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Tuna Baitfish in Fiji and Solomon Islands

Proceedings of a workshop, Nadi, Fiji
17–18 August 1993

Editors: **S.J.M. Blaber, D.A. Milton and N.J.F. Rawlinson**

Contents

Introduction

Tuna are fished throughout the tropical and temperate waters of the world using three main methods: purse seining, longlining and pole-and-line fishing. The pole-and-line fishery is a low-cost high employment fishing technique compared to the purse seiners method. The move to high-capital low employment and high technology resources of purse seiners has increased in the American, and to a lesser extent, Japanese tuna fishing fleets. Most of the tuna catch of the Solomons, Kiribati, and Fiji is made using the traditional pole-and-line method. This technique cannot operate without a regular and adequate supply of suitable baitfish species. These are small fish which are thrown live into the sea to attract tuna schools within fishing range of the boat. The tuna industry is vital in the Solomons, Kiribati and Fiji where it provides a major source of food, much employment and high export earnings.

In Solomon Islands a locally-based commercial tuna fishing industry was established in 1971. It has now developed into a major earner of foreign exchange and is the largest employer in the private sector. One of the objectives of the Fisheries Sector Development Program 1985–90 (Fisheries Division, Ministry of Natural Resources, 1985) was to improve the foreign exchange position of Solomon Islands by import substitution and commercial fisheries by further investments into practical research orientated projects. In 1988 some 35 000 t of tuna were exported from Solomon Islands, earning over $A40 million in export revenue. The pole-and-line fishery in the Solomons is well established and is the basis of a Solomons – Japanese joint venture with boat building facilities, docks and established 'in-country' training capacity. Currently there are 36 pole-and-line vessels operating. Due to the existing training and building infrastructure for the pole-and-line industry, and the low cost of pole-and-line vessels it will be the main method of catching tuna in the medium and long term. The current and future viability of the pole-and-line fleet depends upon an understanding of the fundamentally important baitfish resource. This resource was the subject of a comprehensive ACIAR-funded study from 1986–1989. It has provided a sound base of biological information on which to manage the fishery. With such a sound understanding of the biology of the baitfish, rational management practices can be initiated to ensure a continuing supply of baitfish in the face of overfishing and an expansion of the tuna fishery. Although baitfishing serves the commercial fishery of the Solomons, it is characteristically an artisanal activity and must not conflict with the needs of the traditional owners of the reefs where the baitfish are caught, particularly with regard to the ecological relationships between baitfish and their fish predators, the latter forming the basis of traditional reef fish fisheries. The ACIAR/CSIRO Baitfish Research Project (BRP) showed clearly that baitfishing has little direct effect on reef fisheries in the Solomons and hence that restrictions on baitfishing (and hence tuna fishing) were not warranted for this reason.

The results from the BRP engendered much interest throughout the South Pacific and led to the incorporation of Kiribati mid-way through the project.

Tuna are the largest natural resource of Kiribati and the tuna fishery is the most important industry in terms of employment and foreign currency earnings. A commercial pole-and-line fleet is based at Tarawa. The success of these vessels depends upon an adequate supply of baitfish. A shortage of naturally occurring baitfish is considered a major constraint to further expansion of the fishery as well as the level of fishing that can be maintained by the current fleet. Mariculture of juvenile milkfish for use as bait was attempted but has been unsuccessful due in part to the poor tuna attracting qualities of milkfish. In response to requests by the Government of Kiribati, their Fisheries Division joined the ACIAR-funded BRP in 1988–89. This was completed by June 1991 (ACIAR Technical Report 24), as part of this new project and as recommended by the previous Project Review.

The tuna fishing and canning industry in Fiji employs over 1000 people and generates more than 10% of Fiji's export income. Fiji has gradually built its place in the world markets and today PAFCO (Pacific Fishing Company) tuna is recognised world-wide as of the highest quality. At present IKA Corporation (a government statutory body) owns a fleet of five pole-and-line vessels and a further two such vessels are privately owned. There are also two long-term chartered Japanese vessels, one long-term New Zealand vessel and four Kiribati vessels which occasionally fish in Fiji waters. Despite the success of large purse seiners in tropical areas of the Pacific, the pole-and-line method remains a viable economic enterprise at the latitude of Fiji. In addition, smaller vessels with comparatively high crew numbers fit well with national development objectives. The bait requirements of pole-and-line fishing in Fiji occasionally come into conflict with local interpretations of customary fishing rights and expansion of the fishing fleet will exacerbate the problem. Hence Fisheries Division in Fiji identified the interrelationships between commercial baitfishing and artisanal fishing as a priority area for research. In addition the rational management of Fiji's baitfish resources (which lie almost entirely within customary artisanal fishing areas and are vital for the pole-and-line fleet) is a priority task of the Fisheries Division. Fiji approached CSIRO in 1989 exploring research collaboration. Research undertaken during the BRP indicated that collaborative research between Fiji Fisheries Division and CSIRO could rapidly provide the sound biological base so urgently needed for management. Baitfish research in Fiji was constrained by a shortage of skilled staff, expertise and funding. The research into these vital questions in Fiji was undertaken by the BRP and completed by June 1993. This Proceedings of the final project workshop held in Nadi in August 1993 includes background papers, highlights management issues which need to be addressed' and contains the results of biological studies.

This recently completed second phase of the BRP has had outputs relevant to many South Pacific countries. The experience gained by Australia (CSIRO) in undertaking the research, place it in a unique position to contribute further to such projects in developing countries as well as to recently emerging baitfish problems in eastern Australia.

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Acknowledgments

The staff of the Baitfish Research Project would like to thank the following for their assistance during the project. In Kiribati, all Fisheries Division staff, particularly Mr Tuake Teema; the management and staff of Te Mautari Ltd and the skippers and crews of their pole-and-line boats, and Simon Diffey for assistance with boat trials. In Fiji, the Director and all staff of the Fisheries Division, including the skipper and crew of the R.V. *Tui Ni Wasabula*; Mr Robert Stone and the crew of F.V. *Trapper* for help with collection of samples. We are grateful to the South Pacific Commission for supplying data and for time spent on their tagging vessel in Kiribati. James Ianelli kindly supplied historical catch and effort data for Kiribati.

BACKGROUND

Fiji Baitfishery Status Report

S.P. Sharma*

THE Fiji Baitfishery Project was established to collect and analyse biological information on the important tuna baitfish species in this region. The data were considered essential for the development of rational management strategies to ensure both conservation of stocks and maintenance of supplies for the commercial tuna-fishing operations.

The project had the following objectives:

- to determine species composition of baitfish catches at different sites, including by-catch of juvenile reef species not used as baitfish;
- to provide training in Australia for Fisheries staff in identification of fishes caught in baitfish operations;
- to determine the levels of interaction between reef fisheries and baitfishing (ie. are baitfish important in the diet of species that are part of artisanal reef fishery);
- to undertake biological work on selected baitfish species (reproduction, growth, ageing and feeding.);
- to analyse existing data pertaining to stock assessment;
- to contribute to mapping baitfishing areas and the relationship of these with customary fishing rights boundaries.

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Pole-and-Line Vessels

The Fijian pole-and-line fleet in 1992 comprised 11 vessels: 5 Ika Corporation; 2 chartered Hohsui; 1 Solander Pacific, 2 Stonefish and 1 Fishing Services (Fiji). These fished in Fiji waters during the season from September to May, and several fished in Solomon Islands waters during the Fiji winter off-season for skipjack (June - August). The vessels that fished in Solomon Islands included the *Jay Tee M*, which joined the Fiji pole-and-line fleet late in 1992.

A total of 4105 tonnes of tuna (92% skipjack *Katsuwonus pelamis*) was landed and sold to Pacific Fishing Company by the pole-and-line fleet in 1992. This was a 10% increase in pole-and-line landings over 1991.

Baitfishery

Catch statistics

Catch statistics of the commercial fleet were analysed on a monthly basis.

During 1992, eleven different pole-and-line vessels were active for a total of 97 boat-months. The Fisheries Division received baitfishing logsheets for 98% of the boat-months of activity. The total recorded catch for 1992 was 123 815 buckets (or approximately 272 t) of baitfish from 3057 bait hauls during 1764 nights of vessel operation. (These are the adjusted figures to account for the missing data). The baitfish catch made during 1992 was the highest recorded since the commercial pole-and-line fishery started in Fiji in 1976. The majority of the catch was made from Vanua Balavu (45.7%). The other important baitfishing sites were the islands off western Viti Levu (10.6%), Kia Island (8.0%), Ngau Island (7.5%), Beqa Island (7.5%), Ovalau Island (4.3%) and Kadavu Island (2.7%). The remainder was caught from many different locations within Fiji but effort at each site was low.

The anchovies (Family: Engraulidae) which made up 30.6% of the bait catch were the dominant species group. The sardine (*Amblygaster sirm*) made up a further 20.7%, the sprats (*Spratelloides delicatulus* and *S. gracilis*) 14.4% and cardinal fish (Family: Apogonidae) 12.6% were the other major component of the catch.

Royalty payments

At the beginning of 1992 a royalty payment system was introduced to compensate traditional fishing-right owners for the removal of baitfish and the operation of the commercial pole-and-line vessels within their areas. An initial rate of F$10 per night per vessel was set until results concerning the effects of commercial baitfishing on the subsistence fisheries became available from the Baitfish Research Project (BRP) in June 1993. From the records supplied to the Fisheries Division by the commercial vessels it was possible to assess how many nights baitfishing had occurred in different fishing-right areas during 1992. This has allowed royalty payments to be allocated to the rightful fishing ground owners using boundaries supplied by the Native Lands and Trust Board.

During 1992, a total of F$17 290 was collected from pole-and-line fishing companies in Fiji to cover the royalty payments due to the 56 traditional fishing-right areas where baitfishing took place. This amount has been transferred to an account held by the Fijian Treasury.

Baitfish Research

The project which began in 1991, continued 1n 1992 with further collaboration between staff of the Fisheries Division and CSIRO of Australia. The aim was to address concerns from resource owners about the effects of commercial baitfishing on fish stocks in the traditional fishing areas where baiting takes place. The fieldwork associated with the project aimed to:

(1) identify areas within Fiji where baitfishing effort is presently low but might offer potential for the commercial capture of baitfish;
(2) identify predator fish species of the major species caught in the baitfishery in order to assess the interactions between the commercial baitfishery and the subsistence fishery;
(3) collect information on the level of fishing effort and the major fishing activities within the subsistence fishery.

All the fieldwork was carried out using the Fisheries Research Vessel *Tui Ni Wasabula*. Areas surveyed as alternative baitfishing sites included the islands off the western coast of Viti Levu . Good catches were made at the first two sites in this area and these are considered to offer potential as baitfishing areas for commercial vessels. (After the survey off western Viti Levu in January, 10.6% of the total commercial baitfish catch in 1992 was taken from this area). The results from northwest Vanua Levu were not conclusive. Despite reasonable quantities of baitfish being aggregated around the baitlights, poor weather hampered fishing operations. A trip was made to Vanua Balavu in July to assess baitfish availability during the presently closed season for commercial operations. Large catches were made during this trip, although poor weather made it impossible to undertake operations on many nights of the survey.

Sampling for predatory fish was undertaken at all the above sites as well as Beqa Island, Savusavu Bay , Ngau, Kia and Kadavu. A total of 6393 fish weighing 3.155 t was collected during this work primarily using gill nets and hook and line. The preserved stomachs of fish were analysed in the laboratory to assess their contents. All data were transferred to a computerised database.

To assess subsistence fishing activity, house-to-house questionnaire surveys were carried out in all areas visited. The number of questionnaires completed were: Beqa Island - 24 households, Ngau - 61, Kia - 17, Vanua Balavu - 128, Waya - 26 and Yasawa - 43. All the data were entered on a computerised database at Fisheries Division for analysis. Detailed results of these studies are presented in papers in these Proceedings.

Future Plans

The Resource Assessment and Management section of Fisheries Division will continue to monitor the commercial baitfish catch:effort data for different areas. This will assist the Division in compiling reports on baitfish compensation and to guide Management and Planning section on issues related to baitfish stocks in Fiji waters.

Bait site maps will be distributed to all the pole-and-line skippers and a course will be organised to give skippers a better understanding of the maps and catch log. Fisheries Division staff will be given training in baitfish identification and observers will be placed on board commercial vessels to ensure skippers are filling in catch logs properly. Skippers will be encouraged to collect bait on new sites (see Rawlinson and Sesewa these Proceedings).

Extension staff will be trained to tackle issues related to the baitfishery at Provincial Council level. Baitfish posters will be distributed throughout the country to help the public become fully aware of baitfishing in Fiji. The Division will try to deploy Fish Aggregating Devices in new areas close to new baiting ground to encourage pole-and-liners to use these areas.

All baitfish catch statistics will be continue to be entered as monthly records.

The Division will also continue to carry out subsistence surveys in other areas in Fiji to obtain accurate estimates of subsistence fishing catches.

Pole-and-line skippers will be instructed to improve their relationship with people in the baitfishing areas and, in particular, to prevent their crews fishing illegally in lagoons.

An Industry Perspective

Navitalai Volavola*

IKA Corporation was established in 1975 under Fiji's Land Development Authority which was charged with the responsibility of enhancing the utilisation of marine resources in and around the country's territorial waters.

The Corporation operated successfully as a Government agency until 1 January 1990 when it became the second of the Fiji Government's entities to be converted to corporate status.

At the peak of the fishing season the Company employs 145 people. The full-time staff is 50. The Company owns five pole-and-line boats—two of these were commissioned in 1990 after construction at the Government shipyard.

During the last two years the Corporation faced trying times due to a greater percentage of fishing days affected by bad weather, design limitations of the boats, mechanical problems (particularly with the two new vessels) and the influence of the El Niño phenomenon on both the weather and fish feeding habits.

It is now Ika's goal to fully update the boats, particularly the machinery and equipment, to allow the fleet to follow the skipjack when they move north. Operations will also be expanded to include other members of the Tuna family—especially the prized yellow fin—by embarking on longline and purse seine fishing. The Corporation is therefore poised to enter a new era of fishing in the Pacific.

For pole-and-line fishing the Corporation intends to deploy more fish aggregating devices (FADs) and to train personnel to be fully proficient in fishing operations.

The Corporation is aware that tuna fishing operations have caused concern in many quarters but believes such concern is diminishing as levels of awareness of the industry's activities have increased. The major past (and present) concerns have been:

Baitfish compensation. Prior to the introduction of a royalty payment system in 1992 to compensate traditional fishing-right owners for baitfish taken by pole-and-line boats this was a major issue (see Sharma these Proceedings). The compensation system has now been largely accepted as a fair and equitable way for those with a vested interest to be compensated.

Namena Island. The owners of a tourist resort on this island have lodged numerous complaints stating that noise from boat generators and the bright lights used in baitfishing cause disturbance to resort guests. According to the resort owners baitfishing operations disturb the tranquillity sought by tourists who seek out such a resort.

Illegal fishing. This complaint relates to the view held by some traditional fishing-right owners that the crews of boats were often hand lining and taking larger species while their boats were carrying out baitfish operations. These complaints may have been

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well founded in the past when it was customary for crew to fish to supplement their income. The Fisheries Department has now placed a ban on all forms of fishing by crew engaged in baitfishing operations and therefore this means of generating supplementary income has ceased.

Bycatch. It is a commonly held view amongst fishing ground owners that a large number of marketable species is taken during baitfishing operations. This view is unfounded as in reality very few commercial species are taken in the baitfishing operation.

Ika Corporation is mindful that the tuna industry is a dynamic and important industry to Fiji and whilst there are likely to be new problems to resolve in the future, is confident the Department, the community and the industry will work together to find mutual solutions.

Acknowledgment

Ika Corporation extends thanks to the Fisheries Department for its on-going efforts to secure the future of the tuna industry.

A Review of Previous Baitfish Studies and Reports In Fiji

N.J.F. Rawlinson*

THERE have been a number of studies carried out and reports written about the baitfish utilised by the pole-and-line fishing industry in Fiji. A detailed list of these reports has been compiled in the Fiji Fisheries Bibliography (USP 1993).

Before undertaking the Baitfish Research Project, it was necessary to review the previous work that had been done in Fiji on the subject of baitfish. This report summarises the major points of interest from this review of the literature and helps to portray the circumstances under which the current research project was initiated.

This report categorises the literature into four sections: firstly, surveys that have been undertaken to assess the available baitfish resources in Fiji; secondly, the management of baitfish resources which has included monitoring of yearly activities as documented in the Fiji Fisheries Annual Reports; thirdly studies that have concentrated on the biology of some of the most important species in the baitfishery; and fourthly general reports concerning different aspects of the baitfishery in Fiji.

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I. Surveys To Assess Baitfish Resources

Earliest reports

Commercial exploitation of tuna by pole-and-line fishing was first attempted in Fiji in 1948 by an American operated company, South Seas Marine Products. However, following the lack of success of this venture, it was not until the early 1970s, after the development of sizeable skipjack fisheries in Papua New Guinea and Solomon Islands, that serious attempts were contemplated in Fiji (Kearney 1982).

FAO/UNDP survey

A project between the Food and Agriculture Organisation of the United Nations (FAO), the United Nations Development Programme (UNDP) and the Government of Fiji became operational on 25 May 1971 for an initial duration of two years, but was extended to terminate in November 1973 (FAO/UNDP 1974). The purpose of the project was to assist the Government of Fiji to carry out a feasibility study for the development of a locally-based tuna fishery. The specific objectives of the project were to determine:

- the availability of tuna live-bait and surface tuna schools in waters around the Fiji islands;
- the best means and scale to exploit these stocks rationally;
- the feasibility of such development schemes;

- the acceptability of the various tuna species to the local market, fresh and/or processed;
- the market facilities required.

Activities during the course of the project were also aimed at providing practical training for fishermen-trainees in live-bait pole-and-line tuna fishing methods.

Exploratory fishing cruises commenced in June 1971. However, after two and half months of operation, the boat foundered. Project activities were interrupted for about four and a half months until a replacement boat was provided and fishing resumed in January 1972.

Three types of net were used to capture live bait: the beach seine, the lift net with outriggers and the bouke-ami. The beach seine was used during the day, the lift net with outriggers was used at night in conjunction with either a surface or submerged lamp, and the bouke-ami was used at night with an underwater light.

Catches with the beach seine ranged from 0 to 122 buckets (one bucket was equal to 1.82 kg) and averaged 12.1 buckets per set. Catches with the lift net with outriggers ranged from 0 to 71 buckets and averaged 6.9 buckets per haul. The bouke-ami produced catches that ranged from 0 to 200 buckets and averaged 47.5 buckets per haul. Overall the beach seine and bouke-ami were both considered to be practical and efficient gear for local conditions.

The highest average catch rates by location using the beach seine were recorded at Ono Island which averaged 24.8 buckets per set, Yanuya Island (18.3 buckets per set), Kia Island (16.1 buckets per set) and Vomo Island (16.0 buckets per set).

The most productive locations for bouke-ami fishing were Kadavu Island with an average catch rate of 73.9 buckets per haul, Ovalau Island with 69.1 buckets per haul, Koro Island with 68.3 buckets per haul, Vanua Balavu with 47.5 buckets per haul and Vanua Levu with 20.8 buckets per haul.

Altogether a total of 7194 buckets of baitfish were captured of which 1615 were taken in the daytime and 5579 at night.

The details of the species composition of the catches made during the survey documented in the FAO report are the same as those from Lee (1973) which are summarised in this report.

The basic conclusion of the survey was that suitable baitfish species for catching tuna were available in sufficient quantities in Fijian waters to support a moderate-sized, live-bait pole-and-line fishing fleet. The results of the exploratory fishing trials showed that both skipjack and yellowfin tuna were present in Fijian waters throughout the year to an extent that would support a moderate scale of commercial exploitation i.e. eight to ten 21 to 23 m boats. It was suggested that the boats be deployed as follows: Kadavu Island – 2 to 3 boats, Nadi/Lautoka area – 1 to 2 boats, Vanua Levu (north coast) – 2 boats, Ovalau Island – 2 boats and Vanua Balavu (west coast) – 1 boat. Overall it was estimated that with an annual catch of 462 t per boat, such a fleet would land 3700 to 4600 t of tuna per year.

During the course of the survey it was identified that there was a local misunderstanding of the interpretation of existing legislation regarding customary mataqali rights to baitfish in sea areas fronting a village. Generally all day-baiting operations were preceded by a formal ceremonial request (sevusevu) to the village chief. A proposal to compensate the villagers was not ratified by the Government for fear of setting a precedent. As it was considered that baitfishing in the day would be a useful complement to night time activities, it was recognised that there was a need for the interpretation of the legislation to be clarified.

The main recommendation coming from the survey was that the Government of Fiji should take early steps to develop a moderate-sized, locally-based tuna fishery on a phased basis. Fishing boats should join the fleet at the rate of two per year for four years, to make a fleet of eight modern fishing boats. Further recommendations were given in the report on the best ways to initiate the other facets of the fishery.

The methods used for the capture of baitfish both during the day and night in Fiji waters during the FAO/UNDP-funded project and the most important species caught as well as their size range are given in a seperate report (Lee 1973).

Baitfish caught in the day were located by visual observation i.e scouting accessible beach areas either with a skiff and outboard engine or by walking along the shoreline. The presence of hovering sea birds was a good indicator of the presence of baitfish.

The two predominant species caught in the daytime using a Hawaiian-type beach seine, were the sardine (as referred to in the report) *(Herklotsichthys quadrimaculatus)*, and the silverside *(Atherinomorus lacunosus)*. (Lee used the old scientific names for these species in his paper). The anchovy *(Thrissina baelama)*, was also taken but was found mainly in estuarine areas. The two former species made up 81% of the daytime catch with the latter accounting for the remaining 19%.

Baitfish were caught in the daytime by encircling them with the beach seine. They were concentrated into a small area by gathering up the net. The fish were transferred to a bait receiver which was then towed out to the fishing boat and relocated into the baitwells.

The sardine and the silverside were found to be hardy and vigorous and kept well in the boats bait tanks. They were able to withstand crowding while in the receiver under tow to the boat. If properly cared for they were able to survive for extended periods in captivity. The anchovy however was not as hardy and needed to be handled with care.

At night, a bouke-ami net was used in conjunction with surface or underwater lamps. The size of the net and exactly how the gear was operated are described in the report by Lee (1973).

The most important species, including their size range, taken at night were *Spratelloides delicatulus* from 3.1 to 6.9 cm, *Amblygaster sirm* from 10.1 to 20.1 cm, *Hypoatherina ovalaua* from 4.7 to 8.0 cm and *Encrasicholina punctifer* from 4.7 to 8.5 cm (the new scientific names are used here as opposed to the old ones used in the report). Other important species taken but in lesser quantities were *Encrasicholina heteroloba* from 4.5 to 8.0 cm, *Spratelloides gracilis* from 4.0 to 6.7 cm, *Herklotsichthys quadrimaculatus* from 4.8 to 12.3 cm, *Atherinomorus lacunosus* from 7.4 to 9.8 cm and *Thrissina baelama* from 4.0 to 10.2 cm.

Other species taken which were not as common in the catches were *Rastrelliger kanagurta* from 9.9 to 20.5 cm, *Selar crumenopthalmus* from 6.3 to 14.1 cm, *Rhabdamia gracilis* from 4.1 to 5.9 cm, *Caranx* sp. from 6.3 to 8.5 cm, *Scomberoides tol* from 5.6 to 10.5 cm, *Dussumieria acuta* from 7.3 to 15.3 cm, *Stolephorus indicus* from 3.3 to 15.0 cm and *Stolephorus commersoni* from 5.0 to 9.0 cm.

Lee concluded that the use of a bouke-ami net at night was very effective for catching most baitfish species, the exception being *H. quadrimaculatus* and *T. baelama* which tended to be more 'skittish'. Lee also observed that bays with some but not too much fresh water run-off appeared to be the best places for night baiting in Fiji.

Of the species taken at night, *A. sirm*, *H. ovalaua*, *R. kanagurta*, *S. crumenopthalmus*, *S. tol*, *Caranx* sp., *H. quadrimaculatus* and *A. lacunosus* were the hardiest. These species made up 45.35% of the catch in 1972 and 49.18% in 1973. *T. baelama* and *R. gracilis* made up 2.34% in 1972 and 4.74% in 1973 and were found to be moderately hardy. *S. delicatulus*, *S. graciis*, *E. punctifer* and *E. heterolobus* were delicate and fragile and needed handling with extreme care. They remained alive in the baitwells for up to two days with proper handling. These four species constituted 42.65% of the catches in 1972 and 42.90% in 1973. The three species *D. acuta*, *S. indicus* and *S. commersoni* were extremely fragile and were only able to be utilised as baitfish on a few occasions. These species made up 9.91% of the catch in 1972 and 2.89% in 1973.

Catch rates in 1972 were rather low: 2500 buckets for 29 cruises. However in the second six months of the project, January – June 1973, with better understanding of the local conditions and an improvement in the efficiency of the use of the fishing gear, the catch rate increased by more than 100%, 4000 buckets of bait were supplied from 16 cruises.

During 1972 baitfishing effort was spread throughout the Fijian archipelago. The best catches however were recorded from Momi Bay (Viti Levu) with 18% of the catch, Kia Island (15%), Savu Savu Bay (12.5%) and Ono Island (12.5%). In 1973 the main baitfishing effort was relocated to different positions with Soso Bay (Kadavu) accounting for 46% of the catch and Ovalau island coastal area a further 25%.

During the period of 1972 and 1973 using the baitfish catches recorded above, the research team was able to catch a total of 130 865 kg of pelagic species using the pole-and-line technique. The predominant species taken was the skipjack tuna, *Katsuwonas pelamis*.

A detailed account of all the results coming from this survey work including the baitfish catches from each individual station are reported in Lee, 1974. However Lee's overall results, concluded that the livebait pole-and-line fishing method was suitable for harvesting the surface schools of tuna frequenting Fijian waters, and that local bait resources were available in sufficient supply to support commercial development of such a fishery, at least on a moderate scale.

From the evidence provided by the survey described above, commercial exploitation of skipjack in Fiji commenced in Fiji in 1976 and a total of 625 t was landed in that year (Kearney, 1982).

South Pacific Commission

The Skipjack Survey and Assessment Programme, which was carried out by the South Pacific Commission (SPC) undertook surveys in Fiji in 1978 and 1980, the results of which are presented by Kearney (1978, 1982). The objectives of the program were to survey the skipjack and baitfish resources within the area of the SPC and to assist with the assessment of the status of the stocks and the degree of interaction between individual fisheries within the region and beyond. The program spent 78 days in the waters of Fiji in 1978 and 1980.

Baitfish resources were surveyed by exploratory fishing predominantly at night but sometimes during the day using a beach seine. Both techniques used by the program are described by Hallier and Gillett (1982). Most of the baitfishing carried out in Fiji was using the bouke-ami technique at night.

Kearney reported that the lack of suitable baitfish habitat around Rotuma Island indicated that there was little likelihood of making good catches in this area, which was confirmed by a brief visit to the area in May 1980 during the course of the survey.

Assessments of the baitfish resources were based on the following results: catch and effort figures from the commercial fleet, estimates of the magnitude of suitable baitfish habitat, and knowledge of the utility of the common species as skipjack bait (Kearney 1982).

Due to the fact that little new data had become available since earlier work undertaken by the SPC, the discussion presented by Kearney was taken largely from Ellway and Kearney (1981). A description of this work is given elsewhere in this report.

In conclusion, Kearney reported that although there remain inshore areas of Fiji which have not been surveyed, most of the country's larger baiting grounds had been tested. The existence of the pole-and-line fishery for skipjack in Fiji was evidence of the view that baitfish resources were adequate for at least a moderate-sized industry. However variability in the bait supply indicated that the total resource displays marked seasonal fluctuations. This was in keeping with geographical characteristics of the Fiji Islands, that is, moderate-sized land masses and lagoons at latitudes which are high enough to show pronounced seasonal variability in climate. The lack of substantial quantities of Stolephorid anchovies and the silver sprat, *(Spratelloides gracilis)*, in Fiji detracted from the comparative stability of the baitfisheries in Solomon Islands and Papua New Guinea where these species predominate. The anchovies and the silver sprat appear to be more resilient to continued fishing pressure than do the sardines and blue sprats which are the mainstay of the Fijian baitfishery. However, as Fiji has many lagoons and bays where baitfish are present but are seldom exploited, these areas were anticipated to act as a buffer against long-term decimation of the stocks of the important species.

Kearney suggested that the Fijian baitfish resources should remain resilient to heavy exploitation to the extent that the future survival of the species would not be endangered and the level of recruitment at the beginning of each season would, at present levels of exploitation, not be able to be demonstratively linked to the level of fishing in the preceding season. However, the resources would probably show some effects of heavy fishing pressure in localised areas.

In his report, Kearney considered that it would seem probable that the overall yield from the Fijian baitfish resources could be improved by the introduction of a few basic management strategies, such as the co-ordinated deployment of effort during the fishing season and the maintenance for fishermen of incentives that encourage efficient use of baitfishing time.

Kearney reported that more accurate catch and effort and species composition data than available prior to 1980 would be necessary to monitor accurately changes in the fishery. However, the efforts by Fisheries Division to improve the collection of appropriate statistics, particularly since early 1981, appeared to be adequate for the purpose.

Survey for alternative baitfish resources

Gillett (1982) wrote a trip report concerning activities undertaken for Fiji Fisheries Division by the South Pacific Commission in November and December 1982.

The purpose of the trip was to determine whether baitfish could be captured by a method other than the attraction of fish at night with lights which was being undertaken by the local fleet. The rationale behind this was that the baitfish catches of pole-and-line boats in Fiji were low during the months of October, November and December when tuna schools could be abundant. Hence a lot of potential fishing time was lost due to inadequate supplies of baitfish.

Initially 300 observational dives were undertaken at the islands of Makogai, Makodroga, Ovalau, Beqa and Yanuda to locate species of fish which could be used as baitfish. During these dives small quantities of blue sprats were seen on four occasions and a combined total of 5 kg of apogonids were seen on three coral heads. However, the most promising baitfish resource noted were the fusiliers (Family: Caesionidae). It was observed that virtually every coral head had fusiliers provided it was at least twice as big as an automobile, had crevices and protrusions, and that it was located in at least 2.5 m of water adjacent to a sandy area. Observed quantities ranged from 3 to 40 kg per coral head. Numerical species composition was about 50% *Caesio* sp., 50% *Pterocaesio* sp. at Makogai; 35% *Caesio* sp. and 65% *Pterocaesio* sp. at the northwest of Ovalau, and almost 100% *Pterocaesio* sp. at Beqa.

A fishing technique was developed which incorporated the use of divers and setting a large, flat bouke-ami net over the coral head and attracting the fusiliers to the centre of the net using finely chopped skipjack tuna before hauling the net.

Altogether 33 fishing operations were carried out. Gillett details these in his report as well as including length–frequency data on those fusiliers captured but not used as bait.

Overall, the catches were generally low (maximum of 19.5 kg) but were probably not representative of the true potential of the technique. In addition, maximising baitfish catches was sometimes secondary to gear experimentation, which on several occasions yielded no catch but valuable information on fusilier behaviour.

An important requirement for the success of the technique was the presence of suitable coral heads. In order to locate coral heads, a reconnaissance flight was made over several areas. Many of the locations looked at appeared to have good coral heads far in excess of what was identified at Beqa Island. Namena Island looked particularly promising (Gillett 1982).

The next step in the development of this technique would have been an attempt to maximise catches by the crew of a commercial boat in areas where coral heads were plentiful. This could then be used to evaluate the suitability of the method for use by the local fleet. Using the lift net at night was also identified as a technique for future trials as well as diving on coral heads which have already been fished, in order to see how quickly they are repopulated.

In conclusion, it was estimated that in a good area catches of 10 kg could be expected from one haul of the net and eight sets could be made in one day. Considering a tuna-to-bait ratio of 30:1, and using the prevailing tuna prices in Fiji, it was estimated that a day of catching fusiliers could result in an additional tuna catch valued in excess of US$ 1500 per boat per day. This situation assumed that there are numerous areas where coral heads are concentrated and that the technique could capture significantly more bait on virgin coral heads than on those previously fished.

Japanese International Cooperation Agency

The Japanese International Cooperation Agency (JICA) was commissioned to carry out a survey of fisheries resources in Fiji and Tuvalu waters by the Japanese Government starting in 1984 (JICA, 1987a.)

The objectives of the survey were to obtain information on offshore fisheries with particular reference to seamounts, and to attempt to identify fishing methods for the catching of the above fisheries resources (JICA, 1987a).

Fishing operations used during the survey were pole-and-line, trolling, surface gillnet and bottom line (including drop line) fishing. In order to undertake the pole-and-line operations it was necessary to catch live baitfish. Surveys were conducted to develop new live-bait fishing grounds in parallel with the pole-and-line fishing.

Live-bait surveys were conducted at 19 bait fishing grounds using stick-held dip nets, and 2780 buckets of bait were captured in 108 sets, averaging 26 buckets per set. Major species were sardines, gold-spot herring, blue sprat, silversides and cardinals, with species composition varying with areas and seasons. The catch decreased notably as water temperature dropped to 23 – 24°C on the southern coast of Fiji in August. The atoll of Yasawa was also surveyed for a new baitfishing ground, but bait was not captured in sufficient quantities due to strong winds and tides. It was considerd that if bait could be caught in adequate quantities during July through to October, the operation of payoas (fish aggregating devices) would be possible at both Kia and Koro.

Accurate details of each baitfishing operation, and the amounts of bait collected, classified by month and baitfishing ground, are given in a separate report (JICA, 1987b). The amount of bait caught each month showed great variation over a wide range from 55 buckets to 687 buckets.

The baitfishing grounds used most frequently during the course of this survey were Kia, Ngaloa and Vanua Balavu. These sites produced two-thirds of the total bait catch at an average of 33.6 buckets per set. This was considerably higher than the overall average of 25.7 buckets. It was concluded that small fish were more abundant here than in other baitfishing locations.

During the survey a strong positive correlation between the amount of live-bait collected and the tuna catch for each cruise was recorded.

Live-bait collected during this survey survived in the bait tanks for between 10 and 20 hours though this varied depending on the species. This factor limited the time a pole-and-line boat could stay at sea to about 20 hours, restricting the operational range of boats to a 40 mile radius from the baitfishing site.

In trying to assess the resource potential of baitfish in Fiji, a model developed by Schaefer (1954) was applied in the JICA report to the available catch and effort data from the records of Fiji Fisheries Division. The relationship between catch and effort suggested that optimum fishing effort was about 2200 hauls per annum, a level which had already been exceeded in 1982.

II. Management of the Baitfish Resources in Fiji

Brown (1977) stated that the pole-and-line live-bait fishery for skipjack had reached the stage of being a viable commercial proposition although at present the small fleet was entirely controlled by a Government corporation. Apart from the expected fluctuations due to lunar effects, supplies of live-bait (captured by lift-netting at night) had been adequate. The initial investigatory phase of this industry concluded that the local stocks of baitfish would support a moderate-sized tuna fleet of eight to ten 25 m boats, but as little is known of the population parameters of these species, it was impossible to predict with any accuracy what effect continuing and increasing exploitation would have on the stocks.

Brown also noted that for the tuna pole-and-line fishery in Fiji to expand to any extent, its continued viability would depend on the rational management of the local baitfish resources. He said the management success was dependent in turn on the accuracy and extent of information being provided by the statistician and the biologist. The relationship between catch and effort must be monitored, and biological data relating to growth rates, reproductive potential and environmental requirements of the species concerned should be available to refine management decisions.

Brown therefore conceived a plan in an attempt to provide the sort of information required for effective management. He divided this plan into three sections:

a) Catch analysis

The main purpose of this exercise was to ensure a routine check on the catch–effort relationship to detect any variations which could be attributed to over-exploitation. The data should eventually be sufficient to allow estimation of total, fishing and natural mortality coefficients. Particular attention should be given to periods in which fishing effort is significantly increased by the introduction of more boats or innovations in gear technology. An attempt should also be made to estimate the relative fishing power of the boats in each fishery, and the units of effort should be examined periodically to ensure that they are still relevant.

b) Estimation of Abundance and Availability
Most information relating to the abundance and availability of the baitfish species will be obtained from the tuna fleet's night-baiting operations. However it may be possible to equip a small boat with lights and a 'try-net' so that spot sampling can be carried out in areas not usually fished by the fleet.

c) Biological background
Brown (1977) stated that the resilience of a stock to fishing mortality is largely a function of its rate of production, the main components of which are growth (biomass accumulation) and fecundity (potential recruitment to the population). As growth rates and recruitment are both susceptible to changes in environmental conditions, including 'predation' by fishermen, it seems desirable to estimate the natural capacity for increasing biomass and production of eggs while the populations are still more or less in a state of equilibrium.

Otoliths would be used in conjunction with length–frequency analysis to estimate the age of several of the more important tuna bait species. If annual growth checks were absent it might be necessary to resort to the, then, relatively new technique of counting daily growth increments. The parameters of the Von Bertalanffy growth model would be estimated from the resulting length-at-age data for comparison between species and localities.

Reproductive cycles would be investigated using techniques involving gonad weight, gonad indices (if applicable) and macroscopically-determined development stages. Fecundities would also be determined by standard methods and the ecological characteristics of preferred spawning areas, if located, would be thoroughly documented.

Brown stated one of the most important natural factors influencing the distribution of a fish species to be the availability of suitable food. A 12-month study of the diets of baitfish, taking seasonal and geographical factors into account, should provide a good indication of their trophic availability. This in turn might indicate the extent to which food availability is likely to be a source of potential limitation to the growth of these species.

Brown suggested a similar approach for the management of Spanish mackerel resources in Fiji.

Fiji Fisheries annual report 1977

In the 1977 annual report (Anon. 1977) it was documented that the state of the baitfish stocks and the population biology of selected major species were being studied. Results in 1977 showed that little reliance could be placed on data supplied from Ika Corporation. Identification by species was poor, the estimates of percentage catch composition were inadequate and there was considerable variation in the standard unit of measurement (the 'bucket' of bait). Baitfish samples taken from the commercial catch were reported to have been too small, not randomly selected and not representative of the catch. As a result of this it was decided that a baitfish survey should be undertaken independently of the commercial fleet. Due to lack of funds the boat *Tui-ni-Wasaliwa* could not be used and the *Tavuto* was instead being prepared by equipping it with underwater lights and a lampara net.

With respect to the biological work on baitfish species it was reported that data were collected from over 2000 individuals analysed in the laboratory but these samples lacked any spatial and temporal continuity. Length–frequency distributions, sex ratios and gonad maturation cyles were all being investigated using this data.

Fiji Fisheries annual report 1978

The total baitfish catch for 1978 reported in the Annual Report was 61 574 buckets which was an increase of 36.9% over the previous years catch, primarily due to increased fishing effort. The important fact noted in terms of resource management was that there was no appreciable change in the catch-per-unit effort as a result of this increased effort, which supported the theory that Fiji's baitfish stocks are large and robust.

Baitfishing effort during the year was greatest during the first four months of the year and tailed off towards the end of the season, which suggested that knowledge of tuna abundance influenced (to some extent) the amount of effort put in to fishing for bait.

Catch rates between boats ranged from 44.3 to 64.1 buckets per haul, excluding those boats whose effort was limited and those not using the same fishing method. This was considered to be a relatively small range considering differences between boats in the method of estimating the quantity of bait caught during a haul.

An exercise carried out during the fishing season suggested that the estimate recorded for the number of buckets caught by a boat was about 50% higher than the actual number of buckets transferred.

An analysis of the geographical distribution of the baitfish catch in 1978 showed that Vanua Balavu yielded slightly higher than 10% of the total catch. The three other most productive sites were Soso Bay, Kadavu (9.5%), Nayavu, Savu Savu Bay (8.7%) and Serua Harbour (5.7%). The areas providing the highest catch rates (in excess of 65 buckets of bait per haul) were to the north and east of Vanua Levu. The mean catch rate for Lomaiviti was slightly more than 60 buckets per haul with Savu Savu Bay, Vanua Balavu and Serua Harbour yielding between 50 and 60 buckets per haul. Catch rates less than this were recorded from Kadavu and Beqa.

Fisheries Division carried out an independent baitfish survey during 1978 though many of the planned trips had to be aborted due to problems with the project boat. However samples of baitfish were collected from diverse areas and they were subjected to biological analyses and provided excellent training material for Fisheries Division research staff in fish taxonomy.

Samples collected from the Fisheries Research boat *Tavuto* were frozen and returned to the laboratory for further analysis. The overall species composition coming from the 94 samples originating from 24 sites between 20 April 1978 and 7 October 1978 was detailed in the Annual Report. By weight, *Amblygaster sirm*, was the most dominant species comprising 27.7% of the sampled fish but only 1.48% numerically. By number and weight respectively, *Herklotsichthys quadrimaculatus* (23.34% and 3.75%), *Spratelloides delicatulus* (12.8% and 57%) and *Hypoatherina ovalaua* (19.82% and 23%) were all abundant in the samples.

An initial analysis of the samples collected, revealed that different assemblages of baitfish species may be associated with different habitat types. The dominant species in the 'mainland' bay group of sites by percentage species composition was *Hypoatherina ovalaua* followed by *Amblygaster sirm* and *Spratelloides delicatulus*.

In 'shallow bays near areas of reef', *Amblygaster sirm* predominated followed by *Herklotsichthys quadrimaculatus* and *Spratelloides delicatulus* with *Hypoatherina ovalaua* contributing little to the bait catch at these sites.

At the 'offshore island and reef areas' the most abundant species were *Amblygaster sirm*, *Spratelloides delicatulus* and *Hypoatherina ovalaua* respectively, the same as at 'mainland bay' sites though in a different order of predominance.

Catches from 'offshore island bays' were different from the other three habitat types with 60% comprised of *Herklotsichthys quadrimaculatus* followed by other species, mainly due to an unusually large catch of lantern fish (Myctophidae) from Kadavu.

Other points noted were that *Encrasicholina devisi* was restricted to bay habitats (both mainland and offshore) and appeared infrequently at sites in the vicinity of reefy areas. *Spratelloides gracilis* tended to be found mainly in offshore areas near reefs. The hardyhead, *Atherinomorus lacunosus*, was absent from mainland bay samples and relatively common in shallow reef bay areas. The leatherskin, *Scomberoides tol* was almost entirely restricted to mainland bays. The proportional contribution of *Rastrelliger kanagurta* was generally low but its relative abundance was slightly greater in shallow bay/reef areas than elsewhere.

It was noted that the data available did not allow an analysis by season and area at the same time so some of the habitat-related differences could have been due to seasonal differences.

Length–frequency data for 4309 individuals of nine species were presented graphically in the report. The length range for each species was documented as well as some observations made concerning the length-frequency distributions for each species. Length–weight relationships had also been calculated and these were listed for the nine most important species in the baitfish samples collected.

Fiji Fisheries annual report 1979

Baitfish resource assessment was reported under the Specialist Surveys section of the 1979 Annual Report (Anon, 1979). Due to the expansion of the tuna fleet to 10 boats in 1979, the baitfish resources assumed greater importance and this is reflected in the detailed account given in the 1979 annual report.

It was stated that standard forms were supplied to the tuna fleet for them to fill in details of catch, effort, location and estimated species composition. However a major drawback of this system was the reluctance of skippers to complete the forms and occasionally no data were forthcoming. It was for this reason that the complete 1979 information was not available for this report and therefore the analysis given in this account was based on the tuna fishing seasons – usually October to July or August – rather than on calendar years. The 1979 season actually commenced in September 1978.

Another problem concerning available information that is highlighted in this report was that the baitfish catch data are based on non-standard units (buckets), which themselves were estimated rather than counted. The bucket was found to hold approximately 1.8 kg of baitfish from work carried out in 1978.

Annual catch and effort statistics for the 1976 to 1979 fishing seasons are tabled in this report. The data showed that there was a 36% rise in catch between 1977 and 1978 but in 1979 the levels dropped back to the 1977 levels, despite the greater effort exerted. It was noted that the catch per unit effort had appeared to decline consistently since the commencement of the data recording program. The point was stressed that, even though the data originated from the commercial fishermen themselves, any human errors involved in recording the data contributed, if anything, in only a minor way to the overall trends emphasised in the report.

The data showed a yearly cycle in the capture of baitfish and the cessation of fishing in August and September. The reasons for this period of no fishing were reported as being a pre-knowledge by commercial fishermen of a likely reduction in tuna abundance (at the end of the season) which was often reflected in a diminished amount of effort going into baitfishing, and also an actual seasonal variation in catch per unit effort. Catch per haul was usually highest in mid-season and declined towards the end of the season. The beginning of the season usually produced poor catches with good levels not being reached until January. The seasonal trend showed that catches usually peak from February to June, and in the years 1976–1978 can be seen to have increased, perhaps due to increased catching power of the fleet and possibly improved knowledge and technique of the boat operators. In 1979 the catches were substanially lower than in the previous year, the reasons for which are unclear (this topic was covered in more detail by Ellway and Kearney 1981).

The steady decline in catch per unit effort since the beginning of the exploitation of baitfish stocks was considered to be by no means necessarily indicative of an imminent stock collapse. The pattern was one that may be expected when a new fishery is opened. Most fisheries will stabilise after several years at a somewhat lower level than that orginally experienced. What was considered unusual however, was that the decline in catch per unit effort showed for a 'stock' of fish which is geographically widespread and fished in a shifting spatial pattern. It was reported that the pole-and-line boats followed the northern migration of the tuna during the season and preferred to fish for bait in areas close to the tuna schools. Therefore, as no one area is continually fished throughout the year, and in such a widespread fishery for species which are not known to be highly migratory, it could be expected that the bait communities might respond independently as a discrete local or regional population. However, the situation found was different and seemed to be a general response to the whole baitfish stock and so the declining catch per unit effort figures were actually reflecting a change in abundance of baitfish in response to factors completely unrelated to fishing effort, such as climate, oceanographic conditions etc.

In November and December 1979 the reported catches were extremely poor and justified the Fisheries Research boat *Gonedau* being assigned to seek good baitfishing areas around Kadavu for the fleet. It was considered that if the decline in catch per unit effort continued that Fisheries Division should look into methods of improving catches by investigating alternative sources, methods etc.

From an analysis of the geographical distribution of baifishing effort it was clear that certain areas have been more productive than others, either in terms of total baitfish catch or catch rates. However, the two did not necessarily go hand-in-hand, and some areas which yield below average catch rates are supplying substantial proportions of the baitfish catch. Several areas yielded the largest proportions of the catch and they were well dispersed and did not appear to follow an obvious pattern or be clearly related to a known environmental variable. Some trends were beginning to emerge however, and various zones of baitfishing sites were demarked and said to be generally good, intermediate or bad.

An area around Kubulau Point and Rabi Island off Vanua Levu had the highest overall catch rate of 80.3 buckets per haul. These figures were based on a small sample and it was considered that it might be worthwhile for Fisheries Division to investigate the potential of this region. This also applied, but to a lesser extent, to Vanua Balavu.

The second highest catch rates (75 buckets per haul) came from around Naduri and Macuata-i-Wai on the northern coast of Vanua Levu and also Kia Island. Kubulau Point on the west of Savusavu Bay also recorded fairly high catch rates. Other areas e.g Kadavu, Ovalau and the Serua-Beqa region generally produced medium to poor catch per unit effort figures.

Overall, it appeared the data showed that baitfish were a little more abundant in the northern parts of Fiji than in the south. If this is actually the case, it was considered that part of the actual seasonal increase in catch rates during the fishing season will be attributable to this.

For more solid conclusions it was recognised that it would be desirable to have regular returns from one or a number of baiting areas during at least one twelve-month period. It was hoped that the arrival of a new research boat in 1980 would allow this work to be undertaken.

The continuation of biological work on the baitfish species was hampered in 1979 due to practical problems with equipment and boats. It was therefore reported that little information on biological characters of baitfish could be added to those presented in 1978.

Fiji Fisheries annual report 1980

The annual report in 1980 (Anon. 1980) contained another detailed report on the baitfishing situation in Fiji during that year. Much of the general information reported was similar to that in the previous years report.

The season in 1980 saw the operation of eleven pole-and-line boats in Fiji waters, five owned by Ika Corporation and the remainder on charter. The data for the 1980 season covered the period from 1 September 1979 to 31 August 1980.

The main feature of baitfishing activities during the 1980 season was the continuation of the decline in catches noted through the 1978 and 1979 seasons. The total catch and catch per haul in 1980 were the lowest recorded since 1976, despite the record levels of effort. Due to this, the tuna catch showed a decrease relative to 1979 and seasonal daily tuna catches were the lowest since the fishery commenced in 1976.

Bait catch rates did not exceed 40 buckets per haul in any month during January–June, unlike previous years, and the average catch rate during this period was a low 25.4 buckets per haul. It was considered that the data were representative of the true situation even though some months data were missing from some boats.

In an attempt to alleviate this problem it was reported that Fisheries Division boats were sent to examine alternative baiting sites early in the 1980 season. It became apparent however, that the shortage of bait was not localised to certain areas but was widespread across the group.

This situation caused Fisheries Division to request the services of scientists from the South Pacific Commission to investigate the problem. The results of this work are reported by Ellway and Kearney 1981, which is reviewed in this publication.

During the 1980 season poor catches were experienced across all baitfishing areas in Fiji. Detailed baitfish catch statistics for the season are recorded in the annual report. Marginally higher catch rates were reported from northern Vanua Levu and this area contributed the largest proportion of the baitfish catch (25.3%). Lomaiviti (23.1%) and Ovalau (17.2%) provided over 40% of the total. The individual sites within these areas where baitfishing effort was highest were Kia Island, Sausau Bay, Savusavu Bay, Namena, Ngau, Vagadaci, Levuka and Serua. During 1980, the baitfish effort showed no clear signs of a shift over the season as was experienced in previous years.

Due to the poor baitfishing season, data on the species composition of the catch were analysed for the January to August 1980 period (there were large gaps in the data set for the remainder of the year). The estimates by weight showed that the sardines (24.7%) were the most important species group in the catches followed by sprats (21.7%), mackerels (12.7%), herrings (12.2%) and anchovies (11.8%) with other species making up the remaining 10.6%. The species breakdown of catches did not differ greatly from other years. However, at the beginning of the season not only were catches low, but comprised of very small individuals that had poor survival rates in the bait tanks. *Stolephorus indicus*, a very fragile species, was also abundant in the SPC survey in 1980, as reported by Kearney (1982).

A comparison of the reported species composition of zones classified as 'mainland' (north and south Vanua Levu, central Viti Levu) and 'island' (Ovalau, Lomaiviti and northern Lau) respectively, showed anchovies and mackerel to be more abundant at mainland sites, and sprats and cardinal fish at island sites, with sardines and herrings showing little variation.

During 1980, it was reported that the continued access of commercial pole-and-line boats to traditional fishing areas had become more of a contentious issue and that it was hoped that Fisheries Division staff would be able to visit such areas and provide information on baitfishing activities with the aid of audio-visual equipment, demonstrations etc.

The poor fishing seasons in 1979 and 1980

After the start of commercial pole-and-line fishing in Fiji in 1976, low abundances of baitfish were recorded during the commencement of the 1979/1980 season. Poor catches of skipjack tuna were also recorded at the same time. In January 1980 supplies of baitfish improved but still remained much lower than in previous years.

Ellway and Kearney (1981) documented the trends in the baitfishery from 1976 to 1980 and investigated the poor season in 1979–1980. Alternative hypotheses to explain the 1979 – 1980 season included (a) a decline in baitfish resources due to environmental phenomena (e.g rainfall and temperature); (b) a drop in the intensity of effort or efficiency of the fishing boats; (c) a depletion of baitfish stocks by excessive fishing pressure; (d) the natural variability in the abundance and/or behaviour of baitfish; and (e) an overstatement by the fishing fleet of the magnitude of the drop in baitfish abundance.

The analyses in their report were based on catch and effort records from the pole-and-line boats. For an independent assessment of the situation, interviews were held with the captains of the commercial boats.

The general conclusions for the poor season in 1979/1980 were that:

1) the depletion of resources as a result of fishing pressure and changes in the behaviour of baitfish species, were unlikely causes.
2) no correlation could be found between the environmental factors of temperature and rainfall, and the poor season.
3) the abundance of suitable baitfish in late 1979 was probably due to a late 1979 spawning season for *Amblygaster sirm* and *Spratelloides delicatulus*. It was also possible that the season for both species was poor as well as late and this kept their abundance below normal into 1980.
4) a poor tuna season gave little incentive for fishermen to maximise their baitfish catches as there was a low expectancy of a good catch of tuna and therefore bonus payments.
5) baitfish catches were under-reported in order to keep competition away from sites where good catches were being made.

6) overall, the magnitude of the reduction in total baitfish abundance was exaggerated and over-emphasised, and the poor, or perhaps only late, baitfish season was blamed for a bad year in the Fijian skipjack fishery.

Ellway and Kearney made recommendations to improve the data base concerning the baitfish as their study had highlighted the inadequacies of the available data for assessing the poor season in 1979–1980. Their recommendations included: (a) more accurate estimates of the bait catches, including corrections for underestimates; (b) increased accuracy in estimating species composition and average size distributions; and (c) life history studies on the dominant species.

Fiji Fisheries Division annual report 1981

The 1981 annual report (Anon. 1981) also included a detailed account of Fisheries Divisions activities with regard to baitfish resource assessment during the course of the year.

The number of pole-and-line boats operating in Fiji waters by the end of 1981 had increased to 12 so the management of the baitfish resources was a priority task of the Division.

In June 1981 the existing three-form system for the collection of baitfish catch and effort data recorded by the fishermen, was replaced by a single simplified form. Boats were also supplied with plastic-coated colour photographs of the main species as well as showing the recorders samples of preserved specimens, in order to try to improve the accuracy of data on catch composition.

The main feature coming from the catch records was the reversal in both total catch and catch per set compared with the previous three seasons. The 1981 catch was twice that of 1980 and approached the record from 1978. This supported the Division's belief that years such as 1980 can be expected every three years or so and that such fluctuations are natural episodic events characteristic of small schooling pelagics, rather than fishery-induced changes.

The good bait catches enabled the pole-and-line fleet to reach record tuna catches which exceeded 5000 t for the first time.

Good baitfish catches were recorded at the beginning of the season (October to November), which tapered down slightly before exceeding 40 buckets per haul over the five-month period from February to June. It was noted that this five- to seven-month period of good baiting had been a feature of the fishery since its inception with very little variation in its timing.

As there seemed to be a real decline in the abundance of baitfish during the August to November period, Ika Corporation examined, during 1981 the feasibilty of culturing mollies (*Poecilia mexicana*) to supplement bait supplies during this period (see Lal 1982 in this paper).

