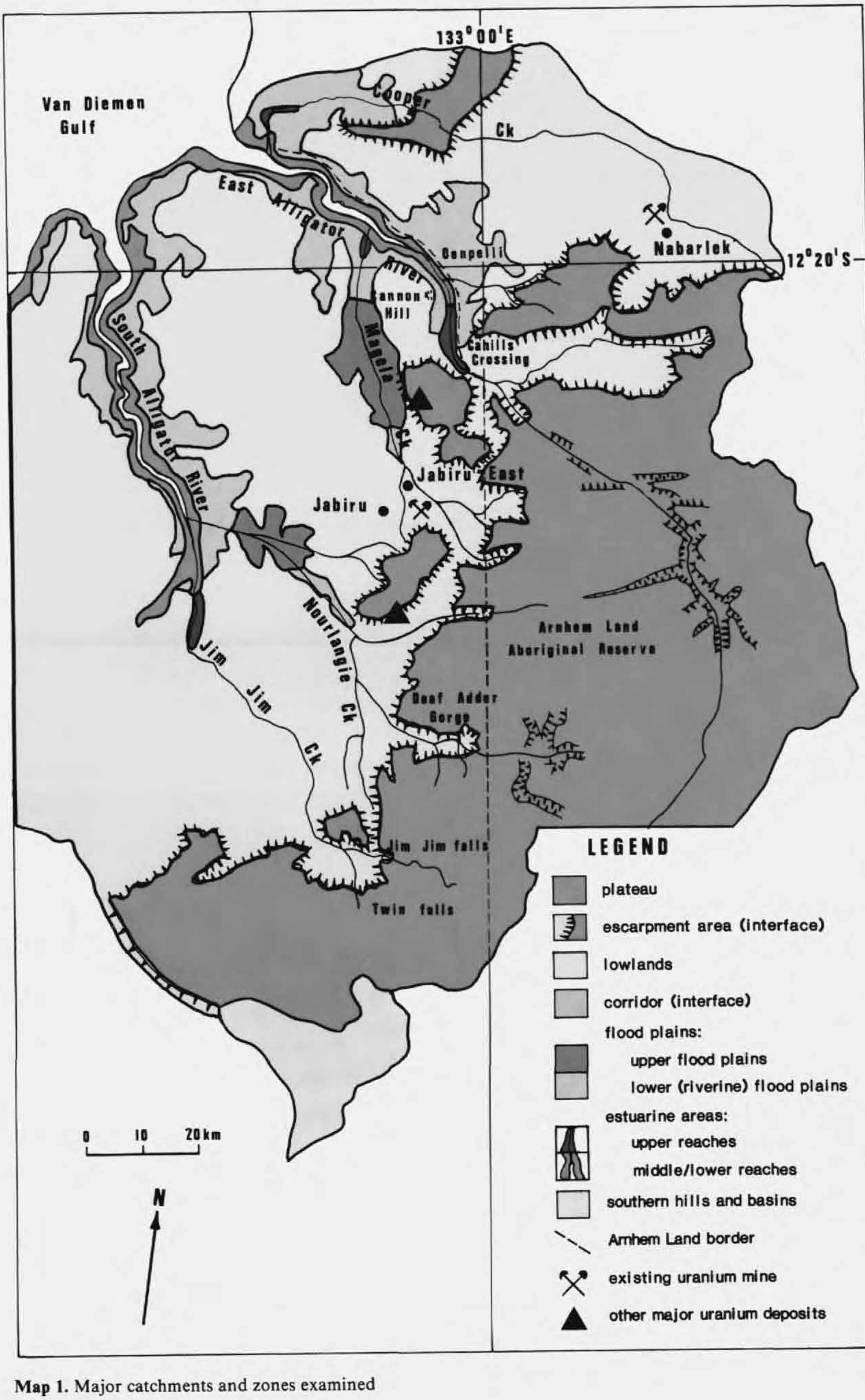
Research Report 4

# Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory

## Volume II: Synecology

K.A. Bishop, S.A. Allen, D.A. Pollard and M.G. Cook

Supervising Scientist for
the Alligator Rivers Region




**Map 1.** Major catchments and zones examined

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Australian Government Publishing Service
Canberra

ISSN 0810-9966
ISBN 0 644 01295 1 (Volume I)
ISBN 0 644 12769 4 (Volume II)
ISBN 0 644 01294 3 (set of three volumes)

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The manuscript, submitted in 1980, represents the results of a detailed ecological study of the freshwater fishes of the area conducted from August 1978 to December 1979. The entire work is divided into three volumes under the following titles:

**Volume I: Outline of study, summary, conclusions and recommendations**
Introduction to the overall study: physiography of the Region; description of aquatic habitats; materials and methods; summary; conclusions; recommendations.

**Volume II: Synecology**
Results and discussions of the synecological studies

**Volume III: Autecology**
Results and discussions of the autecological studies, species arranged in taxonomic order.

The Supervising Scientist for the Alligator Rivers Region manages the Alligator Rivers Region Research Institute, which conducts, co-ordinates and integrates research relating to the effects on the environment of uranium mining in the Alligator Rivers Region. Research findings of projects carried out under contract to the Supervising Scientist or undertaken by the Supervising Scientist's own staff may be published in the Research Report or Technical Memorandum series. Views expressed by authors do not necessarily reflect the views and policies of the Supervising Scientist, the Commonwealth Government or any collaborating organisation.



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Printed in Australia by Alken Press Pty. Ltd. – Smithfield, N.S.W.

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# ACKNOWLEDGMENTS

The authors would like to thank the following people and institutions for identifying specimens: Dr G. Allen (Melanotaeniidae), Ms M. Feinberg (Plotosidae), Dr D. Hoese (Eleotridae and Gobiidae), Ms P. Kailola (Ariidae), Mr G. Crook (anuran larvae) and Dr D. Thomas, Dr H. Ling and Ms J. Kessell (algae). Dr D. Mitchell assisted in the development of the general habitat data cards. Dr D. Hoese and Ms S. Reeder of the Australian Museum, Sydney helped with fish taxonomy. Mr E. Wilson, Mr S. Jacobs and Ms V. May of the Royal Botanic Gardens, Sydney helped with plant taxonomy.

For occasional assistance in the field we thank Mr M. Alderson, Mr J. and Ms P. Bell, Mr W. and Ms E. Bishop, Ms J. Burchmore, Mr S. Clark, Mr M. Giles, Mr R. Goldberg, Dr J. Harvey, Dr N. Mackay, Mr J. and Ms Middleton, Mr P. and Ms G. Parker, Dr B. and Ms E. Pease and Mr F. Reynolds. For assistance in the preparation of the report we would particularly like to thank Mr A. Collins (computing and analyses).

We would like to thank Drs G. Allen, D. Hoese, W. Ivantsoff, S. Kessell, L. Llewellyn, J. Merrick, S. Morton, J. Paxton and J. Pepperell and Ms M. Middleton, who read and discussed sections of the report, and gave helpful suggestions for its improvement.

Thanks are also due for assistance offered and data supplied by Ranger Uranium Mines Pty Ltd, Pancontinental Mining Limited, Queensland Mines Limited, Noranda Australia Ltd, and the Northern Territory Water and Sewerage Division.

# EXPLANATORY NOTES

This volume sets out the synecology of the Alligator Rivers Region and is designed to be read in conjunction with the other volumes in the series, Volume I, *Outline of the study, summary, conclusions and recommendations* and Volume III, *Autecology*.

The definitions of the aquatic seasons, abbreviations used in the study and the use of the term 'billabong' are given in the *Explanatory Notes* in Volume I.

The nomenclatural changes (fish species and place names) outlined in the *Explanatory Notes* of Volume I, have been incorporated into the text, appendixes, figures and tables of this volume.

The status of *Craterocephalus* nov. sp. in the family Atherinidae has been revised since the publication of Volume I; *Craterocephalus* nov. sp. = *Craterocephalus marianae*.

# ABSTRACT

Bishop, K.A., Allen, S.A., Pollard, D.A. and Cook, M.G. (1990). Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory. Research Report 4, vol. II. Supervising Scientist for the Alligator Rivers Region, Australian Government Publishing Service, Canberra.

The tropical climate of the Alligator Rivers Region of the Northern Territory has a distinctive Wet-Dry cycle resulting in seasonal flows in the creeks and rivers of its catchments. The present study, begun in August 1978, was aimed at developing an ecological monitoring system that would detect any changes to the freshwater fish communities brought about by recent uranium mining and processing in the lowlands of the ARR.

The key to this development, and the focus of the synecological studies, was a description of spatial and temporal patterns in the community structure of the fish fauna. Interpretation of these patterns was made possible by the collection of detailed environmental data from the study sites.

From the headwaters to the mouths of the creek systems, the habitat-structural and physico-chemical conditions presented a continuous gradient of conditions; cooler, clearer waters over rocky and sandy substrates moving downstream to hotter, more turbid waters over muddy and clayey substrates with hydrophytes. Distinctive fish communities were present in the upper escarpment and lower reach floodplain zones. These zones contained major refuge habitats for fish.

Superimposed on the longitudinal gradient in environmental conditions, were extensive changes caused by the seasonal nature of water flow. During the Dry season, the conditions were generally heterogeneous between waterbodies, with the most 'favourable' conditions for fish existing in escarpment zone waterbodies and varying 'unfavourable' conditions existing downstream in the lowland and floodplain habitats. This was the season when communities in the upper and lower reaches were most distinctive.

The Early-wet season heralds a rapidly expanding aquatic environment which, by the Wet season, becomes more homogenous between waterbodies, as conditions tend towards and exceeded those recorded in the escarpment zone during the Dry season. In the Wet season, communities in the upper and lower reaches were least distinctive. The community structure recorded during this season in the lowland habitats showed a flux between those recorded in major refuge habitats in the upper and lower reaches.

# 1

# Introduction

## 1.1 Preamble

Ecological studies on the freshwater fishes of the Alligator Rivers Region, (Map 1), were carried out from August 1978 to December 1979 as a part of the initial research program of the Office of the Supervising Scientist. The results of these studies are presented in three volumes.

Volume I, contains the overall introduction to these studies; a description of the physiography of the Region, a brief description of the aquatic habitats and climatic cycle; summary of the results together with the general conclusions and recommendations.

Volume II (this Volume), considers the synecology of the freshwater fishes of the Region. Synecology is the study of relationships of particular populations of organisms, in this case a fish community, with its environment.

Volume III, discusses the autecology of the fish species of the Region. 'Autecology' is the study of the ecology of particular individuals or single species.

## 1.2 Objectives of the synecological studies

The originally stated objectives of the ecological studies on the freshwater fishes of the ARR which are relevant to the synecological studies are:

- to describe fish community structures along watercourses (i.e. through a longitudinal array of habitats) and show seasonal changes;
- to collect environmental information on the study sites for use in interpreting changes in community structures; and
- to advise on the best practical approach for detecting possible adverse effects on the Region's fish fauna due to uranium mining and processing operations (i.e. attempt to delineate those ecological features of the fish fauna and variables of the aquatic environment that are most sensitive to human-induced changes and that are likely to prove of greatest value in a continuing monitoring program, and to indicate how they can be most reliably sampled and usefully measured).

In essence, information in Volume II is directed towards the development of a biological monitoring system, to aid in the detection of any environmental changes, in particular in the freshwater fish communities of the ARR, caused by uranium mining and processing operations (see vol. I for background). In order to detect such effects, an empirical model of 'natural', i.e. pre-mining, patterns in the community structure is required. If these patterns can be defined within certain limits, it may be possible to identify where and when significant changes have occurred.

Accordingly, the data presented here are a sixteen-month reference set of information on the pre-mining patterns in ARR fish community structure together with the associated features of the aquatic environment.

To date, a total of 59 fish species have been collected from the Region, these are listed in order of their phylogeny in volume I (table 1, pp. 3-4). Fifty of these fish species are known from freshwater. Additional species may be found as more collecting is undertaken, especially in estuarine habitats, which have as yet, been little sampled.

During this study, 172 standard samples were taken, yielding 29 507 fish from 45 species. Excluding the six estuarine samples (253 fish belonging to 29 species), the remaining freshwater standard samples yielded 29 254 fish from 35 species. Separate from these collections, were 39 sets of underwater observations made in excarpment area sites, in which 6 276 fish belonging to 28 species, yielded additional information.

In terms of samples taken from freshwaters in the present study, the number of species per family was as follows:

| | |
|---|---|
| Five species: | Teraponidae |
| Four species: | Plotosidae, Centropomidae |
| Three species: | Ariidae, Melanotaeniidae, Atherinidae, Eleotridae |
| Two species: | Toxotidae, Gobiidae |
| One species: | Megalopidae, Clupeidae, Osteoglossidae, Belonidae, Synbranchidae, Apogonidae, Mugilidae |

Some confusion between plotosids identified in the early stages of the study may exist. The difficulties inherent in the identification of catfish species from the Plotosidae are detailed in volume III.

## 1.3 The nature of the expected environmental changes

Fox et al. (1977) predicted that the primary mechanism by which uranium mining and processing operations could possibly change the ARR abiotic aquatic environment and adversely affect its biota, was by the movement of waste waters from mine sites (via controlled releases or by seepage) into the surrounding creek systems. A secondary mechanism, which could also cause abiotic change, would be related to the physical alterations within catchments (e.g. earth-moving, resulting in increased degree of sedimentation in the waterways, or the inundation of creeks following the creation of impoundments). The exact nature of these environmental changes in creek systems, however, cannot be predicted, particularly those causing changes in water chemistry, brought about by the transfer of waste waters. Fox et al., (1977), indicated that these waters were likely to contain mixtures of heavy metals, i.e. be 'complex' wastes. Even if the chemical composition of these waters were to be known, it would be very difficult to postulate the resulting chemical changes in the receiving creek, as unpredictable chemical reactions might occur on mixing and, in the case of waste water seepage, during movement through the soil.

Because of the complexities involved in understanding or 'defining' the probable nature of these environmental changes, it became apparent early during the present study that the delineation of the ecological features of the fish communities and variables of the aquatic environment most sensitive to possible changes resulting from uranium mining and processing, was unattainable. At the beginning of this study no relevant information existed on the tolerance of ARR fish to environmental change of any type, natural or human-induced. Suitable waste water was not available at that time for the experimental investigation of non-toxic behavoural and subchronic and chronic toxicity studies on fish communities or individual species. Preparatory information on fish species (arising from the studies reported in vol. III) and suitable toxicity-testing sites outlined in volume I (section 7), were investigated during this study to ensure a baseline for future experimentation.

The nature of the studies which could be undertaken in relation to the development of field detection methods were dictated by the circumstances outlined above. The present study, therefore, is restricted primarily to an investigation of the response of fish communities to 'natural' changes associated with the Wet-Dry climatic cycle and longitudinal gradients in characteristics of the creek environment. Apart from the direct monitoring application of such information, it is envisaged that these community-response results will be beneficial when assessing the true ecological implications of test data arising from future experimentation with complex wastes.

## 1.4 Monitoring

Until recently in many cases, water quality has been protected from pollution by the enforcement of chemical and physical 'standards', rather than by the enforcement of standards based on the biological response within a system receiving particular waste discharges. Exclusive dependance on chemical and physical standards is now considered not to provide adequate environmental protection for two major reasons (Cairns & Dickson 1980). Firstly, the biota is subjected to an aggregate of stresses in situations where it is exposed to complex wastes. The frequency of similar occurrences in like circumstances suggests such exposures are expected to occur in relation to uranium mining in the ARR. These aggregates are not possible to predict, even if itemised lists of the constituents were available. Secondly, responses of the biota to such constituents are rarely constant, either from place to place or at a single location through time. Environmental management of pollution is currently considered (Cairns & Dickson 1980), to be most effective if biological, chemical and physical data are gathered simultaneously so that any relationships between response and 'dose' can be estimated.

The term 'ecological monitoring' (equivalent here to 'biological monitoring' or 'biomonitoring'), is presently used in the United States to cover three activities: surveying, surveillance, and monitoring. These terms have been used more precisely by Hellawell (1978):

*Survey*: an exercise in which a set of standardised observations is taken from a station (or stations) within a short period of time to furnish qualitative or quantitative descriptive data.

*Surveillance*: a continued program of surveys systematically undertaken to provide a series of observations in time.

*Monitoring*: surveillance undertaken to ensure that previously formulated standards are being met.

According to these definitions, the present study (this Volume), could be most accurately classified as a survey. In this context, stations have been selected to represent the various habitats available to fish in catchments which may be subjected to human-induced changes. The time-period of this survey encompasses one Wet-Dry climatic cycle (12 months, 5 samples) together with some additional information available on the following climatic cycle (4 months, 2 samples). It is intended that a portion of this survey will be extended so that a surveillance system can be instigated. Once the nature of complex effluents arising from uranium mining and processing operations is known, and the associated biological, physical and chemical standards set, it is envisaged that this surveillance system could be extended to a monitoring system.

## 1.5 The role of fish in biological 'monitoring'

Much attention has been afforded fish because they are a valued and familiar resource. People are more familiar with fish than with other forms of aquatic life. As fish are generally well-represented at the top of most aquatic food chains, they have traditionally received considerable attention by environmental managers. For these reasons, fish have been and are likely always to be, included in the biological 'monitoring' of aquatic ecosystems.

The most notable problem to be faced, when using fish in 'monitoring' studies, is their high mobility. High mobility may, in some situations, make them highly suitable monitoring subjects, if they are capable of detecting and avoiding environmental stresses arising from pollution. Stauffer & Hocutt (1980), consider that fish play a central role in many types of ecological 'monitoring' activities because:

- Their presence implies the presence of other phylogenetic groups, since large specimens of omnivores/carnivores occupy the top of the food chain in most aquatic systems (such matters are investigated in the autecological studies presented in vol. III).

- They utilise most trophic levels throughout their development (see vol. III)
- Taxonomically they have been well studied, so accurate and quick identification can be made. This is generally the case for the ARR fish fauna ( see vol. III for a discussion of the species which are the exceptions to this).

## 1.6 Monitoring of community structures

The concept that assemblages of organisms, or communities, could be used to assess the environmental changes caused by pollution, was accepted slowly at first but has gained much credibility in recent years (Cairns & Dickson 1980). This acceptance has developed due to a realization that aquatic communities are interlocking, interdependent systems of species in which an effect on one part, will ultimately affect the whole. In this respect Odum (1971), stated that:

> the community concept is one of the most important principles in ecological thought and ecological practice.

