostrea tulipa* spat, *Nereis* sp. (a polychaete worm), *Membranipora annae* (a bryozoan), *Balanus amphitrite* (a barnacle), *Enteromorpha* sp. (a green alga) and *Polysiphonia* (a brown alga) settled on the cultch to 1 m depth. *Eudendrium* sp. (a hydroid) was found at this depth at Jui, but not at Dare. *Brachyodontes* *puniceus* (a mussel) was found at Dare at this depth, but not at Jui or Kissy Dockyard I. *Eudendrium* sp., *Enteromorpha* sp. and *Balanus amphitrite* settled above 1 m at Kissy Dockyard I, *B. amphitrite* being the main fouling organism at this depth.

From 1 m to 2 m depth, *Balanus amphitrite* was the main fouler at the three stations. About this depth, *C. tulipa* settled at Dare and *M. annae*, *Nereis* sp. and *Eudendrium* sp. were found at Jui. *Polysiphonia* sp., *Enteromorpha* sp., *Eudendrium* sp. and *C. tulipa* were found on the dorsal surfaces of the cultch panels. *M. annae* and *B. amphitrite* set on the under surfaces of the panels. Below 1 m, *B. amphitrite* set on both the upper and lower surfaces of the cultch.

Nereis sp. was found on both surfaces but predominantly on the ventral surfaces, underneath *M. annae*. At Dare, *B. puniceus* was found among the algae on the dorsal surfaces of the cultch. At Kissy Dockyard I, *B. amphitrite* set on both the surfaces of the cultch, from 0.5 m to 2 m depth. *M. annae* was found at the same depth on both the surfaces of the cultch at Jui.

This preliminary short-period investigation gave an indication of the type of fouling organisms colonising raft-cultured oysters at the various stations and the variation of fouling with depth at each locality. It also appeared that there is some synchronisation in the reproductive cycles of the foulers and the oysters. All these aspects of the work are still under fuller observations.

PROJECT SUMMARY
LARVAL OYSTER ECOLOGY IN RELATION TO OYSTER CULTURE

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THOMAS, R. 1976. Project Summary: Larval oyster ecology in relation to oyster culture. Bull. Inst. Mar. Biol. Oceanogr. 1(1): 29-30.

The purpose of the study is to obtain a general seasonal and spatial distribution of the abundance of oyster and other lamellibranch larvae in the plankton of the Freetown Estuary. The larvae of fouling organisms such as barnacle nauplii and cyprids and the cyphonautes larvae of bryozoans are also monitored. Both these parts of the study complement the concurrent studies on the organisms fouling oysters on raft cultures and also on those dealing with the reproductive cycle of the oyster.

Work is done at various stations (Dare, Pothko, Jui and Kissy Dockyard) in the Sierra Leone River Estuary. There is also a station on the Freetown Peninsula at No. 2 River Estuary. Weekly sampling at the various sites for hydrological data and plankton is undertaken. A standard plankton net of No. 21 silk is used and only 5-minutes surface tows are made. When the Clarke-Bumpus sampler and a pump become available, vertical tows and quantitative work will be undertaken. When lamellibranch larvae such as those of oysters, mussels and shipworms are observed in the samples, they are separated from the rest of the plankton. Larval stages of fouling organisms, especially those of barnacles and bryozoans are also noted.

Quantitative analysis of the present samples is difficult because they often contain considerable amount of silt or are dominated by blooms of centric diatoms, mostly *Coscinodiscuss* spp. Thus the samples are analysed qualitatively using an arbitrary scale to indicate relative abundance.

From the results obtained so far (January 1976 to August 1976) it has been observed that the occurrence of oyster larvae in the plankton varies from month to month for each station. Oyster larvae are present at all the stations from January to about August with a decrease in the abundance during July and August. It appears that the larval stages of the oyster spend about a week in the water; however, it is hoped that the correctness of this observation will be established as the work progresses. The different stations have been observed to be rich in plankton species, with a reduction in the number of species when the salinity drops. This was especially marked at the No. 2 River station. Barnacle nauplii are frequently observed and occasionally they become quite abundant. Cyphonautes larvae are rare though the adult colonies are observed on the cultch.

PROJECT SUMMARY:

PRELIMINARY STUDIES ON THE REPRODUCTIVE CYCLE OF THE MANGROVE OYSTER, *CRASSOSTREA TULIPA*

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NDOMAHINA, E.T. 1976. Project Summary: Preliminary studies on the reproductive cycle of the mangrove oyster, *Crassostrea tulipa*. Bull. Inst. Mar. Biol. Oceanogr. 1(1):31-34.

A part of the current Oyster Research Project being carried out by the Fisheries Division of the Ministry of Agriculture and Natural Resources involves the study of the reproductive and gonad changes in the mangrove oyster *Crassostrea tulipa*. It is hoped that at the end of this study the following aspects of the reproductive biology of the oyster will become known:

1. Gonad morphology and development
2. Gonad histology and germ cell development
3. Nuclear maturation and early cleavage
4. Breeding season
5. Age at first maturity
6. Sexuality
7. Glycogen cycle
8. Effects of environmental factors such as temperature and salinity on the gonadal changes.

The specimens of wild oysters were obtained from a station at Jui and were collected at approximately monthly intervals. In the laboratory, a selected number of oysters was divided into size-groups and measured for metrical characters. The hinge or umbonal region is dorsal and the shell edge directly opposite is ventral. Externally the byssal notch is in anterior region. The maximum distance in the dorsoventral direction is referred to as the dorsoventral measurement (D.V.M.). The anterior-posterior measurement is referred to as (A.P.M.). The thickness of the valve at the hinge line is referred to as the heel depth (H.D.). The metrical characters are important in growth studies as well as taxonomic studies. Three size groups have been recognized beginning from the smallest to the largest.

The gonadal tissues were removed, fixed in Buoin fluid and processed using standard method of paraffin section. A group of large oysters was fixed in Bauer-Feulgen so that the glycogen content could be estimated. A limited number of large specimens kept in wax have been sectioned at 15 µ thickness and stained in haematoxylin and eosin.

By looking at the "visceral mass" around which is wrapped the gonads and also making smears of the gonadal tissue there is hardly any specimens above 10 mm (dorsoventral measurement) without a visible trace of gonad. This is in sharp contrast with some bivalves reported in temperate regions e.g., *Pinctada albina, Avicula lucunata* and *Pteria vulgaris,* for which such sizes are regarded as juvenile. This probably suggests that *Crassostrea tulipa* has a shorter life-span.

The cross-section of the gonad is in the form of an inverted U as in *Paphia staminea*. Sections across the same gonad will cut through follicles showing identical gonad condition, thus making the choice of site relatively unimportant. A significant number of male and female gonads in large oysters is normally cream and yellow respectively. But this is not a good method of determining sex since up to 10% error can occur.

Since no sections have yet been taken of young oysters, no definite statement can be made about the exact region from which the gonad arises. It is, however, believed to be due to the activity of a pair of primordia (thin layers of cells) immediately posterior to the urogenital papillae. As each layer spreads, the group of cells attach themselves to thin membranes that later develop into follicles. The primary follicle proliferates longitudinally as far as possible. When the follicles are fully developed, the cells cease to multiply and gametogenesis begins.

There is no set pattern for the classification of gametic activity but three important scales of reference are in wide use:

1. The relative abundance of glycogen in ripe and unripe gonads.
2. The extent of gonad development based on the area occupied by the gonad follicles relative to the connective tissue.
3. Recognition of phases of gamete development based on histological features, e.g., nuclear features, cell sizes and staining characteristics.

As many as eight stages of gonadal activity, (five developmental, and three regressional) have been recognised by earlier workers. There is an additional inactive stage called "i". Dinamani (1973) working on *Crassostrea glomerata* recognised six stages for both males and females and an "R" stage of indeterminate sex. Dinamani's view has been adopted after a careful observation of a few sections of oyster gonads collected from December 1975 to July 1976.

Gonadal smears and the presence of oyster spat on samples of wild oyster colonies obtained each month suggest that spawning occurs for most part of the year. There is a variation in the intensity of spawning from time to time. Observations made so far, strongly suggest that the gonads are in developmental stages during most part of the dry season (December to March). They are mature in April to the end of May when spawning begins in the wet season.

A study of the reproductive cycle of the oyster is important because the information obtained on the spawning times, localities and behaviour may enable spat ("seed") collectors to be set up in time before the spawning peak or peaks. It is also necessary to identify which of the spawning peaks will be more advantageous than others with respect to the growth and fattening of the cultured oysters.

PROJECT SUMMARY:

FISHES TAKEN BY THE BEACH SEINES AT LUMLEY, FREETOWN

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OKERA, W. 1976. Project Summary: Fishes taken by the beach seines at Lumley, Freetown. Bull. Inst. Mar. Biol. Oceanogr. 1(1): 35-37.

The inshore pelagic fisheries of Sierra Leone is of considerable local economic importance. Pelagic fishes account for nearly 80% of the total catch of the indigenous Sierra Leone fishing industry. The entire inshore pelagic fisheries of the coast is presently dependent on the canoe fishermen, also now called the artisanal fishermen. Their main fishing gears are the beach seine, castnet, driftnet, ringnet and setnet.

From July 1974 to May 1976, the author frequently visited Lumley Beach, Freetown, to examine the catches taken by the beach seines. One or two beach seines fish from the sandy Lumley beach daily, except on Sundays. The nets are shot in Cockerill Bay in depths extending from the surf line to approximately 7 m at the farthest point reached by the net.

Sixty two species were recorded from the catches of the beach seines. The five pelagic species *Sardinella eba* (flat herring), *Cybium tritor* (mackerel), *Caranx hippos* (cowreh), *Caranx senegallus* (joe fish) and *Caranx crysos* (pollock) dominated the catches most of the time. Juvenile *Sardinella eba*, and at times mixed with young *Sardinella aurita* (round herring) were the most important, both in numbers as well as weight. Of the larger species, a total of about 1,266 *Cybium tritor*, 791 *C. hippos*, 921 *C. senegallus* and 698 *C. crysos* were counted but in terms of weight, *C. hippos* was probably the most important, followed by *Cybium tritor*, *C. crysos* and *C. senegallus* in that order, the last two species probably occurring in roughly equal proportions by weight. Occasionally, the *Sardinella-Cybium-Caranx* dominance was obscured by the preponderance of one or few of the smaller species such as *Chloroscombrus chrysurus* (cutmoney), *Brachydeuterus auritus* (caiman), *Vomer setapinnis* (pomp), *Engraulis hepsetus* (langa-mina), *Ilisha africana* (lati), *Caranx rhoncus* (?) and young *Sphyraena guachancho* (kinni). Several other species occurred in the individual hauls, mostly in unimportant quantities.

Adult *Cybium tritor*, the three large species of *Caranx* and *Trygon margarita* (stingray or skeete) were most abundant during the last two months of the rainy season (September and October) and first four months of the dry season (November to February). Large quantities of *Chloroscombrus chrysurus*, *Vomer setapinnis* and *Brachydeuterus auritus* were caught during the rainy season (May to October) and they were also present during February.

Young *Sphyraena guachancho* and *Caranx senegallus* also appeared during some months of the rainy season and they probably represented broods spawned during the preceding months of September to February.

For the purposes of managing the pelagic fisheries of Sierra Leone for rational exploitation, it is necessary to monitor all the different pelagic fisheries of the country and collect accurate data on the quantities of fish caught and the biological characteristics of the exploited species. From this study it became apparent that the routine statistical sampling of the beach seine catches for numbers, weights and lengths of each of the major species caught can be achieved without much difficulty.[1]

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1 Note by the editors: This article was later published in the Journal of Fisheries Biology (Okera 1978)

PARTICIPATION IN THE FISHERY RESEARCH EXPEDITION OF THE R.V. FIOLENT - 9 JULY to 6 SEPTEMBER 1976

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FORDE, A.C.V. 1976. Participation in the fishery research expedition of the R.V. FIOLENT - 9 July to September 1976. Bull. Inst. Mar. Biol. Oceanogr. 1(1): 37-41.

In accordance with a contract between FAO and the Soviet Fishing Fleet (SOVRIBFLOT), the RV FIOLENT has been undertaking fisheries research along the West African coast between latitudes 4°N and 17°S. The vessel RV FIOLENT is an 82 m long stern-trawler and had on this expedition, 18 Russian scientists on board, 70 men crew and 7 participants from some of the West African maritime countries (2 from Sierra Leone, 2 from Nigeria, 2 from Benin and 1 from Guinea). I boarded the RV FIOLENT on 5 July at Dakar and the cruise sailed on 9 July 1976.

The aims of the cruise were to investigate resources distribution, evaluation of bottom and pelagic fish stocks and crustaceans and ways of developing the fisheries of the regions. The oceanography of the fishing areas were also studied. The cruises of the RV FIOLENT consisted essentially of background surveys, each series of surveys lasting for six months (January to June and July to December). Each survey covered 75-80 stations. At each station, temperature and salinity were measured by reversing thermometers and electro-salinometers respectively. At the deeper stations, measurements were taken to depths of 1,000-1,500 m. Alternate stations were established for hydrochemical studies but the latter became more frequent with sharp changes in the hydrochemical environment.

During background surveys, biological work included observations on the fish catches to determine the following catch characteristics:

1. species composition;
2. total weights of leading species in each haul; and
3. determination of weight, sex, gonadal state, stomach contents and fat content of individuals of the most important species.

The results of the background surveys were analysed to determine areas to be studied in detail by microsurveys. Two microsurveys were carried out, each lasting for six days, the first between Gabon and Zaire from 1 August to 7 August 1976, and the second along Angola. Hydroacoustic work and controlled fishing were the most important components of these investigations.

The expedition also undertook some tests on fishing techniques and fish processing.

The research activities of the RV FIOLENT started on 18 July 1976, off the island of Marias Ngouema Biyoge (formally Fernando Poo). By 24 July, the vessel was off Gabon but Libreville did not give permission for investigations of the stations within the territorial limits. The RV FIOLENT arrived at Luanda on 16 August but permission was refused by the Angolan government to carry out the microsurvey within the territorial waters. The ship left Luanda on 18 August and arrived at Lagos on 6 September, where I disembarked.

It is hoped that the data collected by the expedition, which were only partially analysed during the expedition for cruise purposes, will yield information on the following topics:

1. oceanographic conditions in the area during the period of investigations;
2. distribution of the main hydrochemical elements;
3. development and distribution of plankton and identification of most productive areas;
4. biological characteristics of the fish population of the area;
5. stock assessment of the commercial fish species and their tendency to change;
6. fishery potential of the different regions, both demersal and pelagic; and
7. techno-chemical, quantitative and economic aspects of the fished species.

Several of the observations made on the fish catches were quite interesting. For example,

a) Some species of fish caught during the cruise such as Pagrus ehrenbergi, Pseudotolithus senegalensis, Dentex angolensis, Sardinella aurita, Torpedo torpedo and Decapterus punctatus were also to be found in Sierra Leone.
b) A total of 27 demersal trawls were made during the background surveys and altogether 243 species of fish were caught. Of these, 136 species were caught only once and one species caught 13 times.
c) A total of 53 species were caught during the two microsurveys of which 27 species were caught more than four times.
d) There were some species which had characteristics of being caught only during the day and some only at night.

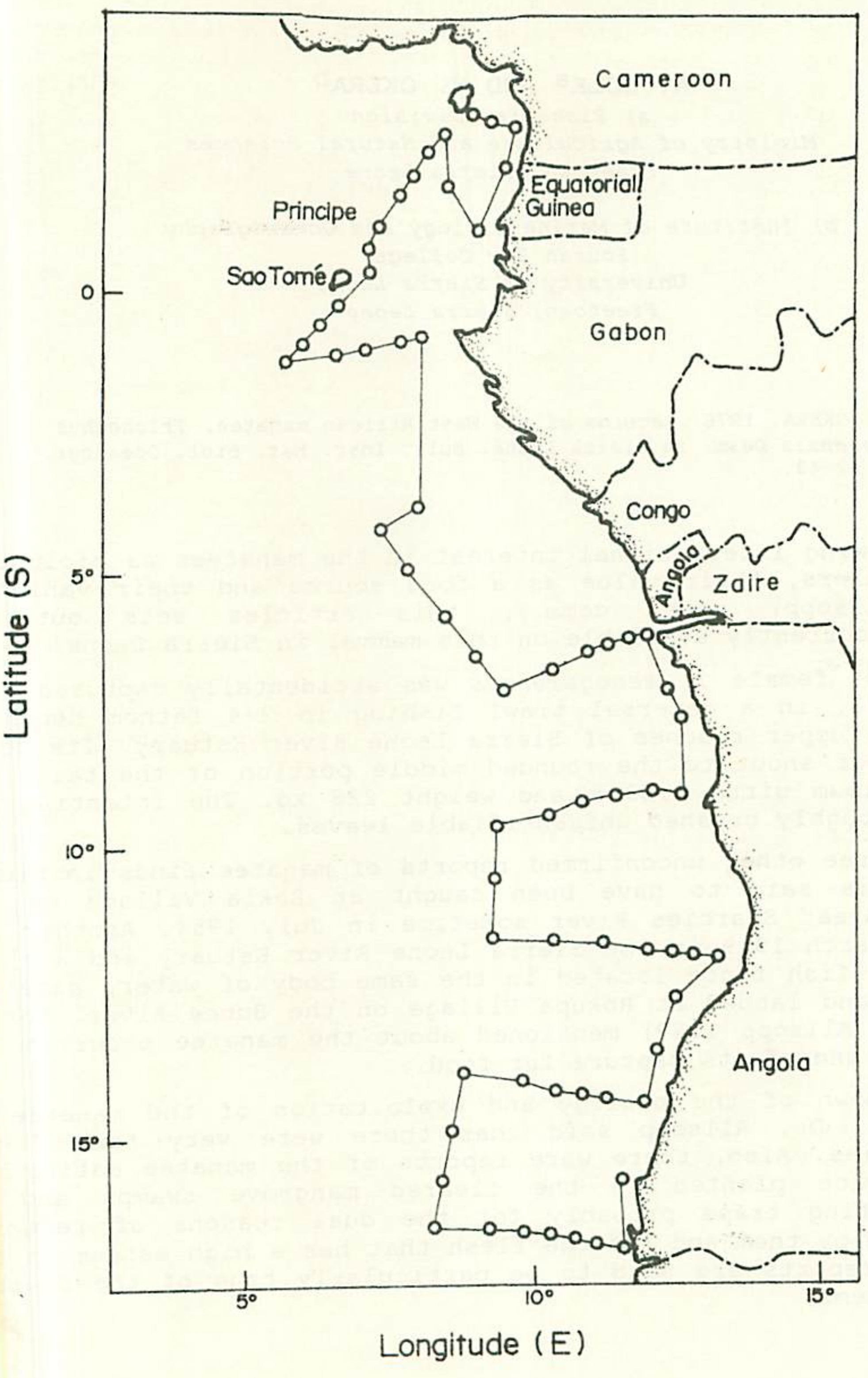

Fig. 1. Map showing the route of the RV FIOLENT during background survey

RECORDS OF THE WEST AFRICAN MANATEE, *TRICHECHUS SENEGALENSIS* DESM. IN SIERRA LEONE

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COLE, A. AND W. OKERA. 1976. Records of the West African manatee, *Trichechus senegalensis* Desm. in Sierra Leone. Bull. Inst. Mar. Biol. Oceanogr. 1(1): 42-43.

With the growing international interest in the manatees as biological weed controllers, their value as a food source and their vanishing numbers (Allsopp, pers. comm.), this articles sets out the information currently available on this mammal in Sierra Leone.

A specimen of female *T. senegalensis* was accidentally captured on 9 December 1973, in a demersal trawl fishing in 2-4 fathom depth of water in the upper reaches of Sierra Leone River Estuary. Its total length (tip of snout to the rounded middle portion of the tail) was 2.43 m, maximum girth 1.63 m and weight 228 kg. The intestine was full of thoroughly crushed unidentifiable leaves.

There are three other unconfirmed reports of manatee finds in Sierra Leone. One is said to have been caught at Rokia Village on the estuary of Great Scarcies River sometime in July 1954. Another was trawled in March 1959 in the Sierra Leone River Estuary and a third trapped in a fish fence located in the same body of water, sometime during 1963 and landed at Rokupa Village on the Bunce River. Morton (quoted form Allsopp 1969) mentioned about the manatee occurring in Sierra Leone and of its capture for food.

Little is known of the biology and exploitation of the manatee in Sierra Leone. Dr. Allsopp said that there were very few of the African species. Also, there were reports of the manatee eating and destroying rice planted in the cleared mangrove swamps and of villages setting traps probably for the dual reasons of reducing damage caused by them and for the flesh that has a high esteem in the area. These reports are said to be particularly true of the Sherbro riverine systems.

SURVEY OF THE SHRIMP STOCKS OF THE SIERRA LEONE INSHORE SHELF - A SUMMARY REPORT OUTLINING OBJECTIVES, OBSERVATIONS AND RECOMMENDATIONS ON THE STATUS OF THE SIERRA LEONE SHRIMP FISHERY

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CHAYTOR, D.E.B. AND W. OKERA. 1977. Survey of the shrimp stocks of the Sierra Leone inshore shelf - a summary report outlining objectives, observations and recommendations on the status of the Sierra Leone shrimp fishery. Bull. Inst. Mar. Biol. Oceanogr. 2(1):10-14.

ABSTRACT

A one week survey of the inshore shrimp stocks off Sierra Leone was carried out in June 1977. Experimental trawling took place at night at depths from 10 to 70 m. Depending on the area and the water depth catch rates ranged from 1 kg/hr to around 18 kg/hr. Species caught comprised *Parapenaeopsis atlantica*, *Parapenaeus longirostris*, *Penaeus kerathurus*, and *Penaeus notialis*. The investigations, however showed that the predominant component in the catch is fish, half of which is usually discarded. The discarded portion contains many of the young of commercially valuable species. Recommendations are spelled out regarding possible shrimp fleet size and future investigations into the shrimp stocks and the by-catch problem.

Introduction

From the 7th to 13th June 1977, a short survey was carried out to assess the condition of the stocks of commercial shrimps in inshore waters of the Sierra Leone shelf. In particular, attention was focused on the catch rates of the different species, their latitudinal and bathymetric distribution and the size composition of the different species in the catches.

Two Soviet shrimpers, identical in their construction, were provided for the survey. Each vessel had the following specifications: 23.7 m length; 225 HP engine and 9 knots average cruising speed. Each boat towed a single shrimp trawl with the following characteristics: length 20 m; head-rope length 12.5 m; ground-rope length 16.2 m; lead-chain weight 22 kg; cod-end mesh size 18 mm. The otter-boards were approximately 2 x 1 m.

Trawling was carried out at night between 19.30 and 05.30 GMT in depths of 10 to 70 m; each trawl lasted for an hour. Four locations were investigated:

1. off Sulima;
2. off north Turner's Peninsula and Sherbro Island;
3. off Bullom and Scarcies; and
4. off Western Area Peninsula.

Eight trawls were made at each of the locations 1, 2 and 4 and six trawls only at location 3. It is felt that the results obtained from these four areas gave an adequate picture of the status of the shrimp stocks off the Sierra Leone coastline at the time of the year.

Observations

The principal results of the survey are outlined below:

1. The average catch rate of shrimps (heads-on) off Sulima was 9 kg per hour. The species consisted mostly of *Parapenaeopsis atlantica*, a commercially valuable species but smaller in size (maximum mean lengths of males and females were 7.3 and 11.9 cm respectively) than the pink and tiger shrimps. An average catch rate of 10 kg per hour of this species in the area is a fair estimate. Small quantities (1 to 2 kg) of *Parapenaeus longirostris* were also taken here at the deeper stations in sub-thermocline waters. The average lengths of males and females of this species were 8.5 and 9.7 cm respectively.
2. Off north Turner's Peninsula and Sherbro Island, the shrimp catch averaged 10.5 kg per hour, consisting almost entirely of *Parapenaeopsis atlantica*.
3. Off Bullom-Scarcies, 1 kg per hour of *Parapenaeopsis atlantica* was obtained in 10-12 m depth. In 20-25 m depth, an average of 8.5 kg per hour of the large tiger shrimps (*Penaeus kerathurus*) were taken. The maximum mean lengths of male and female tiger shrimps were 15.2 and 17.4 cm respectively.
4. Average catch rates off the northern Western Area Peninsula were 50% lower compared to those off Sulima, but off the southern Western Area Peninsula, they were double the yield taken off Sulima. The catch consisted dominantly or entirely of the valuable pink shrimp, *Penaeus duorarum notialis*. The maximum mean lengths of males and females of this species were 14.3 and 18.9 cm respectively. At one station off the north Western Area Peninsula, the species was mixed with the tiger shrimp.
5. At all the trawling sites, large quantities of fish were also taken in the shrimp net. The average total fish catch was about 110 kg per hour, usually made up of 50-60 kg of good fish (such as lady, shine-nose, sole, crocus, grouper and snapper) and the rest of trash species (such as caiman, butterfish, two species of flat fishes, *Monacanthus* and another yet unidentified small species). All the trash species mixed with the young (10-20 cm) of the valuable species were thrown overboard.
6. Off Sherbro and Turner's Peninsula, considerable numbers of young lady or capitan (*Pseudotolithus senegalensis*) and sole (*Cynoglossus* sp.) were caught and thrown dead overboard after

the shrimps and large fishes have been removed from the catch. Off Bullom and Western Area Peninsula, many young snapper (*Pagrus ehrenbergi*) were also caught and thrown dead overboard. Thus, it appears that the shrimps live in the same places as the young of these commercially important species of fish and in fishing for the shrimps, the young lady, sole and snappers are also killed.

Recommendations

On the basis of these initial observations, the following recommendations were made:

1. There is room for expansion of the Sierra Leone-based inshore shrimp trawling fleet. Three fleets, each of 7-10 shrimpers fishing off (i) Turner's Peninsula and (ii) Western Area Peninsula and (iii) Bullom-Scarcies Yeliboya, seem a reasonable proposal.
2. The very low catches of the valuable pink shrimp off the Sherbro and Turner's Peninsula was very puzzling and further studies similar to the present one are planned to find out the causes of its apparent absence. Are the reasons ecological or is it that heavy exploitation over the past several years has already wiped out the stocks?
3. The inshore shrimp trawling grounds need to be mapped out and their extent established. The size of the stocks on these grounds need continual monitoring and study, so that appropriate scientific advice can be made to the fishing industries of Sierra Leone on the deployment of vessels. This spells out an important aspect of our future responsibilities.
4. The complex problem of shrimps being fished together with the young of commercially valuable species of fish needs immediate investigation. This is an important but difficult problem; an attempt to resolve it is urgent. If the fleets expand, it will be an important consideration in determining allowable shrimping intensity.
5. Surveys similar to the present one are very useful for providing spot checks on the condition of the stocks of shrimps and inshore demersal fishes. They are necessary for the continual review and implementation of management policies.