In 1981, the northern Vanua Levu area once again provided the largest proportion of the catch (37.5%). This area combined with Lomaiviti, Ovalau and northern Lau accounted for nearly 80% of the total catch of baitfish. southern Vanua Levu declined in importance (2.45%) with a corresponding increase in effort in Vanua Balavu (11.7%). This was a reflection of increased tuna fishing activities in 'new' areas east of the Koro Sea. However, the overall pattern of fishing effort showed relatively little change from 1980, despite the increase in abundance of baitfish.

The seasonal shift in effort was also not apparent during the 1981 season, as in previous years. Ovalau was fished consistently throughout the year due to its proximity to Levuka, the unloading base. The areas of northern Lau, Lomaiviti, Kadavu, and central Viti Levu were fished most heavily during the months of light winds (January – March) and with the onset of south-easterly winds in May, effort shifted noticeably to the lee that northern Vanua Levu provided.

The introduction of the single log form resulted in significantly more accurate data on the species composition of the baitfish catch. A complete data set was available for the July – December period which was summarised in the 1981 Annual Report (Anon. 1981).

The table presented showed that the proportion of sardines, anchovies, salala (*Rastrelliger* sp.) and silversides is within the range of values observed in previous reports. The proportion of herring (*Herklotsichthys quadrimaculatus*) and cardinal fish were however, higher than previous estimates. In the case of the cardinals this was not considered surprising, since when bait abundance is low (i.e. July–December) areas adjacent to the reefs are fished more frequently and cardinal and fusiliers typically dominate catches in such areas. The proportion of blue sprats estimated (13.2%) was lower than previously observed.

A report on the biological sampling program carried out in 1981 was described. Fortnightly sampling took place from the research boat *Tui Ni Wasabula* around the east coast of Ovalau and eastern Savusavu Bay. A detailed description of sampling techniques is given in Lewis et al. (1983) and a description of the findings described in the 1981 annual report are described in more detail in the account of Biological Reports given in that paper.

The 1981 report highlighted the need for increasing public awareness on the issue of baitfishing and Fisheries Division attempts to ensure that such activities proceeded in harmony with traditional fishing.

It was felt that misunderstandings as to the nature and purpose of baitfishing had given rise to some of the difficulties between the public and the boats in the past. A 20-minute video film was produced in Fijian by Fisheries Division staff and was shown at three Provincial Council meetings - Lau, Lomaiviti and Macuata. The exercise was well received and the intention was then to extend this activity to individual villages.

During 1981, a discussion paper was prepared on the legal background to customary fishing rights and Ika Corporation boats were directed to obtain permits to fish in customary fishing-right areas on a blanket Divisional basis. No payment was to accompany the issue of such a permit, both because of legal complications and because all tuna caught as a result of baitfishing activities are processed within Fiji to Fiji's considerable benefit.

Fiji Fisheries Division annual report 1982

The 1982 annual report (Anon. 1982) covered many of the points made in the 1981 Report. However, new information regarding activities in 1982 pertinent to baitfishing were also given.

During 1982 (the season from 1 September 1981 to 31 August 1982), an increase in total baitfish catches by 33% was reported with a decrease by 21% in the buckets per haul figure from the previous year. The increased catches were attributed to the introduction of two new, privately owned pole-and-line boats (*Lepea* and *Te Tautai*) into the fleet. Less than half of the 90 baitfishing sites within Fiji, were regularly used by fishing boats during the course of 1982. northern Vanua Levu provided the highest proportion of the catch (26.2%) and combined with central Viti Levu and Lomaiviti, these areas accounted for over 63.1% of the total bait catch. During 1982 increased fishing activities were centred around central Viti Levu, Kadavu and southern Vanua Levu, with a decrease in baiting activities in the southern Lau, Ovalau and northern Lau areas.

During the 1982 season, the sardines, herrings and cardinals accounted for approximately 50% of the catch. The anchovies and silversides were the least abundant of the eight species groupings, contributing to about 16% of the catch.

At the end of 1982, day fishing trials on 'fusiliers', using dip nets, were carried out by a South Pacific Commission expert. Observations showed that this method had potential and could be used as a supplement to the bouke-ami during the periods of seasonal decline. Details of the work are given by Gillett 1982 and summarised in this chapter.

Further biological work continued on two of the major baitfish species in 1982 and the findings are summarised in the review of biological studies made in this report.

Fiji Fisheries Division annual report 1983

Details given in the 1983 annual report (Anon. 1983) regarding the baitfish catches covers the period from 1 July 1982 to 31 June 1983.

There was a decline in catch per unit effort during 1983 (wrongly described in the text as an increase) to a figure of 27.4 buckets per haul—a decline over the 1980 and 1981 figures. There was also a decrease in the overall catch and effort from the previous years fishing season. This supported a Fisheries Division belief that such a fluctuation could be expected every three years, and this decline was a natural episodic event charcteristic of small schooling pelagic fish rather than fishery induced changes.

In 1983, northern Vanua Levu again provided the highest proportion of the catch (26.2%) compared to the previous fishing season with a further 37% of the catch coming from Lomaiviti and central Viti Levu.

It was reported that blue sprats, sardines, cardinals and anchovies accounted for about 75% of the catch. Herring, mackerel and silversides made up the remaining 25%. Exact details of the species breakdown by area were tabulated in this report.

Fiji Fisheries Division annual report 1984

The report on baitfish activities in the 1984 annual report (Anon. 1984) was short and gave a brief description on the catch statistics for that years fishing season.

It was stated that the bait catch in 1984 totalled 52 878 buckets (apprximately 95.18 t) from 1092 sets in 794 nights. Lomaiviti (22.4%), Viti Levu (12.7%), northern Vanua Levu (27.2%) and northern Lau (15.5%), accounted for 78.0% of the total bait catch, while 22.0% was caught in the other baiting locations.

The report also stated that 4355.5 t of tuna were landed in 1984 with the baitfish caught, or about 21.85 kg of bait per tonne of fish.

Fiji Fisheries Division annual report 1985

Information on the catches of baitfish was the only information given in the 1985 annual report (Anon. 1985). Total catches were reported to be 31 788 buckets (or approximately 57.2 t) from 1073 set of the net made over 740 nights fishing. Lomaiviti (22.9%), northern Lau (17.4%), and Levuka (14.3%) accounted for 54.6% of the total bait catch, while 45.5% were caught in the other eight areas.

A total of 3252 t of tuna were reported as landed in 1985 using this bait which equated to the use of 17.5 kg per t of tuna.

Biological studies on the growth and mortality of three of the important baitfish species *Herklotsichthys quadrimaculatus*, *Spratelloides delicatulus* and *Rhabdamia gracilis* were concluded and were to be published in 1986. These studies formed the basis of the work of Dalzell et al. (1987), summarised in this paper.

Fiji Fisheries Division annual report 1986

The catch results from the 1986 season were presented in two tables in the 1986 annual report (Anon.1986). The details showed a total catch for the year of 33 089 buckets with Lomaiviti producing 23.3% of the catch and north Vanua Levu (20.8%), Viti Levu (12.8%) and Levuka (11.7%) being the other important sites. The herring was the most dominant species in the catch (24.6% of total) with the sardine (18.6%), the blue sprat (16.2%) and cardinals (14.7%) making an important contribution.

Fiji Fisheries Division annual report 1987

The total baitfish catch for 1987 was reported in the annual report (Anon. 1987) to be 50 t with six boats from Ika Corporation and two from Kiribati operating during the season.

Fiji Fisheries Division annual report 1988

The only information given in the 1988 annual report (Anon.1988) concerning baitfishing was that eight pole-and-line boats were operating during the season and total baitfish catches were 55 t.

Fiji Fisheries Division annual report 1989

Details concerning the baitfishery in 1989 were limited in the annual report (Anon.1989) to the fact that eight pole-and-line boats operated during the course of the year and the total annual baitfish catch was 60 t.

Fiji Fisheries Division annual report 1990

It was reported that 10 pole-and-line boats operated during the season and total baitfish catches were 98.3 t (Anon 1990).

This report also stated that agreeement has been reached with the Australian Centre for International Agricultural Research (ACIAR) and a collaborative research project would start in September 1991.

Fiji Fisheries Division annual report 1991

The annual report (Anon. 1991) confirmed the initiation of the ACIAR Baitfish Research Project in September 1991 and gave details of the planned schedule of fieldwork for 1992.

The pole-and-line fleet in 1991 comprised 11 boats and total catches of baitfish were about 240 t. It was highlighted in this report that complete annual records of baitfishing activities from the commercial boats had not been forthcoming. A factor was applied to the data available to take into account the missing data and this is the reason for the marked increase in reported baitfish catches by the pole-and-line fleet in 1991.

Fiji Fisheries Division annual report 1992

The total baitfish catch reported for 1992 (Anon.1992) was 123 815 buckets (or approximately 272 t) with the operation of 11 pole-and-line boats during the course of the year. This was the highest total catch reported from the baitfishery since its inception.

The site providing most of this baitfish catch was Vanua Balavu (45.7%) with other important sites being western Viti Levu (10.6%), Kia Island (8.0%), Ngau Island (7.4%), Beqa Island (7.5%), Ovalau Island (4.3%) and Kadavu island (2.7%).

The predominant species group was the anchovies which made up 30.6% of the total, with sardines (20.7%), sprats (14.4%) and cardinal fish (12.6%) making important contributions to the remainder of the catch.

Details were also given of the fieldwork undertaken during the course of the ACIAR-supported Baitfish Research Project. As much of the information included will be presented in this proceedings, a summary of the report will not be given here.

The annual report (Anon. 1992) also had details of the initiation of a royalty payment system at the beginning of 1992 to compensate traditional fishing-right owners for the removal of baitfish and the operation of the pole-and-line boats within their areas. An interim rate of F$10 per night per boat was set until results concerning the effects of commercial baitfishing on the subsistence fisheries became available from the findings of the Baitfish Research Project in June 1993.

During the 1992 season, a total of F$17 290 was collected from the pole-and-line fishing companies in Fiji to cover the royalty payments due to the 56 customary fishing-right areas where baitfishing took place.

III. Biological Reports

Prasad

Samples of baitfish used in a study by Prasad (1982) were collected during the period November 1979 to April 1981 from the boat *Sunbird*. The fish taken were caught in a bouke-ami net and a random sample of the catch was preserved in neutral formalin. Information on the total catch of bait, effort, location and surface temperature of water was also recorded.

Each sample was sorted into species, then measured and weighed. Stomach content and gonad analysis was carried out on some of the major baitfish species collected. In his study Prasad considered the following species: *Stolephorus insularis*, *Encrasicholina punctifer*, *Encrasicholina devisi*, *Stolephorus indicus*, *Thrissina baelama*, *Spratelloides delicatulus*, *Spratelloides gracilis*, *Dussumieria acuta*, *Herklotsichthys quadrimaculatus*, *Amblygaster sirm*, *Hypoatherina ovalaua*, *Atherinomorus lacunosus*, *Rastrelliger kanagurta*, *Rhabdamia gracilis* and *Selar crumenopthalmus*.

Approximately 60% of the bait samples came from Kadavu, Beqa, Ovalau, Sausau and Kia but overall samples came from 46 different stations. Prasad tables the species composition of the catches as the percentage by number for three separate time periods: November 1979 – April 1980, May 1980 – October 1980 and November 1980 – April 1981 and as a total of the overall period. The average species composition as a percentage by weight of bait catches were tabled by Prasad for this study as well as the same details from the surveys of FAO/UNDP (1974), Anon. (1978), Kearney (1978) and the South Pacific Commission in 1980 as reported by Ellway and Kearney (1981). Prasad noted that *S. delicatulus* was by far the most abundant species but that *H. quadrimaculatus* and *A. sirm* constituted a larger part of the total catch by weight.

From the total catch and effort of baitfishing provided by *Sunbird* for the whole period on a monthly basis, Prasad noted that the seasonal fluctuations in catch and effort and also catch per unit effort followed the same pattern, with peaks occurring in the first half of the year. However, whether this reflects a real decline in abundance of the common bait species during especially August – October, or merely a change in vulnerability of bait species to the gear, remained to be thoroughly investigated (Prasad 1982).

Prasad plotted monthly size distributions for the species for which there were sufficient data. (Only *S. delicatulus* and *H. ovalaua* were found during all months of the survey). The small specimens of *S. delicatulus* present during all months except February 1980 indicated to Prasad a more or less continuous recruitment (and spawning). For other species the data were too sparse to form any conclusions.

Prasad calculated the functional relationship between length and weight using an allometric model. Due to scarcity of very small specimens in the sample and some difficulties in identification of small specimens (especially the anchovies), the estimates were based mainly on fish exceeding 30 mm fork length. The relationship for all the species detailed above were tabled in the report.

A survey of the diet of all baitfish species encountered in the samples was carried out by Prasad by examing their stomach contents. Twenty specimens of *R. kanagurta* and *S. crumenopthalmus* and 60 specimens of each of the other species were examined. Crustaceans contributed the most important part of the diet of all groups of bait species. The crustaceans included copepods, amphipods, mysids, isopods, euphausids and decapods. Some juvenile bait species were observed in the stomachs of *S. crumenopthalmus*, *R. kanagurta* and *H. quadrimaculatus*.

As the occurrence of many of the species was limited and there was the lack of an adequate time series from particular areas, Prasad considered his gonad analysis data ill-suited for the indication of periodicity of spawning. However, in the case of *S. delicatulus* and *H. ovalaua*, Prasad was able to distinguish between various maturity stages of the gonads following the classifications detailed in his report. Prasad plotted the monthly distribution of the maturity stages for the baitfish species sampled. No definite trend was apparent in the occurrence of ripe eggs for the species considered. Prasad tabled the relevant information on breeding periods for the same species from other sources and compared this with his data.

Lewis et al.

Lewis et al. (1983) concentrated on a preliminary biological study of *Spratelloides delicatulus* and *Herklotsichthys quadrimaculatus* over a 12-month period. Two sites were chosen for fortnightly sampling and they were eastern Savu Savu Bay and eastern Ovalau Island (an alternate site at Rukuruku was also sampled when strong winds and currents were experienced at the latter of the two sites). Samples were also supplemented from other sources from time to time.

The standard length and the sex of samples from both species were taken. Maximum sizes of 125 mm and 62 mm respectively for *H. quadrimaculatus* and *S. delicatulus* were recorded during the study and individuals larger than 80 mm and 30 mm accounted for the greater majority of the catch in each case.

In neither species was there any significant overall deviation from the expected 1:1 sex ratio. In both species, females predominate at larger sizes and for *H. quadrimaculatus*, males significantly outnumbered females in the smaller 80 – 89 and 90 – 99 mm size groups.

A standard length of 90 mm was given as the probable minimum size at first maturity for *H. quadrimaculatus* and 35 mm as the likely minimum size at first maturity for *S. delicatulus*, with 40 mm the typical size at maturity.

Inferences on spawning periodicity were drawn from average gonadosomatic weight ratios for both sexes per sample. For *H. quadrimaculatus* there seemed to be a well defined peak in spawning activity although limited spawning may occur all year. Although there were gaps in the data for *S. delicatulus*, a much longer spawning period was indicated.

The limited data available for *H. quadrimaculatus* provided no grounds to suggest that spawning seasonality varied between sites.

No examination of the hard parts of the fish were made in the study to assess length at age of the two species. Length–frequency data were also not subjected to any of the analytical methods used to derive growth estimates from such data.

The length – frequency data for *S.delicatulus* were combined from all sites on a monthly basis. Distributions were polymodal and no clear modal progressions were present. For *H. quadrimaculatus* a clear mode was apparent from Savu Savu and the mode could be followed from March through to June. This progression showed a growth rate of approximately 15 mm/month.

From their findings and with information available in the literature Lewis et al (1983) concluded that the baitfish species could be grouped into two contrasting life history patterns:

(a) short lived species, relatively small in size, which show rapid growth, attaining maturity within 3 – 4 months, and spawn (as a population) over an extended period. This group is comprised of most of the stolephorid anchovies and the sprats.

(b) Longer lived species which may survive into a second year, but spawn over a more restricted period. This group includes the herring *Herklotsichthys* sp., the sardine *Amblygaster* sp. and the mackerel *Rastrelliger* sp.

Management strategies for each grouping were considered to be quite different but implementing them for the multi-species fishery would be difficult. It was stated that the life histories of some of the other main baitfish species should be investigated, especially *Rhabdamia* sp. due to its increasing importance in the catches.

Munch-Petersen

Munch-Petersen (1983) estimated the growth and mortality parameters of *Spratelloides delicatulus* in Fijian waters based mainly on samples of size frequency. The estimated growth and mortality parameters were applied in preliminary estimates of yield patterns which were compared with those of actual catches. The samples which formed the basis of the study were collected from January 1980 to April 1981.

Estimated growth parameters were based on the modal progression method. The data for growth estimation was reduced to those samples coming from the site of Levuka combined with Ngau and Munia. The von Bertalanffy growth parameters L_∞ and K were estimated by the iteration method presented by Munro (1982).

The best fit was obtained with $L_\infty = 75$ mm giving K of 0.012/day.

An estimate of mortality was derived by a version of the 'catch curve method' in which length groups are converted to (relative) age groups by means of a growth function. All samples from the various localities were pooled, which implied assuming similar mortalities at the different sites. From the length distributions the author concluded that *S. delicatulus* is not fully recruited into the catch until a size of approximately 45 mm fork length. From his analysis Munch-Petersen found the regression estimate of the (instantaneous) total mortality coefficient (Z) to be 0.028/day (10.3/year), a figure which implied a mortality rate of 90% within 3 months. This mortality rate referred to the 1980 fishing season.

Using the empirical relationship for natural mortality presented by Pauly (1980), the author calculated natural mortality (M) as 0.019/day and therefore fishing mortality (F) as 0.009/day and assumed that natural mortality pressure was considerably heavier than fishing mortality pressure during the 1980 season.

Analytical models of yield and production by Beverton and Holt (1957) to a single batch of recruits (cohort) under two different estimates of natural mortality ($M(1)$ = 0.019 and $M(2)$ = 0.009) were applied. The results according to the model showed that the fishery in both cases removes less than the production during the fishable lifespan. The yield per recruit curves for the different mortality rates were compared and the estimated catch and effort for 1976 to 1981 adjusted to the yield per recruit level on the basis of the 1980 figure for fishing mortality. The observed catch and effort data indicated that option 1 (M = 0.019) was the most likely situation which implied some reality behind the estimated large value of natural mortality.

Munch-Petersen (1983) also estimated the average standing crop (biomass)(B) from B = Catch (C)/Fishing mortality (F) based on the 1980 figure of F = 3.3 for *S. delicatulus* in Fijian waters to be a high of 5.2 t and a low of 2.1 t during the period 1976 – 1981.

Baldwin

Baldwin (1984) documented descriptive characters useful in the identification of 33 species of commercially important baitfishes. The families and number investigated include Clupeidae (subfamilies Clupeinae, Dussumieriinae, Spratelloidinae) (11), Engraulidae (8), Atherinidae (3), Apogonidae (2), Lutjanidae (7), and Scombridae (2). In addition a list of 37 families captured incidentally with the above baitfish species was included.

The report by Baldwin was the result of studies conducted at the University of The South Pacific from October 1981 to April 1982, in cooperation with staff from the Institute of Marine Resources. The main aim of the study was to conduct investigations on baitfish and to collate information that would assist in the identification of commercially important species captured in Fiji using the Japanese-style bouke-ami net technique.

Dalzell et al.

Dalzell et al. (1987) determined the age and growth parameters of *Herklotsichthys quadrimaculatus*, *Spratelloides delicatulus* and *Rhabdamia gracilis* by counts of daily growth increments of the sagittae (Panella 1970). Length–frequency analyses for the first two species were also carried out.

The length–frequency data used were from the regular monthly sampling program of Fisheries Division during the 1981 – 82 fishing season (Lewis et al. 1983). The von Bertalanffy growth curve for *H. quadrimaculatus* was fitted by modal progression analysis using the iterative regression technique of Beverton (in Ricker 1975) as well as by the computer program ELEFAN I (Pauly and David 1981). Length–frequency data for *S. delicatulus* were analysed using ELEFAN I only.

Sagittal increment counts were made of 11 specimens of *H. quadrimaculatus*, 10 specimens of *R. gracilis* and 8 specimens of *S. delicatulus*.

The total mortality rate (*Z*) was calculated from the length–frequency distributions converted to a relative age–frequency distribution or catch curve, given values of L_∞ and *K* (Pauly and Ingles 1981; Gulland 1983). Pauly's (1980) empirical method was used to estimate natural mortality (*M*).

Results for *H. quadrimaculatus* using modal progression analysis gave the best fit to the data for L_∞ = 13 cm and provided a *K* value of 2.02/year. ELEFAN I gave results of L_∞ = 13.1 cm and

K = 2.02/year with a period of slower growth in mid year as indicated by the value of the Winter Point (*WP* = 0.5). The best fit from the saggital increment counts was obtained for L_∞ = 12.6 cm and a *K* value of 2.00/year. Dalzell et al. (1987) stated that different methods gave similar estimates of the growth parameters but emphasised that results were based on the analysis of adult specimens only (no fish smaller than 7.2 cm were included in the otolith analysis).

The results of the sagittal increment counts for *R. gracilis* provided a best fit to the von Bertalanffy growth curve with parameters L_∞ = 5.0 cm and *K* = 2.67/year. Again it was emphasised that only adult fish were used in this analysis (no fish smaller than 2.9 cm were available).

The length–frequency analysis for *S. delicatulus* using ELEFAN I provided estimates of L_∞ = 7.3 cm and *K* = 4.38/year. The best fit for this species from the sagittal increment counts were obtained for L_∞ = 7.3 cm and *K* = 4.58/year.

IV. General Reports

Lal

Lal (1982) identified that the use of intensive culture techniques to produce a suitable baitfish would be one method of alleviating the shortage of baitfish supply available to pole-and-line boats. The Mexican molly, *Poecilia mexicana*, was a species that had been successfully raised in American and Western Samoa and Hawaii. Sea tests had already indicated that this species was suitable as live baitfish for skipjack tuna pole-and-line fishing and it could be produced in large quantities in a relatively simple culture system.

The proposal by Lal (1982) included a report by Prof. W. Baldwin with a preliminary plan for a baitfish rearing facility at Togalevu, approximately 10 km west of Lami. Details of the baitfish rearing facility were given along with costings, and a cost – benefit analysis for the introduction of cultured baitfish to the pole-and-line industry was estimated.

Sharma

Sharma (1988) presented a paper at the Inshore Marine Resources Workshop co-ordinated by the South Pacific Commission. The paper gave a general account of the Fijian baitfishery, much of which is covered in Sharma and Adams (1990).

Ram et al.

Ram et al. (1983), give a general account on the importance of adequate supplies of baitfish for the successful operation of pole-and-line boats in Fiji. A general description of the fishing gear and its operation from the research boat *Aphareus* in the area around Mosquito Island in Lami Bay is given. Samples of baitfish taken from this operation were sent to Japan for identification. The main species identified was *Herklotsichthys quadrimaculatus* (72.31% by numbers). A list of the other species caught is also given.

In the paper it is recommended that, due to the fact that baitfishing operations in Fiji are time consuming, juvenile fish should be kept in cages. It was stated that if these juvenile fish were cultured in net cages, this would to some extent alleviate problems of catching baitfish in Fiji.

Sharma and Adams

A detailed summary of the bait catches by pole-and-line boats operating in Fiji waters over the period 1977 – 1989 in respect of seasonal variation, species composition and catch per unit effort for different areas was made by Sharma and Adams (1990). They also discussed the past biological work done on the two major bait species—*Herklotsichthys quadrimaculatus* and *Spratelloides delicatulus*, together with a discussion on management of the baitfishery in relation to traditional fishing rights.

Sharma and Adams stated that although there were more than 100 defined baiting sites that were used from time to time by pole-and-line boats, probably less than half of these were regularly visited. As boats operated individually rather than on a fleet basis, baitfishing effort was widely distributed. Available catch data for the large number of sites was grouped into eight zones which reflected some administrative boundaries as well as some internal consistency in habitat type. These zones along with the more important individual sites were summarised in the paper of Sharma and Adams (1990). They reported seven species groups that dominated the baitfish catches in Fiji, which are as follows: sprats, sardines, herring, hardyheads, mackerels, cardinals, and anchovies. Other species such as fusiliers, the weak herring and scads were also reported to make occasional contributions to the catch.

The methodology for collection of baitfish catch and effort data is described along with the overall trends apparent from the analysis of this data.

Sharma and Adams reported that catch composition varied with site and season. The catch rates have remained fairly stable over the period the fishery has been in operation with an average of 38 buckets of bait being caught for every haul of the net. Catch versus effort plots showed a strong linear relationship which may reflect some underlying assumptions on abundance as discussed by Wetherall (1977). Therefore, with many suitable areas in Fiji as yet unfished, it was concluded there is probably scope to increase existing catches by moving into new areas.

The average monthly catch/haul and total catch showed distinct seasonality with catch rates generally increasing steadily from low levels in October–November to a peak in April–May, then declining over the June – August period. In response to this, fishing effort figures displayed a similar seasonal pattern. The seasonal fluctuation has been regular since the fishery began and, within any given year, is strongly correlated with mean monthly sea surface temperature.

The distribution of baitfishing effort has changed over the years with the major influences being the proximity of good tuna fishing; expected weather conditions; distance from the unloading site; the location of productive fish aggregation devices and access agreements with traditional owners.

The zone of Lomaiviti recorded the highest baitfish catch with 23% of the total for the period monitored, followed by northern Vanua Levu with 21%, Vanua Balavu with 16%, central Viti Levu with 11% and Levuka with 9%. eastern Vanua Levu, Kadavu and Savu Savu were reported to support large quantities of baitfish but generally provided supplementary catches.

Southern Lau recorded the highest overall catch rate of 44 buckets per set although the overall catch from this area was comparatively small. The second highest catch rate was recorded in Levuka zone followed by Lomaiviti. The zones were followed by northern Vanua Levu, eastern Vanua Levu and Vanua Balavu.

Many sites showed a large change in yield or catch rate depending on the anchorage within the site and for catch rates to fluctuate markedly on a daily or weekly basis at the same site. This was thought to be due to a highly concentrated and mobile bait population, but seems more likely to be the result of dilution of bait or seasonal changes.

Species composition also varied between zones although sprats and sardines generally comprised up to 20% of the catches in this period. A comparison between the two major zones: 'mainland' and 'island' showed anchovies and mackerel to be more abundant at 'mainland' sites, and sprats and cardinal fish at 'island' sites, with sardine and herrings showing little variation.

Sharma and Adams (1990) summarised the biological studies that have been carried out on some of the baitfish species in Fiji. They cover many of the points detailed elsewhere in this review so will not be repeated here.

The management of the baitfish resources, which lie almost entirely within the customary fishing areas and are the mainstay of the pole-and-line industry in Fiji, were considered to be one of the priority tasks of the Fisheries Division. As bait requirements of pole-and-line fishing boats occasionally come into conflict with local interpretations of customary fishing rights, and the concept of 'goodwill' payments for the use of customary fishing grounds is gradually becoming an accepted practice, it was considered that it may become necessary to introduce some sort of permit system for the pole-and-line boats. Fisheries Division had also advised pole-and-line boats to improve their relationships with the local people in the baitfishing areas and, in particular, to prevent the crew doing 'extracurricular' illegal fishing in lagoons as a way of keeping conflicts to a minimum.

It was considered that in the short term, the problem above could be eased by diverting effort to little used baiting grounds. Fisheries Division also planned to perform another survey of baitfishing grounds with the aim of producing a comprehensive baitfish 'atlas' detailing likely species assemblages with sonar profiles and including detailed radar and bathymetric charts to assist anchorage changes during the night.

Lewis

In a summary of the history of baitfishing in Fiji, Lewis (1990), stated that the pole-and-line fishery commenced in 1976. The fleet size had fluctuated since, with a peak of 14 boats in 1981 (Sharma 1988). Both tuna and baitfish availability in Fiji show more seasonality than in other Pacific Island pole-and-line fisheries due to its location in more southerly latitudes, but with the availability of baitfish being strongly correlated with sea surface temperature. These two factors combine to reduce the length of the viable fishing season which in most years is approximately eight months (December – July).

Lewis (1990) stated that the yearly total catch of baitfish had never exceeded 150 t, though recent catch data were incomplete. The areas of northern Vanua Levu and Lomaiviti are the most important zones for baitfishing in Fiji. Pole-and-line boats utilised at least 70 different sites within Fiji within which, for analytical purposes, 11 zones with some consistency in habitat type are recognised.

The baitfishery in Fiji is a multi-species one with *Spratelloides delicatulus*, *Amblygaster sirm*, *Herklotsichthys quadrimaculatus*, *Stolephorus* spp. and *Rhabdamia gracilis* all contributing significantly to catches. The species composition of the catches is subject to spatial, temporal and seasonal variation (Lewis et al. 1983) with some relative consistency in species composition by zone between years. The importance of cardinal fish, *Rhabdamia gracilis*, in the catches is due partly to targeting for them with deeper nets in specific areas. The biology of these species as well as *Spratelloides delicatulus* and *Herklotsichthys quadrimaculatus* (Dalzell et al. 1987; Lewis et al. 1983; Munch-Petersen 1983) had all been partly documented for Fiji waters.

Generally the tuna production ratios for the amount of baitfish used are considerably higher than those in Solomon Islands due to more cautious use of the available baitfish.

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Analysis of Historical Tuna Baitfish Catch and Effort Data from Fiji with an Assessment of the Current Status of the Stocks

N.J.F. Rawlinson* and S.P. Sharma**

POLE-AND-LINE fishing in Fiji makes an important contribution to the landings of locally caught tuna that are received by the Pacific Fishing Company (PAFCO) in Levuka. The cannery belonging to PAFCO is an important source of foreign exchange and employment to Fiji. In 1992, 36% of the tuna caught in Fijian waters by local vessels came from the operations of pole-and-line vessels (Anon. 1992).

Pole-and-line vessels undertake the vast majority of commercial skipjack tuna fishing in Fiji waters and rely on adequate supplies of live bait to stimulate the feeding behaviour that results in tuna biting hooks (Sharma and Adams 1990).

The live bait, or baitfish, in Fiji is caught by the commercial pole-and-line vessels using the bouke-ami technique in conjunction with submerged and overhead lights. This technique has become almost universal in South Pacific baitfisheries (Lewis 1990) and has been well documented (Kearney et al. 1972, Evans and Nichols 1984).

The Fiji group is well endowed with anchorages of moderate depth and with some shelter, suitable for baitfishing. Probably over 100 sites have been used by vessels at one time or another. As vessels operate individually rather than on a fleet basis, effort is widely distributed, although it naturally centres on productive areas adjacent to areas of known skipjack abundance (Lewis et al. 1983).

Monitoring of baitfish catch and effort

The Fisheries Division of Fiji monitors changes in bait catches in order to help pole-and-line vessels in their activities (Sharma and Adams 1990).

For the collection of tuna and baitfish catch and effort data, forms are provided to all pole-and-line vessels by Fisheries Division. Before June 1981, three forms giving details of catches, bait catch by species and tuna length-frequency were used. These were replaced in June 1981 by a single form bound as a booklet (Sharma and Adams 1990).

The information recorded on the form included: date, position, catch per set of the net (in buckets), total bait catch, and estimated species breakdown (%) by the seven main species groupings plus an 'others' category.

Each vessel is supplied with plastic-coated colour photographs of the main species within the groupings, with English, Latin, Japanese and Fijian names on the reverse side. Preserved specimens were also shown to the recorders to avoid any misunderstandings about the baitfish species grouping and thus improving the accuracy of catch composition reports (Sharma and Adams 1990).

Baitfish data recorded from 1982 to the present time were entered onto a database that was written in

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Dbase IV software. This system was improved and modified and now operates using FoxPro software after assistance from the South Pacific Commission in 1991.

Methods

One of the first tasks under the Baitfish Research Project was to analyse all existing baitfish catch and effort data that was available in Fiji. The baitfish catch and effort database had records starting from January 1982. Unfortunately after initial interaction with the database it became apparent that there were some problems with the data that had been entered. This invoked a more detailed look at the raw data which uncovered more discrepancies. Major modifications, therefore, had to be made to the database before a meaningful analysis of the data could be undertaken. Some of the problems that had occurred which needed to be addressed were:

1) A large number of logsheets received by Fisheries Division had not been entered into the database. This was corrected by simply key punching the data into the computer. It was difficult from some logsheets to assign the year the data came from. The logsheet itself allowed for the entry of the month of operation by the pole-and-line vessel but not the year. There was space provided in a box, marked confidential, for this information to be recorded when it arrived at Fisheries Division but in many cases this had not been done. As some of the unentered logsheets went back a few years it made it difficult to establish what year the data came from. This was overcome by working out the total tuna catch, also recorded on the same logsheet, for that month by the vessel and comparing this with monthly catch records in the annual reports.
2) Inaccurate data entry was another reason for many discrepancies in the database. These were corrected by referral to the original logsheets.
3) Inaccurate assignment of the positions recorded on the logsheet to the actual locality codes required by the database. The nightly baitfishing position is recorded on the logsheet as a latitude and a longitude. This position under the system used by Fisheries Division had to be interpreted by the data entry clerk who assigned a code for the baifishing area that this position was in. This was often done incorrectly as some data entry clerks were not familiar with plotting a position from a latitude and a longitude, and the baitfishing areas on the list referred to were given by a single latitude and longitude and not as an area. Actual positions of the baitfishing areas often did not match and so the area allocated was often the one that had a latitude or a longitude the same as the position recorded.

   This problem was corrected by describing each baitfishing site as a rectangular area with a north-easterly and south-westerly latitude and longitude and testing whether the position given was actually within the area of the code that had been allocated. In many instances this was not the case. For these records, the raw data was checked and the position correctly entered or the baitfishing area correctly allocated.
4) For some records the latitude and longitude positions that were recorded on the logsheets represented a position which could not have been a baitfishing site e.g. in the middle of an island or a location in the middle of the ocean. In some cases these records were simply wrong data entries but for others this was the data given on the logsheet so the baitfishing position had to be recorded as an 'unidentified' site.
5) Percentage species composition data often did not add up to 100%. Such records were checked against the raw data and corrected accordingly.

Once all the corrections had been made, the months of operation of each vessel recorded on the database were checked against the record for monthly vessel landings as detailed in the annual reports. From this it was possible to identify the boat-months from which data were missing. In some cases it was possible to locate these logsheets from company files and fill in the gaps. However it was not possible to recover all the data so these months had to be considered as suffering from under-reporting and the appropriate adjustments made on the database during the course of the analysis to take this into account.

Table 1 gives a breakdown of the percentage of monthly logsheet returns by vessel by year against actual months of fishing operation that year. This shows a high return of logsheets in 1982 (96%) followed by a gradual decline to levels of about 60% of the expected number in the mid-1980s. The proportion of logsheet returns increased during 1992 to 92% of the boat-months of operation. This was achieved by reminding vessel owners that it was a condition of their licence to give complete catch and effort information from their baitfishing operations and also by contacting the companies when monthly logsheets were not forthcoming.

The analysis in this report uses figures presented in the Fisheries Division Annual reports from 1976 to 1981, and the data coming from the new logsheet system from 1982 through to the present time that have been stored on a computerised database. All annual figures reported are calculated by calendar year (total from January to December inclusive).

Baitfish catch data since 1980 are based on the 'bucket' unit and catches recorded before 1980 have been standardised into these units. The unit of a 'bucket' is not ideal, since there is some variability

Table 1. Percentage of baitfish logsheet returns 1982—1992*

Year/Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	LOGS
1982	92	100	100	100	100	100	86	75	0	100	91	100	96	114
1983	92	86	77	82	55	57	17	50	-	-	60	67	70	91
1984	70	64	73	78	83	100	100	67	0	50	50	67	73	70
1985	57	71	83	83	83	83	67	-	-	0	0	57	67	55
1986	57	71	71	83	83	67	50	25	67	67	67	80	67	61
1987	83	83	83	67	67	50	60	33	50	50	80	71	67	64
1988	63	78	78	67	67	50	43	25	-	0	50	38	58	76
1989	44	64	67	82	78	25	43	0	100	50	83	58	59	92
1990	82	67	69	54	40	71	43	0	0	0	80	67	59	90
1991	75	75	88	60	67	45	20	-	-	50	80	75	65	74
1992	100	91	100	91	100	100	100	100	100	100	100	100	92	97

*This table details the baitfish logsheets returned against the number of vessels operating on a monthly basis and the total number of boat-months of operation per year (LOGS)

depending on the bait species caught, but it is the best compromise suitable for commercial boat crews (Sharma and Adams 1990). The wet weight of fish per bucket in Fiji was considered to be 1.8 kg (Lewis et al. 1983) but there has been a change to the use of larger buckets in recent years so for this report a bucket will be taken to be 2 kg, which can be considered typical (Lewis 1990). Effort has been measured both in terms of how many 'hauls' of the net have been made and how many actual 'nights' of operation took place.

Adjustments of data for under-reporting

As detailed above and as shown in Table 1 a lot of data have been missing on the catch and effort of baitfish during the 1982 to 1992 period. Adjustments to the data have been made to account for this 'under-reporting':

1. As there is a seasonal change in the abundance of baitfish available to the industry (see Figure 4) this had to be taken into account while making the adjustments. Monthly total catch and effort figures were multiplied by a factor that was calculated as the known number of boat-months of operation divided by the number of boat-months of operation that were recorded on the database. It had to be assumed that all months when vessels landed fish were complete months (30 days) of operation. Monthly adjusted figures were totalled to give annual figures.
2. In situations where there was no monthly data recorded on the database but vessels were known to be operating, adjustments were made to annual catch and effort using an annual factor calculated in the same way as the monthly factor above. No monthly figures could be given.
3. It was not possible to determine where the unreported fishing effort were actually carried out. It had to be assumed that the data available for the location of fishing effort was representative of the unreported data hence total catches by site were multiplied by the same annual and monthly factors detailed above. This assumption however, cannot be considered strictly correct as certain vessels, which consistently did not supply their data, usually have preferred baitfishing locations. Weighting towards these favoured areas without the exact catch and effort data was not possible.

Results and Discussion

Overall situation in Fiji

The total catch and effort of baitfish in Fiji waters from 1976 through to 1992 is listed in Table 2. The figures from certain years do not equal those from some previous reports (Sharma 1988, Sharma and Adams 1990) of baitfish catch and effort because the non-return of logsheets had not been taken into consideration.

The catches of baitfish rose from the initial levels in 1976 when commercial operations first took place to their highest recorded total in 1992 of 123 815 buckets (approximately 250 t). The relationship between catch and effort during this period was linear as shown in Figure 1. The average catch rate over this 17-year period was 35.9 buckets of baitfish per haul of the bait net.

The lack of pronounced curvature in the catch-effort relationship is considered by Dalzell and Lewis (1988) to be due to the dynamics of the pole-and-line industry. As baitfish are essential to the capture of tuna, fishermen will quickly leave a baitground when catches decline and will try other locations for bait supply. The linear relationship between catch and effort was also noted for the baitfisheries in Solomon Islands (Rawlinson and Nichols 1990) and Kiribati (Rawlinson et al. 1992).

A plot of catch per unit effort against effort (Fig. 2) does show some trend of lower catch rates at higher

Table 2. Total baitfish catch and effort in Fiji 1976—1992

Year	Hauls	Buckets	Nights	Buckets per haul	Buckets per night	Hauls per night
1976	471	27449	350	58.28	78.43	1.35
1977	942	44771	558	47.53	80.23	1.69
1978	1143	61574	844	53.87	72.95	1.35
1979	1093	42608	787	38.98	54.14	1.39
1980	1172	31346	977	26.75	32.08	1.20
1981	1681	61457	1316	36.56	46.70	1.28
1982	2693	83262	1965	30.92	42.37	1.37
1983	2321	72758	1653	31.35	44.02	1.40
1984	1652	74028	1187	44.82	62.37	1.39
1985	1720	53063	1161	30.85	45.69	1.48
1986	1504	49504	1063	32.92	46.57	1.41
1987	1660	61837	1182	37.25	52.32	1.40
1988	2039	94010	1397	46.11	67.28	1.46
1989	2556	109283	1584	42.75	69.00	1.61
1990	2778	110725	1753	39.85	63.17	1.58
1991	2057	877775	1294	42.67	67.83	1.59
1992	3057	123815	1764	40.50	70.18	1.73

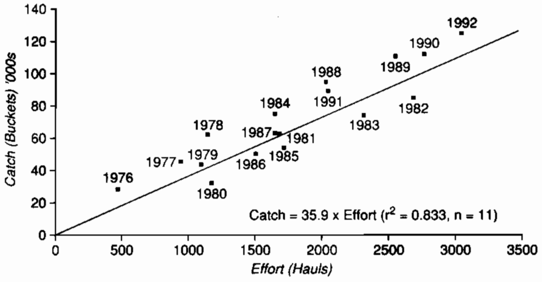

Figure 1. Total catch v. total effort Fiji baitfishery 1976 - 1992

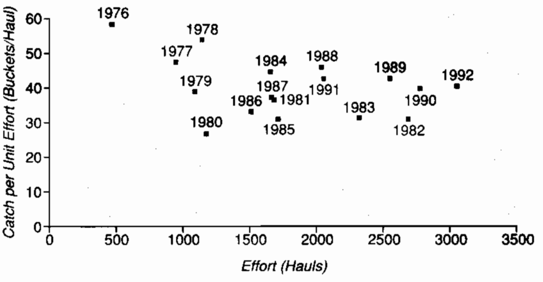

Figure 2. Catch per unit effort v. effort Fiji baitfishery 1976 - 1992

levels of fishing effort but there is so much variation in the data that no definite relationship can be observed. During the 1980 season, poor catch rates caused difficulties for the pole-and-line industry. Ellway and Kearney (1981) examined the situation and suggested that poor recruitment was the major contributor to the low catches. Generally catch rates have been higher from 1988 through to 1992 even though fishing effort during these years has been higher than during the mid-1980s. A definite downward trend would suggest that present levels of fishing effort are affecting the available supplies of baitfish but this does not appear to be the case for the overall situation.

The circumstances within Fiji are that there are many suitable baitfishing areas for the fishing masters to choose from. The selection of the baitfishing site used by the fishing master then becomes a trade-off between being in close proximity to the tuna fishing grounds and the expected baitfish catch rates from that site. This situation makes the baitfishery in Fiji basically self-regulatory. As catch rates from a particular area decline to levels where insufficient baitfish can be caught in order to undertake a successful days tuna fishing, then the vessels will target their effort to a new location. The reduction of effort from the site showing poor catch rates will allow the baitfish stocks to undergo a recovery period. At the present levels of fishing effort in Fiji, and excluding any severe changes in environmental conditions, the catches of baitfish will remain sustainable at levels sufficient to allow the pole-and-line fleet to continue to operate at their current levels.

The overall annual baitfish species composition from 1982 to 1992 is shown in Figure 3. This clearly shows that the Fiji baitfishery is a multi-species one (Lewis, 1990) and there is a great variation in the composition of the catch from year to year. The most dominant changes however, are the decline in the importance of the herring, *Herklotsichthys quadrimaculatus*, in the mid-1980's to a small proportion of the catch in 1992, and

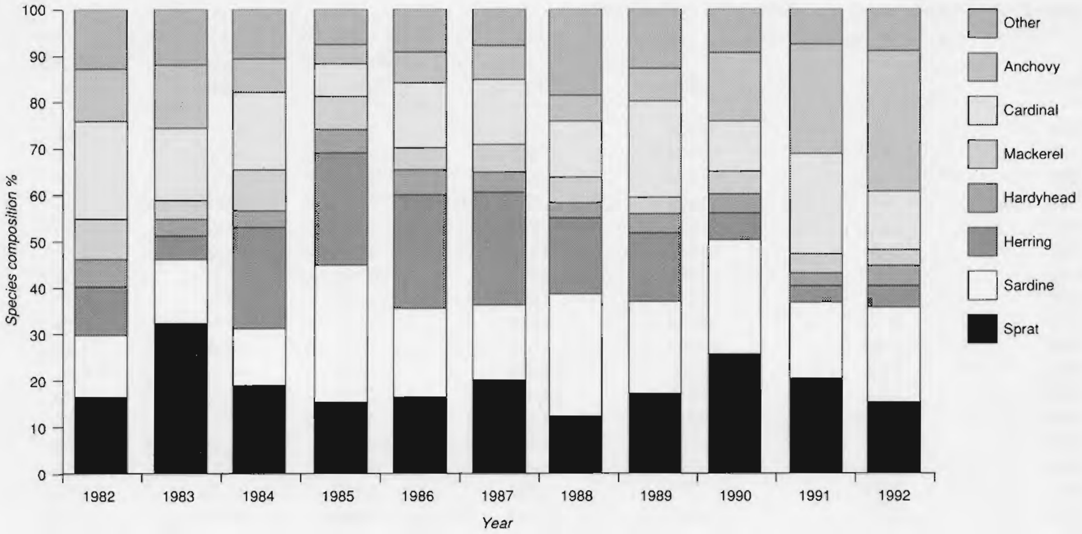

Figure 3. Baitfish species composition for all baitfishing sites in Fiji combined

the increase in importance of anchovies (*Encrasicholina* sp.) in recent years. These effects will be discussed in more detail below.

The seasonal change in abundance of baitfish has been well documented in Fiji (Sharma and Adams 1990). Figure 4 shows the mean catch per unit effort by month over the period 1982 to 1992. The highest catch per unit effort value was in March and the lowest in July. There is another small peak in October, but this was not as high as in March, and a decline to the end of the year before the gradual increase to the high in March. Standard error bars for each month show the variation over the years from the monthly mean catch per unit effort figure. If this variation is due to the different sizes of monthly recruitment of baitfish from year to year, then February to March, and August to November, can be identified as the major recruitment 'windows'. The limited variation in July shows this to be a period of low recruitment of baitfish. A similar situation, though not as pronounced, was identified in the Solomon Islands baitfishery (Rawlinson 1990).

This seasonal variation in the availability of baitfish has led to the pole-and-line vessels ceasing fishing effort over the August to September period, and generally there is a defined fishing season starting from October through to June and July.

As previously mentioned baitfishing effort is widespread across the Fiji group. A percentage breakdown of total annual baitfish catches by island or general area from 1982 to 1992 is given in Table 3. This shows that 17 general areas plus a group of locations listed as 'other' were used over this period but that

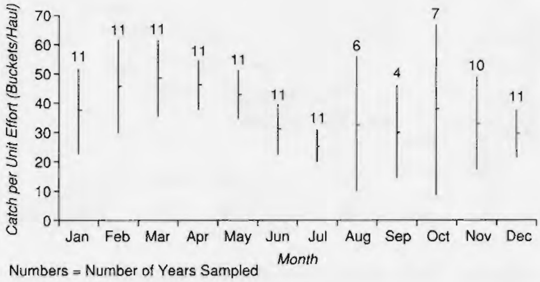

Figure 4. Mean CPUE by month (with standard error bars) Fiji baitfishery 1982 - 1992

only a few were used regularly. In order to detect any effects of fishing effort on baitfish stocks on a local basis, it is important to look at the available catch and effort information on a site-by-site basis.

Baitfishing catch and effort by area

Sharma and Adams (1990) described the following conditions as influencing where pole-and-line fishing vessels choose to undertake baitfishing operations in Fiji:

- proximity to good tuna fishing
- expected weather conditions
- distance from unloading sites
- location of productive fish aggregation devices or payoas
- access agreement with traditional owners.

The most important factor is the proximity of the baitground to expected areas of good tuna fishing. As information is not available on the relative abundance of tuna in and around the waters of Fiji over the time period being considered it is difficult to determine the overall effect of this factor. However, it must be considered as an important influence on the decision of where to catch baitfish and such a decision is not only influenced by the availability of baitfish.

Details of the relative fishing effort by area are given in Table 3. The areas listed are either individual island groups e.g. Vanua Balavu and Ngau, or coastal areas of the two largest islands (Viti Levu and Vanua Levu). The table shows the large number of different geographical areas used but with annual catches primarily coming from three or four main areas. The relative changes in the abundance of bait taken from different areas highlights the shifting variation in importance of areas from year to year. The location of these sites within Fiji can be seen in Figure 1. (Blaber et al. these proceedings p. 52)

The general areas given in some cases are large and have themselves been divided into individual sites. The breakdown in the relative catch taken from each site for Vanua Balavu, north Vanua Levu, Ngau, eastern Vanua Levu, Beqa, Ovalau, Kadavu, western Viti Levu, Savusavu, southern Viti Levu, northern Lau, southern Lau and Other areas are detailed in Tables 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 and 16 respectively. Some areas like Namena are not broken down by sites. Within the areas there is usually one or two sites where most of the fishing effort takes place e.g. Kia Island from northern Vanua Levu, Sawaieke from Ngau etc. A lot of baitfishing effort is therefore not only localised to certain areas but to individual sites within those areas.

Plots of baitfish catch against effort, catch per unit effort against effort and relative annual species composition have been made for all the important baitfishing sites. These plots marked as (a), (b) and (c) respectively for each site have been made for Vanua Balavu (Fig. 5), north Vanua Levu (Fig. 6), Ngau (Fig. 7), eastern Vanua Levu (Fig. 8), Beqa (Fig. 9), Ovalau (Fig. 10), Namena (Fig. 11), Kadavu (Fig. 12), western Viti Levu (Fig. 13), Savu Savu (Fig. 14), southern Viti Levu (Fig. 15) and Suva/Lami Bay (Fig. 16).

In all cases the relationship between catch and effort is linear, However, some areas show more variation in this relationship than others. Table 17 summarises the average catch rate described by the linear relationship for each site together with the correlation (r^2) for each linear regression. There is no downward trend in catch with increased fishing effort which suggests that there is little pressure on the baitfish stocks.

The relationship between catch per unit effort (CPUE) and effort for each area also does not show any decline in relative abundance of baitfish (as described by the CPUE figures) and increased fishing effort. Generally catch per unit effort figures have remained fairly constant even at the higher levels of fishing effort e.g northern Vanua Levu and Ovalau. Some of the areas show two distinct levels in CPUE over the years, the higher often being recorded during periods of higher fishing effort e.g. Vanua Balavu and Ngau. This may be due to an increased abundance of a certain species during some years.

The overall data suggests that commercial bait-fishing has had no significant effects on the stocks of baitfish.

Table 3. Annual baitfish catch by area (expressed as percentage of total catch)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Vanua Balavu	7.85	10.65	13.13	17.61	10.87	14.50	30.83	22.43	32.01	26.74	45.65
North Vanua Levu	24.06	22.10	24.66	3.98	18.78	26.17	12.67	20.22	16.03	7.10	11.09
Ngau	5.46	14.75	12.87	15.99	9.27	7.16	18.55	13.96	10.76	18.10	7.60
East Vanua Levu	4.25	13.79	4.91	5.51	7.64	7.91	3.15	11.74	3.53	15.81	1.95
Beqa	14.53	3.45	7.42	4.62	2.35	3.11	4.90	1.54	10.19	2.92	7.51
Ovalau	5.86	3.88	5.21	15.72	11.97	8.85	6.36	7.64	3.74	1.97	4.31
Namena	8.55	2.55	3.46	2.85	4.84	0.69	6.09	12.04	5.25	13.85	1.35
Other	6.89	4.26	9.26	3.33	8.28	7.03	2.25	1.37	3.35	5.53	2.58
Kadavu	6.47	9.61	2.66	3.08	5.16	7.70	5.05	0.87	4.75	1.55	2.88
West Viti Levu	0.85	1.23	1.70	13.24	0.82	0.00	0.20	0.21	2.40	2.55	10.63
Savusavu	4.44	2.98	4.96	2.98	8.08	3.87	5.57	2.76	4.54	0.74	1.09
Makogai	0.48	3.36	2.25	2.64	1.91	1.00	1.69	1.52	1.36	0.08	0.15
Sava/Lami Bay	2.68	0.93	0.99	0.70	0.70	0.81	0.75	0.69	0.42	0.71	0.64
Southern Lau	3.00	0.53	1.19	1.95	0.00	0.00	0.00	0.00	0.00	0.50	0.40
Northern Lau	0.95	0.70	1.12	0.07	0.20	0.09	0.69	1.93	0.43	0.25	0.28
Koro	1.50	0.46	1.04	0.44	0.04	0.23	0.00	0.00	0.00	0.26	0.00
Motoriki	0.00	0.00	0.00	0.00	0.03	0.00	0.20	0.31	0.11	0.99	0.21
Total catch (buckets)	83 262	72 758	74 028	53 063	49 508	61 837	94 101	109 283	110 725	87 775	123 815

Table 4. Percentage of annual catch from Vanua Balavu by site

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand Total
Daliconi	21	12	26	24	42	14	38	8	14	50	65	39
Qilaqila	33	66	45	35	48	59	29	52	48	23	26	36
Thikombia	4	0	6	0	0	0	0	0	0	0	0	0
Avea	6	1	3	2	0	3	1	9	23	22	2	7
Munia	37	21	20	40	11	24	32	30	14	4	7	17
Total Buckets	6566	7743	9757	9347	5393	8993	28946	24535	35433	23406	56501	216618

Table 5. Percentage of annual catch from northern Vanua Levu by site

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Sausau Bay (Kavewa Is.)	24	26	13	4	4	13	12	9	35	17	11	17
Kia Island	50	45	54	52	55	41	62	80	34	60	72	55
Mali Island	12	8	2	0	14	9	6	1	2	6	0	6
Tilagica Bay/Passage	2	1	1	3	0	0	0	0	0	2	0	1
Macuata Island/Ravi Ravi	3	10	0	4	1	25	2	4	2	1	6	6
Vatuki Island	0	4	0	8	0	0	0	0	0	0	0	1
Bekana Harbour/Lagi Bay	7	5	9	13	10	10	8	2	25	0	2	8
Yadua Island	0	0	0	0	0	0	0	0	0	0	0	0
Nakusa/Udu Point	0	1	18	13	17	0	9	3	1	13	1	5
Natewa Bay	0	0	0	0	0	1	0	0	0	0	0	0
Nadogo Island	0	0	0	0	0	0	1	1	0	0	4	1
Yaqaga Island	1	0	1	3	0	0	0	0	0	0	5	1
Total Buckets	20110	160065	18316	2114	9316	16229	11898	22126	17748	6217	13726	297866

Table 6. Percentage of annual catch from Ngau by site.