The study of communities and their relationships to the environment is called synecology or community ecology. This branch of ecology is a very young science, with almost no work done prior to 1900 and with little theoretical or quantitative development until around 1950. Research into Australia's freshwater fish fauna has not yet progressed to any real extent in these considerations. The only work which has been done at the community level is by Beumer (1976) who emphasised the importance of flooding in assisting the 'recovery' of fish diversity along a tropical stream following periods of low rainfall. Within the ARR, the only contributions towards describing the synecology of the freshwater fishes has been the development of a number of tentative species list (Taylor 1964; Midgley 1973; Pollard 1974).

According to Cairns & Dickson (1980), the use of community structure to assess the effects of environmental change due to pollution is conditioned by four assumptions. The most poignant of these assumptions being that:

> stress arising from pollution will simplify a complex community by eliminating more sensitive species, and at times, increasing the abundance of these species (due to reduced competition) which can tolerate the stress (e.g. Wilhm & Dorris 1968).

The consequences of community change as detailed in this assumption has frequently been measured by examining such features as number of species (Krebs 1972), heterogeneity (Peet 1974), and other diversity indices. Even features such as total abundance or total weight of samples (summed across all species), may be useful in this regard. In this volume such features will be collectively referred to as community summary-feature variables.

In recent years the exclusive use of these features (particularly the diversity indices), for monitoring is now not recommended. It has been suggested (Green 1979) that a multivariate statistical approach which utilises community composition data, is often a more appropriate procedure for monitoring biological response at the community level. This is because a community composition approach retains more information on complex biological data while reducing such data to a more useful form. This approach is more attuned to the subtle community composition changes likely to occur before sensitive species are eliminated from communities. In this volume, 'community composition' will be referred to as 'community composition variables'.

# 2

# Materials and methods

## 2.1 Sampling design

Possible ecological effects of water releases from the Ranger Uranium Mines Pty Ltd development near Jabiru might be expected to become apparent first in Coonjimba, Gulungul, Georgetown and Djalkmara creeks and their associated waterbodies in the Magela Creek system (Map 3). An intensive program to sample the freshwater fishes in these areas was undertaken as a part of the wider survey of the Magela Creek system. Habitats upstream of the Ranger site were used as control sites. The fish faunas of sites adjacent to the other three major uranium deposits (Jabiluka, Koongarra and Nabarlek, see Map 1) were sampled occasionally, as were sites outside the Magela catchment, in order to provide additional information on fish distributions.

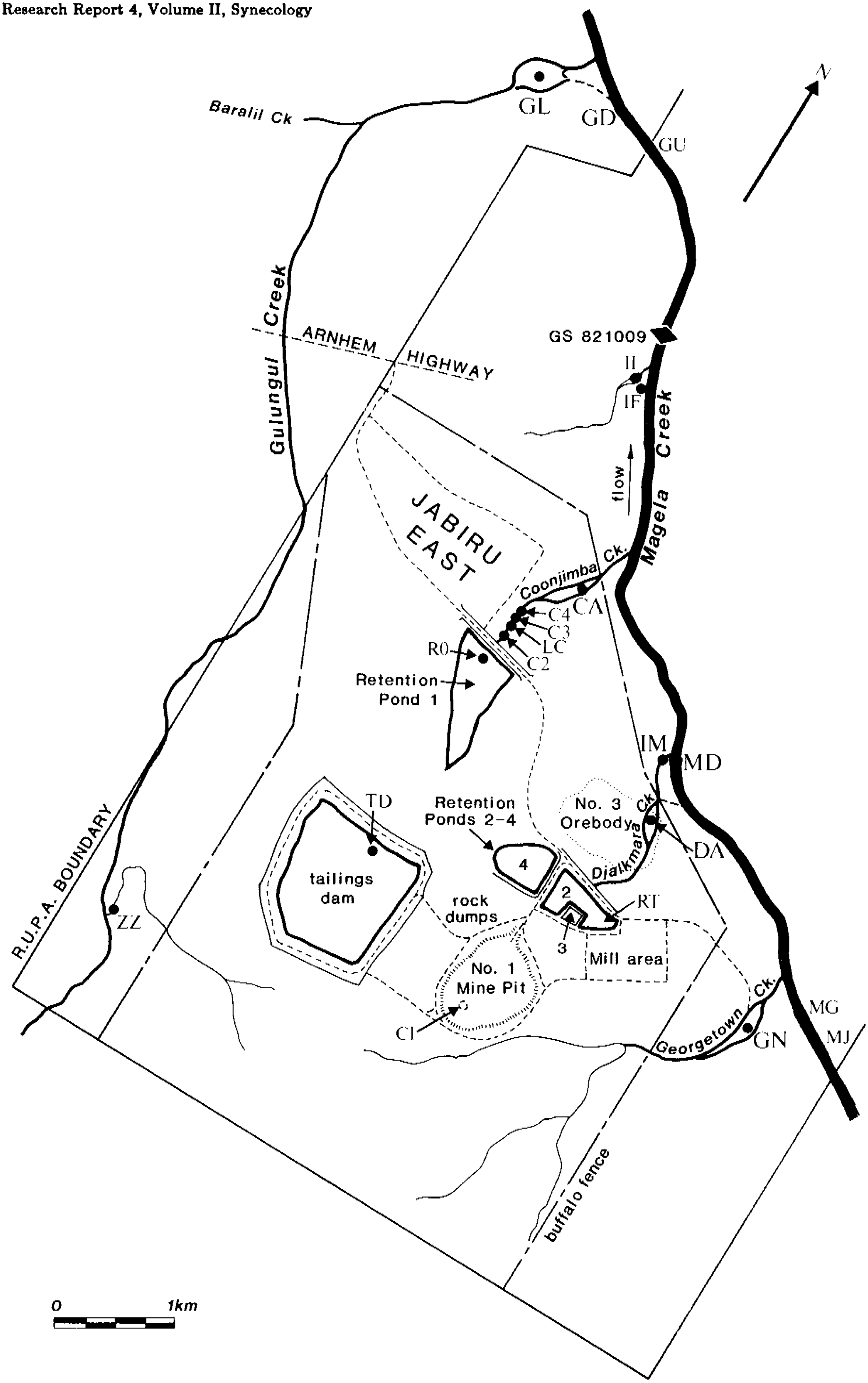
Details of the sampling sequence and sites sampled are given in the 'Materials and methods' section of volume I (section 3.1, pp. 15-19). A summary table of regular and occasional sampling sites, grouped according to drainage systems, geographical zones and habitat types is also given in volume 1 (table 5, p. 19). The sites, site codes, grid references, and latitude and longitude are listed in volume 1, table 4, pp. 16-18. Appendix 3 (this volume) lists the sites alphabetically by site code. Maps 2 and 3 in this volume illustrate site locations with respect to the drainage systems and to the mining operations in the Alligator Rivers Region.

The sampling sites were selected to represent the following twelve aquatic habitats:

- plateau area habitats, (two sites were sampled occasionally);
- escarpment area habitats, comprising main-channel area habitats (two sites were sampled regularly and six sites were sampled occasionally), seasonal feeder streams (one site was sampled regularly and three sites were sampled occasionally) and perennial streams (two sites were sampled regularly and one site was sampled occasionally);
- lowland habitats, containing sandy creek beds pool/channels (three sites were sampled regularly and eight sites were sampled occasionally) and backflow billabongs (ten sites were sampled regularly and ten sites were sampled occasionally);
- corridor habitats (three sites were sampled regularly and seven sites were sampled occasionally);
- lower (riverine) floodplain billabong habitats (two sites were sampled occasionally); and
- estuarine habitats, comprising upper reaches (two sites sampled occasionally) and middle and lower (meandering) reaches (two sites were sampled occasionally).

A detailed description of these habitats is given in volume I (section 2.2, pp. 5-14) and illustrated in plates 1-6 of the same volume.

This habitat classification system provides a consistent geographical/environmental base for the structure of this Volume (Vol. II). Anomalies in community structure, how-




Map 3. Layout of the Ranger Uranium Project Area in relation to the Magela Creek drainage system, showing locations of sampling sites not included on Map 2. Regular sampling sites are identified by larger type, occasional sites by smaller.

ever, particularly those of site groupings, influenced the analysis of aspects of the biology of particular fish species. These aspects are described in volume III.

## 2.2 Recording of environmental data

Habitat-structural, physico-chemical and general habitat variables relating to the whole waterbody, rather than the immediate fishing area, were collected for each site sampled during the study period. The recording methods employed are described in detail in volume I (section 3.2; appendixes 1, 2). Keys to the codes used in the summary figures of habitat-variables used in this volume are given in Appendix 2 (Vol. II, Appendix 2). Site codes used in the tables and illustrations are given in the text and Appendix 3 of this Volume. The map coordinates for the site locations are tabled in volume I (table 4, pp. 16-18).

## 2.3 Collection and observation of fishes

The techniques employed to obtain a representative fish community sample at each site are described in detail in volume I (section 3.3, pp. 20-21). Two standard (regular and repeatable) collecting methods were used, that of multiple-mesh-sized monofilament gillnets (gn) and seine nets (sa). Underwater observations were also used to replace standard netting methods in escarpment sites where these would be likely to create an undesirable fishing pressure. The other collecting and observation methods employed, in addition to the above standard methods, were spears, lines, castnets, dipnets, poisioning and the inclusion of natural fish kills.

## 2.4 Recording of fish catches

### Field and laboratory procedures

These procedures are described in detail in volume I (section 3.4, p. 21; appendix 4, 5). Information on the freshwater and estuarine fish catches and/or fish species observed at the sampling sites were listed by species name and number on data card B (see Appendix 1), in the field. Appendix 1 gives an updated species list, which includes an additional six estuarine species not included in the revelant appendix and table in volume I (appendix 3; section 1, table 1). Each card line in Appendix 1 contains the sample reference number corresponding to that on the environmental card A (see vol. I, appendix 1, pp. 39-40) and the general habitat card E (vol. I, appendix 2).

## 2.5 Data treatment and analysis

A short discussion of the species diversity indices, pertinent to the synecology studies in this volume is given in volume I (section 3.4, p. 21). The sampling unit is the catch of fish collected at each site during a sampling session by means of standard netting methods, normally with a multiple-mesh-sized monofilament gillnet and a 10m long seine net (methods coded as 'gn' and 'sa' respectively; see vol. I, section 3.3, pp. 20-21). In some escarpment sites, however, 'catch' was assessed by underwater observations in preference to netting (see above or vol. I, section 3.3 for a discussion).

The array of numbers of specimens representing each species in each sample, is defined here as the 'catch abundances'. The catch abundances will be referred to for convenience as 'abundances' from here on. The abundances reflect the structure of the sampled community and when compared between sites, habitats or seasons can be used to delineate, by inference, the more obvious spatial and temporal patterns in community structure. Catch abundances, however, cannot accurately enumerate the population densities of each species from the sampled communities.

Catch weights relate to the array of summed weights of specimens representing each species collected by standard sampling techniques. Such catch weights may reflect to some extent the biomass of species both spatially and temporally in the sampled communities. Such delineation is dependant on the standardised nature of the source of these data. Catch weights will be referred to for convenience as 'weights' from here on.

## Community summary-feature variables

There are six derived variables in this set. Two of these relate directly to catch abundances and to catch weights. The *total abundance* of a sample is defined as the catch abundances totalled across all species. The *total weight* of a sample represents the catch weights totalled across all species.

The other four variables are derived measures of species diversity. The *number of species* in each sample reflects, to some extent, the number of species in the sampled community. The concepts and related indices of *richness*, *evenness* and *heterogeneity* are used as a measure of species diversity. These concepts are detailed in volume I (section 3.4, pp. 21-22) and the formulae for their derivations are repeated below.

Heterogeneity (H), was measured by the Shannon-Weaver Index (hereafter referred to simply as the Shannon Index):

$$H = -\sum_{i=1}^{s} \frac{n_i}{N} \ln \frac{n_i}{N}$$

where: s = number of species in the sample
$n_i$ = abundance of species i in the sample
N = abundance of all individuals in the sample

Evenness (E) was measured with the scaled Shannon Index:

$$E = \frac{H}{\ln s}$$

Richness (R) was measured by the Gleason Index:

$$R = \frac{(s - 1)}{\ln N}$$

## Community composition variables

Community composition, refers to the array of abundances of each species collected by standard methods at each sampling site during a season. Community composition data will be referred to for convenience as 'community' data from here on.

The techniques of multivariate analysis were used to reveal the patterns and structures in the multi-dimentional community data collected during this study. Only rudimentary mutivariate analysis of the community abundance data is reported here. Further detailed analysis will take place as additional community data are obtained.

The following analysis are reported Section 4.2:

- Combined-seasons analysis. The composition of community samples from sites sampled regularly was compared after data was combined over five seasons to represent the 'state' over one entire climatic cycle.

- Analysis of seasonal changes. The composition of community samples from sites sampled regularly was compared on a habitat basis between three critical seasons; the 1978 Late-dry, 1978-79 Mid-wet and 1979 Late-wet-Early-dry seasons.

### Combined-seasons analysis

Community data from twenty-six regular sites were considered suitable for analysis. In the Magela catchment these sites were:

- Bowerbird Billabong, an escarpment main-channel waterbody;

- Radon Springs, an escarpment perennial stream;

- the two lowland sandy creek bed sites (GD & MD);

- Fishless, Georgetown, Djalkmara, Indium, Coonjimba, Goanna, Gulungul and Corndorl billabongs, which are classified as lowland backflow billabongs;

- the corridor waterbodies, comprising Buffalo and Island billabongs, and the Mudginberri corridor;

- Ja Ja, Leichhardt, Jabiluka and Nankeen billabongs, which are on the upper floodplain.

In the Nourlangie catchment these sites were:

- Sawcut Gorge, an escarpment main-channel waterbody;

- Noranda pools and a Hickey Creek tributary pool (SZ), which are escarpment seasonal feeder streams;

- Baroalba Springs, an escarpment perennial stream;

- Nourlangie crossing 2, a lowland sandy creek bed pool; and

- Anbangbang and Malabanbandju billabongs, which are lowland backflow billabongs.

Where possible, community data were summed across five seasons (1978 Late dry to 1979 Mid-dry) to give the combined-season composition for each site. For some sites, where no data were available for 1978, data from the 1979 Late-dry and 1979-80 Early-wet were used. Complete seasonal community data were not available for three of the sites: Fishless Billabong (FS), Noranda pools (NS), and the Hickey Creek tributary pool site, SZ (see Map 2). They were included in the analysis, however, as the available data appeared to be comparable in terms of the extent of within-year variation present. All *Ambassis* species were grouped together because of taxonomic difficulties.

The resultant community data matrix had 32 species-columns by 26 site-rows. Two multivariate analysis techniques were used to examine this matrix:

*Ordination.* Ordination summarises community data by displaying them in a low-dimensional (2-3 dimensions or factors) ordination space in which species with similar distributions or samples with similar compositions are grouped together. Reciprocal Averaging (Hill 1973) was used from the DECORANA (Hill 1979*a*) computing package. Reciprocal averaging is related to simple weighted averages and to eigenvector ordinations. The option in which rare species are down-weighted was used in all analyses to ensure the emergence of major patterns.

*Classification.* Two-way Indicator Species Analysis was performed, using the TWINSPAN (Hill 1979*b*) computing package. This technique is a polythetic (e.g. using abundance data rather than just presence-absence data) divisive hierarchical (showing a heirarchy of relationships arranged in a tree diagram or dendrogram) classification technique. Such a classification is used to summarise large community data sets by hierarchically clustering species with similar abundance distributions across the sites, or sites with similar community compositions. Only the latter classification approach, (site clustering) was applied.

**Factors associated with community composition differences.** Factors contributing to community composition differences were investigated by calculating Pearson's product moment correlation coefficients between five physiographic variables and the first two axes of the reciprocal averaging site ordination.

The physiographic variables which were recorded for each of the 26 sites were as follows:

- distance to estuarine reaches (km)
- stream order
- elevation (height above sea level; m)
- volume factor ($\log_e$ of volume factor in $m^3$)
- gradient (m rise/km)

(see vol 1, section 3.2-3.3; gradient measurements were calculated from topographical maps).

The relationships amongst these variables were investigated as it was unlikely that any of these variables was completely independent of the others. Pearson's correlations were calculated to identify these variable complexes.

**Analysis of seasonal changes**

Seasonal changes in community composition were examined using reciprocal averaging ordination analysis. The matrix to be ordinated comprised 32 species columns by 21 habitat-season rows. The 21 rows were for the following seven habitats in each of the three seasons:

- Escarpment seasonal streams (ESS)
- Escarpment perennial streams (EPS)
- Escarpment main-channel waterbodies (EMW)
- Lowland sandy creek beds (LSC)
- Lowland backflow billabongs (LBB)
- Corridor waterbodies (CW)
- Floodplain billabongs (FB)

Where a given habitat type was represented by more than one site, the abundance values were means of the values at the various sites.

This grouping of sites by habitat type was used in preference to the groupings revealed by the ordination and classification analyses discussed above in order to make it easier to relate findings to the environmental changes described in the summary section. Within the habitat type groupings, some compromise in the use of data was made where data were not available for a particular season; the most notable was where Mid-dry season data for the escarpment main-channel waterbodies (EMW), were used to represent the Late-wet-Early-dry season condition.

The data in this matrix were then subject to ordination analysis. In the course of the ordination analyses some habitat groups were removed in order to clarify the patterns of seasonal composition changes. The escarpment stream groups (ESS and SPS), were removed from the habitat data matrix as their characteristic communities accounted for the majority of variation in the ordination analyses and so masked the effects of other factors affecting community composition.

# 3

# Results

A key to the habitat-structural variables, used in the figures of the following sections, is given in Appendix 2. Appendix 3 (this Volume) lists the sites aphabetically by site code. The exact locations of the sampling sites and the codes used in the maps, figures and tables for this volume are detailed in table 4, vol. I, pp. 16-18 and their use for regular or occasional sampling in table 5, vol. I, p. 19.

## 3.1 Plateau habitats

The Arnhem Land plateau in this area is rarely entered by Europeans, because of its Aboriginal reserve status and the wild and inaccessible nature of its rugged terrain. Fish sampling in these areas, therefore, has been limited to the brief reconnaissance surveys by Midgley (1973) and by the present authors. The fish species surveyed, appear representative of the communities present in these habitats.