Acknowledgments

We extend our sincere thanks to the Soviet Fishing Fleet and the Government of USSR for placing at our disposal the shrimp vessels and the fisheries research vessel PROGNOZ for 7 days to undertake the survey; to Dr. Serge Overko (ATLANTNIRO Fisheries Scientist) for his invaluable assistance in the implementation of our wishes to carry out the survey and to the Russian crew of the vessels for their cooperation.

BIOLOGY OF THE MULLET SPECIES OCCURRING IN THE ESTUARIES OF FREETOWN PENINSULA

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ABSTRACT

Preliminary findings of a research project on the biology of mullets have confirmed the existence of five species of mullets occurring around the Freetown Peninsula belonging to the genus *Liza* and *Mugil*. Feeding seems to be little selective but determined by particle size . It shows a change from detritus during the rainy season to predominantly algae in the dry season.

This study embraces several aspects of the biology of the mullet species found in and around Freetown. The main objective is to find out which species of mullet will be most suitable for estuarine or freshwater pond culture. It is hoped that by the end of this study sufficient data would be available to shed light on:

1. Feeding rate and assimilation efficiency of the different mullet species.
2. Fraction of organic matter in the sand actually utilized by the fish.
3. Spawning season or seasons of the main species.
4. Rate of growth of the different species.
5. Age and size at maturity.
6. Species most tolerant to fresh water.

The main project site is a small estuary called the Black-Johnson Estuary, some five miles off York.

During the course of the investigation, other estuaries were also examined for mullet populations. These included, Aberdeen Creek, No. 2 River Estuary, Jui and Hastings (especially by the New Orogu Bridge). Originally, samples were collected from Black-Johnson every week for population study, growth rate and rate of feeding. On completion of these aspects of the study, visits to the site became less frequent. Presently, the greater part of the investigation is concentrated at Aberdeen Creek, which is within easy reach and supports a much larger fish population.

It is outside the scope of this Bulletin to give the detailed methods employed in the present study. Briefly, the following data are collected on almost every sample: total length and standard length of the fish, depth of body, weight and gutted weight; and where possible, sex of the individuals and their gonad condition. A sub-sample is retained for further investigation, such as microscopic examination of the gut contents and scales. Preliminary investigations confirmed the findings of Payne (1976) that there are five species of mullets occurring around the Freetown Peninsula: *Liza falcipinnis* (Cuvier and Valenciennes), *Mugil cephalus ashanteensis* (Bleeker), *Liza dumerili hoefleri* (Steindachner), *Liza grandisquamis* (Cuvier and Valenciennes) and *Mugil curema* (Cuvier and Valenciennes). Of all the species, *Liza grandisquamis* appears the most restricted in its distribution - occurring by and large, only in muddy areas, frequently around mangroves. This species is completely absent at Black-Johnson Estuary. The other four species occur along the Peninsula but further work is needed before a conclusive mapping of their distribution is made. *Liza falcipinnis* so far appears the most widely distributed.

Salinity tolerance tests reveal that *M. cephalus ashanteensis* and *M. curema* are the least tolerant to fresh water; while *L. falcipinnis* and *L. dumerili hoefleri* survive in fresh water. These last two species have been caught in wholly freshwater habitats on different occasions. Payne (1976) cited D.E.B. Chaytor collecting both the species from the River Taia. In 1974 and again in May 1977 Dr. Payne and I collected *Liza falcipinnis* from the Little Scarcies. Shoals of these species were observed in the Rokel in May this year. Experiments on the salinity·tolerance are still underway.

The indications thus far show that mullets feed on every conceivable fine particles occurring in the vicinity provided it is small enough to be ingested. There is no selection, except for that based on particle size. The major constituents of their diet however, show a clear change from detritus in the rainy season to algae (both green and blue-green) in the dry season. It has been shown by various workers that the assimilation efficiency in mullets ranged from 45-52%. In the present study, *L. falcipinnis* has been shown to assimilate 53-56% of the organic matter ingested (c.f. 52% by A.I. Payne), for *L. dumerili hoefleri* it is 32-43%. Work in this area continues, but it is evident that the assimilation efficiency varies with the species.

Nothing conclusive can be said at the moment about the spawning season, until the interpretation of all the data collected is completed. The are indications that there are slight differences and considerable overlaps in the spawning seasons of the different species. For *L. grandisquamis* the spawning season has been tentatively fixed from August to November; for *L. falcipinnis* and *L. dumerili* it is from mid-October to early January.

A LIST OF THE ESTUARINE AND MARINE FISHES AND SOME SHELLFISHES OF SIERRA LEONE, WITH THEIR COMMON NAMES IN EITHER KRIO OR ENGLISH

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KAMARA, A.B. 1977. A list of the estuarine and marine fishes and some shellfishes of Sierra Leone, with their common names in either Krio or English. Bull. Inst. Mar. Biol. Oceanogr. 2(1):47-53.

Introduction

Sierra Leone has a population of over three million people, an area of 27,925 square miles (73,326 km^2) and a coastline of about 210 miles (approx. 340 km). The country lies on the west coast of Africa between latitudes 6°55' and 10°N, and longitudes 10°16' and 13°8'W. The continental shelf (the area within the 100 fathom depth) is twenty miles wide near the Liberian border to the south and approximately ninety miles wide at the Guinea border to the north. The major estuaries are the Scarcies in the north, the Sierra Leone or Rokel River in the middle and the Sherbro in the south.

The fishing activities center around longlines ("Morren" and "Flotin"), hook-and-line and various kinds of fishing nets operated from several types and sizes of canoes. Several trawlers also fish in Sierra Leone territorial waters. The canoe fleet consists of about 600 canoes operated by about 12,000 part-time and full-time fishermen. Their catch amounts to over 36,000 metric tons annually of locally consumed fish. During the off season (July to September), when the weather is unsettled, the activities of the canoe fishermen are reduced considerably. The catch comprises mostly of pelagic species, e.g. bonga, herring and lati. Some bottom species such as the sole, gwangwa and snapper are also taken. The beach-seines operated from the shore may also catch pelagic, mid-water and demersal species. Part of the commercial trawlers' catch is consumed locally and an unknown quantity is exported. A significant quantity of tinned fish is also imported.

There are about sixteen tribes in Sierra Leone, but those concerned with fishing mostly reside along the coast, the estuaries and the river systems. The major marine fishing tribes are the Susu along the Bullom shore in the north, the Temnes in the central coastline and the Sherbros in the south. Over the years there has been a lot of mixing of these tribes, dictated primarily by the migratory patterns of the most sought-out fish, namely the bonga and herring. Inland communities residing along freshwater systems practice mostly subsistence fishing using nets, traps and the hook-and-line.

In the coastal villages, the fishes are mostly known by their local names in Krio because most residents of the fishing villages, often comprising of more than two tribes, can communicate in Krio. Also, many fishes are popularly known today by their English names; their tribal names may be restricted to particular geographical areas. The same species of fish may have two or more common names and two or more species may be known by the same common name. For example, both *Sardinella eba* and *Sardinella aurita* are called herring; in some cases, where species differentiation occurs, it is done by adjectives, e.g. gwangwa and black gwangwa; lady and longneck lady; black joe-fish and white joe-fish, etc.

Most of the fishes on this list are eaten locally. Sharks, eels, cephalopods and tunas caught by foreign fleets ar exported. The trigger-fishes are reported to be poisonous. Many other edible shellfishes are not listed.

The following list aims at standardizing the common names of the fishes and shellfishes with reference to their scientific names. The list is far from complete and it is hoped that it will be updated sometime in the future.

Fishes

Common Name (in Krio or English)	Scientific Name
angle fish	*Monodactylus (=Psettus) sebae*
awefu	*Ethmalosa fimbriata (juvenile)*
blaku; smooth puffer	*Lagocephalus laevigatus*
blaku; common puffer or swamp	*Hemiconiatus (=Ephippion) guttifer*
bearbear; beardfish	*Polynemus (=Pentanemus) quinquarius*
bigeye fish	*Priacanthus sp.*
bonga	*Ethmalosa fimbriata (adult)*
boarfish	*Antigonia capros*
bonito	*Sarda sarda*
butterfish	*Gerres melanopterus*
catfish; sea-cats	*Arius spp.*
cowreh	*Caranx carangus; Caranx hippos*
couta; barracuda	*Sphyraena spp.*
crocus	*Pomadasys jubelini* (other species of Pomadadsys?)
cutmoney	*Chloroscombrus chrysurus*
damselfish; abudefduf	*Chromis spp.*
dogsole; flounder	*Psettodes belcheri*
doctor penknife; surgeon fish	*Acanthurus (=Xesurus) spp.*
dolphin fish	*Coryphaena spp.*
eels; congers	*Conger conger*
eels; snake eels	*Ophichthus spp.; Myrichthys spp.; Pisodonophis spp*
eels; morays	*Lycodontis spp.*
flying fish	*Exocoetus spp.; Cypselurus spp.*
frogfish; toad fishes	*Batrachus liberiensis; B. decadactylus*
grainger; needlefishes	*Ablennes hians*
grouper (rose or red)	*Lutjanus agennes*
grouper (grey or black)	*Lutjanus goreensis*
grouper (brown)	*Lutjanus dentatus; Lutjanus modestus*

Common Name (in Krio or English)	Scientific Name
gwangwa	*Pseudotolithus elongatus*
gwangwa (black)	*Pseudotolithus epipercus*
herring (flat)	*Sardinella maderensis*
herring (round)	*Sardinella aurita*
hognose	*Plectorhynchus macrolepis*
joefish (blackish); sand mackerel	*Trachinotus goreensis*
joefish (whitish); sand mackerel	*Trachinotus goreensis*
johndories	*Cyttus; Zenopsis; Zeus* spp.
kinni (juvenile barracuda)	*Sphyraena* spp.
kaiman	*Brachydeuterus auritus*
ladyfish	*Pseudotolithus senegalensis*
ladyfish (long-neck)	*Pseudotolithus typus*
langa-mina	*Achoviella guineensis*
lati	*Ilisha africana*
mackerel	*Cybium tritor*
mangopage	*Tilapia* spp.
mollit (jumbo)	*Mugil cephalus*
mollit (flat)	*Mugil (= Liza) falcipinnis*
mollit (round)	*Mugil curema*
mollit (trangabak)	*Mugil (= Liza) grandisquamis*
moonfish; headfish; sunfish	*Mola mola*
needle fishes	*Ablennes; Belone; Strongylura* spp.
ninebone	*Elops lacerta; Elops senegalensis*
parrot fish; wrasse	*Coris julis*
pente; half beaks	*Hyporhamphus unifaciatus; Hemirhampus brasiliensis*
picardo; remosas	*Echeneis naucrates*
pollock	*Decapterus rhonchus; D. punctatus; Trachurus trachurus*
pomp	*Alectis alexandrinus; Selene dorsalis*
porcupine fish	*Diodon* spp.; *Chilomycterus* spp.
record; seabasses	*Serranus* spp.; *Epinephelus* spp.
rogie; red mullet; goatfish	*Pseudupeneus prayensis*
sailfish; billfish	*Istiophorus; Tetrapturus spp.*
swordfish	*Pristis pristis; Xiphias gladius*
scorpion fishes	*Helicolenus; Pontinus; Scorpaena spp.*
dogfish (shark)	*Squalus sp. (?)*
basking shark	*Cetorhinus maximus*
white shark	*Scoliodon terra-novae*
whale shark	*Rhincodon (=Rhiniodon) typus*
hammerhead shark	*Sphyrna spp.*
sharpnose shark	*Carcharhinus spp.*
sheephead	*Drepane africana*
shinenose	*Galeoides decadactylus*
silversides	*Atherina spp.*
silverfish	*Trichiurus lepturus*
skeete	*Pteroplatea micrura; Raja (Raia) spp.; Zanobatus sp.*
skeete; cownose rays	*Rhinoptera bonasus; R. marginata*
skeete; devilfish; mantaray	*Mobula spp.; Manta birostris*
skeete; eagle rays	*Myliobatis; Pteromylaeus spp. Aetobatus; Rhinoptera spp.*
skeete; electric rays	*Torpedo spp.*
skeete; shovel nose; guitarfish	*Rhinobatis spp.; Rhinobatus spp.*
skeete; stingray; whipray	*Dasyatis margarita; Dasyatis spp.*

Common Name (in Krio or English)	Scientific Name
squirrel fishes	*Holocentrus*; *Myripristis* spp.
sleepfish	*Lobotes surinamensis*
snapper (red)	*Pagrus; Dentex; Pagellus* spp.
snapper (black)	*Lethrinus atlanticus*
sole	*Cynoglossus* spp.
spanish	*Polydactylus quadrifilis*
tarpon	*Megalops atlanticus*
tenny; bonefish	*Albula vulpes*
trigger fish; hard-skin fish	*Balistes* spp.
tuna (albacore)	*Thunnus alalunga*
tuna (skipjack)	*Katsuwonus pelamys*
tuna (bluefin)	*Thunnus thynnus*
tuna (yellowfin)	*Neothunnus albacore*
tuna (bigeye)	*Thunnus obesus*
tuna (little)	*Euthynnus alleteratus*
Whiting; Cassada-fish	*Pseudotolithus brachygnathus*

Shellfish

Common Name (in Krio or English)	Scientific Name
mangrove oyster	*Crassostrea tulipa* (= *C. rhizophorae*); *C. gasar*
rock oyster	*Crassostrea denticulata*
cockle	*Arca* (= *Senilia*) *senilis*
sorongbah	*Tagelus angulatus*
gbende-gbende	*Tympanotonus sp.*
octopus	*Octopus sp.*
cuttle fish; ink fish	*Sepia sp.*
pink shrimp	*Penaeus duorarum*
tiger shrimp	*Penaeus kerathurus*
lobsters	*Panulirus sp.*

A LIST OF THE FRESHWATER FISHES AND SOME SHRIMPS OF SIERRA LEONE WITH THEIR VERNACULAR NAMES IN MENDE, TEMNE AND LIMBA

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ISCANDARI, N. 1977. A list of the freshwater fishes and some shrimps of Sierra Leone, with their vernacular names in Mende, Temne and Limba. Bull. Inst. Mar. Biol. Oceanogr. 2(1):54-56.

Introduction

Sierra Leone has over 6,000 km of rivers and streams net-work and a few medium-sized lakes. Most of the main rivers tend to run in a north to south direction, with numerous tributaries. A provisional and partial list of the fishes and a few shrimps is given below, with their vernacular names in Mende, Temne and Limba.

Fish

Scientific Name	Mende	Temne	Limba
Protopterus annectens	vomgboli hemei; ndorgoe; tupu-nyei	bopr; afak	kutha
Polypterus senegalus	jeyei	keskla	kutenkellie
Cynothrissa	polie	kokoro	inkuinie
Papyrocranus afer	ndanyei	fak	kudamgba
Xenomystus nigri	patapan	fak	k-bopoh
Hyperopisus occidentalis	bebee	thoth	kusumgbun
Mormyrus macrophthalmus	magbukpui	mahereh	n'heren
Mormyrus rume	kayani	kururu	lollie
Mormyrops deliciosus	ndurguy	aloh	mamankalay
Isichthys henryi	vomgboi	karump	?
Gymnarchus niloticus	kpoyei	t-gbaren	kuninay
Hydrocynus brevis	njengbei	t-gbaren	bathain
Hyrocynus somonorum	jumboi	ta poff	rek-rek-ma
Hyrocynus lineatus	njaar	ka-gbith	kywanka
Hyrocynus forskalii	magborgboi	ka-gbith	sumuneh
Microalestes acutidens	kaar	keria	n'keria
Alestes sethente	vuer	talmant	kippie
Alestes baremose	konguy	a-gbantan	ba-borah
Alestes chaperi	kartei	serekulay	kay-ray-day
Hepsetus ode	njamgbe	k-thin	pohie
Phago loricatus	fasinyamgbei	k-nepl	bathegeyama
Bagrus macropterus	gbokiboi	T-yainthain	ba-sagoin
Chrysichtys furcatus	korsie	kibbie	ba-sagoin bethuguye

Fish (cntd.)

Scientific Name	Mende	Temne	Limba
Auchenoglanis occidentalis	konkoie	kuthunthun	gbada
Siluranodon auritus	kulaha	t-foam	siankay
Clarias lazera	harlei	t-nima	thamba
Malapterurus electricus	kpikpi	ka-nink	gbi gbi na
Synodontis omias	kongongboie	gbokobo	n'keselanie
Epiplatys sp.	ndondoay	k-gbuth	kudu okamanko
*Trachinotus goreensis**	mbolei	ka thin	n'heren kikaman
Lutjanus sp.*	pelei	k-yale; k-feth	thenky
*Pristipoma jubeleni**	sengie	ta-bupp	sompie
*Mugil cephalus**	kunungui	ma sek	lombbie
Polynemus guadrifilis	piati	boi sont	basoie
Ctenopoma kangaa	kangaa	kotie	thekoh
Tetraodon strigosus	gbatagbotei	an-belan	baraka
Potamotrygon garouensis	gbikpi	agboloh	kugboloh
Hemichromis fasciatus	koeyei	ku-wale	gbamgbama; mafarato
Hemichromis bimaculatus	gboblie	ta pirr	kuduguthe
Tilapia monodi	kpeloi	an-boh boh	sayray
Tilapia zillii	*ngorkei*	*gba gba ferah*	*ka-yainkain*
Tilapia melanopleura	ngipie	a-sannoh	tha thompo
Tilapia mariae	pondaworkei	a-sannoh	tha thompo

Crustaceans

Scientific Name	Mende	Temne	Limba
Atya gabonensis	kpaa	ka-samp	ku-thanda
Palaemon paucidens	fascei	ka-samp	ku-thanda

* Estuarine species.

THE EFFECT OF SUBLETHAL CONCENTRATION OF DIMILIN^{R} (TH6040) ON THE LARVAL DEVELOPMENT OF THE MUD-CRAB *RHITHROPANOPEUS HARRISII* (GOULD)

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WILSON, J.E.H. 1978. The effect of sublethal concentration of Dimilin^{R} (TH6040) on the larval development of the mud-crab *Rhithropanopeus harrisii* (Gould). Bull. Inst. Mar. Biol. Oceanogr. 3(1): 1-11.

ABSTRACT

The effects are investigated of sub-lethal doses of the insecticide Dimilin^{R} on the larval development of the mud-crab *Rithropanopeus harrisii* reared at different temperature/salinity combinations. Survival of the larvae was significantly lower at the sub-lethal concentration of 1 ppb Dimilir^{R}, while the duration of development for those surviving was not markedly affected. Sub-lethal doses of Dimilin^{R}, however, tended to become toxic, if a second stress factor is added, such as low salinity or high water temperature. This suggests that the use of Dimilin^{R} at concentrations above 1 ppb in the vicinity of estuaries with low salinity (<5 ppt) might have an adverse effect on the survival of *Rithropanopeus harrisii*

Introduction

Dimilin^{R} (TH6040) is a member of the large group of 1-(2,6-disubstituted benzoyl) -3 -phenylureas discovered by Philip-Duphar B.V. of the Netherlands and is being developed in the United States by Thompson-Hayward Chemical Company. According to the developer, this compound has been shown to be very effective in reducing the population of a wide range of invertebrates especially the dipterans. Field experiments with the black salt marsh mosquito, *Aedes taeniorhynchus*, showed that concentrations of 0.001 - 0.003 ppm Dimilin^{R} caused a mortality of 96-100%, while 20 ppm had no effect on juvenile Cray fish reared in the laboratory (Thompson-Hayward Chemical Company 1974). Similarly there was no effect on the fiddler crab, *Uca* sp., at 0.01-0.075 lb ai/A (active ingredient per acre).

The effect of this compound on the larval development of non-target invertebrates i.e., invertebrates other than insects is little known. Christianson et al. (unpublished data) have however studied the effect of this compound on the larval development of two estuarine crabs - *Rhithropanopeus harrisii* (Gould) and *Sesarma reticulatum* (Say). Working with concentrations ranging from 0.5 to 10 ppb, it was demonstrated that the survival of larval stages of both species of crab decreased as the concentration increased. Significant decrease in survival started at 1 ppb and 3 ppb for *R. harrisii* and *S. reticulatum* respectively. The aim of the present investigation is to demonstrate the effects (if any) of sublethal doses of Dimilin^R on larval development of *R. harrisii* reared at different temperature - salinity combinations.

Materials and Methods

The method of rearing the larvae of *R. harrisii* is that described by Costlow, Bookhout and Monroe (1966).

Ovigerous females of *R. harrisii* were collected from the East Coast of Florida and air-shipped to Beaufort in May 1978. They were maintained at 20 ppt filtered sea water in large finger bowls until hatching occurred. Immediately after hatching larvae were transferred into the already prepared experimental bowls (small finger bowls) in series. Each series consisted of five bowls, each containing ten larvae in 50 cm^3 of the culture solution maintained at the experimental temperature. A concentration of 1.0 ppb Dimilin^R was used throughout as the sublethal dose. This concentration was chosen because the results of earlier workers and that of my preliminary experiments showed that 1.0 ppb represented the sublethal level at 20 ppt and 25°C (optimum for *R. harrisii*).

A sublethal concentration of Dimilin^R was obtained by appropriate dilution of a prepared stock solution, with filtered sea water of the required salinity (i.e., 5, 20, 35 ppt). For each experimental series, an acetone-control series was set up. One cm^3 of acetone (pesticide grade) was made up to 1 liter with sea water of the required salinity. The battery of finger bowls was then kept in separate culture cabinets maintained at 25° and 30° C respectively and subjected to a photoperiod of alternating 12 hours light and darkness.

Everyday the number and stage of dead larvae together with the number of exuviae were noted. Living ones were transferred into clean finger bowls containing fresh medium plus one drop of recently hatched *Artemia* nauplii. Due to their cannibalistic tendency, megalopa were kept in plastic compartment boxes, thereby making it easy to note the time of metamorphosis to the first crab stage.

Every container was washed in acetone and rinsed preferably with hot water, followed by washing with non-toxic cleaning agent (Cake Boniami) and final rinsing in hot water. They were then allowed to air-dry on paper towels.

Results and Discussion

The results of the preliminary experiments are given in Tables 1 and 2. It is evident that the survival of the larvae is significantly lower at the 1 ppb concentration when compared with the acetone control. At a concentration of 10 ppb all the larvae succumbed by the fourth day. Duration of development as shown in Table 2, is not significantly affected by 1 ppb Dimilin^R. There was relatively close fit of figures from the present study with that of earlier workers (Christianson et al., unpublished data).

Survival

The percentage survival of *R. harrisii* from hatching to megalopa stage, megalopa to crab stage and total development, when reared at 5, 20 and 35 ppt at 25° and 30°C are shown in Tables 3 and 4 respectively. Taking the acetone-control series only, the results show that 20 ppt and 25°C had the highest survival at all stages of development, with a very significant decrease at 5 ppt and 35 ppt at 30°C. This is in agreement with the findings of Costlow et al. (1966). Working with eight different salinities (ranging from 1 to 40 ppt) and three temperature combinations (20 to 30°C) they observed that the highest percentage survival occurred in 15 to 25 ppt and 25°C combinations.

Comparing percentage survival in 1 ppb Dimilin^R and the controls at 25°C, a decrease of 38 and 20% is observed for hatching to megalopa stage and from megalopa to crab stage respectively at 5 ppt. No such decrease occurred at 20 ppt. At 35 ppt there was a decrease of some 18% for development to crab, but no difference was observed between control and experiment for hatching to megalopa stage. Considering that 25°C is the optimum temperature for the development of the species, these figures indicate strongly that at salinities as low as 5 ppt, 1 ppb Dimilin^R is more than sublethal in its effect. This fact is clearly borne out at the megalopa to crab stage when survival is zero percent as compared with 20% for the control. Thus it is possible that the sublethal concentration of this compound may become toxic for the development of *R. harrisii* when a second stress factor such as low salinity is introduced. Looking at Table 4, the same pattern as before is observed, with the following differences: (1) at 5 ppb some of the megalopa at least managed to reach the first crab stage (cf. nil for 25°C). This is to be expected as it has been demonstrated by Costlow et al. (1966) that elevation of temperature accelerates development of the species slightly. This together with the fact that the larvae succumb most easily to Dimilin^R during molting (Costlow, pers. comm.) may account for the observed results. Indeed during the present investigation almost 90% of the dead larvae had, in all cases observed, only the tail region freed from the exuviae; (2) the decrease in survival at 20 ppt might be due to the high temperature alone.

Duration of Development

Both range and mean duration of development for zoea and megalopa and from hatching to first crab stage are given in Table 5. It can be observed that there is no significant difference in the time required to reach the megalopa or the crab stage for all the temperature - salinity combinations, when controls are compared with the experiments. Level of significance refer to the 0.001 and 0.05 levels. There is only a slight increase in duration of development at 5 and 35 ppt as compared with 20 ppt. Thus the effect of salinity is very slight. When comparing the effect of temperature, there was however a significant decrease in duration at 30°C for all stages of development and at the three salinities used. It has been reported by Bookhout et al. (1977) that sublethal concentrations of Malathion caused anatomical abnormalities in megalopa and first crab stage of *R. harrisii*. Also sublethal effects of Mirex^R on *R. harrisii* is that it increased the duration of development to the megalopa (Bookhout, pers. comm.). No such abnormalities or prolonged larval development were observed for sublethal concentrations of Dimilin^R. The results therefore indicated that sublethal Dimilin^R concentrations did not affect duration of development even in extremes of salinity.

Summary

(1) Sub-lethal Dimilin[R] concentration decreased significantly the percentage survival of larval *R. harrisii*. This decrease was marked at low salinities, when it may have become toxic. This was true for both 25° and 30°C.

(2) Duration of larval development did not seem to be affected by sublethal Dimilin[R] concentrations even in extremely low or high salinities. High temperature however shortened the time of development.

(3) No anatomical abnormality was observed.

It will be desirable to work with more salinity - temperature combinations to get a complete picture of sublethal effects under different environmental conditions.

Ecological Implications

These findings are only tentative as more replicates of the experiments are needed before definite conclusions can be reached. Assuming those findings are true, it will be good to avoid the use of Dimilin[R] at concentrations above 1 ppb for spraying especially in regions with salinity lower than 5 ppt.

Acknowledgments

This work was conducted at Duke University Marine Laboratory in Beaufort, during my participation in the 1978 International Training Program in the Marine Sciences. I thank the Director and his staff for the award which made participation possible and every member of the Crab Laboratory for their interest and all their technical assistance.