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Somosomo	7	5	1	63	41	6	4	23	19	13	29	18
Nawaikama	23	1	0	4	9	0	1	4	2	3	2	3
Qarani	9	0	0	3	3	0	2	0	0	0	0	1
Sawaieke	55	88	98	30	44	91	80	60	73	83	57	71
Nukuloa	6	6	1	0	4	2	14	14	6	1	12	7
Total Buckets	4561	10721	9564	8487	4601	4439	17414	15271	11910	15843	9406	112217

Table 7. Percentage of annual catch from eastern Vanua Levu by site

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Qamea Island	12	2	36	2	2	1	4	1	0	0	0	4
Kubulau/Napuku	8	2	0	3	0	7	0	2	7	34	22	10
Rabi Island	2	0	0	0	0	1	0	0	0	0	0	0
Kioa Island	1	0	7	11	4	7	0	1	0	1	13	3
Viani Bay	75	95	57	83	94	85	96	96	93	65	65	82
Fawn Harbour	2	0	0	0	0	0	0	0	0	0	0	0
Total buckets	3556	10023	3650	2925	3790	4904	2956	12840	3906	13844	2409	64803

Table 8. Percentage of annual catch from Beqa by site

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Vaga Bay Rakeus	73	47	72	65	69	68	40	36	16	57	89	58
Maturma Bay	23	27	2	4	0	0	23	23	44	11	9	20
Total buckets	12 149	2510	5515	4046	1164	1927	4605	1687	11276	2559	9300	56738

Table 9. Percentage of catch from Ovalua by site

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Levuka	19	40	60	2	22	8	26	41	9	14	6	21
Vagadaci	0	5	0	2	1	0	0	2	0	0	0	1
Nasova	28	16	6	0	14	9	6	8	20	4	5	10
Viřo	6	4	7	31	18	0	6	3	53	0	27	15
Rukuruku	15	28	18	58	43	82	51	43	9	82	62	45
North Ovalau	32	7	9	8	3	0	11	3	8	0	1	8
Total buckets	4896	2822	3866	8346	5939	5485	5969	8255	4140	1729	5330	56876

Table 10. Percentage of catch from Kadavu by site

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Galea	26	53	15	37	24	23	7	55	53	5	79	38
Yauravu	15	8	0	1	9	14	55	5	11	0	2	13
Moani Bay	1	0	0	0	16	0	9	0	0	0	0	2
Drue/Namalata Bay	0	1	0	5	7	1	0	0	0	0	5	2
Soso Bay	17	5	0	4	1	18	0	0	0	14	0	6
Kavala Bay	4	6	19	0	0	0	4	0	15	3	0	5
North Bay/Namara	35	27	66	52	43	44	25	31	22	78	14	34
Daviqele	1	0	0	0	0	0	0	9	0	0	0	0
Dravuni	1	0	0	0	0	0	0	0	0	0	0	0
Total buckets	5412	6987	1975	1637	2562	4775	4745	956	5257	1356	3561	39223

Table 11. Percentage of annual catch from western Viti Levu by site

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Nacula Island (Yasawas)	0	0	0	1	0	0	0	0	0	0	0	0
Momi Bay	31	2	11	4	0	0	0	0	8	11	0	4
Yasawa Island	0	0	0	7	0	0	0	58	19	59	16	15
Waya Island	0	0	0	0	0	0	0	0	0	0	1	1
Naviti Island	12	11	0	1	0	0	0	0	0	0	6	4
Malolo Island	37	87	89	16	14	0	0	0	27	17	55	43
Mana Island	0	0	0	56	86	0	33	42	46	13	11	23
Yanuya Island	20	0	0	14	0	0	0	0	0	0	2	4
Nadi Waters	0	0	0	0	0	0	0	0	0	0	2	1
Vomo Island	0	0	0	0	0	0	0	0	0	0	7	4
Lautoka	0	0	0	0	0	0	0	0	0	0	1	1
Ba	0	0	0	0	0	0	67	0	0	0	0	0
Total buckets	713	891	1259	7028	406	0	191	230	2661	2236	13156	28772

Table 12. Percentage of annual catch from Savu Savu by site.

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Vatuiele	8	5	18	4	17	47	19	12	16	41	20	17
Savarekareka	11	0	0	1	4	18	3	0	14	0	0	5
Valaga Bay	3	9	3	3	9	9	8	10	12	0	8	7
Urata	0	4	14	3	0	9	9	11	26	19	8	9
Kubulau	65	62	40	43	51	0	52	39	26	33	12	42
Naisonisoni	4	13	2	0	11	9	0	0	2	0	6	4
Wainunu Bay	2	0	6	10	0	0	0	6	2	8	7	3
Savusavu Bay	1	0	4	1	1	6	0	18	0	0	5	3
Nayavu	6	7	13	34	7	1	10	5	2	0	33	10
Total buckets	3933	2340	4227	2407	4298	2423	5784	3185	5106	651	1346	35700

Table 13. Percentage of annual catch from southern Viti Levu by site

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Serua Harbour	96	99	100	76	84	74	100	100	100	90	68	86
Lomeri	0	0	0	0	0	0	0	0	0	0	22	2
Deuba	4	1	0	24	16	26	0	0	0	10	10	12
Total buckets	1600	3020	1814	393	4204	6719	413	675	1164	293	1388	21684

Table 14. Percentage of annual catch from northern Lau by site

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Nukutolu Islet	0	0	0	0	0	0	0	0	0	0	21	2
Qelelevu	98	12	70	60	100	0	100	96	79	67	66	80
Wailagilala Island	2	88	30	40	0	100	0	4	21	33	13	18
Total buckets	796	508	830	36	100	59	652	2115	479	222	350	6146

Table 15. Percentage of annual catch from southern Lau by site

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Moala	37	72	41	0	0	0	0	0	0	100	0	34
Naroi/Cakova	1	0	0	0	0	0	0	0	0	0	0	1
Matuku Island	3	24	0	0	0	0	0	0	0	0	0	3
Aiwa	0	3	0	0	0	0	0	0	0	0	0	0
Yagasa	35	0	0	6	0	0	0	0	0	0	61	25
Ogea	8	0	40	80	0	0	0	0	0	0	26	24
Oneata	11	0	19	15	0	0	0	0	0	0	13	11
Reid Haven	4	0	0	0	0	0	0	0	0	0	0	2
Totoya	1	0	0	0	0	0	0	0	0	0	0	1
Total buckets	2505	385	883	1034	0	0	0	0	0	441	499	5746

Table 16. Percentage of annual catch from other baitgrounds by site

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Grand total
Nanaku-Ra	0	0	0	22	4	0	0	0	0	0	0	1
Thuvu Harbour	1	2	0	0	0	0	0	0	0	0	0	0
Rewa	1	0	0	0	0	0	0	0	0	0	1	0
Ruku Ruku Bay	3	6	2	14	7	0	8	7	5	0	4	4
Nabouwalu	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified	95	92	98	64	89	100	92	93	95	100	95	94
Total buckets	5 758	3 101	6 879	1 766	4 109	4 361	2 112	1 502	3 703	4 844	3 197	41 332

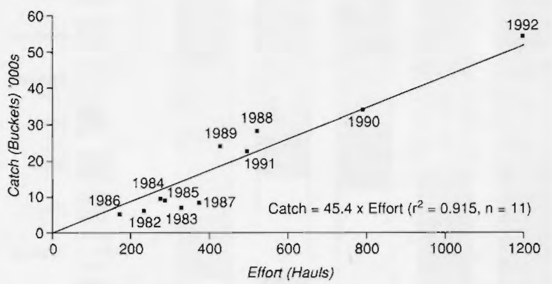

Figure 5a. Baitfish catch v. effort Vanua Balavu

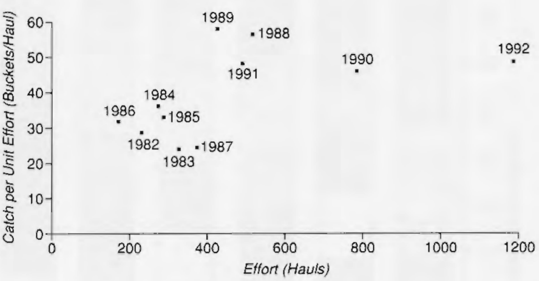

Figure 5b. Baitfish CPUE v. effort Vanua Balavu

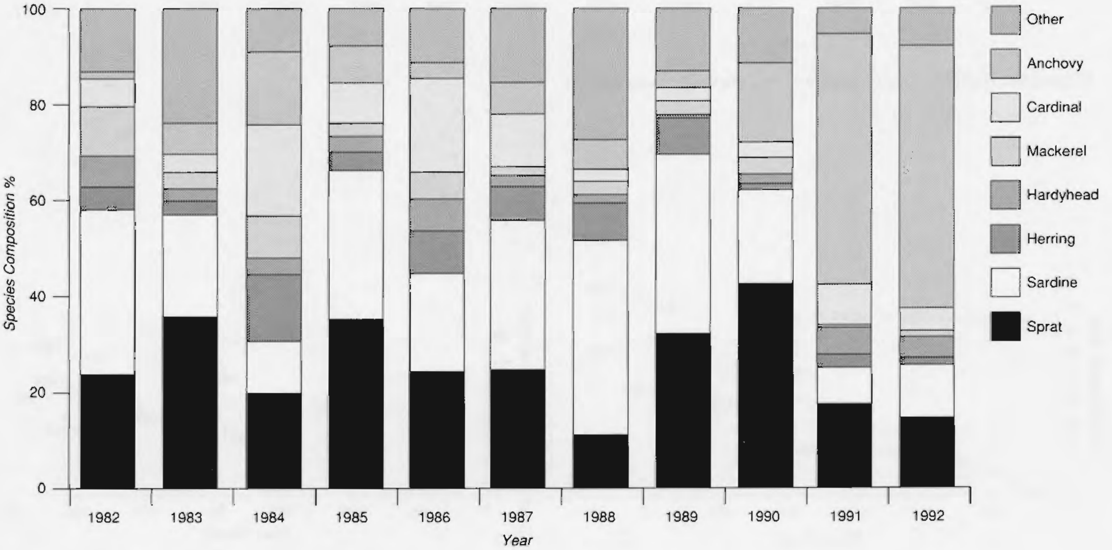

Figure 5c. Baitfish species composition Vanua Balavu

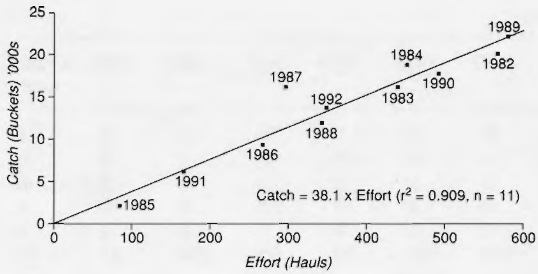

Figure 6a. Baitfish catch v. effort northern Vanua Levu

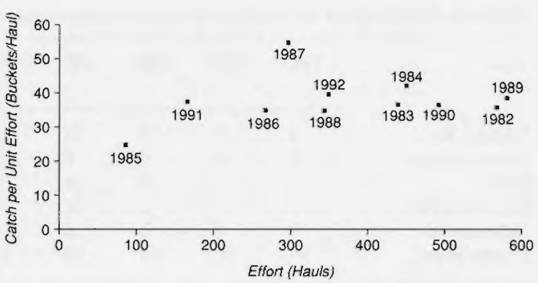

Figure 6b. Baitfish CPUE v. effort northern Vanua Levu

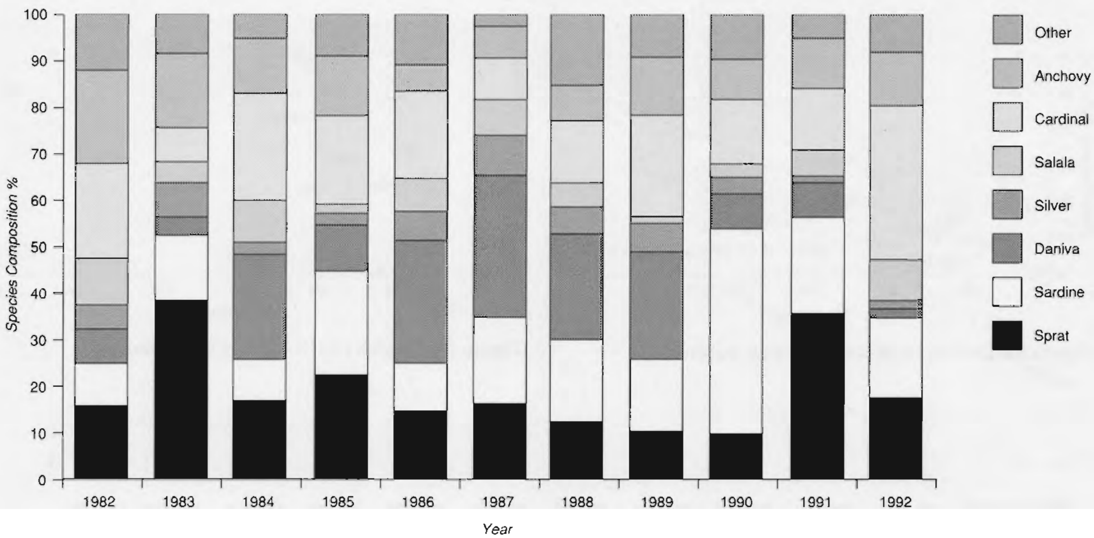

Figure 6c. Baitfish species composition northern Vanua Levu

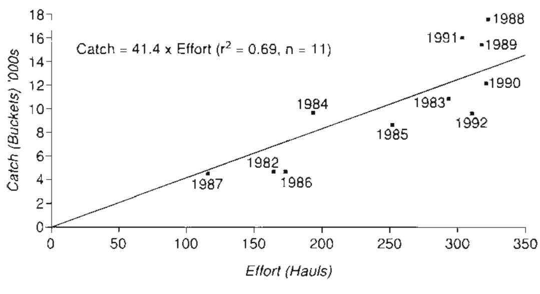

Figure 7a. Baitfish catch v. effort Ngau

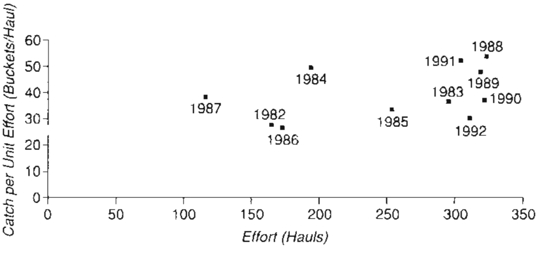

Figure 7b. Baitfish CPUE v. effort Ngau

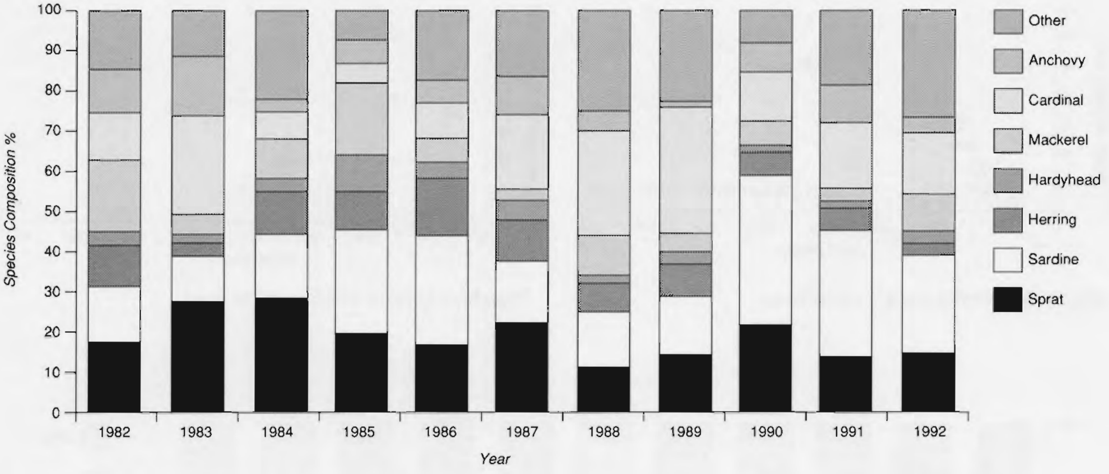

Figure 7c. Baitfish species composition Ngau

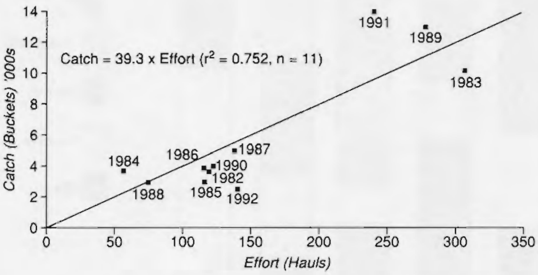

Figure 8a. Baitfish catch v. effort eastern Vanua Levu

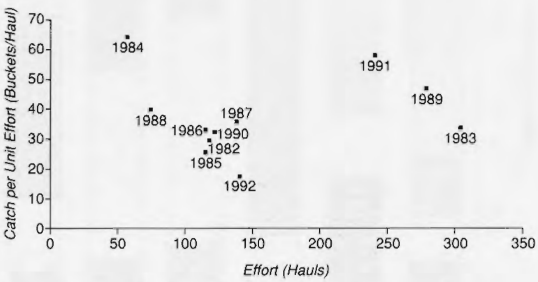

Figure 8b. Baitfish CPUE v. effort eastern Vanua Levu

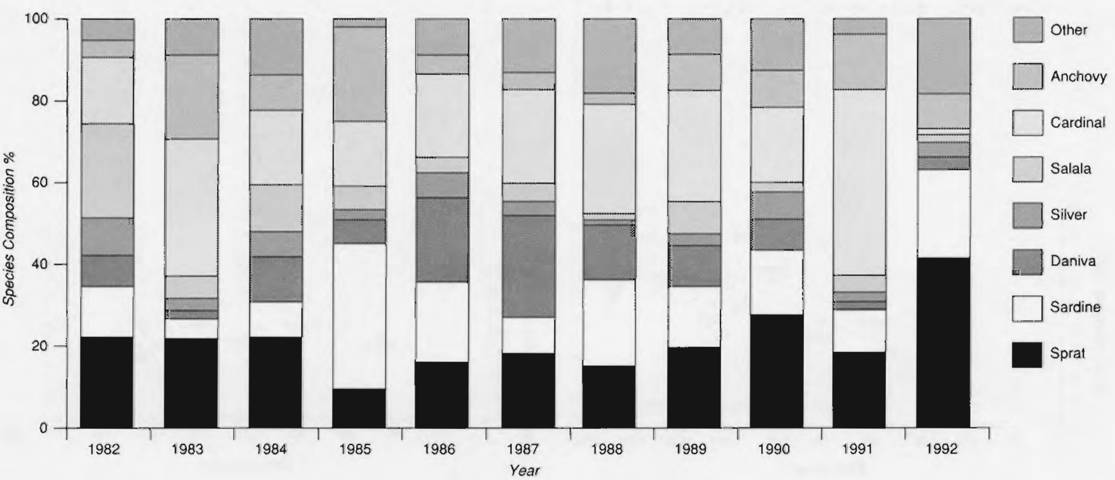

Figure 8c. Baitfish species composition eastern Vanua Levu

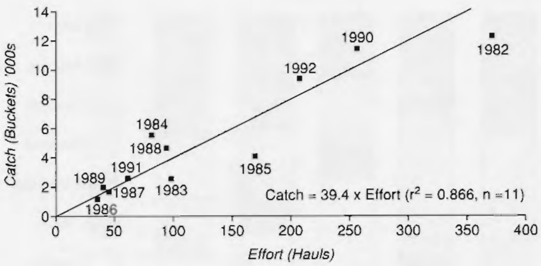

Figure 9a. Baitfish catch v. effort Beqa

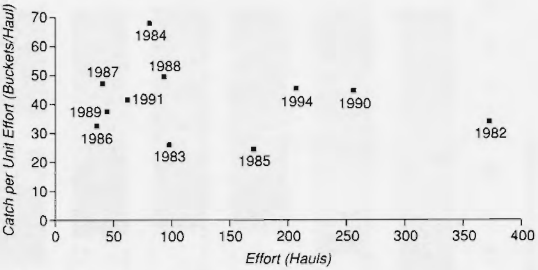

Figure 9b. Baitfish CPUE v. effort Beqa

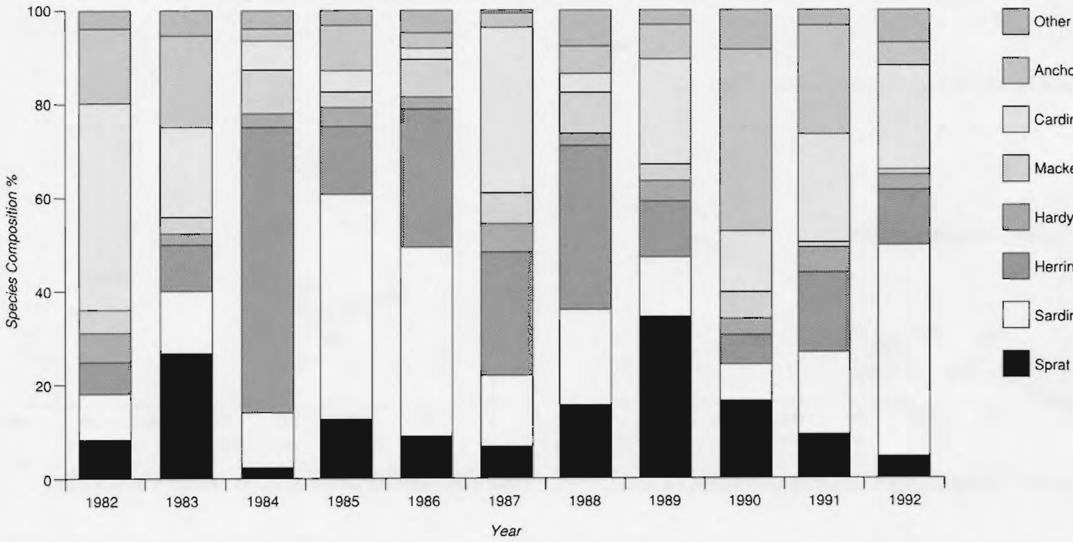

Figure 9c. Baitfish species composition Beqa

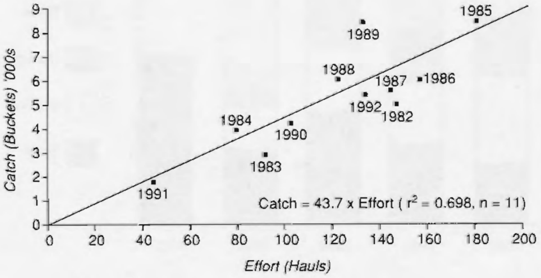

Figure 10a. Baitfish catch v. effort Ovalau

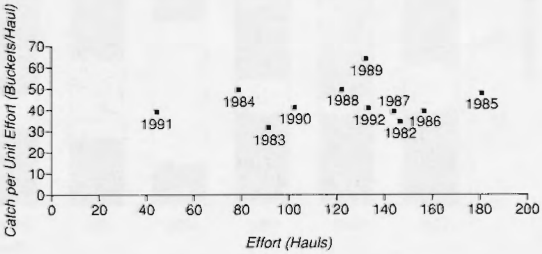

Figure 10b. Baitfish CPUE v. effort Ovalau

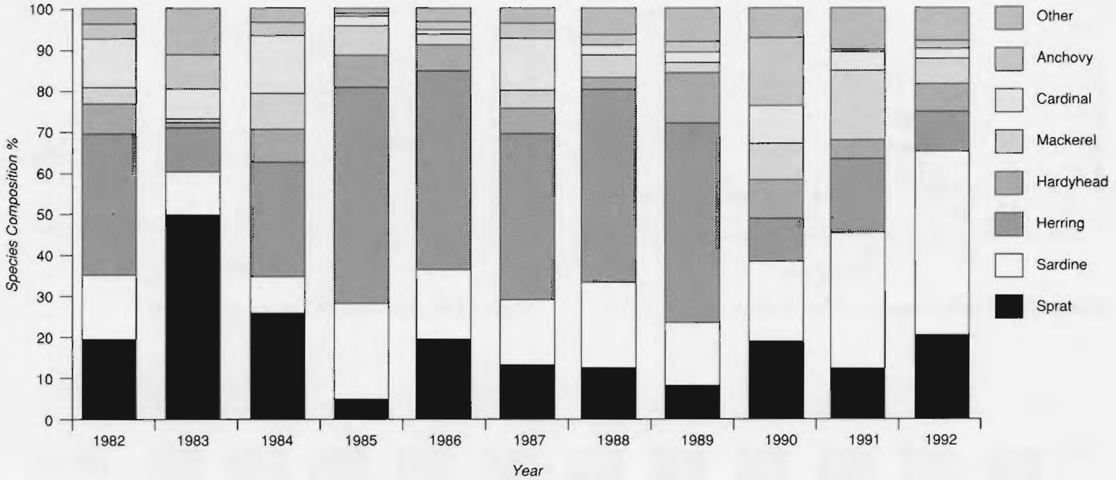

Figure 10c. Baitfish species composition Ovalau

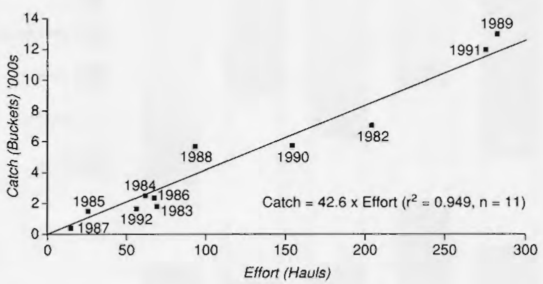

Figure 11a. Baitfish catch v. effort Namena

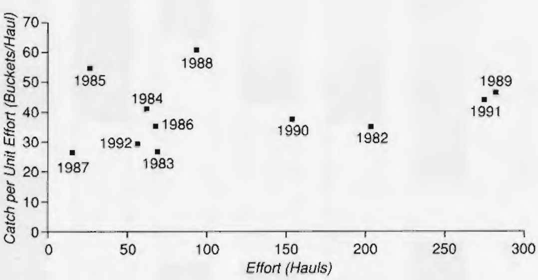

Figure 11b. Baitfish CPUE v. effort Namena

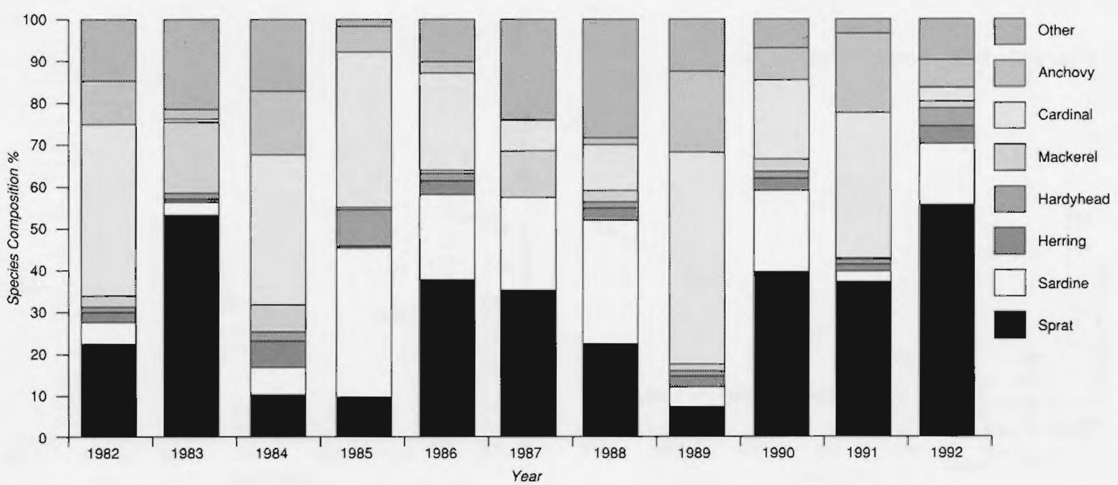

Figure 11c. Baitfish species composition Namena

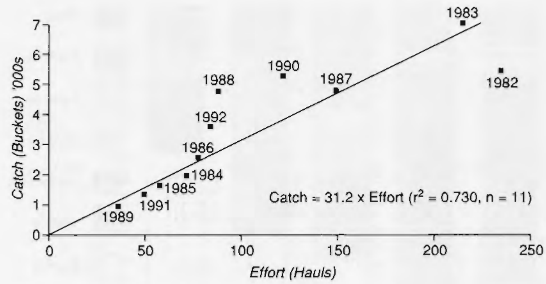

Figure 12a. Baitfish catch v. effort Kadavu

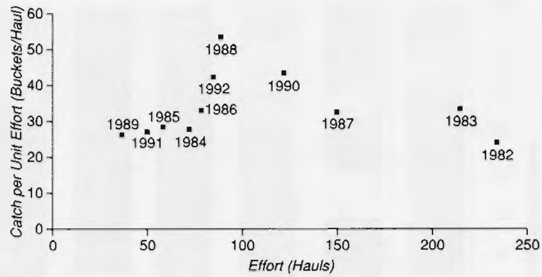

Figure 12b. Baitfish CPUE v. effort Kadavu

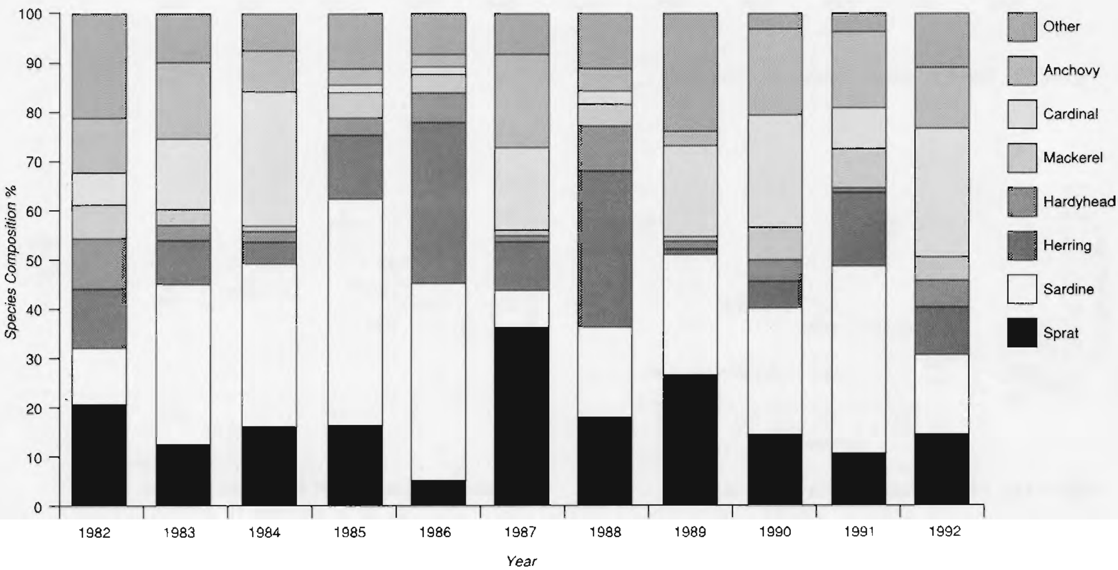

Figure 12c. Baitfish composition Kadavu

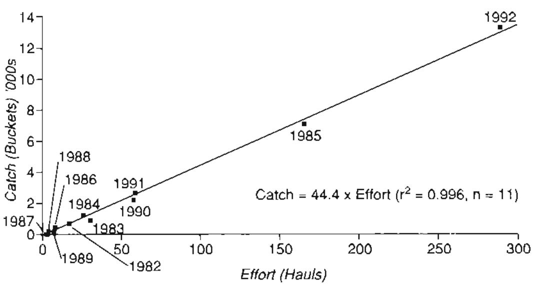

Figure 13a. Baitfish catch v. effort western Viti Levu

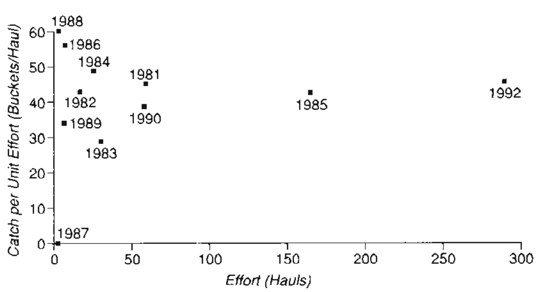

Figure 13b. Baitfish CPUE v. effort western Viti Levu

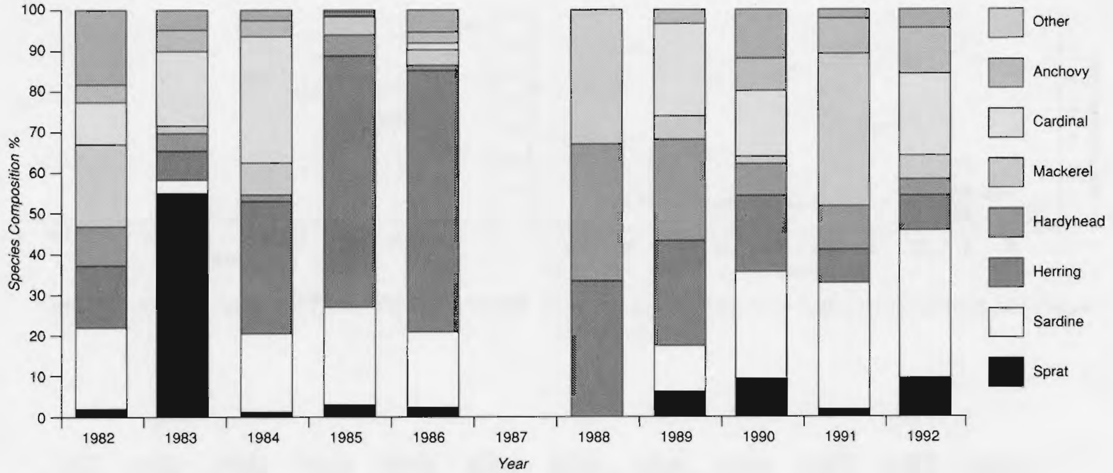

Figure 13c. Baitfish species composition western Viti Levu

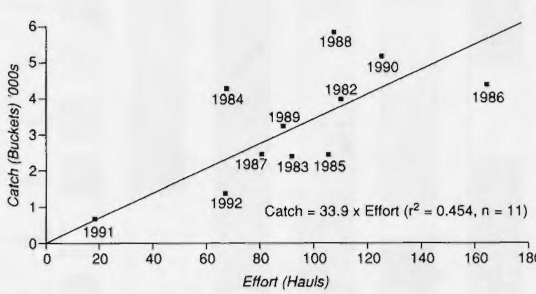

Figure 14a. Baitfish catch v. effort Savu Savu

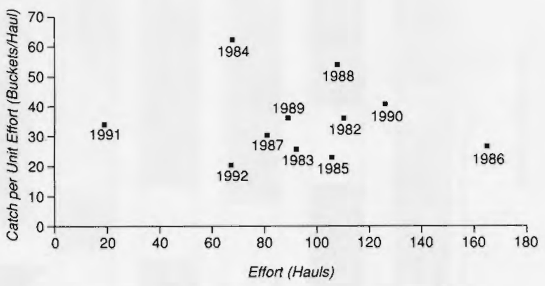

Figure 14b. Baitfish CPUE v. effort Savu Savu

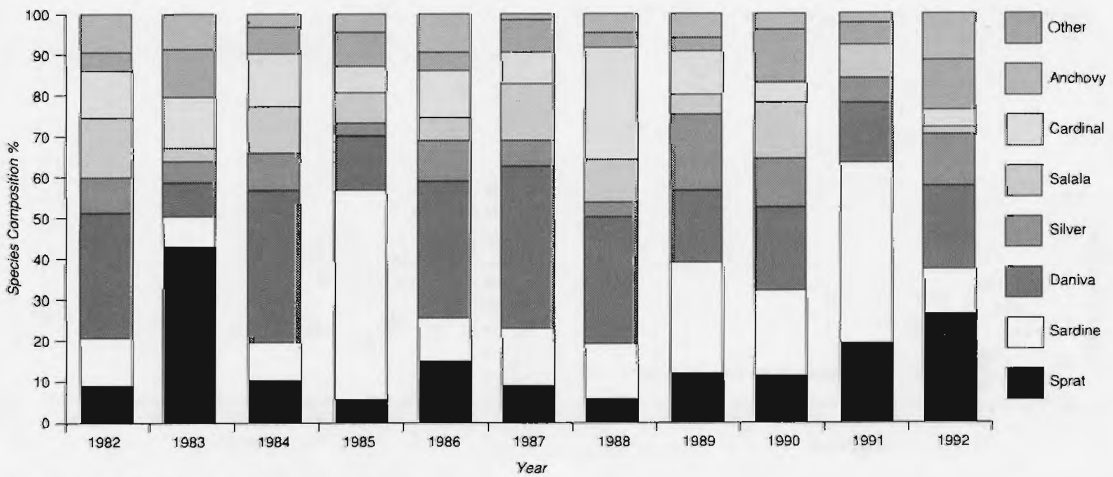

Figure 14c. Baitfish species composition Savu Savu

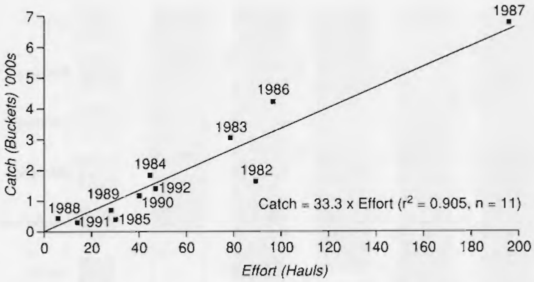

Figure 15a. Baitfish catch v. effort southern Viti Levu

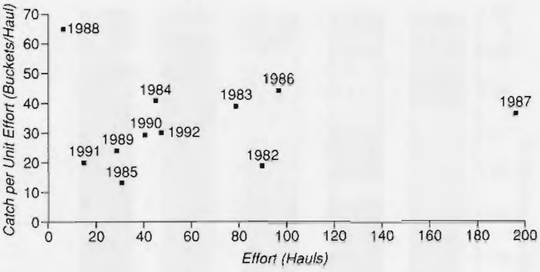

Figure 15b. Baitfish CPUE v. effort southern Viti Levu

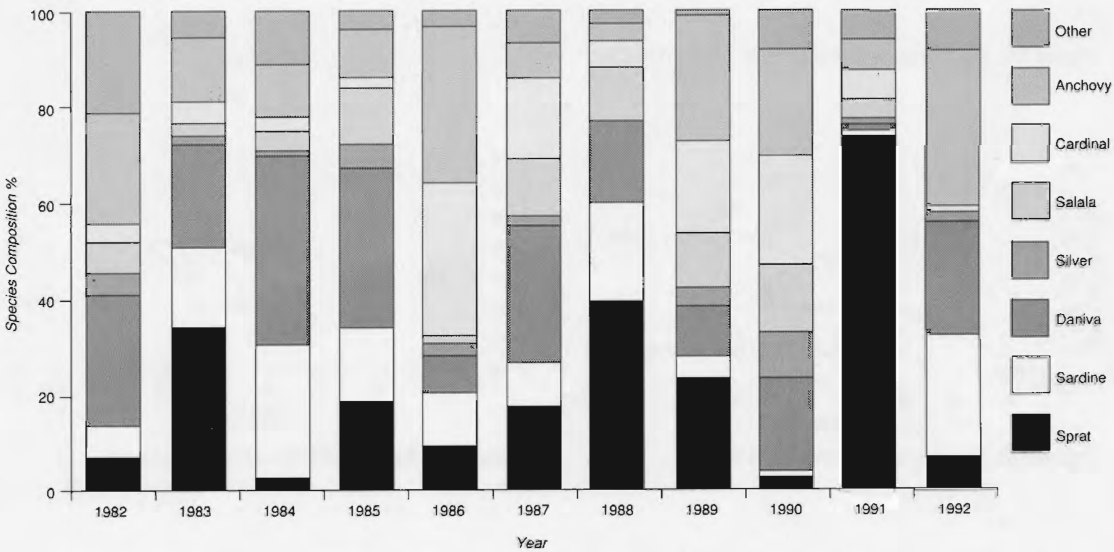

Figure 15c. Baitfish species composition southern Viti Levu

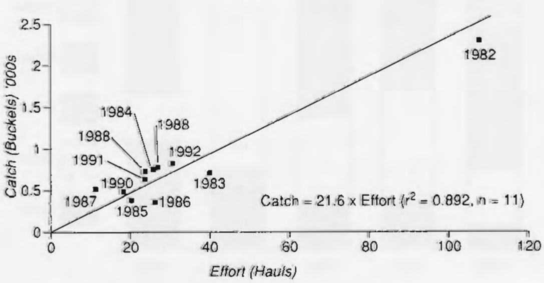

Figure 16a. Baitfish catch v. effort Suva/Lami Bay

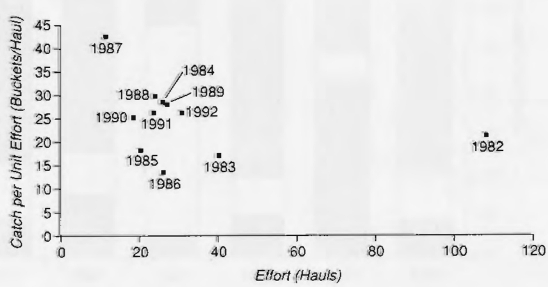

Figure 16b. Baitfish CPUE v. effort Suva/Lami Bay

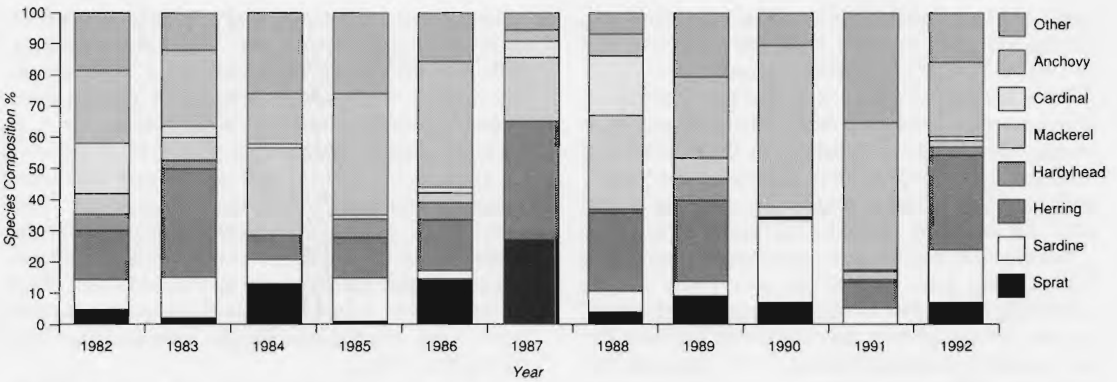

Figure 16c. Baitfish species composition Suva/Lami Bay

The breakdown of the catch by species for the different areas gives valuable information on the relative abundance of species groups during different years. This helps to explain some of the variations in annual fishing effort in some areas.

The species composition data shows that all seven species groupings are found at all sites. The sprat (mainly *Spratelloides delicatulus* but with some *Spratelloides gracilis*) and the sardine (*Amblygaster sirm*) make on important contribution (between 30-40%) to catch at each site. Some of the other species groupings however, dominate at certain sites but not at others e.g. the herring (*Herklotsichthys quadrimaculatus*), at Ovalau and Savusavu; cardinal, (mainly *Rhabdamia gracilis*), at Namena and eastern Vanua Levu; and in recent years anchovy, (primarily *Encrasicholina punctifer*), at Vanua Balavu.

Generally where these species were dominant there has been increased fishing effort e.g. Vanua Balavu in 1992 for the anchovy, Namena and eastern Vanua Levu in 1989 and 1991 for cardinal, and Ovalau in 1985 and 1986 for herring.

Table 17. Average catch rate by area. 1982–1992 and degree of goodness of fit (r^2) described by the linear regression between baitfish catch and effort.

Area	Average catch rate (buckets per haul)	goodness of fit (r^2)
Vanua Balavu	45.4	0.915
North Vanua Levu	38.1	0.909
Ngau	41.4	0.690
Eastern Vanua Levu	39.4	0.750
Beqa	39.4	0.866
Ovalaua	43.7	0.698
Namena	42.6	0.949
Kadavu	31.2	0.730
Savu Savu	34.7	0.542
Southern Viti Levu	33.3	0.905
Suva/Lami Bay	21.6	0.892
Western Viti levu	44.4	0.996

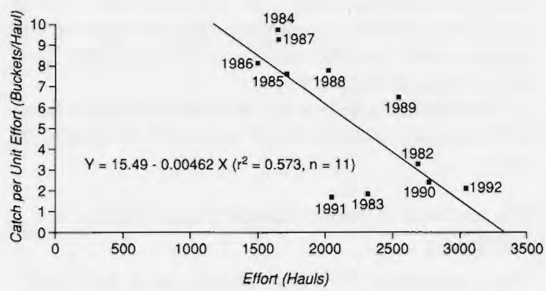

Figure 17. Herring: CPUE v Effort for all sites combined

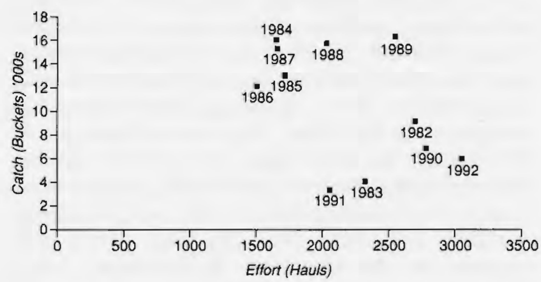

Figure 18. Herring: total catch and effort for all sites combined

Catch and effort by species

Looking at the effects of fishing on individual species within the baitfish catch there was little suggestion of any influence of fishing effort on the abundance of a particular species group, except for the herring. A plot of catch per unit effort against effort (Fig. 17) suggests a lowering of the catch per unit effort with increased fishing pressure. However, a plot of the catch of herring against effort (Fig. 18) would suggest that there have been two distinct levels in their abundance. During the years between 1984 and 1989 levels of herring catch were substantially higher.

From the data available it is however, difficult to decide whether the obvious decline in the abundance of herring was caused by baitfishing, by the movement of fishing effort away from areas normally dominated by catches of herring or by some variation in the overall stock size of herring caused by poor recruitment.

It is cértainly true that there has been a movement of fishing away from Ovalau, an area where herring previously dominated the baitfish catches. However, it is not known whether this movement has been due to a decline in available herring stocks (although data from the 1990s does suggest a real decline in its contribution to the catches) or that the movement of effort away from Ovalau has been due to some total change in fishing strategy of the fleet. The fishing base of Levuka, where the pole-and-line vessels unload their catches, is situated in the Ovalau area and vessels would use this area for baitfishing once they had discharged their catch.

It is interesting to note that the decline in abundance of herring has occurred at all sites over the period of study.

The increase in importance of Vanua Balavu for baitfishing

The importance of Vanua Balavu as a baitfishing location has increased over the years to the extent that 45.7% of the total catch taken in 1992 came from this area. Its proximity to productive seamounts for tuna fishing and the increased abundance of available baitfish have contributed to this increased importance. Figures 5(a) and 5(b) show the relationship between catch and effort, catch per unit effort and effort from Vanua Balavu. There is a strongly linear relationship between catch and effort, with a mean catch rate of 45.4 buckets per haul. Figure 5(b) shows a distinct increase in catch rate from 1988 to 1992 over the years prior to this. Assuming there has not been a change in recording procedures over this time period, this suggests that the abundance of baitfish at Vanua Balavu has increased since 1988.

The breakdown of catches from Vanua Balavu by species shows that in 1988 and 1989 there was an increased contribution of sardines (*Amblygaster sirm*) to the catch followed by an increasing amount of anchovy (*Encrasicholina* sp) from 1990 to 1992 (Fig. 5.(c). Data from actual samples of baitfish taken from Vanua Balavu during 1991 and 1992, showed the catch consisted of large numbers of *E. punctifer*, (Rawlinson and Sesewa these proceedings). This oceanic anchovy is a stenohaline species which Dalzell (1990) found declined in importance in the baitfish catches in Papua New Guinea with increasing rainfall.

The reason for the occurrence of large numbers of anchovy in inshore waters of Vanua Balavu during 1991 and 1992 is not fully understood. However, as this species was seldom recorded in catches from Vanua Balavu in years before 1988, their residency in the lagoon may be a temporary phenomenon that may be affected by factors such as reduced predation, calmer conditions for breeding or increased food. However, *E. punctifer* has been the mainstay of the baitfishery in Fiji for the years of 1991 and 1992 and has contributed greatly to the increased fishing effort taking place in Vanua Balavu and the increased catch rates being experienced by the pole-and-line fleet during this period.

It will be interesting to monitor the anchovy catches from Vanua Balavu and the effect that any decline in the abundance and availability of the anchovy will have on the overall distribution of fishing effort by pole-and-line vessels during years to come.

The lagoon area around Vanua Balavu is large and there are a number of different locations that the pole-and-line vessels use for baitfishing. A breakdown of percentage catches from each site from 1982 to 1992 is given in Table 4. The areas around Daliconi and Qilaqila within the narrow lagoonal area on the western side of the island are the most important in terms of amount of baitfish taken.

Conclusions

From available data baitfishing by pole-and-line vessels has not caused any long termdetrimental effects on available stocks of baitfish in Fiji. The large number of sites allows the fleet to move away from areas that show reduced catch rates thus allowing a recovery period for resident stocks.

The pole-and-line fleet concentrates its effort on catching baitfish during periods of peak recruitment and catching species which show pulses of increased abundance. Depending on the size of the recruitments at different locations and the areas where pulses of fish increase the availability of baitfish, this has a significant effect on the distribution of fishing effort (taking into consideration the location of available tuna schools).

This type of fishing regime is unlikely to cause any lasting damage to the baitfish stocks but the pole-and-line fishery could be affected by any natural changes in the abundance of certain species caused by external factors such as environmental conditions.

The decline in the abundance of the herring (*Herklotsichthys quadrimaculatus*), is a cause for concern, especially as this is a species often caught and consumed by local fishermen. The pattern of change in its abundance across a wide geographical area in Fiji suggests that outside factors other than fishing have caused this general reduction in herring stocks.

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MANAGEMENT ISSUES

Customary Fishing Rights in Fiji and Their Effects on Compensation Payment for Commercial Baitfishing Activities in Fiji

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IN Fiji the international waters are 'owned' in much the same way as land. Such ownership accords customary fishing rights to mataqali, who since the 1950s have sought compensation from pole-and-line fishermen harvesting baitfish in their waters.

Native Fisheries Commission

The Native Land Fisheries Commission was formed in 1958 to look into the affairs of Customary Fishing Rights and was charged with the following duties:

1) to ascertain what customary fishing rights in each province of Fiji are the rightful and hereditary property of native owners, whether of mataqali or in whatsoever manner or way by whatsoever Division or of the people the same may be held; and
2) to record in writing the boundaries and situation of such rights, together with the names of the respective communities claiming to be owners.

A total of 410 fishing grounds were established throughout the foreshores of Fiji including those along the main rivers of Viti Levu and Vanua Levu. For fishing rights over smaller rivers, creeks, ponds or lakes in the interior or main islands the Commission also awarded ownership to the mataqali that owned the surrounding or adjacent land.

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Compensation

In the 1970s Fijians were not happy about reclamation work and raised concern about damage to their fishing rights. In some instances, private agreements to pay for deprivation of rights had been made. This was not sufficient so the government agreed to appoint an independent arbitrator to assess the actual loss. As a result, more and more people are now turning to development of foreshore resources. Fijians have become increasingly concerned about their rights and ownership entitlements.

Compensation Payments

The baitfishing operations of pole-and-line vessels in Fiji has come into conflict with local interpretations of customary fishing rights. Normally, artisanal (commercial) fisherman must obtain a permit to fish in customary fishing-right areas, and it has become accepted practice in some areas to pay a goodwill fee for the permission. There have been several cases where the fishing-right owners have complained that pole-and-line vessels should pay a fee to fish within the fishing-right areas.

In 1991 the Ministry of Primary Industries agreed to establish compensation payments to customary fishing-right owners, whose areas were being utilised by commercial pole-and-line vessels for the capture of baitfish. The amount of payment settled upon was F$10 per night for each vessel operating within a customary fishing-right area. This level of compensation was set as an interim rate until the results of an in-depth study into the effects of commercial baitfishing are completed. Tui Lau put a ban on pole-and-line vessels fishing in his area. The fishing-right owners believe that baitfishing damages their resource and have asked for compensation payments before allowing access to fishing grounds. The results of the Baitfish Research Project will assist the Ministry in further negotiations should these be needed.

The Ministry of Primary Industries and Cooperatives invited the Cabinet to endorse the current levy of F$10/night/vessel until conclusive results became available. Cabinet reviewed this proposal for compensation payment for commercial baitfishing activities and decided the procedure recommended was the appropriate one to follow. They approved this proposal in 1991 and it became effective from January 1992.

From the records supplied to the Fisheries Division by commercial vessels it has been possible to assess how many nights baitfishing occurred in different fishing-right areas during 1992. This has allowed the allocation of royalty payments to the rightful owners using the boundaries supplied by the Native Land Trust Board.

During 1992 a total of F$17 290 was collected from pole-and-line fishing companies. The amount was transferred to the central Fijian Treasury at the Ministry of Fijian Affairs and Rural Development. The fund can then be divided into the relevant holdings of the appropriate Vanua's using the records compiled by Fisheries Division. Future payments will be calculated by Fisheries using the logsheets from the commercial fishing vessels and assigned to the Vanua's and Yavusa's from the boundaries supplied by the Native Land Fisheries Commission.

Fisheries Division is in the process of producing mapbooks showing the boundaries of all the customary fishing-right areas. Each pole-and-line vessel will be issued with a copy of these maps so they can properly identify the area they are using and correctly mark the logsheets with catch information.

Predators of Tuna Baitfish and the Effects of Baitfishing on the Subsistence Reef Fisheries of Fiji

S.J.M. Blaber*, D.A. Milton*, N.J.F. Rawlinson* and A. Sesewa**

THE pole-and-line tuna fishery in Fiji depends upon regular and adequate supplies of live baitfish. At least 250 tonnes per annum of small engraulids and clupeids are caught by light fishing in fringing reef lagoons at night (Fiji Fisheries Division 1992). Traditional reef owners and artisanal and subsistence reef fishermen have been very concerned that baitfishing has detrimental effects on the lagoons and their livelihoods by reducing the numbers of larger reef fish. This could be for several reasons; firstly, through the food chain where the removal of small fish causes a decline in numbers of reef predators that feed on baitfish; secondly, by the capture of many larger reef species by dropline fishing from tuna boats during baiting operations; and thirdly, by the incidental capture during baitlighting of large numbers of juveniles of reef species. These concerns and the question of possible monetary compensation for reef owners led the Fiji Fisheries Division to seek the assistance of the ACIAR/CSIRO Baitfish Project. This project had addressed the first of these questions in Solomon Islands and found that most of the reef fish of importance in the subsistence and artisanal fisheries did not feed primarily on baitfish—those that did were mainly pelagic species taken by trolling, rather than the more widely practised droplining or handlining. The results from Solomon Islands could not be applied directly to the situation in Fiji because, although it may be assumed that some of the baitfish species and their predators were the same, no accurate information was available on the diets of predators nor on the species taken or the fishing methods used by Fijian subsistence fishermen. Therefore the possible interactions between baitfishing and the reef fishery, as well as the second question of incidental dropline catches by tuna boats in lagoons, were studied during the Fijian phase of the project.