**Environment.** As research workers rarely visit the plateau, environmental information is scant. Stream flows scour the plateau creekbed channels in the Wet season, from December to April. Spectacular cascades and large, swirling pot-hole pools are characteristic of this habitat in the Wet. As the flow subsides isolated pools are left on the plateau. Some of the deeper ones, with bedrock substrates, last throughout the Dry season. In some areas, such as above Kolondjarluk Falls (KD, Map 2), a slight flow persists throughout the Dry season.

The pools generally contract in the Dry season to < 20 m in length and < 1.5 m in depth. Their substrate is mainly bedrock interspersed with areas of sand, gravel and shingle. Bank vegetation is usually scant, being restricted mainly to terrestrial grasses, shrubs and *Pandanus aquaticus*. Water temperatures (surface and bottom), fluctuate around 30°C towards the Late-wet season and may reach 35°C during the Late-dry season. The low turbidity readings, usually Secchi depth > 1.5 m, indicate clear water with good light penetration. Large blooms of benthic filamentous green alga (e.g. *Mougeotia* sp.), occur during the Late-wet and Dry seasons. Other aquatic vegetation is very limited, though *Eriocaulon setaceum*, *Myriophyllum* spp., *Vallisneria* sp. and *Nymphoides furculifolia* may occur on suitable sand and gravel substrates in the Wet season.

**Fish communities.** The numbers of fish, captured or surveyed during underwater observations in plateau habitats, by Midgley (1973) and in this study, are shown in Table 1.

Seven species of fish have been recorded from streams on the sandstone plateau. These species have also been collected from habitats below the plateau and are frequently common to the escarpment zone. Sampling suggests that the plateau fish fauna contains fewer species than that of most downstream habitats. An inverse relationship between the number of fish species found and the elevation of a given site is described in Section 4.2. The escarpment habitat sites showed the greatest rate of change in this relationship.

The most abundant fish species found on the plateau were the melanotaeniids (possibly only two species, as *Melanotaenia* sp. may be either *M. nigrans* or *M. splendida australis*), followed by *Mogurnda mogurnda*, *Leiopotherapon unicolor*, *Ambassis* sp. and *Neosilurus* sp. The most widely distributed fish on the plateau was *M. mogurnda*, which was the only species collected at two of the sites.

The most diverse plateau fish fauna recorded was collected above Jim Jim Falls, by Midgley on 13.x.72.

## 3.2 Escarpment area habitats

### Main-channel waterbodies

**Environment.** In the Wet season the plateau floodwaters cascade and fall into large, extremely turbulent main-channel rock pools in the upper reaches near the escarpment. As the Wet season flow subsides, these rock pools usually become isolated from other main-channel waterbodies. Areas of steeply shelving bedrock, strewn with large boulders and interrupted by a series of vertical drops (> 1 m), are frequently encountered when approaching these pools from the lower reaches of the escarpment area. The pools below Kolondjarluk Falls (≈ 30 m long × 20 m wide × 15 m deep; KD, Map 2), at the base of the Magela Falls (≈ 40 m long × 30 m wide × 8 m deep; BF, Map 2) and Jim Jim Falls (≈ 100 m long × 120 m wide × 10 m deep; JD, south of Map 2), were surveyed during the 1978 Late-dry, 1979 Mid-dry and 1979-80 Early-wet (no flow) seasons.

In 1978 during the Mid-dry season, the lowest turbidity reading of this study was recorded at the Kolondjarluk Falls site. The bottom of the pool could be clearly seen by a diver on the water surface, a depth of > 15 m. Visibility through the water at this site, however, was reduced to approximately 5 m in the following Late-dry season. Higher turbidity was recorded at Magela Falls (Secchi depth = 2 m) and Jim Jim Falls (Secchi depth = 5 m), where the water was less clear. These lower Secchi depth readings resulted from the high densities of phytoplankton in these main-channel waters. When Magela Falls was surveyed there was a very thick phytoplankton 'soup' to a depth of 1 m across the bottom. The horizontal, vertical and undercut bedrock and boulder substrates, characteristic of these habitats, were also found to be covered by 10 to 20 mm of thick diatomaceous slime. Even the sandy substrates, less common in these habitats, had a layer of this periphyton present. No hydrophytes were found at these sites.

Surface and bottom temperatures were 29°C and 27°C at Magela Falls and 30°C and 26°C at Jim Jim Falls. These are small temperature differences for relatively deep pools. Conductivities ranged from 6 to 10 $\mu$S/cm and the pH ranged from 6.4 to 7.0.

Figure 1 and Fig. 2 summarise the habitat-structural and physico-chemical variables recorded while sampling fish in the lower reaches of escarpment main-channel waterbodies at Bowerbird Billabong on the Magela Creek (BD, Map 2) and Sawcut Gorge, on Hickey Creek (ST, Map 2).

Water flowed through Bowerbird Billabong and the Sawcut Gorge waterbody throughout the study period. In the Dry season, however, the flow was reduced to a discharge of < 0.01 $m^3/s$. During the Wet season, Sawcut Gorge was sampled in a period of relatively low throughflow, giving the appearance of a consistent area factor throughout the study (Appendix 2, Fig. 2a). Sawcut Gorge also had much steeper banks than Bowerbird Billabong, which reinforced this effect. Bowerbird Billabong was sampled in the Wet season during a waning flood peak. At this time, a large area of the gently sloping banks, depressions and low level sandy/rocky anabranches had become inundated. This waterbody no longer had a discrete exit, as in the 1978 Late-dry season, but rather a multitude of outflows, from torrents to trickles, running through the surrounding bushland. Torrential flows with velocities 1 to 2 m/s were recorded in the upper sections of Bowerbird Billabong where a shelf of bedrock emerged. Although this flow was substantially reduced when it met the main body of water, large eddy currents and water velocities up to 0.5 m/s were recorded.

Cover over the water from surrounding bank vegetation and other material remained consistently high at both sites throughout the study. *Pandanus aquaticus* and *Melaleuca* spp. offered the most cover at Bowerbird Billabong. Rainforest trees and partly submerged logs, as well as *P. aquaticus*, covered the water at Sawcut Gorge. During the Wet season, terrestrial

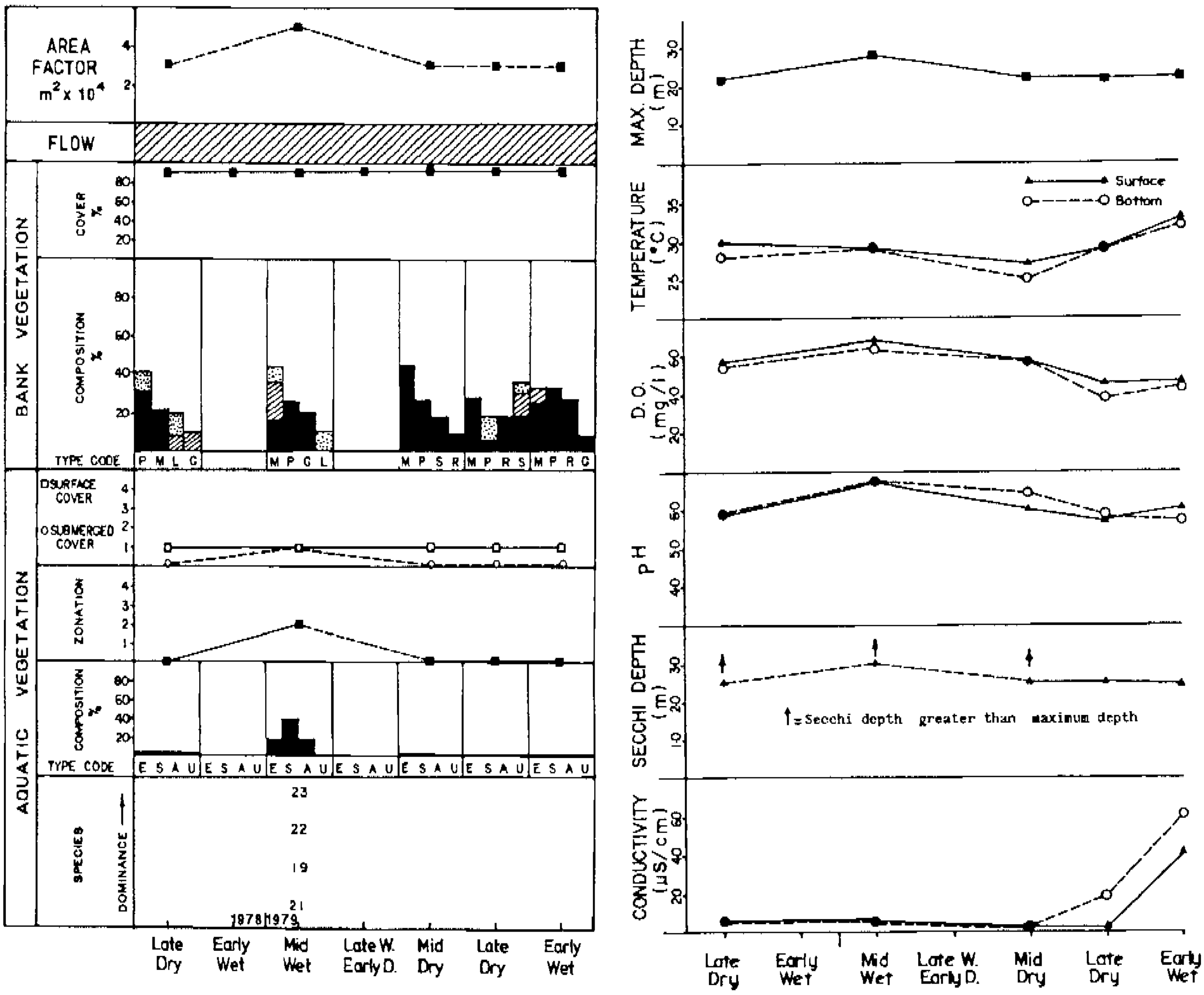



Figure 1. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a main-channel escarpment waterbody, Bowerbird Billabong (BD). See Appendix 2 for a key to the habitat-structural variables.

grasses became important at Bowerbird Billabong, with the submerged roots of rainforest trees becoming an important facet of cover at Sawcut Gorge. The contribution of bedrock and boulders to the cover at both sites was low and variable, as was that of the rainforest, at Bowerbird Billabong. This probably reflects some inaccuracy in the visual estimation of cover at these sites.

Aquatic hydrophytes are rare in the escarpment habitats; hence both the surface and the submerged cover were consistently low at both sites. Floating leaves from terrestrial plants contributed most to the water surface cover. A limited growth of aquatic hydrophytes, however, did occur in the Wet season over some submerged clayey banks and in the more permanently submerged, slow-flowing anabranches where there were suitable sand/silt and leaf litter-rich substrates. This effect was most apparent at Bowerbird Billabong, where some slow-flowing anabranches contained submerged (*Vallisneria* sp., *Hydrilla verticillata* and *Myriophyllum* spp.), emergent (*Eriocaulon setaceum*) and floating attached (*Nymphoides* sp.) aquatic vegetation. The increase in the degree of zonation at Bowerbird Billabong, corresponded to the occurrence of such hydrophytes during the Wet season. Patches of *Myriophyllum* spp. were recorded in the Dry season on shingle-based riffle areas upstream and downstream of the major waterbodies. Aquatic mosses and fungi were observed on submerged living and

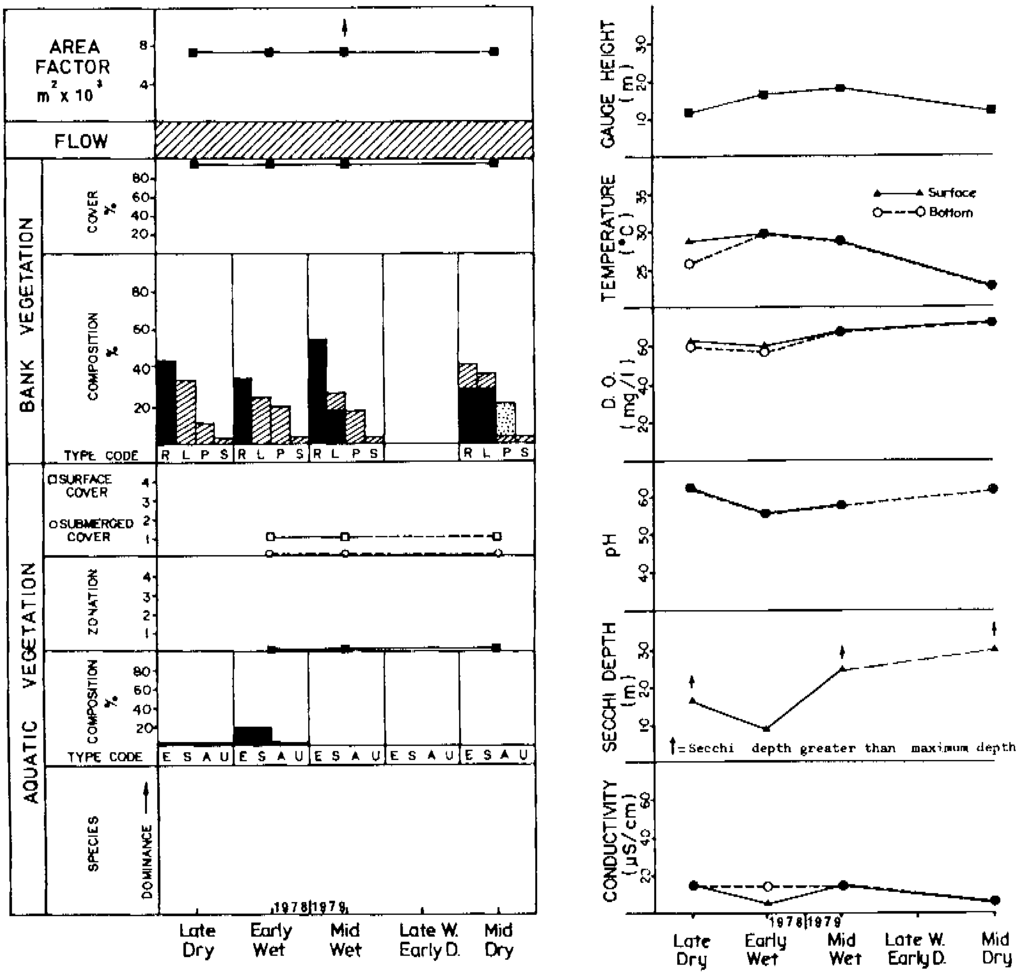


Figure 2. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a main-channel escarpment waterbody, Sawcut Gorge (ST). See Appendix 2 for a key to the habitat-structural variables.

dead wood substrates at both sites throughout the study.

Sand was the dominant substrate at both sites. The next most important substrates present were horizontal shelving at Bowerbird Billabong and vertical outcropping bedrock at Sawcut Gorge. Submerged (normally terrestrial) clay/sand substrates with mixed leaf litter became more important in the Wet season at both sites.

The Bowerbird Billabong sampling site had a maximum depth range of 2.5 m to 3.5 m, while that at Sawcut Gorge ranged from 1.5 m to 3.0 m. During the Dry season, Bowerbird Billabong was 40 m × 1000 m with a maximum depth of 5.5 m, while the waterbody at Sawcut Gorge was 25 m × 300 m and had a maximum depth of 6.7 m. Gauge height readings at both sites peaked during the Wet season. Surface water temperatures, ranging from 27°C to 33°C at Bowerbird Billabong and from 23°C to 30°C at Sawcut Gorge, were highest during the Early-wet and lowest during the Mid-dry seasons, at both sites. Bottom water temperatures ranged from 25°C to 32°C at Bowerbird Billabong and from 23°C to 30°C at Sawcut Gorge. Surface and bottom water temperatures were essentially the same at Sawcut Gorge, except during the 1978 Late-dry season. Water temperatures at Bowerbird Billabong were most similar in the 1979 Mid-wet and Late-dry seasons and most dissimilar in the 1978 Late-dry and 1979 Mid-dry seasons.

Dissolved oxygen concentrations at the surface ranged from 4.5 to 6.5 mg/L at Bowerbird Billabong and from 6.0 to 7.2 mg/L at Sawcut Gorge. The surface waters were therefore always well oxygenated, with the highest dissolved oxygen concentrations occurring during the Mid-wet at Bowerbird Billabong and the Mid-dry season at Sawcut Gorge. Dissolved oxygen concentrations at the bottom were always very close to surface concentrations (especially at Sawcut Gorge) and ranged from 3.8 to 6.3 mg/L at Bowerbird Billabong and from 5.9 to 7.2 mg/L at Sawcut Gorge.

Surface pH ranged from 5.7 to 6.7 at Bowerbird Billabong and from 5.6 to 6.3 at Sawcut Gorge. Bottom pH closely followed surface pH, with the greatest differences occurring at Bowerbird Billabong during the 1979 Mid-dry and 1979-80 Early-wet seasons. Surface and bottom conductivity remained similar and low (2 to 16 $\mu$S/cm), at both sites through to the 1979 Mid-dry season. Thereafter the surface conductivity began to rise at Bowerbird Billabong, so that, by the 1979-80 Early-wet season, the surface and bottom conductivities were 40 and 60 $\mu$/cm respectively. No corresponding conductivity results exist for Sawcut Gorge, as sampling at this site ceased after the 1979 Mid-dry season.

Between the 1978 Late-dry season and the end of the following Wet season, the clear water at Bowerbird Billabong ensured that the bottom was visible from the water surface. After the Wet season, as the phytoplankton population built up through the 1979 Dry season, the increasing turbidity at this site reduced the visibility through the water, (Secchi depth = 2.5 m). At Sawcut Gorge, however, the water remained clear and the bottom visible from the water surface, except at the commencement of the water flow during the 1978-79 Early-wet season. At this time the turbidity increased and the Secchi depth readings dropped to < 1 m. After the Wet season, the turbidity stabilised at a Secchi depth of 2.5 m, as phytoplankton populations built up through the 1979 Dry season.

Twin Falls Billabong (on Jim Jim Creek; TW, south of Map 2) and Camp 1 Billabong (on Kolondjarluk Creek; CP, Map 2) are lower-reach main-channel escarpment waterbodies which resemble both Bowerbird Billabong and Sawcut Gorge in many respects. Both of these waterbodies (Twin Falls and Camp 1 billabongs), however, have a higher proportion of submerged or vertical outcropping bedrock substrates.