Table 1. *Rhithropanopeus harrisii*. Survival to megalopa and first crab stages when reared in acetone control and three concentrations of Dimilin[R] at 25°C and 20 ppt salinity. Initial zoeal population was 100 in each series, representing two replicate experiments.

Concentration (ppb)	Hatch to megalopa No.	%	Megalopa to crab No.	%	Hatch to crab No.	%
0.1	93	93.0	84	90.3	84	84.0
1.0	86	86.0	74	86.0	74	74.0
10.0	0	0	0	0	0	0
Acetone Control	95	95.0	89	93.7	89	89.0

Table 2. Duration (days) of zoeal, megalopa and total development of *Rhithropanopeus harrisii* reared in Acetone control and three concentrations of Dimilin[R] at 25°C and 20 ppt salinity. Figures in brackets are from M.E. Christianson et al. (unpublished data)

Concentration (ppb)	Hatch to megalopa Range	Mean	Megalopa to crab Range	Mean	Hatch to crab Range	Mean
0.1	10 - 12	10.9	4 - 7	5.4	15 - 18	16.3
1.0	10 - 12	11.1 (11.7)	5 - 8	5.3 (4.7)	15 - 20	16.4 (16.4)
10.0	- -	-	- -	-		
Acetone control	10 - 13	10.8 (11.8)	5 - 8	5.4 (5.0)	14 - 19	16.2 (16.8)

Table 3. Percent survival of the mud crab *Rhithropanopeus harrisii* from hatching to the megalopa stage, megalopa to crab, and from hatch to first crab, when maintained in three different salinities (5, 20 and 35 ppt) at 25°C and at sublethal Dimilin[R] concentration (1 ppb).[2]

[2] Note by the editors: This table was missing in the original publication and hence can not be reproduced here.

Table 4. Percent survival of the mud crab *Rhithropanopeus harrisii* from hatching to the megalopa stage, megalopa to crab, and from hatch to first crab, when maintained in three different salinities (5, 20 and 35 ppt) at 30°C and at sublethal Dimilin[R] concentration (1 ppb). (Ac = acetone control; DSL = Dimilin[R] sublethal concentration).

Salinity (ppt)	Culture media	Initial no. of larvae	Hatch to megalopa No.	Hatch to megalopa %	Megalopa to crab No.	Megalopa to crab %	Hatch to crab No.	Hatch to crab %
5	Ac	50	13	26	2	4	2	15.4
	DSL	50	11	22	2	4	2	18.2
20	Ac	50	33	66	27	54	27	81.8
	DSL	50	21	42	19	38	19	90.5
35	Ac	50	27	54	17	34	17	60.71
	DSL	50	23	46	10	20	10	43.48

Table 5. Duration (days) of zoeal, megalopa and total development of *Rhrithropanopeus harrisii* when reared at different salinity and temperature (Ac = acetone control; DSL = Dimilin[R] sublethal concentration).

Salinity (ppt)	Temperature (°C)	Culture media	Hatch to megalopa Range	Hatch to megalopa Mean	Megalopa to crab Range	Megalopa to crab Mean	Hatch to crab Range	Hatch to crab Mean
5	25	Ac	12 - 15	12.93	5 - 8	7.0	17 - 23	19.93
		DSL	11 - 16	13.11	-	-	-	-
5	30	Ac	9 - 11	9.7	3	3	12 - 14	12.7
		DSL	9 - 10	9.6	3	3	12 - 13	12.6
20	25	Ac	10 - 13	11.55	4 - 9	5.6	14 - 22	17.15
		DSL	11 - 13	11.52	4 - 7	4.9	15 - 20	16.39
20	30	Ac	8 - 11	8.9	1 - 5	3.5	10 - 16	12.4
		DSL	8 - 10	8.5	2 - 4	2.8	10 - 14	11.3
35	25	Ac	11 - 12	12.95	2 - 8	5.8	13 - 20	18.65
		DSL	12 - 14	13.2	4 - 8	6.0	16 - 22	19.36
35	30	Ac	10 - 11	10.1	2 - 4	3.0	12 - 15	13.1
		DSL	9 - 11	10.4	2 - 5	3.6	11 - 16	14.0

SOME DATA ON LANDINGS OF PELAGIC FISH BY THE ARTISANAL FISHERMEN NEAR FREETOWN, SIERRA LEONE, DURING JANUARY TO DECEMBER 1978

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BRAINERD, T.R. 1978. Some data on landings of pelagic fish by the artisanal fishermen near Freetown, Sierra Leone during January to December 1978. Bull. Inst. Mar. Biol. Oceanogr. 3(1): 12-26.

ABSTRACT

This report investigates the landings of the pelagics *Sardinella maderensis* and *Ethmalosa fimbriata* at two major landing sites of the artisanal fishery in Sierra Leone during 1978. Detailed information is obtained on catch, effort and value of the landings. The data are used to present the fluctuations over the year of indices such as catch per unit of effort, price per tonne of fish, landings per day and total landings. The *Sardinella* and *Ethmalosa* fishery at Tombo village clearly shows the influence of the rainy season (July - September), which leads to a decrease in fishing effort and, thus, total landings, coupled with a marked increase in the unit price of fish. Results from Goderich village are less obvious but still reflect this general trend.

Introduction

Pelagic fish (except for tuna) are landed in Sierra Leone mainly by the artisanal fishermen. The UNDP/SF Sardinella Project collected catch statistics on the artisanal fishery as part of its research program on pelagic fish stocks. The data were collected spasmodically. The Fisheries Division carried out a National Fisheries Survey in 1974 covering all landing sites in Sierra Leone. Emphasis was put on catch statistics, and pelagic species formed the bulk of the total catch.

After the 1974 survey the Division continued with the collection of statistical data. The system has been improving with more extensive coverage. Most of the landing sites in the western area are covered daily, as well as those in other areas in the country.

The two most important pelagic species are the "herring" (*Sardinella*) and the "bonga" (*Ethmalosa fimbriata*), the juvenile form of which is commonly called "awefu". Two species of *Sardinella* occur in Sierra Leone: *Sardinella maderensis* and *Sardinella aurita*. *S. maderensis* occur in depths of 7-20 fathoms of water near the coast. *S. aurita* are usually found in deeper water about 40 fathoms deep, well out of reach of the artisanal fishermen. The stocks are exploited mainly by purse-seiners of foreign countries. Thus, the landings of herrings by the artisanal fishermen are largely comprised of *S. maderensis*. and *Ethmalosa fimbriata* which are found in depths similar to that of *S. maderensis* near the coast.

Landing data on herrings at Tombo and Goderich, and bonga at Tombo are presented here in tabulated form.

Methods

Collection of data

A field assistant is based at each landing site. Statistical information were collected on every fishing day except in cases of illness, or when a field assistant is on leave. He records the number of canoes that go fishing, and the number that returns after each day's trip. Five of the landed canoes are sampled everyday using a table of random numbers. The total weight of fish landed on each fishing day is calculated using a raising factor.

The following indices are calculated each month for both species: a) average landings per day; and b) catch per unit effort.

Definition of the unit of fishing effort

The unit of fishing effort is defined as one fishing trip by one canoe. Since canoes make only one fishing trip everyday during the year, the unit of fishing effort is normally equivalent to one canoe/day.

Fishing gears

The ring net is used mainly for catching herring. It is essentially the gilling type, but it is used to surround the fish. It is heavily floated on the head line to keep it on the surface and adequately weighted on the foot line to sink it quickly. The average measurements of the nets are 320 fathoms long and 18 fathoms deep. Nylon webbings with minimum mesh size of 1.75 inches are used. The twine size of webbings vary from 210/3 to 210/9. The ring net is operated from open boats up to 50 feet long and 8 feet wide powered by outboard motors ranging from 15 to 40 horsepower, and with a crew of 9 to 15 men. The boats are operated within 30 miles off the shore.

The fish shoal is detected either when they break the sea surface or are given away by birds preying upon them. The canoe closes in quickly and makes a set. The first end of the net is buoyed. It is picked up and joined to the other end very tightly and dropped in the water. The circle formed ensures that the fish are enclosed in the net. The outboard motor on the canoe is then lifted up and the fishermen get the canoe over the net into the enclosure. The engine is then started and several runs are made inside the net enclosure to drive the fish into the net. When this has been done the fishermen retrieve both ends of the net again fastening one end of the net to the canoe and hauling the net in from the other end.

One type of drift net is also used for catching herring. It has an average length of 150 fathoms and 3 fathoms deep. It is made of nylon webbings of 1.75 to 2 inches mesh size and 210/3 to 210/9 twine. It is similarly buoyed and weighted for floating. The bulk of herring caught by artisanal fishermen is made by using the ring net.

Another type of drift net is used to catch bonga. It is made of nylon webbings of 2.75 to 3 inches mesh size and 210/3 to 210/9 twine. It has an average length of 200 to 300 fathoms and 3 to 5 fathoms deep. The headline is sufficiently corked to get proper buoyancy and the footline weighted to match. Boats used in fishing for bonga are of similar size. Fish are caught at night by this method and landings are made early in the morning.

Results

Sardinella maderensis

Landings of *S. maderensis* were recorded in number of "pans" at Goderich and in dozens at Tombo. Numbers of pans and dozens have been converted into kilograms. The average weight of one pan is equivalent to 18.2 kg. The weights were checked monthly to make adjustments for seasonal variation in sizes.

Catch statistics of *S. maderensis* are presented in Tables 1 to 3, *Sardinella* landings at Tombo are displayed in Fig. 1. High catches were made during the months of January to May and October to December, with two peaks in January and November (two dry season months). Catches were poor during the rainy season months of July through September. Several fishing days were lost during August and September due to bad weather.

Landings of *S. maderensis* at Tombo during the year have been estimated at 1,301.71 tonnes, at a landed cost of Le 106,645. The estimated figures for Goderich are 1,919.79 tonnes and at a landed cost of Le 1,115,538. The total 1978 landings at Tombo and Goderich in the western area have been estimated at 3,221.50 tonnes and at a landed cost of Le 1,222,183.

The landed price at both sites sometimes varies daily during the year. At times, the first fisherman to land his catch fixed the landed price for that day. In general, the landed price dropped when there were good catches, and rose when catches were poor. There were times during the peak months when fishermen were unable to dispose of all their catches.

Ethmalosa fimbriata

Landings of *E. fimbriata* were recorded in dozens of fish. The average weight of one dozen was equivalent to 1.82 kg. The weights were checked monthly to make adjustments for seasonal variation in sizes.

Catch statistics from Tombo of *E. fimbriata* are presented in Table 4 and Fig. 2. High catches were again recorded during January to May, and October to December with peaks around April to May, and October to December. Catches were again poor during the rainy seasons months.

Landings of *E. fimbriata* at Tombo during the year have been estimated at 1,258.10 tonnes, at a landed cost of Le 437,262. The landed price fluctuated according to the catch rates. When the catches were good, prices fell and when catches were poor prices go up. There was an unusual drop in landings during February and March brought about by strong winds during these months which affected the drift nets.

Discussion

Fishing Effort

Sardinella

The highest fishing effort was recorded in August and the second highest in July. However, the average landings per day for these months do not reflect the number of canoe trips made during these months. This was due to the poor weather conditions and other limiting factors.

Low fishing effort figures were recorded during the first half of the year and they corresponded to the period when the highest catches were made.[3]

Ethmalosa

High fishing effort figures were recorded during the peak months, that is the dry season months; while low figures were recorded during the rainy season months. This is due to the fact that the set nets could not be operated successfully during heavy rains and there was also the risk of the net drifting away during storms.

Catch per unit effort (CPUE)

Sardinella

Taking the combined figures for Goderich and Tombo, the highest CPUE was recorded in December when the lowest number of canoe trips were made. This trend indicated that December was the best month in terms of landings and fishing effort during the year. In January, the second highest CPUE and the highest landings were recorded. This could be related to the increase in fishing effort as compared to December. This relationship is also true for the other months during the peak season.

The artisanal fishermen attribute the high catches during these months to the favorable weather conditions, but the biology of this species is likely to have some bearing on their abundance.

The low CPUE figures for the rainy season months of June to September were attributed to unfavorable weather conditions which grossly limited the fishermen's range of operation over this period. There is also the possibility that during the rainy season the herrings moved away from the inshore areas because of the dilution of the sea water by increased run-off from the land.

Ethmalosa

Apart from February and March, during which strong winds were experienced, high CPUE figures were recorded during the other dry

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[3] Note by the editors: The results for Goderich should be treated with a certain skepticism, as they are in clear contrast to the usual observation that fishing effort is lowest during the peak months of the rainy season and highest during the dry season..

season months. The lowest figure was recorded in August, the month where rainfall is heaviest.

Price per tonne

Sardinella

The price per tonne was high when the CPUE was low. However, this relationship showed no proportionality. The factor which determined the price was the quantity of fish landed during each month.

Ethmalosa

The price rose from January to August except for a slight difference in July. After August the price per tonne dropped continuously until December. From observations, it appears as if two factors were responsible for fixing the price - the quantity of fish landed during each month and the demand. There were times when the weights of fish landed were high, but the price per tonne went up due to the demand.

Tables

Table 1. *Sardinella* landings at Tombo, 1978.

Month	Total Weight (tonnes)	No. of days sampled	Average landings per day (tonnes)	Fishing effort (canoe trips)	Catch per unit effort (tonnes/ canoe trips)	Price per tonne (Leones)	Total Cost (Leones)
January	237.04	15	15.80	252	0.94	43	10,278
February	122.12	20	6.11	222	0.55	98	12,021
March	113.90	18	6.33	164	0.69	103	11,724
April	99.74	17	5.87	166	0.60	98	9,737
May	111.64	19	5.88	176	0.63	64	7,102
June	69.22	19	3.64	148	0.47	112	7,719
July	53.49	17	3.15	125	0.43	120	6,443
August	35.79	14	2.56	86	0.42	166	5,940
September	69.02	19	3.63	128	0.54	105	7,251
October	104.91	16	6.56	159	0.66	101	10,574
November	112.48	13	8.65	167	0.67	82	9,197
December	172.36	12	14.36	142	1.21	50	8,659
Totals	1,301.71	199		1,935			106,645

Table 2. Sardinella landings at Goderich, 1978.

Month	Total Weight (tonnes)	No. of days sampled	Average landings per day (tonnes)	Fishing effort (canoe trips)	Catch per unit effort (tonnes/ canoe trips)	Price per tonne (Leones)	Total Cost (Leones)
January	179.40	15	11.96	692	0.26	355	63,713
February	137.37	14	9.81	586	0.23	499	68,485
March	181.62	18	10.09	841	0.22	530	96,344
April	189.84	15	12.66	699	0.27	527	100,049
May	157.57	16	9.85	791	0.20	545	85,932
June	125.90	17	7.41	794	0.16	581	73,101
July	111.65	20	5.58	1,010	0.11	701	78,239
August	169.78	24	7.07	1,332	0.13	796	135,211
September	115.27	18	6.40	803	0.14	728	83,865
October	180.57	16	11.29	655	0.28	673	121,551
November	259.79	24	10.83	960	0.27	579	150,545
December	111.03	14	7.93	461	0.24	527	58,503
Totals	1,919.79	211		9,624			1,115,538

Table 3. Sardinella landings at Tombo and Goderich, 1978.

Month	Total Weight (tonnes)	Average No. of days sampled	Average landings per day (tonnes)	Fishing effort (canoe trips)	Catch per unit effort (tonnes/ canoe trips)	Price per tonne (Leones)	Total Cost (Leones)
January	416.44	15	13.88	944	0.44	178	73,991
February	259.49	17	7.63	808	0.32	310	80,506
March	295.52	18	8.21	1,005	0.29	366	108,068
April	289.58	16	9.05	865	0.34	379	109,786
May	269.21	18	7.69	967	0.28	346	93,034
June	195.12	18	5.42	942	0.17	414	80,820
July	165.14	19	4.46	1,135	0.15	513	84,682
August	205.57	19	5.41	1,418	0.15	687	141,151
September	184.29	19	4.98	931	0.20	494	91,116
October	285.39	16	8.92	814	0.35	463	132,125
November	372.27	19	10.06	1,127	0.33	429	159,742
December	283.39	13	10.90	603	0.47	237	67,162
Totals	3,221.50			11,559			1,222,183

Table 4. Ethmalosa landings at Tombo, 1978.

Month	Total Weight (tonnes)	No. of days sampled	Average landings per day (tonnes)	Fishing effort (canoe trips)	Catch per unit effort (tonnes/ canoe trips)	Price per tonne (Leones)	Total Cost (Leones)
January	115.18	17	6.78	428	0.27	176	20,266
February	57.03	19	3.00	372	0.15	315	17,976
March	74.34	19	3.91	341	0.22	341	25,356
April	164.23	17	9.66	348	0.47	370	60,783
May	153.94	20	7.70	342	0.45	428	65,948
June	61.72	17	3.63	281	0.22	579	35,757
July	93.15	16	5.82	303	0.31	534	49,698
August	38.25	21	1.82	274	0.14	637	24,359
September	61.19	21	2.91	299	0.21	477	29,186
October	144.36	18	8.02	285	0.51	336	48,562
November	113.61	18	6.31	305	0.37	218	24,740
December	181.10	15	12.07	420	0.43	191	34,631
Totals	1,258.10	218		3,998			437,262

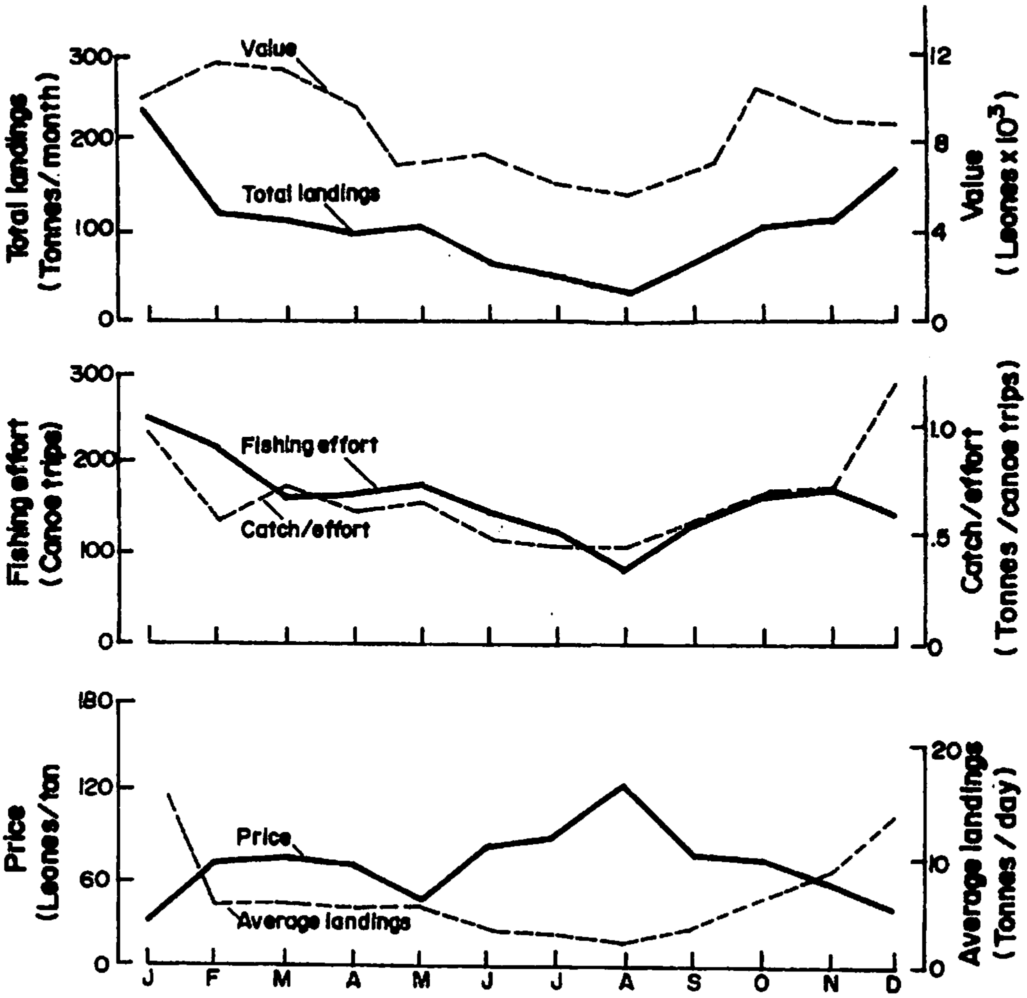

Fig. 1. *Sardinella* landings at Tombo, 1978.

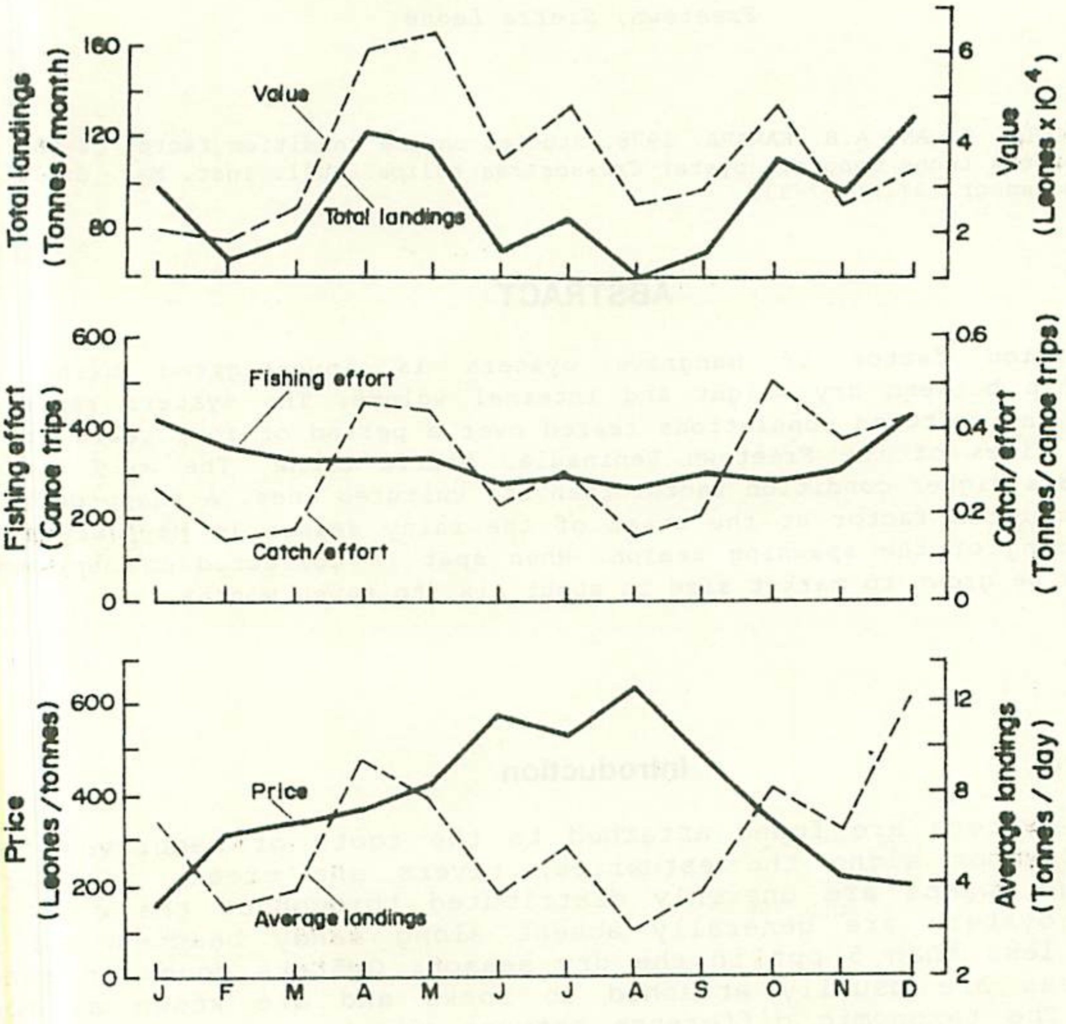

Fig. 2 *Ethmalosa* landings at Tombo, 1978.

STUDIES ON THE CONDITION FACTOR OF THE SIERRA LEONE MANGROVE OYSTER *CRASSOSTREA TULIPA*

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WELLESLEY-COLE, C. AND A.B. KAMARA. 1978. Studies on the condition factor of the Sierra Leone mangrove oyster *Crassostrea tulipa*. Bull. Inst. Mar. Biol. Oceanogr. 3(1): 27-33.

ABSTRACT

The condition factor of mangrove oysters is investigated using the relationship between dry weight and internal volume. The oysters represent both wild and cultured populations reared over a period of four years at two different sites of the Freetown Peninsula, Sierra Leone. The wild oysters always had a higher condition factor than the cultured ones. A sharp decrease in the condition factor at the onset of the rainy season in May/July marks the beginning of the spawning season. When spat is collected in September, oyster can be grown to market size in about six to seven months.

Introduction

Mangrove oysters are found attached to the roots of mangroves that grow in swamps along the estuaries, rivers and creeks in Sierra Leone. The swamps are unevenly distributed throughout the country. Mangrove oysters are generally absent along sandy beaches and in water of less than 5 ppt in the dry season. Oysters found in sandy beach areas are usually attached to rocks and are known as rock oysters. The taxonomic difference between the two types of oysters has not yet been established.

The oyster moves actively during its larval phases which last for less than two weeks. Once the larva is attached to a suitable solid object, it remains sessile for the rest of its life.

Quayle (1969) has suggested that Pacific oysters develop gonads by conversion of the winter store of glycogen when water temperatures begin to rise in March. Under normal weather conditions full ripeness is attained in most British Columbian waters by the end of June. As Sierra Leone is a tropical country water temperatures are high (greater than 24°C) throughout the year. Consequently the local oysters tend to spawn all year round with one or two spawning peaks. The condition factor of such tropical oysters may not be as high as those oysters in temperate countries since the stored glycogen is regularly utilized to form gonads. A high condition factor value indicates that the oysters have accumulated glycogen and/or gonads, whereas a low condition factor value indicates that oysters have spawned and are in the process of accumulating glycogen, which may later be utilized for gonad development. In oyster culture, condition factor studies may be supported by plankton and oyster spat settlement studies in the culture area. These studies give an indication of when oyster larvae and spat settlement are at their peak values. In Sierra Leone studies of the plankton and spat settlement are undertaken every week, throughout the year.