The goals of the current study were to determine the diets of all potential baitfish predators in representative baitgrounds in Fiji; to establish the relative significance of baitfish in the diets of the various piscivores, both under natural situations and feeding around baitlighting operations; to estimate whether baitfish predators are a large component in the subsistence fishery; and to quantify the species composition of the incidental dropline catches.

Materials and Methods

Field sampling

Potential baitfish predators were collected from nine bait grounds in Fiji (Fig. 1). Fish were caught using two fleets of monofilament gill nets (stretch mesh sizes of 25, 50, 75, 100, 125 and 150 mm, each net 60 m long) set on the surface and the bottom, and by droplining, handlining and trolling. Predatory fish were also collected from around night-time

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baitlighting operations by droplining and from the bouke-ami baitnet itself. The sampling times and methods used at each baitground are shown in Table 1. All fish were measured (standard length) and weighed and the stomachs of piscivores frozen for analyses in the laboratory.

Information on the seasonal abundances of baitfish species at the various sampling sites were collected during the project (Rawlinson and Sesewa these proceedings).

Laboratory

Stomach contents were sorted as far as possible, usually to species, and weighed. The diets of each species are expressed in terms of the percentage contribution of each prey category to the total weight of stomach contents.

Baitfish species

The taxa of baitfish and those used in this study were: *Spratelloides delicatulus, Spratelloides gracilis, Herklotsichthys quadrimaculatus, Encrasicholina devisi, Encrasicholina punctifer, Amblygaster sirm, Amblygaster clupeoides, Rhabdamia* spp., *Atherinomorus lacunosus* and *Hypoatherina ovalaua.*

Other Apogonidae, Caesionidae and Atherinidae were of minor importance as baitfish.

Table 1. Sampling sites, months, and capture methods

Site	Date	Methods
Vanua Balavu	October 1991	bouke-ami, dropline
	July 1992	bouke-ami, dropline, gill netting, trolling
Yasawas & Mamanuca Group	January - February 1992	bouke-ami, dropline, gill netting, trolling
Suva harbour	July 1992	bouke-ami
S. Vanua Levu	October 1991	dropline, gill netting, trolling
	June 1992	dropline, gill netting, trolling
Beqa	March 1992	dropline, gill netting, trolling
Ngau	October 1991	dropline, gill netting, trolling
	September 1992	dropline, gill netting, trolling
N. Vanua Levu	September - October 1992	bouke-ami, dropline, gill netting, trolling
Moala	November 1992	bouke-ami, dropline, gill netting, trolling
Kadavu	December 1992	dropline, gill netting, trolling

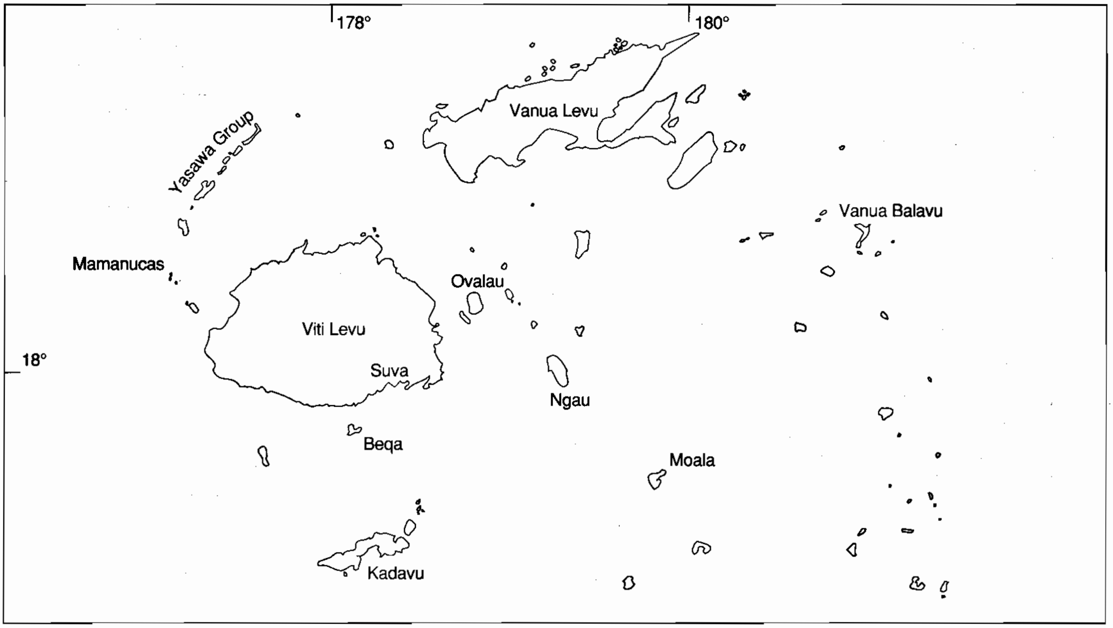

Figure 1. Fiji Islands showing sampling sites and major baitgrounds.

Data on the abundance of baitfish species at the sampling sites were taken from the logsheet catch returns of the commercial pole-and-line fleet in 1992 (Rawlinson and Sharma these proceedings). These data could only be divided into the species categories recognised by the fishermen, rather than into definite species. As no commercial baitfishing occurred in the Yasawas or at Moala, data from these areas is taken from experimental bouke-ami catches during the Baitfish Research Project.

Subsistence Fishery data

The relative importance of the species groups caught and fishing methods used in each area were obtained from the questionnaire survey undertaken during the Baitfish Research Project (see Rawlinson and Sesewa these Proceedings)

Results

Natural diets of baitfish predators

Stomach contents were analysed from 1774 individuals of 117 potential baitfish predator species from all sampling sites (Table 2). The proportions of different baitfish species in the diets of the 39 species that ate baitfish are shown in Table 3.

Following Blaber et al. (1990) the baitfish eaters were divided into 'major predators' (>10% baitfish in diet) and 'minor predators' (<10% baitfish in diet). Twenty-three species were 'major predators' and the remainder 'minor predators'. The 'major predators' were almost entirely pelagic or benthopelagic species of the families Carangidae, Scombridae and Sphyraenidae whereas the 'minor predators' chiefly

Table 2. Numbers of each species analysed for baitfish predation

Ablennes hians	1	*Gymnocranius robinsoni*	2	*Paraupeneus barberinoides*	1
Albula neoguinaica	5	*Gymnocranius* sp.	20	*Paraupeneus barberinus*	8
Alectis ciliaris	2	*Hemigymnus melapterus*	1	*Paraupeneus cyclostomus*	3
Anampses caeruleopunctatus	1	*Hologymnosus doliatus*	2	*Paraupeneus indicus*	20
Aprion virescens	6	*Lactarius lactarius*	5	*Paraupeneus multifasciatus*	1
Atule mate	3	*Lagocephalus sceleratus*	1	*Plectorhynchus chaetodontoides*	2
Carangoides caeruleopinnatus	56	*Lethrinus atkinsoni*	7	*Plectorhynchus obscurum*	7
Carangoides chrysophrys	12	*Lethrinus harak*	1	*Plectropomus leopardus*	14
Carangoides ferdau	3	*Lethrinus lentjan*	5	*Plectropomus maculatus*	1
Carangoides hedlandensis	3	*Lethrinus mahsena*	6	*Polydactylus microstomus*	2
Carangoides oblongus	10	*Lethrinus nebulosus*	5	*Polydactylus plebius*	9
Carangoides plagiotaenia	20	*Lethrinus obsoletus*	5	*Priacanthus cruentatus*	5
Caranx ignobilis	6	*Lethrinus olivaceous*	6	*Priacanthus hamrur*	30
Caranx melampygus	42	*Lethrinus variegatus*	7	*Rastrelliger brachysoma*	19
Caranx papuensis	28	*Lethrinus xanthochilus*	8	*Rastrelliger kanagurta*	26
Caranx sexfasciatus	20	*Lutjanus argentimaculatus*	12	*Sargocentron diadema*	4
Caranx tille	11	*Lutjanus biguttatus*	9	*Sargocentron melanospilos*	4
Carcharhinus amblyrhynchos	3	*Lutjanus bohar*	32	*Sargocentron spiniferum*	7
Carcharhinus melanopterus	6	*Lutjanus boutton*	6	*Scomberoides lysan*	32
Cheilinus fasciatus	1	*Lutjanus ehrenbergi*	21	*Scomberoides tol*	40
Chirocentrus dorab	55	*Lutjanus fulviflamma*	50	*Scomberomorus commerson*	8
Coris aygula	5	*Lutjanus fulvus*	125	*Scorpaenopsis venosa*	1
Coris gaimardi	2	*Lutjanus gibbus*	117	*Selar crumenopthalmus*	51
Echeneis naucrates	4	*Lutjanus kasmira*	21	*Siderea picta*	1
Elops machnata	1	*Lutjanus monostigma*	8	*Sphyraena actupinnis*	1
Epinephelus caeruleopunctatus	2	*Lutjanus quinquelineatus*	28	*Sphyraena barracuda*	12
Epinephelus fuscoguttatus	2	*Lutjanus rivulatus*	1	*Sphyraena flavicauda*	62
Epinephelus howlandi	4	*Lutjanus russelli*	13	*Sphyraena forsteri*	61
Epinephelus maculatus	3	*Lutjanus semicinctus*	9	*Sphyraena jello*	1
Epinephelus malabaricus	2	*Megalaspis cordyla*	9	*Sphyraena obtusata*	1
Epinephelus merra	4	*Megalops cyprinoides*	21	*Sphyraena putnamiae*	51
Epinephelus ongus	4	*Monotaxis grandoculis*	4	*Sphyrna lewini*	8
Epinephelus polyphekadia	5	*Mulloides vanicolensis*	4	*Strongylura incisa*	6
Gazza minuta	6	*Muraenesox bagio*	11	*Terapon jarbua*	25
Gnathanodon speciosus	33	*Neoniphon argenteus*	190	*Tylosurus acus*	2
Gnathodentex aurolineatus	3	*Neoniphon opercularis*	3	*Tylosurus crocodilus*	4
Grammatorcynus bicarinatus	6	*Neoniphon sammara*	52	*Upeneus tragula*	13
Grammatorcynus bilineatus	3	*Novalichthys taeniourus*	2	*Upeneus vittatus*	14
Gymnocranius grandoculis	1	*Paracirrhites forsteri*	3	*Variola albimarginata*	1

consisted of Lutjanidae, Holocentridae and Priacanthidae (Table 3). There were some interesting exceptions to the above generalisations, e.g. four carangids were 'minor predators' while the primarily pelagic *Lutjanus biguttatus* was a 'major predator'; *Neoniphon opercularis* ate significant numbers of *Spratelloides delicatulus* but its congeners were only very minor baitfish predators (Table 3).

Predation on baitfish around underwater lights

A total of 455 individuals of 32 predator species were captured during baiting operations and 20 (including one *Loligo* sp. squid) were consuming baitfish (Table 4). All took more than 10% baitfish (Table 5). Excluding the squid this list contains eight species that were not 'major predators' under natural conditions. Four of these are generally considered zooplanktivores:

Table 3. Percentages (by wet weight) of each baitfish species in the diets of predators (1= *Spratelloides delicatulus*, 2= *Stolephorus* spp., 3= *Spratelloides gracilis*, 4= *Spratelloides* spp., 5= *Encrasicholina devisi*, 6= *Rhabdamia gracilis*, 7= *Amblygaster* spp., 8= *Amblygaster sirm*, 9= *Encrasicholina* spp., 10= *Stolephorus punctifer*, 11= *Herklotsichthys* spp, 12= unidentified Clupeidae, 13= *Atherinomorus lacunosus*, 14= *Hypoatherina ovalaua*, 15= unidentified Atherinidae, n = number of stomachs analysed; **M** = major baitfish predator)

Baitfish prey Predator		n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Carangoides caeruleopinnatus	**M**	56	-	-	-	-	-	<1	-	5	-	9	-	-	4	-	-
Carangoides oblongus		10	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-
Carangoides hedlandensis	**M**	4	-	-	-	-	6	-	-	-	-	-	-	8	-	-	-
Carangoides plagiotaenia	**M**	20	1	-	-	<1	-	-	-	-	-	66	-	-	-	-	-
Carangoides chrysophrys	**M**	12	-	-	<1	-	-	-	17	-	-	2	17	-	-	35	-
Caranx papuensis	**M**	37	-	-	-	-	-	-	-	6	-	-	-	5	30	-	-
Caranx sexfasciatus	**M**	24	-	-	-	-	-	-	-	15	-	-	9	-	-	-	3
Caranx tille		11	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-
Caranx melampygus		42	<1	-	-	1	-	-	<1	-	-	-	-	-	-	-	1
Caranx ignobilis	**M**	8	11	-	-	-	-	-	-	-	-	8	-	-	-	-	-
Carcharhinus melanopterus		6	-	-	-	-	-	-	-	-	-	-	-	-	4	-	<1
Chirocentrus dorab	**M**	55	4	1	<1	<1	<1	-	13	20	<1	-	-	-	32	-	2
Echeneis naucrates		4	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gazza minuta	**M**	6	-	-	-	-	-	-	-	-	-	-	-	49	-	-	-
Gnathanodon speciosus	**M**	33	1	-	-	-	-	-	-	-	-	44	-	-	-	-	-
Grammatorcynus bicarinatus	**M**	6	25	-	-	-	-	-	-	-	-	34	-	-	-	-	-
Grammatorcynus bilineatus	**M**	3	18	-	-	-	-	-	-	-	-	-	-	-	68	-	-
Lutjanus biguttatus	**M**	9	-	-	-	-	-	52	-	-	-	-	-	-	-	-	-
Lutjanus fulviflamma		50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Lutjanus fulvus		125	-	-	-	-	-	<1	-	-	-	-	-	-	-	-	-
Lutjanus bohar		33	9	-	<1	-	-	-	-	-	-	-	-	-	-	-	-
Lutjanus gibbus		118	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lutjanus ehrenbergi		21	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-
Megalops cyprinoides		21	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Muraenesox bagio		11	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-
Neoniphon sammara		52	-	-	-	-	-	<1	-	-	-	-	-	-	-	-	-
Neoniphon argenteus		190	-	-	<1	-	-	-	-	-	-	-	-	-	-	-	-
Neoniphon opercularis	**M**	4	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Priacanthus hamrur		30	-	-	-	-	-	<1	-	-	-	-	-	-	-	-	-
Scomberoides lysan	**M**	32	71	-	-	-	<1	-	-	-	7	-	-	-	12	23	
Scomberoides tol	**M**	40	-	-	-	-	-	-	-	-	1	-	-	-	53	-	-
Scomberomorus commerson	**M**	8	-	-	-	-	-	-	-	32	-	-	-	-	-	-	-
Selar crumenophthalmus	**M**	51	-	-	-	<1	-	27	-	-	<1	-	-	<1	-	-	9
Sphyraena forsteri	**M**	61	2	-	<1	-	-	<1	10	-	-	-	-	-	5	1	10
Sphyraena putnamiae	**M**	51	<1	-	<1	-	-	<1	-	3	-	-	4	<1	2	-	1
Sphyraena flavicauda	**M**	62	3	-	-	-	<1	-	1	-	2	-	-	-	4	-	5
Sphyraena barracuda		12	2	-	-	-	-	-	-	-	-	-	-	2	-	-	1
Strongylura incisa	**M**	6	-	-	-	-	-	-	-	-	-	-	-	-	-	26	42
Tylosurus crocodilus	**M**	4	-	-	-	-	-	-	-	-	-	-	-	82	-	-	-

Table 4. Numbers of predators captured during bouke-ami baitfishing operations (n = number of individuals; + = baitfish predator; - = non-baitfish predator)

Species	n	
Amblygaster sirm	1	-
Atherinomorus lacunosus	27	+
Carangoides hedlandensis	1	-
Caranx ignobilis	2	-
Caranx melampygus	6	+
Caranx papuensis	6	-
Caranx sexfasciatus	4	-
Caranx tille	5	+
Chirocentrus dorab	32	+
Dussumieria sp.	15	+
Epinephelus ongus	3	-
Epinephelus suillus	2	+
Gazza minuta	30	+
Herklotsichthys quadrimaculatus	19	+
Lethrinus mahsena	3	-
Lethrinus olivaceous	2	+
Loligo sp.	1	+
Lutjanus biguttatus	32	+
Lutjanus bohar	1	-
Lutjanus gibbus	1	-
Neoniphon opercularis	1	+
Rastrelliger brachysoma	1	-
Rastrelliger kanagurta	38	+
Scomberoides tol	4	+
Scomberomorus commerson	1	+
Selar crumenopthalmus	63	+
Sphyraena flavicauda	61	+
Sphyraena forsteri	62	+
Sphyraena jello	1	-
Sphyraena obtusata	1	+
Sphyraena putnamiae	10	+
Terapon jarbua	1	-

Atherinomorus lacunosus, Dussumieria sp., *Herklotsichthys quadrimaculatus* and *Rastrelliger kanagurta*; and two are themselves important baitfish species. Both *Caranx melampygus* and *C. tille* ate baitfish around the lights, and as under natural conditions, *Neoniphon opercularis* was the only holocentrid eating baitfish.

Occurrence of baitfish species at different sites

The baitfish component of predator diets at the nine sampling sites are shown in Table 6. Data has only been included in Table 6 for those predators for which more than 10 non-empty stomachs were obtained. The proportions of each baitfish category available at each site, based on commercial catch records and project sampling, are listed in Table 7.

Comparing the species category data in Table 7 with the predator diets in Table 6 it is evident that the predators were feeding mainly on the most abundant baitfish in each area. *Spratelloides* spp. were the most abundant category and the most commonly eaten group; *Encrasicholina* spp. and *Stolephorus* spp. (anchovies) were most abundant at Vanua Balavu where they were a common prey item; *Amblygaster sirm* was the most important baitfish after *Spratelloides* spp. and an important prey at northern Vanua Levu, Kadavu and Yasawas where it was abundant; and the consumption of Atherinidae at southern and northern Vanua Levu and Vanua Balavu corresponds with areas of abundance. *Herklotsichthys* spp. (herrings) (Table 7) were not common in most areas and were seldom eaten by predators—the only exception being *Caranx sexfasciatus* at northern Vanua Levu.

The subsistence reef fishery

During fieldwork for the Baitfish Research Project, a household questionnaire survey was undertaken to assess the fishing activity at the following research sites: Beqa, Ngau, northern Vanua Levu, Vanua Balavu and Yasawas. A total of 299 households were surveyed. Further details of this exercise are given in Rawlinson and Sesewa (these Proceedings p.62). As part of the survey, questions were asked concerning the species composition of catches and the fishing methods used.

Respondents were asked to identify their catches. These could be categorised into Family and the results are summarised in Table 8. Approximately one-third of the catch consisted of Lethrinidae, with other sedentary reef species comprising the bulk of the remainder. Pelagic 'major baitfish' consuming families only accounted for 18.3% of the reported catch. If the reported subsistence catches from inside fringing lagoons only are analysed, then the figures for 'major baitfish families' range from 10.2% to 16.2%.

Analyses of fishing methods indicate that hand-lining is the most commonly used method. Trolling lines (tow) that would catch mainly baitfish eaters were used by only 10% of households. Droplines which take some baitfish predators, such as carangids and sphyraenids were used by 28% of households (Table 9).

Species composition of the incidental dropline fishery

Dropline fishing from the Research Vessel *Tui Ni Wasabula* was undertaken at the lagoon study sites during 1992 and 1993. Other dropline data were obtained by examining the catches of local fishermen in some areas.

A total of 678.6 fishing hours in lagoons under natural conditions (in the absence of bouke-ami baitlights) caught 570 individuals of 83 species weighing 605 kg (Table 10). Droplining for 74.5 fishing hours around baitlights during baitfishing

Table 5. Percentages (by wet weight) of each baitfish species in the diets of predators around bouke-ami baitfish operations (baitfish prey numbers as for Table 3.)

Baitfish prey Fish species	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Atherinimorus lacunosus	27	21	-	6	1	-	-	-	-	-	-	-	-	-	-	-
Caranx melampygus	6	7	-	11	-	-	-	-	-	-	-	-	-	-	-	-
Caranx tille	5	-	-	-	26	-	-	-	-	8	-	-	-	-	-	-
Chirocentrus dorab	32	55	-	<1	-	4	3	-	-	<1	-	-	-	-	13	-
Dussumieria sp.	15	4	-	7	-	-	-	-	-	-	-	-	-	5	-	-
Epinephelus suillus	2	-	-	-	-	<1	50	-	-	-	-	-	-	-	-	-
Gazza minuta	30	47	-	-	3	-	-	-	-	-	-	-	-	-	-	3
Herklotsichthys quadrimaculatus	19	7	-	17	-	-	17	-	-	-	-	-	-	-	-	-
Lethrinus olivaceous	8	-	-	-	-	-	-	-	-	-	-	26	-	-	-	-
Lutjanus biguttatus	32	8	-	4	-	45	1	-	16	<1	9	-	-	-	-	-
Neoniphon opercularis	4	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rastrelliger kanagurta	38	82	-	2	-	3	-	-	-	-	-	-	-	-	-	-
Scomberoides tol	4	92	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scomberomorus commerson	1	-	-	-	-	-	-	100	-	-	-	-	-	-	-	-
Selar crumenophthalmus	63	53	-	9	-	-	1	-	-	<1	-	-	-	-	-	-
Sphyraena forsteri	62	15	-	-	-	9	<1	15	2	2	6	-	-	2	10	-
Sphyraena putnamiae	10	<1	2	-	-	-	-	-	64	1	-	-	-	3	-	-
Sphyraena flavicauda	61	12	3	-	-	9	12	-	-	-	-	-	-	-	-	2
Sphyraena obtusata	2	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loligo sp.	1	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-

operations yielded 153 fish of 34 species weighing 183 kg (Table 11). Hence the catch rate per fishing-hour of droplining was approximately three times greater around the baitlights than under natural conditions (0.892 kg/fishing-hour versus 2.456 kg/fishing-hour).

Twenty-four of the 83 species caught under natural conditions, representing 57% of the biomass, were baitfish predators (Tables 3 and 10) of which 15 species (41% of biomass) were 'major predators' of baitfish. Nine of the species caught by droplining around baitlights, representing 44% of the biomass, were eating baitfish (Tables 4 and 11).

About half the overall biomass of fish caught in baitfishing lagoons by dropline fishing, either under natural conditions or around lights, are baitfish predators.

Discussion

Baitfish predators and the lagoon subsistence fishery

One of the chief concerns expressed by traditional reef owners and subsistence fishermen in Fiji was that commercial bouke-ami net baitfishing may affect the numbers of reef fish by removing the main food source of the reef fish. This concern has been widespread in Pacific Island countries (Nichols & Rawlinson 1990, Rawlinson et al. 1992). Research indicates however, that in Solomon Islands and Kiribati, such interaction between baitfishing and reef fishing through the food chain is likely to be minimal; only pelagic and bentho-pelagic predators were major consumers of baitfish in Solomon Islands and Kiribati, and these fishes formed only a small proportion of the catches of the subsistence fisheries.

The 'major predators' of baitfish in Fiji were also mostly pelagic or bentho-pelagic species, mainly of the families Carangidae, Sphyraenidae and Scombridae. The majority of the more sedentary reef-associated groups, such as Lethrinidae, Lutjanidae and Serranidae, either ate no baitfish or were only 'minor predators' of baitfish. The diets of the 117 predator species did not differ markedly from those reported in previous baitfish predator studies (Blaber et al. 1990, Rawlinson et al. 1992) or in the general literature (Hiatt & Strasburg 1960, Randall and Brock 1960, Hobson 1974, Randall 1980, Collette and Nauen 1983, Allen 1985).

If the data from all subsistence fishing methods in Fiji are combined, then 18.3% of the subsistence catch consists of major baitfish predators. This proportion is similar to that obtained in Solomon Islands (Blaber et al. 1990). In Solomon Islands most baitfish predators caught in the subsistence fishery are taken mainly by trolling, a method used by only about 10% of fishermen. In Fiji a similar situation occurs where only 10% of households use troll lines. In both Solomon Islands and Fiji, droplining (including

Table 6. Diets (%wet weight) of predators at each sampling site. Only species for which >10 non-empty stomachs were obtained are included (Baitfish prey numbers as for Table 3.)

		Baitfish prey											
Predator	Site	1	2	3	4	6	8	10	11	12	13	14	15
Carangoides caeruleopinnatus	Yasawas	-	-	-	-	-	-	42	-	-	-	-	-
	N. Vanua Levu	-	-	-	-	-	21	-	-	-	15	-	-
Caranx melampygus	Ngau	1	-	-	-	-	-	-	-	-	-	-	-
	Kadavu	5	-	-	-	-	-	-	-	-	-	-	8
Caranx papuensis	Vanua Balavu	-	-	-	-	-	-	-	-	9	71	-	-
Caranx sexfasciatus	N. Vanua Levu	-	-	-	-	-	34	-	21	-	-	-	7
Carcharinus melanopterus	N. Vanua Levu	-	-	-	-	-	-	-	-	-	4	-	<1
Chirocentrus dorab	Vanua Balavu	62	-	1	-	-	-	-	-	-	-	14	-
	S. Vanua Levu	67	-	-	-	-	-	-	-	-	-	-	10
	Kadavu	-	-	1	<1	-	60	-	-	-	6	-	1
Gnathanodon speciosus	Vanua Balavu	1	-	-	-	-	-	44	-	-	-	-	-
Lutjanus biguttatus	Vanua Balavu	33	-	15	-	-	-	27	-	-	-	-	-
Lutjanus fulvus	S. Vanua Levu	-	-	-	-	<1	-	-	-	-	-	-	-
Lutjanus fulviflamma	Ngau	-	-	-	-	-	-	-	-	-	-	-	25
Lutjanus gibbus	Yasawas	10	-	-	-	-	-	-	-	-	-	-	-
Megalops cyprinoides	N. Vanua Levu	-	-	-	-	1	-	-	-	-	-	-	-
Neoniphon argenteus	Beqa	3	-	-	-	-	-	-	-	-	-	-	-
Neoniphon sammara	Beqa	-	-	-	-	1	-	-	-	-	-	-	-
Rastrelliger kanagurta	N. Vanua Levu	93	-	-	-	-	-	-	-	-	-	-	-
Scomberoides lysan	Beqa	78	-	-	-	-	-	-	-	-	16	-	3
Selar crumenophthalmus	Yasawas	65	-	-	1	2	-	-	-	-	-	-	-
	Ngau	-	-	-	-	45	-	-	-	-	-	-	8
	Moala	23	-	47	-	1	-	-	-	-	-	-	-
Sphyraena flavicauda	Vanua Balavu	50	-	-	-	-	-	-	-	-	-	-	4
	Suva harbour	-	22	-	-	-	-	-	-	-	-	-	-
	S. Vanua Levu	22	-	-	-	-	-	-	-	-	-	-	8
Sphyraena forsteri	Vanua Balavu	15	-	-	-	-	-	55	-	-	14	-	20
	Yasawas	-	-	-	-	-	4	-	-	1	26	4	-
	Moala	36	-	-	-	-	-	-	-	-	-	26	-
Sphyraena putnamiae	Vanua Balavu	-	-	-	-	-	-	-	-	-	5	-	8
	Yasawas	<1	-	-	-	-	64	-	-	4	-	-	-
Strongylura incisa	N. Vanua Levu	-	-	-	-	-	-	-	-	-	-	38	62

handlining) is the most commonly used technique in the lagoons. In Solomon Islands almost all the fish caught by this method are not baitfish predators (Blaber et al., 1990), and hence it was concluded that trophic interactions between subsistence reef fishing and commercial baitfishing were likely to be minimal. However, in Fiji the situation appears to be rather different because experimental dropline fishing (and catches from local fishermen in the same areas) during the present project showed that about half the biomass of fish caught are baitfish eaters, with carangids and sphyraenids particularly significant components of the catch. This difference in catch composition might also be partly because much of the dropline fishing in Fiji takes place at night. Nevertheless, the possibility of real or potential trophic interactions between the fisheries in Fiji must be considered seriously, particularly with regard to carangids and sphyraenids.

The results of the questionnaire surveys suggest that overall, the carangids and sphyraenids may not be dominant components of the subsistence fishery as together they only account for 10.5% of reported catches. Lethrinidae (non-baitfish eaters) make up about one third of the reported subsistence catch. This family is also the dominant component of the reported subsistence fisheries catches in Solomon Islands (21%) (Blaber et al. 1990), New Caledonia (38%) (Loubens 1978) and Kiribati (20%) (Rawlinson et al. 1992).

As stated by Wright and Richards (1985), high species diversity is characteristic of small-scale subsistence fisheries using a variety of techniques in coral reef waters. Hence considerable site-to-site differences in the relative importance of species groups must be expected. Therefore although trophic interactions between baitfishing and reef fishing may not appear significant in Fiji when the overall catches are examined, it is very likely that it may be

Table 7. Baitfish catch and effort data (1992) for project sample sites during 1992 and percentages of total catch contributed by each baitfish category (* data from project sampling only; bait species numbers as table 3).

Site	Month	Hauls	Buckets	CPUE (t)	1,3,4	7,8	11	13,14, 15	6 + other	2,5,9,10	Other
Beqa	February	7	125	17.9	12.8	8.0	4.0	0.0	32.8	17.6	25.6
	March	22	949	43.1	1.7	52.7	0.0	1.5	32.3	0.4	11.4
	April	12	1056	88.0	11.1	55.8	9.9	0.0	14.2	0.7	8.4
S. Vanua Levu	May	5	78	15.6	0.0	20.5	0.0	28.2	0.0	28.2	23.1
	June	10	135	132.5	3.7	77.0	0.0	0.0	0.0	11.9	7.4
	July	1	10	10.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Vanua Balavu	July	43	1436	33.4	9.1	15.2	0.0	5.2	10.9	49.4	10.1
	August	46	1256	27.3	24.1	42.0	0.0	11.7	3.7	9.5	8.8
	September	49	1694	34.6	21.7	19.0	0.0	3.7	13.1	10.1	32.1
Daliconi	July	17	660	38.8	16.2	11.5	0.0	0.0	4.7	54.5	12.9
(Vanua Balavu)	August	7	133	19.0	28.6	62.4	0.0	5.3	0.0	3.0	1.5
	September	3	97	32.3	49.4	0.0	0.0	0.0	18.6	0.0	32.0
Ngau	August	17	184	10.8	0.5	42.4	16.3	0.0	0.0	1.6	38.6
	September	29	1247	43.0	7.6	17.5	3.8	0.0	29.4	0.0	41.6
	October	24	138	5.8	5.8	29.7	1.4	0.0	21.0	5.8	35.5
Kadavu	December	11	600	54.5	23.1	10.3	13.8	0.0	13.7	18.3	20.5
Kia Island	August	42	607	14.4	16.0	16.8	0.0	0.2	44.2	14.5	8.4
(N. Vanua Levu)	October	24	879	36.6	23.2	0.0	0.7	0.0	40.6	9.8	25.7
*N. Vanua Levu	September /October	-	-	-	27.08	-	-	38.94	0.60	0.12	33.28
*Moala	November	-	-	-	41.34	0.40	-	26.80	3.97		16.50
*Yasawas	January/ February	-	-	-	9.35	54.08	2.96	7.62	10.62	1.79	10.46

Table 8. Reported target species of subsistence fishermen from study sites based on questionnaire survey data

Catch	% Total Catch
Lethrinidae	31.0
Serranidae	13.6
Scombridae	7.8
Sphyraenidae	5.8
Carangidae	4.7
Gerreidae	4.2
Hemiramphidae	3.6
Acanthuridae	3.5
Lutjanidae	3.3
Other Fish	12.8
Non-Fish	6.7

potentially serious at a local level in areas where droplining catches large numbers of carangids and sphyraenids. Such detrimental trophic interactions must particularly be considered if baitfishing is shown to significantly reduce the populations of baitfish. The ongoing study of the subsistence fishery in Fiji (CSIRO/ACIAR & Fisheries Division) should provide more accurate regional data on subsistence catches and hence be able to pinpoint accurately areas where serious trophic interaction may be occurring.

Interactions with the artisanal fishing sector

The artisanal fisheries sector in Fiji is more significant than those of either Solomon Islands or Kiribati and has annual catches in excess of 3000 tonnes (Fiji Fisheries Division 1992). Baitfishing operations take place in some important areas for artisanal fishing, e.g. around Labasa in the Northern Division (Rawlinson, these Proceedings). In this Division, Carangidae, Scombridae and Sphyraenidae—the main baitfish predators—caught mainly by droplining, made up 56% of artisanal catch sales in 1992. Hence it is likely that baitfishing has significant trophic effects, certainly at a local level, on important artisanal reef fisheries.

Dropline fishing during bait operations

Although generally illegal it is a common practice for crews of tuna boats to dropline in lagoons during baitfishing operations (Sharma & Adams, 1990). The catches are usually iced and often sold on municipal markets. This has led to complaints by customary owners of the resource, regarding depletion and overexploitation of the reef fish resources by tuna fishermen.

Table 9. The different fishing methods utilised by households and the number of houses (House) and; the percentage of the houses (% House) using the technique. The table also lists the percentage of the households using the technique that reported the method was undertaken by adult males only (AM), adult females only (AF), both adult males and females (AMF), and children (C). The number of households not supplying information are detailed under NI.

Fishing Method	House	% House	AF	AMF	C	NI	AM
Bait net	14	4.7	78.6	14.3	-	7.1	-
Cast net	3	1.0	33.3	-	-	33.3	33.3
Collection	75	25.1	73.3	10.7	1.3	-	14.7
Crab trap	12	4.0	83.3	8.3	-	-	8.3
Dive	2	0.7	-	-	-	100.0	-
Dropline	85	28.4	8.2	44.7	-	9.4	37.6
Duva	1	0.3	-	-	-	100.0	-
Gill net (drive)	19	6.4	10.5	5.3	5.3	42.1	36.8
Gill net (group)	11	3.7	100.0	-	-	-	-
Gill net (set)	41	13.7	24.4	24.4	2.4	14.6	34.1
Handline	257	86.0	33.5	25.3	3.9	8.2	29.2
Land crabs	6	2.0	100.0	-	-	-	-
Lawa	3	1.0	100.0	-	-	-	-
Push net	44	14.7	88.6	-	6.8	2.3	2.3
Spearfishing	108	36.1	1.9	-	6.4	21.3	70.4
Towline (troll)	30	10.0	-	-	-	26.6	73.3
Wading net	3	1.05	100.0	-	-	-	-

Table 10. Species caught by dropline under natural conditions (no lights)

Species	Wt (g)	% Wt	N	%N
Abalistes stellaris	4550	0.75	3	0.52
Alectis ciliaris	5020	0.82	2	0.35
Aprion virescens	13125	2.16	6	1.05
Carangoides caeruleopinnatus	24660	4.07	45	7.89
Carangoides chrysophrys	7115	1.17	5	0.87
Carangoides hedlandensis	805	0.13	1	0.17
Carangoides oblongus	3900	0.64	2	0.35
Carangoides plagiotaenia	5285	0.87	6	1.05
Caranx ignobilis	54950	9.07	7	1.22
Caranx papuensis	6350	1.04	3	0.52
Caranx sexfasciatus	11675	1.92	4	0.70
Caranx tille	12175	2.01	5	0.87
Cheilinus fasciatus	275	0.04	1	0.17
Echeneis naucrates	2665	0.44	4	0.70
Epinephelus areolatus	250	0.04	1	0.17
Epinephelus cyanopodus	15440	2.55	8	1.40
Epinephelus fuscoguttatus	2120	0.35	3	0.52
Epinephelus macrospilus	185	0.03	1	0.17
Epinephelus maculatus	27315	4.51	22	3.85
Epinephelus malabaricus	24100	3.98	10	1.75
Epinephelus merra	359	0.05	5	0.87
Epinephelus microdon	524	0.08	2	0.35
Epinephelus ongus	621	0.10	3	0.52
Epinephelus polyphekadia	14845	2.45	12	2.10
Epinephelus sp.	500	0.08	1	0.17
Epinephelus suillus	7500	1.23	1	0.17
Epinephelus timorensis	1115	0.18	5	0.87
Gazza minuta	377	0.06	6	1.05

Table 10. (Cont'd)

Species	Wt (g)	% Wt	N	%N
Gnathanodon speciosus	13775	2.27	10	1.75
Grammatorcynus bicarinatus	525	0.08	1	0.17
Gymnocranius sp.	1090	0.18	2	0.35
Gymnocranius robinsoni	8025	1.32	3	0.52
Lactarius lactarius	495	0.08	1	0.17
Lagocephalus sceleratus	3550	0.58	2	0.35
Lethrinus atkinsoni	14530	2.40	26	4.56
Lethrinus elongatus	5225	0.86	3	0.52
Lethrinus mahsena	2755	0.45	8	1.40
Lethrinus nebulosus	12050	1.99	6	1.05
Lethrinus olivaceous	12950	2.13	4	0.70
Lethrinus semicinctus	142	0.02	1	0.17
Lethrinus variegatus	2435	0.40	9	1.57
Lethrinus xanthochilus	4025	0.66	2	0.35
Lutjanus argentimaculatus	17425	2.87	8	1.40
Lutjanus biguttatus	259	0.04	2	0.35
Lutjanus bohar	19200	3.17	10	1.75
Lutjanus boutton	8839	1.45	9	1.57
Lutjanus ehrenbergi	562	0.09	3	0.52
Lutjanus fulviflamma	1191	0.19	5	0.87
Lutjanus fulvus	4093	0.67	17	2.98
Lutjanus gibbus	13070	2.15	26	4.56
Lutjanus kasmira	3037	0.50	23	4.03
Lutjanus monostigma	755	0.12	1	0.17
Lutjanus quinquelineatus	1444	0.23	10	1.75
Lutjanus rivulatus	4225	0.69	1	0.17
Lutjanus russelli	3110	0.51	8	1.40
Lutjanus semicinctus	500	0.08	2	0.35
Muraenesox bagio	10875	1.79	4	0.70
Paraupeneus cyclostomus	280	0.04	1	0.17

Table 10. (Cont'd)

Species	Wt (g)	% Wt	N	%N
Paraupeneus heptacanthus	505	0.08	3	0.52
Platax orbicularis	2110	0.34	2	0.35
Plectropomus leopardus	7600	1.25	4	0.70
Plectropomus maculatus	600	0.09	1	0.17
Priacanthus cruentatus	5790	0.95	7	1.22
Priacanthus hamrur	4475	0.73	3	0.52
Pristipomoides sp.	3000	0.49	1	0.17
Pseudobalistes flavimarginatus	2150	0.35	1	0.17
Rastrelliger brachysoma	470	0.07	1	0.17
Rastrelliger kanagurta	285	0.04	1	0.17
Sargocentron spiniferum	995	0.16	4	0.70
Scolopsis monogramma	450	0.07	2	0.35
Scolopsis temporalis	565	0.09	3	0.52
Scomberomorus commerson	57025	9.41	6	1.05
Selar crumenopthalmus	280	0.04	1	0.17
Sphyraena flavicauda	335	0.05	1	0.17
Sphyraena forsteri	33340	5.50	69	12.10
Sphyraena jello	3410	0.56	2	0.35
Sphyraena putnamiae	56170	9.27	59	10.35
Symphorus nematophorus	3500	0.57	1	0.17
Terapon jarbua	572	0.09	3	0.52
Trichiurus haemula	550	0.09	1	0.17
Trichiurus lepturus	480	0.07	1	0.17
Upeneus vittatus	981	0.16	6	1.05
Variola albimarginata	1540	0.25	5	0.87
Totals	605 416		570	

Table 11. Species caught by dropline around lights set for bouke-ami nets

Species	Wt (g)	%Wt	N	%N
Aprion virescens	14200	7.76	5	3.27
Carangoides chrysophrys	2350	1.28	2	1.31
Carangoides hedlandensis	480	0.25	1	0.65
Caranx ignobilis	13165	7.20	4	2.61
Caranx melampygus	5700	3.12	2	1.31
Caranx papuensis	6225	3.40	2	1.31
Caranx sexfasciatus	7145	3.91	8	5.23
Caranx tille	11150	6.10	6	3.92
Cephalopholis sexmaculata	390	0.21	1	0.65
Echeneis naucrates	2090	1.14	2	1.31
Epinephelus malabaricus	2350	1.29	2	1.31
Epinephelus polyphekadia	3770	2.06	5	3.27
Epinephelus suillus	3250	1.78	1	0.66
Gazza minuta	265	0.15	2	1.31
Gymnocranius robinsoni	3800	2.08	1	0.66
Lethrinus atkinsoni	1265	0.69	3	1.96
Lethrinus mahsena	425	0.23	1	0.65
Lethrinus nebulosus	1650	0.90	1	0.65
Lethrinus olivaceous	2725	1.49	1	0.65
Lutjanus argentimaculatus	3040	1.66	3	1.96
Lutjanus biguttatus	185	0.10	1	0.65
Lutjanus bohar	2225	1.22	1	0.65
Lutjanus boutton	655	0.36	1	0.65
Lutjanus fulviflamma	545	0.30	2	1.31
Lutjanus fulvus	250	0.14	1	0.65
Lutjanus gibbus	3045	1.67	5	3.27
Lutjanus monostigma	1300	0.71	1	0.65
Lutjanus russelli	1250	0.68	1	0.65
Muraenesox bagio	4275	2.34	2	1.31
Scomberomorus commerson	10500	5.74	1	0.65
Sphyraena barracuda	13150	7.19	2	1.31
Sphyraena forsteri	24095	13.17	35	22.88
Sphyraena jello	13500	7.39	5	3.27
Sphyraena putnamiae	22470	12.29	42	27.45
Totals	182 880	100.00	153	100.00

Experimental droplining in shallow and deep lagoons from the research vessel during this study indicated that catch rates were high and where this method is used regularly it may have a substantial impact on local stocks. Catch rates are three times greater from droplines around baitlights than from droplines under natural conditions. Questionnaire survey data indicate that shallow and deep lagoons inside the reef are one of the most important subsistence fishing areas (44%), second only to fishing along shorelines (63%). Lagoons adjacent to villages are especially important to household subsistence fishing activities (Rawlinson and Sesewa, these proceedings p. 62).

Therefore incidental droplining by tuna fishermen in lagoons may have detrimental effects on subsistence and artisanal fisheries by removing fish that would otherwise be available for local villagers. It should where possible be prevented.

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A Survey of Fishing Activities by Coastal Villagers in Fiji and the Possible Conflict with Commercial Baitfishing

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ONE of the primary concerns expressed by traditional reef owners is that commercial baitfishing has detrimental effects on the lagoons and their livelihoods by reducing the numbers of larger reef fish (Blaber et al. these Proceedings).

In order to assess whether any credence can be given to these claims it is important to have an understanding of the types of fishing activities taking place within the artisanal and subsistence fisheries in areas where commercial baitfishing is also taking place.

As such information was not available, a household questionnaire survey was undertaken during the course of the Baitfish Research Project in Fiji.

Survey objectives

The data collected during the questionnaire survey were used to:

- assess the number of people undertaking fishing activities in coastal areas and the importance of these activities as a source of income to individual households;
- assess the frequency of fishing activities;
- assess the relative importance of the different fishing methods used;
- assess the relative importance of the different fishing grounds used;
- assess the ownership of fishing assets;
- identify the major fish groups which are targeted by fishers;
- assess potential interactions between the fishing activities of coastal villagers and the baitfishing operations of commercial pole-and-line vessels.

Methods

Questionnaires were undertaken as time allowed during the course of fieldwork for the baitfish research project. Members of the research team would go into a selected village, and after making the appropriate introductions to the village chief, or his representative, would question individual members of as many houses as possible. The interviewees were asked standard questions and their responses were recorded on the questionnaire form by the interviewer. A copy of the questionnaire form used is shown in Appendix 1. The length of time taken to interview a representative from one household was dependent on the types of fishing activities undertaken by members of the household. However, it usually took from 15 to 20 minutes to complete an interview with one household.

All the interviews were undertaken in coastal villages. The four sites of Vanua Balavu, Ngau, Kia,

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and Beqa are all areas where substantial baitfishing effort takes place. The two other areas where interviews took place (Rawlinson and Sharma these proceedings) were Waya Island and southern Yasawa Island, areas of negligible baitfishing effort.

Raw data were entered into a computer database using the software package dBaseIII. The analysis of the databases to produce the results presented in this report were also undertaken using the same software package.

Results

Survey profile. The number of households interviewed during the survey at each site and the total population size represented were as follows:

a) Total number of households surveyed = 299
b) Total number of households surveyed by area = Beqa Island, 24 households; Ngau Island, 61 households; Kia Island, 17 households; Vanua Balavu, 128 households; Waya Island, 26 households, and Yasawa Island 43; households.
c) The numbers of people living in the 299 households surveyed are shown in Table 1

Table 1. Profile of households.

	Total number	Average no. per house	Min. no. per house	Max. no. per house
Adult male	461	1.54	1	7
Adult female	463	1.55	0	6
Child male	429	1.43	0	6
Child female	360	1.20	0	5
Total	1713	5.73	1	19

Household Income. The main sources of household income reported are shown in Table 2

Table 2. Income profile of surveyed households

	No. of households	Percentage of households
Sale of marine products	187	62.5
Sale of copra	174	58.2
Sale of garden produce	119	39.8
Wage income	69	23.1
Own business	20	6.7
Other	17	5.7

Sale of marine products. The importance of the sale of marine products as an income source is shown in Table 3.

Table 3. Household dependence on marine products as an income source

	No. of households	Percentage of households
Most important source	91	30.4
Second most important source	71	23.7
Third most important source	23	7.7

The sale of copra was the most important source of income for 105 of the households interviewed (35.1% of the households) which was the highest percentage value for any of the sources of income.

Participation in fishing. The numbers of people who undertake fishing activities from the households surveyed are shown in Table 4.

Table 4. Profile of household fishing activity

	Total number	Average no. per house	Min. no. per house	Max. no. per house
Adult male	262 (56.8)*	0.88	0	5
Adult female	253 (66.9)	0.85	0	5
Child male	20 (4.7)	0.07	0	3
Child female	10 (2.8)	0.03	0	3
Total	545 (31.8)	1.82	0	7

* Values in parenthesis are percentages

Type of fishing activity. By defining households that carry out subsistence fishing activities as those that consume all of their catch and artisanal as those households that sell at least part of their catch, it was possible to define the number of households by area involved in these different strategies. Table 5 details the percentages of households involved.

Table 5. Effort expressed in percentages of fishing effort by area

Location	Artisanal	Subsistence	No fishing
Beqa	62.5	37.5	
Ngau	26.2	70.5	3.3
Kia Island	100.0		
Vanua Balavu	62.5	34.4	3.1
Waya	100.0		
Yasawa	39.5	51.2	9.3
Overall percentage	57.1	39.6	3.3

Fishing activity within households. Using the definitions above it was possible to assess the members of the households who were involved in undertaking subsistence or artisanal fishing activities. Table 6a shows the subsistence activities and 6b artisanal activities.

Table 6a. Subsistence fishing activities expressed as percentage of group involved

Location	Males	Females	Child male	Child female
Beqa	26.7	72.2	0.0	0.0
Ngau	37.8	80.7	3.4	1.7
Vanua Balavu	34.4	65.1	1.4	5.7
Yasawa	47.4	40.5	0.0	0.0

Table 6b. Artisanal fishing activities expressed as percentage of group involved

Location	Males	Females	Child male	Child female
Beqa	79.2	72.7	3.7	0.0
Gau	72.2	64.3	0.0	6.7
Kia Island	90.3	78.4	11.3	5.0
Vanua Balavu	71.2	55.0	7.1	3.1
Waya	57.9	22.9	10.3	2.5
Yasawa	66.7	22.2	0.0	0.0

Frequency of fishing effort. Table 7 summarises the number of fishing trips reported as carried out over a week or monthly period. People fishing reported carrying out three to six trips per week, one to two trips per week, more than one trip per month or less than one trip per month. The number of people (NI) who did not supply this information is also detailed. The frequency of these activities is summarised by both age and sex classes.

These results indicate that of the people who go fishing; 90.8% of the males and 92.9% of females undertake at least one fishing activity per week; 46.6% and 54.9% of males and females respectively reported undertaking trips more frequently than this (greater than twice a week).

The information received indicates that just over half the adult population (51.2%) undertake fishing activities at least once a week and that only a small proportion (3.8%) of the child population do any fishing at all.

Fishing methods utilised by coastal villagers. The different fishing methods utilised by households are detailed in Table 9 of Blaber et al. (these Proceedings).

From the information received it became clear that the most common form of fishing was the use of handlines (86.0% of the households reported using this method). Other techniques which appeared to be important were spearfishing (36.1%), dropline fishing (28.4%), the collection of shells etc (25.1%) and the use of gill nets (13.7%)

Household fishing assets. Table 8 summarises the percentage of households (House %) owning at least one of the fishing assets, the overall total of the different assets owned (Number), the mean number of assets for all households (Mean), and the Minimum and Maximum number of assets per household under the categories of fishing gear, boats and ice boxes.

Table 8. Household fishing assets

	House (%)	Number	Mean	Min.	Max.
Fishing gear					
Handline	87.3	856	2.86	0	15
Dropline	25.1	213	0.71	0	12
Towline	11.0	47	0.16	0	4
Spear (gun)	24.1	97	0.32	0	4
Spear (hand)	23.4	102	0.34	0	6
Dive goggle	39.5	179	0.60	0	6
Gill net	18.7	108	0.36	0	20
UW torch	21.7	72	0.24	0	2
Other gear	20.7	83	0.28	0	5
Boats					
Paddle canoe	6.0	20	0.07	5	5
Sail canoe	0.0	0	0.00	0	0
Canoe + engine	0.3	1	0.00	1	1
Fibreglass	1.7	5	0.02	0	1
Wooden punt	23.7	71	0.24	0	1
FAO design	3.3	10	0.03	0	1
Boats overall	32.4	107	0.36	0	1
Ice Boxes					
Homemade	4.7	16	0.05	0	3
Plastic 'Eskie'	1.3	0	0.00	0	0
H'holds using ice	6.3	0	0.00	0	0

Table 7. Frequency of fishing effort

	3-6 Trips / wk	1-2 trips / wk	> 1 trip / month	< 1 trip / month	NI	Total
Adult male	122	116	22	0	2	262
Adult female	139	96	12	1	5	253
Child male	5	12	3	0	0	20
Child female	5	5	0	0	0	10
Total	271	229	37	1	7	545

The data show the predominance of handlines as the major fishing gear owned both in terms of numbers per household and the proportion of houses owning the gear. Ownership of boats was limited to approximately one third of the households interviewed.

Areas fished. The main habitat areas where household fishing activities are carried out are shown in Table 9.

Table 9. Number of surveyed households (and percentage of surveyed households) fishing the designated habitat areas

Habitat area	No. of h'holds	Percentage of h'holds
Distant area	49	16.4
Outside edge of outer reef	82	11.2
On outer reef	84	11.4
Inside lagoon (deep)	153	51.2
Inside lagoon (shallow)	132	44.1
Along shoreline	190	63.5
Along edge of mangroves	15	5.0
Amongst mangroves	13	4.3
Estuary/rivers	9	2.7
Wharf	1	0.3

These results emphasise the importance of the shoreline and within the lagoons (both in shallow and deep water) adjacent to villages for the fishing activities of households. The results also show that there is not one particular habitat area where fishing effort is concentrated.

Target catch identified by people interviewed. Respondents were asked to identify the target catch of their fishing activities. Generally Fijian names were used and these have been categorised into their family names and the results summarised in Table 8 of Blaber et al. (these Proceedings). The percentages of the target catch identified are the proportion of the frequency a family name was identified to the number of different target items identified.

The results emphasise the importance of lethrinids as the predominant fish group targeted by coastal villagers, followed by serranids and scombrids.

Fish families caught. The data was analysed further by identifying the major fish families targeted from the most important habitat areas utilised. Percentage values are the proportions a particular fish family is targeted, compared with the total number of reports of the target catch mentioned. Fish groups caught from the three most important habitat areas are detailed in Table 10.

Table 10. Fish families targeted within three habitats

Fish group	Percentage
Along the shoreline	
Lethrinidae	24.3
Hemiramphidae	12.1
Gerreidae	10.7
Serranidae	9.5
Mugilidae	6.3
Mullidae	6.1
Lutjanidae	4.5
Inside lagoon (shallow water)	
Lethrinidae	33.4
Serranidae	12.0
Sphyraenidae	6.4
Carangidae	6.0
Scombridae	6.0
Gerreidae	4.5
Inside lagoon (deep water)	
Lethrinidae	40.7
Serranidae	16.2
Scombridae	12.4
Sphyraenidae	9.8
Carangidae	6.1
Acanthuridae	2.5

In all three habitat areas, the lethrinids were reported as the most important fish family targeted. This family can be seperated to species level by habitat area as local Fijian names are available for individual species. This was not the case for some of the other fish groups where a general name is used for all species in the family.

Table 11 details the lethrinids targeted from the same three habitat areas.

Table 11. Letherinids targeted in the three habitats

Lethrinus sp.	Percentage
Along the shoreline	
L. harak	56.1
L. mahsena	26.8
L. xanthochilus	5.7
L. nebulosus	4.1
Inside lagoon (shallow water)	
L. mahsena	50.6
L. harak	20.2
L. nebulosus	10.1
L. xanthochilus	9.0
Inside lagoon (deep water)	
L. mahsena	43.5
L. nebulosus	24.3
L. xanthochilus	5.7
L. olivaceous	8.7

As a large proportion of fishing effort takes place in shallow water using hook and line techniques *Lethrinus harak* and *L. mahsena* is likely to form a considerable component of the overall coastal fishing catch.

Effects of baitfishing

At the end of each interview the respondents were asked whether they felt there had been any changes in the availability of fish over the years. The question did not specifically mention the effects of baitfishing but certain responses referred to this concern. A range of the answers given are summarised in Table 12. Many of the respondents made no comments at all.

There were two concerns voiced about the effects of commercial baitfishing by pole-and fishing:

1) the abundance of fish usually taken by coastal villagers has decreased due to commercial baitfishing was identified by 9.3% of the respondents. Of the 24 comments received, 13 of these concerned the decline of the Spanish mackerel *(Scomberomorus commerson).*
2) the opinion that the abundance of baitfish species around the villages had declined due to commercial baitfishing was given by 3.3% of the respondents. The baitfish groups that were reported to have declined were the herring *(Herklotsichthys quadrimaculatus),* and the hardyheads (Atherinidae).