**Fish communities.** The abundances of species and size ranges of fish observed in various main-channel escarpment waterbodies at specific times during the study are shown in Table 2. Samples from waterbodies closer to the lowlands (Bowerbird, Twin Falls and Camp 1 billabongs), were more diverse (18, 19 and 19 species respectively), than sites in the upper reaches of the escarpment area immediately below large waterfalls dropping from the plateau, (i.e. sites at Magela Falls, Jim Jim Falls and Kolondjarluk Falls, which had 3, 4 and 4 species, respectively). These terminal waterbodies of the upper reaches contained few species and were occupied by large populations of *L. unicolor* and *Hephaestus fuliginosus* and, to a lesser extent, *Syncomistes butleri* and *Pingalla midgleyi*. *Melanotaenia nigrans* was less frequently observed in the terminal waterbodies of Magela Creek catchment and *Glossogobius giurus* in those of the South Alligator River catchment.

The number of fish species detected by underwater observations in the lower reaches of the main-channel escarpment waterbodies was greater than that in any of the seasonal or perennial escarpment streams. *Craterocephalus* nov. sp., *Ambassis* spp., *Amniataba percoides* and *L. unicolor* were abundant in the lower reach main-channel habitats, while *Melanotaenia splendida inornata*, *H. fuliginosus*, *S. butleri*, *P. midgleyi* and *Toxotes chatareus* were also commonly observed. *Anodontiglanis dahli* and *Toxotes lorentzi* were observed only in the South Alligator River catchments.

Standard netting methods, in preference to underwater observation, were used regularly at the Bowerbird Billabong site and at Sawcut Gorge to survey the fish fauna and to permit seasonal comparisons to be made with the fish communities in the more turbid habitats further downstream from the escarpment area. Sampling could not be undertaken during every sampling period owing to difficulty of access.

The abundance and weight of fish species captured during the study using standard netting methods in Bowerbird Billabong and Sawcut Gorge are shown in Tables 3a and 3b, respectively. The seasonal total abundance, total weight, number of species, richness and Shannon diversity and evenness indices obtained with standard netting methods at these sites is summarised in Fig. 3.

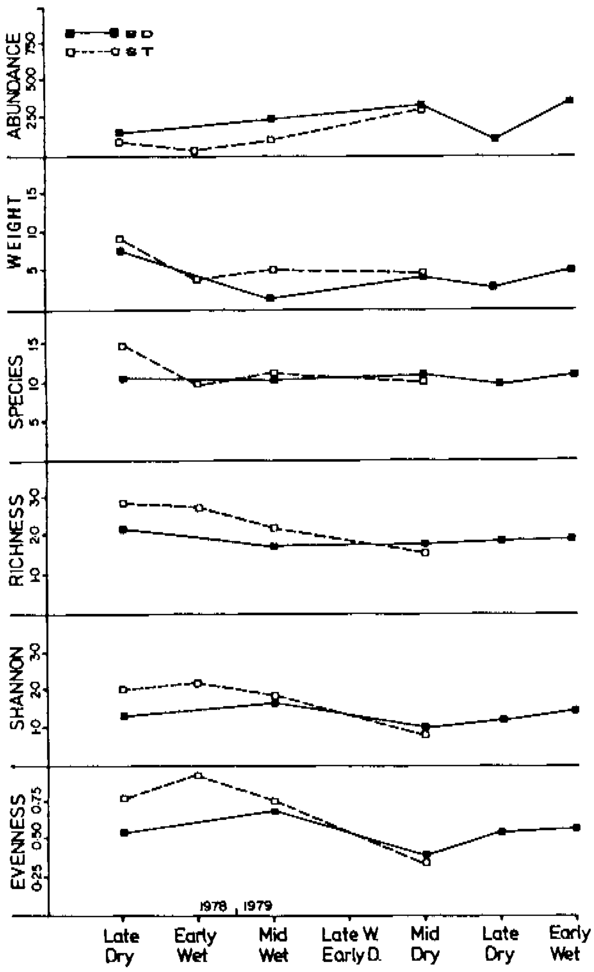



Figure 3. Summary of seasonal abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken at the main-channel escarpment waterbodies, Bowerbird Billabong and Sawcut Gorge.

Catches were obtained using standard netting methods.

The total number of fish species collected by standard netting methods during the study was 19 at Bowerbird Billabong and 18 at Sawcut Gorge. Additional species were shown to be present when non-standard capture methods were employed at these sites. Three fish species, *Pseudomugil tenellus* (poisoning), *Ambassis agrammus* (underwater observation) and *M. mogurnda* (spear fishing) brought the total number of fish species present at Bowerbird Billabong to 22. Five additional fish species were shown to be present at Sawcut Gorge, giving a total fish species number of 23; *Scleropages jardini* (baited hook and line and underwater observation), *Lates calcarifer* (underwater observation), *P. midgleyi* (morning netting in multiple-mesh-sized monofilament gill nets), *Glossamia aprion* (underwater observation) and *Oxyeleotris lineolatus* (dip netting).

The five most abundant species over the whole sampling period at Bowerbird Billabong were *Caterocephalus* nov. sp, *Craterocephalus stercusmuscarum, Ambassis macleayi, M. splendida inornata* and *A. percoides* and the five most abundant species at Sawcut Gorge were *Craterocephalus* nov. sp., *A. percoides, M. splendida inornata, Tandanus ater* and *A. agrammus.* Three of these species were common to both sites.

At both sites, seasonal trends in the total abundance (Fig. 3) generally followed changes in the catches of *Craterocephalus* nov. sp. Catches of *C. stercusmuscarum* also contributed to trends in the total abundance at Bowerbird Billabong. Trends in the Shannon diversity and evenness indices were, therefore, usually inversely related to patterns of changing abundance. At Bowerbird Billabong, total abundance was lowest during the Late-dry seasons and increased to a maximum at this site in the 1979-80 Early-wet season. At Sawcut Gorge, total abundance was reduced to its lowest value during the 1978-79 Early-wet season. Catches peaked in total abundance during the 1979 Mid-dry season at both sites. The total number of species captured at each site was generally stable throughout the study, with 10 to 12 species being captured during each sampling period. During the 1978 Late-dry season, however, 13 species were caught at Sawcut Gorge.

The richness indices were also stable throughout the sampling period at Bowerbird Billabong, but at Sawcut Gorge species richness decreased as total abundance increased.

The five species which contributed most to the total weight of fish captured during the whole sampling period were *T. ater*, *A. percoides*, *Nematalosa erebi*, *S. butleri* and *S. jardini* at Bowerbird Billabong and *Arius leptaspis*, *T. ater*, *S. butleri*, *T. chatareus* and *N. erebi* at Sawcut Gorge. Three of these species, therefore, contributed most to the total weight at both sites. From the 1978 Late-dry season into the Wet season, total weight at both sites decreased as a result of reduced catches of *A. leptaspis* and *T. ater*. During the later sampling periods, the total weight at Sawcut Gorge stabilised at lower levels, with *S. butleri*, *T. chatareus* and *A. percoides* contributing most to the weight of the catch. *A. dahli* and *Strongylura krefftii*, however, dropped out from the catch altogether. At Bowerbird Billabong, however, the total weight increased steadily up to the following Early-wet season from a minimum total weight in the Mid-wet season. *Tandanus ater*, *N. erebi* and *S. butleri* were the main contributing species.

*Hephaestus fuliginosus* was observed regularly and was easily captured at both sites using a baited hook. This species was not captured regularly by the standard netting methods, indicating that some behavioural factor was causing it to avoid our nets. Midgley (pers. comm.) noted that only 2 or 3 specimens were observed, but none caught, in a few kilometres of the main channel at Bowerbird Billabong and Sawcut Gorge during the 1979-80 Wet season. Similar evasion of our nets by *S. jardini* and *L. calcarifer* may have occurred. *Mogurnda mogurnda* was found, commonly after poisoning, in a rocky anabranch off Bowerbird Billabong during the Mid-wet season, indicating that this species may be more common and widespread than is indicated by standard netting methods, which are effective in rocky streams. Only one large adult specimen of *O. lineolatus* was found in the main-channel waterbody at Sawcut Gorge and none at Bowerbird Billabong, which suggests that this species is probably rare in these habitats.

A small weir (0.4 m high) across Hickey Creek near Sawcut Gorge undoubtedly affected catches of fish in adjacent areas of the creek. During low flow conditions many species (*Megalops cyprinoides*, *A. percoides*, melanotaeniids and *P. midgleyi*) were observed schooling below the dam, presumably attempting to migrate upstream past this barrier.

**Seasonal feeder streams**

**Environment.** The sampling site at Noranda pools (on Noranda Creek; NS, Map 2) is part of an escarpment seasonal stream which runs downstream across rocky terrain to the sandy lowlands and does not feed into a main-channel waterbody. This area overlies the Koongarra uranium deposit near the Mount Brockman/ Nourlangie rock massif and the catchment is barren rocky country with thin sandy soils and scant dry sclerophyll forests. There was seepage between the pools along the stream bed when the area was examined in the 1978 Late-dry season and a substantial flow in the Early-wet season. The rock pool surveyed was approximately 4 m in diameter and 0.5 m deep. It was surrounded by sparse *Melaleuca* forest and bordered by grass (*Cyperus* sp.) on its shallow, sloping banks. This pool was positioned on a bedrock outcrop with a substrate mainly composed of leaf litter and sand. The water contained many fallen branches. There was also another sedge, *Fimbristylus minima* present, and submergent (not emergent as it was not flowering), *Eriocaulon setaceum*. No filamentous algae were apparent. In the Late-dry season, the surface and bottom water temperatures were 33°C and 31°C respectively. During the Early-wet season temperatures were a uniform 29°C. Conductivity was a low, 4 μS/cm in the Late-dry season and 6 μS/cm in the Early-wet season. The water was generally well oxygenated with a surface dissolved oxygen concentration of 6.5 mg/L and a bottom dissolved oxygen concentration of 5.3 mg/L. The pH was always extremely low, 4.2 in the Late-dry and 3.9 in the Early-wet seasons.

Site SZ (Map 2), is a pool on an escarpment seasonal stream which feeds into Hickey Creek, a main-channel waterbody, during the Wet season. It is isolated from Hickey Creek in the Dry season by a rocky, tree-root-entangled creekbed area just below the pool. This creekbed area drops sharply (20 m vertically in 100 m), to a dry, sandy creek bed 300 m upstream of the main-channel escarpment stream sampling site at Sawcut Gorge. Upstream from site SZ, the creek bed rises sharply, (30 m vertically in 100 m), across steeply sloping bedrock strewn with large boulders, making the ascent difficult. In this upstream section, there are a number of small rock pools in the Dry season which are transformed into scenic cascades in the Wet season. The largest cascade is at the base of Sawcut Gorge Falls, a drop of 100 m.

The pool at site SZ is 10 m wide and 20 m long, with a maximum depth of 2 m in the Dry season and 2.5 m in the Wet season. It is surrounded by overhanging rainforest vegetation, the roots of which bind the rocky substrate that borders the downstream end of the pool. Partly submerged *Pandanus aquaticus* are also present. Outcropping bedrock, which steeply borders most of the pool, is the dominant substrate. Smaller rocks and sand are less frequent substrates. There were no hydrophytes. Aquatic mosses, fungi and the sponge *Spongilla* sp. covered some rocky substrates. During the Early-wet and Mid-wet seasons, the bottom was clearly visible from the surface of the water. An increase in the phytoplankton density, however, caused an increase in turbidity (Secchi depth = 1.5 m) during the Mid-dry season. Epiphytic algae and a green surface alga also appeared in the pool during the 1979 Mid-dry season.

Surface (28°C) and bottom (26°C) water temperatures at site SZ were highest and most dissimilar from each other in the Early-wet season. Both fell to 23°C, one of the coolest temperatures recorded at any site during the study, during the Mid-wet and Mid-dry seasons. The surface and bottom waters were always well oxygenated (the dissolved oxygen level = 7.2 mg/L). Surface and bottom pH (6.2) and conductivity (6 $\mu$S/cm) were usually stable.

**Fish communities.** The abundances and weights of fish species collected with a 5 x 2 m seine net (mesh size = 2 mm), at the Noranda pools site, during the 1978 Late-dry and 1978-79 Early-wet seasons are shown in Table 4. Only three species were found at this site, *M. nigrans*, *M. mogurnda* and *L. unicolor*. By far the most abundant species was *M. nigrans*.

The abundances and size ranges of the fish species observed at site SZ during the Early-wet, Mid-wet and Mid-dry seasons are shown in Table 5. Six species were observed in the pool during the study. Three of these species were present in the 1978-79 Early-wet season, *M. nigrans*, *L. unicolor* and *P. midgleyi*. *M. cyprinoides*, *M. splendida inornata* and *H. fuliginosus* were also present by the Mid-wet season. During the following Mid-dry season, however, when the pool had become isolated from Hickey Creek, *M. cyprinoides* was no longer observed in the pool. The most abundant fish species at site SZ were *M. nigrans* and *L. unicolor* and the least abundant were *M. cyprinoides* and then *H. fuliginosus*. The abundances and size ranges of fish species observed during the 1978-79 Mid-wet season from a Hickey Creek tributary pool, site SY (Map 2), a sandy reach downstream of SZ, to above site SZ along the seasonal escarpment feeder stream are shown in Table 6. The number of fish species observed decreased with increasing elevation upstream from the pool at the SZ sampling site. Only 2 species, *L. unicolor* and *H. fuliginosus*, were observed in the stream 10 m above this pool. No fish were found in the stream below Sawcut Gorge Falls (about 30 m above site SZ). *Megalops cyprinoides* was not found below the pool at site SZ, probably because of the scant cover available at that site. In this feeder stream, the fish fauna contained fewer species (6) than downstream in the main Hickey Creek channel (24 species). All the species collected in the stream were also collected in Hickey Creek itself.

### Spring-fed perennial streams

The spring-fed perennial stream sites sampled were at Radon Springs in the upper reaches of Magela Creek (East Alligator River; RS, Map 2) and Baroalba

Springs, Nourlangie Creek (South Alligator River) systems (BS, Map 2). Standard netting methods were replaced with regular underwater observations at these sites after the initial sampling period, as netting was considered to be too damaging to the unique and restricted fauna.

**Environment.** The habitat-structural and physico-chemical variables recorded while sampling the pools at Radon Springs and Baroalba Springs are summarised in Fig. 4 and Fig. 5.

Water flowed through both of these streams throughout the study, although it was markedly reduced (to approx. 0.001 cumecs) in the Dry season when flow depended exclusively on spring sources. Radon Springs was visited in the Wet season during a period of relatively low throughflow, giving the appearance of a consistent area factor throughout the study (Fig. 4a). Flood debris indicated that the flat land surrounding Radon Springs had been inundated to a depth of 1 m during some Wet season peak flows. In contrast, Baroalba Springs was visited in the Wet season during a period of peak flow, when the floor of the rainforest and the *Melaleuca* forest surrounding the pool was covered by a network of torrents and, in places, sheet water 0.2 m deep. Water velocities through Radon Springs and Baroalba Springs during the Wet season ranged from 0.25 to 0.75 m/s.

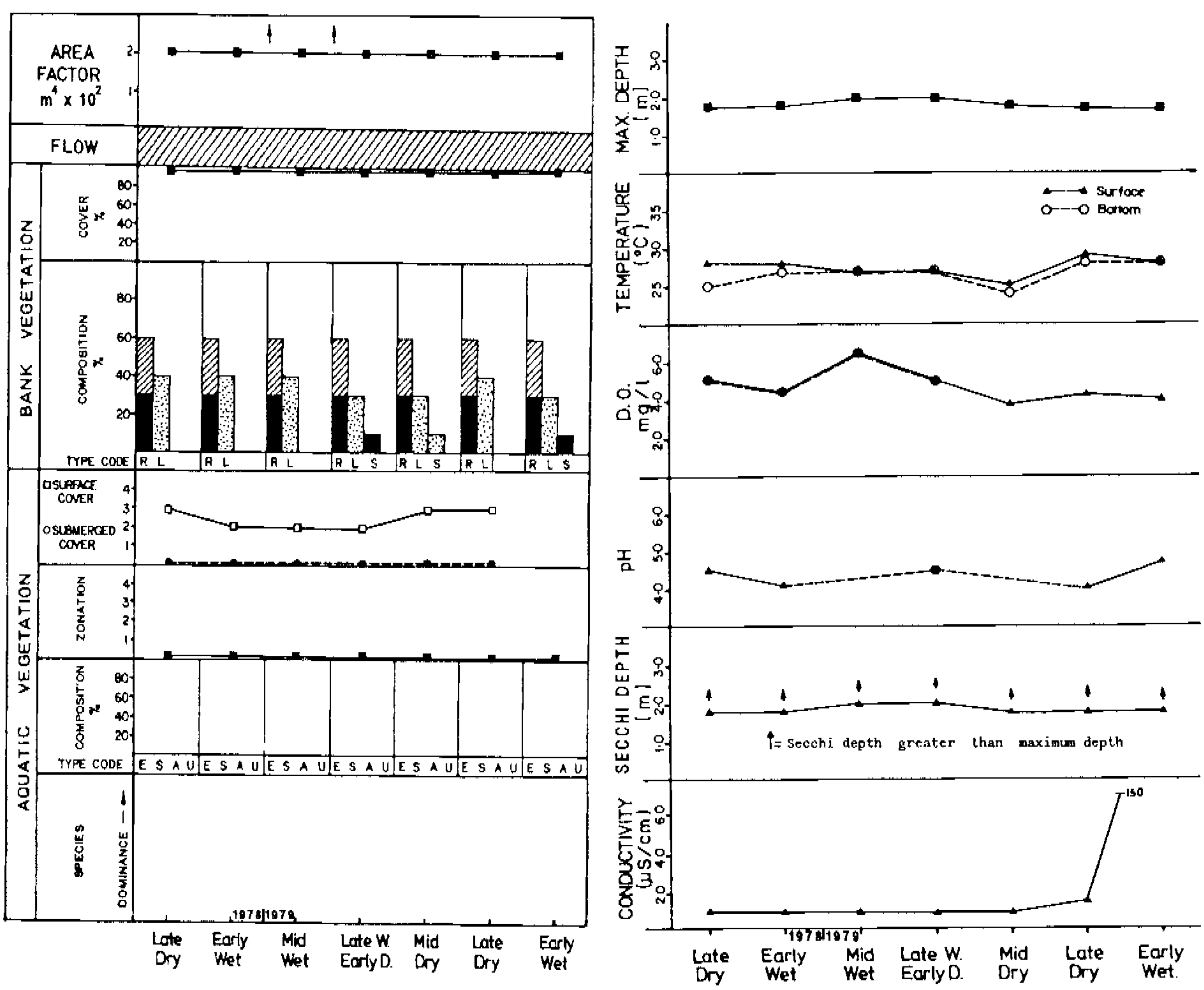



Figure 4. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a perennial escarpment spring-fed stream, Radon Springs (RS). See Appendix 2 for a key to the habitat-structural variables.