Methods for Determination of Condition Factor

In the oyster industry the word 'condition' describes the state of an oyster during its seasonal cycle of change from glycogen storage to spawning. Because the size of meat, either by weight or volume between two oysters of equal shell dimensions may be very different, a more precise measure of condition in oyster known as 'condition factor' is needed. The condition factor is obtained from the ratio:

$$\frac{\text{weight of dry oyster meat} \times 1000}{\text{internal volume}}$$

The internal volume or shell cavity volume is the difference between the volume of a whole closed, intact oyster and the volume of the oyster meat after it has been removed from its shell. Volumes are determined as displacement volumes. The oyster meat is dried to a constant temperature of 65°C to obtain the dry meat weight. The volume of an oyster can be used to obtain the condition factor, but the water content of oysters is extremely variable. There may be rapid changes in the volume after the oyster has been shucked and this gives rise to unreliable results. To avoid these problems and obtain more reliable results, the dry weight measurement is used. Therefore the greater the dry weight of the meat relative to the size of its shell cavity, the larger the numerical ratio and the better the condition of the oyster.

Sample sizes of fifty wild and fifty cultured oysters per station per month were used to determine the condition factor. The following factors could be sources of error in obtaining the condition factor:

a) Oysters, whether wild or cultured, must be clean. That is, no other spat or fouling organisms should have set on them. If any of these organisms have set on the oysters, they should be carefully removed with as little damage to the oysters as possible. If this exercise is not carried out, the displacement volume recorded will be greater than the true value.

b) If the shells are accidentally damaged during shucking care must be taken to ensure that all the pieces of the shell are used when measuring the shell volume. If this is not done, the displacement volume recorded will be less than the true value.

c) The oyster meat must be dried to a constant weight. If this is not done, an unusually high condition factor will be obtained.

The oyster samples were taken from Jui and No. 2 River. Jui is situated on the east coast of the Freetown Peninsula, off Bunce River, a tributary of the Sierra Leone River. Jui is 17.7 km from Freetown. No. 2 River is a small tidal river on the west coast of the

Freetown Peninsula. It is approximately 2.5 km long and varies from 40 to 60 meters in width. No. 2 River is 35.4 km from Freetown.

Results

The average monthly condition factor curves for wild and cultured oysters at No. 2 River and Jui, over a four year period in relation to salinity changes are shown in Fig. 1. The wild oysters at both sites gave the higher condition factor than the cultured ones during the dry season and the first month of the rainy season. The highest condition factor values were obtained in May when salinity was at a maximum. The lowest values for the wild oysters were obtained during the last three months of the rainy season. The cultured oysters were usually harvested at the beginning of the rainy season and consequently no condition factor values could be determined for them during the rainy season.

The condition factor of the wild oysters at Jui was usually higher than that of the No. 2 River ones. The salinity was usually lower at Jui than at No. 2 River except during the rainy season. A large drop in salinity of 32 ppt during the first three months of the year at No. 2 River reduced the condition factor of the oysters by 60 units. At Jui the drop in salinity of 18 ppt produced a reduction in condition factor of 40 units.

The condition factor of the cultured oysters varied between 70 and 80 units at Jui and between 65 and 75 units at No. 2 River. The drop in salinity at both sites during the second month of the rainy season seemed to have had little effect on the condition factor of the cultured oysters.

Discussion

In Sierra Leone under normal circumstances, the rainy season starts in May and ends in October, while the dry season starts in November and ends in April.

From plankton and oyster spat settlement studies in these areas it is believed that high condition factor values indicate that the gonads are ripe for spawning in the wild oysters. As soon as this stage has been reached, the oysters spawn with a resulting drop in the condition factor values of the oysters. From Fig. 1 it can be seen that the values rise and fall throughout the year but that at No. 2 River there is a major spawning peak for the wild oysters in May, wile at Jui two peaks occur in May and July. The wild oysters at both stations are in their poorest condition in October.

In the case of the cultured oysters it is not yet known whether their condition factor of 80 units indicate that they are ripe for spawning.

Detailed spatfall studies (Kamara & McNeill 1976) at No. 2 River and Jui have shown that the spatfall at No. 2 River is very much less than at Jui, so oyster spats are only collected at Jui and a requisite number transported to No. 2 River which is used as a growing area. Studies on spatfall and fouling organisms have shown that the best time to collect spats from Jui is from the end of September to the end of October. The oysters then grow to market size in six to seven months and harvesting can commence in May. These studies also show that oyster spat can be collected from the middle of May to the middle of June. Studies are in progress to see whether the oysters can be collected and grown through the rains to give a second crop of oysters six or seven months later in December or January.

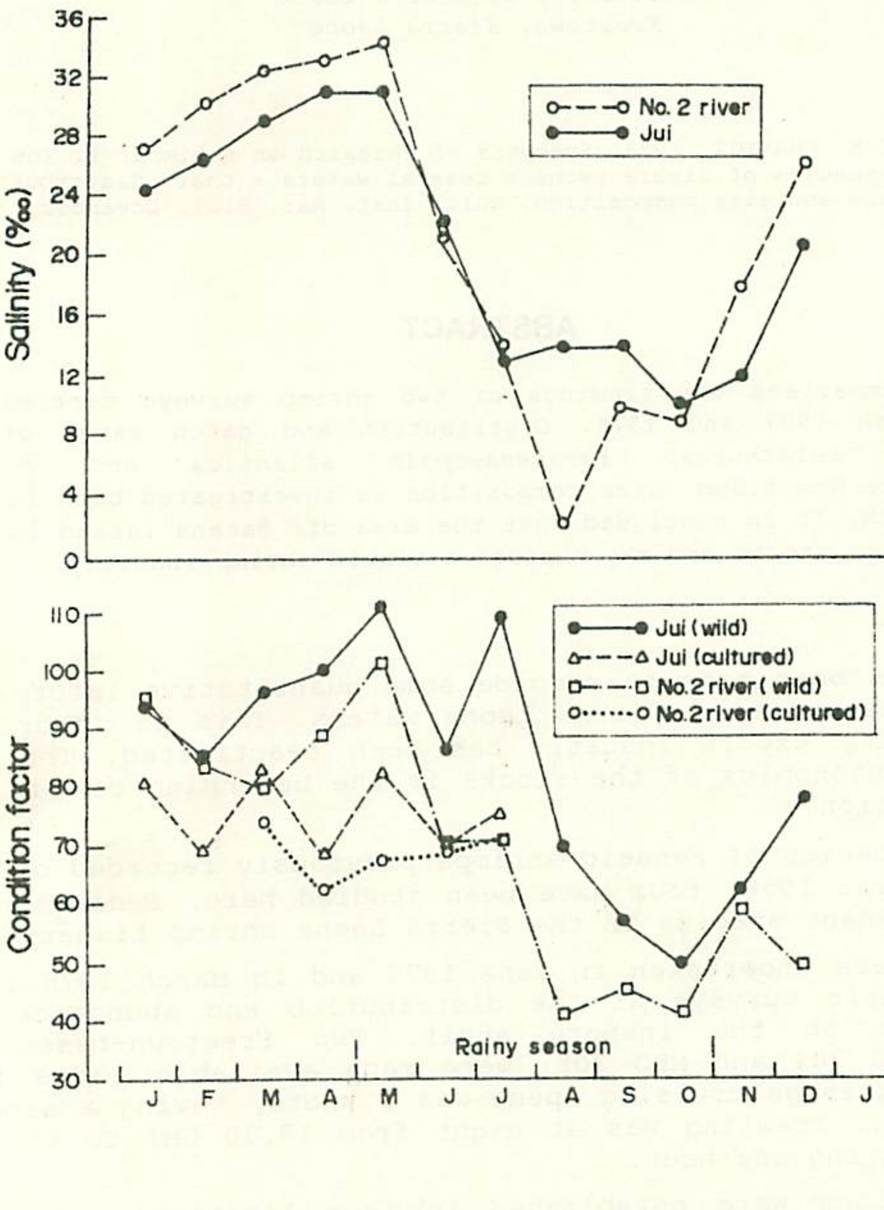

Fig. 1. Average monthly condition factor of wild and cultured oysters at Jui and No. 2 River in relation to salinity changes from 1975 to 1978.

SYNOPSES OF RESEARCH ON SHRIMPS I. THE COMMON SHRIMP SPECIES OF SIERRA LEONE'S COASTAL WATERS: THEIR DISTRIBUTION, ABUNDANCE AND SIZE COMPOSITION

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W. OKERA AND D.E.B. CHAYTOR. 1978. Synopsis of research on shrimps. I. The common shrimp species of Sierra Leone's coastal waters - their distribution, abundance and size composition. Bull. Inst. Mar. Biol. Oceanogr. 3(1):34-40.

ABSTRACT

This report summarises the findings of two shrimp surveys carried out off Sierra Leone in 1977 and 1978. Distribution and catch rates of *Penaeus notialis*, *P. kerathurus*, *Parapenaeopsis atlantica* and *Parapenaeus longirostris* are described. Size composition is investigated both in relation to sex and depth. It is concluded that the area off Banana island is the most productive shrimp ground and may support a viable shrimp industry.

An attempt has been made to provide some quantitative information on the shrimp resources of Sierra Leone waters. This is important now that the shrimp export industry has been reactivated. The present study of the bionomics of the stocks is the beginning of our efforts in this direction.

Of the nine species of Penaeid shrimps previously recorded off Sierra Leone (Longhurst 1958) four have been studied here, *Penaeus notialis* being the dominant species in the Sierra Leone shrimp fishery.

Two cruises were undertaken in June 1977 and in March 1978 in order to make synoptic surveys of the distribution and abundance of the shrimp stocks on the inshore shelf. Two Freetown-based Soviet shrimpers (MRC 304 and MRC 305) were made available to us for the surveys. The average cruising speed was 9 knots, towing a single net from the stern. Trawling was at night from 19.30 GMT to 05.30 GMT, each trawl lasting one hour.

Trawling stations were established in four locations, namely, off Bullom; Freetown Peninsula; Sherbro Island and North Turner's Peninsula; and South Turner's Peninsula. The ATLANTNIRO fishery research vessels SRTM PROGNOZ and SRTM VYKMA carried out hydrographic surveys during the two periods respectively and their data have been used to obtain some information on the hydrographic conditions prevailing at the time of the shrimp surveys.

During the second survey, the attempts to trawl stations off Sherbro Island and North Turner's Peninsula were given up because of massive catches of rhizostome jellyfish (up to 1 ton for every 30 minutes of trawling) posing risks of loss or damage to the gear.

The Temperature, Salinity and Depth curves for the fishing grounds showed the existence of three water masses as follows:

(i) A tropical superficial water (TSW) with temperatures greater than 24°C. This extended down to 35 to 45 m in June (wet season) and 20 to 30 m in March (dry season). During the former period this top layer may itself consist of two layers: a) an upper desaline layer called "Guinean" or "Liberian" water with salinities less than 35 ppt and temperatures greater than 27°C at depths of 20 to 30 m; and b) a lower layer with salinities of 35-35.5 ppt, temperatures greater 24°C at depths of 30 to 45 m. In March the desaline layer was closer to shore and the high salinity layer came close to the surface along Sherbro Island and Turner's Peninsula.

(ii) Discontinuity zone with temperatures 24°C-18°C from top to bottom, at depths of 35-43 m to 65 to 70 m in June; and in March close to the surface. Salinity was over 35.5 ppt.

(iii) Cool subtropical waters (T=18°C; S = 35.6-35.85 ppt) below layer (ii).

The ichthyofaunal composition for the trawls was mainly Sciaenidae at depths of 10 to 25 or 30 m, with patches of mixed sparid and sciaenid fauna in the central and norther parts of the coast.

The shrimp distribution and abundance were as follows: *Penaeus notialis* and *Penaeus kerathurus* were found at depths of 10 to 70 m; *Parapenaeus longirostris* at depths of 40 to 70 m. In June 1977 *P. notialis* was almost absent from the northern coast but in March 1978 it was taken mixed with the more numerous *P. kerathurus*. *P. notialis* was most abundant off the Freetown Peninsula especially at the Banana Islands shrimp grounds where smaller quantities of *Parapenaeopsis atlantica* and *P. kerathurus* were also taken. Further south, off Sherbro Island and Turner's Peninsula *P. notialis* was virtually absent.

Catches of *P. notialis* varied from 0.4 to 43 kg/hr off Banana Island and 3.5 to 7.5 kg/hr off Bullom. Catches of *P. kerathurus* averaged 3.8 kg/hr off Bullom (1.9-10 kg/hr) and at Banana Islands grounds they varied from 0.6 to 4 kg/hr. Further south it was almost absent. Here *Parapenaeopsis atlantica* was dominant with catches ranging from 0.5 to 16 kg/hr at depths of 14 to 70 m.

The size composition revealed that females were of consistently greater lengths than males of *P. notialis*, maximum recorded lengths being 22.3 and 18.1 cm respectively, immature forms were absent (i.e. those 7.5 cm). Females were also very abundant than males, except at four stations on the Banana Islands grounds. There was evidence of a modal progression with depth.

For *P. kerathurus* the maximum sizes were 18.0 and 22.5 cm for males and females respectively. The sizes were usually smaller at the sits of maximum concentration of the stocks i.e. at the shallowest depth. But there was little evidence of size-depth relationship. In general the Bullom populations were older than those of the Banana Islands, and consisted of more than one size group with females outnumbering males by 2:1.

At the Banana Islands sex ratios were roughly 1:1 for *P. notialis* and *P. kerathurus*. But with *Parapenaeopsis atlantica* the females outnumbered the males at all stations. The maximum sizes attained were 14.7 cm for females and 10.9 cm for males. While the frequency distribution curves for males were unimodal those for females were biomodal or even trimodal, the respective models being 6.8 or 7.3 cm and any between 10.3 and 11 cm. There is evidence that there might be three size groups increasing in size as follows: smallest at 10 to 12 m; intermediate at 38 to 46 m; and largest at 20 to 24 m.

Parapenaeus longirostris consisted of small samples which do not allow significant generalizations to be made about the populations.

The ecological association of the shrimp species were as follows:

P. kerathurus was dominant in the northern part of the coast off Bullom at depths of 10 to 25 m over shelly sand and silt; and in association with a mixed sparid and sciaenid fish fauna in desaline "Guinean" waters of the Tropical Surface Water (TSW). This is similar to the conditions reported by Crosnier (1963) off Zaire. Southwards at the Freetown Peninsula - Banana Islands grounds over shelly sand and shelly mud, the species diminished in quantity as the pink shrimp became dominant.

P. notialis in this area was most abundant at depths of 15 to 40 m associated with a similar sparid-sciaenid fish fauna in TSW and thermocline waters. Off Banana Islands the fish fauna was mostly juvenile sparid and polynemid species; and off Sherbro Island smaller quantities were taken at 20 to 70 m depths in similar TSW and thermocline waters, associated with the sciaenid community. These observations agree with the reports for the Gulf of Guinea (Monod 1966 and Garcia 1974).

Parapenaeopsis atlantica was most abundant in the south off Sherbro Island and Turner's Peninsula at depths of 14-70 m where muddy deposits predominate, in TSW and thermocline waters. This is evidence of an extension of its range which Crosnier (1963, 1964) reported to be strictly coastal "Guinean" waters. Over such muddy deposits we had expected to take greater quantities of *P. notialis* (Garcia 1974) but unless the sites have already been overexploited, we can only suggest that its relative absence is due to lack of nursery grounds for the post-larval forms.

The Bullom populations probably receive recruits from the Sierra Leone River Estuary while the Banana Islands populations receive from the Yawri Bay and Sherbro River estuaries. This promises to be the subject of a future study. Also to be investigated is the effect of shrimping on the mortality of young Sparidae and Sciaenidae and hence on the recruitment to the adult populations that form such an important component in our commercial fisheries. Present indications have given us cause for concern in this regard.

The two surveys have shown that the Banana Islands are the most productive shrimp grounds in the country. We believe that they can support a viable shrimp industry for several years to come at present rates of exploitation.

MAKING KIPPERS FROM LOCAL HERRING (*SARDINELLA* SPP.) SMOKE-CURED IN THE TORRY KILN

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MASON, E.D.C. Making kippers from local herring (*Sardinella* spp.) smoke-cured in the Torry Kiln. Bull. Inst. Mar. Biol. Oceanogr. 3(1): 41-47.

ABSTRACT

Herrings (*Sardinella maderensis* and *S. aurita*) are commonly caught by the artisanal fishery in Sierra Leone. A detailed description is presented of how to cure this fish in form of a "Kipper", which is a herring with gut and gills removed, split down its while length along the back, lightly brined and cold smoked. Various forms of smoking the fish are discussed.

Introduction

A kipper is a herring with gut and gills removed, split down its whole length along the back, lightly brined and cold smoked.

Herrings are available all year round in Sierra Leone but the best time to use them for making kippers is during the dry season when they are fattest and feeding very well. They account for over 20% of the total amount of fish landed in the whole country and their distribution and use is widespread in the country. The most common method of processing herring locally is hot smoking to give either a soft, moist and cooked product or a dry, brittle product with a very low moisture content. These are rigid preservative measures for a highly perishable foodstuff.

The process described in this paper is a cure intended to add variety to the types of products that can be obtained from local herring. It is only mildly preserved since the product cannot be kept for more than 24 hours without refrigeration.

The Source and Quality of the Raw Material

Herrings (*Sardinella aurita* and *S. maderensis*) are landed mainly by the canoe fishermen along the coast. When landed they are not usually one hundred percent fresh as the fishermen may take a few hours to return from the fishing grounds. They do not use ice to keep their catch fresh. Consequently by the time the fish is landed, at times it is already deteriorating.

The processor must by very careful to select fish which is of very high quality. Here are some features to look for:

- bright red gills,
- firm round body,
- slight clear slime on the body and gills,
- absence of bruising or any damage to the skin, and
- fresh fish odour.

Washing

The herring is a very delicate fish and should be handled carefully. The scales are removed with a scraper and the fish is then washed in clean fresh water before splitting.

Splitting

For splitting, the herring is laid on its ventral side on a smooth wooden filleting board. The blade of a sharp small kippering knife is inserted in the center of the dorsal part of the head and a cut made through the skull to the mouth. The knife is re-inserted in the initial cut on the head and a second deep cut is made from head to tail keeping the blade of the knife close to the backbone. The fish is then opened and the gills and gut are removed. The split herring is washed before brining.

Brining

The brining time for kippers depends on the size of the fish and the fat content. Bigger, fatty fish require more time than smaller lean fish.

A 70°-80° brine (1 lb 10 ounces salt/gallon of water) is prepared and the fish is soaked in it for several minutes. Medium-sized herrings 10-20 cm in length require about 15 mins. The brine bath should be stirred several time to even out the brining. Any scum settling on the top should be removed. After the fish has absorbed enough salt it is removed and drained on a wiremesh tray. The brine can be used 2-3 times, after which it should be discarded.

Smoking

The fish can be hung on hooks or spread out on wire gauze trays for smoking. Both methods have their disadvantages. In the hanging method the hooks leave unsightly holes in the fish, and they can be difficult to keep clean. Also during smoking some of the fish tend to fall off the hooks and these cannot be hung again as they become contaminated. The tray method is better because the fish cannot fall off but it has the disadvantage of leaving marks on the skin of the fish if the wire is too thick. Also if the fish is not properly drained a small pool of brine will collect in the cavity which was occupied by the gut to form a white patch when dried.

The average time required for smoking is 3-4 hours in the Torry Kiln at 40°C and 5-6 hours in non-mechanical chimney kilns. There should be a weight loss of about 20% to give a not too dry product.

Smoke from firewood has two effects:

1) the chemical constituents of the smoke are deposited on the surface of the fish to give the characteristic color and flavor; and

2) acts as a mild preservative. The heat from the fire dries the fish.

The Torry Fish Smoking Kiln

The Torry Fish Smoking Kiln is a mechanical smoking kiln designed by the Torry Research Station in Aberdeen, Scotland for smoking fish, etc., under controlled conditions.

Smoke is produced in a special type of insulated furnace and conducted by an electric fan through ducts leading into the kiln. Fresh air can be sucked into the kiln and part of the humid smoky air leaves the kiln through a chimney. Heaters, which are usually electrically operated and thermostatically controlled, are used to maintain the temperature of the smoke circulating in the kiln.

The kiln* is fitted with doors and quick-release catches for easy access to ducts and chambers, so that the whole equipment can be readily cleaned.

Smoking in the Traditional Kiln

Herring is smoked locally in a traditional kiln known as the 'banda'. However, there are several drawbacks in its construction and the desired end product is hard to achieve. The 'banda' is a platform of wire gauze mounted on a drum with both ends cut out over an open fire. The fire is often difficult to control and maintaining a constant temperature is virtually impossible. Moreover a lot of ash can settle on the fish and make an undesirable coating, and the intense heat overcooks the fish.

The `banda' can be modified to form a covered oven with doors and air vents and a chimney whereby air flow and temperature can be somehow controlled.

Smoking in the modified oven is slower and less efficient than in the mechanical oven and it is impossible to give a standard smoking time because a lot depends on outside weather conditions and the smoker's ability to control the fires. However with constant attention an approximate temperature and the right amount of smoke needed can be obtained and the product can be finished in about 5-6 hours as compared to 3-4 hours in the mechanical kiln.

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* The general principles involved in the operation of the kiln are given in Fisheries Division, Technical Paper No. 2. A more detailed description of the Torry Kiln and its operation and maintenance is given in a booklet "Fish Smoking-Torry Kiln operators' handbook, issued by Torry Research Station, and published by Her Majesty's Stationery Office.

Packing and Storage

The kippers are allowed to cool at room temperature before they are packed in polythene bags and sealed. Care must be exercised when the product is handled, to avoid damage and contamination.

The kippers can be distributed for sale soon after processing but should be displayed in refrigerated cabinets. The kippers can be kept chilled for 1 or 2 days but for longer storage freezing is advisable. When packing for freezing the kippers should be wrapped in polythene or cellophane wrappers and packed in cardboard boxes and placed in a blast freezer. Frozen kippers can be stored at -20°C or below for 1-2 months in first class condition.

MARINE BIOLOGY OF THE SIERRA LEONE RIVER ESTUARY.

I. THE PHYSICAL ENVIRONMENT

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FINDLAY, I.W.O. 1978. Marine biology of the Sierra Leone River estuary. I. The physical environment. Bull. Inst. Mar. Biol. Oceanogr. 3(1): 48-64.

ABSTRACT

The estuary of the Sierra Leone river covers an area of approximately 260 km^2 . This article describes the physical and hydrographic characteristics of the estuary in relation to the prevailing climatic conditions. It covers aspects such as bottom nature, tides, salinity, temperature, turbidity and nutrients. Twelve sectional profiles across the river estuary are presented to show the bottom profile of the river. The deepest part lies close to the Freetown shoreline, where a water depth of more than 25 m is reached.

Introduction

The Sierra Leone River Estuary is in effect the drowned estuary of the Rokel River or Seli as it is known in its upper reaches. It is bounded on the north by a coastal plain indented by creeks and on the south by a mountainous peninsula with peaks ranging from 1,000 to 2,900 ft (330 to 950 m) in height. It extends 27 miles (44 km) from its mouth to Tumbu Island, beyond which the Port Loko Creek joins the Rokel River (Fig. 1). From Tumbu Island southwestward the Estuary assumes a width of 2.5 miles (4 km) until it reaches Tagrin point, where it turns northwestward and widens gradually to about 7 miles (11 km) before it reaches the Atlantic Ocean.

The Rokel River rises in the Futa Jallon Highlands on the border of Guinea and Sierra Leone at an altitude of approximately 1,600 ft (500 m). It is about 180 miles (290 km) long, being the longest river in Sierra Leone. It makes a marked westward swing as it leaves the interior plateau near Magburaka (100 miles or 160 km from source) for the plains. This change in direction of flow probably results from processes of river capture consequent on a period of uplift or emergence; but subsequent submergence has resulted in the present form of the estuary (Clarke 1966).

The Estuary is about 100 square miles (259 km^2) in area. Most of it is shallow except for a narrow, moderately deep channel which follows its course until off Tagrin Point it becomes nearly parallel to the northern shores of the peninsula. The channel varies in depth from 4 fathoms (7 m) opposite Pepel to about 18 fathoms (33 m) opposite Cline Bay through its mouth in a downstream direction. On either side of the channel the depth of the water is considerably less than 5.5 fathoms (10 m) and in the upper reaches extensive mud flats are exposed during low tide. There is no sand bar at the mouth of the Estuary where the deep channel joins the Atlantic Ocean off Cape Sierra Leone. However, the deposit of sand, especially on the northern side of the Estuary results in the formation of a relatively broad sand bank, the Middle Ground, which becomes exposed at low water springs. This sand bank reduces the depth of the mouth of the Estuary but does not seem to reduce the amount of the water entering or leaving it as the strength of the tidal stream is often very great and keeps the channel clear. Leigh (1973) has accounted for the sand bank by the change in direction of flow of the riverine water from southwest to northwest coupled with the setting of the tides in a northwest-southeast direction across the mouth of the Estuary. Bainbridge (1960) found greater turbidity at springs than at neaps in the mid-estuarine region and suggested that it was due to the greater scouring action of very strong tidal streams (4 knot) on the ebb of the springs. However Watts (1957a) has shown that the soft black muds deposited in the mid-estuarine region of the estuary is favoured by the water being at rest for a sufficient length of time at each turn of the tide.

The amplitude of the tide ranges from about 2.8 ft (0.9 m) at lowest neaps to 10.2 ft (3.0 m) at highest springs, with a mean of about 6.2 ft (1.9 m). Strong tidal currents are characteristic of the Estuary as large areas are flooded and drained during a tidal cycle. During the dry season the stream on the flood runs at 1 to 1.5 knot (2-3 km/hr) and on the ebb at 2 to 2.5 knot (4-5 km/hr) at springs. At neaps it is about 0.5 knot (1 km/hr) on the flood and 1 knot (2 km/hr) on the ebb. During the wet season it is much faster on the ebb, reaching up to 5 knot (10 km/hr). The duration of the flood stream is about 5 hours and the ebb about 7 hours (Admirality Hydrographic Department 1953).

On the northern side of the Estuary are numerous creeks, principal of which is the Port Loko Creek. It is tidal and navigable for about 15 miles (24 km). On the southern side a few mountain streams enter the Estuary and at the southwestern corner the Bunce River forms a confluence with it. The creeks and upper reaches of the Estuary are lined by large areas of mangrove swamp.

The series of sectional profiles of the Estuary presented in Fig. 1. and 2. show that the deepest part of the channel lies very near the northern shore of the Freetown Peninsula between White Man's Bay and Cline Bay.