Two respondents felt that baitfishing was beneficial to them as they would receive tuna from the pole-and-line boats when they came to anchor in the lagoons for baitfishing.

Other comments received made no mention of baitfishing and were general comments about generally less fish being available, pollution, overfishing and bad weather being reasons for changes in their areas over the years.

Conclusions

The results from this survey suggest that the major fishing activities undertaken by the coastal villagers in the areas sampled do not target those species found to be predators of baitfish species by Blaber et al. (these Proceedings). This would suggest that interactions between the commercial pole-and-line fishery and the subsistence fishery are minimal.

Interactions are potentially more likely to occur in areas where there is an active artisanal dropline fishery with increased proportions of sphyraenids and scombrids in the catch, combined with high commercial baitfishing effort e.g. around Kia Island.

Table 12. Comments made about the effects of baitfishing.

Comment	Beqa	V. Balavu	Kia	Yasawa	Ngau	Waya
Less fish due to baitfishing	4	20	2 (shark)		2	
Baitfish less due to baitfishing	3	7				
Generally less fish		12	1		6	
Overfishing	1	12	5		3	
Bad weather		13				1
Baitfishing good	1	1				
No problems		5				
Other**	1	8				
No comment	14	55	10	43	48	24

* of 24 comments regarding species of reef fish declining due to baitfishing, 13 were about *S. commerson.* Of 14 comments regarding species of reef fish generally declining, 8 were about *S. commerson.* The two baitfish groups that were reported to be declining were herring and hardyheads.

** Other comments included: no boat, village commitments, sick family members, no money and fish getting smaller.

FISHING INTERVIEW SURVEY QUESTIONNAIRE

Confidential

SECTION 1: RESPONDENTS IDENTIFICATION

1. INTERVIEWER		2. CODE NUMBER	
3. DATE		4. TIME	
5. VILLAGE		6. TIKINA	
7. AREA CODE		8. RESPONDENT	
9. HOUSEHOLD STATUS		10. RACE	

SECTION 2: PERSONAL AND SOCIOECONOMIC

1. NUMBER PERMANENTLY LIVING IN HOUSEHOLD

2. COMPOSITION OF HOUSEHOLD:-

	NUMBER	AGES				
ADULT MALE						
ADULT FEMALE						
CHILD MALE						
CHILD FEMALE						

3. HOUSEHOLDS MAIN SOURCES OF INCOME:	RANK	SEASON
SALE OF MARINE/FRESHWATER PRODUCTS		
SALE OF COPRA		
FARMING		
WAGE EMPLOYMENT		
OWN BUSINESS		
OTHER		

4. IF MARINE/FRESHWATER PRODUCTS ARE SOLD, THEN HOW OFTEN? →

HOW OFTEN?	
FREQUENTLY (> 1/WEEK)	
OCCASIONALLY (> 1/ MONTH)	
INFREQUENTLY (< 1/ MONTH)	

5. WHAT TYPES OF MARINE/FRESHWATER PRODUCTS ARE SOLD?

	RANK	TO WHAT MARKET?	AT WHAT PRICE? DOLLARS/AMOUNT	HOW MUCH/HOW OFTEN AMOUNT/TIME PERIOD
FISH		→	→ /	→ /
SHELLFISH		→	→ /	→ /
BECHE-DE-MER		→	→ /	→ /
SHARK FIN		→	→ /	→ /
SHELLS		→	→ /	→ /
OTHER		→	→ /	→ /

6. MEMBERS OF THE FAMILY WHO GO FISHING AND HOW OFTEN DO THEY MAKE FISHING TRIPS?

	NUMBER	3-7 WEEK	1-2 WEEK	> 1 MONTH	<1 MONTH
ADULT MALE					
ADULT FEMALE					
CHILD MALE					
CHILD FEMALE					

7. AMOUNT OF FISH CAUGHT BY HOUSEHOLD WHICH IS CONSUMED BY THE HOUSEHOLD?

ALL	
SOME	
NONE	

8. IF NOT ALL WHAT ABOUT REST	RANK
SOLD	
GIVEN TO FAMILY	
GIVEN TO FRIENDS	
GIVEN TO ANIMALS	
OTHERS	

SECTION 3: FISHING METHODS

1. WHAT ARE THE MAIN FISHING METHODS USED BY THE MEMBERS OF THE HOUSEHOLD?

	RANK	BY WHO	USUAL TIME	MOON PHASE	JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
HAND LINE					
DROP LINE					
TOW LINE					
GILL NET (SET)					
GILL NET (DRIVE)					
SPEAR					
COLLECTION					
DUVA					
YAVIRAU					
QOLI SAMU					
FISHING POLE					
CAST NET					
PUSH NET					
CRAB TRAP					
OTHER					

2. WHAT IS THE MAIN HOOK BAIT USED?

	RANK
CRAB	
SQUID/OCTOPUS	
SMALL FISH	
LARGER FISH	
OTHER	

3. DOES ANYONE IN YOUR HOUSEHOLD USE LIGHTS DURING ANY OF THEIR FISHING OPERATIONS? YES or NO

IF YES, GIVE DETAILS?

SECTION 4: FISHING ASSETS

1. NUMBER POSSESSED BY HOUSEHOLD?

	NUMBER	SIZE
HAND LINE		
DROP LINE		
TOW LINE		
SPEAR (GUN)		
SPEAR (HAND)		
DIVING GOGGLES		
GILL NET		
PUSH NET		
FISHING POLE		
U/W TORCH		
SCUBA GEAR		
OTHER		

2. NUMBER POSSESSED BY HOUSEHOLD?

	NUMBER	BOAT SIZE			ENGINE HP
PADDLE CANOE					
MARINE PLYWOOD BOAT					
FIBREGLASS BOAT					
LOCAL WOODEN PUNT					
FAO DESIGN					
OTHER					

3. NUMBER OF ICE BOXES OWNED BY HOUSEHOLD?

	NUMBER
HOMEMADE ICEBOX	
PLASTIC ESKIES	

4. DOES YOUR HOUSEHOLD USE ICE?	YES		NO	
5. IF YES, FROM WHERE?				

SECTION 5: FISHING GROUNDS

1. DOES ANYONE IN YOUR HOUSEHOLD GO FISHING IN THE FOLLOWING AREAS?

	RANK	BY WHO	J F M A M J J A S O N D	FISHING METHOD	TARGET SPECIES
DISTANT AREA					
FISH AGGREGATING DEVICE (FAD)					
OUTSIDE EDGE OF OUTER REEF					
ON OUTER REEF					
INSIDE LAGOON (DEEP WATER)					
INSIDE LAGOON (SHALLOW WATER)					
ALONG SHORELINE					
ALONG EDGE OF MANGROVES					
AMONGST MANGROVES					
ESTUARY or RIVER					
OTHER					

2. ARE THERE ANY AREAS WHERE YOUR HOUSEHOLD HAS OWNERSHIP/FISHING RIGHTS?	YES or NO	
IF YES, WHERE?		
3. DOES YOUR HOUSEHOLD ALLOW OTHER PEOPLE TO FISH IN THESE AREAS?	YES or NO	
4. ARE THERE AREAS WHERE YOUR HOUSEHOLD IS NOT ALLOWED TO FISH?	YES or NO	

SECTION 6: FISHING EFFORT

1. WHAT IS THE AVERAGE LENGTH OF A FISHING TRIP?		RANK	BY WHO
	0 - 4 HOURS		
	4 - 12 HOURS		
	12 - 24 HOURS		
	1 - 2 DAYS		
	3 - 7 DAYS		
	> THAN 1 WEEK		

2. ARE THERE DAYS NOT AVAILABLE FOR FISHING?	YES or NO		IF ANY WHICH?	

SECTION 7: FISH CONSUMPTION

1. HOW OFTEN DOES YOUR HOUSEHOLD CONSUME FISH?	TICK	2. WHAT IS THE SOURCE OF THIS FISH?	RANK	3. WHERE DOES THE FISH COME FORM? EG. NAME OF FISHING AREA OR SUPPLIER
EVERY DAY		OWN CAUGHT FISH		
4 - 6 TIMES PER WEEK		BOUGHT FISH		
1 - 3 TIMES PER WEEK		FREE FISH		
1 TIME PER WEEK		TINNED FISH		
NEVER		OTHER		

SECTION 8: FISHING LICENCE

1. DOES YOUR HOUSEHOLD POSSESS A FISHING LICENCE?	YES		NO		IDA or ODA	

SECTION 9: MISCELLANEOUS

Potential Sites for Commercial Baitfishing in Fiji

N.J.F. Rawlinson* and A. Sesewa**

THE Fiji group is well endowed with anchorages of moderate depth and with some shelter, suitable for baitfishing. Probably over one hundred sites have been used by vessels at one time or another (Lewis et al. 1983). However probably less than half of these are regularly visited (Sharma and Adams 1990).

Annual baitfish catches tend to come from three or four main areas and within these areas a disproportionate amount of effort is exerted on certain individual sites (Rawlinson and Sharma, these Proceedings). Due to this Kearney (1982) considered that baitfish resources would probably show some effects of heavy fishing pressure in localised areas.

Any effects of baitfishing that cause concern to customary fishing-right owners are likely to be more pronounced in areas of high baitfishing effort. Therefore Fisheries Division wanted to try to encourage the vessels in the pole-and-line fleet to spread their effort over a wider area of the Fiji group. For this reason, it was decided that one of the priorities of the Baitfish Research Project was to identify new and underutilised areas suitable for commercial baitfishing.

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Identification of sites to be surveyed

The first step in selecting new sites was to identify areas that were presently not being used (or lightly used) for commercial baitfishing in Fiji, and which looked to hold potential as additional/alternative sites to those regularly used by the commercial pole-and-line fleet.

Past baitfishing effort by the pole-and-line fleet was assessed by an analysis of catch returns which had been collected over the years, see Rawlinson and Sharma these proceedings. This analysis enabled the identification of the most commonly used baitfishing sites in Fiji, (see Fig.1 Blaber et al. these Proceedings p.52) Using this as a guide and getting the views of the pole-and-line industry as to the areas they would be interested in opening up as new baitfishing sites it was possible to come up with a list of potential sites that should be surveyed. These were: southern Yasawas and the Mamanuca Group, north-west Vanua Levu, Moala and southern Lau.

Ika Corporation was also interested in knowing the availability of baitfish in Fiji during the normal closed season for fishing to the pole-and-line fleet i.e. July to September. The most productive baitfishing site of Vanua Balavu was also added to this list as an area to be surveyed during the closed season.

A further site around Kia Island and north Vanua Levu was also included in the survey in an attempt to capture anchovies in order to carry out an age validation experiment on this species (see Milton and Blaber these Proceedings).

A timetable of survey cruises was drawn up to cover these areas during the course of 1992.

Method

All the baitfish survey cruises were made using the 20 m Fisheries Research vessel *Tui-Ni-Wasabula* (TNW).

The baitfishing technique employed during the course of the survey followed as closely as possible the method used by the commercial pole-and-line fishing vessels in Fiji. A scaled down version of a bouke-ami net was set from the boat using bamboos as the main supporting beam and for the 'side-arms' of the net. The net was the length of the TNW (approximately 20 m) and two lengths of bamboo (approximately 15 m in length) were joined to push the net away from the side of the vessel. The net was set along port side of the vessel.

The lights used to attract the baitfish had to be powered by a portable generator that was placed on deck. The underwater light was 1000 watts and the surface light was 500 watts. Different combinations of the lights were used but finally in an attempt to reduce the fuel consumption of the portable generator the attraction of the baitfish was carried out using a single underwater light. Using the single light alone led to greater catch rates when the net was hauled as the surface light, although efficient at attracting the sprats and the sardines, also seemed to make them a lot easier to scare. The baitfish seemed more comfortable to remain around the underwater light.

The dimming of the light was only possible by controlling the speed of the generator which caused some problems. The sudden fluctuations in the brightness of the underwater light would have been responsible for scaring baitfish away from the net on a number of occasions, resulting in lower catch rates.

All other operations involved in shooting and hauling the net were the same as carried out by commercial vessels except that a crew of between 8-10 men only were available for these operations. This is approximately half the man power available on a commercial vessel.

The position of each haul of the net was recorded as well as relevant physical data. A sub-sample of the catch was taken and sorted in order to provide an estimate of the species composition of the baitfish at each site.

Results

Position of baitfishing operations and catch rates

Tables 1, 2, 3, 4 and 5 give details of the operations undertaken at the locations of the southern Yasawas and the Mamanuca Group, Vanua Balavu, northern Vanua Levu, north-west Vanua Levu and Moala respectively. Due to engine problems on the research vessel the trip to southern Lau had to be cancelled.

Each table details the position, date and time that the haul of the bait net was made and the depth of water the TNW was anchored in. The exact latitude and longitude positions were taken from the Global Positioning System (GPS) installed in the TNW and depth recordings were taken from the vessels echo-sounder. The number of buckets of bait caught is also recorded along with the major species present in the catch.

It should be noted that the number of buckets of fish caught is not a good indication of the amount of baitfish present at each location. During the early days of the survey there were problems associated with the hauling of the bait net as it was a new method to many of the people involved in the survey. However, as time progressed, the difficulties were ironed out and a much more efficient operation was performed.

Species composition of the catch

A sub-sample of the bait catch was taken from each haul of the net. The sample was weighed and then sorted by species. Each species group was counted and weighed.

A summary of these results is presented in Tables 6, 7, 8, 9 and 10 for the operations undertaken at the locations of the southern Yasawas and the Mamanuca Group, Vanua Balavu, northern Vanua Levu, north-west Vanua Levu and Moala respectively. The major baitfish species (those from the families Clupeidae, Engraulidae, Apogonidae and Atherinidae) present in the catch as a proportion of the total numbers taken (%N) and the total weight taken (%Wt) are shown in each table. The average weight of each species taken is also shown along with the number of times the species occurred (% Occ), expressed as a percentage of the overall number of hauls of the bait net made during each survey.

In terms of catch rates, the sites of the southern Yasawas and the Mamanuca Group, and Moala, showed the most potential as new baitfishing sites. The majority of the catch at both sites was comprised of species considered to be effective as baitfish e.g. *Spratelloides delicatulus, Spratelloides gracilis, Rhabdamia gracilis* and *Amblygaster sirm*. It must be stressed again that at nearly every location within these sites the catch rates are expected to be much higher for a commercial vessel because of the increased size and depth of the net and the more experienced fishing masters and crews. On many occasions large schools of baitfish, especially the sardine *(Amblygaster sirm)*, had aggregated around the light but were not caught during the haul of the net.

Unfortunately the survey to north-west Vanua Levu was hampered by bad weather and results were

Table 1. Positions of nightly baitfishing operations during the survey to southern Yasawas and Mamanuca Islands including buckets (Bkt) of bait caught

No.	Date	Time	Site	Lat. S	Long. E	Depth	Bkt	Major Species
1	22/01/92	03.30	Malolo	17°44.3'	177°11.5'	25 m	3	*R.gracilis, S. delicatulus*
2	22/01/92	20.30	Soso Bay	17°10.3'	177°13.5'	32 m	15	*R. gracilis*
3	23/01/92	04.15	Soso Bay	17°10.3'	177°13.5'	32 m	2	*R. gracilis, A. sirm*
4	23/01/92	21.45	Limaneitui Tova	17°10.7'	177°15.7'	25 m	3	*R. gracilis, A. sirm*
5	25/01/92	02.15	Soso Bay	17°08.6'	177°13.4'	27 m	14	*H. ovalaua, A. lacunosus*
6	25/01/92	22.45	Nacilau Point	17°10.0'	177°14.3'	31 m	10	*R. gracilis*
7	27/01/92	04.00	Drawaqa Island	17°10.9'	177°11.8'	36 m	½	*S. delicatulus*
8	28/01/92	01.45	Nabawaqa Island	17°12.6'	177°13.3'	36 m	15	*S. delicatulus*
9	29/01/92	02.30	Tobani Qarau Reef	17°14.9'	177°15.2'	29 m	40	*A. sirm, S. delicatulus*
10	30/01/92	03.30	Nalauwaki Bay	17°15.8'	177°07.7'	34 m	7	*S. delicatulus*
11	31/01/92	04.45	NE of White Rock	17°19.2'	177°17.0'	34 m	½	*A. sirm, S. delicatulus*
12	04/02/92	01.15	White Rock	17°22.7'	177°15.3'	30 m	3	*A. sirm*
13	05/02/92	02.30	Yalobi	17°19.1'	177°07.6'	30 m	50	*R. gracilis*
14	06/02/92	02.30	Tobani Qarau Reef	17°16.3'	177°15.9'	28 m	60	*S. delicatulus, A. sirm*
15	07/02/92	03.45	Tokoriki Island	17°34.4'	177°07.2'	35 m	50	*A. sirm, S. delicatulus*
16	08/02/92	03.15	Tai Island	17°37.4'	177°14.3'	33 m	75	*S. delicatulus*
17	11/02/92	02.45	North of Vomo Is.	17°26.4'	177°18.4'	35 m	54	*A. sirm, Rastrelliger* sp
18	12/02/92	00.45	Kadomo Island	17°29.8'	177°02.7'	47 m	60	*S. delicatulus, A. sirm*
19	13/02/92	02.15	Mana Sand Cay	17°40.4'	177°08.9'	29 m	70	*S. delicatulus, A. sirm*
20	14/02/92	04.15	Matamanoa	17°37.8'	177°03.1'	36 m	25	*S. delicatulus, R. gracilis*

Table 2. Positions of nightly baitfishing operations during the survey to Vanua Balavu including buckets (Bkt) of bait caught

No.	Date	Time	Site	Lat. S	Long. W	Depth	Bkt	Major Species
1	22/07/92	23.25	Daliconi	17°13.9'	178°58.9'	35 m	80	*E. devisi, E. punctifer*
2	24/07/92	05.00	Susui	17°20.5'	178°56.5'	13 m	½	*H. ovalaua*
3	25/07/92	05.15	Susui	17°19.7'	178°56.7'	35 m	10	*S. gracilis, A. sirm*
4	27/07/92	04.30	Muamua	17°14.5'	178°58.9'	24 m	10	*H. quadrimaculatus, G. minuta*
5	11/08/92	04.50	Daliconi	17°13.9'	178°58.9'	36 m	2	*E. punctifer, H. ovalaua*

Table 3. Positions of nightly baitfishing operations during the survey to northern Vanua Levu including buckets (Bkt) of bait caught

No.	Date	Time	Site	Lat. S	Long. W	Depth	Bkt	Major Species
1	24/09/92	04.00	Vorovoro Island	16°21.9'	178°23.8'	28 m	30	*S. delicatulus, H. ovalaua*
2	25/09/92	04.30	Naviri	16°08.0'	179°29.0'	30 m	3	*S. delicatulus, H. ovalaua*
3	26/09/92	04.00	Mali	16°21.3'	179°19.4'	20 m	2	*S. delicatulus, H. ovalaua*
4	30/09/92	03.00	Kia Island	16°14.3'	179°04.3'	34 m	1	*S. delicatulus, H. ovalaua*
5	01/10/92	04.30	Kia Island	16°14.3'	178°04.3'	24 m	10	*H. ovalaua, A. lacunosus*

Table 4. Positions of nightly baitfishing operations during the survey to north-west Vanua Levu including buckets (Bkt) of bait caught:-

No.	Date	Time	Site	Lat. S	Long. W	Depth	Bkt	Major Species
1	06/10/92	01.30	Nadogo Island	16°32.1'	178°45.7'	27 m	2	*S. delicatulus, H. ovalaua*
2	07/10/92	04.00	Yaqana Island	16°34.8'	178°33.7'	28 m	1	*S. delicatulus, Apogonids*
3	08/10/92	–	West Ovatoa Reef	16°33.3'	178°39.2'	36 m	–	No Haul – Weather too rough
4	09/10/92	–	Monkey Face	16°33.3'	178°39.2'	30 m	–	No Haul – Very heavy rain

Table 5. Positions of nightly baitfishing operations during the survey to Moala including buckets (Bkt) of bait caught

No.	Date	Time	Site	Lat. S	Long. W	Depth	Bkt	Major Species
1	21/11/92	22.30	Moala	18°34.7'	179°57.2'	29 m	6	*S. delicatulus, S. gracilis*
2	23/11/92	03.45	Moala	18°39.6'	179°51.8'	27 m	10	*H. ovalaua*
3	24/11/92	00.30	Moala	18°37.7'	179°51.3'	32 m	40	*S. delicatulus, H. ovalaua*
4	25/11/92	02.00	Moala	18°39.9'	179°52.2'	23 m	60	*A. sirm, S. delicatulus*
5	26/11/92	02.00	Moala	18°33.2'	179°57.0'	38 m	80	*S. delicatulus, S. gracilis*

Table 6. Major species of baitfish caught during the course of the survey of southern Yasawas and the Mamanuca Group

SPECIES	% N	% Wt	Av.Wt (g)	% Occ.
Spratelloides delicatulus	46.19	8.61	0.22	95
Rhabdamia gracilis	13.69	10.10	0.86	100
Amblygaster sirm	13.20	53.11	4.68	100
Clupeidae juveniles	7.78	0.97	0.14	53
Hypoatherina ovalaua	4.06	3.80	1.09	74
Atherinomorus endrachtensis	2.11	3.82	2.11	37
Spratelloides gracilis	1.79	0.74	0.48	47
Rhabdamia cypselurus	1.55	0.52	0.39	95
Rastrelliger sp.	1.52	6.86	5.24	42
Encrasicholina devisi	1.45	1.79	1.43	95
Rastrelliger faughni	1.45	1.73	1.39	32
Herklotsichthys sp.	0.74	2.96	4.63	37
Rastrelliger kanagurta	0.61	1.87	3.58	21
Percentage of Total Samples	96.14	96.88		–
Total Sample Sizes	45 626	53 108g	1.16	100

inconclusive. Although catch rates were low there was evidence of large quantities of baitfish at all sites where the light was set but strong winds made the shooting and hauling of the net an extremely difficult operation. Although results in terms of catch suggest that this area is lacking in available baitfish resources, it is considered that this was primarily a function of the poor weather conditions experienced and that this area does provide some potential as an alternative baitfishing site.

During the trip to Vanua Balavu in July, the normal closed season for pole-and-line fishing, the nightly catch on the first sampling occasion was very high and made up predominantly of *Encrasicholina* anchovies, which are highly regarded as baitfish. For the remainder of the survey period however, the weather conditions were poor with strong winds experienced which made baitfishing operations extremely difficult. However, there were undoubtedly still considerable quantities of baitfish within the lagoon area that could have been captured given better conditions.

Discussion

All the areas surveyed have potential as alternative locations for pole-and-line vessels to capture baitfish for the next days tuna fishing operations. However, the main stimulus to where pole-and-line vessels undertake their nightly baitfishing activities is the presence of tuna schools in the immediate area. If vessels know that they are likely to find schools adjacent to the baitfishing locations, there is a greater likelihood that they will attempt to catch baitfish from those locations.

It is therefore considered that if the pole-and-line fishing vessels are to be actively encouraged to catch baitfish in and around any of the areas surveyed, thereby reducing baitfishing effort away from currently heavily fished sites, an incentive that tuna schools can be found in the area is required. This incentive can best be provided in the form of fish aggregating devices (FAD) anchored in positions close to the baiting sites.

If any of the areas surveyed are needed as additional baitfishing locations for the pole-and-line boats an active FAD deployment programme is required in the waters immediately adjacent to the area.

Table 7. Major species of baitfish caught during the course of the survey of Vanua Balavu

Species	% N	% Wt	Av.Wt (g)	% Occ.
Spratelloides delicatulus	20.19	2.56	0.94	60
Hypoatherina ovalaua	19.43	6.53	2.50	40
Encrasicholina devisi	12.11	3.75	2.30	60
Atherinomorus endrachtensis	11.46	12.70	8.23	20
H. quadrimaculuatus	9.52	33.04	25.78	20
Encrasicholina punctifer	8.22	2.30	2.08	80
Spratelloides gracilis	3.04	0.21	0.51	40
Dussumieria sp.	2.93	13.71	34.76	60
Atherinomorus lacunosus	0.98	0.02	0.18	20
Amblygaster sirm	0.79	5.92	55.82	80
Siphamia versicolor	0.51	0.04	0.58	60
Siphamia sp.	0.45	<0.01	0.09	60
Thryssa baelama	0.23	0.03	10.00	20
Rhabdamia gracilis	0.06	<0.01	0.08	40
Archamia lineolata	0.06	<0.01	0.09	20
Apogon sp.	0.06	<0.01	0.03	20
Pseudamia gelatinosa	0.03	<0.01	2.49	20
Cheilodipterus macrodon	0.03	0.10	3.49	20
Apogon fraenatus	0.03	<0.01	0.10	20
Percentage of Total Samples	90.14	81.13	–	
Total Sample Sizes	3551	26379.49	6.69	100

Table 8. Major species of baitfish caught during the course of the survey of north Vanua Levu

Species	% N	% Wt	Av.Wt (g)	% Occ.
Spratelloides delicatulus	52.82	24.87	0.77	100
Hypoatherina ovalaua	22.92	22.05	1.57	100
Atherinomorus lacunosus	4.72	9.15	3.17	80
Apogon fraenatus	3.03	0.18	0.10	40
Hypoatherina barnesi	1.34	0.69	0.84	40
Apogon sp.	1.09	0.01	0.01	20
Amblygaster sirm	0.84	30.80	59.70	60
Cheilodipterus zonatus	0.82	0.03	0.07	40
Archamia lineolata	0.70	1.35	3.17	40
Encrasicholina devisi	0.47	0.11	0.42	20
Atherinomorus endrachtensis	0.39	2.20	9.21	20
Stolephorus insularis	0.26	0.31	1.95	20
Rhabdamia gracilis	0.24	0.05	0.37	20
Apogonidae unid. sp.	0.24	<0.01	0.02	20
H. quadrimaculatus	0.14	2.00	22.78	40
Rhabdamia cypselurus	0.10	0.04	0.68	60
Siphamia sp.	0.01	<0.01	0.09	20
Archamia zosterophora	0.08	0.01	0.22	20
Spratelloides gracilis	0.08	0.02	0.36	40
Siphamia versicolor	0.04	0.02	0.82	20
Encrasicholina juveniles	0.02	<0.01	0.06	20
Apogon kallopterus	0.02	0.03	2.21	20
Percentage of Total Samples	90.54	94.01	–	
Total Sample Sizes	4850	7946.92	1.70	

Table 9. Major species of baitfish caught during the course of the survey of north-west Vanua Levu

Species	% N	% Wt	Av.Wt (g)	% Occ.
Spratelloides delicatulus	59.12	33.75	0.23	100
Hypoatherina ovalaua	19.30	58.67	1.26	100
Apogon fraenatus	3.07	0.75	0.10	100
Apogon unidentified sp.	2.49	0.14	0.02	100
Spratelloides gracilis	1.79	0.67	0.15	50
Caesio caerulaureus	1.16	0.85	0.16	50
Rhabdamia cypselurus	0.91	0.85	0.39	50
Encrasicholina devisi	0.51	0.10	0.08	100
Atherinomorus lacunosus	0.38	1.23	1.34	50
Rhabdamia gracilis	0.33	0.02	0.02	50
Amblygaster sirm	0.06	0.01	0.08	50
Apogon bandanensis	0.03	0.19	2.40	50
Clupeidae juveniles	0.10	<0.01	0.05	50
Cheilodipterus zonatus	0.03	<0.01	0.05	50
Pterocaesio sp.	0.01	0.01	0.31	50
Siphamia sp.	0.01	<0.01	0.03	50
Percentage of Total Samples	89.30	96.42	–	
Total Sample Sizes	6018	2513.75	0.45	100

Table 10. Major species of baitfish caught during the course of the survey of Moala

Species	% N	% Wt	Av.Wt (g)
Spratelloides delicatulus	54.54	39.93	0.58
Spratelloides gracilis	29.46	14.19	0.38
Hypoatherina ovalaua	3.19	15.91	3.96
Clupeidae juveniles	1.99	0.20	0.08
Gymnocaesio gymnopterus	1.11	0.60	0.43
Rhabdamia gracilis	1.05	1.73	1.31
Siphamia tubulata	0.66	0.11	0.13
Atherinomorus lacunosus	0.55	5.38	7.73
Apogon kallopterus	0.48	0.23	0.38
Apogon sp.	0.29	0.02	0.04
Amblygaster sirm	0.25	10.21	32.99
Caesio caerulaureus	0.17	0.28	1.34
Siphamia sp.	0.10	<0.01	0.05
Apogonidae unid. sp.	0.10	0.01	0.09
Pseudamia gracilicauda	0.05	0.01	0.15
Encrasicholina devisi	0.04	0.06	1.38
Hypoatherina barnesi	0.04	0.03	0.59
Thryssa baelama	0.01	0.10	6.53
Pseudamia sp.	0.01	<0.01	0.12
Rhabdamia cyselurus	0.01	0.01	0.53
Herklotsichthys sp.	0.01	<0.01	0.25
Apogon fraenatus	<0.01	<0.01	0.11
Apogon bandanensis	<0.01	0.03	3.63
H. quadrimaculatus	<0.01	0.23	29.35
Percentage of Total Samples	94.15	89.23	–
Total Sample Sizes	16251	12929.61	0.75

FAD might not be required around Moala as there are sea mounts within the vicinity of this island that are fished by the pole-and-line fleet. Presently vessels will capture baitfish from more distant baitgrounds eg. Ngau before fishing at these sea mounts. Catching bait from Moala could reduce travelling time and cost if these sea mounts were fished regularly.

Acknowledgments

Thanks are expressed to the captain and crew members of the *Tui-Ni-Wasabula* for their assistance throughout the whole survey and the fisheries officers especially at Lautoka and Labasa who were quick to offer help whenever the TNW came to port.

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BAITFISH BIOLOGY

Aspects of Growth and Reproduction Relevant to Managing Tuna Baitfish Stocks in Fiji

D.A. Milton and S.J.M. Blaber*

ACCURATE estimates of age and growth are important prerequisites when attempting to model fish populations and provide stock assessments (Sparre et al. 1989). Length and age at sexual maturity are also important in order to assess the impact of fishing gear on immature fish that may not have entered the breeding population.

Unlike in other countries where there are pole-and-line tuna fisheries, the species composition of the baitfish in Fiji is very diverse with several species of similar importance (Lewis et al. 1983; Sharma and Adams 1990; Rawlinson and Sharma these Proceedings). Previous studies of baitfish age and growth have concentrated on the sprat *(Spratelloides delicatulus)* (Munch-Petersen 1983, Dalzell et al. 1987), the herring *(Herklotsichthys quadrimaculatus)*, and cardinalfish *(Rhabdamia gracilis)* (Dalzell et al. 1987). These studies have estimated age and growth from small samples of length-frequencies (Munch-Petersen 1983) and counting increments in otoliths (Dalzell et al. 1987). The technique of counting daily increments in otoliths has been used recently to estimate the age and growth of baitfish in the Solomon Islands (Milton et al. 1991) and Kiribati (Milton et al. 1994). These studies have shown that growth of some species is very variable and that it is unwise to extrapolate results from one area to another (Milton et al. 1991).

Similarly, there is little information on reproduction of many of the major baitfish from Fiji. Lewis et al. (1983) examined breeding seasonality and length at sexual maturity of *S. delicatulus* and *H. quadrimaculatus*. They found that the sprat was sexually mature at 35mm and bred for an extended period during the year. The herring reached sexual maturity at 90mm and had distinct breeding season in the late spring. A recent study of reproduction of these species in Kiribati has shown that *H. quadrimaculatus* bred throughout the year and was sexually mature at 70mm (Milton et al. 1994). No details are available on the reproduction of other important baitfish groups such as the cardinal fishes.

One of the first indications of the status of a fish stock is obtained by estimating mortality. It gives an estimate of the level of exploitation of a stock and provides a baseline from which more detailed analysis can be made. In Fiji, mortality has only been estimated for *S. delicatulus* and was high relative to temperate fish species (Munch-Petersen 1983, Dalzell et al. 1987). Mortality of another species (*A. sirm*) in Kiribati was very high, particularly on spawning adults, and such high levels could lead to over-exploitation of the stocks (Rawlinson et al. 1992).

The aims of this study were: (a) to examine the age and growth of the nine major baitfish species in Fiji; (b) to estimate their length and age at sexual maturity and compare these values with age at full selection by

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baitfishing gear; and (c) estimate total mortality of each species for a range of populations and years to assess whether the current levels of exploitation of baitfish are sustainable.

Materials and Methods

Sampling

Fish were collected from the bouke-ami catches of the Baitfish Research Project (BRP) bait site survey during 1992. Details of methods used in this survey are given in Rawlinson and Sesewa (these Proceedings). Further samples of baitfish were collected opportunistically aboard the commercial pole-and-line boat, *'Trapper'*, between October 1991 and July 1992. Representative samples of baitfish were taken from the first haul on a night and frozen. These were returned to the laboratory for analysis.

Ageing

In the laboratory, fish were measured (± 1 mm), weighed (± 0.001 g), and their gonads and otoliths removed and gonads weighed (± 0.001g). Otoliths were cleaned of excess tissue, and assigned a sequential number. Each otolith was mounted on microscope slides with a thermo-plastic cement. The upper surface was polished with 800 grit wet-and-dry sandpaper before being examined with a video-enhanced light microscope attached to a microcomputer with distance measuring software. Increments were counted along the posterior axis at 400 - 1000× magnification.

Data analysis

The length-at-age data were fitted to the re-parameterised von Bertalanffy growth curve of Francis (1988). This method has the advantage that the parameters estimated are independent and can be compared directly between species and populations. It has been used previously to compare growth among short-lived tropical clupeids in other parts of the south Pacific and will enable the results to be compared directly (Milton et al. 1991, 1993).

Most previous studies of baitfish age and growth in the south Pacific have fitted the von Bertalanffy growth equation to data on length-at-age (e.g. Munch-Petersen 1983, Dalzell et al. 1987, Milton et al. 1991). However, several authors have noted that the estimated parameters L_∞, K and t_0 either do not have direct biological meaning (e.g. Knight 1968, Schnute and Fournier 1980, Ratkowsky 1986) or are extrapolations from the data (Ratkowsky 1986). Values of L_∞, in particular, are dependent on adequate sampling of fish in the larger length classes, so estimates are an extrapolation beyond the data and therefore prone to inaccuracy (Knight 1968). Problems in fitting the von Bertalanffy function have been tackled by re-parameterising the equation with new variables or fitting more stable growth equations (Schnute 1981). Ratkowsky (1986) showed that the parameters proposed by Schnute and Fournier (1980) had the best statistical properties of eight versions examined, especially for comparative studies of populations. Francis (1988) extended the equation of Schnute and Fournier (1980) to derive a new set of parameters L_1,L_2 and L_3 (his l_ϕ ,l_χ and l_ω), which correspond to the length at the lower, middle and upper limits of any arbitrarily defined age range, such that:

$$L_t = L_1 + (L_3-L_1)(1-r^{2(t-\phi)/(\omega-\phi)})/(1-r^2) \qquad (1)$$

where $r = (L_3-L_2)/(L_2-L_1)$, L_t is the mean length of a fish at age t and L_1,L_2 and L_3 are the length at the lower, middle and upper limits of two arbitrary ages ϕ and ω. By fitting a curve of this form, extrapolations beyond the data are avoided, as the three fitted parameters are chosen from within the range of the data and hence can be directly compared with the results of previous studies.

In this study, we set $\phi = 30$ and $\omega = 90$ increments for all species except for *Amblygaster sirm* where $\phi = 150$ and $\omega = 350$ and *Herklotsichthys quadrimaculatus* where $\phi = 50$ and $\omega = 200$. These values were all within the range of the data and were the same values used in previous studies of age and growth of these species (Milton et al. 1991, 1993). This equation has the advantage that the age range to be examined can be chosen by the investigator, rather than having to be the largest and smallest age classes found, as required by the Schnute and Fournier (1980) equation. These parameters (L_1,L_2 and L_3) can also be expected to have similar properties to those of Schnute and Fournier (1980) and not to show the high negative correlation between L_∞ and K (Francis 1988).

Francis (1988) also gave equations for the relationship between his parameters and L_∞, K and t_0, which makes it possible to compare our estimates of L_∞ and K with those in the literature.

All parameters were estimated by an iterative least-squares method (SAS NLIN procedure with the Marquardt option) (SAS 1989). Vaughan and Kanciruk (1982) found that this procedure consistently showed the least bias in parameter estimates, converged rapidly and provided more precise estimates than standard linear techniques. Accuracy of the parameter estimates was also improved by increasing the sample size (Vaughan and Kanciruk 1982). To reduce the number of iterations, initial estimates of the parameters were obtained from plots of length and age of each species at each site. A measure of goodness-of-fit was obtained by calculating an r^2 value from the residual and explained sums of squares derived from the least-squares regression.

Reproduction

After gonads were removed and weighed, ovaries were examined macroscopically to determine their stage of development (Milton and Blaber 1991). Gonosomatic index (GSI) was estimated as gonad weight/(total weight – gonad weight) (Milton and Blaber 1991). As ovaries were not examined histologically, fish with spent (Stage 6) or developing gonads (Stage 2) could not be separated. However, many of the species have previously been examined at other sites and the proportion of sexually mature fish that were running-ripe (Stage 5) or recently spent was estimated using the gonosomatic index criteria of Milton and Blaber (1991) and Milton et al. (1993–4) (Table 1). The daily proportion spawning was estimated from the combined estimates of running ripe and spent fish as previous studies have found that tropical clupeiods only develop running-ripe eggs within 2–3 hours prior to spawning (Somerton 1990). Spent fish could only be recognised within 24 hours of spawning (Milton and Blaber 1991, Milton et al. 1993–4). Fish were scored as being sexually mature if their ovaries had ripe (Stage 4) eggs visible when examined.

Table 1. Gonosomatic index (GSI, %) criteria used to estimate the proportion running-ripe (Stage 5) or spent (Stage 6) of each baitfish species in Fiji based on the studies of Milton and Blaber (1991) and Milton et al. (1994).

Species	Running-ripe (%)	Spent (%)
A. sirm	> 4.1	< 1.3
E. devisi	> 7.0	< 1.5
E. heterolobus	> 8.8	< 1.5
E. punctifer	> 8.0	< 1.5
H. quadrimaculatus	> 5.5	< 1.6
R. cypselurus	> 3.8	< 1.0
R. gracilis	> 3.8	< 1.0
S. delicatulus	> 5.7	< 1.5
S. gracilis	> 11.9	< 1.3

Mortality

Annual total mortality (Z) was estimated for sites and years where length-frequency data were available. Large samples of fish collected during 1992 at several sites (see Rawlinson and Sesewa these Proceedings) were measured (SL ± 1mm). Other length-frequency samples taken during 1979–82 from four major baitfishing areas (northern Vanua Levu, Lomaiviti, western Viti Levu and Vanua Balavu) by Lewis et al. (1983) were also used in the analysis. Fish length was converted to age with length-age keys (Gulland and Rosenberg 1992). The total number of fish in fortnightly age classes was summed and total mortality was estimated from the slope of the regression of the natural logarithm of these numbers against age (in fortnights) (Sparre et al. 1989). Annual total mortality was estimated by multiplying these values by 26. The percentage survival per month was estimated by taking the exponential of –Z and multiplying by 200.

Results

Age and growth

A total of 613 fish of nine species were aged by counting increments in their otoliths (Table 2). *Amblygaster sirm* was the longest-lived with fish having up to 450 increments. Most species lived up to four months and *H. quadrimaculatus* lived up to one year.

The growth parameters of the three species of *Encrasicholina* did not differ much between species (Table 3). L_2 was significantly smaller for *E. devisi* than *E. heterolobus* (P<0.05) and L_3 was lower than that of *E. punctifer* (P<0.05). Both *E. devisi* and *E. punctifer* lived to similar ages (Table 1; Fig. 1) but *E. punctifer* grew to a larger size and had a better growth rate (Table 4). The two *Spratelloides* species grew more slowly when young and L_1 was lower than for *E.*

Table 2. Details of the samples of the 9 baitfish species examined from Fiji for age and growth.

Species	Site[a]	Length Range (mm)	Weight Range (g)	Age Range (increments)	N[b]
A. sirm	V. Levu	24-191	0.126–125.9	20-451	81
E. devisi	V. Levu	27-62	0.164–2.012	37-122	68
E. heterolobus	V. Levu/V. Balavu	29-60	0.229–3.007	32-77	44
E. punctifer	V. Balavu	26-80	0.098–4.968	30-114	75
H. quadrimaculatus	V. Levu	33-105	0.523–20.37	45-384	72
R. cypselurus	V. Levu	16-45	0.057–1.428	30-105	66
R. gracilis	V. Levu	15-46	0.044–1.896	28-108	60
S. delicatulus	V. Levu	15-56	0.023–2.112	23-121	92
S. gracilis	V. Levu	17-57	0.048–2.127	22-78	55

[a] V. Levu = Viti Levu; V. Balavu = Vanua Balavu.
[b] N = number examined

devisi or *E. heterolobus* (P<0.01)(Fig. 2). However, these differences reduced among older fish (Table 3). Growth parameters and the growth rates of both *Rhabdamia* species were similar (Tables 3 and 4) but fish were smaller at all ages than *Encrasicholina* and *Spratelloides* of similar age (Fig. 2; Table 3). The growth of *A. sirm* or *H. quadrimaculatus* was not directly compared with the other species (Table 3). However, the growth curves of both species show that they grew rapidly during the first six months at rates similar to those of the shorter-lived species (Fig. 3).

Reproduction

Samples of female *E. devisi* and *E. heterolobus* from Viti Levu showed that both species became sexually mature at 40mm and an age of 50–60 increments (Fig. 4). Fish with ripe eggs (Stage 4) had a minimum GSI of 2.5%. No female of either species had running-ripe eggs in their ovaries but 10% of the *E. devisi* and 24% of the *E. heterolobus* had a GSI < 1.5% and may have been spent. Unlike the other species, *E. punctifer* became sexually mature at 48mm and over 75 increments old (Fig. 4). Of females over this length, none had running-ripe eggs in their ovaries, but 22% had a GSI < 1.5%.

All female *S. delicatulus* examined were over 40mm and 50 days and were sexually mature (Fig. 5). The minimum GSI of ripe females examined was 2%. There were no females that had running-ripe eggs in their ovaries, but 50% had a GSI < 1.5% and may have been spent. This differed from *S. gracilis* which were sexually mature at 35mm and 40 days old. The minimum GSI of sexually mature *S. gracilis* was about 5% and 41% of sexually mature fish examined (from February 1992) had running-ripe eggs in their ovaries. A further 44% had a GSI < 1.3% (Table 1) and were classified as spent. These fish were collected over two days, which gives a daily proportion spawning of 42.5% or a spawning frequency of every 2.4 days for *S. gracilis* at that time.

Both species of *Rhabdamia* became sexually mature at 36mm and about 70 increments old (Fig. 5).

Table 3. Growth parameters (SL ± se) of the re-parameterised von Bertalanffy growth equations for *A. sirm* (150–350 days), *H. quadrimaculatus* (50–200 days) and other species (30–90 days) from Viti Levu (VL) or Vanua Balavu (VB) in Fiji.

Species	Site	L_1	L_2	L_3	r^2
A. sirm	VL	130.4±1.6	166.6±1.3	184.0±2.0	0.98
E. devisi	VL	27.0±0.4	40.4±0.3	50.8±0.4	0.96
E. heterolobus	All	30.4±0.8	49.9±0.9	56.7±2.9	0.85
E. punctifer	VB	8.7±19.6	39.6±2.9	62.3±1.9	0.60
H. quadrimaculatus	VL	39.4±1.3	62.1±0.8	79.5±1.0	0.95
R. cypselurus	VL	13.9±1.6	32.1±0.5	42.2±0.7	0.86
R. gracilis	VL	14.4±1.0	33.0±0.4	41.3±0.4	0.92
S. delicatulus	VL	21.2±0.7	45.9±0.5	52.3±1.3	0.89
S. gracilis	VL	24.6±0.5	48.9±0.4	61.1±1.7	0.96

Table 4. Von Bertalanffy growth parameters of the growth curves of the major baitfish species based on otolith increments. Curves were calculated from the best-fit a re-parameterised by equation of Francis (1988). Growth rate is calculated for fish at length $L_\infty/2$ using the formula GR=$K.L_\infty/2$.

Species	K per yr	L_∞ (mm)	t_0 (yrs)	Growth rate (mm/yr)
A. sirm	2.7	200	0.01	270
E. devisi	3.0	88	–0.04	132
E.heterolobus	12.9	60	0.03	387
E. punctifer	3.7	126	0.06	233
H. quadrimaculatus	1.3	135	–0.13	88
H. quadrimaculatus[a]	1.8	128	–0.16	115
R. cypselurus	7.2	55	0.04	198
R. gracilis	9.8	48	0.05	235
R. gracilis[a]	2.7	50	–0.08	68
S. delicatulus	16.6	54	0.05	448
S.delicatulus[a]	6.4	65	–0.006	208
S gracilis	8.3	74	0.03	307

[a] results from Dalzell et al. (1987)

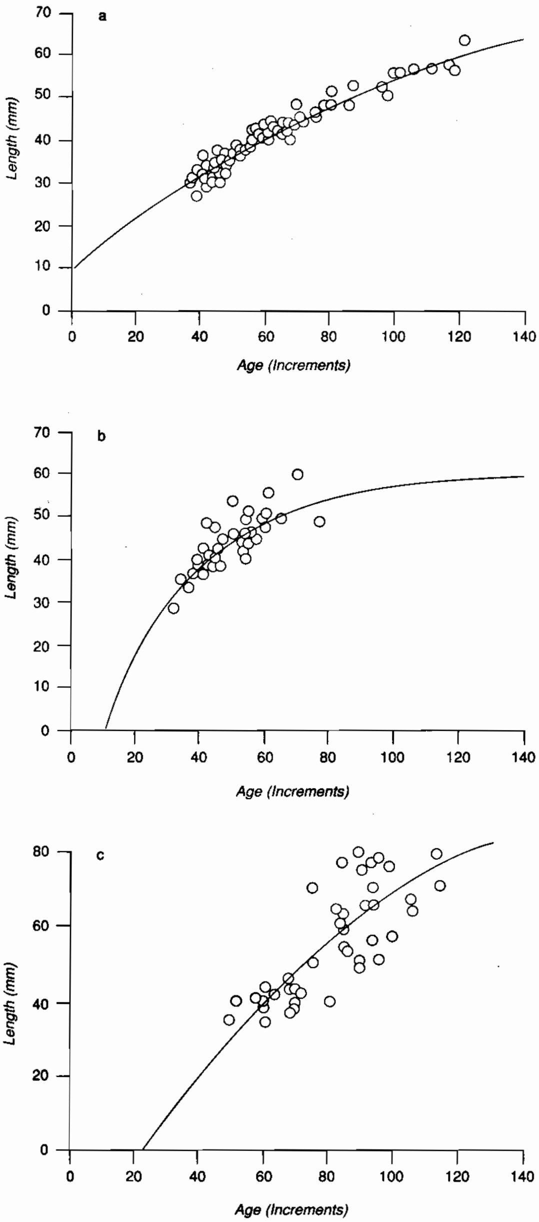

Figure 1. Relationship between length (mm) and the number of increments in the otoliths of (a) *Encrasicholina devisi*, (b) *E. heterolobus* from western Viti Levu and (c) *E. punctifer* from Vanua Balavu, Fiji.

No fish examined, of either species, were brooding eggs in their mouth. Two *R. cypselurus* (33%) and one *R. gracilis* (4%) had running-ripe eggs in their ovaries. Many *R. gracilis* had a GSI < 1%, but appeared to be reproductively inactive when examined under the microscope.

Amblygaster sirm from western Viti Levu became sexually mature at approximately 150mm and 7 months of age (Fig. 6). Of the sexually mature fish, six (18%) had running-ripe eggs in their ovaries and 3 (9%) had a GSI < 1.3% and may have been spent. These fish were collected over two days in February 1992 and the data give an estimated daily proportion spawning of 14% and a spawning frequency of once every 7.3 days.

Among *H. quadrimaculatus*, only those over 100mm and one year old had ripe (Stage 4) eggs in their ovaries (Fig. 6). Of these, 5 (18%) had running-ripe eggs (Stage 5). All of the fish with a GSI < 1.6% were collected in August when no female with ripe eggs was observed and suggests that these fish were inactive (Stage 2) rather than spent. Consequently, no estimate of spawning frequency could be made as all reproductively-active females were in spawning condition (N=5).

Mortality

Mortality estimates of *Encrasicholina* species varied greatly among samples (Table 5). Catch curves combined all samples collected within a year at each site and fish were fully selected by the bouke-ami nets at 2 months of age (~ 40mm) and sexual maturity. Estimates of total mortality of *E. devisi* varied between 5.56 and 15.35 per year. Estimates from recent years (1991–1992) were higher than most of those prior to 1991 (Table 5). The estimates for *E. punctifer* from Vanua Balavu in 1991 were much higher than during 1992 (P<0.001). Commercial fishing targeted all species so no direct estimates of natural mortality could be made.

Total mortality estimates for both species of *Rhabdamia* from Viti Levu in 1992 were similar and lower than that estimated for a sample from Moala (P<0.01); (Table 6). No commercial fishing occurred at either site in 1992 so that total mortality equalled natural mortality of these fish. The age at which *R. gracilis* was fully selected by the gear was higher at Moala than Viti Levu where fish over one month (20mm) were most susceptible to the gear.

Large length-frequency samples of *S. delicatulus* were collected from five regions in Fiji during 1980–81 (Table 6). At all sites, estimates of total mortality were significantly higher during 1980 than at other times (P<0.05). The highest estimate was from Vanua Balavu during 1991 (Table 6). The three estimates based on fish collected during 1992 were all from sites where no fishing was taking place and so are estimates of the natural mortality of this species. Similarly, the estimate of total mortality of *S. gracilis* from Moala in 1992 is also an estimate of natural mortality.

Unlike other species, *A. sirm* were not fully selected until 6–7 months old (~ 120mm). Estimates of total mortality of fish over this length were high, especially

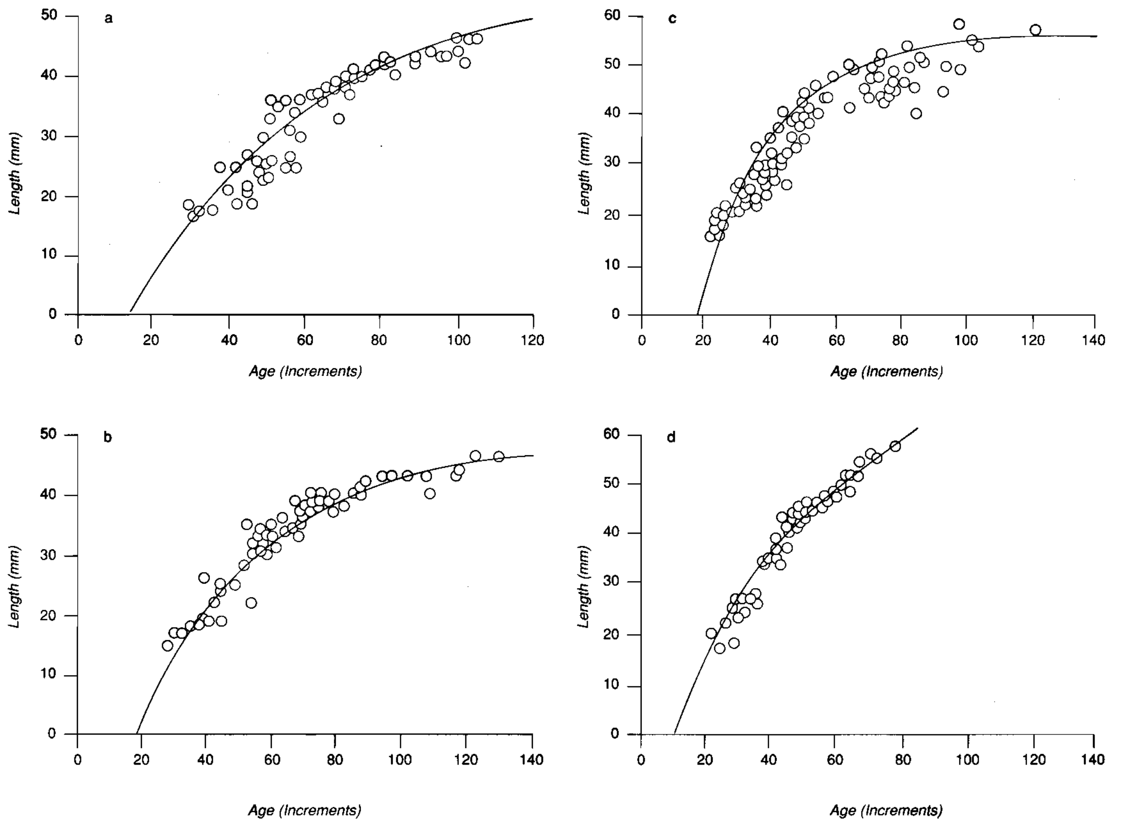

Figure 2. Relationship between length (mm) and the number of increments in the otoliths of (a) *Rhabdamia cypselurus*, (b) *R. gracilis*, (c) *Spratelloides delicatulus* and (d) S. gracilis from western Viti Levu, Fiji.

at Vanua Balavu (Table 7). Mortality estimates for *H. quadrimaculatus* were lower in all years at all sites. The highest estimate was from northern Vanua Levu during 1981. Except for this estimate, total mortality of *H. quadrimaculatus* was higher in all regions during 1980 than in other years ($P<0.05$). Only one sample (Viti Levu in 1992) could be used to estimate natural mortality.

Discussion

Age and growth

The age and growth of tuna baitfish in the south Pacific has been studied intensively during the past decade. Age and growth of several species has been examined by counting increments in their otoliths and from studies of length-frequencies (Dalzell et al. 1987, Dalzell 1990, Conand 1991, 1993, Milton et al. 1990, 1991, 1993). These studies have revealed the variability in growth of species such as *S. delicatulus* and highlighted the need to examine age and growth of these species in each area that needs study (Milton et al. 1991).

Other species, like *A. sirm* and *H. quadrimaculatus*, grow at similar rates throughout their range, but may have different von Bertalanffy growth parameters in each of the areas studied (Milton et al. 1993). In Fiji, *H. quadrimaculatus* grew at a similar rate to those in neighbouring Kiribati but L_∞ and *K* differed because fish grew to a larger size in Fiji than Kiribati. Similarly, Fijian *A. sirm* grew faster than Kiribati fish up to one year old but did not grow as large as fish in Kiribati. As a consequence the estimated growth rate (at $L_\infty/2$) was higher in Fiji, but similar to that in the Solomon Islands (Milton et al. 1993).