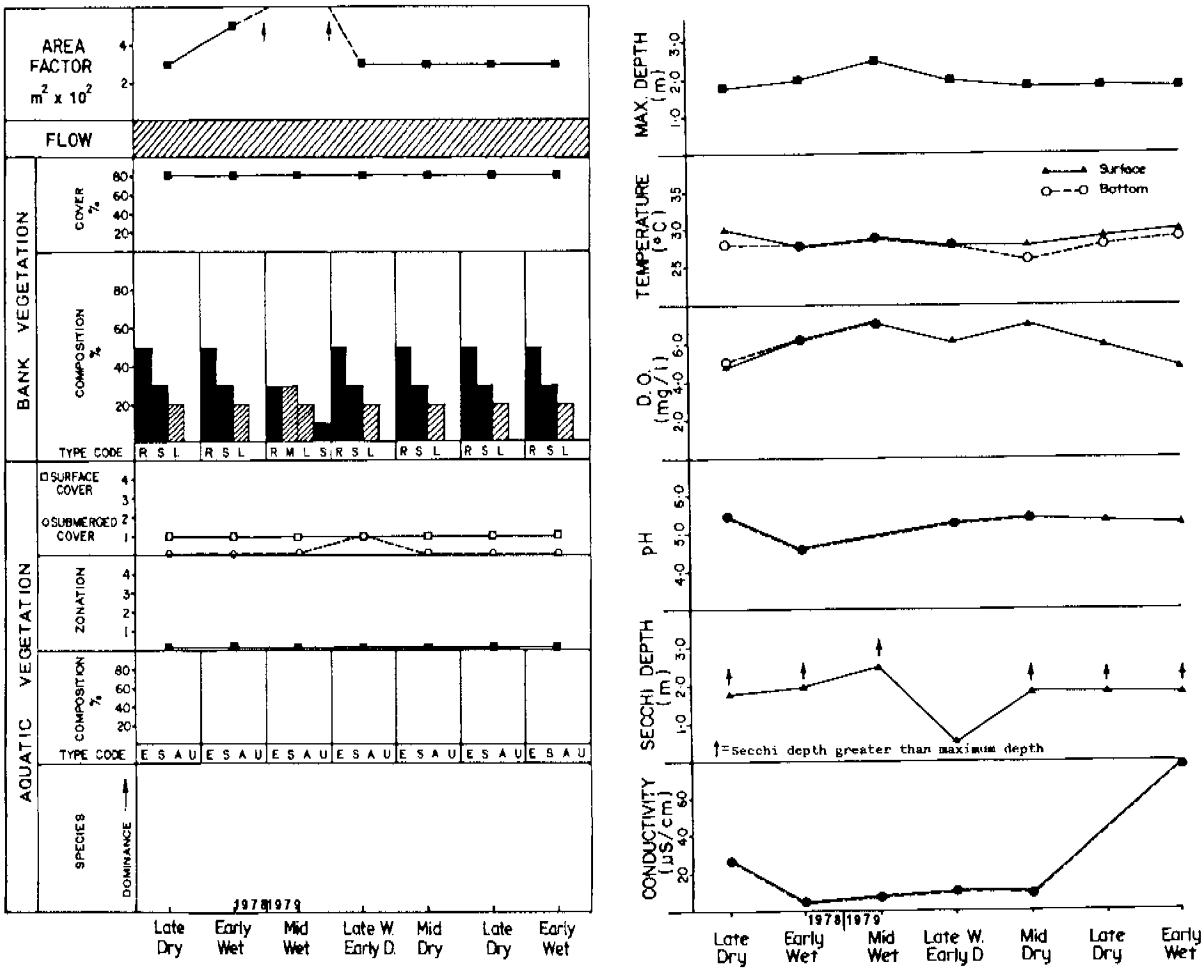



Figure 5. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a perennial escarpment spring-fed stream, Baroalba Springs (BS). See Appendix 2 for a key to the habitat-structural variables.

Cover from the surrounding thick rainforest bank vegetation was high at both sites and highest at Radon Springs during the study. The roots of the rainforest species bind the rock and gravel substrates which surround these pools. In places, large overhanging shelves of this root/rock/gravel matrix formed the banks of the pools. Partly submerged logs and branches also contributed to the cover at both sites, particularly at Radon Springs. The contribution of *Melaleuca* to the cover became apparent at Baroalba Springs in the Wet season when sections of the surrounding forest became inundated during the flood peak mentioned above. The major substrates at Radon Springs were sand, leaf litter and rocks and at Baroalba Springs, sand and outcropping bedrock. Submerged (normally terrestrial) clay/sand substrates mixed with leaf litter became more important in the Wet season at both sites.

Hydrophytes were absent from both sites during the study. *Eriocaulon setaceum* was present upstream of Radon Springs in rock pools which received midday sunlight through gaps in the rainforest canopy. Aquatic mosses, fungi and *Spongilla* sp. were present on submerged rock and wood substrates at both sites. Floating leaf litter and plant material contributed to the surface cover at both sites throughout the study, although this material was more important at Radon Springs during periods of low, Dry season flows.

During the Dry season, the size of the standard sampling pool measured 5 m × 30 m at Radon Springs and 10 m × 30 m at Baroalba Springs. These pool lengths were estimated as the distance between the upstream and downstream riffle areas. The maximum depth of the pools at both sites was 1.8 m during the Dry season, but increased during the Wet season to 2.0 m at Radon Springs and to 2.5 m at Baroalba Springs. Surface water temperatures ranged from 25°C to 29°C at Radon Springs and 27°C to 30°C at Baroalba Springs. The highest temperatures were recorded at both sites during the Late-dry season, with high temperatures extending into the 1979-80 Early-wet season at Baroalba Springs. Bottom water temperatures followed the same trends as those of surface waters and were most similar to surface temperatures in the Wet season; they ranged from 24°C to 27°C at Radon Springs and from 26°C to 29°C at Baroalba Springs.

Dissolved oxygen concentrations at the surface were always high, ranging from 3.8 to 6.4 mg/L at Radon Springs and from 4.8 to 7.0 mg/L at Baroalba Springs. Dissolved oxygen concentrations at the bottom were the same as the surface concentrations, peaking in the Mid-wet season at both sites and falling to a minimum in the Mid-dry season at Radon Springs and during the 1978 Late-dry and 1979-80 Early-wet seasons at Baroalba Springs. Surface and bottom pHs were generally the same at both sites and ranged from 4.0 to 4.7 at Radon Springs and from 4.5 to 5.5 at Baroalba Springs. Surface and bottom conductivities were also usually the same at both sites and remained at a low stable level of around 10 $\mu$S/cm from the 1978-79 Early-wet to the 1979 Mid-dry, although higher conductivities were initially recorded at Baroalba Springs during the 1978 Late-dry season. After the Mid-dry season, however, conductivity increased dramatically at both sites. Flow had not increased markedly at either site during the 1979-80 Early-wet season.

Low turbidity at both sites ensured that the bottom was clearly visible from the water surface throughout most of the study. An increase in the density of the phytoplankton during the 1979 Late-wet-Early-dry season in the pool at Baroalba Springs, especially in the sun-exposed, upstream end, led to increased turbidity (Secchi depth = 0.5 m) at this time. A green surface alga was also present at Baroalba Springs during both Late-dry seasons. During the Dry season, surface algae were very common upstream of Radon Springs, in side pools isolated from creek waters by the buttress root systems of rainforest trees. Further upstream again of Radon Springs, along the creek channel, there were a number of deep waterbodies in a narrow (10 m) canyon running along a major fault line into Mount Brockman. Radon Falls (RF, Map 2) is one of these waterbodies, isolated upstream and downstream by a series of waterfalls and boulder-strewn cascades. It has vertical bedrock walls and a maximum depth of approximately 10 m. This site has some sandy substrates and is well scoured by torrential Wet season flows. Green surface algae were regularly observed in this waterbody but there were epiphytic algae on the submerged bedrock substrates during the Dry season.

**Fish communities.** During the 1978 Late-dry season, six fish species were captured at Radon Springs and five species at Baroalba Springs, using standard sampling methods. *Melanotaenia nigrans* and *P. midgleyi* were the most abundant fish sampled at both sites and *H. fuliginosus* and *S. jardini* contributed most to the weight of fish captured at Radon Springs and Baroalba Springs respectively. The usefulness of these results is dubious, however, when compared with the following results obtained from underwater observations.

The abundances and size ranges of fish species surveyed by underwater observation in the standard sampling pools at Radon Springs and Baroalba Springs, between the Early-wet seasons of 1978-79 and 1979-80 are given in Tables 7a and 7b. A total of 10 fish species was observed at Radon Springs and 22 at Baroalba Springs. All species observed at Radon Springs were also seen at Baroalba Springs. The most abundant species observed at Radon Springs were *M. nigrans*, *Neosilurus hyrtlii*, *L. unicolor* and *P. midgleyi* and the most abundant species at Baroalba Springs were *M. nigrans* and *M. splendida inornata*, *P. midgleyi*, *N. hyrtlii* and *Porochilus rendahli*. The least abundant species at Radon Springs were *S. jardini*, *M. splendida inornata* and *C. stercusmuscarum* and the least abundant at Baroalba Springs were *C. stercusmuscarum*, *Ambassis* spp. and *L. calcarifer*. *Toxotes lorentzi* was observed at Baroalba Springs, but was not captured anywhere in the East Alligator River catchment.

Seasonal trends in species diversity and fish species numbers were apparent. Most species were observed at Radon Springs during the Late-wet-Early-dry season and at the end of the 1979 Dry season. During the Mid-wet through to the Late-wet-Early-dry seasons, most fish species were observed at Baroalba Springs, with a slight increase in diversity being apparent in the 1979 Late-dry season. An influx of large numbers of plotosid catfishes into both sites occurred during the Wet season. Species which were less common or had not been observed at Baroalba Springs before the 1978-79 Mid-wet season were *P. tenellus*, *L. calcarifer*, *S. butleri*, *T. lorentzi*, *T. chatareus* and *S. krefftii*. During the 1979 Late-dry season, *C. stercusmuscarum* and *M. mogurnda* appeared at Radon Springs and the plotosids, together with *P. tenellus* and *S. butleri* reappeared at Baroalba Springs.

At Radon Springs, the lowest number of species was observed during the Mid-wet and Mid-dry seasons, and at Baroalba Springs during both Early-wet seasons and the Mid-dry season. The reduced numbers of species observed at these sites during both the Early-wet and the Mid-wet samplings may be attributed to difficulties with underwater surveys in turbulent waters. Phytoplankton blooms in sections of the pool at Baroalba Springs may also have provided cover for many species during the Mid-dry season. The species which appeared to persist throughout the sampling period at both sites, were *M. nigrans*, *H. fuliginosus*, *L. unicolor* and *P midgleyi*. *Melanotaenia nigrans* was least abundant at Baroalba Springs in the Late-dry and Early-wet seasons and at Radon Springs during the Late-wet-Early-dry season. The abundances and size ranges of fish species observed further along the reaches of Baroalba Springs near the escarpment during the 1979 Mid-dry season are shown in Table 7b and Table 8.

The total number of fish species observed decreased with increasing elevation. Only *M. mogurnda* was found at the highest elevation (Baroalba Springs). Numerous large and small specimens of this species, however, were found at this site. The total number of species observed from the lowest to the highest elevation sites dropped from 13 to 1 at Baroalba Springs and from 9 to 0 at Radon Springs. The fish species which penetrated to the elevation below that solely occupied by *M. mogurnda* were: *H. fuliginosus*, *L. unicolor*, *P midgleyi*, the plotosids and *M. nigrans* at Baroalba Springs and *M. nigrans* at Radon Springs. *Melanotaenia nigrans* was observed leaping upstream out of the water in an attempt to negotiate a 0.3 m waterfall at Radon Springs. Species which were found only at the lower elevation sites either at Radon Springs (70 to 59 m) or at Baroalba Springs (40 to 35 m) were *M. cyprinoides*, *M. splendida inornata*, *Craterocephalus* nov. sp., *A. percoides*, *S. butleri*, *T. lorentzi*, *T. chatareus* and *S. krefftii*.

## 3.3 Lowland habitats

### Sandy creek beds

**Environment.** The habitat-structural and physico-chemical variables recorded at the Magela Creek bed sites MD and GD (Map 3) are summarised in Fig. 6 and Fig. 7. Those recorded at the Nourlangie crossing 2 site (NC, Map 2) are given in Fig. 8.

Water flowed through the lowland sandy creek bed sites between the Early-wet and Late-wet-Early-dry seasons. The Wet season flows scoured the creek beds, while peak floods spread water across large areas of adjacent low-lying land.

*Pandanus aquaticus*, *Melaleuca* spp. and terrestrial grasses generally provided most of the available bank cover at the Magela Creek bed sites MD and GD, with terrestrial grasses and *Melaleuca* contributing most of the cover in the Wet season and *Pandanus aquaticus* (usually one clump on the edge of a Dry season pool) contributing the most cover in the Dry

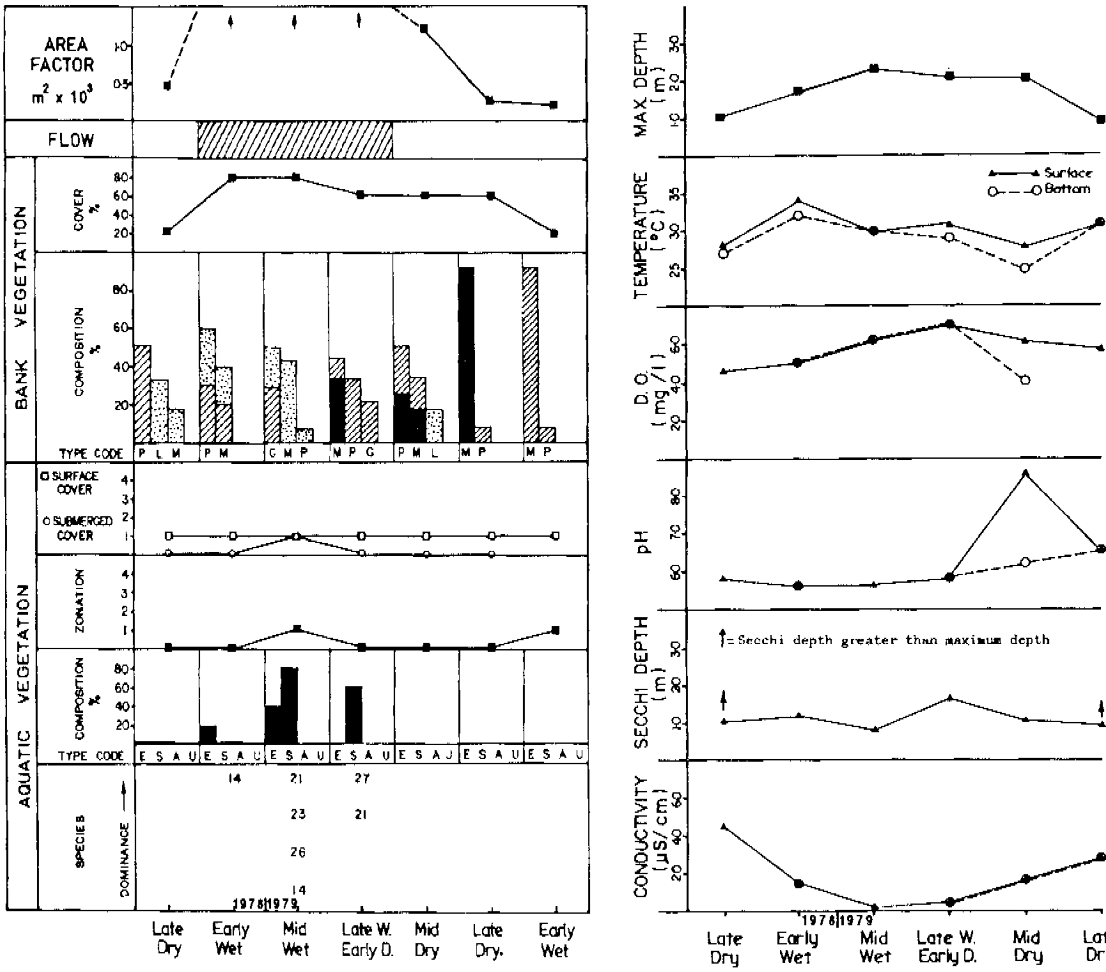



Figure 6. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland sandy creek bed pool, site MD in the Magela Creek bed. See Appendix 2 for a key to the habitat-structural variables.

seasons. *Melaleuca* spp., *Pandanus aquaticus*, *Barringtonia acutangula* and plant debris were important bank cover plants at the Nourlangie crossing 2 site. Terrestrial grasses were also an important feature of the cover at this site during the Wet season. Bank cover along the sandy creek beds appeared to change within sites and between periods with a similar flow regime; this was mainly due to the changing characteristics of the creek beds. Standard sampling pools were filled in by shifting sands, while other pools appeared in association with washouts around nearby *Pandanus*, *Melaleuca*, *Barringtonia* clumps or large fallen logs. The relative amount of bank cover was at a maximum at the Magela Creek bed site GD between the Mid-wet and Late-wet-Early-dry seasons and at a maximum at site MD and the Nourlangie crossing 2 site between the Early-wet and Mid-wet seasons, when large areas of the surrounding forests and grasses were submerged.