Along the Estuary are two ports - Freetown and Pepel. Freetown is the only importing port while Pepel (until recently) was used for the export of iron ore. Freetown has the best natural harbor in West Africa with the deepest part of the channel near its shore. The entrance to the harbor is three quarter mile wide and a controlling depth of 6 fathoms (11 m), and lies between O'Farrell Shoal and Aberdeen Point. The harbor extends 8 miles in length with a width of 1½ miles and has anchorage room for 240 ships of unrestricted depth.

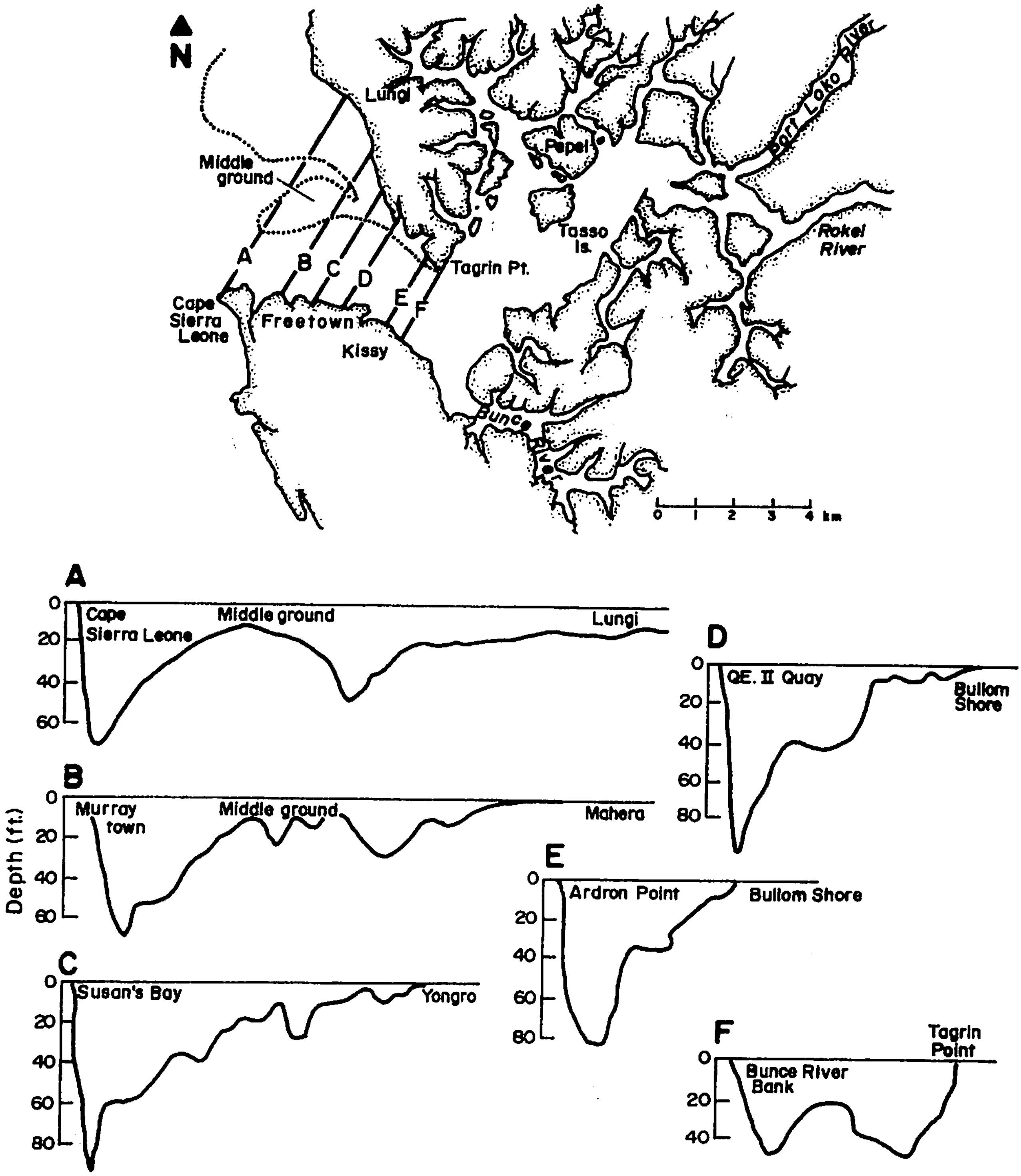

Fig. 1. Map of the Sierra Leone Riverine Estuary and sectional profiles across the entrance of the Estuary drawn from the Admirality Chart 689 (new ed. 1967). The Admirality Chart Datum is 20.43 ft (6.23 m) below the base of the harbor lighthouse on Aberdeen Point (Cape Sierra Leone), or 5.57 ft (1.70 m) below Sierra Leone Datum.

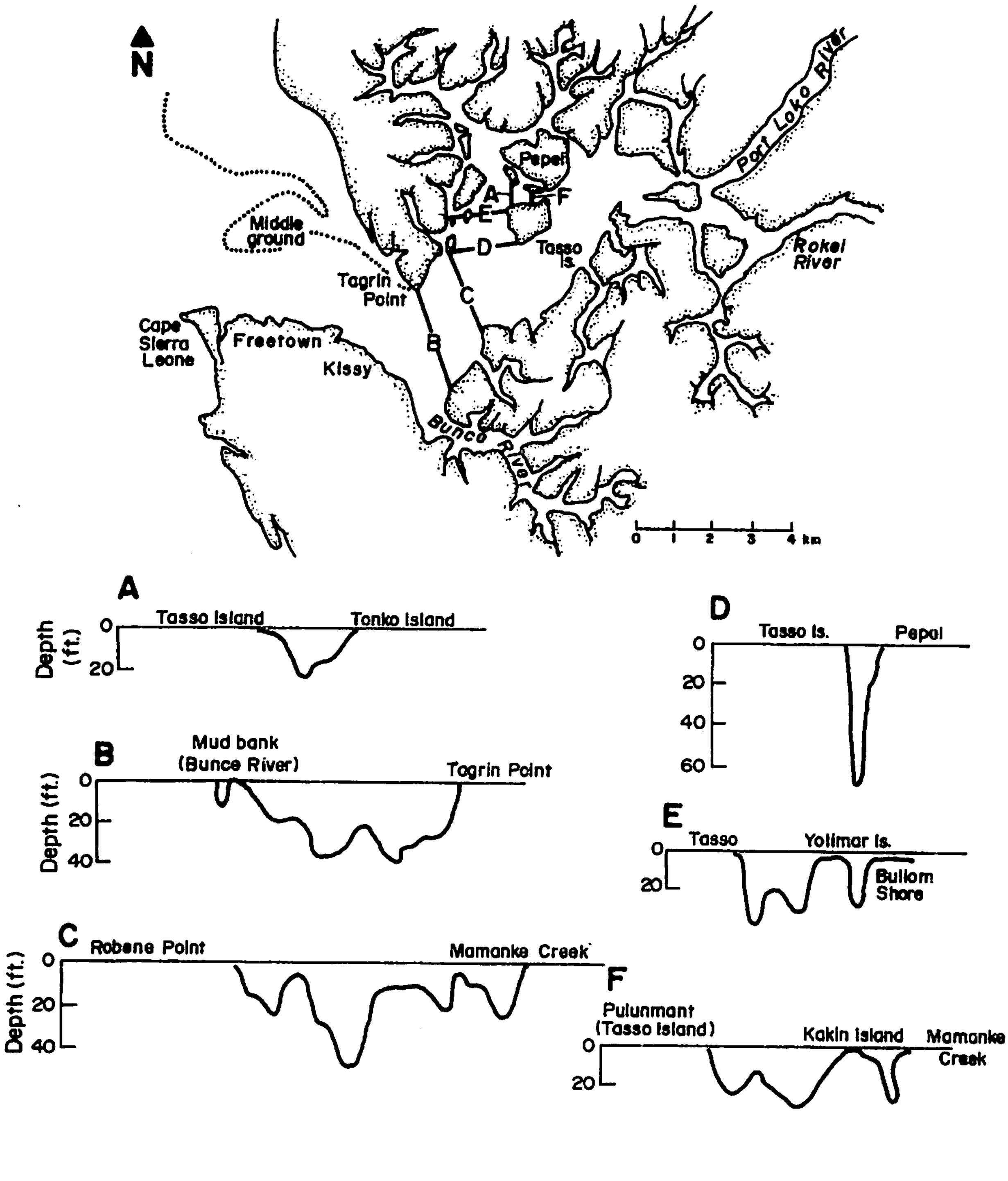

Fig. 2. Map of the Sierra Leone Riverine Estuary and sectional profiles across the inner part of the Estuary drawn from the Admirality Chart 689 (new ed. 1967). The Admirality Chart Datum is 20.43 ft (6.23 m) below the base of the harbor lighthouse on Aberdeen Point (Cape Sierra Leone), or 5.57 ft (1.70 m) below Sierra Leone Datum.

Along the northern shore of the Freetown Peninsula are located some of the major industries as well as the Queen Elizabeth II Quay which is at the eastern end of the harbor. The industries include the Kissy Oil Refinery Terminal, the Sierra Fish Industries also at Kissy, the Wellington Distilleries and Brewery, all of which discharge raw or partially treated waste waters directly into the Estuary.

In the central part of Freetown, at King Tom, there is an electric power station which uses the estuarine water for its secondary cooling circuit and discharges the heated water into the estuary. The main concentration of industry is found to the east and west of the center of Freetown in a government-established industrial zone, stretching from Kissy to Wellington. At present, most of the factories are small but pose a threat to the water quality of the Estuary as most of them do not treat their wastes which eventually get into the estuarine water.

The city of Freetown is largely unsewered except for four short sewer lines which discharge untreated sewage at two points directly into the Estuary and at a third near the shore. The sewer lines serving the hotel complex at Aberdeen also discharge untreated waste directly into the Estuary.

The Shores and Bottom

The northwestern shore (Bullom shores) facing the Atlantic is characterized by extensive mud banks. On the estuarine side of Bullom shores are creeks and islands whose shores are lined with mangrove swamps. The southern shore, from Cape Sierra Leone up to the mouth of the Bunce River, is rocky as the deep channel passes close inshore and the tidal streams along the shore are very strong. However, the rocky shore is indented by creeks and bays where mangrove swamps are found. Beyond the Bunce River estuary in an upstream direction until Bunce Island is reached, there appears to be no rocky shore except at Bunce Island and the neighboring Trinidad Rocks. In the mid-estuarine region between the entrance to the Bunce River and Tasso Island there are relatively small banks of mud and stones which become exposed at low water.

Immediately outside the mouth of the Estuary there is a wide area of largely sand or shell sand deposits whereas at the other end of the Estuary above the Tasso Island they are predominantly of coarse sand. At the lower reaches of the Bunce River the deposits are largely of mud while Kumrabi Creek is mainly sandy (Longhurst 1958). The bottom deposits on the northern side of the Estuary are mostly sand along the region of raised beaches, giving way to an admixture with silt further up as the region of fringing mangrove swamps is reached. Watts (1957a) found that the bed of the mid-estuarine region is composed of alternating patches of black mud and sand mixed in varying proportions.

The unconsolidated nature of the deposits and the strength of the tidal stream results in a rapid and uninterrupted redistribution of the sediments, such that the character of the bed of the estuary is continually changing. Where the current slackens silt is deposited, such that intertidal rocks in sheltered bays are coated with soft brown mud, e.g., at Cline Bay. In the deep channel and the channel between Kakim Island and the Bullom shores where the bottom currents are most intense, the bottom is largely composed of broken shells and fine lateritic gravel. Between Tasso Island and Robene Point there are extensive flat areas of reddish muddy sand.

The black muds of the mid-estuarine region have a relatively high organic content attributed to the presence of undecomposed or partially decomposed organic matter. In general the estuarine muds contain relatively large amounts of sulphur. In the muds of the mangrove swamps, the sulphur is in the reduced state but becomes oxidized as the soil becomes extremely acid on drying out (Jordan 1964).

Geologically speaking, the Estuary is considered relatively young. Dixey (1919) and Gregory (1962) have suggested a Pleistocene dating for the series of raised beaches in this region. Many recent drainage systems traverse the raised beaches, whose distribution in the Peninsula, suggests their formation before the Estuary. It is believed that the rise in sea level which followed drowned the Estuary and generated the present accumulation on the middle ground and the formation of the mangrove swamps.

Climate

The climate of the Guinea coast, from Cape Palmas in the south to the north of Conakry, is directly influenced by the inter-tropical or trade wind belt. Consequently the "Tropical Continental" airmass or dry northeast trades or Harmattan from the Sahara and the "Equatorial Maritime" airmass or the monsoon or humid south westerlies dominate the climate of this region. In the Freetown area the rains last from May to November with two maxima during May and June and during September and October. The dry season extends from December to April, during which period the area comes under the influence of the northeast trade winds blowing from the Sahara.

The mean temperatures are lower in the middle of the rains than at any other time of the year, with a diurnal range of about 72-82°F (22-28°C). The skies are often overcast with relative humidity over 80%. Visibility is generally better than during the middle of the dry season, but worse at the beginning and end of the rainy season. Winds are mainly from the southwest bringing heavy rains at the beginning and towards the end of the season.

During the dry season the diurnal range of temperature is 70-90°F (21-32°C), becoming hotter as the season advances. Relative humidity varies between 65% and 90% during the day. The skies are fairly clear although the predominant northeasterly winds during the period of December to March frequently bring dust from the Sahara thus reducing visibility.

The catchment area of the Rokel River has a mean annual rainfall of between 90 and 130 inches of which just over 90% falls between May and November. Most of the rainfall enters the Estuary as run-off due to the topography of the drainage basin and the relatively impermeable soil structure. Within the catchment area there is a longitudinal change in intensity and duration of the wet season from west to east, intensity being greatest in the west and duration greatest in the east (Gregory 1966). Consequently there is a seasonal fluctuation in the river discharge which complicates the hydrography of the Estuary.

Hydrography

The Estuary is tidal and of the semi-mixed type with the saline water from the Atlantic Ocean entering it on a diurnal cycle. Tidal variations are recorded as far as 42 miles inland along the water courses of the Rokel River and its tributaries as well as the Bunce River and several small streams, Kumrabi and Port Loko Creeks. The rate of outflow of the Rokel River has so far not been investigated but the extent of its discharge into the Estuary can be roughly estimated from salinity values.

Salinity

Watts (1958) has shown that there is a very strong seasonal fluctuation of salinity due to the heavy precipitation between May and October (Table 1). He suggested that the distribution of salinity in the main estuary is a result of the circulatory current system. There is a tendency towards a two layered transport system with an offshore movement of relatively brackish water compensated for by an onshore counter current of saline water close to the bottom of the estuary. As a result the water becomes stratified and the salinity increases with depth. This vertical salinity gradient is influenced by the changes in tidal range and the rate of river discharge. In the wet season the stratification is more marked at springs whereas in the dry season it is generally not appreciable. The large dilution of the surface water results in low salinity in the rainy season. The bottom waters near the mouth are relatively immune except during heavy floods when large changes in salinity become noticeable at neaps. This is not the case in the dry season when conditions are such that the water column is almost homogeneous.

Table 1. Seasonal fluctuations in the vertical and horizontal salinity profiles at the time when the maximum and minimum values were obtained.

		Dry season		Wet season	
		L.W.	H.W.	L.W.	H.W.
Mouth	Surface	33.3	34.1	27.2	29.3
(Cape Sierra Leone)	Bottom	34.0	34.3	30.1	30.5
Middle Reaches	Surface	27.5	31.5	16.1	20.9
(Tagrin Point)	Bottom	29.8	32.9	23.0	26.7
Upper Reaches	Surface	21.6	26.8	8.2	9.8
(Pepel)	Bottom	22.6	27.6	11.0	12.9

Leigh (1973) found that in the main estuary the differences between surface and bottom water salinities during the dry season were comparatively small but increased upstream. These differences tended to be large towards the end of the rainy season at the mouth of the Estuary but extended to early dry season in the middle and upper reaches. The observed trends result from considerable long and short term variations in the amount of water entering the Estuary from the sea as well as the amount flowing out.

So far there is little hydrographic data for the higher reaches of the Estuary and for the creeks. However, the data available (Longhurst 1958) indicate that during the dry season, fairly saline water reaches the heads of the creeks and fresh water is only found in the Rokel River 20 miles beyond Pepel. During the wet season surface salinity may drop to about 8 ppt at Pepel, and to 16 ppt at the head of the Bunce River (a mangrove creek) and fresh water probably occurs 9 miles beyond Pepel.

Temperature

Leigh (1973) has shown that the annual difference between the maximum and the minimum temperatures were of the order of 2-7° (air), 2-4°C (surface water) and 2-3°C (bottom water, depth: 17.4 to 29.3 m) from the mouth of the Estuary upstream to a station on the axis between Tagrin Point and Robene Point. Also the monthly average temperature variations for air, surface and bottom waters were small; varying between 27.3° and 30.1°C (air), 26.6° and 29.7°C (surface water) and 26.4° and 28.7°C (bottom water). In general the average monthly air temperature were higher immediately towards the beginning and end of the rainy season and lower in the middle of the dry and rainy season. The monthly average surface and bottom water temperatures followed the same pattern as for the air temperature but with a month's lag at their maximum and minimum.

Leigh's findings confirm Watts' (1958) observations that both the horizontal and vertical range of temperature in the Estuary is small with only minor seasonal fluctuations. He observed that the minimum surface temperature occurred at the height of the monsoon period (August). The increase in temperature after the rains is related to the decreased rainfall until the maximum is reached in November, when the development of the easterly continental winds and later the Maritime trade winds cause a further fall in temperature, observed in March (Leigh 1973). Watts (1958) felt that as the Maritime trade winds weaken and the Canary Current retreats northwards the sea and estuarine surface water temperatures rise to a maximum in May. He attributed the rise in temperature to the higher air temperature and the northerly set in the coastal current which transport relatively warmer water from the counter equatorial current northwards along the coast. Later, as the southwest monsoon strengthen and replaces the retreating maritime trade winds, temperatures fall with the increased rainfall (Fig. 3).

Turbidity

Turbidity is a very variable and transient property, depending upon the weather and tide. Bainbridge (1960) observed that the color and turbidity of the Estuary water are conspicuous features of the central and upper reaches when considered against the background of the spring to neap cycle of the tidal range. They are most pronounced during the dry season. At springs the water is brown and turbid while at neaps it is green and more transparent in contrast to the blue-grey color and fairly transparent water outside the mouth of the Estuary. He obtained a mean extinction coefficient from weekly measurements during the period December 1954 to August 1955 in the central part of the Estuary shortly before low water of 1.26 (range 3.4 to 0.6) at springs, and a mean of 0.54 (range 0.9 to 0.3) at neaps.

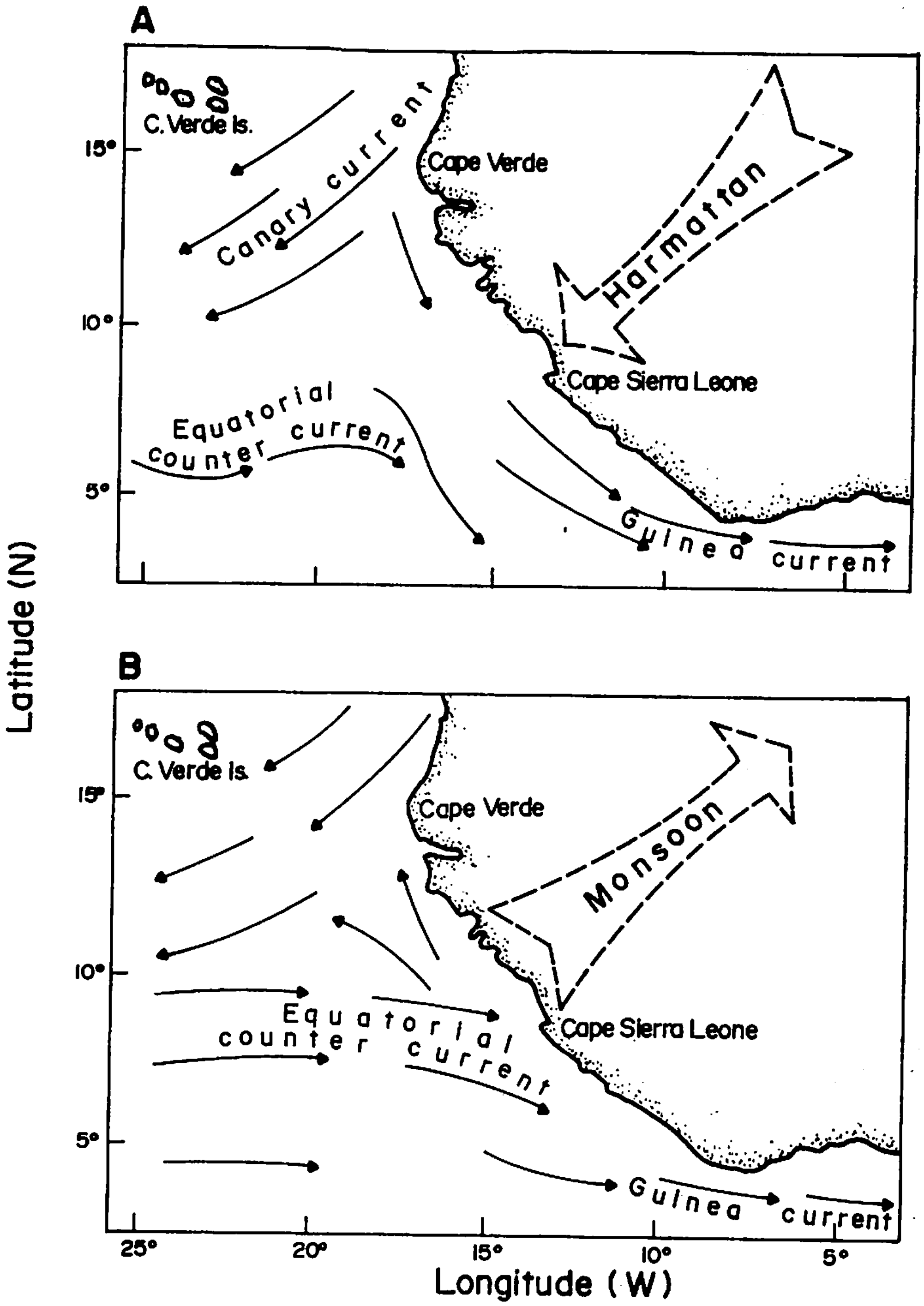

Fig. 3. The general pattern of winds and surface currents off the Guinea coast (adapted from Bainbridge 1960). In Fig 3.A thin arrows show currents from February to April; the wide arrow indicates the direction and southward extent of the Harmattan in January. In Fig. 3.B thin arrows show currents from May to July, while the wide arrow shows the direction and extent of influence of the monsoon in July.

Bainbridge (1960) further found that outside the mouth of the Estuary there was no clear cycle of turbidity between springs and neaps and the extinction coefficients varied between 0.5 to 0.1 with a mean of 0.27. Plankton samples taken simultaneously showed that the estuarine water carried much organic detritus, especially during spring tides when the current velocities are highest and larger areas of the mangrove swamps are scoured.

Watts (1958) found that turbidity is greater in the wet season than in the dry and the concentration of suspended matter increased in an upstream direction. Taylor (1966) noted that during the wet season solar radiation is also decreased, thus greatly reducing the depth of the photosynthetic zone. However it would appear that with the increased inflow of sea water into the Estuary from October to May when freshwater discharge is diminishing as a result of decreasing rainfall, flocculation reduces the amount of suspended matter. As a result, transparency is increased during the dry season - December to February - as was observed by Watts (1958).

Dissolved oxygen

Watts (1958) made monthly determinations of the concentrations of dissolved oxygen in a series of water samples of different salinities taken over a period of six months (September 1954 to February 1955). The period covered the last three months of the rainy season and the first three months of the dry season. He found values ranging from 109-56% saturation, with no seasonal variation, the maximum and minimum values both occurring in February. A few observations in the upper reaches and creeks gave values ranging from 66-83% saturation, while outside the mouth of the Estuary values ranged from 63-103% saturation. He also found that the average concentration varied from 80-86% saturation within the salinity range of 5 to greater than 30 ppt and a temperature range of 25-30°C.

Leigh (1973) made determinations from weekly samples taken at 5 m depth intervals from surface to bottom at high and low tide during the period October 1970 to November 1971. One station was located just outside the mouth of the Estuary and another in the mid-estuarine region. He found no seasonal variation although concentrations tended to be slightly higher during the rainy season than during the dry season especially in the mid-estuarine region. Also the oxygen content of the surface water was continuously higher than those of the bottom water throughout a greater part of the period except at low tide immediately outside the mouth of the Estuary during September when the bottom water concentrations were higher than those at the surface. Generally there was not much difference in the dissolved oxygen concentration between each of the stations at all depths. The concentration ranged from 55-90% saturation immediately outside the mouth of the Estuary and 55-97% saturation in the mid-estuarine region.

Leigh (1973) has proposed that the slightly higher surface values are a consequence of wind action on the surface waters; the slight increase in concentration in the mid-estuarine region during the rainy season could be due to the influx of freshwater from the Rokel River. Moreover the drop in the oxygen content of the bottom water could result from the breakdown of organic matter which Watts (1957a) found to be abundant in the bottom deposits of the Estuary.

Nutrients - Inorganic Phosphorus

Bainbridge (1960) gave the results of a series of dissolved phosphate determinations carried out by P. Hansen from April to December 1953. The dissolved phosphate content of the water was found to be slightly higher in the central region of the Estuary (0.3-0.97 µg-at P/l) than at its mouth (0.25-0.72 µg-at P/l). These amounts were considerably higher than those of Wattenberg (1957) obtained for the open Atlantic Ocean water just off the West African coast (0.0-0.36 µg-at P/l at 25 m, and at the surface it was undetectable). At the upper reaches of the Estuary, Watts (1958) found that the average concentration was 0.15 µg-at P/l. Bainbridge (1960) therefore concluded that the relatively high concentrations of dissolved phosphate in and off the mouth of the Estuary may be due to the continual tidal mixing and frequent re-suspension of organic detritus derived from the river, the mangrove swamps and the plankton.

Leigh (1973) carried out weekly determinations of inorganic phosphate and nitrate-nitrogen concentrations at 5 m depth intervals down to 15 m in the sea at the mouth of the Estuary and in the central region of the Estuary from October 1970 to November 1971.

He found that the inorganic phosphate concentration ranged from 0.10 to 0.76 µg-at P/l; that during the dry season (especially from late January to the end of March) it was undetectable at all depths from just outside the mouth up to the central region of the Estuary. With the onset of the rains (April) the concentration increased and was maintained at a high level until the end of the rainy season.