Spratelloides have been the most intensively studied of the baitfish species groups in Fiji. Both *S. delicatulus* and *S. gracilis* grew rapidly in Fiji during early life and reached sexual maturity earlier than in Kiribati or Solomon Islands (Milton and Blaber 1991, Milton et al. 1993). For *S. delicatulus*, growth rates were similar to those of fish at similar latitudes at Townsville and Lizard Island, northeastern Australia (Milton et al. 1991). Despite this rapid growth, the

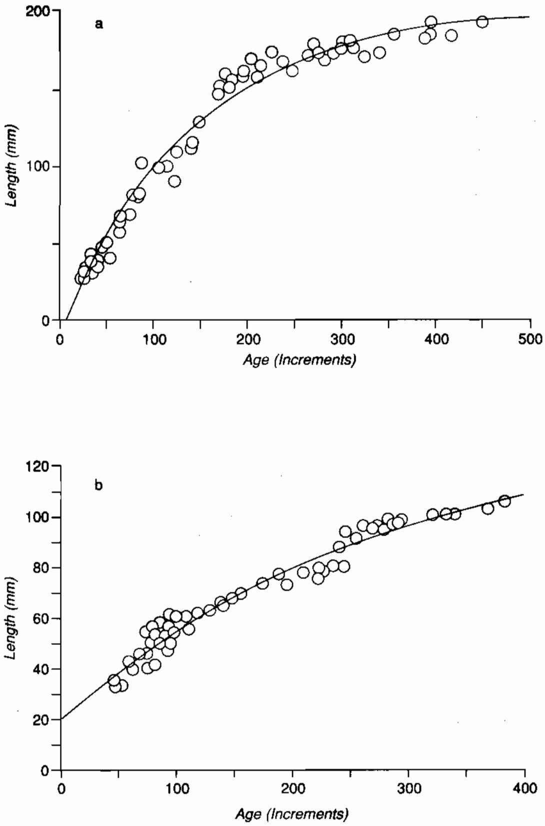

Figure 3. Relationship between length (mm) and the number of increments in the otoliths of (a) *Amblygaster sirm* and (b) *Herklotsichthys quadrimaculatus* from western Viti Levu, Fiji.

maximum size of *S. delicatulus* in Fiji was smaller than in many other parts of its range (Milton et al. 1991, 1993). This suggests that mortality is high in Fiji, either from high predation rates (Blaber et al. these Proceedings) or high exploitation rates by the commercial baitfishery where it is an important species (Rawlinson and Sharma these Proceedings). Growth of *S. gracilis* in Fiji was similar to that at Tulagi, Solomon Islands, and significantly faster than that recorded at other sites in the Indo-Pacific (Milton et al. 1991). In the Solomon Islands, this rapid growth only occurred in one of two years that fish were studied and our results in Fiji may not be representative of the possible range in growth of this species. Further study of otolith microstructure and examination of increment widths in populations with different growth rates and hence different prey densities (Molony and Choat 1990) may help to understand the conditions under which this species maintains rapid growth throughout its life cycle.

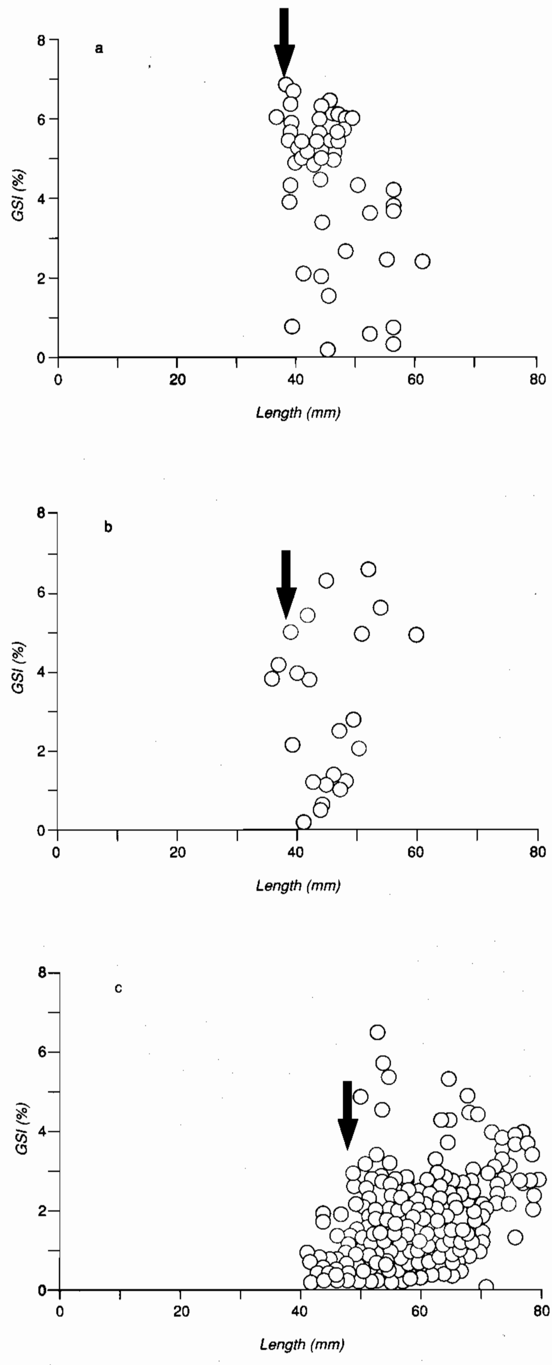

Figure 4. Relationship between length (mm) and GSI (%) of (a) *Encrasicholina devisi*, (b) *E. heterolobus* from western Viti Levu and (c) *E. punctifer* from Vanua Balavu, Fiji. Arrows indicate the length at which ripe eggs (Stage 4) were observed in the ovaries.

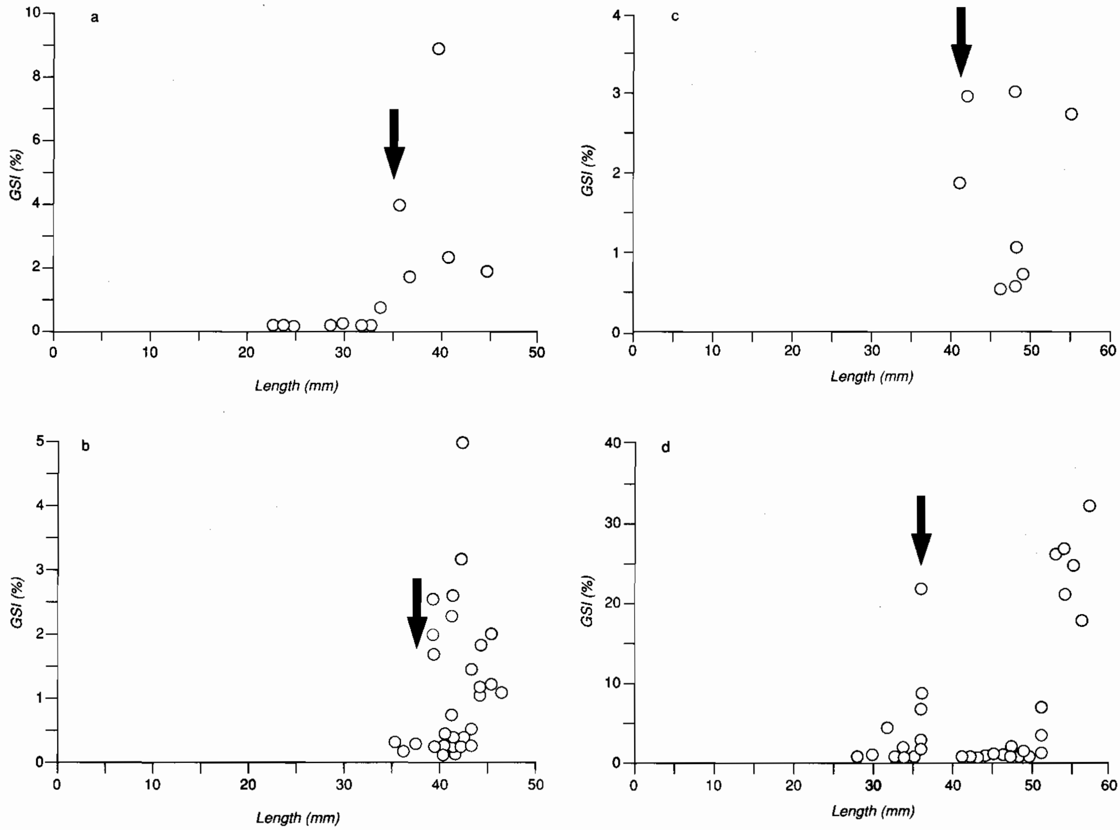

Figure 5. Relationship between length (mm) and GSI (%) of (a) Rhabdamia cypselurus, (b) R. gracilis, (c) Spratelloides delicatulus and (d) S. gracilis from western Viti Levu, Fiji. Arrows indicate the length at which ripe eggs (Stage 4) were observed in the ovaries.

The rate of increment formation in otoliths of other baitfish species in Fiji have not been validated as daily. As a result, the interpretation of the growth data of these species are less reliable and should be treated with caution. This problem is apparent in *R. gracilis* which had been previously been aged in Fiji by Dalzell et al. (1987) by counting increments in otoliths. They found that it lived for a year and grew much more slowly than our data suggest. We need to validate the rate of formation of the structures we counted before the real age structure of the population can be determined.

The growth of *Encrasicholina* species in Fiji was similar to that of *E. heterolobus* in the Solomon Islands and Maldives (Milton et al. 1990). These results contrast with those from length-frequency analysis by Dalzell (1990) and Tiroba et al. (1990) for the same species. Wright et al. (1990) identified two types of growth increments of *E. heterolobus* from Indonesia and indirectly validated that the smaller increment was formed daily which suggests that this species lived for up to a year. Subsequent studies of otolith increments in other anchovies have also discussed the different types of increments in otoliths but showed that the larger increments were formed daily (Hoedt 1992a). In another study of a tropical anchovy, Hoedt (1992b) estimated that *Thryssa hamiltoni* from Townsville reached about 175 mm after one year. His study site was at similar latitudes to Fiji and suggests that anchovies can easily grow to 60 - 80 mm in four months.

Reproduction

Our study provides the first estimates of size and age at sexual maturity of many of the important baitfish species in Fiji. A previous study in Fiji focussed on the herring *H. quadrimaculatus* and the sprat *S. delicatulus* (Lewis et al. 1983). In this study *H. quadrimaculatus* reached sexual maturity at 90mm and had a definite spawning season during October - December. Our results support these conclusions. *Herklotsichthys quadrimaculatus* matured at 100mm, a length reached after one year. As a consequence, reproductive lifespan must be much shorter in Fiji

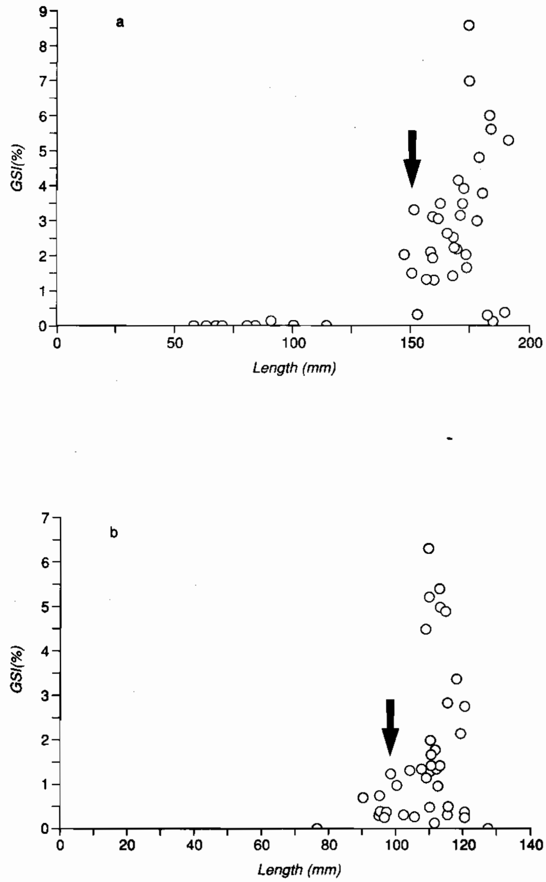

Figure 6. Relationship between length (mm) and GSI (%) otoliths of (a) *Amblygaster sirm* and (b) *Herklotsichthys quadrimaculatus* from western Viti Levu, Fiji. Arrows indicate the length at which ripe eggs (Stage 4) were observed in the ovaries.

than Kiribati, where fish are mature at 6 months of age and spawn continuously thereafter (Milton et al. 1994). Lower temperatures and unfavourable spawning conditions throughout the rest of the year must restrict spawning to the period when rising water temperatures should ensure that conditions are favourable for larval growth for the longest period. Conand (1988, 1991) found a similar reproductive pattern for *H. quadrimaculatus* and *A. sirm* in New Caledonia.

In Fiji, *A. sirm* matured in seven months and we found spawning fish in February suggesting that young born at that time could be ready to reproduce the following spring. Our data did not indicate that fish live more than one spawning season even though fish were up to 18 months old in February. Preliminary estimates of spawning frequency were also similar to those estimated from Kiribati in the only other detailed study of reproduction of *A. sirm* (Milton et al. 1994).

Rapid growth, early sexual maturation and frequent spawning are phenomena common to many anchovies (e.g. *Anchoa mitchilli*, Luo and Musick 1991; *Encrasicholina purpurea*, Clarke 1987). Our data show that the three species of anchovy we examined in Fiji reach sexual maturity in 2-3 months at similar sizes to fish in Solomon Islands (Milton and Blaber 1991). There were no previous studies of reproductive activity by *E. punctifer* and our results show that this species has a similar reproductive cycle to the other species. Based on the GSI criteria of previous studies of the other two species, *E. punctifer* spawned almost daily at Vanua Balavu during the warmer months of the year (Table 8).

Cardinal fish are known to be mouth-brooders that keep eggs in the buccal cavity until hatched (Thresher 1984). Of the *Rhabdamia* collected during this study, we saw no fish with eggs in their mouth so we have no direct evidence of reproduction in these species. Both species had a very similar life history pattern and grow at similar rates, reaching sexual maturity at

Table 5. Total annual mortality (Z ± s.e) of three species of *Encrasicholina* based on length-converted catch curves from length-frequency samples collected in four parts of Fiji in 1980, 1981 and 1992. (95% CL = 95% confidence limits)

Species	Site	Year	Age at full selection (months)	Annual total mortality (Z ± s.e)	Survival (% per month) (95% CL)	r^2
E. devisi	Vanua Balavu	1991	3.5	14.48±0.07	0.0005–0.0007	0.92
	Lomaiviti	1980	2.5	5.56±0.07	4.0–5.3	0.82
	Vanua Levu	1980/81	2	15.35±0.09	0.0002–0.0003	0.95
	Viti Levu	1980	4	6.34±0.08	1.8–2.5	0.84
		1992	2	12.48±0.19	0.003–0.007	0.75
E. heterolobus	Viti Balavu	1991/92	2	16.4±0.17	0.00006–0.0001	0.99
E. punctifer	Viti Balavu	1991	2	13.62±0.51	0.0005–0.004	0.91
		1992	2	5.11±0.18	5.1–10.3	0.78

Table 6. Total annual mortality (Z ± s.e) of two species of *Rhabdamia* and *Spratelloides* based on length-converted catch curves from length-frequency samples collected in four parts of Fiji in 1979, 1980, 1981 and 1992.(95% CL = 95% confidence limits)

Species	Site	Year	Age at full selection (months)	Annual total mortality (Z ± s.e)	Survival (% per month) (95% CL)	r^2
R. cypselurus	Viti Levu	1992	1	9.72±0.50	0.03–0.19	0.84
R. gracilis	Moala	1992	2.5	13.98±0.60	0.0003–0.003	0.94
	Viti Levu	1992	1	9.96±0.56	0.02–0.17	0.92
S. delicatulus	Kadavu	1980	1	9.19±0.16	0.09–0.17	0.85
		1981	1.5	6.76±0.05	1.3–1.5	0.86
		1982	1.5	4.23±0.03	16.5–18.5	0.79
	Moala	1992	2	9.33±0.24	0.07–0.17	0.90
	Vanua Balavu	1981	1	6.94±0.03	1.1–1.2	0.87
		1991	2	13.44±0.07	0.0016–0.002	0.98
	Lomaiviti	1980	1	9.77±0.08	0.06–0.08	0.94
		1981	1	6.50±0.03	1.7–1.9	0.88
		1982	1	12.04±0.13	0.005–0.009	0.91
	Vanua Levu	1980	1.5	8.22±0.03	0.30–0.34	0.92
		1981	1	7.25±0.03	0.80–0.90	0.87
		1982	1.5	4.55±0.06	11.3–14.3	0.80
		1992	2	4.52±0.10	10.7–15.9	0.99
	Viti Levu	1979	1	6.85±0.04	1.2–1.4	0.97
		1980	1	10.25±0.11	0.03–0.05	0.93
		1981	2	6.83±0.05	1.2–1.4	0.90
		1992	1.5	8.75±0.16	0.14–0.26	0.91
S. gracilis	Moala	1992	1.5	6.70±0.52	0.53–4.1	0.93
	Vanua Balavu	1981	1	6.38±0.03	1.9–2.2	0.99
	Lomaiviti	1980	1.5	9.76±0.16	0.05–0.09	0.91

Table 7. Annual estimates of total mortality (Z ± s.e) of *Amblygaster sirm* and *Herklotsichthys quadrimaculatus* from length-frequency samples collected during 1980, 1981 and 1992 at several sites in Fiji.(95% CL = 95% confidence limits)

Species	Site	Year	Age at full selection (months)	Annual total mortality (Z ± s.e)	Survival (% per month) (95% CL)	r^2
A. sirm	Vanua Balavu	1992	7	15.08±0.09	0.0003–0.0004	0.89
	Viti Levu	1992	6.5	11.96±0.08	0.0066–0.009	0.88
H. quadrimaculatus	Vanua Balavu	1981	11	5.72±0.06	3.5–4.4	0.80
	Lomaiviti	1980	2.5	6.76±0.08	1.2–1.6	0.82
		1981	8	4.68±0.03	10.5–11.8	0.71
	Vanua Levu	1980	7	3.38±0.02	39.3–42.5	0.88
		1981	11	10.66±0.05	0.025–0.031	0.88
	Viti Levu	1980	2.5	7.72±0.03	0.50–0.56	0.82
		1981	10	2.60±0.06	79.2–98.0	0.79
		1992	3	7.54±0.08	0.55–0.75	0.78

similar size and age. We found fish with running-ripe eggs (Stage 5) in catches during February and it is likely that these species have a protracted spawning season throughout the summer. Although no estimates of fecundity are available, it is likely that fish do not spawn as frequently as the clupeoids so lifetime egg production is likely to be much lower. This suggests that populations of these species would be unlikely to sustain such high fishing pressure as clupeoid baitfish.

Mortality

Total mortality estimates of all species of baitfish in Fiji were high compared to those found for comparable temperate species and reflected the higher predation rates found in tropical inshore waters (Blaber et al. 1990a, 1990b, Blaber et al. these Proceedings). As a result, total mortality varied widely between years and between sites during a single year. This variation in

Table 8. The proportion of female *Encrasicholina punctifer* spawning at Vanua Balavu during the summer of 1991/92 and the estimated inter-spawning interval (in days) and its overall monthly range (N = sample size; 95% CL = 95% confidence limits).

Month	Date	Proportion spawning (%)	Inter-spawning interval (days)	Monthly Range (days) (95% CL)	N
October 1991	14-Oct-91	87.5	1.1	1.7 - 1.9	24
	16-Oct-91	67.4	1.5		43
	17-Oct-91	27.2	3.7		11
	19-Oct-91	83.9	1.2		31
	20-Oct-91	13.2	7.6		38
November 1991	30-Nov-91	76.9	1.3	1.1 - 1.5	13
December 1991	15-Dec-91	72.7	1.4	1.1 - 1.3	22
	18-Dec-91	96.9	1.0		33
	19-Dec-91	75	1.3		28
January 1992	13-Jan-92	53.8	1.9	1.6 - 2.2	13
February 1992	01-Feb-92	66.7	1.5	1.7 - 1.9	6
	04-Feb-92	100	1.0		25
	07-Feb-92	100	1.0		9
	24-Feb-92	3.1	32.3		32
March 1992	14-Mar-92	16.7	6.0	5.8 - 6.2	18

total mortality was as high for species that were not being fished as among fish collected from exploited populations and shows that natural mortality rates are highly variable for these short-lived species. Consequently, empirical estimates of natural mortality (e.g. Pauly 1980) are likely to be highly inaccurate and this in turn makes estimating exploitation rates difficult.

Despite these potential problems, there are some general trends in the total mortality estimates that have implications for the tuna baitfishery. The total mortality estimates for *A. sirm* were high for a species that lives for up to 2 years. Fish do not recruit to the fishery until they reach sexual maturity and high mortality on adult fish could not be sustained. Rawlinson et al. (1992) found similar high levels of mortality among *A. sirm* in Kiribati. They found that catches of large *A. sirm* were often high as the fish was highly photo-positive and were readily attracted to underwater lights. They also believed that these fish were moving into the lagoons to spawn and that the baitfishery may be catching spawning aggregations. We have no evidence that this high fishing pressure on adult *A. sirm* is having an impact on the stocks, but fisheries managers should be aware of the potential to over-fish this species because of their attraction to underwater lights. A measure of the exploitation rate by the baitfishery can be gained from the difference in mortality between western Viti Levu and Vanua Balavu. Around Viti Levu, *A. sirm* were caught only by the artisanal fishers for use as bait (Rawlinson pers. comm.). Assuming natural mortality was similar in both areas, the exploitation rate for baitfishing at Vanua Balavu was at least 21% higher than that on the Viti Levu populations.

Total mortality estimates for *H. quadrimaculatus* from Fiji were lower than those reported by Rawlinson et al. (1992) in Kiribati. These estimates were also lower than we estimated for the longer-lived *A. sirm*. The estimate of total mortality from western Viti Levu during 1992 was taken from an area where little baitfishing occurred. It provides the best estimate of natural mortality of *H. quadrimaculatus* in Fiji. It highlights the variability in mortality of these species as this estimate is higher than those from areas and years where baitfishing occurred.

Our estimates of total mortality of *Encrasicholina* species in Fiji were extremely variable and in some cases, may have overestimated mortality because older age classes were underrepresented in the catches due to the general rarity of all species except *E. punctifer*. Even for this species, total mortality was much higher in 1991 than 1992 at Vanua Balavu. Total anchovy catch at Vanua Balavu in 1992 was almost double that in 1991 (Rawlinson and Sharma these Proceedings). However, both *E. devisi* and *E. punctifer* total mortality estimates were much higher in 1991. Fishing effort was more restricted in 1992 and a greater proportion of effort was made at the site where our samples were taken (Daliconi). There are at least two possible explanations as to why this occurred. The first is that our sampling gear may have undersampled older fish. This is unlikely as large samples were collected from both commercial and research netting operations. The second alternative is that the assumptions of constant recruitment and constant mortality were not met during 1991. If recruitment was poor that year, the mortality rate would be overestimated. Other estimates of total mortality of *E. aevisi* and *E. heterolobus* where recruitment was known to be relatively constant (e.g. Tiroba et al. 1990) were much lower than the 1991 estimates and similar to the 1992 estimates.

Mortality estimates for *S. delicatulus* from Vanua Balavu during 1991 were also higher than other estimates for this species. It suggests that a common factor was affecting all species at that site during 1991. Mortality estimates from earlier studies also had a common pattern, being higher at all sites during 1980. All estimates were within the range of those estimated previously for *S. delicatulus* in Fiji (Munch-Petersen 1983; Dalzell et al. 1987) and elsewhere in the Pacific (Tiroba et al. 1990; Rawlinson et al. 1992). Based on estimated monthly egg production in Kiribati (Milton et al. 1994), each female *S. delicatulus* on average produces 7500 eggs/month. If mortality is assumed constant throughout life then this species can sustain an annual total mortality of Z = 8.9–10.5 depending on the spawning frequency. Seven of the 20 mortality estimates made for *S. delicatulus* were within this range or higher. This suggests that mortality rates during 1980 were not, or barely sustainable. A similar pattern exists for *S. gracilis* with a high mortality estimate for 1980.

Conclusions

This study has shown that most species of baitfish in Fiji are short lived and have high mortality rates. Only *A. sirm* and *H. quadrimaculatus* live longer than six months and both these species did not live more than 18 months. Due to their rapid growth rates, all species except *H. quadrimaculatus* were not fully selected by the baitfishing gear until they were sexually mature. This occurred at approximately two months of age for the *Encrasicholina* spp., *Rhabdamia* spp. and *Spratelloides* spp.

Mortality estimates of these species reflected their short life cycle and there was some evidence that recruitment was poor for *Encrasicholina* species and *S. delicatulus* from Vanua Balavu in 1991 and for *S. delicatulus* at all sites in 1980. However, overall there was no evidence that baitfish were being overexploited in Fiji.

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Species Composition and Community Structure of Tuna Baitfish Populations in Fiji

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THERE have been few studies of the community structure of small pelagic fishes in the tropical oceans. Kikawa (1977) found distinct groups of species caught in baitnets that associated with lagoon habitats and reef passages in New Guinea. He also correlated the relative abundances of each species and found that catches of certain baitfish species, such as *Encrasicholina devisi* and *Spratelloides gracilis*, were postively correlated with coral reef-associated species such as Apogonids, Lutjanids and Lethrinids.

In New Caledonia, Conand (1988) examined baitfish community structure at a large number of sites across a wide range of environmental conditions. He found that most species were mobile and formed schools and that catches varied greatly both within and between sites. However, there were species groups characteristic of three habitats : coral reefs, shallow coastal bays and deeper bays. A fourth group were ubiquitous and occurred in more than one habitat.

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Many of the species found in New Caledonia also occur in Fiji and are important in baitfish catches (Lewis et al. 1983, Sharma and Adams 1990). Lewis (1990) noted that baitfishing in Fiji occurred at a mixture of coral atoll and 'high island' sites. Elsewhere in the Pacific, catches at atoll sites are dominated by *Spratelloides* spp. and sardines, whereas 'high island' baitfish catches contain mainly anchovies. Preliminary data suggested that this habitat segregation may not exist in Fiji as the major 'high island' anchovy species (*Encrasicholina devisi* and *E. heterolobus*) were rare in baitfish catches.

Multivariate representation of fish community structure is often undertaken using non-metric multidimensional scaling (MDS) (e.g. Blaber et al. 1993). This method has the advantage of being very flexible in accommodating biologically relevant definitions of similarity in the species compositions of two samples. It maintains the rank-order relations amongst those similarities in the placing of samples in an ordination (Clarke and Ainsworth 1993). These ordination values can then be related to the environmental conditions that may help explain the community structure.

The aims of this study were (1) to examine the catch rates and species composition of suitable baitfishing areas outside the current fishing grounds in Fiji in order to expand the potential range of the tuna fishing fleet and (2) to examine the baitfish community structure at these sites with MDS methods and identify some of the environmental factors that affect baitfish distributions in Fiji.

Materials and Methods

Baitground surveys

Following consultation with the tuna industry, the Fiji Fisheries Division identified four areas in Fiji where information was needed on potential baitgrounds and their species composition. Exploratory surveys were then undertaken with the 18m RV *Tui Ni Wasabula*. The baitfishing methods used were siimilar to those of commercial vessels and are described in detail by Rawlinson and Sesewa (these Proceedings).

In the laboratory, fish in each sample were sorted, identified, and the major baitfish species counted, measured and weighed (± 0.001 g). By-catch species often included larval fish. These were identified to at least family from the classification in Leis and Rennis (1983) and Leis and Trnski (1989).

Community structure

Patterns in baitfish species composition and species associations were examined using numerical classification and multidimensional scaling techniques (MDS) (PATN: Belbin 1991). Forty baitfishing operations and sixteen species of fish were included in the analyses. Species were included if they were identified as important baitfish species by Sharma and Adams (1990). Fish numbers were transformed ($\log_{10}X + 1$) to decrease the dominance of large catches of small fish. Transformed catches for each operation *(i)* at each taxon *(j)* were range standardised by $(x_{ij}-xmin_j)/(xmax_j-xmin_j)$ where $xmin_j$ and $xmax_j$ were the minimum and maximum abundances recorded for the j^{th} taxon in the data set. This has the effect of re-scaling all values between zero and one and weights all attributes equally (Blaber et al. 1993). A *q*-mode cluster analysis (clustering stations on species composition) was performed with a Bray-Curtis dissimilarity measure (Bray and Curtis 1957) to produce a dissimilarity matrix. This matrix was sorted by a flexible UPGMA hierachical agglomerative fusion ($\beta = -0.1$) method to produce a dendrogram of similarity among sites.

A 'semi-strong' hybrid multidimensional scaling was used on the same matrix to represent the association between site and species groups (Belbin 1991). Data from the MDS analysis was produced in 2 dimensions; the smallest number of dimensions through which the data maintained acceptably low stress ($\approx$ 0.16) and therefore minimum distortion. Cramer values were calculated for each species in the analysis. These represent a relative measure of the variation in the species composition (Brewer et al. 1993). Species with the highest Cramer values were those that had the greatest variation in abundance between baitfishing operations, and therefore have the most influence on the patterns of association. Correlations between MDS values and abiotic parameters at each site were used to help explain the factors that influenced the MDS axis loadings.

To help understand which abiotic factors affect baitfish species distribution and abundance, the number and weight of each species in a sub-sample were standardised to a sample size of 10 000 fish and weight of 10.0kg. The relative abundance and weight of each species was compared separately to the following abiotic factors by stepwise linear regression: depth (m), water temperature (°C), turbidity (NTU), current speed (m./sec), wind speed (knts) and distance from shore (km). Abiotic variables that were not correlated between the sites were used in the analysis. The analysis was stopped when the best three variable model was chosen. Only variables that significantly improved the model ($P<0.05$) were allowed. Separate analyses were undertaken for the relative abundance and weight data and only those factors that significantly correlated with both data sets were accepted. All analyses were made using the SAS Reg procedure (SAS 1989). Milton and Blaber (1991) used a similar procedure to explain the relationship between baitfish spawning patterns and local environmental conditions in the Solomon Islands.

Results

Species composition

A total of 66 507 fish representing 167 species were collected from the 40 sites in Fiji (Table 1). The most abundant species was *Spratelloides delicatulus* followed by *Rhabdamia gracilis* and *Amblygaster sirm.* Clupeids were the most important family numerically, but Apogonids were the most specious family caught. Most species were caught at fewer than five sites and only 30 species occurred at more tha 8 sites (> 20%). Species important in the subsistence and artisanal fisheries (from Blaber et al. these proceedings) were not caught in significant numbers and each contributed less than 1% of the catch by numbers (Table 1). The avaerage weight of each fish caught was 1.1 g although most non-target species (all families except Apogonids, Clupeids and Engraulids) weighed less than 0.5 g each and were usually juveniles.

Community structure

Sites The total number of fish of the 16 species used in the pattern analysis varied from 8 to 7513 and averaged 1548 ± 221 fish per sample (Table 2). The most widespread species was *Spratelloides delicatulus* which occurred at 36 of the 40 sites. It was also the most abundant species in the samples. The next most widespread and abundant species was *Amblygaster sirm* occuring at 27 of the 40 sites and it dominated the catches at many sites.

Table 1. Species collected during the baitfish survey throughout Fiji from October 1991 to September 1992 (Sample = percentage of sites that species occurred).

Family	Species	Total Number	Total Weight (g)	Sample (%)
Acanthuridae	*Acanthurus triostegus*	9	1.43	5.0
	Acanthurus sp.	226	187.76	12.5
	Zebrasoma veliferum	41	13.52	10.0
	Ctenochaetus striatus	74	90.60	5.0
	Acanthuridae unid. sp.	39	21.53	35.0
Apogonidae	*Apogon bandanensis*	3	8.43	5.0
	A. fraenatus	334	34.14	15.0
	A. kallopterus	80	32.31	12.5
	Apogon sp.	117	3.46	20.0
	Archamia biguttata	2	2.17	2.5
	A. lineolata	62	128.92	17.5
	A. zosterophora	31	3.57	5.0
	Cheilodipterus quinquelineata	2	1.88	2.5
	C. zonatus	41	2.92	7.5
	Cheilodipterus sp.	17	1.38	15.0
	Pseudamia gracilicauda	8	1.18	2.5
	Pseudamia sp.	2	0.24	2.5
	Rhabdamia cypselurus	769	300.55	60.0
	R. gracilis	6451	5593.94	65.0
	Rhabdamia sp.	5	1.00	7.5
	Siphamia tubulata	108	14.23	7.5
	S. versicolor	3	2.54	5.0
	Siphamia sp.	35	1.92	22.5
	Apogonidae unid. sp.	225	6.44	20.0
Ariommidae	*Ariomma indica*	11	1.92	7.5
Atherinidae	*Atherinomorus endrachtensis*	982	2205.30	20.0
	A. lacunosus	414	1526.53	32.5
	Atherinomorus sp.	30	68.00	2.5
	Hypoatherina barnesi	68	57.10	12.5
	H. ovalaua	4701	7158.24	70.0
	Hypoatherina sp.	141	116.00	2.5
Aulostomidae	*Aulostomus chinensis*	1	1.88	2.5
Balistidae	*Abalistes stellaris*	2	1.33	5.0
	Balistipus undulatus	2	1.58	2.5
Belonidae	*Tylosurus crocodilus*	1	0.97	2.5
	Belonidae unid. sp.	1	0.44	2.5
Blenniidae	*Aspidontus* sp.	1	0.67	2.5
	Plagiotremus tapeinosoma	2	0.87	2.5
	Xiphasia setifer	1	1.23	2.5
	Blenniidae unid. sp.	70	5.17	40.0
Bothidae	*Bothus pantherinus*	32	18.83	7.5
Bregmacerotidae	*Bregmaceros nectabanus*	23	15.00	2.5
	Bregmaceros sp.	165	39.00	37.5
Caesionidae	*Caesio caerulaureus*	97	47.49	7.5
	Gymnocaesio gymnopterus	182	84.47	10.0
	Pterocaesio diagramma	1	5.70	2.5
	Pterocaesio sp.	4	1.74	10.0
Caracanthidae	*Caracanthidae* unid sp.	7	0.47	5.0
Carangidae	*Carangiodes plagiotaenia*	45	23.80	17.5
	Carangiodes sp.	5	2.30	5.0
	Caranx ignoblis	1	1.85	2.5
	C. melampygus	2	13.26	2.5
	C. papuensis	4	15.12	5.0
	C. sexfasciatus	2	2.58	5.0

Table 1. (Cont'd)

Family	Species	Total Number	Total Weight (g)	Sample (%)
	Caranx sp.	3	0.21	2.5
	Decapterus russelli	19	15.23	20.0
	Decapterus sp.	22	13.95	12.5
	Gnathanodon speciosus	4	1.06	7.5
	Scomberoides lysan	2	1.37	5.0
	Scomberoides sp.	11	3.86	10.0
	Selar crumenopthalmus	20	644.02	25.0
Chaetodontidae	*Chaetodon citrinella*	13	9.27	5.0
	C. mertensii	1	0.90	2.5
	C. unimaculatus	1	0.76	2.5
	Heniochus chrysostomus	1	0.90	2.5
Clupeidae	*Amblygaster sirm*	6074	30810.41	67.5
	Dussumieria sp. B	2	29.74	2.5
	Dussumieria sp.	93	3275.40	2.5
	Herklotsichthys quadrimaculatus	7	159.50	5.0
	Herklotsichthys sp.	423	2560.90	22.5
	Spratelloides delicatulus	32586	9863.93	90.0
	S. gracilis	2603	993.64	57.5
Dactylopteridae	*Dactylopteridae* unid. sp.	1	1.32	2.5
Diodontidae	*Diodontidae* unid. sp.	10	1.86	7.5
Engraulidae	*Encrasicholina devisi*	724	970.83	62.5
	E. punctifer	210	132.95	22.5
	Encrasicholina sp.	212	35.77	27.5
	Stolephorus insularis	21	72.70	5.0
	Stolephorus sp.	6	0.70	5.0
	Thryssa balaema	5	26.66	5.0
Fistulariidae	*Fistularia commersonii*	53	20.09	17.5
	Fistularia sp.	2	0.36	5.0
Gerreidae	*Gerres* sp.	3	0.39	7.5
Gobiidae	*Gobiidae* unid. sp.	12	2.14	15.0
Holocentridae	*Myripristis adusta*	9	8.34	10.0
	Myripristis sp.	33	16.79	22.5
	Neoniphon argenteus	3	1.77	2.5
	N. aurolineatus	6	4.68	5.0
	N. opercularis	11	16.95	12.5
	N. sammara	5	3.22	2.5
	Sargocentron spiniferum	69	11.42	15.0
	Sargocentron sp.	7	5.46	10.0
	Holocentridae unid. sp.	28	2.61	10.0
Labridae	*Halichoeres* sp.	1	4.97	2.5
	Stethojulis strigiventer	1	2.82	2.5
	Labridae unid. sp.	44	9.72	22.5
Leiognathidae	*Gazza minuta*	11	221.20	10.0
Lethrinidae	*Gnathodentex aurolineatus*	4	9.87	5.0
	Lethrinus olivaceus	2	0.80	2.5
	Lethrinus sp.	1	0.15	2.5
Lutjanidae	*Lutjanus biguttatus*	1	8.92	2.5
	L. bohar	2	1.02	5.0
	L. boutton	7	2.99	5.0
	L. kasmira	2	2.42	2.5
	Lutjanidae unid. sp.	73	8.01	40.0
Monocanthidae	*Acreichthys* sp.	60	6.54	37.5
	Aluterus scriptus	1	0.11	2.5
	Oxymonocanthus longirostris	2	0.28	5.0
	Pervagor melanocephalus	2	2.43	2.5

Table 1. (Cont'd)

Family	Species	Total Number	Total Weight (g)	Sample (%)
Mugilidae	*Mugil cephalus*	7	2.79	12.5
	Mugilidae unid. sp.	1	0.02	2.5
Mullidae	*Mulloides flavolineatus*	21	166.34	15.0
	M. vanicolensis	1	0.41	2.5
	Mulloides sp.	83	28.00	37.5
	Paraupeneus barberinoides	3	1.88	7.5
	P. multifasciatus	1	1.94	2.5
	P. porphyreus	2	4.05	5.0
	Upeneus tragula	5	2.74	10.0
	Mullidae unid. sp.	1	0.05	2.5
Nemipteridae	*Pentapodus* sp.	2	1.29	2.5
Ostraciidae	*Ostracion cubicus*	1	0.24	2.5
	Ostracion sp.	4	0.90	7.5
Pempherididae	*Parapriacanthus* sp.	1	2.49	2.5
	Pemphris dispar	17	35.08	15.0
Pomacanthidae	*Centropyge bicolor*	1	0.08	2.5
	Pomacanthidae unid. sp.	98	3.17	10.0
Pomacentridae	*Abudefduf sexfasciatus*	3	0.34	5.0
	Chromis amboinensis	1	0.11	2.5
	Chrysiptera sp.	1	0.07	2.5
	Pomacentrus molluccensis	1	1.09	2.5
	P. pavo	37	1.07	5.0
	Pomacentridae unid sp.	417	25.93	50.0
Priacanthidae	*Priacanthus cruentatus*	43	95.08	15.0
	P. tayenus	28	56.25	10.0
Scaridae	*Scaridae* unid sp.	6	19.3	7.5
Scombridae	*Rastrelliger brachysoma*	1	64.89	2.5
	R. faughni	163	215.00	2.5
	R. kanagurta	787	2447.29	30.0
	Rastrelliger sp.	695	3645.14	20.0
	Scomberomorus commerson	9	10.32	17.5
Scorpaenidae	*Scorpaenodes* sp.	2	1.52	2.5
Siganidae	*Siganus argenteus*	22	38.98	5.0
	Siganus sp.	51	9.45	15.0
Sphyraenidae	*Sphyraena flavicauda*	42	360.75	15.0
	S. novaehollandiae	9	58.44	7.5
	S. obtusata	1	1.00	2.5
	Sphyraena sp.	7	0.39	7.5
Syngnathidae	*Corythoichthys amplexus*	1	0.08	2.5
	C. intestinalis	1	1.54	2.5
	Doryrhamphus dactyliophorus	13	0.69	7.5
	Syngnathidae unid. sp.	2	0.06	2.5
Synodontidae	*Saurida* sp.	28	9.85	10.0
	Synodontidae unid. sp.	70	16.00	25.0
Tetraodontidae	*Arothron* sp.	4	1.53	5.0
	Canthigaster margaritatus	15	6.30	2.5
	Canthigaster sp.	5	4.09	10.0
	Lagocephalus spadiceus	67	46.2	30.0
	Tetraodontidae unid. sp.	3	1.80	7.5
Invertebrates	*Crustacea*	417	80.30	37.5
	Octopus sp.	115	33.22	52.5
	Sepia sp.	17	23.57	20.0
	Loligo sp.	31	44.96	15.0

Table 2. Details of the catches of the sixteen baitfish species at the 40 sites used in the cluster analysis (Freq. Occur. = Frequency of occurrence).

Species	Mean ± se	Range	Freq. Occur. (%)
Amblygaster sirm	117 ± 72	1-2689	67.5
Archamia lineolata	6 ± 3.7	1-32	17.5
Atherinomorus endrachtenesis	76 ± 33	1-266	20.0
Atherinomorus lacunosus	28 ± 10	1-91	32.5
Encrasicholina devisi	15 ± 4	1-88	62.5
Encrasicholina heterolobus	2 ± 1	1-2	5.0
Encrasicholina punctifer	338 ± 192	1-1694	22.5
Herklotsichthys quadrimaculatus	3.5 ± 1	3-4	5.0
Herklotsichthys sp.	26 ± 11	1-105	22.5
Hypoatherina ovalaua	105 ± 33	0-684	70.0
Rhabdamia cypselurus	16 ± 5	0-129	60.0
Rhabdamia gracilis	117 ± 37	0-931	65.0
Spratelloides delicatulus	519 ± 111	1-2837	90.0
Spratelloides gracilis	74 ± 26	1-523	57.5
Stolephorus insularis	11 ± 2	8-13	5.0
Stolephorus sp.	6 ± 1	5-7	5.0

Baitfish sites separated into 6 groups, based on their species composition (Fig. 1). Groups 1 and 2 comprised mainly sites in the Yasawa Islands, north-west Viti Levu. Sites from northern Vanua Levu and Moala also clustered into Group 2. The dominant species at sites in Group 1 were *Rhabdamia gracilis* and *Hyopatherina ovalaua*. The species composition at sites in Group 2 were dominated by *Spratelloides delicatulus* and *Amblygaster sirm*. Group 3 comprised sites from northern Vanua Levu and one each from Moala and Vanua Balavu and the most abundant species at these sites were *Spratelloides delicatulus* and *Hypoatherina ovalaua*. The single sample from Suva Harbour separated from all other sites into a single site group (Group 4) as the catch was mainly *Herklotsichthys* sp. The other two cluster groups in Figure 1 contained sites from southeastern Fiji with Group 5 made up of sites from Moala and Vanua Balavu. The most abundant species at these sites were *Spratelloides gracilis* and *S. delicatulus*. The other sites from Vanua Balavu grouped separately (Group 6) as *Encrasicholina punctifer* and *Spratelloides delicatulus* dominated the catches (Fig. 1). Cramer values showed that the sites from northwestern Viti Levu contributed most to the separation of the site groups (Table 3). Fifteen of the 20 sites with the highest Cramer values came from this area.

These patterns persist in the multi-dimensional scaling (MDS) analysis (Fig. 2). Two dimensions adequately separated the sites with a relatively low stress (0.18). An analysis in three dimensions lowered the stress (0.13) but did not separate sites any further. Partial correlation analysis of the site MDS values and abiotic variables at each site found significant positive relationships between MDS 1 and water current speed

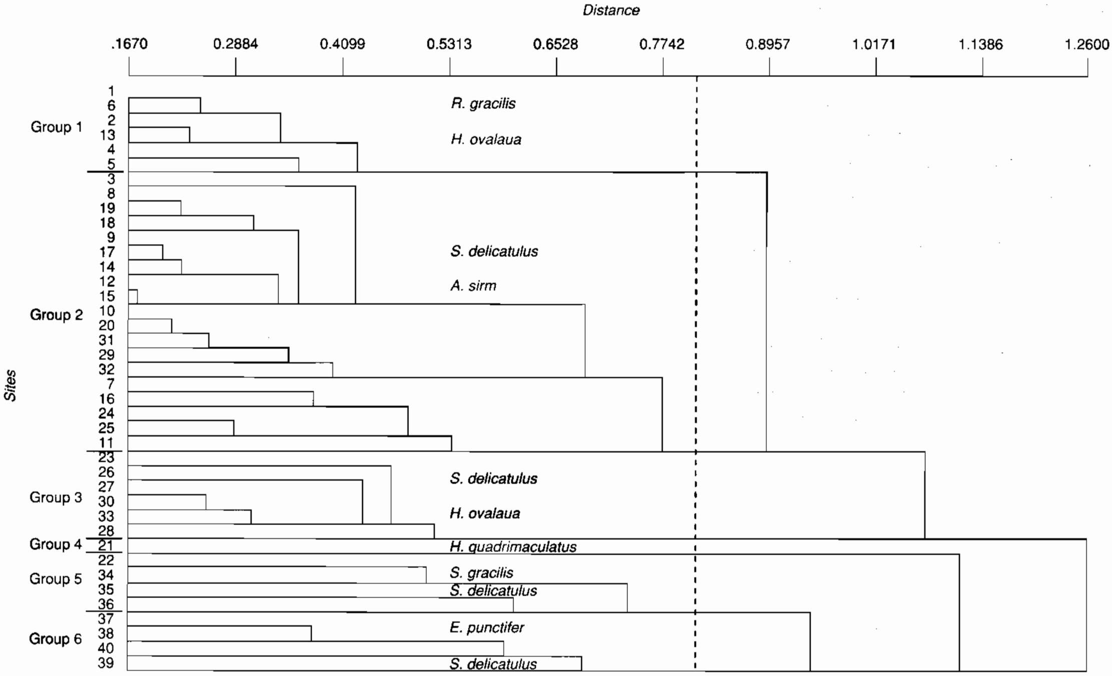

Figure 1. Dendrogram of the 40 sites sorted by Bray-Curtis dissimilarity values and clustered using the UPGMA strategy ($\beta = -0.1$) (Sites 1–20 = Yasawa Is. group, 21 = Suva Harbour, 22–23 = Vanua Balavu 1992, 24–30 = northern Vanua Levu, 31–35 = Moala, 36–40 = Vanua Balavu, Oct 1991).

Table 3. Cramer values for the 20 sites that contributed most to the group separation in the *q*-mode cluster analysis. High values correspond to sites that contributed most to the separation.

Sites	Cramer value
1	0.5029
15	0.4968
4	0.4945
10	0.4710
6	0.4494
5	0.4462
13	0.4394
12	0.4376
29	0.4320
19	0.4268
23	0.4267
17	0.4118
33	0.4039
14	0.3973
34	0.3878
20	0.3859
9	0.3813
2	0.3725
18	0.3622
39	0.3508

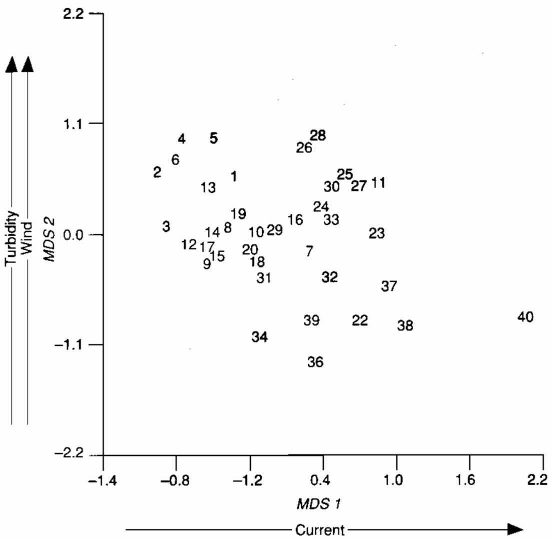

Figure 2. Plot of the 2-dimension MDS values of the 40 sites based on their Bray-Curtis dissimilarity (Sites 1–20 = Yasawa Is. group, 21 = Suva Harbour, 22–23 = Vanua Balavu 1992, 24–30 = northern Vanua Levu, 31–35 = Moala, 36–40 = Vanua Balavu, Oct 1991).

(r^2=0.32;N=40; P<0.05) and MDS 2 correlated with both turbidity and wind speed (r^2=0.43; N=40; P<0.01 and r^2=0.39; N=40; P<0.05 respectively).

Species The *r*-mode cluster analysis of baitfish species formed two groups plus a number of outlier species

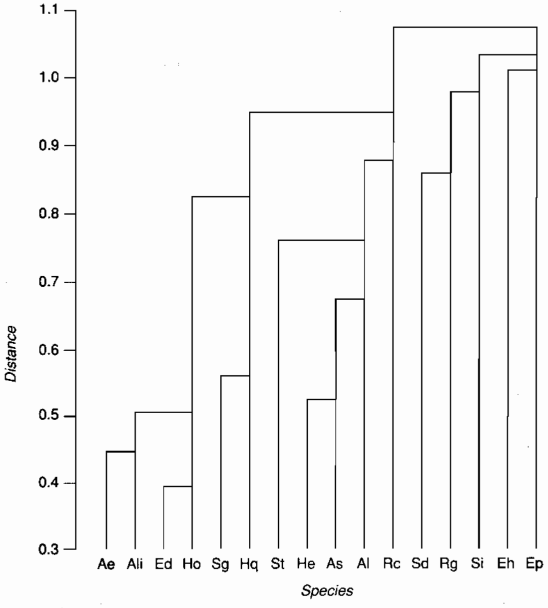

Figure 3. Dendrogram of the 16 baitfish species sorted by Bray-Curtis dissimilarity values and clustered using the UPGMA strategy (β=-0.1) (Ae = *Atherinormorus endrachtensis*, Al = *Atherinomorus lacunosus*, Ali = *Archamia lineotata*, As = *Amblygaster sirm*, Ed = *Encrasicholina devisi*, Eh = *Encrasicholina heterolobus*, Ep = *Encrasicholina punctifer*, He = *Herklotsichthys* sp., Ho = *Hypoatherina ovalaua*, Hq = *Herklotsichthys quadrimaculatus*, Rc = *Rhabdamia cypselurus*, Rg = *Rhabdamia gracilis*, Sd = *Spratelloides delicatulus*, Sg = *Spratelloides gracilis*, Si = *Stolephorus insularis*, St = *Stolephorus* sp.).

Table 4. Cramer values for the 16 species in the *r*-mode cluster analysis. High Cramer values correspond to species that contributed most to the separation.

Species	Cramer value
Stolephorus sp.	0.9750
Rhabdamia cypselurus	0.8907
Herklotischthys quadrimaculatus	0.8619
Archamia lineolata	0.8260
Spratelloides gracilis	0.8237
Herklotsichthys sp.	0.7995
Amblygaster sirm	0.7471
Encrasicholina heterolobus	0.6552
Stolephorus insularis	0.6445
Atherinomorus endrachtensis	0.6167
Hypoatherina ovalua	0.5738
Rhabdamia gracilis	0.5418
Encrasicholina devisi	0.5338
Encrasicholina punctifer	0.3984
Spratelloides delicatulus	0.3598
Atherinomorus lacunosus	0.2801

Table 5. Stepwise linear regression of baitfish relative abundance and abiotic factors at sites where they occurred. Only factors that significantly improved the model (P<0.05) were included (r_{p^2} = partial correlation coefficient).

Species	Factor	r_{p^2}	r^2	Prob.	N
A. sirm	current	0.23	0.28	<0.01	27
	distance	0.05			
A. lineolata	no factor	-	-	-	7
A. endrachtensis	temperature	–0.45	0.45	<0.05	8
A. lacunosus	turbidity	–0.38	0.59	<0.01	13
	current	–0.21			
E. devisi	wind	0.18	0.18	<0.05	25
E. heterolobus	no factor	-	-	-	2
E. punctifer	turbidity	–0.39	–0.39	<0.05	9
H. quadrimaculatus	no factor	-	-	-	2
Herklotsichthys sp.	temperature	–0.38	–0.64	<0.01	9
	turbidity	–0.26			
H. ovalaua	turbidity	–0.32	–0.32	<0.01	28
R. cypselurus	depth	–0.16	–0.27	<0.05	24
	temperature	0.05			
	turbidity	–0.06			
R. gracilis	turbidity	–0.15	–0.15	<0.01	26
S. delicatulus	temperature	–0.09	–0.16	<0.05	36
	current	0.07			
S. gracilis	temperature	–0.21	–0.21	<0.01	23
S. insularis	no factor	-	-	-	2
Stolephorus sp.	no factor	-	-	-	2

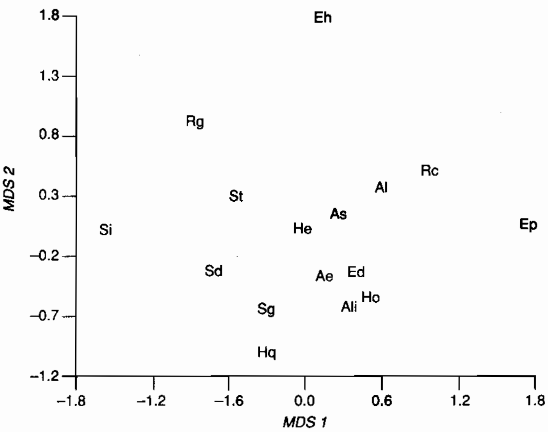

Figure 4. Plot of the 2-dimension MDS values of the 16 baitfish species based on their Bray-Curtis dissimilarity (Ae = *Atherinormorus endrachtensis*, Al = *Atherinomorus lacunosus*, Ali = *Archamia lineotata*, As = *Amblygaster sirm*, Ed = *Encrasicholina devisi*, Eh = *Encrasicholina heterolobus*, Ep = *Encrasicholina punctifer*, He = *Herklotsichthys* sp., Ho = *Hypoatherina ovalaua*, Hq = *Herklotsichthys quadrimaculatus*, Rc = *Rhabdamia cypselurus*, Rg = *Rhabdamia gracilis*, Sd = *Spratelloides delicatulus*, Sg = *Spratelloides gracilis*, Si = *Stolephorus insularis*, St = *Stolephorus* sp.)

(Fig. 3). Both groups contained a representative of the common baitfish families: Engraulidae, Clupeidae, Apogonidae and Atherinidae. Closely related species were separated in this analysis. Rare species such as *Stolephorus insularis* and *Encrasicholina heterolobus* were not grouped with other species. Less common species also had higher Cramer values and the most widespread species, *Spratelloides delicatulus* contributed little to group separation (Table 4).