Hydrophytes flourished on the submerged clayey banks of the Magela Creek bed sites between the Early-wet and Late-wet-Early-dry seasons. These hydrophytes, however, soon desiccated as the water level fell in the Dry season. At the Nourlangie crossing 2 site, hydrophytes were more abundant and persisted into the 1979 Mid-dry season. These seasonal fluctuations in hydrophytes, therefore, were related to changes in zonation and to the surface and bottom cover. Various grasses at the Magela Creek bed sites, as well as *Pseudoraphis*

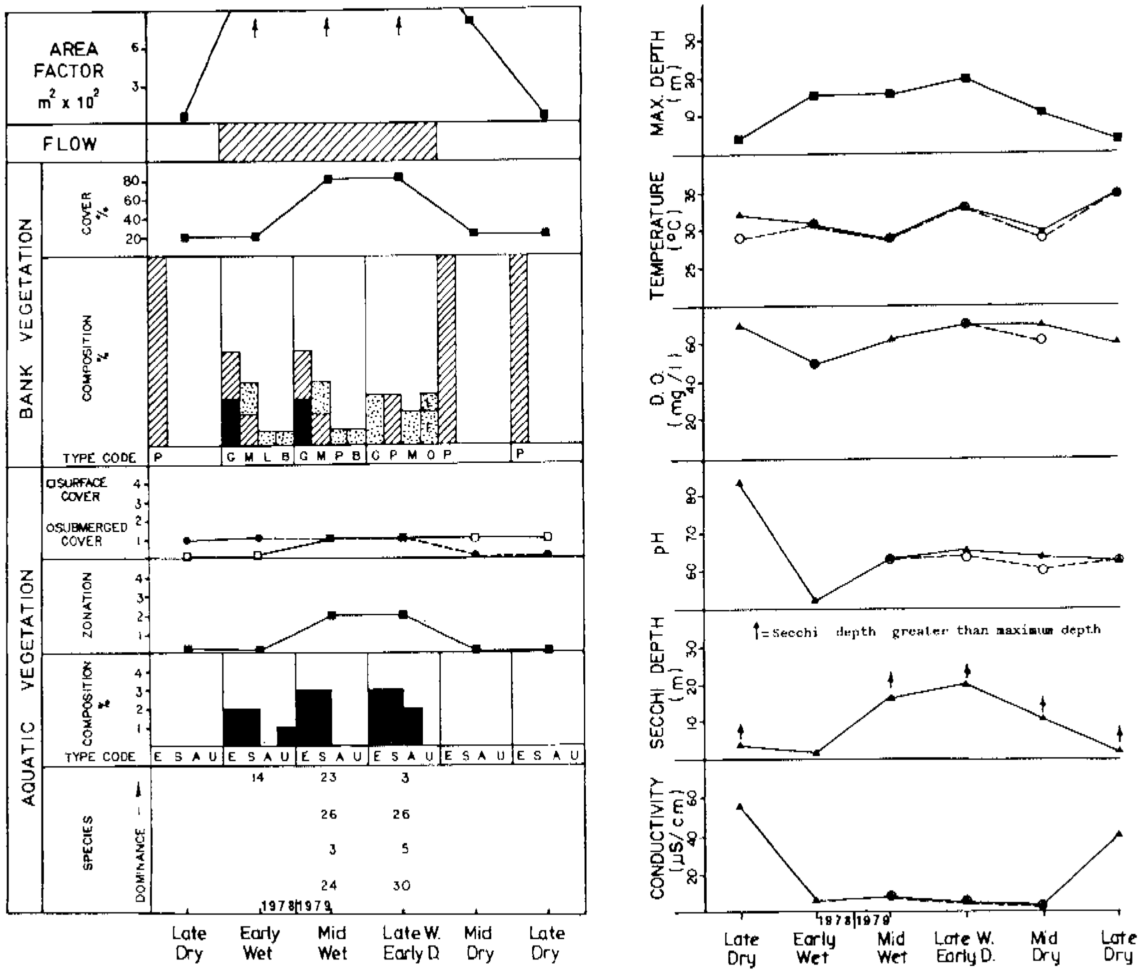



Figure 7. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland sandy creek bed pool, site GD in the Magela Creek bed. See Appendix 2 for a key to the habitat-structural variables.

*spinescens* at the Nourlangie crossing 2 site, were the first submergent and emergent hydrophytes to appear during the Early-wet season. Later in the Wet season, *Eriocaulon setaceum*, *Vallisneria* sp., *Cyperus javanicus*, *Limnophila* sp., *Eleocharis dulcis* and *Nymphoides indica* appeared on and adjacent to the banks of the Magela Creek bed sites and *Caldesia oligococca* and *Myriophyllum* sp. were also present at the Nourlangie crossing 2 site. Large blooms of a benthic filamentous green alga (*Mougeotia* sp.) subsequently grew at the Magela Creek bed site MD during the Late-wet-Early-dry season. Sand was the dominant substrate at all sites, although the proportion of clay substrates increased during the Wet season.

The maximum depths recorded between the Dry and Wet seasons at the sampling sites ranged from 0.9 to 2.3 m at the Magela Creek bed site MD, 0.4 to 2.0 m at the Magela Creek bed site GD and from 0.2 to 1.1 m at the Nourlangie crossing 2 site. Surface water temperatures ranged from 27°C to 34°C at the Magela Creek bed site MD, 29°C to 35°C at the Magela Creek bed site GD and 25°C to 30°C at the Nourlangie crossing 2 site. Surface water temperatures were highest during the 1978-79 Early-wet season at the Magela Creek bed site MD and in the 1979 Late-dry season at the Magela Creek bed site GD. During the 1979 Mid-dry season at the Magela Creek bed site MD and in the Mid-wet season at the Magela Creek bed site GD, surface water

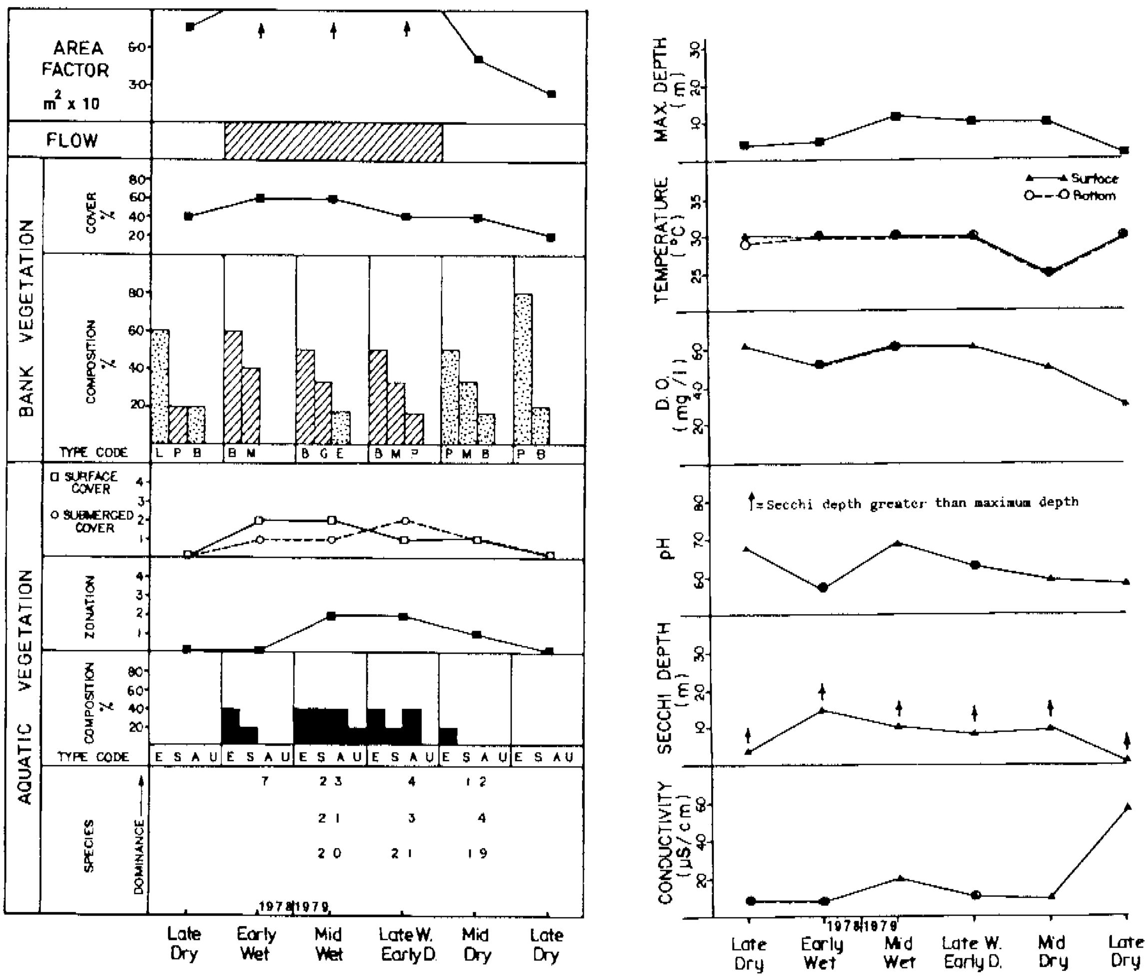



Figure 8. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland sandy creek bed pool, Nourlangie crossing 2 site (NC). See Appendix 2 for a key to the habitat-structural variables.

temperatures were at their lowest. Surface water temperatures at the Nourlangie crossing 2 site were fairly uniform, except for a drop during the Mid-dry season. Bottom water temperatures generally followed similar trends to surface water temperatures and ranged from 25°C to 31°C at the Magela Creek bed site MD; from 29°C to 35°C at the Magela Creek bed site GD and from 25°C to 30°C at the Nourlangie crossing 2 site.

The surface and bottom waters were well oxygenated throughout the study at all three sites. Dissolved oxygen concentrations at the surface ranged from 4.6 to 6.8 mg/L at the Magela Creek bed site MD; from 5.0 to 7.0 mg/L at the Magela Creek bed site GD; and from 3.0 to 6.0 mg/L at the Nourlangie crossing 2 site. Surface dissolved oxygen concentrations were highest during the Late-wet-Early-dry season at the Magela Creek bed sites MD and GD and highest at the Nourlangie crossing 2 site during the 1978 Late-dry and the Mid-wet season. Concentrations of dissolved oxygen at the bottom were generally similar to those at the surface, although the small range recorded may reflect the infrequency of bottom dissolved oxygen sampling owing to the shallowness of the pools. Dissolved oxygen concentrations did vary at the Magela Creek bed sites MD and GD during the 1979 Mid-dry season, however, when it appeared that water buffalo had been wallowing and defecating in the pools. These bottom concentrations ranged from 4.0 to 7.0 mg/L at the Magela Creek bed site MD; from 5.0 to 7.0 mg/L at the Magela Creek bed site GD; and from 5.2 to 6.0 mg/L at the Nourlangie crossing 2 site.

Surface pH ranged from 5.6 to 8.5 at the Magela Creek bed site MD, from 5.2 to 8.3 at the Magela Creek bed site GD; and from 5.8 to 6.9 at the Nourlangie crossing 2 site; bottom pH readings ranged from 5.6 to 6.5, from 5.0 to 6.4, and from 5.2 to 6.4, respectively. Surface and bottom pH generally followed each other closely, except at the Magela Creek bed site MD in the 1979 Mid-dry season when there was a very high surface pH.

Turbidity was generally low and the bottom clearly visible from the water surface at the Nourlangie crossing 2 site and the Magela Creek bed site GD, although it increased at site GD during the Early-wet season when flow had just begun (Secchi depth = 0.2 m). At the Magela Creek bed site MD between the Early-wet and the 1979 Mid-dry season, the Secchi depth reading was usually 1 m, indicating some turbidity. Conductivity at all sites was generally less than 20 μS/cm for surface and bottom waters, although it tended to rise towards the end of the Dry season and fall again in the Early-wet season.

The occasional sampling sites, GU, in Magela Creek (Map 3) and UU, a site upstream in Magela Creek (Map 2), were sandy creek bed pools which persisted through the Dry season into the following Wet season. Site GU closely resembled the Magela Creek bed site at GD. The Magela upstream site UU, was much deeper, surrounded by very thick bank vegetation and contained red floating surface algae during the 1979 Late-dry season. The control sites on Magela Creek, MG and MJ (Map 3), dried up towards the 1979 Mid-dry season, but MU, a Magela upstream site (Map 2), persisted further into the Dry season as it was fed by an escarpment main-channel creek for many months after the end of the Wet season.

**Fish communities.** The abundances and weights of those fish species captured during the study at the Magela Creek bed sites MD, GD, MJ, GU, MU and also the Nourlangie crossing 2 site, using standard netting methods, are shown in Tables 9a-9f.

Figures 9 and 10 summarise the seasonal total abundance, total weight, number of species, richness, Shannon diversity and evenness indices for the standard netting methods at these sites. No information is included on the Magela Creek bed site MG because MJ, a Magela Creek bed site in its vicinity, persisted longer and so provided more data.

The total number of fish species collected by standard netting methods during the study was 17 at the Nourlangie crossing 2 site with a total of 19 at the Magela Creek bed site MD and 20 at site GD. The total number of species collected or observed by

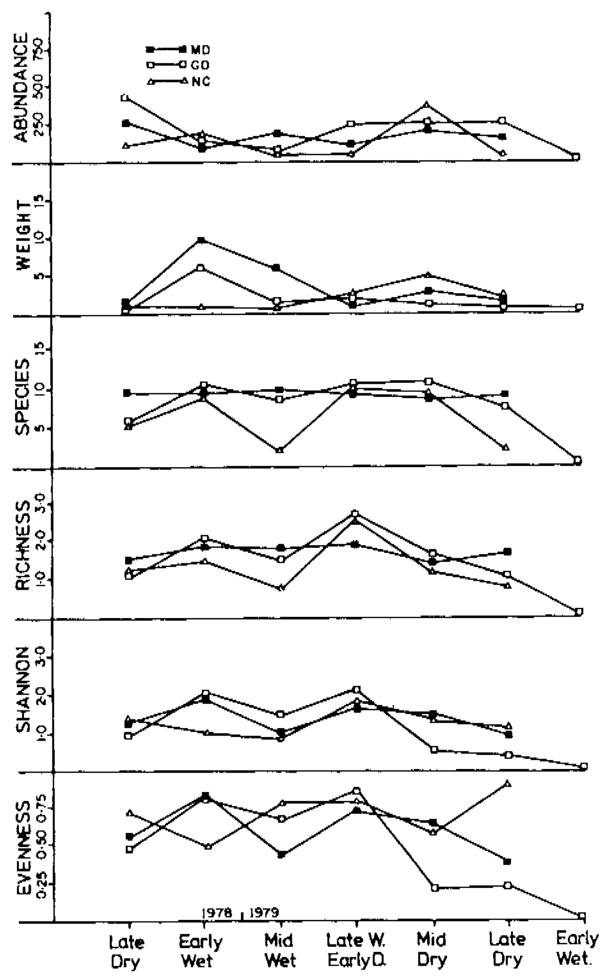



Figure 9. Summary of seasonal abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken in lowland sandy creek bed pools, the Magela Creek bed sites at MD and GD, and the Nourlangie crossing 2 site.

Catches were obtained using standard netting methods.

all methods, increased the fish species number at the Magela Creek bed sites MD and GD to 21. Non-standard collecting and observation methods failed to find any additional species at the Nourlangie crossing 2 site during the study. Not captured by standard methods at site MD, were *G. giurus* (captured with a 10 m x 2 m deep seine net; 5 mm mesh size), *H. fuliginosus* (spears and underwater observations) and *M. cyprinoides*, (captured by the daytime use of a multiple-mesh-sized monofilament gillnet). The latter species was present but not captured at site GD. The five most abundant fish species were *Craterocephalus* nov. sp., *M. splendida inornata, C. stercusmuscarum, A. percoides* and *N. erebi* at site MD; *Craterocephalus* nov. sp., *M. splendida inornata, C. stercusmuscarum, A. agrammus* and *L. unicolor* at site GD; and *A. agrammus, M. splendida inornata, Denariusa bandata, A. macleayi* and *C. stercusmuscarum* at the Nourlangie crossing 2 site. The Magela Creek bed sites, MD and GD, had three abundant species, *Craterocephalus* nov. sp, *M. splendida mornata* and *A. agrammus.* These were also common in the escarpment main-channel habitat sites at Bowerbird Billabong and Sawcut Gorge. The Nourlangie crossing 2 site samples contained a dissimilar fauna dominated by the *Ambassis* spp. and the melanotaeniids.

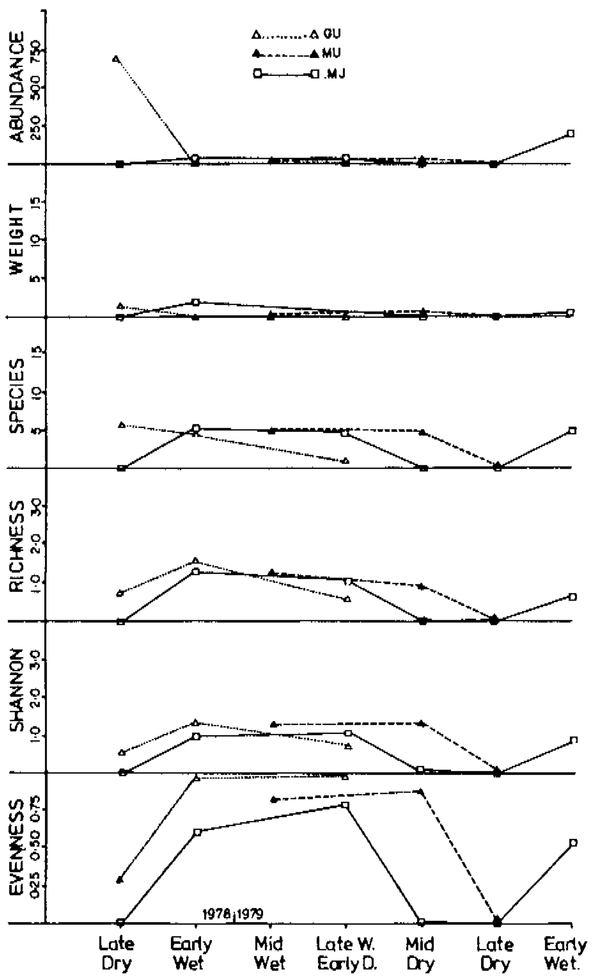



**Figure 10.** Summary of seasonal abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken in lowland sandy creek bed pools, the Magela Creek bed sites at GU and MJ, and the Magela Creek upstream site MU.

Catches were obtained using standard netting methods.

Samples from the Magela Creek sites MJ, GU and MU contained 10, 9 and 6 fish species respectively. These sites were relatively poor in fish species, with the most abundant species being *Craterocephalus* nov. sp., *C. stercusmuscarum, M. splendida inornata* and *A. percoides. Melanotaenia nigrans* was present at the Magela Creek site closest to the escarpment, MU. These three sites, MJ, GU and MU, disappear during the Dry season.