There was an increase in concentration with depth at all states of the tide during most of the rainy season (April to September) just outside the mouth of the Estuary. The same pattern was observed in the central region of the Estuary but in May and June the concentration was not uniformly distributed in the water column as higher concentrations were detected at either 5 m or 10 m depths.

During the rainy season at the entrance to the Estuary the concentrations at the surface and bottom were higher at high tide than at low tide whereas during the dry season there was little difference in concentration at both states of the tide. In the central region of the Estuary the concentration at low tide in the surface water in June, and from September to November was higher than that at high tide. The pattern was reversed during May and July while during August the surface concentration at both states of the tide were almost similar (0.15 µg-at P/l). The bottom concentrations at low tide was higher than that at high tide during April, July and September, whereas the opposite trend was observed in May, August and November. During the dry season the concentrations at both states of the tide were almost similar.

Leigh (1973) has suggested that the absence of inorganic phosphate in the Estuary water during late January to early March in the lower reaches and the central region could be due to its rapid uptake by phytoplankton which is usually in great abundance from January to June/July (Bainbridge 1960; Watts 1961). Associated with the latter is the penetration of sea water into the Estuary during this period when land run-off has decreased. Wattenberg (1957) has shown that open sea water outside the Estuary is usually poor in inorganic phosphate, hence the total absence of phosphate at all depths. The increase of inorganic phosphate concentration from late March to November is attributed to tidal mixing and turbulence generated by the strong incoming westerly winds. Such a view has buttressed that of Bainbridge (1960) that the inorganic phosphorus is brought into circulation from re-suspension of the bottom sediments and can account for the increased concentration with depth during a greater part of the period.

Nitrate-Nitrogen

Single nitrate analysis carried out in November 1954 (Watts 1958) gave an average concentration of 5.29 µg-at N/l for both the central region of the Estuary and at its mouth. In the upper reaches he obtained an average of 10.13 µg-at N/l and suggested that river discharge must make a significant contribution to the nitrate concentration of the Estuary.

Leigh (1973) found that the concentration of nitrate-nitrogen range from 0.1-66.6 µg-at N/l. Except on a few occasions the concentration increased upstream and was more pronounced during the rainy season. The concentration at the mouth of the Estuary was generally low from mid-January to mid-September (below 5.5 µg-at N/l) and the lowest concentrations were observed in the central region in late February (0.3-0.1 µg-at N/l from surface to bottom). In general the concentration was higher during the rainy season than during the dry season; it decreased with depth except during the dry season; the greatest difference in concentration between the surface and bottom waters was observed at low tide during January and that the concentration was usually higher at low tide than at high tide. His findings support Watts' view that increased river discharge during the rainy season contributed largely to its level of concentration in the Estuary water.

Summary

The Sierra Leone River Estuary is a relatively young drowned river valley, probably formed in Pleistocene times when there was a general rise in sea level. Most of the Estuary is shallow except for a deep channel which passes close to the Freetown shoreline. The upper reaches merge into a network of creeks and channels fringed by large areas of magrove swamps. It is a tidal estuary of the semi-mixed type with the saline oceanic water entering it on a diurnal cycle.

The climate of Sierra Leone is marked by a very distinct change between a very wet rainy season and a dry season. The rainfall pattern comprises the conventional thunderstorm rains of the early and late wet season, mainly related to disturbance lines moving from east to west across the country, and the steady monsoonal rains of the main wet season, roughly from mid-June to late September, moving into the country from the southwest off the equatorial Atlantic. The tidal range of the Estuary (spring = 3.03 m; neap = 2.28 m) does not impede normal use of the harbor. The tidal variations can be felt as far as 42 miles inland along the water courses of the Sierra Leone River and its attributes. The volume of fresh water entering the Estuary is large during the rainy season and greatly reduced during the dry season. Consequently there is a marked fall in salinity during the rainy season and higher salinities prevail during the dry season.

The nature of the shores and bottom, the hydrography and chemistry of the estuarine system have been outlined in relation to the prevailing climatic conditions.

SIZE COMPOSITION OF THE CATCHES OF THE PINK SHRIMP *PENAEUS NOTIALIS* IN THE SHRIMP FISHERY OF SIERRA LEONE

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SCOTT, R.B.S. 1978. Size composition of the catches of the pink shrimp *Penaeus duorarum notialis* in the shrimp fishery of Sierra Leone. Bull. Inst. Mar. Biol. Oceanogr. 3(1): 65-66.

ABSTRACT

A preliminary report is presented on the investigation into the size composition of *Penaeus notialis* in commercial landings, which was carried out between October 1977 and March 1978. First entry into the fishery occurs at a total length of around 10.5-11.0 cm. Typical length of the shrimp caught ranged from 12 to 14 cm total length. Sex ratio was usually 1:1.

The aim of this study was to determine the size composition of the pink shrimp (*Penaeus notialis*) by sampling catches of the commercial shrimp fisheries of Sierra Leone, over a period of six months, from October 1977 to March 1978.

Juvenile pink shrimps are associated with decaying mangrove vegetation in Sierra Leone. The adults are found mainly where the substratum is muddy as observed from samples, taken from the commercial catches, which had mud deposits underneath their carapace and at the junctions between body segments.

Pink shrimps caught from the Banana Islands shrimp grounds are regularly landed at the Sierra Fishing Co. Shrimp Processing Plant. During processing, the "heads" (cephalothorax) are removed from the "tail" (abdomen). Measurements on whole shrimps were first obtained for 1,000 specimens and used to derive a relationship between carapace length and total length for both male and female shrimps. The remainder of the sampling measurements were then carried out on the heads only, of which a total of 8,500 were sampled and the corresponding total lengths calculated using the derived relationships. These were then used to plot weekly frequency distribution curves for both male and female shrimps.

From the frequency distribution curves it was observed that the curves for male shrimps show only one or two major modes, which show prominence between 12.5 and 14.1 cm of total length. Females mostly exhibited size groups with three or four different length ranges and occasional occurrence of one to five modes. These size groups were observed to show continuous changes. No one group could be said to be permanent. The point of entry into the fishery of male shrimps was found to be at an average total length of 10.5 cm, while females did so at 11.0 cm. Thus males enter the fishery at a smaller length than the females. This recruitment was observed to take place periodically and in small numbers.

The sex ratios in the different samples were usually 1:1 but in one case the males were more numerous by 2:1 and in four other samples females were significantly preponderant. These departures from the 1:1 ratio may have been artificially created by sorting of the catches on board the ships.

This study has provided the first data base for the local shrimp fishery. It needs to be supplemented, verified and built up more substantially in order to serve management purposes. Later studies could deal in more detail with the migrations of the juveniles from the nursery grounds to the Banana Islands grounds and subsequently of the different sexes to deeper waters.

The assistance and cooperation of the Sierra Fishing Company Ltd., during this study are acknowledged.

REPORT ON

THE PHYSICAL, BACTERIOLOGICAL AND BIOCHEMICAL ANALYSES OF SEAWATER SAMPLES COLLECTED OFF EXISTING SEWAGE OUTFALLS IN THE SIERRA LEONE RIVER ESTUARY

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FINDLAY, I.W.O., Editor. 1980. Report on the physical, bacteriological and biochemical analyses of seawater samples collected off existing sewage outfalls in the Sierra Leone River Estuary. Bull. Inst. Mar. Biol. Oceanogr. 4(2): 1-52.

ABSTRACT

The studies reported here were undertaken as part of a wider environmental feasibility study for the establishment of a modern sewage system in Freetown. The aim was to determine whether the hydrological regime of the Sierra Leone River estuary would permit the large-scale introduction of sewage into the estuary without damaging the environment. The important factors were whether (i) there will be sufficient dilution of the sewage and (ii) fleatable particles or other substances would create significant adverse effects in the estuarine ecosystem. To this end, water samples were collected from the outfall sites for the following chemical analyses: dissolved oxygen content, biological oxygen demand, and the concentrations of chloride, nitrate, nitrite, phosphate and ammonium. Other analyses made were for total suspended solids and total and faecal coliforms. The results suggest that it would be inadvisable to locate untreated sewage outfalls at points where local circulation occur. Such points are frequently observed in small embayments. The present study has been of short duration but the data could serve a baseline for more extended investigations which would give a more complete picture of the seasonal patterns in the estuary.

1. Introduction

The Sierra Leone River Estuary is a tidal estuary of the semi-mixed type with the saline oceanic water entering it on a diurnal cycle. Most of it is shallow except for a deep channel which passes close to the Freetown shoreline.

The climate of Sierra Leone is marked by a very distinct change between a very wet rainy season and a dry season. The rainfall pattern comprises the conventional thunderstorm rains of the early and late wet season, mainly related to disturbance lines moving from east to west across the country, and the steady monsoonal rains of the main wet season, roughly from mid-June to late September, moving into the country from the southwest off the equatorial Atlantic.

The volume of fresh water entering the Estuary is large during the rainy season and greatly reduced during the dry season. Consequently, there is a marked fall in salinity during the rainy season and higher salinities prevail during the dry season. The tidal range of the Estuary (spring: 3.03 m; neap: 2.28 m) does not impede normal use of the Freetown harbor. The tidal variations can be felt as far as 42 miles inland along the water course of the Sierra Leone River and its tributaries.

The nature of the shores and bottom, the hydrography and chemistry of the estuarine system in relation to the prevailing climatic conditions have been reviewed by Findlay (1978).

The city of Freetown is largely unsewered. There are many short sewer lines which discharge directly into the Estuary. Nearly all of them have a sea- wall discharge point with the exception of the Kingtom outfall which is submarine and the Queen Elizabeth II Quay collecting system which discharges close to the shoreline at Cline Point. All the sewer discharge untreated sewage and with the exception of that at the Government wharf, the volume of discharge is relatively small.

Along the northern shore of the Freetown Peninsula are located some of the major industries as well as the Queen Elizabeth II Quay which is at the eastern extremity of the harbor. The industries include the Kissy Oil Refinery Terminal, the Sierra Fishing Company also at Kissy, the Wellington Distilleries and Brewery. All of them discharge raw or partially treated waste waters directly into the Estuary.

The proposal to construct a sewerage system for Freetown and Greater Freetown has necessitated a study of the existing chemical and bacteriological conditions of the water and sediments in the vicinity of the sewage outfalls at Murray Town, Kingtom, Government Wharf and Cline Point.

2. Description of Outfall Sites

The locations of the four outfall sites along the shores of the Sierra Leone River Estuary are shown in Fig. 1. The shores along the Freetown mainland are mainly of lateritic headlands projecting into the Estuary. These headlands alternate with bays where the nature of the soil (either clay or an agglomerate of sand and pebbles) appear to be weak to resist marine erosion. Numerous streams which show a clear seasonal fluctuation in their discharge drain the Freetown Peninsula into the bays.

The positions of the outfalls investigated with respect to their location on the headlands and bays on the northern shore of the Freetown Peninsula are shown in Fig. 2.

Outfall 1 is situated immediately west of Cline Point which is a lateritic headland. The effluent pipe stands about 0.5 m above high water mark at neap tide among rocks of gabbro which were deposited there during the construction of the Queen Elizabeth II Quay.

The movement of currents at this site appears to be upstream when the tide is running out (that is at low tide) and upstream again at high tide. This indicates that the outfall is in a sheltered location where the exchange of water between that trapped in the Queen

Elizabeth II Quay and the main estuary water is very small. Intense mixing of these two bodies of water appears to take place about 0.2 km upstream immediately opposite the Cline Point headland.

The depth of the water at approximately 10 m offshore from the outfall varies from about 0.5 m at low tide to 2.0 m at high water neaps. It gradually increases to about 20 m approximately 100 m away from the outfall site. The deep channel of the Estuary (Fig. 1) with a depth varying between 25 and 30 m lies approximately 250 m north of the outfall site.

Outfall 2 at Government Wharf stands about 1.5 m above surface water at high water neaps. The sewage effluent pipe is about 2.0 m underneath the floor of Pier No. 1. This pier is about 0.2 km west of the Falcon Bridge headland which is also lateritic but contains some outcrops of gabbro that extend 10 to 20 m into the estuary water. Immediately west of the pier is Kroo Bay.

The area is greatly affected by water coming from Kroo Bay especially at low tide. The quality of this water appears to be extremely poor being heavily loaded with debris and detritus, and a lot of plastics, piassava and empty tin cans. Very little or no mixing appears to take place between the bay water and the estuary water except in the area immediately opposite the Falcon Bridge headland.

Front-lines separating the bay water from the main estuary water are clearly visible on the water surface around the area. and are demarcated by floating tin cans, bamboo, pieces of sticks and detritus. Usually, the bay water is pale brown or yellow and murky, while the estuary water is green or blue. These front-lines migrate inshore and offshore depending on the tide. At low tide the bay water extends to about 50 to 100 m offshore but at high tide this zone reduces to about 5 to 10 m from the shore at the outfall site.

The depth of the water 10 m from the outfall varies from 2.5 m at low tide to about 5 m at high tide neaps. This increases to about 8 to 11 m and 14 to 17 m at 50 and 100 m offshore respectively.

The shore of the Kingtom Peninsula, at the northern end of which Outfall No. 3 is located (Fig. 2), is composed mainly of sand with outcrops of gabbro and laterite that extend 5 to 10 m into the estuary water. The sewage effluent pipe, leading from a septic tank on the shore, dips and extends about 3 m into the estuary water. The outfall lies in a sheltered area to the east of which is a smaller headland on which the Sierra Leone Electricity Power Station is sited.The nature of the currents affecting this area appear to be extremely complex since the Peninsula lies between Kroo Bay on the east and Whiteman's Bay on the west (Fig. 2). The exchange of water between the two bays is probably more pronounced than between the bay water and the estuary water. Clearly visible front-lines indicate where bay waters separate from estuary water. At low tide, the movement of water is more in an upstream direction with counterclockwise circulation within the bays. Some amount of exchange of water between the two bays seems to take place during this state of the tide. The reverse trend however appears to take place at high tide when the circulation of water in the bays is more or less clockwise with little or no exchange. It is suggested that the area in which Outfall 3 is sited is a "dead spot", with hardly any movement of water during high tide.

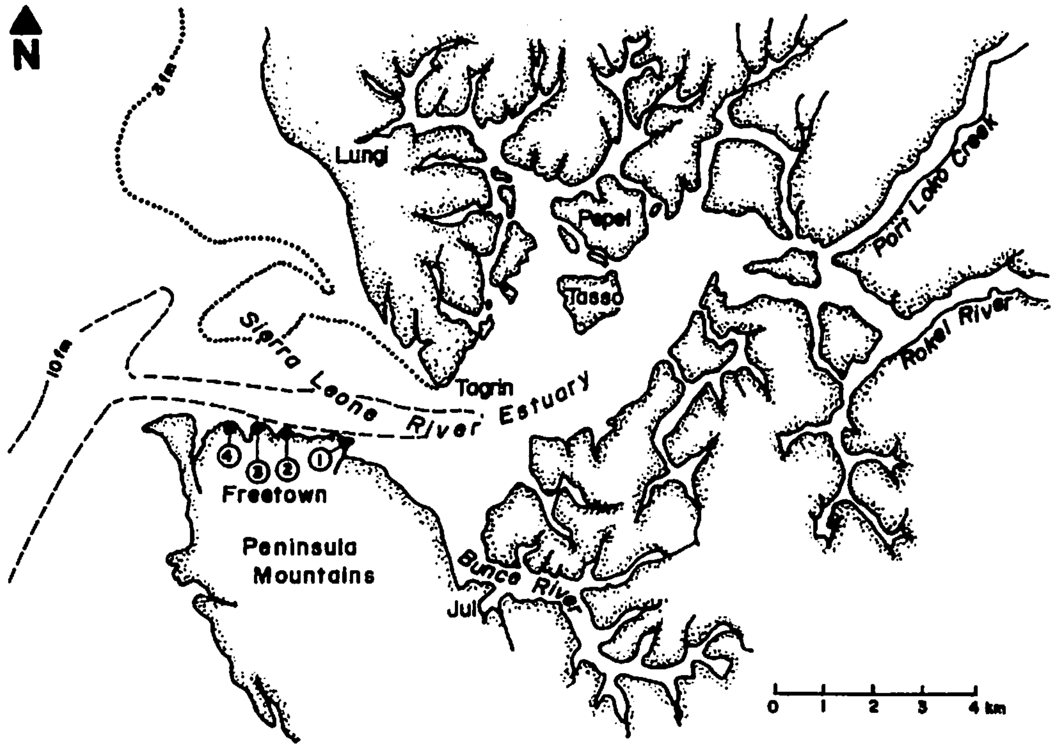

Figure 1 Location of outfalls along the Sierra Leone River Estuary.

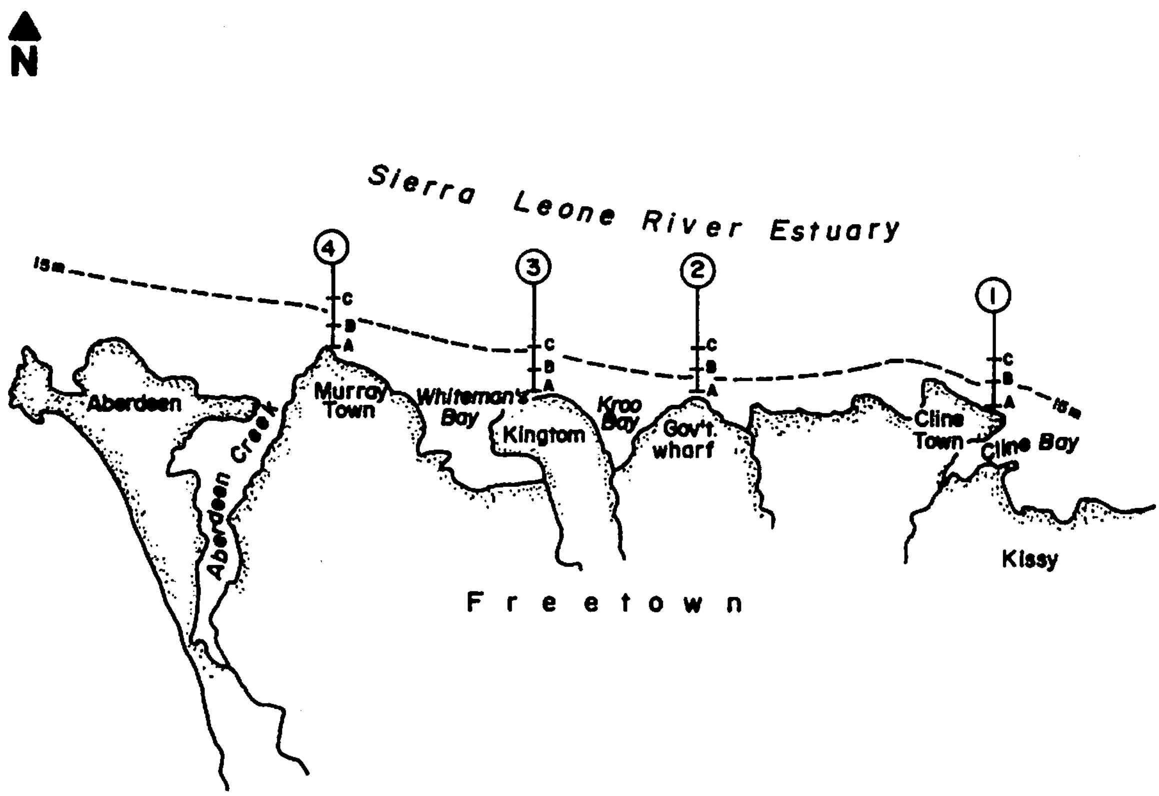

Figure 2 Location of outfalls and sampling stations along the Freetown mainland.

The depth of the water at this outfall varies from 2.5 m about 10 m offshore and about 9 to 11 m and 15 to 17 m at 50 m and 100 m offshore respectively.

Outfall 4 is sited east of the Murray Town headland which is mainly composed of gabbro. It stands about 3 m above surface water at high water neaps. Mixing of the water at this site appears to be more intense at low tide than at high tide. At high tide however, the water passing this point flows into Whiteman's Bay (Fig. 2). Front lines, quite common at Outfalls 2 and 3, are less evident here, probably a consequence of the intense mixing which takes place at the mouth of the Estuary. The depth of the water at this site varies from about 2.5 m onshore to about 17 to 19 m approximately 100 m offshore from the outfall.

3. Sampling Stations and Sampling Regime

Sea water samples for chemical analysis were collected from the four outfall sites at various tidal regimes using an inflatable rubber dinghy powered by a 40-HP outboard engine. Cruises, which lasted for about 5 to 6 hours were arranged such that on a sampling date if outfalls No. 1 or 4 was sampled at high tide the intermediate outfalls were subsequently sampled serially until No. 4 or 1 was eventually sampled at low tide.

Two fixed stations (B and C) were placed 50 m and 100 m offshore at each outfall site (Fig. 2). The "A" stations were fixed on every occasion according to the state of the tide, being 5 m offshore at high tide or 10 m at low tide. The samples for chemical analyses were taken at each hydrographic station from the surface and bottom and at mid-water, except at the "A" stations where the depth of the water did not warrant the collection of mid-water samples. The depth of the water at each station varied according to the state of the tide. It never exceeded 5 m at any of the "A" stations. At the "B" and "C" stations, the depth ranged from 6 to 20 m and 14 to 20 m respectively. Mid-water samples were then collected after recording the depth of the water.

Water temperature and salinity observations during sampling were carried out using an MC.5 Temperature/Salinity Bridge manufactured by the National Institute of Oceanography, UK. Observations on the two factors were made at each station at the surface and at 1 m depth intervals until the bottom was struck. Changes in the water with reference to current velocity and direction, occurrence of front-lines, and water quality were routinely observed and recorded.

All sea water samples for chemical determinations were taken using a Van Don sampler with a holding capacity of approximately 10 l. Surface water samples were taken at 0.5 m depth. Afterwards, the sampler, weighted with a 4 kg metal piece of iron, was then dropped to the bottom and the depth of the water noted. Bottom water samplers were then taken 1 m above the bottom. The depth recorded was then halved, after which mid-water samples were taken.

Water samples for dissolved oxygen and BOD determinations were taken from the Van Don sampler before drawing water for any other analyses. Care was taken to avoid contamination of the sample with outside air by introducing the water into 250 ml BOD bottles by means of a rubber tube touching the bottom and flushed three times. Each sample for dissolved oxygen determination was immediately treated with 1 ml manganese sulfate and 1 ml of a mixed reagent of potassium iodide and sodium hydroxide and kept in an insulated ice box.

Sea water samples for the determination of chloride, nitrate, nitrite, phosphate and ammonium concentrations were stored in 1 l plastic bottles and kept in a cool place.

Samples for total and faecal coliform counts were collected in 250 ml glass-stoppered bottles and kept in the insulated ice box. Again, water samples for the determination of heavy metal concentrations were stored in glass-stoppered bottles and kept in a cool place onboard.

Bottom mud samples were taken with a Van Essen grab sampler having a holding capacity of 2 l. Samples collected were stored in about 4 l capacity plastic packets.

4. Methods of Analysis

Temperature - Salinity

Temperature-salinity was determined using a salinity and temperature measuring bridge, type MC.5 designed by the National Institute of Oceanography, UK. With this instrument *in situ* measurements can be made.

Dissolved oxygen

A modification of the classical Winkler procedure as described by Strickland and Parsons (1968) was used routinely. Duplicate tests were fixed in the field and 100 ml titrated as soon as possible on return to the laboratory.

Chloride

Chloride was determined from salinity measurements with the MC.5 bridge or from determinations of salinity by the microtitration method of Kalle (1951).

Nitrate-nitrogen

The determination of nitrate-nitrogen is based on the Strickland and Parsons (1968) combination of the methods of Grasshoff (1964) and Wood et al. (1967). In it, about 95% of the nitrate is reduced to nitrite by passing the sample after treatment with an ammonium chloride buffer, through a column containing cadmium-copper filings. The nitrite is then determined by the method of Bendschneider and Robinson (1952).

Nitrite-nitrogen

The determination is based on Shinn's (1941) modification of the classical Greiss-Ilosvay method as adapted for sea water analysis by Bendschneider and Robinson (1952).

Ammonia-nitrogen

The determination is based on the modified Koroleff (1969) method in which ammonia reacts with sodium hypochlorite and phenol in an alkaline medium in the presence of catalytic amounts of sodium nitroprusside to give indophenol blue, an intensely colored compound. Sodium citrate is added to prevent the precipitation of magnesium hydroxide from the sea water (Solorzano 1969).

Phosphate-phosphorus

The determination is based on the modified single solution method of Murphy and Riley (1962) in which the sample is treated with an acidic reagent containing molybdate, ascorbic acid and antimony III.

Total suspended solids

Replicate samples of water are filtered through a Whatman No. 2 filter paper and the retained dried matter is determined by weighing.

Total coliform

The determination is based on the MPN method using a modified formate lactose glutamate medium as recommended by PHLS Standing Committee (1969) on the bacteriological examination of water supplies.

Faecal coliform

The determination is made using brilliant green lactose bile broth. The methods for total and faecal coliforms determination are described in the HMSO Report (1969).

5. Results

Bacteriological

The probable number of total and faecal coliforms for the various outfall stations are given in Tables 1A and 1B. Faecal coliforms were found in every sample taken. The numbers were usually greater in the bottom layers than in the surface layers and also nearer the point of discharge than away from them except at Outfall 2 stations. Gross pollution from coliforms was found at the Government Wharf outfall and slightly so at the Murray Town outfall at all states of the tide. Pollution was not heavy at the other two outfalls, which may probably be due to their design and discharge characteristics.

Table 1A. Total coliforms (per 100 ml) found at the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	22/4	110		8	25		
	5/5	80	80				
	13/5	350	350	50	140	110	99
2	22/4	1,800+			35		
	5/5	1,800+	1,600				
	7/5			550		1,800+	6
	13/5	1,800+	1,800+		1,800+		
3	29/4	35	110	250	350	170	80
4	7/5	900	1,600	550	350	350	20

Table 1B. Faecal coliforms (per 100 ml) found at the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	22/4	17		2	2		
	5/5	17	80				
	13/5	170	130	17	70	35	70
2	22/4	1,800+			35		
	5/5	1,800+	1,600				
	7/5			170		900	4
	13/5	1,800+	1,800+		1,800+		
3	29/4	5	7	14	80	14	50
4	7/5	350	1,600	250	170	110	7

Chemical

Salinity and temperature of the estuary water were high throughout the period of investigation (Tables 2 and 3). By mid-May salinity dropped slightly due to the dilution of the estuary water by run-off from the land, a consequence of the first squalls which mark the start of the rainy season. The chloride content (Table 4) is related to the salinity and there is no evidence of sewage contributing to its concentration.