The baitfish distribution data could be explained in two dimensions with an acceptable stress level (0.17). The relative position of species was similar to that seen in the cluster analysis. *Encrasicholina heterolobus* and *E. punctifer* both had high values on one dimension that caused them to separate from other species (Fig. 4).

The relative abundance of most species was related to a small range of abiotic factors (Table 5). The relative abundance of three species was related to current speed; six species were negatively correlated with turbidity and four species with temperature. Only the abundance of *Encrasicholina devisi* was related to wind speed (Table 5). Within the Apogonidae, the abundance of both *Rhabdamia* species was related to decreasing turbidity. Among the Clupeidae, the abundance of three of the four species for which there were sufficient data was negatively related to temperature. For the other two families (Atherinidae and Engraulidae), turbidity was the factor most related to species relative abundance.

Discussion

There was a clear pattern in the baitfish species composition within Fiji. Sites grouped on a regional basis with catches from western and northwestern sites dominated by *Rhabdamia gracilis*, *Spratelloides delicatulus* and *Amblygaster sirm*. These areas have some characteristics of 'high island' sites (cf. Lewis 1990) but the major species were more characteristic of atoll catches from elsewhere in the Pacific. This is probably due to the limited runoff and nutrient input of terrigenous origin (Lewis pers. comm.). The major baitfish species at sites further east were *Encrasicholina punctifer* and *Spratelloides gracilis*. The sites in these areas were within lagoons of isolated small islands and coral atolls and the oceanic *E. punctifer* is an important baitfish species in this area (Rawlinson and Sharma these proceedings). However, catches of large numbers of *E. punctifer* in baitfish hauls in Fiji has only occuered relatively recently (see Rawlinson and Sharma these proceedings) and thus may not be a true reflection of the resident species composition.

The pattern analysis (MDS) showed that sites could be adequately explained by two dimensions with an acceptable degree of stress. These axes were significantly correlated with wind speed, turbidity and current speed and indicated that these factors have a strong influence on the species composition of baitfish catches in Fiji. The highly turbid Suva harbour site (21) had a high value on dimension 2 and the sites in eastern Fiji had high loadings on MDS 1 suggesting that the species there prefer stronger currents.

Spratelloides delicatulus was widespread throughout the country and was the most ubiquitous baitfish species. It occurred at all sites that had sheltered lagoons of depths less than 30m. Sharma and Adams (1990) found no difference in the importance of sprats in baitfish catches from 'mainland' and 'island' sites. In New Caledonia, *S. delicatulus* was strongly associated with coralline habitats (Conand 1988). Lewis (1990) suggested that sprats were a major component of bait catches from atolls. Our data indicate that *S. delicatulus* is less habitat-specific within Fiji. This species may have expanded the range of habitats that it can occupy due to the absence of the *Encrasicholina* species that occupy the nearshore habitats of high islands elsewhere in the Pacific (Conand 1988, Dalzell 1990, Rawlinson 1990). Dalzell (1990) showed that there was an inverse relationship between catches of *Encrasicholina devisi* and *E. heterolobus* and those of *Spratelloides gracilis* from high island lagoons in Papua New Guinea.

Unlike New Caledonia, Fiji has few baitfishing areas that have significant freshwater influences or could be classified as 'deep bays' where larger baitfish species like *Amblygaster sirm* predominate (Conand 1988). Northern Vanua Levu is an exception and consists of a large, deep lagoon with several passages to the open ocean. *Amblygaster sirm* was the major baitfish species at all sites in this area. High catches were also made among sites in the Yasawa Islands, north-west of Viti Levu (Fig. 1). The distribution of *Amblygaster sirm* was related to current, with higher catches occurring where the current was stronger (Table 5). Its relative abundance was also related to distance from shore. These results, in combination with those of Conand (1988), suggest that *A. sirm* prefer deeper, offshore waters near barrier reef passages.

The pattern analysis also shows that closely-related species prefer different habitats and were rarely found together in large numbers. The three *Encrasicholina* species separated widely in the analysis. Catch rates of *Encrasicholina devisi* were related to wind, which reflects the seasonal aggregation of this species during the cyclone season from December to March. This is a period when northwesterly winds cause turbid conditions nearshore that probably favour this species. Conand (1988) found that *E. devisi* preferred more turbid nearshore habitats in New Caledonia. Of the other species, *E. punctifer* was more abundant around the smaller islands and atolls in eastern Fiji. This normally oceanic species periodically migrates into these areas and high catches in Papua New Guinea are associated with low rainfall (Dalzell 1984) and presumeably less runoff and clearer water conditions. The recent colonisation of Vanua Balavu has coincided with an El Niño period when rainfall would be reduced. Its catch rate was related to water clarity, reflecting its offshore distribution. The third species, *E. heterolobus* was rare in Fiji, being caught at only two sites. This is in contrast with its abundance in the western Pacific where it occurs in high densities around high islands (Conand 1988, Lewis 1990).

The other important baitfish species group in Fiji are the cardinalfish, *Rhabdamia*. Both species were widespread but were rarely caught together in large numbers. *Rhabdamia gracilis* was more abundant at most sites than *R. cypselurus* and was relatively abundant in both eastern and western Fiji. The highest catches of *R. cypselurus* were from a few sites in the Yasawa Islands, northwest of Viti Levu. Its catch rate was correlated with depth; being higher in shallow water. However, catch rate was not related to distance from shore which would be expected if this species preferred shallower water. Rather, the data suggests that higher catches of *R. cypselurus* may occur at shallower sites adjacent to the coral reefs when the bouke-ami net is almost as deep as the water and can catch species that stay close to the bottom when attracted to the light.

Overall, the community structure of baitfish populations in Fiji appears to be influenced by two major factors. There is a geographic shift in species composition from west to east causing changes in the relative importance of species. These changes in species composition reflect differences in the physical environment between these regions and the relative amounts of different habitats in these areas. The second factor to influence community structure is the low densities of *Encrasicholina* species and *H. quadrimaculatus*; species that are ubiquitous elsewhere in the south Pacific with similar habitats to Fiji (Conand 1988, Lewis 1990). This means that other species such as *Spratelloides delicatulus* have a greater relative importance in baitfish catches and that the overall catch rates are lower in Fiji than in other Pacific countries with high islands (e.g. Solomon Islands) due to the absence of these species.

Acknowledgment

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A Checklist of Fishes Recorded by the Baitfish Research Project in Fiji from 1991 to 1993

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THE fish species recorded in Fiji during the CSIRO/-ACIAR Baitfish Research Project (1991–1993) are listed. In all, 355 species of 66 families were identified from seven areas. Almost all fishes were collected from atoll lagoons, fringing reef lagoons or open shoreline areas.

The Fiji group of islands lie about 2500 km east of Australia in the southwest Pacific. They stretch for about 600 km from 175°E to about 175°W between latitudes 15°S and 20°S. They range in type from large high islands such as Viti Levu and Vanua Levu to small rocky islets and coral cays.

From 1991 to 1993 CSIRO Division of Fisheries and Fiji Fisheries Division conducted a collaborative research program on tuna baitfish. This program investigated all aspects of the biology of baitfish relevant to the fishery, the interrelationships between baitfish and other species, and the impact of the bait-fishery on artisanal and subsistence fisheries. Results of the program and further details of the sampling sites, fishes and their interrelationships are described elsewhere in these proceedings.

During the course of the study large numbers of many species of fish were collected from a variety of sites and habitats. Fishes were captured by gill netting, droplining, handlining and using bouke-ami baitfishing nets at all study sites. In this report all species captured during the Baitfish Research Project are documented. While this checklist is in no way comprehensive or complete, its compilation may provide the basis for more detailed and comparative future work. Only taxa sampled by the project team are included.

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Study Areas

For the purposes of this checklist the sampling areas were divided into seven regions (see Blaber et al. these Proceedings):

- The Yasawa Islands and Mamanuca Group
- Beqa Island
- Kadavu
- Lomaiviti (including Ngau)
- Vanua Levu
- Vanua Balavu
- Moala

Materials and Methods

Bouke-ami tuna baitfish nets

Fish were collected at night after being attracted to a 1000 W incandescent electric lamp suspended in midwater (10m). A large, fine-mesh net (bouke-ami) is used to surround the fish, the light is then dimmed to aggregate them before lifting the net to the surface. A wide variety of non-target species, mainly juveniles, were also collected from the bouke-ami nets (Rawlinson, this report).

Lagoon Fishes

The fish fauna of relevance to the subsistence fishery were investigated from four sources:

1) gill nets of 50, 75, 100, 125 and 150 mm stretch mesh were deployed for about two weeks at each site,
2) the catches from experimental dropline fishing during bouke-ami sessions,
3) larger species caught incidentally by bouke-ami net were retained,
4) subsistence catches of local fishermen were examined.

Species identification

All fish were identified from specialist taxonomic keys. Where difficulties were encountered, specimens were sent to appropriate taxonomic authorities. A few species remain unidentified or undescribed.

Checklist of Species

A total of 355 species of 66 Families were recorded. These are listed alphabetically by Family in Table 1. The largest Families were Serranidae (24 species), Carangidae (21 species) and Apogonidae (20 species). This checklist differs from that compiled for the Solomon Islands phase of the Baitfish Research Project (Blaber et al. 1991) in that no rotenone sampling was undertaken nor were estuaries sampled. Hence many of the smaller species were not collected in Fiji.

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Table 1. Checklist of species caught in Fiji during the Baitfish Research Project
1 = Yasawas & Mamanuca Group, 2 = Beqa, 3 = Vanua Levu, 4 =Vanua Balavu, 5 = Lomaiviti & Ngau, 6 = Moala, 7 = Kadavu, X = present, - = absent)

FAMILY	SPECIES	1	2	3	4	5	6	7
ACANTHURIDAE	*Acanthurus nigricauda* Duncker & Mohr, 1929	-	X	X	-	-	-	-
	Acanthurus nigrofuscus (Forsskal, 1775)	-	-	X	-	-	-	-
	Acanthurus olivaceous Forster, 1801	-	X	-	-	X	-	-
	Acanthurus triostegus (L.,1758)	-	X	X	-	X	X	-
	Acanthurus xanthopterus Val.,1835	-	-	-	-	X	-	-
	Ctenochaetus binotatus Randall,1955	-	X	-	-	-	-	-
	Ctenochaetus striatus (Q. & G.,1825)	-	X	X	-	X	X	-
	Ctenochaetus strigosus (Bennett,1828)	-	-	-	-	X	-	-
	Naso brevirostris (Val.,1835)	X	-	-	-	-	-	-
	Naso lituratus (Schneider,1801)	-	-	X	-	-	-	-
	Naso tuberosus Lacepede, 1802	-	X	-	-	X	-	-
	Naso unicornis (Forsskal, 1775)	-	-	-	-	X	-	-
	Zebrasoma veliferum (Bloch,1797)	-	-	-	-	X	X	-
	Zebrasoma scopas (Cuvier, 1829)	-	X	-	-	-	-	-
ALBULIDAE	*Albula neoguinaica* Val., 1846	-	-	X	-	-	-	-
APOGONIDAE	*Apogon bandanensis* Bleeker, 1854	-	-	X	-	-	X	-
	Apogon darnleyensis (Alleyne & Macleay, 1877)	-	-	-	X	-	-	X
	Apogon exostigma (Jordan & Starks,1906)	-	-	X	X	-	-	-
	Apogon fraenatus Val.,1832	-	-	X	-	X	X	-
	Apogon guamensis Val.,1832	-	-	-	-	X	-	-
	Apogon kallopterus Bleeker,1856	-	-	X	-	-	X	X
	Apogon lateralis Val.,1832	-	-	-	X	-	-	-
	Apogon trimaculatus C. & V.,1828	-	-	X	-	-	-	-
	Archamia biguttata Lachner,1951	X	-	-	-	-	-	-
	Archamia lineolata (Ehrenberg,1828)	X	-	X	-	-	-	-
	Archamia zosterophora (Bleeker,1856)	X	-	X	-	-	-	-
	Cheilodipterus quinquelineatus Cuv.,1828	X	-	X	-	-	-	-
	Cheilodipterus zonatus Smith & Radcliffe,1912	-	-	X	-	-	-	-
	Pseudamia gelatinosa Smith,1955	-	-	-	X	-	-	-
	Pseudamia gracilicauda (Lachner, 1953)	-	-	-	-	-	X	-
	Rhabdamia cypselurus Weber,1909	X	-	X	X	-	X	-
	Rhabdamia gracilis (Bleeker,1856)	X	X	X	X	X	X	-
	Rhabdamia sp. cf *cypselurus* Weber,1909	X	-	-	-	X	-	-
	Siphamia tubulata (Weber,1909)	-	-	X	-	-	X	-
	Siphamia versicolor (Smith & Radcliffe,1911)	-	-	X	X	-	-	-
	Sphaeramia orbicularis (Kuhl & Von Hasselt,1828)	-	-	X	-	-	-	-
ARIOMMATIDAE	*Ariomma indicum* (Day,1870)	X	-	-	X	-	X	-
ATHERINIDAE	*Atherinomorus endrachtensis* (Q. & G.,1824)	X	-	X	X	-	-	-
	Atherinomorus lacunosus (Forster,1801)	X	-	X	X	-	X	-
	Hypoatherina barnesi Schultz,1953	-	-	X	-	-	X	-
	Hypoatherina ovalaua (Herre,1935)	X	X	X	X	X	X	-
AULOSTOMIDAE	*Aulostomus chinensis* (L., 1758)	-	-	-	-	-	X	-
BALISTIDAE	*Abalistes stellatus* (Lacepede,1798)	X	-	X	-	-	-	-
	Balistapus undulatus (Mungo Park,1797)	-	X	X	-	-	X	-
	Balistoides viridescens (Bloch & Schneider,1801)	-	-	X	-	X	-	-
	Pseudobalistes flavimarginatus (Ruppell,1829)	-	X	-	-	X	-	-
	Rhinecanthus aculeatus (L.,1758)	-	-	-	-	-	-	X
	Sufflamen chrysopterus (Bloch & Schneider,1801)	-	-	-	-	X	-	-
BELONIDAE	*Ablennes hians* (Val., 1846)	-	X	X	-	-	-	-
	Strongylura incisa (Val.,1846)	-	X	X	X	X	X	-

Table 1. (Cont'd)

FAMILY	SPECIES	1	2	3	4	5	6	7
	Strongylura leiura (Bleeker,1851)	-	-	X	-	-	-	-
	Tylosurus acus (Lacepede,1803)	-	X	X	-	X	X	X
	Tylosurus crocodilus (Peron & Lesueur,1821)	X	X	X	-	X	-	X
BLENNIIDAE	*Aspidontus* sp.	-	-	-	-	-	X	-
	Plagiotremus tapeinosoma (Bleeker, 1857)	-	-	-	-	-	X	-
	Xiphasia setifer Swainson, 1839	X	-	-	-	-	-	-
BOTHIDAE	*Bothus pantherinus* (Ruppell,1830)	-	-	-	-	-	X	X
BREGMACEROTIDAE	*Bregmaceros nectabanus* Whitley,1941	X	-	X	X	-	X	-
CAESIONIDAE	*Caesio caerulaureus* Lacepede,1801	-	X	X	X	-	X	X
	Caesio lunaris Cuvier, 1830	-	-	-	-	X	-	-
	Dipterygonotus balteatus (Val.,1830)	-	-	-	X	-	-	-
	Gymnocaesio gymnopterus (Bleeker,1856)	X	-	X	-	X	X	-
	Pterocaesio diagramma (Bleeker,1865)	X	-	-	-	-	-	X
	Pterocaesio pisang (Bleeker,1853)	-	-	-	-	-	-	X
	Pterocaesio tile (Cuv.,1830)	X	-	X	-	-	-	-
	Pterocaesio trilineata Carpenter, 1987	-	X	-	-	-	-	-
CARACANTHIDAE	*Caracanthus* sp.	-	-	X	-	-	X	-
CARANGIDAE	*Alectis ciliaris* (Bloch,1787)	-	-	X	-	-	-	-
	Atule mate (Cuv.,1833)	X	X	X	X	X	-	-
	Carangoides caeruleopinnatus (Ruppell,1830)	-	X	X	-	X	-	X
	Carangoides chrysophrys (Cuv.,1833)	X	-	X	-	X	-	X
	Carangoides ferdau (Forsskal,1775)	X	X	-	X	-	-	-
	Carangoides hedlandensis (Whitley,1934)	X	X	X	-	-	-	-
	Carangoides oblongus (Cuv.,1833)	-	-	X	-	X	-	-
	Carangoides plagiotaenia Bleeker,1857	X	X	X	X	X	X	X
	Caranx ignobilis (Forsskal,1775)	X	-	X	X	X	X	-
	Caranx melampygus Cuv.,1833	X	X	X	X	X	X	X
	Caranx papuensis Alleyne & Macleay,1877	X	X	X	X	X	X	X
	Caranx sexfasciatus Q. & G.,1825	X	X	X	X	-	-	X
	Caranx tille Cuv.,1833	-	-	X	-	-	-	-
	Decapterus macrosoma Bleeker,1851	-	-	-	X	-	-	-
	Decapterus russelli (Ruppell, 1830)	X	-	-	-	-	-	-
	Elagatis bipinnulatus (Q. & G.,1825)	-	-	-	-	-	-	X
	Gnathanodon speciosus (Forsskal,1775)	X	-	X	-	-	-	X
	Megalaspis cordyla (L.,1758)	X	X	X	-	X	-	-
	Scomberoides lysan (Forsskal,1775)	X	X	X	X	X	-	X
	Scomberoides tol (Cuv.,1832)	X	X	X	-	X	-	-
	Selar crumenopthalmus (Bloch,1793)	X	X	X	X	X	X	X
CARCHARHINIDAE	*Carcharhinus amblyrhynchos* (Bleeker,1856)	-	-	X	X	-	-	-
	Carcharhinus cautus (Whitley,1945)	-	-	X	-	-	-	-
	Carcharhinus limbatus (Val.,1839)	-	X	-	-	X	-	-
	Carcharhinus melanopterus (Q. & G.,1824)	-	X	-	X	X	X	-
	Galeocerda cuvier (Peron & Lesueur, 1822)	-	-	X	-	-	-	-
	Triaenodon obesus (Ruppell,1837)	-	X	X	-	X	-	X
CHAETODONTIDAE	*Chaetodon citrinellus* Cuvier, 1831	-	-	-	-	-	X	-
	Chaetodon mertensii Cuvier, 1831	-	-	-	-	-	X	-
	Chaetodon plebeius Cuvier, 1831	-	-	X	-	-	-	-
	Chaetodon trifasciatus Mungo Park,1797	-	X	-	-	-	-	-
	Chaetodon unimaculatus Bloch, 1787	-	-	X	-	X	X	-
	Heniochus chrysostomus Cuv.,1831	-	-	-	-	X	X	-
	Heniochus varius (Cuv.,1829)	-	-	X	-	-	-	-

Table 1. (Cont'd)

FAMILY	SPECIES	1	2	3	4	5	6	7
CHIROCENTRIDAE	*Chirocentrus dorab* (Forsskal,1775)	X	X	X	X	X	X	X
CIRRHITIDAE	*Paracirrhites forsteri* (Schneider,1801)	-	X	-	-	X	-	-
CLUPEIDAE	*Amblygaster clupeoides* Bleeker,1849	X	X	X	X	X	-	X
	Amblygaster sirm (Walbaum,1792)	X	X	X	X	X	X	X
	Dussumieria sp.A (of Lewis et al.1983)	X	-	-	X	X	-	-
	Dussumieria sp.B (" " " " ")	X	-	-	X	-	-	-
	Herklotsichthys quadrimaculatus (Ruppell,1837)	-	X	X	-	-	-	-
	Herklotsichthys sp.	X	-	X	X	X	X	-
	Sardinella fijiense (Fowler & Bean, 1923)	-	-	X	-	-	-	-
	Spratelloides delicatulus (Bennett,1832)	X	X	X	X	X	X	-
	Spratelloides gracilis (Schlegel,1846)	X	-	X	X	X	X	-
DACTYLOPTERIDAE	*Dactylopterus* sp.	-	-	X	-	-	-	-
DIODONTIDAE	*Diodon* sp.	-	-	-	X	-	-	-
ECHENEIDIDAE	*Echeneis naucrates* L.,1758	X	X	X	X	X	-	-
ELOPIDAE	*Elops machnata* (Forsskal, 1775)	-	X	-	-	-	-	-
	Megalops cyprinoides (Broussonet, 1782)	-	-	X	-	-	-	-
ENGRAULIDIDAE	*Encrasicholina devisi* (Whitley,1940)	X	-	X	X	X	X	-
	Encrasicholina heteroloba (Ruppell,1837)	-	-	-	X	-	-	-
	Encrasicholina punctifer Fowler,1938	X	X	X	X	-	-	-
	Stolephorus indicus Von Hasselt,1823	-	-		X	-	-	-
	Stolephorus insularis Hardenberg,1933	-	-	X	X	-	-	-
	Thryssa balaema (Forsskal,1775)	-	-	X	-	-	X	-
EPHIPPIDAE	*Platax batavianus* Cuvier, 1831	-	-	X	-	-	-	-
	Platax orbicularis (Forsskal,1775)	-	-	X	-	-	-	-
FISTULARIIDAE	*Fistularia commersonii* Ruppell,1838	-	-	X	-	-	X	-
	Fistularia petimba Lacepede, 1803	-	-	X	-	-	-	-
GERREIDAE	*Gerres filamentosus* Cuv.,1829	X	-	-	-	X	-	-
	Gerres macrosoma Bleeker, 1854	-	-	X	-	X	-	-
	Gerres oyena (Forsskal,1775)	X	X	X	X	X	-	X
	Gerres poieti (Cuv.,1830)	-	-	X	-	-	-	-
HAEMULIDAE	*Plectorhinchus chaetodontoides* (Lacepede,1800)	-	-	X	-	X	-	-
	Plectorhinchus gibbosus (Lacepede,1802)	-	X	X	-	-	-	-
	Plectorhinchus obscurum (Gunther, 1871)	-	-	X	-	-	-	-
HARPADONTIDAE	*Saurida gracilis* Q. & G.,1824	X	X	-	X	-	X	X
	Trachinocephalus myops (Forster, 1801)	-	-	-	-	-	-	X
HEMIRAMPHIDAE	*Hemiramphus far* (Forsskal,1775)	X	X	X	X	X	X	X
	Hyporhamphus dussumieri (Val., 1846)	-	X	X	-	X	-	X
HOLOCENTRIDAE	*Myripristis adusta* (Bleeker,1853)	-	-	X	X	-	X	-
	Myripristis berndti (Jordan & Evermann, 1903)	-	-	X	-	-	-	-
	Myripristis kuntee Val.,1831	-	X	-	-	X	-	-
	Myripristis murdjan (Forsskal,1775)	-	X	X	-	X	X	-
	Myripristis pralinia Cuv.,1829	-	-	X	-	X	-	X
	Myripristis violacea Bleeker,1851	-	-	X	X	-	-	X
	Neoniphon argenteus (Val.,1831)	-	X	X	X	X	X	X
	Neoniphon aurolineatus (Lienard, 1839)	X	-	-	-	-	-	-

Table 1. (Cont'd)

FAMILY	SPECIES	1	2	3	4	5	6	7
	Neoniphon opercularis (Val.,1831)	X	-	X	X	-	X	-
	Neoniphon sammara (Forsskal,1775)	-	X	X	X	X	X	X
	Sargocentron diadema (Lacepede,1802)	-	X	-	-	-	-	-
	Sargocentron melanspilos (Bleeker, 1858)	-	-	X	X	-	-	-
	Sargocentron rubrum (Forsskal,1775)	-	-	X	-	-	-	-
	Sargocentron spiniferum (Forsskal,1775)	X	X	X	X	X	-	X
	Sargocentron violaceum (Bleeker,1853)	-	X	-	X	-	-	-
KUHLIIDAE	*Kuhlia bilunata*	-	-	X	-	-	-	-
KYPHOSIDAE	*Kyphosus cinerascens* (Forsskal,1775)	-	-	X	X	X	-	-
	Kyphosus vaigiensis (Q. & G.,1825)	-	-	X	-	-	-	-
LABRIDAE	*Anampses caeruleopunctatus* Ruppell,1829	-	-	-	-	X	-	-
	Cheilinus diagrammus (Lacepede,1801)	-	X	X	X	X	-	-
	Cheilinus fasciatus (Bloch,1791)	-	-	X	X	-	-	-
	Cheilinus oxycephalus Bleeker, 1853	-	X	-	-	-	-	-
	Cheilinus trilobatus Lacepede,1801	-	X	X	-	-	-	-
	Coris aygula Lacepede, 1801	-	-	-	-	X	-	-
	Coris gaimardi (Q & G, 1824)	-	-	-	-	X	-	-
	Gomphosus varius Lacepede, 1801	-	X	X	-	-		
	Halichoeres chrysus Randall, 1981	-	-	-	-	X	-	-
	Halichoeres trimaculatus (Q & G, 1834)	-	X	X	-	-	-	-
	Hemigymnus fasciatus (Bloch, 1792)	-	-	-	-	X	-	-
	Hemigymnus melapterus (Bloch,1791)	-	X	X	-	X	-	-
	Hologymnus doliatus (Lacepede, 1801)	-	-	-	-	X	-	-
	Novalichthys taeniourus (Lacepede,1801)	-	-	-	-	X	-	-
	Stethojulis strigiventer (Bennett,1832)	-	-	X	-	-	-	-
	Stethojulis trilineata (Bloch & Schneider,1801)	-	X	-	-	-	-	-
	Thalassoma hardwicke (Bennett,1828)	-	X	X	-	-	-	-
LACTARIIDAE	*Lactarius lactarius* (Bloch & Schneider, 1801)	-	-	X	-	-	-	-
LEIOGNATHIDAE	*Gazza minuta* (Bloch,1797)	-	-	X	X	-	-	X
	Leiognathus bindus (Val.,1835)	-	-	X	X	-	-	-
	Leiognathus equulus (Forsskal,1775)	-	-	X	-	-	-	-
	Leiognathus fasciatus (Lacepede,1803)	-	-	X	-	-	-	-
	Leiognathus smithursti (Ramsey & Ogilby, 1886)	-	-	X	-	-	-	X
	Leiognathus sp. (of Jones 1985)	X	-	X	-	-	-	-
LETHRINIDAE	*Gnathodentex aurolineatus* (Lacepede,1802)	-	X	-	-	-	X	-
	Gymnocranius grandoculis (Val., 1830)	-	-	-	-	X	-	-
	Gymnocranius robinsoni (Gilchrist & Thompson,1908	X	-	X	-	-	X	-
	Gymnocranius sp. (of Carpenter & Allen 1989)	-	X	X	-	X	-	X
	Lethrinus atkinsoni Seale, 1909	X	X	X	-	X	X	-
	Lethrinus elongatus Val.,1830	X	-	X	-	-	-	-
	Lethrinus harak (Forsskal,1775)	-	-	X	X	X	X	-
	Lethrinus lentjan (Lacepede,1802)	-	-	X	-	-	-	-
	Lethrinus mahsena (Forsskal,1775)	-	-	X	X	-	X	-
	Lethrinus miniatus (Schneider, 1801)	-	X	-	-	-	X	-
	Lethrinus nebulosus (Forsskal,1775)	X	X	X	-	-	X	-
	Lethrinus obsoletus (Forsskal, 1775)	-	-	X	-	X	X	X
	Lethrinus olivaceous Val.,1830	-	-	X	X	X	-	X
	Lethrinus semicinctus Val.,1830	X	-	-	-	-	-	-
	Lethrinus variegatus Ehrenberg,1830	X	X	X	-	X	X	-
	Lethrinus xanthochilus Klunzinger,1870	-	-	-	-	X	X	X
	Monotaxis grandoculis (Forsskal,1775)	-	X	X	X	X	-	X

Table 1. (Cont'd)

FAMILY	SPECIES	1	2	3	4	5	6	7
LUTJANIDAE	*Aprion virescens* Val.,1830	-	-	-	-	X	X	-
	Lutjanus argentimaculatus (Forsskal,1775)	X	X	X	-	-	-	-
	Lutjanus biguttatus (Val.,1830)	X	-	X	X	X	X	-
	Lutjanus bohar (Forsskal,1775)	X	X	X	-	X	X	X
	Lutjanus boutton (Lacepede, 1803)	X	-	X	-	X	X	-
	Lutjanus ehrenbergi (Peters,1869)	-	X	X	-	X	-	X
	Lutjanus fulviflamma (Forsskal,1775)	X	X	X	X	X	X	-
	Lutjanus fulvus (Schneider,1801)	-	X	X	X	X	X	X
	Lutjanus gibbus (Forsskal,1775)	X	X	X	X	X	X	X
	Lutjanus kasmira (Forsskal,1775)	-	X	X	-	X	X	X
	Lutjanus monostigma (Cuv.,1828)	-	X	X	X	X	X	-
	Lutjanus quinquelineatus Bloch,1790	X	X	X	X	X	-	X
	Lutjanus rivulatus (Cuv.,1828)	-	-	X	-	-	-	-
	Lutjanus russelli (Bleeker,1849)	X	-	X	X	X	X	-
	Lutjanus semicinctus Q. & G.,1824	-	-	X	-	-	-	-
	Pristipomoides sp.	-	-	X	-	-	-	-
	Symphorus nematophorus (Bleeker, 1860)	X	-	-	-	-	-	-
MONACANTHIDAE	*Acreichthys tomentosus* (L.,1758)	X	-	-	X	-	-	-
	Aluterus scriptus (Osbeck,1765)	X	-	-	-	-	-	-
	Oxymonacanthus longirostris (B & S, 1801)	X	-	-	-	-	X	-
	Pervagor melanocephalus (Bleeker, 1853)	-	-	-	-	-	X	-
	Pseudalutarius nasicornis (T. & S., 1850)	X	-	-	-	-	-	-
MUGILIDAE	*Crenimugil crenilabis* (Forsskal, 1775)	-	-	-	-	-	X	-
	Crenimugil labiosus (Val., 1836)	-	-	X	-	-	-	-
	Liza subviridis (Val.,1836)	-	-	X	X	-	-	-
	Liza vaigiensis (Q. & G.,1824)	-	-	X	X	X	X	-
	Mugil cephalus L. 1758	-	-	X	X	-	X	-
	Oedolechilus sp.	-		X	-	-	-	-
	Valamugil buchanani (Bleeker, 1853)	-	X	-	-	-	-	-
	Valamugil seheli (Forsskal,1775)	-	X	X	-	-	-	-
MULLIDAE	*Mulloides flavolineatus* (Lacepede,1801)	X	X	X	X	X	X	X
	Mulloides vanicolensis (Val., 1831)	-	-	-	X	X	X	X
	Parupeneus barberinoides (Bleeker,1852)	-		X	X	-	X	-
	Parupeneus barberinus (Lacepede,1801)	-	X	X	-	X	-	X
	Parupeneus bifasciatus (Lacepede,1801)	-	X	X	-	-	-	-
	Parupeneus cyclostomus (Lacepede,1801)	-	X	X	X	X	-	-
	Parupeneus heptacanthus (Lacepede, 1801)	X	X	-	-	-	-	-
	Parupeneus indicus (Shaw, 1903)	-	-	X	X	X	-	-
	Parupeneus multifasciatus (Q & G, 1825)	X	X	X	X	-	-	-
	Parupeneus pleurostigma (Bennett, 1830)	-	-	-	-	X	-	-
	Parupeneus porphyreus Jenkins, 1902	-	-	-	-	-	X	-
	Parupeneus spilurus (Bleeker, 1854)	-	-	-	-	X	-	-
	Parupeneus trifasciatus (Lacepede, 1802)	-	-	X	-	X	-	-
	Upeneus arge Jordan & Evermann,1903	-	-	-	-	-	-	X
	Upeneus sundaicus Bleeker, 1855	-	-	X	-	-	-	-
	Upeneus tragula Richardson,1846	X	-	X	X	-	X	-
	Upeneus vittatus (Forsskal,1775)	-	X	X	X	X	X	X
MURAENESOCIDAE	*Muraenesox bagio* (Hamilton-Buchanan, 1822)	-	-	X	-	-	-	X
MURAENIDAE	*Siderea picta* (Ahl, 1789)	-	-	X	-	-	-	-
MYCTOPHIDAE	unidentified species	-	-	-	X	-	-	-
NEMIPTERIDAE	*Nemipterus vitiensis* Russell, 1990	-	-	X	-	X	-	-
	Pentapodus sp.	-	-	-	-	-	X	-
	Scolopsis bilineatus (Bloch, 1793)	X	X	X	X	-	-	X

Table 1. (Cont'd)

FAMILY	SPECIES	1	2	3	4	5	6	7
	Scolopsis monogramma (Kuhl & Van Hasselt,1830)	X	-	-	-	-	-	-
	Scolopsis temporalis (Cuv.,1830)	-	-	X	-	X	-	X
	Scolopsis trilineatus Kner,1868	-	X	X	-	X	-	-
OSTRACIIDAE	*Ostracion cubicus* L.,1758	-	-	X	-	-	X	-
PEMPHERIDIDAE	*Parapriacanthus ransonneti* Steindachner,1870	X	-	X	X	-	X	-
PLATYCEPHALIDAE	*Suggrundus arenicolus* (Schultz, 1966)	-	-	-		X	-	-
	Suggrundus chiltoni (Schultz, 1966)	X	-	-	-	-	-	-
PLOTOSIDAE	*Plotosus lineatus* (Thunberg,1791)	-	-	X	-	-	-	-
POLYNEMIDAE	*Polydactylus microstomus* (Bleeker, 1851)	-	-	X	-	-	-	-
	Polydactylus plebeius (Broussonet, 1782)	-	-	X	-	-	-	-
POMACANTHIDAE	*Centropyge bicolor* (Bloch,1787)	-	-	-	-	-	X	-
POMACENTRIDAE	*Abudefduf septemfasciatus* (Cuv.,1830)	-	-	X	-	-	-	-
	Abudefduf sexfasciatus (Lacepede, 1802)	X	-	X	-	-	-	-
	Abudefduf vaigiensis (Q & G, 1825)	-	-	X	-	-	-	-
	Chromis amboinensis (Bleeker,1873)	-	-	-	-	-	X	-
	Chrysiptera sp.	-	-	-	-	-	X	-
	Pomacentrus brachialis Cuv.,1830	-	X	-	-	-	-	-
	Pomacentrus imitator (Whitley, 1964)	-	X	-	-	-	-	-
	Pomacentrus molluccensis Bleeker,1853	-	-	-	-	-	X	-
	Pomacentrus nigromarginatus Allen, 1973	-	-	-	X	-	-	-
	Pomacentrus pavo (Bloch,1787)	-	-	X	X	X	-	-
	Stegastes nigricans (Lacepede,1803)	-	X	X	-	-	-	X
PRIACANTHIDAE	*Heteropriacanthus cruentatus* (Lacepede,1801)	-	-	X	X	X	X	-
	Priacanthus hamrur (Forsskal, 1775)	-	X	X	X	X	-	X
	Priacanthus tayenus Richardson, 1846	-	-	-	-	-	X	-
RHINOBATIDAE	*Rhinobatus batillum* Whitley, 1939	-	-	X	-	-	-	-
	Rhynchobatus djiddensis (Forsskal, 1775)	-	X	-	-	-	-	-
SCARIDAE	*Calostomus carolinus* (Val.,1840)	-	X	-	-	X	-	-
	Calostomus spinidens (Q & G, 1824)	-	-	-	-	-	X	-
	Cetoscarus bicolor (Ruppell,1829)	-	X	-	X	X	-	-
	Hipposcarus longiceps (Val.,1840)	-	X	X	-	X	-	-
	Scarus altipinnis (Steindachner, 1879)	-		X	-	X	-	-
	Scarus dimidiatus Bleeker,1859	-	X	X	-	X	-	-
	Scarus forsteri (Bleeker, 1861)	-	X	-	-	-	-	-
	Scarus frenatus Lacepede, 1802	-	-	-	-	X	-	-
	Scarus ghobban Forsskal,1775	-	X	X	-	X	-	X
	Scarus gibbus Ruppell, 1828	-	-	-	-	-	-	X
	Scarus globiceps Val.,1840	-	X	X	-	X	-	-
	Scarus oviceps Val., 1840	-	-	-	-	X	-	-
	Scarus psittacus Forsskal, 1775	-	X	X	-	X	-	-
	Scarus rivulatus Val., 1840	-	-	X	-	-	-	-
	Scarus rubroviolaceus Bleeker, 1847	-	-	-	-	X	-	-
	Scarus schlegeli (Bleeker, 1861)	-	X	X	-	X	-	-
	Scarus sordidus Forsskal,1775	-	X	X	-	X	-	-
	Scarus spinus Kner,1868	-	-	X	-	-	-	-
SCOMBRIDAE	*Grammatorcynus bicarinatus* (Q & G, 1824)	X	-	-	-	-	-	-
	Grammatorcynus bilineatus (Ruppell,1836)	-	-	-	X	X	-	-
	Rastrelliger brachysoma (Bleeker,1851)	X	X	X	X	X	-	X

Table 1. (Cont'd)

FAMILY	SPECIES	1	2	3	4	5	6	7
	Rastrelliger faughni Matsui,1967	X	-	-	X	-	-	-
	Rastrelliger kanagurta (Cuv.,1816)	X	X	X	X	X	-	X
	Scomberomorus commerson (Lacepede,1802)	X	-	X	X	X	X	X
SCORPAENIDAE	*Scorpaenodes* sp.-	-	-	X	-	-	-	-
	Scorpaenopsis venosa (Cuvier, 1829)	-	-	X	-	-	-	-
SERRANIDAE	*Cephalopholis argus* Bloch & Schneider,1801-	-	X	X	-	-	-	-
	Cephalopholis leopardus (Lacepede,1801)	-	-	-	-	X	-	-
	Cephalopholis sexmaculata (Ruppell,1830)	-	-	-	-	-	X	-
	Epinephelus areolatus (Forsskal,1775)	X	-	-	-	-	-	-
	Epinephelus caeruleopunctatus (Bloch, 1790)	-	-	X	X	-	-	-
	Epinephelus cyanopodus (Richardson,1846)	X	X	X	-	X	-	-
	Epinephelus fuscoguttatus (Forsskal, 1775)	X	X	X	-	-	-	-
	Epinephelus hexagonatus (Bloch & Schneider,1801)	-	-	X	-	-	-	-
	Epinephelus howlandi (Gunther, 1873)	-	-	X	-	X	-	-
	Epinephelus macrospilos (Bleeker, 1855)	-	-	X	-	-	-	-
	Epinephelus maculatus (Bloch,1790)	-	-	X	-	X	-	-
	Epinephelus malabaricus (Bloch & Schneider,1801)	X	-	X	-	-	X	X
	Epinephelus merra Bloch,1793-	-	X	X	X	X	X	-
	Epinephelus microdon (Bleeker,1856)	-	-	X	-	-	-	-
	Epinephelus ongus (Bloch,1790)	X	-	X	-	X	-	-
	Epinephelus polyphekadion (Bleeker,1849)	X	-	X	X	X	X	X
	Epinephelus suillus (Val.,1828)	X	-	X	-	-	-	-
	Epinephelus tauvina Forsskal,1775	-	-	X	-	-	-	-
	Epinephelus timorensis	-	-	X	-	X	-	-
	Plectropomus areolatus (Ruppell, 1830)	X	-	-	-	-	-	-
	Plectropomus laevis (Lacepede, 1802)	-	-	-	X	-		-
	Plectropomus leopardus (Lacepede,1802)	X	X	X	X	X	X	-
	Plectropomus maculatus (Bloch,1790)	-		X	-	-	X	-
	Variola albimarginata Baissac, 1953	-	-	-	-	X	-	-
SIGANIDAE	*Siganus argenteus* (Q & G, 1825)	-	X	-	-	-	X	X
	Siganus doliatus Cuvier, 1830	-	X	X	-	-	-	X
	Siganus punctatus (Bloch & Schneider,1801)	-	X	-	X	-	-	-
	Siganus randalli Woodland, 1990	-	-	X	-	X	-	-
	Siganus spinus (L., 1758)	-	-	X	-	-	-	X
	Siganus vermiculatus (Val.,1835)	-	-	X	X	-	-	
	Siganus virgatus (Val.,1835)	X	X	-	-	-	-	-
SPHYRAENIDAE	*Sphyraena acutipinnis* Day, 1876	X	-	-	-	-	-	-
	Sphyraena barracuda (Walbaum,1792)	X	-	X	X	-	X	X
	Sphyraena flavicauda Ruppell,1838	X	X	X	X	X	X	X
	Sphyraena forsteri Cuvier, 1829	X	X	X	X	X	X	X
	Sphyraena jello Cuvier, 1829	X	-	X	-	-	-	-
	Sphyraena novaehollandiae Gunther, 1860	X	-	-	X	-	X	-
	Sphyraena obtusata Cuvier, 1829	X	-	X	-	-	-	-
	Sphyraena putnamiae Jordan & Seale,1905	X	X	X	X	X	X	X
SPHYRNIDAE	*Sphyrna lewini* (Griffith & Smith,1834)	-	-	X	X	-	-	-
SYNGNATHIDAE	*Corythoichthys amplexus* Dawson & Randall, 1975	-	-	-	-	-	X	-
	Corythoichthys intestinalis (Ramsay, 1881)	-	-	-	-	-	X	-
	Doryrhamphus dactyliophorus (Bleeker,1853)	-	-	-	-	-	X	-
SYNODONTIDAE	*Synodus* sp.	-	-	-	X	-	-	-
TERAPONTIDAE	*Terapon jarbua* (Forsskal,1775)	-	-	X	X	-	-	X
TETRAODONTIDAE	*Arothron manilensis* (de Proce, 1822)	-	-	X	-	-	-	-
	Arothron nigropunctatus (Bloch & Schneider,1801)	-	-	-	-	X	-	-
	Canthigaster margaritata (Ruppell,1828)	-	-	X	-	-	-	-
	Lagocephalus sceleratus (Forster,1788)	-	-	X	-	-	-	-
	Lagocephalus spadiceus (Richardson, 1845)	X	-	X	X	-	-	-
TRICHIURIDAE	*Trichiurus lepturus*	-	-	X	-	-	-	-

Total number of species = 355

SOLOMON ISLANDS

Current Status of Commercial Baitfishing in Solomon Islands

Gideon Tiroba*

BAITFISHING in Solomon Islands was started in 1973 by Solomon Taiyo Ltd (STL) after a successful survey of the country's tuna resources. The initial fleet comprised eight chartered pole-and-liners but by 1992 the STL fleet comprised 20 boats.

National Fisheries Development (NFD) began operation in 1978. NFD was 100% owned by the Solomon Islands Government. The main objective of the company was to involve Solomon nationals in the fishing industry. The company did not do as well as anticipated and was sold to a Canadian company in 1990. Last year (1992) the company operated 13 boats from its Tulagi base after STL moved to Noro in the Western Province.

A total of 901 224 buckets (corresponding to 1.9 million kg of baitfish) was caught from a total of 21 079 hauls made in 1992 by the pole-and-liners from both companies. This was higher than the long-term average of 75 102 buckets or 165 224 kg of baitfish harvested each year.

As is usually the case, Western Province contributed over 70% of the baitfish catch in 1992. There are 78 baitgrounds in the Western Province. Munda bait-ground in Roviana Lagoon and Mbili in Marovo Lagoon are the most important areas of baitfishing in Western Province. Isabel Province was the second most important province with catches making up more than 10% of the total catch. Thousandships Bay baitground in Southern Isabel and Rakata in Nothern Isabel are important baitgrounds in this province. Central Islands Province made up slightly more than 5% of the catch and Ndandala was an important baitfishing area.

Baitfish Research Project

In November 1987 a Memorandum of Understanding was signed by the Solomon Islands Government and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia to undertake research on the baitfish resources in Solomon Islands. The project was funded by ACIAR and the study continued until 1989 when an international workshop on tuna baitfish was held in Honiara, Solomon Islands. The broad aims of the project were to determine the population dynamics and biological parameters of the important baitfish stocks, determine if there is a direct trophic interaction between baitfishing and reef fish communities, determine whether management of the existing baitfishery is necessary to assure its future viability and identify management options as necessary. The results obtained from the Project are reported in ACIAR Proceedings No.30.

The fisheries Division has continued monitoring the activity of the pole-and-line vessels each year by

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collecting and compiling catch and effort data for individual baitgrounds. Munda, Ndandala, Mbili and Thousandships Bay baitgrounds were monitored very closely. This report presents the analysis of catch and effort data from Munda and Mbili in the Western Province, Ndandala in the Central Islands Province and Thousandships Bay in Isabel Province. For comparison, all baitgrounds from Central Islands Province were combined (Tulagi) and this is also included in the analysis.

The relationship between catch and effort for each baitground are given in Figures, 1a–1e. These data show a strong linear retionship as is usual for many baitfisheries in the Pacific (Lewis 1990).

From plots of catch per unit effort (CPUE: buckets of bait per haul) against effort (hauls) for each baitground it is apparent that CPUE has undergone a rapid decline in recent years as effort increased (Fig. 2a–2e). Theoretical yield curves for Munda, Mbili and Thousandships Bay baitgrounds give an estimate of maximum sustainable yield for each baitground (Fig. 3a–3c). The MSY from each curve are given in Table 1.

Table 1. Estimated maximum sustainable yield and maximum effort for Munda, Mbili and Thousandships Bay (TSB) based on the yield curves in Figure 3.

Baitground	MSY(Buckets)	Max Effort
Munda	243544	9716
TSB	162163	6064
Mbili	230011	7026

The MSY analysis for Ndandala and even combined Tulagi, was not possible as it was difficult to determine.

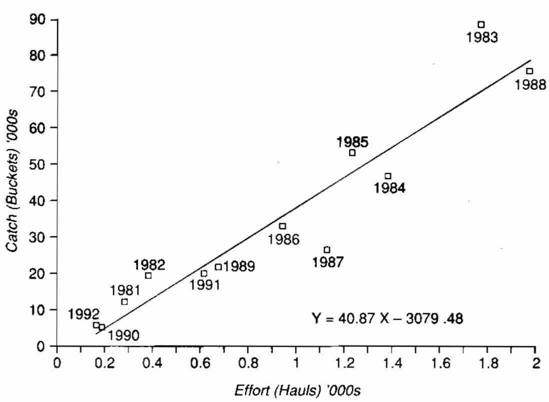

Figure 1a. Catch (Buckets) vs effort (Hauls) Ndandala baitground 1981–92

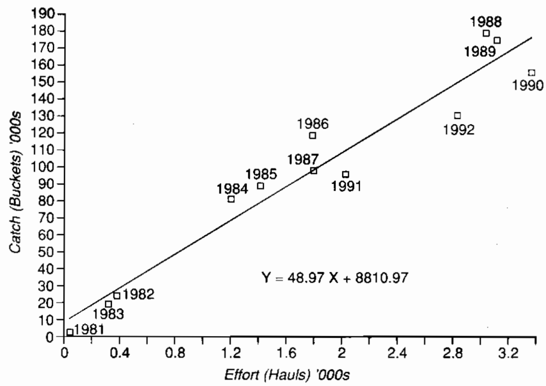

Figure 1b. Catch vs effort Mbili baitground 1981–92

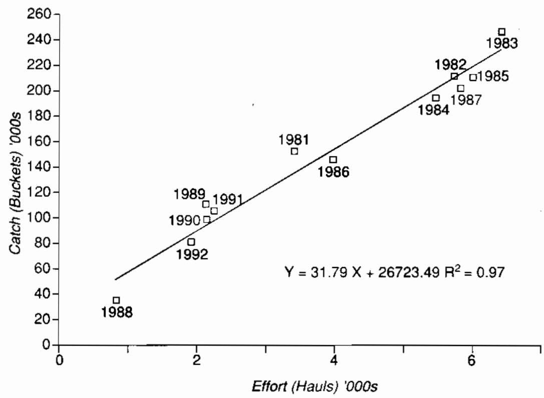

Figure 1c. Catch vs effort Munda baitground 1981–92

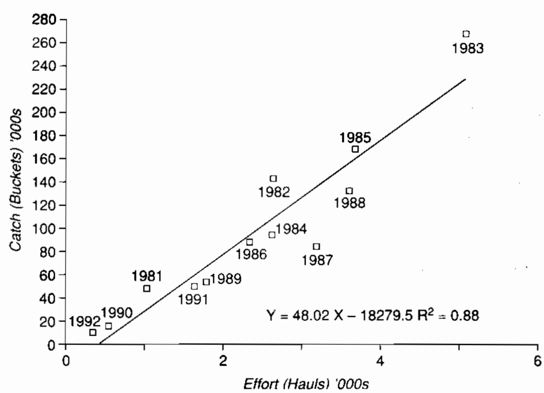

Figure 1d. Catch (Buckets) vs effort (Hauls) Tulagi baitground 1981–92

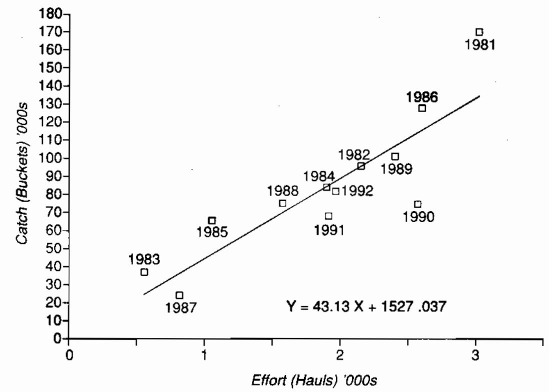

Figure 1e. Catch (Buckets) vs effort (Hauls) Thousandships Bay 1981–92

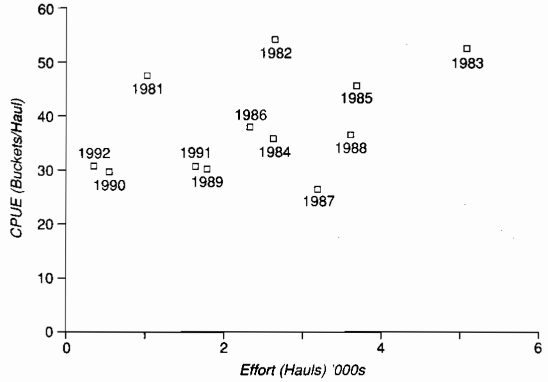

Figure 2c. Catch per unit effort (Buckets/Haul) vs effort (Hauls) Tulagi baitground 1981–92

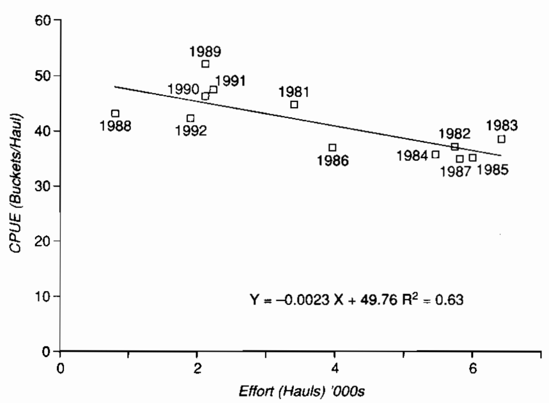

Figure 2a. Catch per unit effort (Buckets/Haul) vs effort (Hauls) Munda baitground 1981–92

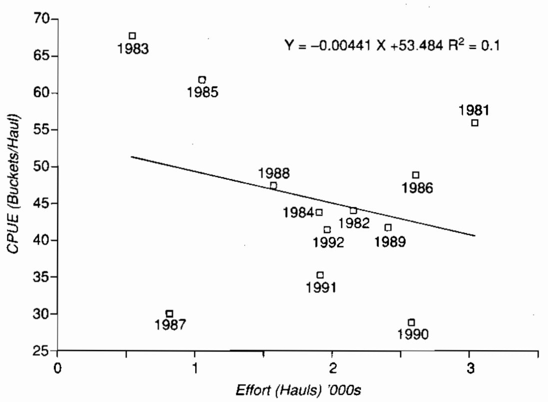

Figure 2d. Catch per unit effort (Buckets/Haul) vs effort (Hauls) Thousandships Bay

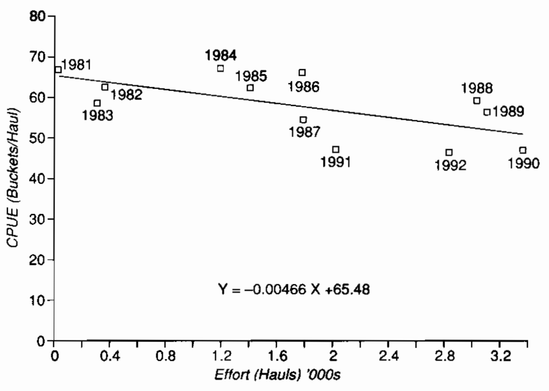

Figure 2b. Catch per unit effort (Buckets/Haul) vs effort (Hauls) Mbili baitground 1981–92

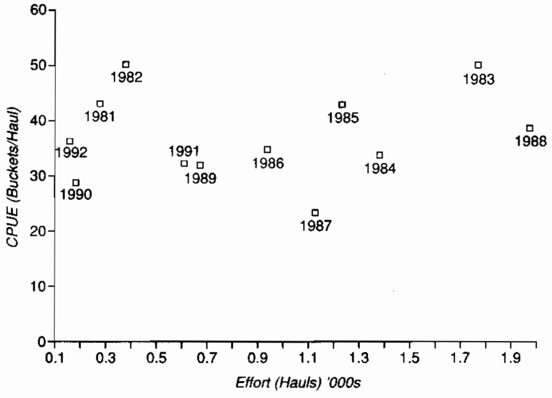

Figure 2e. Catch per unit effort (Buckets/Haul) vs effort (Hauls) Ndandala baitground 1981–92.