The seasonal total abundance at the Magela Creek bed sites MD and GD (Fig. 9), was generally most affected by changes in the catches of *Craterocephalus* nov. sp. This species was most numerous in the Dry seasons, although during the Wet season the contribution from *M. splendida inornata* became more important. At the Nourlangie crossing 2 site, seasonal total abundance followed trends in the catches of the two melanotaeniids and the two *Ambassis* species. In general these species were most abundant in the Dry season and least abundant in the Wet season. Sites on Magela Creek MJ, GU and MU, usually showed very low catches (Fig. 10), although there were large catches of *Craterocephalus* nov. sp. at site GU during the 1978 Late-dry season and large catches of *M. splendida inornata* at site MJ during the 1979-80 early Wet season.

The total number of fish species at the Magela Creek bed site MD was generally stable throughout the study, with 8 to 10 species being captured during each sampling period. Samples from the Magela Creek site GD and the Nourlangie crossing 2 site showed an increase in diversity in the 1978-79 Early-wet season, followed by a decrease (particularly at the Nourlangie crossing 2 site), during the Mid-wet season. The decreased diversity apparent in the Wet season possibly reflects the difficulties inherent in sampling creeks with swiftly flowing water. The diversity increased again to a maximum at both the the Magela Creek site GD and the Nourlangie crossing 2 site (10 to 12 species), during the Late-wet-Early-dry season, but then gradually decreased towards the end of the 1979 Dry season. Magela Creek sites, MJ and MU, showed peaks in species diversity (5 species) in sampling periods when flowing water was present. Samples from the Magela Creek bed site GU, showed highest diversity during the 1978 Late-dry season, but this then decreased, probably mainly due to the difficulty of sampling the creek bed in this area during periods of swift flow.

At all the sites, the richness index followed a similar pattern to the total number of species sampled. Richness was at a maximum during the Late-wet-Early-dry season at the Magela Creek bed site GD and at the Nourlangie crossing 2 site, and during the 1979-80 Early-wet season at the Magela Creek bed site GU. The Shannon diversity index showed similar trends to the indices mentioned above for all sites. Generally, the evenness index inversely followed trends in total abundance, particularly when the community was dominated in numbers by a few species. Evenness dropped at the beginning of the 1978-79 Wet season at the Nourlangie crossing 2 site, but increased at the Magela Creek bed sites MD and GD, when sampling coincided with the start of creek flow. At the latter two sites, evenness dropped again in the 1979 Dry season after peaking at the end of the Wet season. High evenness indices were recorded at the Magela Creek bed sites, GU, MJ and MU, during the 1978-79 Wet season.

The fish species which contributed most to the total weight of fish captured over the sampling period were *T. ater*, *A. leptaspis*, *N. erebi*, *S. krefftii* and *L. unicolor* at the Magela Creek bed site MD; *T. ater*, *N. erebi*, *T. chatareus*, *L. unicolor* and *A. leptaspis* at the Magela Creek bed site GD; and *M. splendida inornata*, *A. agrammus*, *M. mogurnda*, *S. krefftii* and *A. macleayi* at the Nourlangie crossing 2 site. Sites MD and GD on the Magela Creek, therefore, shared species which contributed most to the total weight of the catch (these species also occurred in communities from main-channel escarpment sites). A dissimilar fish fauna was present at the Nourlangie crossing 2 site. The total weights at the Magela Creek bed sites MD and GD, increased to a maximum during the 1978-79 Early-wet season when large numbers of *T. ater* (some contamination from *N. hyrtlii* and *P. rendahli* may have occurred in these samples), *N. erebi*, *T. chatareus* and *S. butleri* moved into the previously dry sandy creek bed from adjacent permanent waterbodies. Total weight decreased at these sites through the Wet season and into the 1979 Dry season, with *N. erebi*, *A. percoides* and *L. unicolor* subsequently contributing most to the catch. Total weight at the Nourlangie crossing 2 site remained low to the end of the 1978-79 Wet season but began to increase from the beginning of the 1979 Dry season, with *M. splendida inornata* and *A. agrammus* contributing most to the catch. Total weight of catches at the Magela Creek bed site MJ, GU and MU remained low throughout the entire study as gillnets were seldom used.

The fish community samples from a sandy creek bed site near Nabarlek, Adgibongololo Creek in the Cooper Creek system (AU, Map 2), were similar to those found in the sandy Magela Creek bed at sites MD and GD (Table 10), i.e. *Craterocephalus* nov. sp. and *A. percoides* were the most numerous of the eight fish species present and contributed most to the total weight of the catch.

**Backflow billabongs**

For ease of presentation, these sites have been arranged into the following small groups based on their catchment position and subjective impressions of habitat similarity:

Fishless Billabong (FS, Map 2). The most upstream Magela Creek backflow billabong studied. A small, shallow billabong with gently sloping banks, well isolated from the main creek.

Djalkmara (DA, Map 3) and Coonjimba (CA, Map 3) billabongs. Small, shallow Magela Creek billabongs with gently sloping banks, isolated from the main creek.

Georgetown (GN, Map 3), Indium (IM, Map 3) and Goanna (GA, Map 2) billabongs. These are billabongs with steeply sloping banks, located adjacent to or on the main creek channel of the Magela Creek.

Gulungul (GL, Map 3) and Corndorl (CL, Map 2) billabongs. These are the most downstream Magela Creek backflow billabongs studied and are large, shallow billabongs with gently sloping banks. The sites are isolated from the main creek in a similar manner to those sites at Djalkmara and Coonjimba Billabongs.

Malabanbandju Billabong (formerly Baroalba crossing; BX, Map 2), Anbangbang Billabong (formerly Nourlangie Rock = Umbungbung; NR, Map 2) and Deaf Adder Creek (DR, Map 2). These are Nourlangie Creek backflow billabongs. Malabanbandju Billabong resembles the Georgetown, Indium and Goanna billabong group. Anbangbang Billabong resembles the Gulungul and Corndorl billabong group.

Nabarlek Dam (AM, Map 2), Bullwidgi Billabong (CD, Map 2), Birraduk Creek (BC, Map 2). These are waterbodies on Cooper Creek.

*Fishless Billabong*

**Environment.** The habitat-structural and physico-chemical variables recorded during the study at Fishless Billabong are summarised in Fig. 11.

Flow was apparent at this site only during the 1978-79 Mid-wet season, although this normally discrete Dry season billabong was part of a large, inundated backwater of the nearby flooded Magela Creek from the 1978-79 Early-wet to the 1979 Late-wet-Early-dry. The cover available from bank vegetation was at a minimum during the Dry seasons when water had receded from the surrounding forested area. *Melaleuca* and associated fallen logs offered most cover throughout the study.

Hydrophytes flourished in the Wet season and persisted into the 1979 Mid-dry season. The amount of surface and submerged cover available from these plants was at a maximum during the Wet season (plant zonation peaked in the Mid-wet season, Fig. 11a). The most abundant submergent, floating attached and emergent hydrophytes were *Nymphoides minima*, *Nymphaea gigantea*, *Vallisneria* sp. and *Myriophyllum* sp. in the Mid-wet season and *Najas tenuifolia*, *Caldesia oligococca*, *Nymphoides indica* and *Nymphoides minima* in the Mid-dry. Mud substrates were predominant in the Dry season and clay substrates became more important on the banks of the billabong in the Wet season.

Fishless Billabong was 0.6 m to 1.0 m deep in the Dry season and filled to just over 2 m in depth during the Wet season. Surface water temperatures ranged from 27°C in the Mid-dry season to 40°C in the 1979-80 Early-wet season. Bottom water temperatures ranged from 26°C to 31°C and were generally 2°C cooler than surface waters between the Mid-wet season and the 1979 Late-dry season, and 6°C to 11°C cooler than surface waters in the 1978 Late-dry and later in the 1979-1980 Early-wet season.

Dissolved oxygen concentrations at the surface of the billabong ranged from 4.0 to 7.6 mg/L and were highest in the 1978-79 Mid-wet and lowest in the 1979 Late-dry season. Concentrations of dissolved oxygen at the bottom ranged from 0 mg/L in the 1979-80 Early-wet season to 5.8 mg/L in the 1978 Late-dry season. Bottom dissolved oxygen concentrations were 3 to 5 mg/L less than those for surface waters during the Mid-wet and Late-wet-Early-dry seasons. Throughout the 1979 Dry season bottom dissolved oxygen concentrations decreased markedly, dropping to 0 mg/L during the 1979-80 Early-wet season, when the billabong had nearly dried up (though it had received some local rainfall).

Surface pH (range 5.5 to 6.7) and bottom pH levels (range 4.5 to 6.0) were most dissimilar during the Mid-wet season.

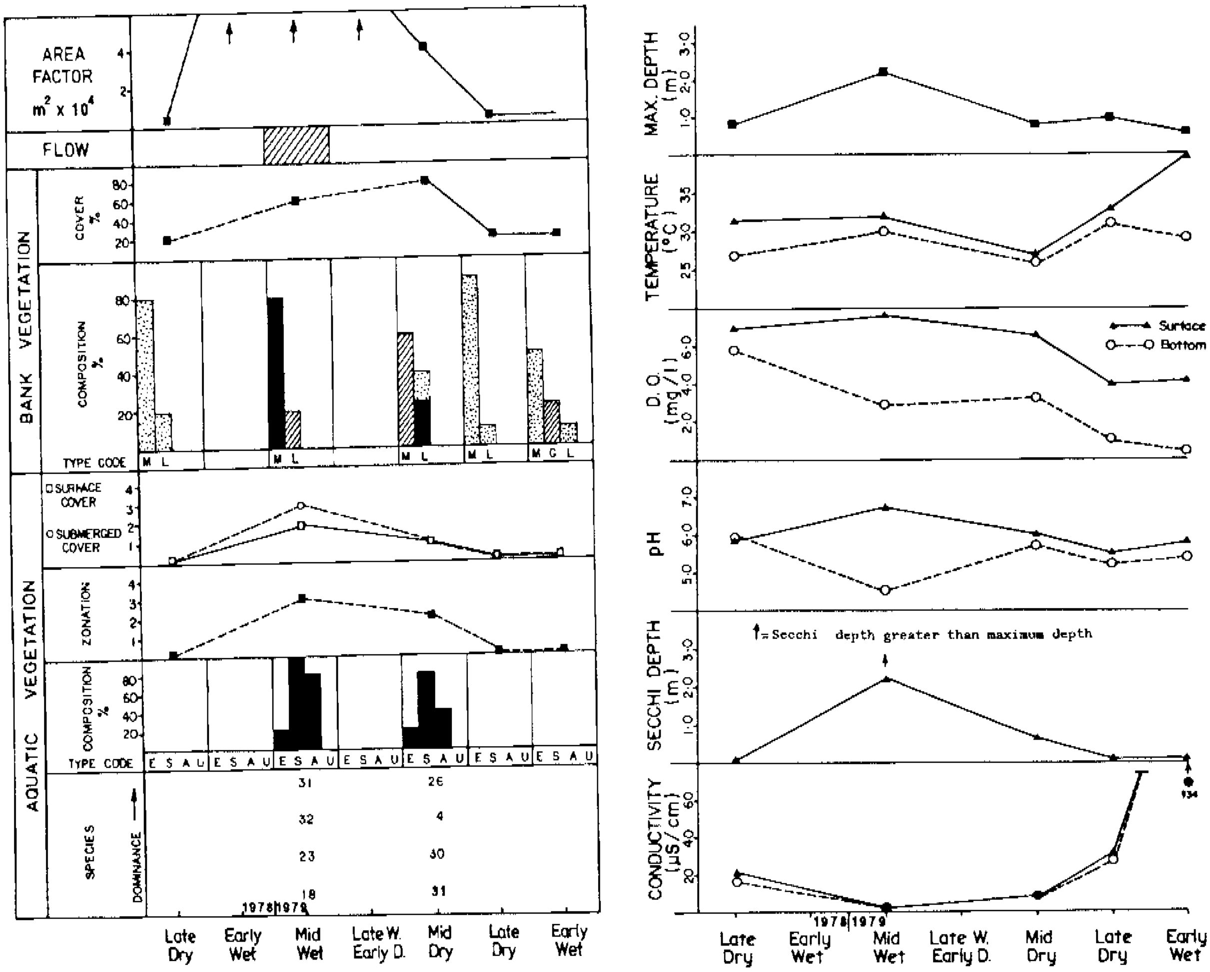



Figure 11. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland backflow billabong, Fishless Billabong (FS). See Appendix 2 for a key to the habitat-structural variables.

Conductivities were lowest (6 to 20 $\mu$S/cm) between the 1978-79 Mid-wet and 1979 Mid-dry seasons, and then dramatically increased to 930 $\mu$S/cm as the billabong was drying out towards the 1979-80 Early-wet season.

Turbidity was high (Secchi depth < 1 cm) during most of the study, except over the Mid-wet season, when the bottom of the 2.2 m deep billabong could be seen from the water surface. The wallowing activities of buffalo contributed to the increased turbidity recorded during the 1979 Mid-dry season.

**Fish communities.** Figure 12 summarises total abundance, total weight, number of species, Shannon diversity and evenness indices for samples taken from Fishless Billabong. Thirteen fish species were collected at Fishless Billabong by standard netting methods. No extra species were collected by non-standard methods. The five most abundant species collected at this depauperate site were *A macleayi*, *A. agrammus*, *M. splendida inornata*, *D. bandata* and *P. rendahli*. Seasonal total abundance generally followed trends in catches of the two *Ambassis* species, with the highest catches occurring in the 1978 and 1979 Late-dry seasons. It appears from Table 11a, that *A. agrammus* was replaced by *A. macleayi* as the most abundant species after the 1978-79 Wet season, although this may have been at least partly due to difficulties in distinguishing these two ambassid species (see vol. III). The total number of species per season remained stable at nine, up to the 1979-80 Early-wet season, when only one species (*A. macleayi*) was found in the nearly dried-up billabong. The richness indices peaked during the Mid-wet season and then gradually decreased to almost zero by the 1979-80 Early-wet season. The catchment of Fishless Billabong had received rains but, as no flow had entered the billabong from Magela Creek during this season, there were apparent dissimilarities in the community samples between this Early-wet season and the previous one (1978-79). Trends in Shannon diversity and evenness indices generally followed that of the richness index.

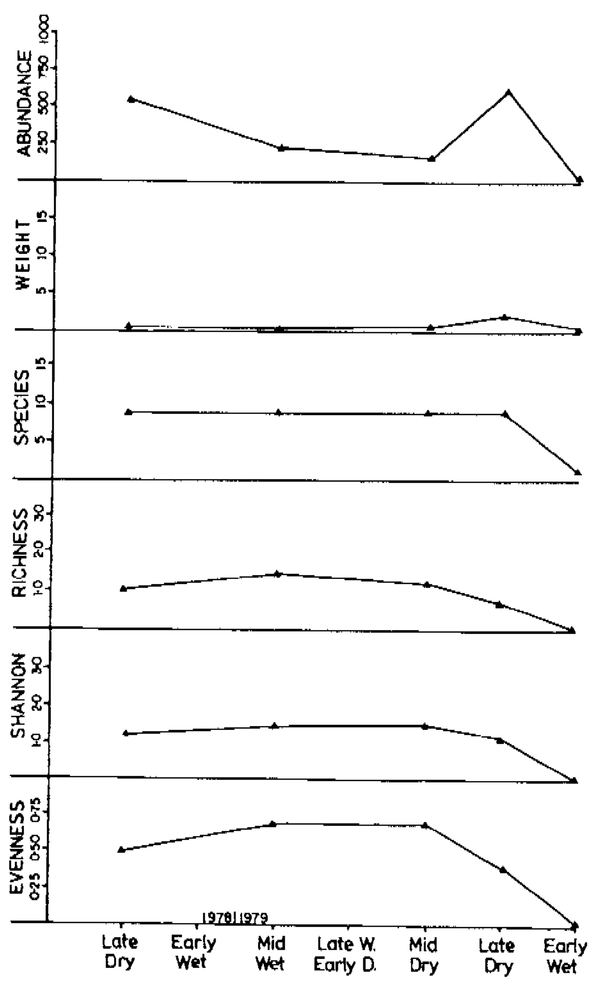



Figure 12. Summary of seasonal abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken in a lowland backflow billabong, Fishless Billabong (FS)

Catches were obtained using standard netting methods.

The five species which contributed most to the total weight of fish captured at Fishless Billabong over the total sampling period were *P. rendahli, A. macleayi, L. unicolor, A. agrammus, M. splendida inornata* and *G. aprion*. Overall, total weight was stable from the 1978 Late-dry through the Wet season to the 1979 Mid-dry season, but later peaked in the 1979 Late-dry season (when large numbers of *P. rendahli* were captured) and then dropped to a minimum in the following Early-wet season. Before the Wet season, *A. agrammus* contributed most to the total weight of fish caught at Fishless Billabong, but during the Wet season *L. unicolor* contributed most to the total weight. In the 1979 Late-dry season *P. rendahli, A. macleayi* and *S. krefftii* contributed most to the total weight of fish caught.

*Djalkmara and Coonjimba billabongs*

**Environment.** The habitat-structural and physico-chemical variables recorded for Djalkmara Billabong are given in Fig. 13 and for Coonjimba Billabong in Fig. 14.

Water flowed swiftly through the downstream end of Djalkmara Billabong and through an anabranch of the Magela Creek during the Wet season. Water also flowed through Coonjimba Billabong from the 1978-79 Early-wet and during the Mid-wet season. Both these sites became part of a large backwater area inundated by Magela Creek during peak Wet season flow but became isolated early in the Dry season as the water receded. Djalkmara Billabong dried up completely in the 1979 Dry season, while Coonjimba Billabong persisted in a much diminished form.