The dissolved oxygen concentration (Table 5) is high at all depths at all states of the tide. Only on few occasions was undersaturation observed. This feature of the estuary water has also been recorded by Watts (1958) and Leigh (1973).

The biochemical oxygen demand of the estuary water indicates that it is of fairly good quality (Table 6). It is probable that at the point of discharge (the shoreline which is rocky) the liquid part of the sewage rapidly becomes diluted and dispersed whereas the solid part becomes held in suspension in the tidal currents which flow into the nearby bays where they become broken up and dispersed. The low concentration of total suspended solids (Table 7) appears to support the idea of rapid dilution and dispersal of the sewage.

The data for nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen and phosphate-phosphorus are given in Tables 8 to 11.

The nitrate-nitrogen and nitrite-nitrogen values were high at Outfall 2 than at any of the others. At Outfall 2 it decreased as one moved away from the shore and also with depth. At the other outfalls the concentrations were higher in the bottom layers than at the surface. The same trend was observed in the distribution of nitrite-nitrogen at the outfalls.

The concentration of the ammonia-nitrogen in the surface layers of Outfalls 2, 3 and 4 stations was greater than in the bottom layers. At Outfall 1 stations the reverse trend was observed. At Outfalls 1 and 2 stations the highest values were obtained during low water conditions and the lowest values during the change from low water to high water conditions. At Outfalls 3 and 4 stations the lowest values were obtained during the change from low water to high water conditions and the highest values under predominantly low water conditions.

The phosphate-phosphorus concentration was high at Outfall 3 stations than at the other stations and appears to decrease with depth. At the other outfall stations the pattern of distribution was not clearly defined.

The heavy metals appear to be absorbed and concentrated in the bottom muds (Table 12).

Table 2. Salinity (ppt (‰)) of the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	18/4	33.78	34.70	33.19	33.19		
	22/4	33.42	33.54	33.35	34.25		
	25/4	34.65	34.65	34.35	34.55		
	7/5	32.75	32.85	32.40	32.90		
	13/5	29.20	29.20	29.20	29.20	29.00	29.00
2	22/4	34.65	34.75	34.75	34.75+		
	25/4	34.25		34.85			
	29/4	33.35	33.4	33.00	33.40	33.50	
	7/5	33.20	33.40	33.15	33.65	33.10	33.60
	13/5	30.90	31.00	30.20	30.70	30.00	30.50
3	22/4	34.80		34.70	35.20		
	29/4	33.56	33.57	33.55	33.56	33.56	33.56
	7/5	33.15	33.60	33.00	33.45	33.05	33.65
	13/5	31.00	31.00	30.70	30.90	30.50	30.70
4	22/4	34.49	35.15				
	29/4	33.56	35.55	33.57	33.55	33.51	
	7/5	33.10	33.20	33.30	33.55	33.45	33.65
	13/5	30.50	30.50	30.60	30.60	30.60	30.60

Table 3. Temperature (°C) of the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	Stations A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	18/4	27.21		27.25	27.00		
	22/4	29.80	29.40	29.80	29.00		
	25/4	28.80	28.80	29.20	29.00		
	7/5	29.80	29.80	30.20	29.00		
	13/5	30.00	30.00	30.00	30.00	30.40	30.20
2	22/4	29.00	28.60	28.50	28.20		
	25/4	28.80		28.40	28.80	28.40	28.40
	29/4	29.00	28.60	28.80	28.60	29.00	
	7/5	29.40	28.90	29.40	28.80	29.40	28.80
	13/5	30.00	29.60	29.80	29.60	29.80	29.60
3	22/4	29.00		29.00	28.60		
	29/4	28.20	28.20	28.20	28.20	28.20	28.10
	7/5	29.50	29.00	29.80	28.70	29.20	28.70
	13/5	29.80	29.70	29.80	29.50	29.60	29.50
4	22/4	29.40	28.00				
	29/4	28.20	28.25	28.20	28.20	28.20	
	7/5	29.00	28.78	28.90	28.80	28.90	28.80
	13/5	29.40	29.40	29.40	29.20	29.40	29.20

Table 4. Chloride content (ppt at 25°C) of the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	Stations A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	18/4	19.12	19.65	18.78	18.78		
	22/4	18.91	18.98	18.87	19.39		
	25/4	19.62	19.62	19.45	19.57		
	7/5	18.52	18.58	18.32	18.61		
	13/5	16.47	16.47	16.47	16.47	13.36	16.36
2	22/4	19.62	19.68	19.68	19.68		
	25/4	19.39		19.74			
	29/4	18.87	18.89	18.67	18.89	18.96	
	7/5	18.78	18.89	18.75	19.04	18.72	19.01
	13/5	17.45	17.51	17.05	17.34	16.93	17.22
3	22/4	19.71		19.65	19.94		
	29/4	18.99	18.99	18.99	18.99	18.99	18.99
	7/5	18.75	18.93	18.67	19.01	18.69	19.04
	13/5	17.51	17.51	17.34	17.45	17.22	17.34
4	22/4	19.53	19.91				
	29/4	18.99	20.15	18.99	18.99	18.96	
	7/5	18.72	18.78	18.84	18.99	18.93	19.04
	13/5	17.22	17.22	17.22	17.28	17.28	17.28

Table 5. Dissolved oxygen (% saturation) of the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	Stations A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	18/4	127.67	132.04	121.68	113.52		
	22/4	150.99		147.82	69.74		
	25/4	122.33		141.31	140.77		
	7/5	157.29		152.20			
	13/5	116.55	114.32	100.98	112.09	133.11	116.96
2	22/4	138.70		131.02	134.89		
	25/4	104.15		103.73	126.31	126.31	135.26
	29/4	133.32	141.36				
	7/5	124.89	142.12	143.11	139.91	136.32	96.91
	13/5	90.52	132.81	98.97	107.89	130.29	128.06
3	22/4	136.51		136.63	136.14		
	29/4	129.45	130.56	131.67	127.24	131.67	135.94
	7/5	129.74	135.62	143.67	110.32	146.89	135.14
	13/5	121.97	98.43	108.13	107.73	101.11	133.21
4	22/4	107.71	100.13				
	29/4	138.30	135.68	137.23	136.69	137.17	
	7/5	151.07	138.15	101.54	137.61	136.49	109.47
	13/5	116.19	134.15	110.64	89.19	126.49	132.80

Table 6. Biochemical oxygen demand (mg/l) of the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	Stations A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	18/4	3.19	2.34	1.57	10.48		
	22/4	3.22		1.47			
	25/4	1.61		0.96	2.62		
	5/5	1.24	1.29	0.08	0.63	1.39	
	7/5	1.26		0.65			
	9/5	1.91	3.61	0.80	4.94	1.61	2.02
	13/5	1.61	2.22	0.81	1.81	1.41	2.62
2	22/4	1.71		0.81	1.41		
	25/4	3.43		0.24	0.71	0.46	0.81
	29/4	1.21	1.41		1.41	11.90	
	5/5	0.87	0.22	0.28	0.65	0.68	1.09
	7/5	1.10	1.11	0.60	0.60	0.81	0.91
	9/5	1.21	0.40	0.40	0.30	0.31	0.81
	13/5	1.62	1.31	0.11	0.91	2.12	2.42
3	22/4	0.66		3.62	2.84		
	29/4	0.76	0.91	0.71	0.41	0.66	1.01
	7/5	0.31	0.45	2.22	0.40	1.41	0.40
	9/5	1.11	1.11	1.11	1.41	0.19	
	13/5	0.20	0.44	0.40	0.40	0.30	1.46
4	22/4	0.39	0.24				
	29/4	1.11	1.01	0.76	0.91	0.66	
	7/5	1.10	1.26	1.00	0.81	0.66	0.55
	13/5	0.30	1.21	0.55	1.01	0.56	1.16

Table 7. Total suspended solids (mg/l) of the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	Stations A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	18/4	1.25	1.00	1.05	0.96		
	22/4	0.68		0.40	0.62		
	25/4	0.52	0.26	0.45	0.75		
	7/5	0.73		1.10			
	13/5	0.31	0.68	0.36	0.84	0.64	0.52
2	22/4	0.69		0.68	0.63		
	25/4	0.15		0.49	0.005	0.73	0.45
	29/4	1.395	1.105	0.96	1.25	1.32	
	7/5	0.82	0.70	0.89	0.80	0.58	
	12/5	0.33	0.46	0.29	0.42	0.34	0.37
3	22/4	0.61		0.48	0.58		
	29/4	1.23	1.08	1.22	1.38	1.17	1.24
	7/5	0.86	0.76	0.72	0.74	0.69	0.66
	13/5	0.45	0.35	0.29	0.22	0.37	0.31
4	22/4	0.55	0.77				
	29/4	1.16		1.20		1.18	
	7/5	0.58	0.66	0.82	0.98		
	13/5	0.25	0.30	0.27	0.27	0.35	0.34

Table 8. Nitrate-nitrogen content (mg/l) of the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	Stations A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	18/4	4.70	7.84	1.57	7.84		
	22/4	4.74		1.58	7.20		
	25/4	5.08	5.08	1.69	7.57		
	5/5	6.14	10.23	2.05	9.33	5.12	
	7/5	4.58		1.74			
	9/5	4.77	8.28	4.39	7.26	3.98	4.23
	13/5	4.59	7.54	1.996	7.13	3.96	5.16
2	22/4	29.20		8.31	6.79		
	25/4	31.82		8.93	7.29	5.08	3.39
	29/4	29.59	3.36	5.12	6.72		
	5/5	37.78	40.94	6.55	8.39	6.14	4.09
	7/5	29.23	31.28	4.74	6.79	4.74	3.32
	9/5	27.47	30.65	4.77	6.37	5.57	5.57
	13/5	29.30	30.51	4.75	6.75	4.75	3.33
3	22/4	7.89		5.31	2.84		
	25/4	7.68	8.41	5.28	3.04	5.12	6.24
	7/5	7.90	8.63	5.47	2.84	5.06	6.32
	9/5	7.96	8.69	5.41	3.02	5.41	
	13/5	7.76	8.71	5.32	3.01	5.16	6.34
4	22/4	6.73	5.15				
	29/4	6.81	7.29	6.40	8.00	7.61	
	7/5	6.48	6.95	6.48	7.90	7.58	7.90
	13/5	6.65	7.07	6.34	7.92	7.76	7.92

Table 9. Nitrite-nitrogen content (mg/l) of the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	Stations A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	18/4	0.34	0.02	0.30	0.02		
	22/4	0.39		0.32	0.39		
	25/4	0.44	0.40	0.35	0.48		
	5/5	0.40	0.40	0.31	0.40	0.12	
	7/5	0.40		0.29			
	9/5	0.41	0.42	0.32	0.42	0.13	0.23
	13/5	0.45	0.45	0.35	0.45	0.18	0.33
2	22/4	1.32		0.81	0.26		
	25/4	1.57		0.97	0.33	0.04	0.46
	29/4	1.42	1.46	0.84	0.88		
	5/5	1.36	1.46	0.85	0.88	0.04	0.40
	7/5	1.36	1.46	0.81	0.90	0.03	0.40
	9/5	1.19	1.27	0.85	0.89	0.08	0.23
	13/5	1.37	1.42	0.91	0.93	0.14	0.45
3	22/4	0.52		0.16	0.02		
	29/4	0.52	0.65	0.15	0.20	0.50	0.60
	7/5	0.52	0.62	0.13	0.21	0.21	0.29
	9/5	0.51	0.58	0.13	0.23	0.23	
	13/5	0.58	0.64	0.21	0.25	0.25	0.35
4	22/4	0.24	0.11				
	29/4	0.25	0.45	0.46	0.56	0.40	
	7/5	0.21	0.12	0.48	0.54	0.40	0.40
	13/5	0.25	0.195	0.55	0.595	0.44	0.45

Table 10. Ammonia-nitrogen content (mg/l) of the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	Stations A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	5/5	0.48	0.96	0.29	1.34		
	7/5	1.64		0.98			
	9/5	0.00	0.07	0.00	0.00	0.00	0.00
	13/5	1.20	1.04	0.80	0.88	0.80	1.36
2	29/4	17.61	1.91	3.45	1.72	1.34	
	5/5	0.86	0.96	0.57	1.15	1.44	1.44
	7/5	0.98	0.82	0.98	0.57	0.82	0.00
	9/5	0.00	0.00	0.00	0.00	0.00	0.00
	13/5	10.80	1.20	0.80	1.44	1.20	1.00
3	29/4	7.37	1.53	1.91	4.59	3.06	2.20
	7/5	0.82	0.74	0.57	0.57	1.23	2.05
	9/5	0.07	0.00	0.83	0.14	0.42	
	13/5	0.96	0.80	0.72	0.40	0.40	0.40
4	29/4	1.63		2.29			
	7/5	0.82	0.41	0.74	0.49	1.80	0.41
	13/5	1.20	0.72	1.12	0.40	0.80	0.32

Table 11. Phosphate-phosphorus content (µg-at/l) of the surface and bottom layers of the various outfalls as sampled per station.

Outfall	Date	Stations A Surface	A Bottom	B Surface	B Bottom	C Surface	C Bottom
1	18/4	0.041	0.041	0.204	0.00		
	22/4	0.041		0.082	0.326		
	25/4	0.16	0.40	0.28	0.08		
	5/5	0.157	0.157	0.00	0.434	0.118	
	7/5	0.035		0.035			
	9/5	0.79	0.79		0.95	0.83	0.79
	13/5	1.54	0.98	0.58	0.93	0.62	1.13
2	22/4	0.00		0.082	0.245		
	25/4	0.12		0.04	0.04	0.00	0.04
	29/4	0.697	0.375	0.161	0.134	0.027	
	5/5	0.078	0.157	0.667	0.00	0.157	0.039
	7/5	0.035	0.105	0.035	0.035	0.035	0.105
	9/5	0.75	0.99	0.99	0.79	0.99	0.79
	13/5	1.85	1.29	1.08	1.24	1.29	1.34
3	22/4	0.082		0.123	0.163		
	29/4	0.857	0.00	0.214	0.214	0.214	0.186
	7/5	0.07	0.14	0.035	0.035	0.00	0.035
	9/5	0.75	0.79	0.79	0.83	0.79	
	13/5	0.62	0.82	0.93	1.13	0.00	0.34
4	22/4	0.204	0.367				
	29/4	0.295	0.027	0.107	0.00	0.214	
	7/5	0.07	0.035	0.07	0.07	0.07	0.114
	13/5	0.72	0.67	0.88	0.62	0.31	0.62

Table 12. Atomic absorption analyses for heavy metals of water and mud samples (concentration in ppm).

Oufall stations	WATER Cu	Pb	Zn	Cr	Ni	MUD Cu	Pb	Zn	Cr	Ni
1B	0.09	2.0	0.14	2.0	6.0	5	17	28	122	73
1C	0.05	2.6	2.15	2.0	6.0	5	18	34	62	43
2A	0.12	1.3	0.21	3.8	6.0	9	17	34	63	43
2B	0.05	2.7	0.14	2.0	5.0	8	18	38	63	69
2C	0.11	1.7	0.29	2.5	6.0	8	17	61	64	47
3A	0.09	1.3	0.14	2.0	7.0	20	33	25	63	76
3B	0.12	2.1	0.14	2.5	6.0	6	32	17	125	60
4A	0.05	1.2	0.50	2.5	7.0	15	67	46	312	125
4B	0.05	2.7	0.14	2.0	5.0	6	33	18	125	60
4C	0.05	2.7	0.14	2.5	6.0	3	58	39	125	43

6. Annexes

In this annex two reports are presented that contain complementary information to the subject discussed above. One deals with the possible distribution of water bodies in the Sierra Leone River Estuary, while the second one reviews articles being written on various species assemblages of the Estuary, covering plancton, the benthic community and the fishery

6.1 A Suggested Pattern of Water Bodies Within the Sierra Leone River Estuary from a Study of Temperature/Salinity Profiles Along Outfalls Under Investigation

Layering resulting from the intrusion of oceanic water into the Estuary during ebb tide in the dry season, produces a complex pattern of water bodies which could be easily discerned from their color. Distinct lines which are glossy or smooth and shiny when viewed from above indicate the areas where these bodies of water meet. These lines are not only marked by debris, detritus, empty tin cans, piassava and used plastics but also by large quantities of untreated sewage. The lines tend to run parallel to the estuarine shore along the long-axis of the estuary. During recent investigations, results of which are shown in Figs. 3 and 4, it was apparent that at least three types of water could be present in the estuary at low tide (Fig. 5). These diagrams also throw some light on a possible movement of water in the Estuary. The three types of water which could be present in the Estuary at low tide are:

(i) bay water, which is found in the bays along the southern shores of the Estuary;

(ii) estuary water which extends from the bays to about 250 m off the mainland; and

(iii) oceanic water which extends from midstream to the Bullom shore.

Bay water

This water which is either brown or yellow in color appears to be of the poorest quality, being heavily polluted with organic materials - refuse, garbage, sewage and oil which are being dumped into streams that empty into the bays by the local Freetown population and the Sierra Leone Oil Refinery at Kissy. Three species of fouling organisms, *Crassostrea tulipa* (oyster), *Balanus amphitrite* and *Cthamalus stellatus* (barnacles) characterize this body of water. These species are known to settle on piers and steel pipes and in the latter case blocking the sea water intake pipes in the cooling systems of the electricity generators of the Sierra Leone Electricity Corporation at Kingtom. In the dry season, this body of water appears to be more or less permanently locked up in the bays with little or no mixing with the estuary water. These bay waters apparently move upstream when the tide at mid-stream in the Estuary is running out (ebbing). The water is highly mixed probably due to wave action along the shore (Figs. 3 and 4). The area occupied by this body of water extends about 5 to 10 m outside the mouth of the bays and only about 10 m offshore at the headlands. The depth of this body of water ranges from 0 m at the shore to about 10 m offshore.

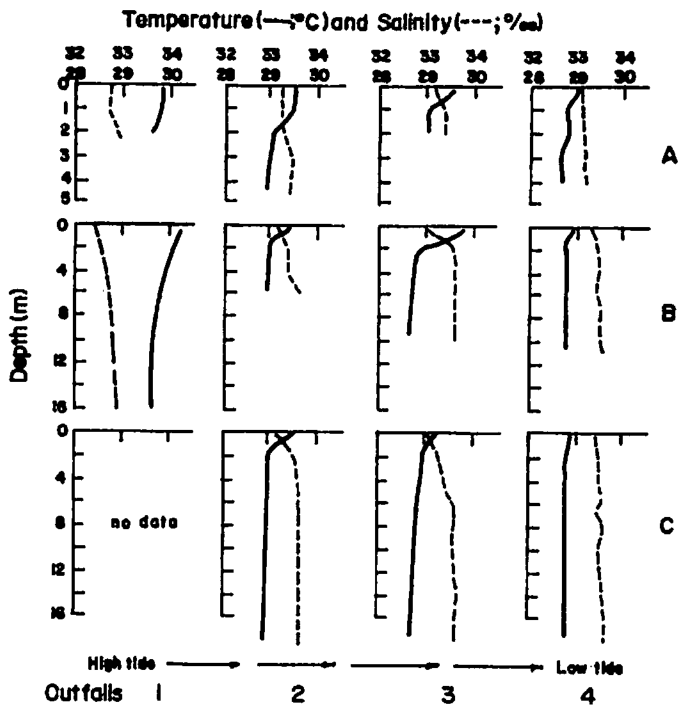

Figure 3 Temperature/salinity profiles at three stations 10 m (A), 50 m (B) and 100 m (C) offshore at each outfall site along the northern shores of the Sierra Leone Peninsula on May 7, 1980.

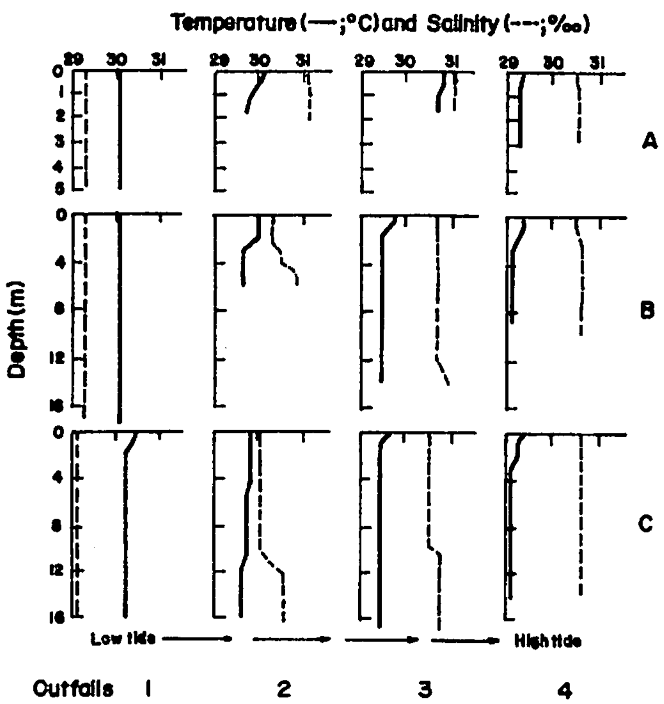

Figure 4 Temperature/salinity profiles at three stations 10 m (A), 50 m (B) and 100 m (C) offshore at each outfall site along the northern shores of the Sierra Leone Peninsula on May 13, 1980.

Estuary water

The estuary water, which is usually green or light brown in color lies between the bay waters and the more or less oceanic water at the middle of the Estuary. It is separated from the bay water by a distinct front-line (which is termed here as the bay water discontinuity) and from the oceanic water offshore by the estuarine front-line. This body of water appears to be mostly stratified during the dry season (Figs. 3 and 4) although the depth at which the thermocline lies does not exceed 5 m. At most, the thermocline is about 2 m below the surface. Organic pollution is relatively low although it increases in an upstream direction. Decaying parts of plants form the bulk of suspended matter in this body of water. The water is characterized by typically estuarine species of zooplankton, e.g., *Temora turbinata* and *Schmeckeria serricaudatus*.

Oceanic water

Oceanic water occupies the deep channel and the middle ground areas. Patches of this water type could be seen floating within the estuary water. Although the formation of these clean, clear, blue/green patches of water in the Estuary is unknown nevertheless it is suggested that knowledge gained from studies on their origin, growth, movements and decay, would throw light on the dissipation of pollutants and the flushing rate of the estuary water. The presence of oceanic water in the Estuary can be noted by the occurrence of *Sagitta enflata* which is a zooplankton species common in the continental shelf of Sierra Leone. The oceanic water invading the Estuary is not stratified probably due to the high current velocities experienced within it.

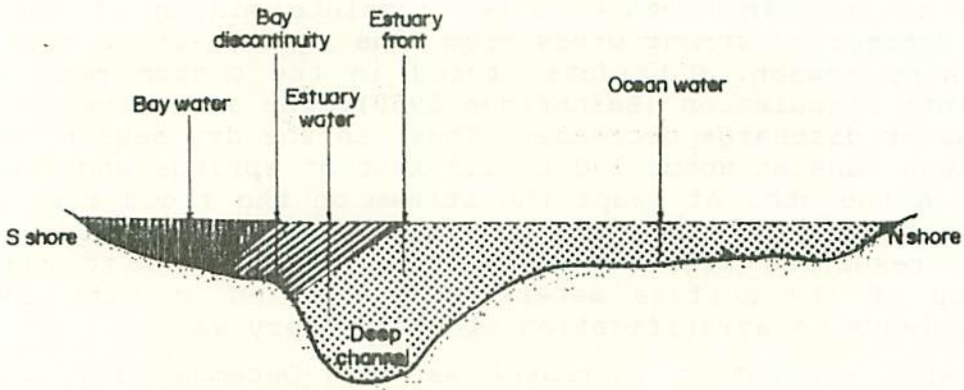

Figure 5   A schematic cross-section of the estuary showing water-types front and discontinuity at low tide.

6.2 Review of Articles on the Sierra Leone River Estuary

6.2.1 Plankton of the Sierra Leone River Estuary

The Sierra Leone River Estuary is located in a geographical region which experiences two clearly defined climatic seasons: a rainy season which starts in April or May and continues to October or November and a dry season from October or November to April or May. Frequent line squalls in May and again in October herald the beginning and end of the rainy season. Monthly maximum rainfall occurs either in August or September. Sea water temperature drops to a minimum during this season due to increased cloud cover resulting from the invasion of the area by the southwest monsoon or equatorial maritime airmass from the Atlantic in the south and west.

During this season numerous streams and rivers which drain the northern part of the Freetown Peninsula and the catchment area of the Sierra Leone River, discharge large volumes of fresh water and consequently decreasing the salinity of the estuary water. Thus, the month of minimum salinity (August or September) of the estuary water coincides with the month of maximum rainfall in the area. The velocity of the stream just outside Freetown then becomes much greater than in the dry season, sometimes running at a rate of 5.0 knot on the ebb.

Turbidity is greatly increased due to intense mixing of the estuary water by strong winds and the introduction of debris and detritus resulting from increased run off from the land.

Zooplankton numbers decline likewise due to the intense flushing of the Estuary by fresh water (Leigh 1973), the dilution effect of which can be felt almost 200 miles outside the Estuary's mouth and over the Sierra Leone continental shelf (Watts 1958). Instability of the estuary water and reduced light intensity militate against phytoplankton production at this time when in general nutrient concentrations separating different bodies of water, e.g., bay waters and estuary waters, disappear due to the intense mixing. In general, the whole Estuary appears to be completely flushed and cleaned physically during the rainy season.

Stability returns in November after complete mixing of the estuary water in October by strong winds from line squalls which mark the end of the rainy season. Nutrients stored in the bottom muds are then brought into circulation (Bainbridge 1960). The stream velocity drops as freshwater discharge decreases. Thus, in the dry season the stream on the flood runs at about 1.0 to 1.5 knot at springs and from 2.0 to 2.5 knot on the ebb. At neaps the stream on the flood runs at about half a knot and on the ebb at about 1.0 knot. Increase solar radiation resulting from reduced cloud cover leads to the direct warming up of the surface waters which coupled up with increasing stability leads to stratification of the estuary water.

Phytoplankton production increases as from December followed by an increase in the numbers of zooplankton in January and February. Rapid intake of nutrients by the phytoplankton reduces the nutrient concentration to only trace levels.

Reduced freshwater discharge facilitates the intrusion of oceanic water into the Estuary at the bottom (Watts 1958). This condition is more pronounced at neaps than at springs. As a result of this and extreme evaporation of the surface water, salinity gradually increases reaching a maximum in May or June. The intrusion of cold bottom oceanic water into the Estuary and the prevailing Harmattan winds (dust laden) depress water temperatures at a time when the salinity is intermediate between the maximum and minimum for the year. Leigh (1973) has shown that two of the main factors affecting the abundance and distribution of plankton in the Estuary are salinity and temperature. Thus, lower water temperatures and optimum salinities probably favor the high standing stock of plankton found in the middle reaches of the Estuary in the middle of the dry season.