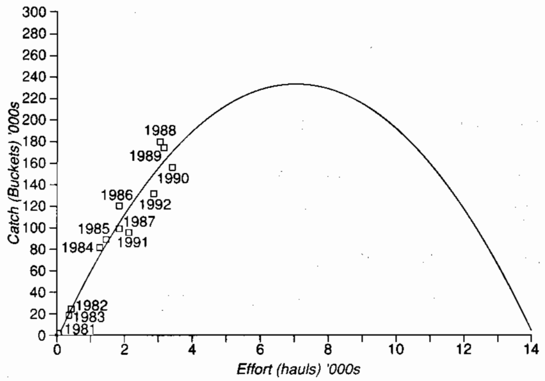

Figure 3a. Yield curve Mbili baitground 1981–92

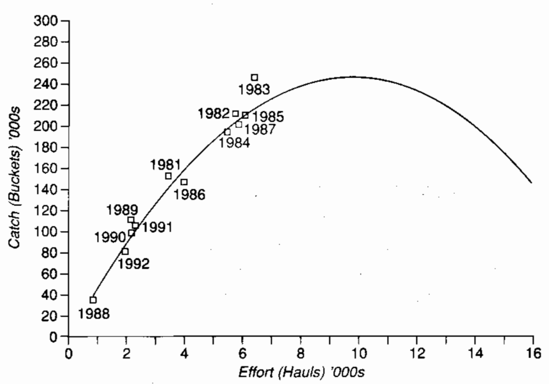

Figure 3b. Yield curve Munda baitground 1981–92

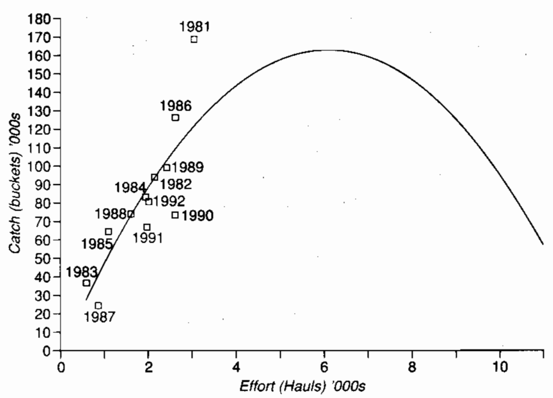

Figure 3c. Yield curve Thousandships Bay 1981–92

Conclusions and Recommendations

It is apparent that the results obtained during the Project need to be substantiated. A complete stock assesssment has to be undertaken so that mortality and sustainable yield can be determined. A stock assessment expert is required so the Fisheries Division in Solomon Islands can develop a management strategy for its baitfish resources. Throughout the past decade the activity of the pole-and-line boats and their catch each year have been largely self-regulated. When catches in one baitground have decreased, boats have moved to other areas to give stocks time to recover.

In Solomon Islands there is a by-catch problem. Further research is needed to determine the effect that the incidental capture of juvenile fish might have on the by-catch species harvested each year by the pole-and-line boats. Species of carangid, baracuda and other species which might be caught during baitfishing are important in the diet of most people in Solomon Islands living in coastal areas. These species have been exploited to such an extent that there is concern that these species might disappear in the future.

The Solomon Islands Fisheries Division is keen that the following recommendations are considered:

1. Stock assessment should be pursued when results of the analysis of length-frequency and otolith data are confirmed and should involve baitfish fisheries staff.
2. A by-catch study should be considered, if possible, in order to ascertain the effect of the pole-and-line fleet on non-target species that are important in the diet of coastal villagers.
3. Analysis of catch and effort data should be done each year on baitgrounds that are heavily fished.

Acknowledgments

The Fisheries Division of the Ministry of Natural Resources acknowledges the support and help during the collection and analysis of baitfish data provided by staff from CSIRO Fisheries; and ACIAR for funding the project. Special thanks go to Nick Rawlinson who initiated the collection, the data input into a computer and analysis of earlier baitfish data that the Division compiled.

Reference

Lewis, A.D. 1990. Tropical South Pacific baitfisheries. In: Blaber, S.J.M. and Copland, J.W. ed. 1990. Tuna baitfish in the Indo-Pacific region: proceedings of a workshop, Honiara, Solomon Islands. 11–13 December 1989. ACIAR Proceedings No. 30, 10–21.

Length-frequency Data for Tuna Baitfish (*Encrasicholina heterolobus* and *Spratelloides delicatulus*) and the Cardinal Fish (*Apogon rueppellii*): guidelines for employing computer packages to use length-frequency data to analyse age composition and growth of fish populations

B.S. Wise and I.C. Potter*

THE management of fisheries resources is dependent on an understanding of the population dynamics of the species comprising those resources (Pauly 1987, Smith 1993). Furthermore, knowledge of the population dynamics of any given species cannot be acquired without first obtaining reliable information on the age and growth of that species (Casselman 1987, Summerfelt and Hall 1987).

The age of fish is traditionally determined by counting the number of annually-formed growth zones (annuli) on hard structures, such as scales, otoliths or spines (Casselman 1987, Beamish and McFarlane 1983, Hyndes et al. 1992). However, annuli are sometimes not formed regularly on such structures or are difficult to discern. Furthermore, under certain circumstances, it may not be feasible to extract, prepare and examine these hard structures. In these cases, the age composition of populations are often obtained by analysing the modes in length-frequency distributions determined for samples collected at regular intervals (Pauly 1987, Pauly and Morgan 1987).

During recent years, microcomputers have increasingly been used to analyse fisheries data. This has led to the development of a number of computer packages aimed specifically at analysing length-frequency data for fish populations in order to determine the age composition and pattern of growth in those populations. These computer packages include MIX, which analyses each individual set of length-frequency data independently from those calculated for the preceding and following samples, and ELEFAN and MULTIFAN which analyse the trends shown by modes in sequential sets of length-frequency distributions (Gayanilo et al. 1989; Fournier and Sibert 1990, Macdonald and Green 1990).

ELEFAN has been widely used for determining the age and growth of tuna baitfish populations (e.g. Dalzell and Wankowski 1980, Dalzell 1984, Dalzell et al. 1987, Tiroba et al. 1990). However it is now apparent that the growth parameters, and particularly *K*, calculated using ELEFAN for data on populations of the tuna baitfish *Encrasicholina heterolobus* and *Spratelloides delicatulus* in the Solomon Islands, differ from those calculated using the growth zones that are formed daily on otoliths (Milton et al. 1990, Milton et al. 1991, Milton and Blaber 1991).

The present paper demonstrates that length-frequency data collected for *E. heterolobus* and *S. delicatulus* are inappropriate for analysis by computer packages. The reasons for this inappropriateness are discussed. The length-frequency data collected for *Apogon rueppellii*, which show conspicuous and consistent modes in sequential monthly samples (Chrystal et al. 1985), have been analysed using MIX, ELEFAN and MULTIFAN to illustrate the type of data that is required to use these packages. *Apogon*

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rueppellii was also chosen because, like the above tuna baitfish, it occurs in the Indo-Pacific region (Allen and Cross 1989) and has a relatively short life cycle (c.f. Chrystal et al. 1985, Milton and Blaber 1991). The results obtained with *A. rueppellii* highlight the essential requirements of length-frequency data for use in age and growth studies, and emphasise the importance of selecting an appropriate sampling regime and considering the possibility that growth may be seasonal and vary with sex. Finally, guidelines are given for the requirements that should be met to produce and analyse length-frequency data by computer packages.

Materials and Methods

Tuna baitfish

Fish species used as tuna bait were collected at the Munda baitground in the Roviana Lagoon, and in the southern part of the similar Vona Vona Lagoon, both of which are located in the Western Province of Solomon Islands (for location of sampling sites see Fig.1 in Rawlinson 1990). Munda is exposed to heavy commercial fishing pressure for baitfish, whereas Vona Vona is not fished for bait.

An underwater light was used to attract the fish, which were then sampled using a large 4mm mesh net and then subsampled using a <1mm mesh net as the fish in the buckets were being transferred into the baitwells (Rawlinson 1990). Fish were placed in 10% formalin and later sorted into separate species. It should be noted, however, that the smaller representatives frequently could not be identified at the species level. Identification of small fish was a particular problem with *Encrasicholina heterolobus* which, at fork lengths less than 25 mm, generally could not be distinguished from the co-occurring and also abundant *E. devisi*. The fork length of each identifiable representative of *E. heterolobus* and *Spratelloides delicatulus* was measured to the nearest 1 mm.

Apogon rueppellii.

This species was collected using seine nets during the day and otter trawls during the day and occasionally during the night at sites located throughout the Swan Estuary, Western Australia. Seine netting was carried out in near-shore shallow waters in each month between January 1979 and February 1982, while otter trawling was undertaken in offshore deeper water in each month between January 1979 and December 1982. The location of sampling sites and the depths of the trawl sites are given in Chrystal et al. (1985). The seine net was 133 m in length and comprised mesh of 25.4 mm in the wings and 9.5 mm in the pocket. The net swept an area of 2815 m^2. The otter trawl, which was 5 m long and consisted of 51 mm mesh in the wings and pocket, respectively, was towed for 5 min at 3–4 km/hour at each site on each sampling occasion. The cod end of the otter trawl consisted of 25 mm mesh in all but the months between July and December 1982, when it was replaced with 9 mm mesh.

The total length of each fish caught was recorded to the nearest 1 mm, except in the case of very large samples, when the measurements were restricted to a random subsample of at least 100 fish. Individuals in random subsamples of each sex were measured between May 1981 and December 1982 to allow the growth of males and females during this period to be plotted separately.

Analysis of length-frequency data

Details of the reproductive biology which provide information on the spawning times of the tuna baitfish *E. heterolobus* and *S. delicatulus* and of *A. rueppellii*, and thus the time when recruitment would be expected, are given in Milton and Blaber (1991) and Chrystal et al. (1985), respectively.

The lengths of the tuna baitfish species and *A. rueppellii* caught in each month were grouped into 2mm size classes. Visual inspection was used in an attempt to elucidate the number of size cohorts in each of the length-frequency histograms and whether (if present) they followed a consistent pattern through each of the sequential monthly data sets.

Since the length-frequency data for the two baitfish species were unsuitable for analysis by computer packages (see later), the following account is restricted to the analysis of length-frequency data for *A. rueppellii*. MIX was used to determine the distributions of the size cohorts and the mean lengths of the normal curves fitted to those distributions in each of the sequential monthly histograms (Macdonald and Pitcher 1979, Macdonald and Green 1990). Growth curves were then constructed using a modification of the von Bertalanffy growth function, which was fitted to the mean lengths of the size classes in the sequential sets of length-frequency data using ELEFAN (Pauly 1987, Gayanilo et al. 1989) and MULTIFAN (Fournier et al. 1990, Fournier and Sibert 1990) and also another nonlinear curve fitting technique (Hall 1992) that employed the results of MIX. They each utilised a sinusoidal oscillation that simulated the seasonal trends exhibited by growth (Pauly and Gaschütz 1979). The equation is:

$$L_t = L_\infty\{1-\exp[-K(t-t_0) - C[K/(2\pi)]\sin(2\pi(t-t_s))]\}$$

where L_t is the length at age t (in years), L_∞ is the mean asymptotic length predicted from the equation, K is the growth coefficient, t_0 is the hypothetical 'age' at which a fish would have zero length if growth followed that predicted by the equation, C is a factor which expresses the amplitude of the growth oscillations and t_s sets the beginning of sinusoidal growth oscillation with respect to $t = 0$ (Pauly 1987).

A birth date of 1 January was estimated for the population of *A. rueppellii* in the Swan Estuary, on the basis of a combination of the trends shown by gonadosomatic indices and backwards extrapolation of the lengths of the 0+ age class in the months when they are first recruited (Chrystal et al. 1985). This birth date was utilised by MULTIFAN to set the first month for each age class. The nonlinear curve fitting technique described by Hall (1992) was adapted to fit a curve to the means of the modes produced by MIX. The sums of squares of the mean lengths were weighted by $1/SE^2$, where the standard error of the mean of the mode (SE) was obtained from MIX. The ELEFAN procedure involved first obtaining a seed value of L_∞ using ELEFAN II. This value was then used in ELEFAN I to obtain estimates from L_∞, K, C and t_s. Further details of the above computer packages can be found in Macdonald and Pitcher (1979), Pauly (1987), Gayanilo et al. (1989), Fournier and Sibert (1990), Fournier et al. (1990) and Macdonald and Green (1990).

Results

Tuna baitfish

Extensive sampling at Munda yielded large numbers of *Encrasicholina heterolobus* in most months between March 1987 and May 1989 (Fig. 1). Small fish less than 25 mm, could only occasionally be identified and fish greater than 60 mm were abundant only in a few months (Fig. 1). Although modes were present in some months, these did not follow any consistent trend with time.

The restricted size range and absence of conspicuous trends in modal lengths exhibited by the length-frequency data for *E. heterolobus* at Munda was paralleled by the data collected at Vona Vona (Fig. 2).

In contrast to the situation with *E. heterolobus*, small representatives of *Spratelloides delicatulus*, i.e. <25 mm, were collected and could be identified, particularly from Vona Vona (Figs 3, 4). Thus, for example, a well defined mode of 15-17 mm was present in September, October and November of 1987 (Fig. 4). However, the corresponding fish were not nearly as well represented in the following three months and it is thus not clear from the length-frequency data how growth progressed. There was some indication from the length-frequency data that a single cohort might have been present in March, April and May of 1989, with the mode increasing from 25 mm to 39 mm during these three months (Fig. 4). However, there was no conspicuous and consistent progression exhibited by modes in the length-frequency data for either of the two species over a series of months.

Apogon rueppellii

The monthly catches of *A. rueppellii* taken by seine net in the shallows varied markedly (Fig. 5). However catches tended to be greatest in summer or autumn and were often low in winter. Although the monthly catches in otter trawls also showed considerable variability, they tended to be greatest in winter (Fig. 5). The increase in otter trawl catches in winter represents an offshore movement at that time (see Chrystal et al. 1985).

Two well defined size cohorts were present in many of the individual monthly length-frequency histograms for *A. rueppellii* in each of the four years (1979-1982) that this species was sampled in the Swan Estuary (Figs 6, 7). The cohorts of the smallest fish, which represent the new 0+ recruits, first appeared in numbers in January in 1979 and 1980 and in February in 1981 and 1982. However, the marked similarity in the modes of this cohort in February of each year, when they ranged only from 33 to 36 mm, indicates that spawning occurred at a similar time in each of those years.

The mode for the 0+ age class in 1980, i.e. the 1980 year class, increased progressively from 36 mm in February, to 49 mm in May, to 57 mm in October and 60 mm in December (Fig. 6). The corresponding mode in 1981, i.e. when the fish had become one year old, increased from 67 mm in January to 77 mm in April, and remained at about this latter length until October (Fig. 7). By December 1981, the length distribution of the 0+ age class had merged with that of the 1+ age class (Fig. 7).

The trends exhibited by the modal lengths of the 1979, 1981 and 1982 year classes were similar to those described above for the 1980 year class (Figs 6, 7). However, the modal length for the 0+ age class did decline during the winter of 1981 and 1982 and the 1+ age class was not well represented in the second half of 1982. It should also be recognised that the 1+ age class was not always well represented in some of the monthly samples. The reasons for the above declines in length in winter and the occasional poor representation of the 1+ age class are discussed later.

The growth curves produced by the non-linear technique of Hall (1992), using the mean lengths of the 1980 year class in each of the monthly samples derived by MIX, show a pronounced seasonal pattern (Fig. 8). Thus, growth of this age class was rapid during the first summer and early autumn and slowed during winter, before increasing slightly in the following summer. This seasonal pattern was even more pronounced with the 1979 and 1981 year classes, to the extent that conspicuous 'negative growth' took place, particularly in the case of the latter year class. The 'negative winter growth' is reflected by values greater than 1 for C in the growth equations for these two years (Table 1).

The value for K in the growth equations was 0.66 for both the 1980 and 1981 year classes, which was

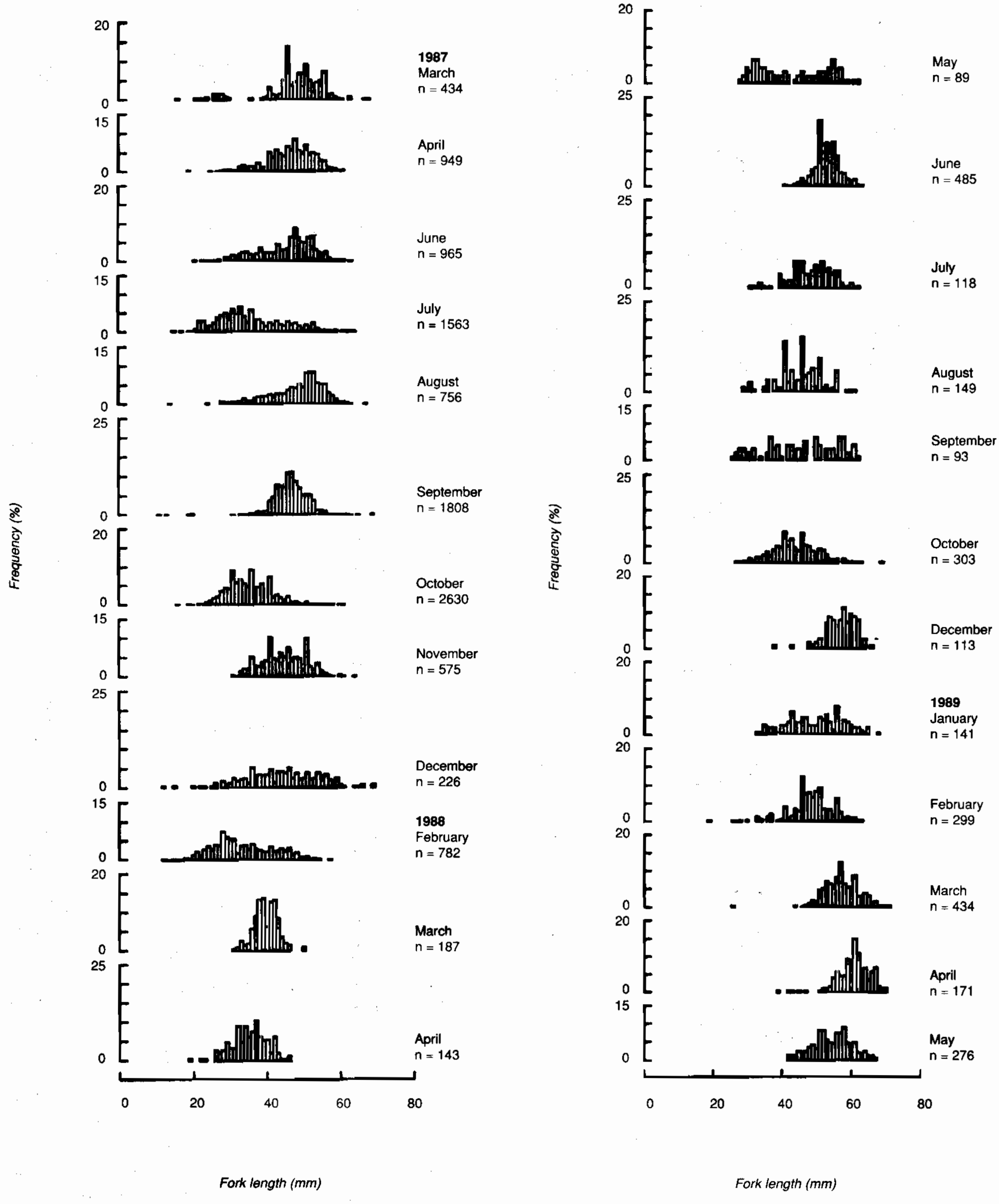

Figure 1. Length-frequency histograms for *Encrasicholina heterolobus* caught at Munda in the Solomon Islands.

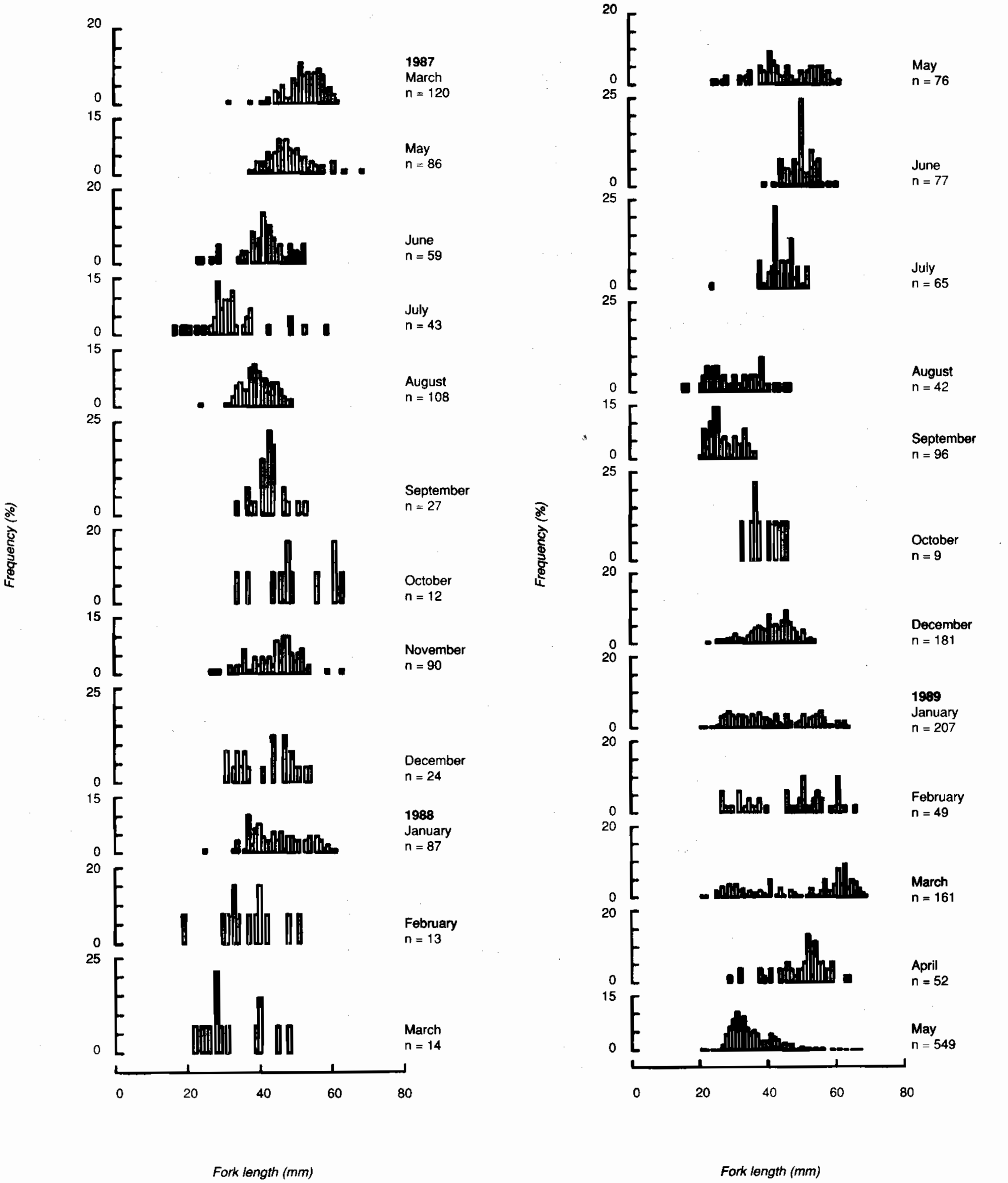

Figure 2. Length-frequency histograms for *Encrasicholina heterolobus* caught at Vona Vona in Solomon Islands.

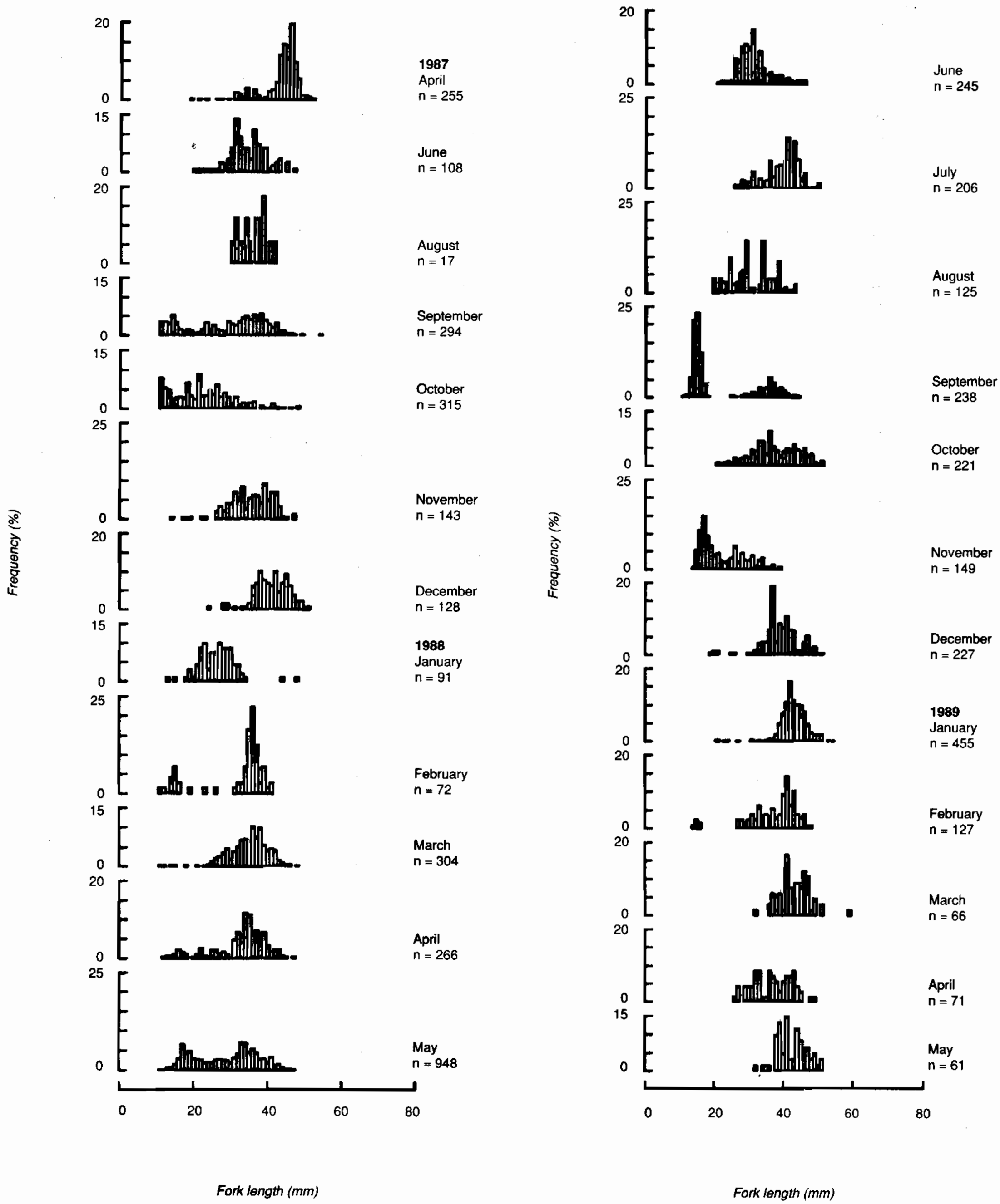

Figure 3. Length-frequency histograms for *Spratelloides delicatulus* caught at Munda in Solomon Islands.

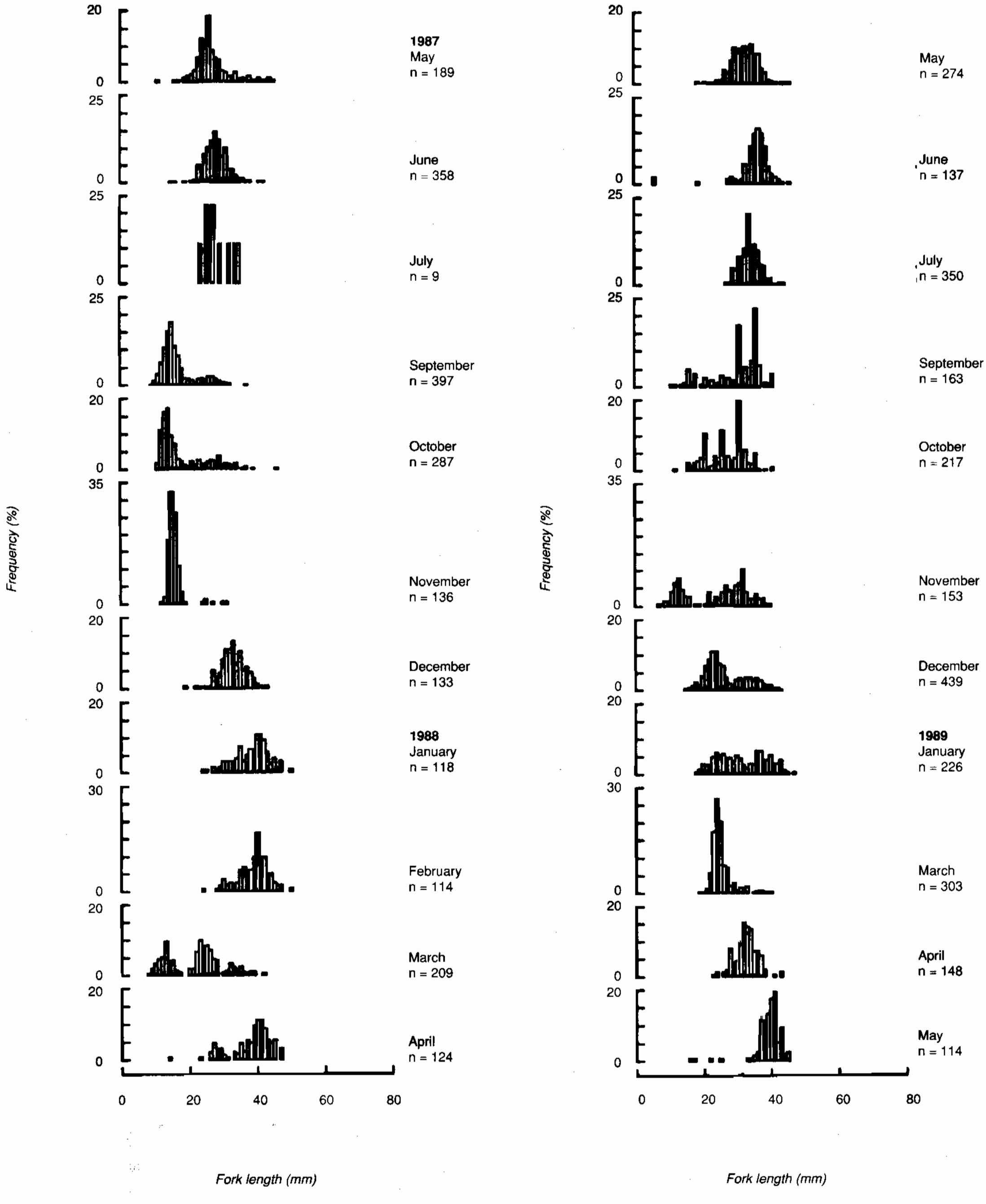

Figure 4. Length-frequency histograms for *Spratelloides delicatulus* caught at Vona Vona in Solomon Islands.

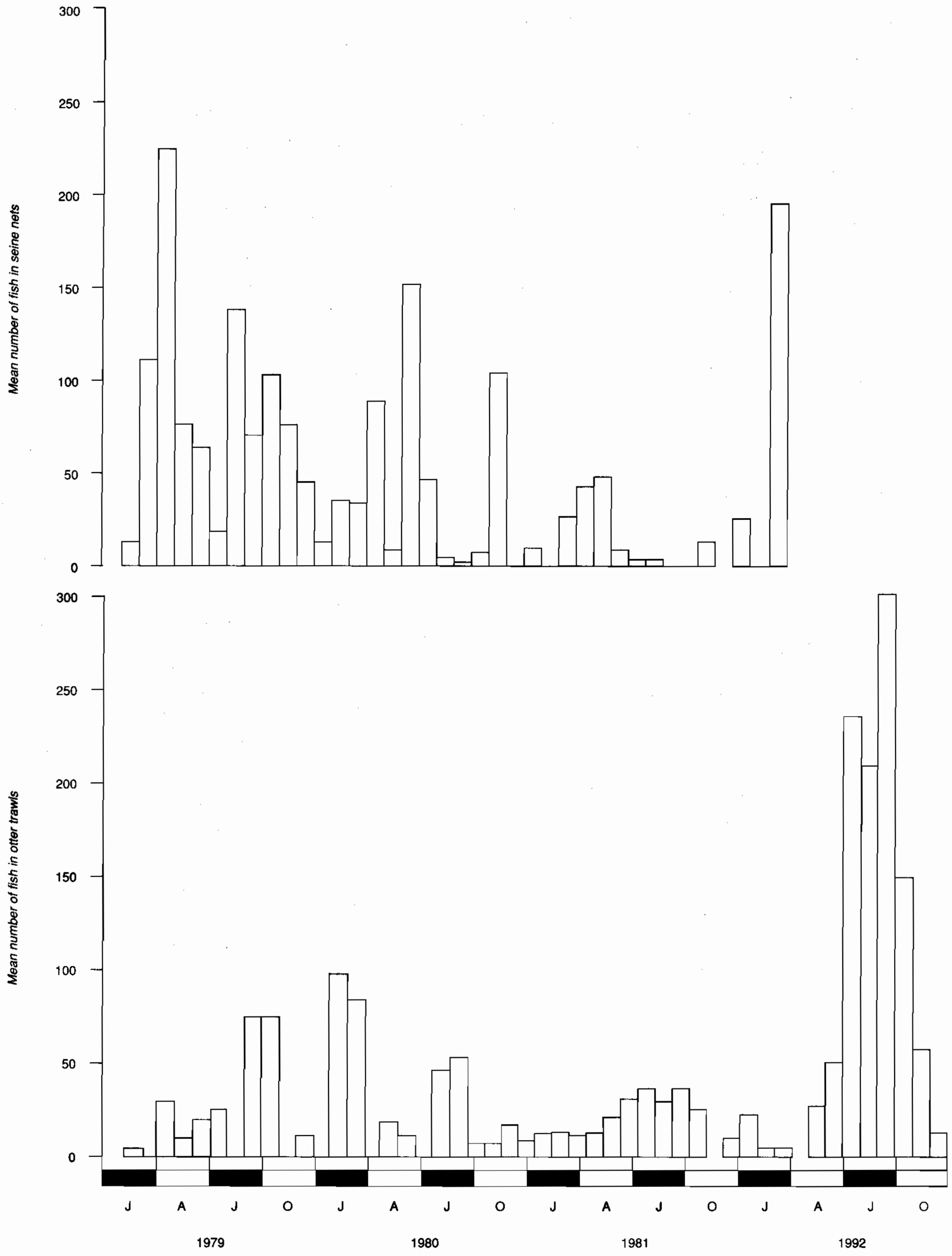

Figure 5. Mean monthly numbers of *Apogon rueppellii* caught by seine nets and otter trawls in the Swan Estuary, Western Australia, between January 1979 and November 1982. The horizontal black rectangles represent the summer and winter months and the open rectangles the spring and autumn months.

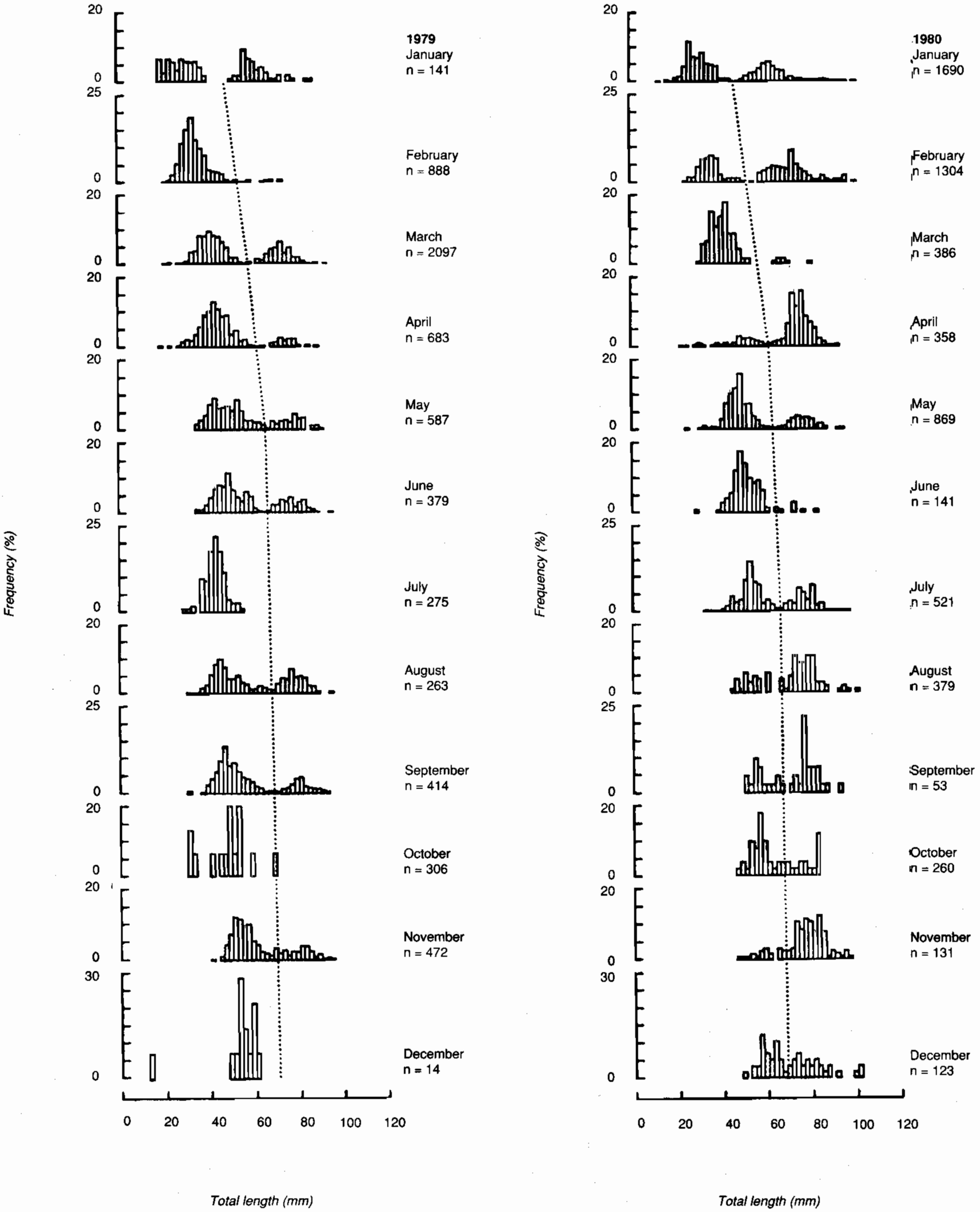

Figure 6. Length-frequency histograms for *Apogon rueppellii* caught throughout the Swan Estuary, Western Australia, between January 1979 and December 1980. The line separates the distributions corresponding to the 0+ and 1+ age classes.

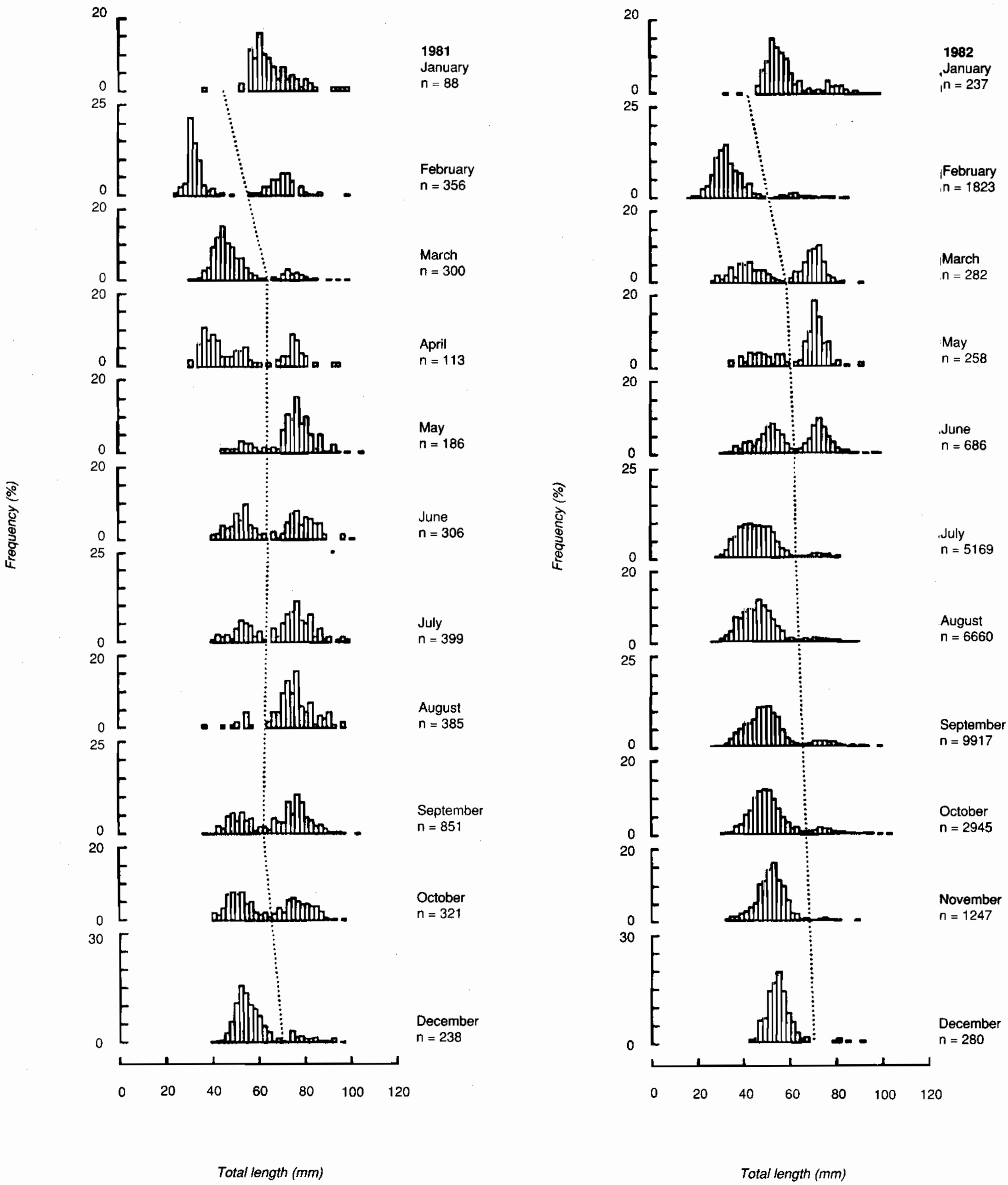

Figure 7. Length-frequency histograms for *Apogon rueppellii* caught throughout the Swan Estuary, Western Australia, between January 1981 and December 1982. The line separates the distributions corresponding to the 0+ and 1+ age classes.

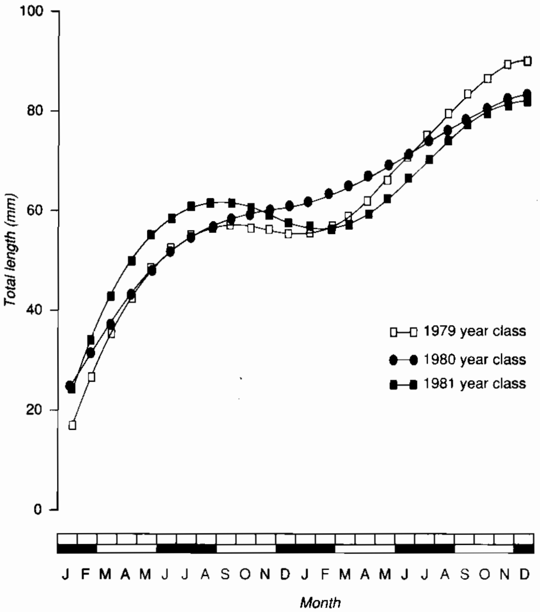

Figure 8. The growth curves for the three year classes of *Apogon rueppellii*, calculated using the mean lengths produced by MIX. The horizontal black rectangles represent the summer and winter months and the open rectangles the spring and autumn months.

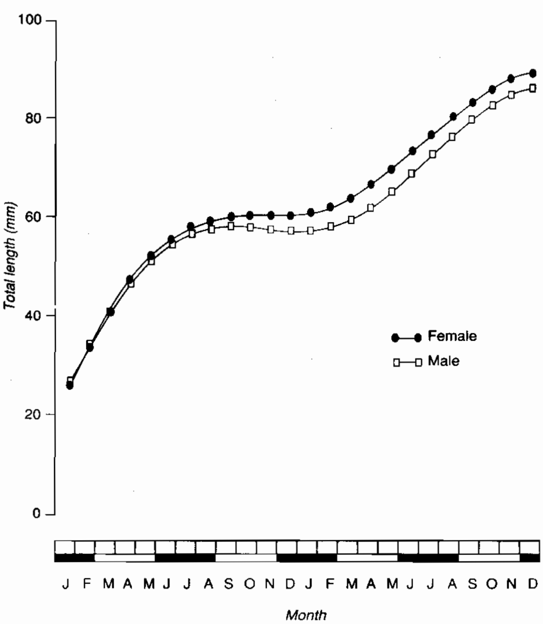

Figure 9. The growth curves for male and female *Apogon rueppellii*, calculated using the mean lengths produced by MIX. The horizontal black rectangles represent the summer and winter months and the open rectangles the spring and autumn months.

slightly higher than the 0.53 recorded for the 1979 year class. Although L_∞ for the three year classes ranged from 96 to 121 mm, these values were associated with a relatively high standard error. Despite this high standard error, the presence of correlation coefficients of 0.97 to 0.99 for the three year classes demonstrates that the curves fitted the data very well.

When the length-frequency data for the 1979 and 1981 year classes were subjected to MULTIFAN and ELEFAN, the values for L_∞ in the growth equations were always greater than 173 mm and on one occasion was 196 mm. These values are far higher than the maximum length recorded (105 mm), a feature attributable to the fact that the above two computer packages cannot effectively analyse length data which show 'negative growth' at some stage of the year, i.e. when the value for C is greater than 1.

The values for the parameters in the growth curve equations produced by MULTIFAN for the 1980 year class, which did not show 'negative growth', were virtually identical to those produced using the mean length calculated by MIX (Table 1). The corresponding values using ELEFAN did not correspond so closely (Table 1).

The growth of males and females started diverging after they had reached 48 mm (Fig. 9), which is reflected by differences in the values for K for the two sexes (Table 1). A likelihood ratio test (Kimura 1980) showed that the growth curves of males and females were significantly different ($P<0.001$). 'Negative growth', reflected by a C value conspicuously above 1, was observed with males (Table 1).

Discussion

Tuna baitfish

Examination of the length-frequency data for the tuna baitfish *Encrasicholina heterolobus* and *Spratelloides delicatulus*, demonstrates that there were no conspicuous and consistent size cohorts that could be traced through the length-frequency histograms for these species in sequential months. However MULTIFAN and ELEFAN, which use length data obtained from sequential samples to derive growth curves, will both produce a curve or curves, even though clear-cut modal length progressions were not present. Furthermore MIX, which analyses the distributions in length-frequency data for individual samples, separated each of those distributions into cohorts which generally bore no resemblance to those produced for the preceding and following distributions. The lack of continuity in modes in sequential samples suggests that the sampling regime was not collecting comparable representatives of the populations in each month. Certainly, a lack of consistent representation could easily occur with baitfish, where their schooling and mobile behaviour could

Table 1. The parameters and their standard errors (in brackets) for the von Bertalanffy growth curves of *Apogon rueppellii*, constructed using the mean lengths produced by MIX, MULTIFAN and ELEFAN. L_∞ is given in mm. See Materials and Methods for definitions of these parameters. NA, not applicable.

		L_∞	K	t_o	C	t_s	r^2
MIX	1979 year class	121	0.53	−0.37	1.20	0.07	0.99
		(17)	(0.16)	(0.10)	(0.10)	(0.01)	
	1980 year class	102	0.66	−0.50	0.63	0.13	0.99
		(9)	(0.15)	(0.10)	(0.15)	(0.04)	
	1981 year class	96	0.66	−0.61	1.74	0.10	0.97
		(11)	(0.19)	(0.14)	(0.25)	(0.02)	
	Female	114	0.56	−0.46	1.02	0.16	0.99
		(9)	(0.10)	(0.07)	(0.10)	(0.02)	
	Male	117	0.46	−0.58	1.22	0.16	0.99
		(11)	(0.09)	(0.58)	(0.11)	(0.02)	
MULTIFAN	1980 year class	103	0.67	NA	0.65	0.12	NA
		(0.6)	(0.02)	NA	(0.01)	(0.002)	
ELEFAN	1980 year class	107	0.71	NA	0.96	0.10	NA

result in the collection of different size cohorts in different months.

It is essential to recognise that the data for the two baitfish species have other inherent deficiencies which would essentially invalidate any attempt to construct growth curves. For example, since these species spawn throughout the year and with highly variable intensity (Milton and Blaber 1991), it is not possible to assign a precise birth date to any cohort. While this problem could be overcome by estimating a birth date using the trends shown by the growth of the smallest fish, small fish were not well represented in the data. This was particularly the case with *E. heterolobus*, where the small members of this species could not be separated from those of *E. devisi* with which they co-occurred. However, even in the case of *S. delicatulus*, where small fish (<25 mm FL) were present and could be identified in a few months, there were no corresponding cohorts in the following months that would be consistent with the type of modal progression that would represent growth.

The ability to use MULTIFAN and ELEFAN to analyse length-frequency data also depends on recruitment occurring at regular intervals. However, since tuna baitfish spawn throughout the year and the precise timing and intensity is highly variable at Munda and Vona Vona (Milton and Blaber 1991), recruitment must be highly uneven. This feature by itself precludes the use of MULTIFAN and ELEFAN.

Any difficulty in tracing size cohorts that might have been present in the length-frequency data for tuna baitfish would have been exacerbated by a number of other factors. For example, the mesh size employed (4 mm) was too large to have sampled adequately the smallest fish, which are often used to help define the birth date of the cohort.

Although *E. heterolobus* and *S. delicatulus* apparently spawn throughout the year but with irregular intensity (Milton and Blaber 1991), the spawning of another Indo-Pacific species, *Stolephorus nelsoni*, occurs in the spring (Hoedt 1990). As a result, recruitment of this latter species is restricted to one time of the year and the mode corresponding to the 0+ age class can be clearly traced through length-frequency data for sequential months (Hoedt 1990).

Apogon rueppellii

As with the length-frequency data for *S. nelsoni*, those for *A. rueppellii* show clearly defined cohorts, whose modes could be traced through sequential monthly length-frequency histograms. The well defined modes reflect a relatively narrow spawning season. The presence of a single annual spawning season means that a new 0+ age class is recruited only once in each year. An ability to define a realistic birth date, both from reproductive data and from the trends shown by the modes corresponding to the smallest size class, combined with the presence of well defined cohorts, make the length-frequency data for *A. rueppellii* ideal for analysis using either MIX, ELEFAN or MULTIFAN.

It is noteworthy that the growth curve parameters calculated using MULTIFAN and employing the mean lengths generated by MIX were almost identical in the case of the 1980 year class. However, the presence of apparent 'negative growth' for the 1979 and 1981 year classes in the winter resulted in the production of completely unrealistic values for L_∞ in those year classes when using MULTIFAN and ELEFAN. This is because these two computer packages cannot accommodate 'negative growth' since C is constrained between 0 and 1 (Fournier and

Sibert 1990, Gayanilo et al.. 1989). The apparent 'negative growth' of the 1979 and 1981 year classes reflected a relative reduction in the proportion of the catches of larger fish in the winter. In the case of the 1979 year class, this was due to the fact that the catches made in winter by seine netting in shallow water were greater than in otter trawls in deeper water where the larger fish tend to be found at that time. With the 1981 year class, the 'negative growth' was related to a shift from the use of 25 mm to 9 mm mesh in the cod end of the otter trawl in July and the resultant retention of a higher proportion of smaller fish. The absence of 'negative growth' with the 1981 year class can be attributed to the better balance between the catches of fish in seine nets and otter trawls, with the smaller fish of both the 0+ cohort being taken in shallow waters and the larger fish of this cohort being collected in deeper waters. Furthermore, the catches included good numbers of the 0+ and 1+ cohorts (see also Chrystal et al. 1985).

The above examples demonstrate that the size composition of fish in catches can be influenced by such factors as the mesh size of the net and the seasonal movements of fish. Our data also demonstrate that, as *A. rueppellii* approaches maturity for the first time, the growth of males and females started to diverge. While this did not produce a very marked change in K in the growth equation, it is important to recognise that, in those cases where differential growth between the sexes is conspicuous, separation of the sexes will lead to greater definition of the age classes in length-frequency data.

Guidelines for Acquiring Data for Computer Analysis

Sampling regime

The ability to use a computer package successfully is dependent on establishing the type of sampling regime that will yield appropriate length data. The sampling regime should thus be designed to obtain a full range of fish sizes. This may require more than one method in the case of fish that grow to a relatively large size.

It is also necessary to ensure that a fully representative sample is obtained by sampling widely in a given area to avoid any bias that might be incurred through schooling and seasonal or other movements, such as from inshore to offshore. It is also important to use a mesh size sufficiently small to catch the smaller representatives of the species. Furthermore in the case of small fish, it is important to measure the length accurately, usually to the nearest 1 mm.

For small, fast growing fish, e.g. tuna baitfish, it is advisable to sample at least fortnightly, whereas monthly sampling should be adequate for fish species that grow to a large size, such as snappers and emperors.

The gonads of representative fish should be collected and allocated to stages to determine whether spawning is continuous or occurs at regular intervals. If the latter is the case, the data can be used to calculate the spawning period and thereby assign a birth date for use in growth equations.

Type of computer package

Prior to analysing length-frequency data, it is important to examine the data visually to determine whether there are a series of well defined modes that can be traced through length-frequency data for sequential samples. Consequently, the way in which the data are plotted is crucial. Small class intervals or even individual lengths of fish should be used for small species.

The choice of computer package depends on the characteristics of the data set. MULTIFAN and ELEFAN analyse the lengths in preceding and following samples to elucidate the distribution of the size cohorts and then uses the mean lengths of those cohorts to produce a von Bertalanffy growth curve. The use of MULTIFAN and ELEFAN thus depends on growth conforming to the von Bertalanffy growth equation, i.e. growth becomes increasingly asymptotic with age. These two computer packages also assume that recruitment occurs at regular intervals, e.g. once yearly or once every six months, and they cannot accommodate "negative growth".

In contrast, MIX determines the distribution of the size cohorts in each sample separately. The means of the distributions of those cohorts in successive samples can then be used to construct a growth curve. These curves do not necessarily have to conform to the von Bertalanffy growth equation, or require recruitment to have occurred at regular intervals.

In summary, the successful use of each of the above computer packages requires the following:

1. The presence of conspicuous and consistent modes which can be traced through sequential length-frequency data. Unless this requirement is met, it is thus not appropriate to submit length-frequency data to MIX, MULTIFAN or ELEFAN.
2. Length measurements of a sufficiently large number of fish covering the complete range of fish lengths.
3. Samples should be collected at regular intervals, the precise interval betwen sampling depending on the lifespan of the species. Sampling should also attempt to collect representatives from throughout the range of distribution of the population.
4. Measurements should be made in units appropriate for the length range of the species (i.e. 1 mm for small and short-lived species) and the data plotted in appropriate size intervals.
5. Ideally, the data should include details on the reproductive cycle so that a birth date can be assigned.

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