As the dry season progresses, sea water temperatures increase reaching a second peak in either April or May. This coincides with the retreat of the Harmattan northwards. Plankton production declines as from February probably because of increased water temperatures and salinity. The decrease continues gradually until May or June when increased freshwater flow from the land flushes out the plankton in the estuary into the sea.

From the foregoing, the pattern of plankton production is such that from the end of the rainy season to the middle of the dry season, a high standing stock of plankton builds up in the region covering the mouth and middle reaches of the Estuary. During this period (October to February), the salinity and temperature of the water in the two areas suggest a penetration of sea water into the Estuary as freshwater discharge decreases. The cladoceran, *Penilia avirostris;* the copepod, *Temora turbinata;* and numerous species of phytoplankton, *Biddulphia, Coscinodiscus, Rhizosolenia, Tricodesmium, Thalassiothrix,* and *Thalassiosira*, become very abundant.

From March to June, the estuary water becomes more saline, and with a slightly higher temperature, there follows a subsequent drop in plankton production. However, slightly higher numbers of plankton are maintained by addition from members of the benthic community by turbulence caused by squalls at the beginning of the rainy season. With the start of the rainy season, salinity begins to fall as rainfall and run-off from the catchment area increases. Plankton production declines likewise with a few individuals of typical estuarine species forming the bulk of the plankton.

6.2.2 The Benthic Community of the Sierra Leone River Estuary

The role of the nature of the bottom deposits in determining the distribution of the benthic organisms is of great significance and has in fact been used by Jones (1950) as the basis of his classification of the animal communities in the Atlantic boreal regions. Based on a similar biocoenosis classification Longhurst (1958) has identified the following assemblages of benthic organisms in the Sierra Leone River Estuary:

1) The *Venus* community - occurring near the mouth of the Estuary, or in the deep channel as far up as No. 1 buoy on shelly-sand and fine lateritic gravel.

2) The *Amphioplus* sub-community - occurring on muds, shelly-mud and sandy-mud in the mid-estuarine region.

3) The *Venus/Amphioplus* transition - occurring only in the Estuary where the two communities integrate in the lower sections of it. It becomes progressively less common towards Tasso Island, the upper limit of its occurrence.

4) The *Pachymelania* community - occurring on deposits of coarse sand in the upper estuarine region.

5) The Estuarine gravel community - occurring on lateritic gravel in the deep channel of the Sierra Leone River.

The *Venus* community contains a predominance of periferans, nemerteans, small crustaceans, pagurid, procellanid and brachyuran crabs, gastropods, suspension feeding lamellibranchs, asteroids, echinoids and ascidians. Similarly, the *Amphioplus* sub-community has a few species of all these groups, and a dominance of gephyreans, thalasanid crustaceans, polychaetes, deposit feeding lammelibranchs and ophiuroids. The composition of the *Venus/Amphioplus* transition is in some groups intermediate between the two main communities, while in others it has characteristics of its own.

The *Pachymelania* community replaces the *Amphioplus* community at the upper reaches of the Estuary and the subsidiary creeks It contains the bulk of the truly estuarine species. The members are found on sands and muddy sands which are common high up the creeks, with the filter-feeding gastropod *Pachymelania aurita* being the most dominant.

The estuarine gravel community, occurs on the patches of lateritic gravel that are found in the Sierra Leone River where the bottom currents are most intense. The fauna here is specialized, consisting mostly of sedentary, epifaunal organisms. The characteristic species are *Astrangia* sp., *Actinian* sp., *Thelepus* sp., *Balanus amphitrite*, *Aspidosiphon venatulum* and *Arca imbricata*.

In the Sierra Leone River Estuary there appears to be little overlap between the *Amphioplus* sub-community and the *Pachymelania* community which replaces it at the heads of estuaries and creeks. The upper limit of the *Amphioplus* sub-community lies in the region of the Bunce Island in the main estuarine axis. Above the island the muddy sand deposits are very sparsely populated and the muddy deposits inhabit a fauna clearly related to the *Pachymelania* community. The seaward limit of the sub-community corresponds to the boundary between the relatively soft estuarine deposits and the hard shelly-sand grouped around the mouth of the Estuary.

The assemblages that may be affected by the discharge of untreated sewage into the Estuary are therefore the *Venus* and the *Amphioplus* communities and the *Venus/Amphioplus* transition. The characteristic species of these communities are listed below.

Venus community: Branchiostoma leonense, Aloidis sulcata, Astropecten sp., Turris carbonarea, Luidia alternata, Modiolus stultorum, Astrangia sp., Oliva accuminata, Rotula orbiculus.

Amphioplus community: *Upogebia furcata, Callianassa balssi, Alpheus pontederiae, Acrocnida semisquamata, Amphioplus congensis, Clymene monilis, Pectinaria sourei, Squilla africana, Marginella amygdala, Natica marochiensis, Cerebratulus sp., Iphigenia laevigate, Cultellus tenuis, Clibinarius cooki.* The clams *Tellina angulatus, Talona explanata, Macoma cumana, Arca senilis* and *Tellina nymphalis* are abundant in the intertidal areas.

Venus/Amphioplus transition: There are no species characteristic of these assemblages, however the assemblages in the Estuary consist mainly of an *Amphioplus* sub-community with the addition of isolated individuals from the *Venus* community. The members from the *Venus* community are *Nassa tritoniformis, Olivia* sp., *Pusionella nifat, Luidia alternata, Astropecten michaelseni, Rotula orbiculus,* and *Brachiostoma leonense. B. leonense* and *Upogebia* sp. occur in their greatest densities in the *Venus* and *Amphiolus* sub-community respectively. The *Pachymelania* community members are *P. aurita, Iphigenia truncata, Aloidis trigona, Neritina glabrata, Neritina oweniana.*

6.2.3 Commercially important shrimps found in the Sierra Leone River Estuary

Shrimps represent a principal fishery resource of Sierra Leone waters. The shrimp industry of Sierra Leone is based on four species of the family Penaeidae namely *Penaeus notialis* (the pink shrimp), *Penaeus kerathurus* (tiger shrimp), *Parapenaeopsis atlantica* and *Parapenaeus longirostris*.

Of these, only *P. notialis*, *P. atlantica* and *P. kerathurus* are found in the Sierra Leone River Estuary. They occur mostly in the main axis of the Estuary on sandy-mud and muddy-sands; with only *P. atlantica* penetrating into the creeks.

Spawning occurs offshore, and the larvae and post-larvae are normally planktonic in offshore waters. Upon reaching a certain size, they enter the estuarine nursery grounds where they become benthic, congregating in waters generally less than 1 m deep (i.e., the shallows). Eventually the rapidly-growing juveniles migrate from the shallows into deeper waters of the estuary before returning to the sea.

Penaeid larvae subsist on yolk granules until the protozoa I stage, when feeding commences (Lindner and Cook 1970; Cook and Lindner 1970; Costello and Allen 1970). Lindner and Cook (1970) consider shrimp to be selective and particulate feeders. Their observations reveal that shrimp select food items after searching through sand grains with their pereiopods. Williams (1955), however, suggests that any available organic material may be ingested. Although shrimp are able to ingest a wide variety of potential food items, much of the actual material digested is believed to consist of soft parts, because large, hard fragments cannot pass through the straining apparatus of the pyloric stomach (Williams 1955).

6.2.4 Oysters

The creeks and bays of the Estuary are bordered by mangrove trees on the roots of which occur the mangrove oysters, *Crassostrea tulipa*. The oysters are active during larval life (10-12 days) and become sessile when they settle on the roots of mangroves and other solid objects for the rest of their life. Oysters are filter-feeders and the discharge of untreated domestic sewage has a threefold effect on them. It covers the bottom with a sludge which smothers the oyster bed, affects the normal functions of molluscs by reducing the oxygen content of the water, and at the same time greatly increases the bacterial content of the water.

Oysters, in common with other water-filtering molluscs, retain and accumulate these bacteria in their bodies.

6.2.5 The Sierra Leone River Estuary Fisheries

The fishery resources of Sierra Leone are of two kinds - pelagic and demersal. The pelagic fish species live in the surface waters and feed on other fish or plankton, whereas the demersals feed largely on the benthos living on the bottom.

Pelagic fish species

The main pelagic fishe species of commercial importance in the Sierra Leone River Estuary are members of the Clupeid family, namely, *Ethmalosa fimbriata, Sardinella maderensis,* and *Ilisha africana*. Not much work has been done on the biology and ecology of the latter.

E. fimbriata is called by various names according to the size (Watts 1963). They are awefu, bonga and bonji or cowre bonga, and they refer to the immature, mature and extra large fish respectively. Salzen (1958) gave the modal lengths of this species caught in the Estuary as follows: awefu about 120 to 150 mm; bonga about 280 mm; and bonji about 330 to 390 mm. These size classes probably refer to first, second and third year classes. Watts (1963) observed that bonga formed the bulk of the catch within the Estuary and bonji in the open sea, the average modal length of *E. fimbriata* from the Estuary being 270 mm and outside the Estuary about 310 to 350 mm.

Salzen (1958), Postel (1950) and Watts (1963) have shown that the *Ethmalosa* fishery in West Africa is to a large extent seasonal, the fish entering the estuarine areas during the dry season and disappearing with the onset of the rains. The bonga is euryhaline (tolerant of salinities ranging from 11 to 42%) and is thus able to enter estuarine areas of low salinity. The tagging experiments of Longhurst (1960) suggest that a considerable exchange of individuals or shoals takes place between the Estuary and offshore banks as far north as the border with Guinea. Since Bainbridge (1961) did not find eggs or larvae of *Ethmalosa* in the Estuary he felt that no appreciable spawning takes place in it. He suggested that spawning takes place in the vicinity of the shallow offshore banks and that after metamorphosis the young migrate inshore.

Bainbridge (1957) found that adult *Ethmalosa* are relatively non-selective feeders and that those caught within the Estuary during the dry season are feeding intensively on phytoplankton, thus increasing their fat content (Watts 1957b). Bainbridge (1960) however felt that the aggregation of *Ethmalosa* in the Sierra Leone River during the dry season is probably related to the very high standing crop of diatoms present at that time of the year.

A more detailed study of the feeding habits of *Ethmalosa* in the Lagos Lagoon, Nigeria has been done by Fagade and Olaniyan (1971). They identified three size groups according to their food namely 35 to 69 mm, 70 to 169 mm and 170+ mm.

The food of the 35 to 69 mm size range comprised of zooplankton (mainly copepods) and the large centric diatoms, *Biddulphia* and *Coscinodiscus*. That of the 70 to 169 mm size group was found to be largely zooplankton, with the copepod *Acartia* sp. dominating the stomach contents. In the 170 mm and above size group diatoms, zooplankton and unidentified organic matter appeared in large quantities. The large centric diatoms, *Coscinodiscus* and *Biddulphia* form 19.6% of the stomach contents, the zooplankton, 20.3%, sand grains, 1.4% and unidentified organic matter, 58.6%.

The 170 mm and above size group has a slightly different diet from the bonga of the Sierra Leone River Estuary as the centric diatoms formed the major part of their food. It does appear that with increase in size, more phytoplankton is taken as food by *Ethmalosa*.

There are two main species of *Sardinella* in the waters of Sierra Leone. They are *S. aurita* and *S. maderensis*. *S. maderensis*, like the bonga is, euryhaline and *S. aurita* is stenohaline with a salinity tolerance of only 1%.

S. aurita is an offshore species which seems to be restricted to a zone twenty miles from the coast (Longhurst 1963).

S. maderensis is most abundant in the shallow coastal waters. Information received from the Fisheries Division, Ministry of Natural Resources, indicate that this fish spawn in October outside the Estuary. After spawning they migrate to the Estuary where they develop to a size of 180 mm during the dry season. The migration of spent *S. maderensis* out of local coastal waters was evident from their absence in commercial landing samples and samples taken at sea by the *Sardinella* Project vessel during the FAO Pelagic Fisheries Survey in 1970. Juvenile fish measuring 50 to 110 mm are usually abundant and distributed throughout the Estuary from October to April. It appears that during the rains the fish migrate out of the Estuary and offshore since few juveniles were found in inshore areas during the rains.

The diet of *S. maderensis* is composed mainly of zooplankton (copepods). Larvae and juveniles of the tunas have also been encountered in the Estuary.

Demersal fish species

The biology of the demersal species has been studied by a number of workers including Fager and Longhurst (1968), Longhurst (1957, 1962, 1965, 1966) and Watts (1959). Like the pelagic, the estuarine fauna is very similar in composition to the ichthyofauna of the coastal waters of Sierra Leone. The two kinds of fauna have been described with respect to the thermocline by Longhurst (1962, 1966) the Sciaenid fauna and the Sparid fauna. This thermocline is absent in the Estuary, consequently, adult Sparids are absent. The fauna is essentially mixed. The following are the important demersal species within the Estuary:

Family	Genus/species
· Sciaenidae	*Pseudotolithus elongatus,* *P. senegalensis,* *P. brachygnatus,* *P. typhus*
· Polynemidae	*Galeoides decadactylus* *Pentanemus quinquarius* *Polydactylus quadrifilis*
· Drepanidae	*Drepane africana*
· Pomadasydae	*Pomadasys jubelini,* *Pomadasys peroteli*
· Cynoglossidae	*Cynoglossus senegalensis,* *Cynoglossus goreensis*
· Aridae (catfish)	*Arius gambensis,* *Arius heudoloti*
· Squalidae	*Scoliodon sp.*
· Pristidae	*Pristis sp.*
· Dasyatidae	*Dasyatis margarita*

Very little is known about the biology of the demersal species as a group within the Estuary with the exception of a few, such as *Pseudotolithus elongatus*. Watts (1959) reported on some marking experiments on the more common demersal species in the Sierra Leone River Estuary. He found that there was little interchange of the estuarine fish stocks with the stocks on the open shelf.

Generally, Sciaenids prefer shallow waters where temperature averages are about 27°C. The distribution of the species is also related to both the bottom characteristics and salinity.

These species like most tropical species are short-lived with an average of between 3-5 years. Some of the species are perhaps better suited to estuarine life than the open sea and grow larger. These include the sole (*Cynoglossus senegalensis, C. gorensis*) and the catfishes (*Arius* sp.). The abovenamed species are strongly euryhaline. The Drepanidae and Polynemidae show limited tolerance to changes in salinity and prefer medium-mud sandy conditions.

Among the Sciaenidae, *P. elongatus* penetrates deeply into the upper reaches of the Estuary off the grounds at Rogbaray and Potko. The stingray, *Dasyatis margarita* are very common. Within the Estuary most of the demersal species breed during the dry season (September-April).

Longhurst (1957, 1960) has studied the food and feeding habits of demersal fishes in the Sierra Leone River Estuary. He identified three types of feeding habits namely:

(i) those that feed on fish (Icthyophages);

(ii) those that feed on active epifauna and fish; and

(iii) those that feed on sedimentary epifauna and infauna.

These three types closely fit the classification system proposed by Lagler et al. (1977) as predators, grazers and suckers. The main predatory species listed by Longhurst (1966) are *Pristis* and *Pseudotolithus senegalensis*. To this list could be added *Sphyraena* sp. The minor prey species taken by these predators are Penaeids, Brachyura, Stomatopoda, Polychaeta and Cephalopoda. The major grazers are Ariidae, *Lutjanus* sp., *Pseudotolithus elongatus, Pseudotolithus senegalensis* and *Polydactylus quadrifilis*. The prey species are Penaeids, Brachyura, Mysids and Cumacea, Stomatopoda, Polychaeta, Amphipoda, Gastropoda, Lamellibrachia, Cephalopods, Ophuiroidae and fish. The Polychaeta, Molusca and Crustacea are most important. The most important prey species are given in Table 13.

Table 13. Major food organisms of grazers.

Polychaeta	Crustacea	Mollusca	Echinodermata
Glymene monolis	*Panopeus africanus*	*Surcula coerula*	*Ophiuroidea* sp.
Pectinaria sourei	*Menippe nodifrons*	*Tellina* sp.	*Holothuria* sp.
Goniada multidentata	*Callianassa balsii*	*Donax oweni*	
Nereid sp.	*Aquilla africana*	*Glycimeris* sp.	
	Amphipoda sp.		
	Callinectes sp.		

Major suckers are Dasyatis margarita, Drepane africana, Galeoides dacadactylus, Cynoglossus goreensis, Gerres melanopterus and Pomadasys jubelini. The major prey species are listed in Table 14.

Table 14. Major food organisms of suckers.

Polychaeta	Crustacea
Clymene monilis	*Squilla africana*
Pectinaria sourei	*Latiuetus parvalus*
Diopatia neapolitanea	*Parapenaeopsis atlantica*
Gylcera convoluta	*Polyonix sp.*
Terebellid sp.	*Callianassa balsii*
Lumbrinecis impatiens	*Alpheus pontederiae*
	Porcellana longicornis
	Lyosquilla septenspinosa

Longhurst (1957, 1960) pointed out that there were a high percentage of empty stomachs during the rainy season and that in general the icthyophagous fish tend to have a higher proportion of empty stomachs. Also there was a general tendency for smaller-sized fishes of the same species to have proportions of empty stomachs. This latter observation may well be due to regurgitation.

Generally the suckers are able to take a wider variety of foods and the harder species such as Mollusca and Echinodermata.

REFERENCES

Admiralty Hydrographic Department. 1953. Africa pilot, Part I. London.

Aleem, A.R. and D.E.B. Chaytor. 1980. Further observations on the marine mollusca of Sierra Leone. Bull. IFAN, T 42 Ser. A(3): 571-585.

Allsopp, W.H.L. 1969. Aquatic weed control by manatees - its prospects and problems, p. 344-351. *In* L.E. Obeng (ed.) Man-made lakes: the ACCRA Symposium. Ghana University Press, Ghana.

Bainbridge, V. 1957. Food of *Ethmalosa dorsalis* (Cuvier and Valenciennes). Nature (Lond.) 179:874-875.

Bainbridge, V. 1960. The plankton of the inshore waters off Freetown, Sierra Leone. HMSO Fish. Bull. 13:1-48.

Bainbridge, V. 1961. The early life history of the bonga *Ethmalosa dorsalis* (Cuvier and Valenciennes). J. Cons. Perm. Int. Explor. Mer. 26:347-353.

Bendschneider, K. and R.J. Robinson. 1952. A new spectrophotometric method for the determination of nitrate in sea water. J. mar. Res. 11:87-96.

Bookhout, C.E. and R.J. Monroe. 1977. Effects of Malathion on the development of crabs. Reprint from Physiological Responses of Marine Biota to Pollutants.

Christianson, M.E., J.D. Costlow and R.J. Monroe. Effects of the insect growth regulator Dimilin^{R} (TH6040) on the development of two estuarine crabs. (unpublished)

Clarke, J.I. 1966. Drainage, p. 16-17. *In* J.I. Clarke (ed.) Sierra Leone in maps. University Press Ltd., London.

Cook, H.L. and M.J. Lindner. 1970. Synopsis of biological data on the brown shrimp *Penaeus aztecus aztecus*, Ives, 1891. FAO Fish. Rep. 57(4):1471-1497.

Costello, H.L. and M.J. Linder. 1970. Synopsis of biological data on the pink shrimp *Penaeus duorarum duorarum*. FAO Fish. Rep. 57(4):1499-1537.

Costlow, J.D., C.G. Bookhout and R.J. Monroe. 1966. Studies on the larval development of the crab *Rhithropanopeus harrisii* (Gould) (I). Phys. Zool. 39(2).

Crosnier, A. 1963. Fonds de peche le long de la Republique Federal du Cameroun. ORSTOM (Mimeo). 66 p.

Crosnier, A. 1964. Fonds de peche le long des côtes de la Republique du Cameroun. Cahs. Oceanogr. 133 p.

Dixey, F. 1919. Pleistocene movements in Sierra Leone. Trans. Geol. Soc. S. Afr. 22:1-112.

Fagade, S.O. and C.I.O. Olaniyan. 1971. The biology of the West African shad *Ethmalosa fimbriata* (Bowdich) in the Lagos Lagoon, Nigeria. J. Fish Biol. 4:519-533.

Fager, E.W. and A.R. Longhurst. 1968. Recurrent group analysis of species assemblages of demersal fish in the Gulf of Guinea. J. Fish. Res. Board. Can. 25:1405-1421.

Findlay, I.W.O. 1978. Marine biology of the Sierra Leone River Estuary. I. The physical environment. Bull. Inst. Mar. Biol. Oceanogr. (Sierra Leone) 3:48-64.

Garcia S. 1974. Biologie de *Penaeus duorarum notialis* en Côte d'Ivoire. 4. Relations entre la repartition et les conditions du millieu. Etude des variations de sex-ratio. Doc. Sci. Cent. Rech. Oceanogr. Abidjian ORSTOM 5(3-4):1-39.

Grasshoff, K. 1964. Zur Bestimmung von Nitrat in Meer- und Trinkwasser. Kiel. Meeresforsch. 20:5-11.

Gregory, S. 1962. The raised beaches of the Peninsula area of Sierra Leone. Trans. Paps. Inst. Brit. Geog. 31:15-37.

Gregory, S. 1966. Rainfall, p. 20-21. *In* J.I. Clarke (ed.) Sierra Leone in maps. University Press Ltd., London.

HMSO. 1969. The bacteriological examination of water supplies. HMSO Report 71. Department of Health and Social Security, London.

Jones, N.S. 1950. Marine bottom communities. Biol. Rev. 25:283-313.

Jordan, H.D. 1964. The relation of vegetation and soil to development of mangrove swamps for rice growing in Sierra Leone. J. Appl. Ecol. 1:209.

Kalle, K. 1951. Einige Vereinfachungen der Chlor-Titration für biologische und wasserbaukundliche Zwecke in Küstengewässern. Deutsch. Hydrogr. Z. 4:13-16.

Kamara, A.B. and K.B. McNeill. 1976. Preliminary oyster culture experiments in Sierra Leone. Occasional Paper No. 1.

Koroleff, F. 1969. Direct determination of ammonia in natural waters as indophenol blue. ICES C.M. 1969/C:9.

Lagler, K.F., J.E. Bardach and R.R. Miller. 1977. Ichthyology. John Wiley & Sons, New York. 506 p.

Leigh, E.A.M. 1973. Studies on the zooplankton of the Sierra Leone Riverine Estuary. M.Sc. Thesis, University of Sierra Leone. 223 p.

Lindner, M.M. and H.L. Cook. 1970. Synopsis of biological data on the white shrimp *Penaeus setiferus* (Linn 1767). FAO Fish. Rep. 57(4):1439-1469.

Longhurst, A.R. 1957. The food of the demersal fishes of a West African Estuary. J. Anim. Ecol. 26:369-387.

Longhurst, A.R. 1958. An ecological survey of the West African marine benthos. HMSO Lond., Fish Publ. 11, 102 p.

Longhurst, A.R. 1960. Local movement of *Ethmalosa fimbriata* off Sierra Leone from tagging data. Bull. IFAN 22:1337-1340.

Longhurst, A.R. 1962. A review of the oceanography of the Gulf of Guinea. Bull. IFAN 24:633-663.

Longhurst, A.R. 1963. The bionomics of the fisheries resources of the eastern tropical Atlantic. HMSO Lond., Fish. Publ. 20, 66 p.

Longhurst, A.R. 1965. A survey of the fish resources of the eastern Gulf of Guinea. J. Cons. 29:302-334.

Longhurst, A.R. 1966. Species assemblages in tropical fisheries, p. 147-148. Proceedings of the Symposium on Oceanography and Fisheries Resources of the Tropical Atlantic. UNESCO, Rome.

Monod, Th. 1966. Crevettes et crabes de la côte occidentale de L'Afrique. Memoir IFAN No. 77.

Murphy, J. and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta 27:31-36.

Okera W. 1978. Fishes taken by the beach seines fishing at Lumley, Freetown (Sierra Leone). J. Fish. Biol. 12: 81-88

Postel, E. 1950. Poissons de surface: campagne de chalutier 'Girard Treca'. Peche sur les côtes d'Afrique Occidental 2:1-77.

Quayle, D.B. 1969. Pacific oyster culture in British Columbia.

Salzen, E.A. 1958. Observations on the biology of *Ethmalosa fimbriata*. Bull. IFAN 18:335-371.

Shinn, M.B. 1941. Calorimetric method for determination of nitrite. Ind. Eng. Chem. (Anal. ed.) 13:33-35.

Solorzano, L. 1969. Determination of ammonia in natural waters by the phenol hypochlorite method. Limnol. Oceanogr. 14:799-801

Strickland, J.D.H. and T.R. Parsons. 1968. A practical handbook of sea water analysis. Fish. Res. Board. Can. Bull. 167, 311 p.

Taylor, F.J. 1966. Phytoplankton in the Sierra Leone River. J.W. Afr. Sci. Ass. 11:107-122.

Thompson-Hayward Chemical Company. 1974. (TH6040) Insect Growth Regulator. THCC Tech. Inf. 2:1-25.

Wattenberg, H. 1957. Die Verteilung des Phosphats im Atlantischen Ozean. Wiss. Ergbn. dtsch. atlant. Exped. "Meteor" 9:133-180.

Watts, J.C.D. 1957a. The chemical composition of the bottom deposits from Sierra Leone River Estuary. Bull. IFAN 19:1020-1029.

Watts, J.C.D. 1957b. The chemical composition of West African fish. I. The West African shad, *Ethmalosa fimbriata* (Cuvier and Valenciennes) Bull. IFAN. 19:539-54.

Watts, J.C.D. 1958. The hydrology of a tropical West African estuary. Bull. IFAN 20:697-752.

Watts, J.C.D. 1959. Some observation on the marking of demersal fish in the Sierra Leone River Estuary. Bull. IFAN 21:1237-1252.

Watts, J.C.D. 1961. Seasonal fluctuations of nitrite in a tropical West African estuary. Nature (London) 191:929.

Watts, J.C.D. 1963. A note on *Ethmalosa fimbriata* (Bowd) from Sierra Leone. Bull. IFAN 25:235-236.

Williams, A.B. 1955. A contribution to the life histories of commercial shrimps (Penacidae) in North Carolina. Bull. Mar. Sci. (Gulf Caribb.) 5:117-146.

Wood, E.D., F.A.J. Armstrong and F.A. Richards. 1967. Determination of nitrates in sea water by cadmium-copper reduction to nitrite. J. mar. Biol. Ass. UK 47:23-31.