Cover from surrounding bank vegetation at both sites increased to a maximum during the Mid-wet and Late-wet-Early-dry seasons as the billabongs swelled and inundated the vegetated banks. In the Dry season however, the billabongs contracted and bank vegetation stood many metres away from the water (especially at Djalkmara Billabong), making little contribution to the available cover. *Melaleuca* spp., grasses, fallen timber and *Eucalyptus papuana* contributed most of the bank cover, with the grasses becoming more important as cover when the banks were

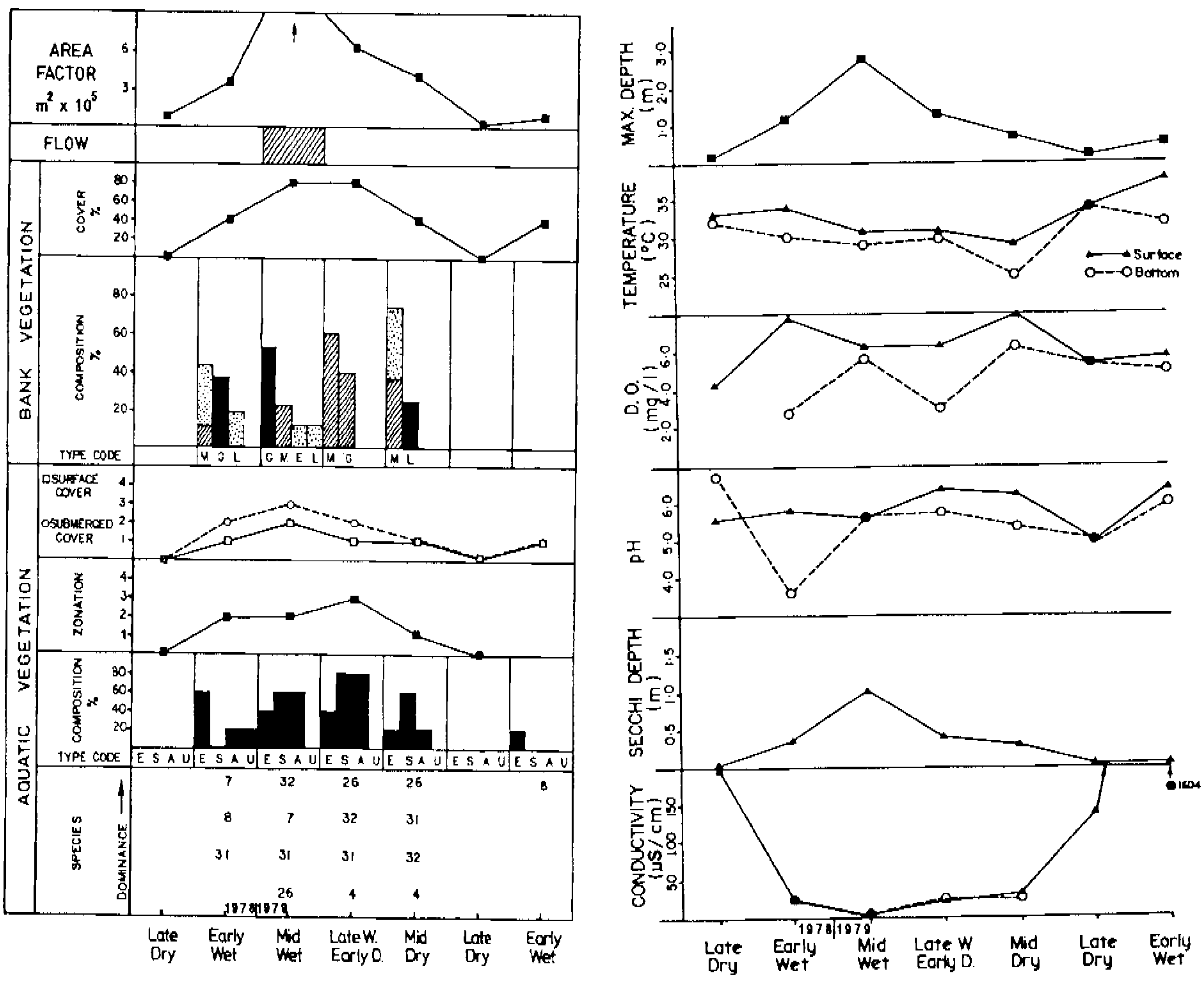



Figure 13. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland backflow billabong, Djalkmara Billabong (DA). See Appendix 2 for a key to the habitat-structural variables.

inundated in the Wet season. The banks of the billabongs were very shallow, with clay shelving which became muddy when submerged.

Hydrophytes flourished in these backflow billabongs during the Wet season. Surface and submerged cover peaked at Djalkmara Billabong in the Mid-wet and at Coonjimba Billabong this cover remained at a high level until the 1979 Mid-dry season and persisted throughout the Dry season. Hydrophyte zonation became most complex at Djalkmara Billabong in the Late-wet-Early-dry and at Coonjimba Billabong in the Mid-wet and Late-wet-Early-dry seasons. *Pseudoraphis spinescens*, *Fimbristylis minima*, *Nymphoides minima* and *Cyperus javanicus* were the first hydrophytes to contribute significantly to cover at both sites in the Early-wet season. Submerged and floating attached hydrophytes then became important at both sites, with *Nymphaea gigantea*, *Najas tenuifolia*, *Caldesia oligococca*, *Eleocharis dulcis* and *Vallisneria* sp. being most important.

Both billabongs became very shallow (< 0.5 m), in the Dry seasons and, as described above, Djalkmara Billabong dried up just before the 1979 Early-wet season. During the Mid-wet season Djalkmara Billabong was 2.8 m and Coonjimba Billabong was 2.1 m deep when they were sampled. Surface water temperatures for the entire study ranged from 29° to 38°C at Djalkmara Billabong and from 28° to 38°C at Coonjimba Billabong. Highest temperatures were experienced in the 1978-79 and

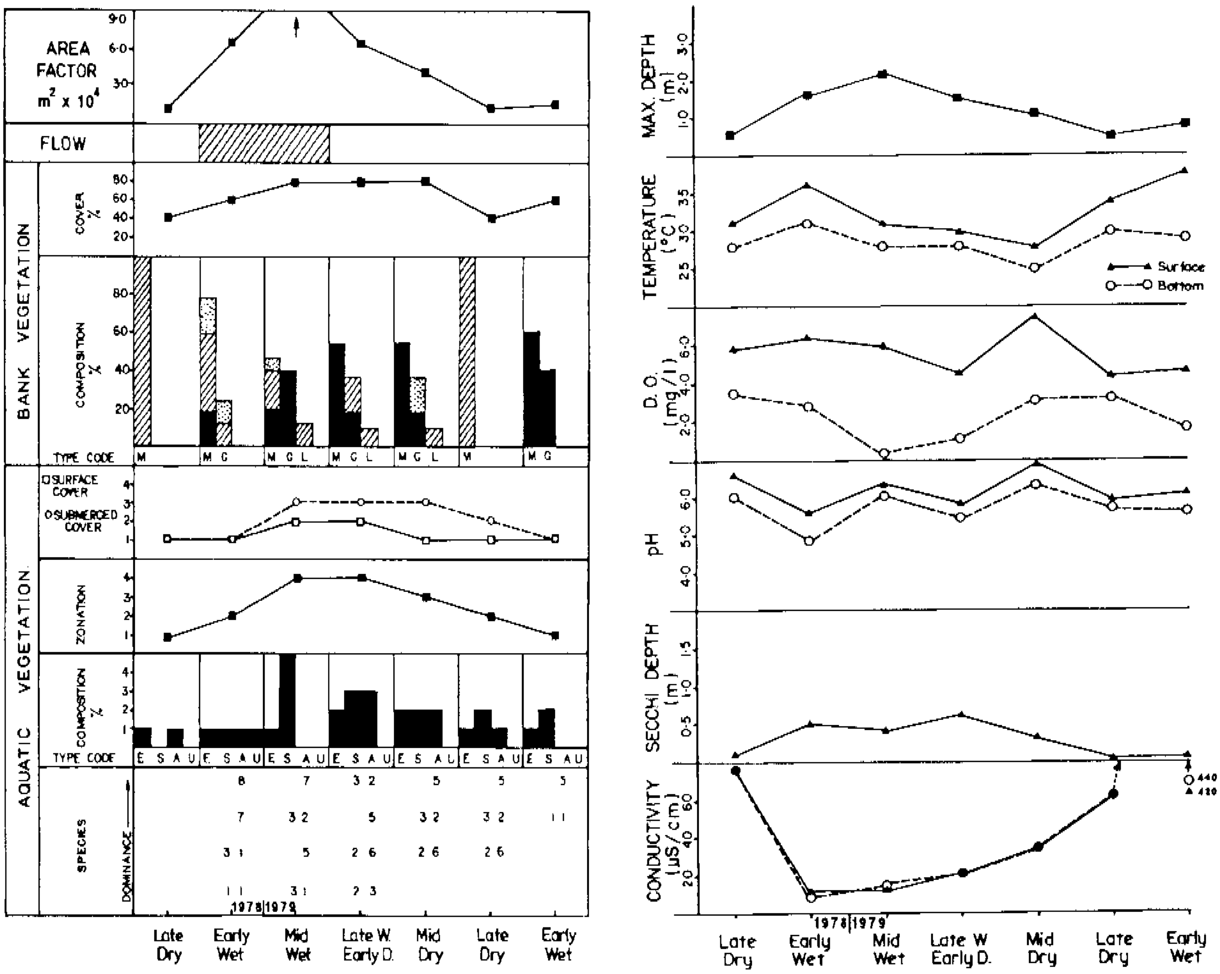



Figure 14. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland backflow billabong, Coonjimba Billabong (CA). See Appendix 2 for a key to the habitat-structural variables.

1979-80 Early-wet seasons. Water temperatures in the well-vegetated littoral zone reached 42°C during these seasons at Djalkmara Billabong, with dissolved oxygen concentrations showing supersaturation. Bottom water temperatures ranged from 25° to 34°C at Djalkmara Billabong and from 25° to 31°C at Coonjimba Billabong. The bottom temperatures were therefore generally 3-4°C cooler than those of surface waters, with the greatest differences occurring in the Early-wet seasons.

Dissolved oxygen concentrations at the surface of the billabongs ranged from 4.2 to 8.0 mg/L at Djalkmara Billabong and from 4.3 to 7.6 mg/L at Coonjimba Billabong. Highest surface dissolved oxygen concentrations were recorded during the 1979 Mid-dry season at both sites, but concentrations were also high during the 1978-79 Early-wet season. Concentrations of dissolved oxygen at the bottom ranged from 2.8 to 6.2 mg/L at Djalkmara Billabong and from 0.2 to 3.5 mg/L at Coonjimba Billabong. Bottom dissolved oxygen concentrations were generally lower at Coonjimba Billabong than at Djalkmara Billabong and were from 3.0 to 5.0 mg/L lower than those for surface waters, especially at Coonjimba Billabong. Bottom and surface dissolved oxygen concentrations were most similar at Djalkmara Billabong during the Mid-wet and 1979 Late-dry seasons and most similar at Coonjimba Billabong during the 1979 Late-dry season; they were most dissimilar at Djalkmara Billabong during the 1978-79 Early-wet season and at Coonjimba Billabong during the Mid-wet season.

Surface pH ranged from 4.8 to 6.3 at Djalkmara Billabong and from 5.6 to 6.8 at Coonjimba Billabong, while bottom pH ranged from 3.5 to 6.7 at Djalkmara Billabong and from 4.8 to 6.3 at Coonjimba Billabong. Surface and bottom pH were generally similar at Coonjimba Billabong, although at Djalkmara Billabong differences were apparent in the 1978 Late-dry and the following Early-wet season. Surface and bottom conductivities ranged from a low 5 up to 35 μS/cm from the 1978-79 Early-wet to the 1979 Mid-dry season at both sites. Subsequently the conductivities rose dramatically at both sites to levels similar to those of the 1978 Late-dry season, as the billabongs dried out towards the end of the Dry season. Surface and bottom conductivities reached 1600 μS/cm before Djalkmara Billabong dried out during this period.

Turbidity remained high (Secchi depth < 0.5 m) at both sites for most of the study period and increased (Secchi depth < 1 cm), at the end of both Dry seasons. During the Wet season the turbidity was generally lower at both sites, with a maximum Secchi depth reading of 1.0 m at Djalkmara Billabong during the Mid-wet season. The turbidity at Coonjimba Billabong, however, increased markedly in this season owing to runoff from earthworks at the Ranger Uranium Project Area in the Coonjimba Creek catchment. Coonjimba Billabong also received an unknown quantity of diesel oil from a spill in the Ranger Uranium Project Area during the 1978-79 Mid-wet season (pers. obs.).

**Fish communities.** Figure 15 summarises the seasonal total abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken from Coonjimba and Djalkmara billabongs. A total of 22 fish species was collected at Djalkmara and Coonjimba billabongs by standard netting methods. No extra species were captured by non-standard methods. The five most abundant fish species at Djalkmara Billabong (Tables 11b-11c) were *A. agrammus, M. splendida inornata, D. bandata, L. unicolor* and *C. stercusmuscarum*, and the five most abundant species at Coonjimba Billabong (Table 11c) were *A. agrammus, M. splendida inornata, D. bandata, N. erebi* and *A. macleayi*. Three of these species were therefore among the five most abundant species at both sites. Except in the 1978 Late-dry season, total abundance was higher at Djalkmara Billabong than at Coonjimba Billabong. Seasonal total abundance dropped at Coonjimba Billabong after the 1978 Late-dry season and remained low at both sites in the 1978-79 Early-wet and Mid-wet seasons. Total abundance increased in the following Late-wet-Early-dry season to peak in the 1979 Mid-dry season. By the Late-dry season, however, total abundance had fallen again, and by the 1979-80 Early-wet season, when the respective catchments had received

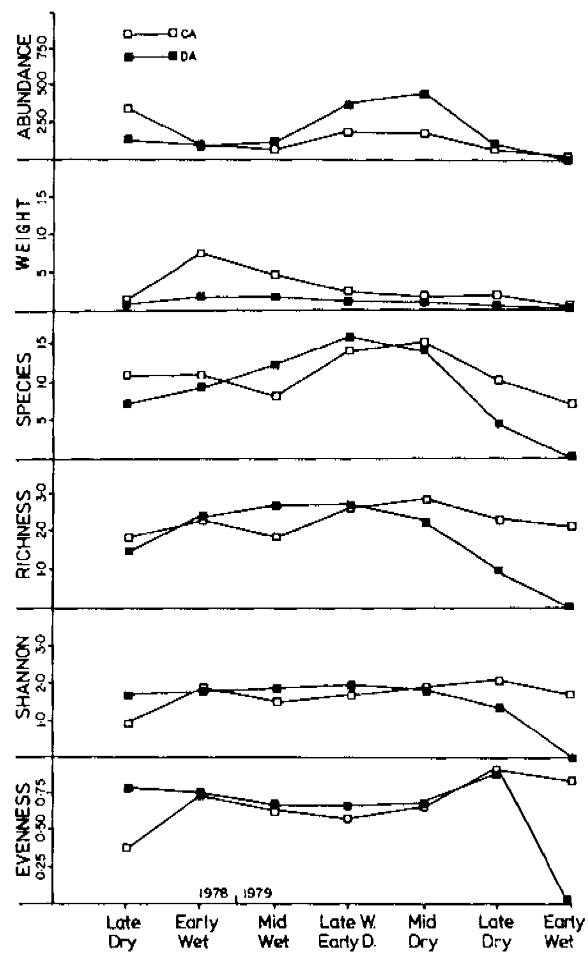



Figure 15. Summary of seasonal abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken in the lowland backflow billabongs, Coonjimba and Djalkmara billabongs

Catches were obtained using standard netting methods.

rain, but flow had not commenced, they were at a minimum. A reduction in the catch of the two *Ambassis* species at both sites was the main cause for the Wet season slump in total abundance. The post-Wet-season increase in total abundance was attributed to increased catches of these two *Ambassis* species and *M. splendida inornata*, with the high catches of the *Ambassis* spp. continuing further through the Dry season.

The total number of species in the samples at both sites peaked during the Late-wet-Early-dry and Mid-dry seasons, and then decreased towards the following 1979-80 Early-wet season, when Djalkmara Billabong was found to contain a single species. The number of species captured at Djalkmara Billabong increased steadily from the 1978 Late-dry season to the Late-wet-Early-dry season, but at Coonjimba Billabong, even though species numbers generally followed the same trend, there was an obvious slump in the Mid-wet season. The richness and Shannon diversity indices followed similar patterns to these changes, in total species number, although the Shannon diversity index showed more stability. The evenness index, after initially being lower at Coonjimba Billabong in the 1978 Late-dry, was similar and relatively stable at both of the sites until the 1979 Late-dry season, when this index dropped to zero for Djalkmara Billabong because the site had nearly dried up in the last few weeks of the Dry season.

The five fish species which contributed most to the total weight of fish captured over the total sampling period were *N. erebi, A. leptaspis, L. unicolor, T. ater* and *T. chatareus* at Djalkmara Billabong, and *A. leptaspis, N. erebi, T. chatareus, L. unicolor* and *O. lineolatus* at Coonjimba Billabong. Four of these species therefore, contributed most to the total weight of catches at both sites. During the 1978-79 Early-wet season, the total weight increased six-fold in Coonjimba Billabong and two-fold in Djalkmara Billabong after the Late-dry season and then decreased gradually after the Wet season. The total weights of the catches were usually higher at Coonjimba than at Djalkmara Billabong. During the 1978 Late-dry season *P. rendahli* and *A. agrammus* at Djalkmara Billabong, and *N. erebi, O. lineolatus,* and *A. agrammus* at Coonjimba Billabong, contributed most to the total weight of the catches. After flow started *A. leptaspis, T. ater, N. erebi, T. chatareus* and *L. unicolor* contributed most to the total weight of fish at both sites, and after flow had ceased *P. rendahli* and *L. unicolor* contributed most the total weight at Djalkmara Billabong and *N. erebi, L. unicolor, G. aprion* and *M. splendida inornata* contributed most to the total weight at Coonjimba Billabong.

### *Georgetown, Indium and Goanna billabongs*

**Environment.** The habitat-structural and physico-chemical variables recorded while sampling fish during the study are summarised for Georgetown Billabong in Fig. 16, for Indium Billabong in Fig. 17 and for Goanna Billabong in Fig. 18.

Georgetown Billabong is a much larger billabong (note the change in scale on the area factor axis, Fig. 16a), than either Indium or Goanna. There was flow in all these billabongs between the 1978-79 Early-wet season and the following Mid-wet season. During peak flow periods, Indium Billabong became an anabranch of Magela Creek. All sites, including Goanna Billabong, which is many kilometres upstream from the site closest to the Magela Creek at Gulungul Billabong, backfilled from the floodwater-swollen Magela Creek in the 1978-79 Early-wet season and, in the same way as the other lowland shallow backflow billabongs already described, then became part of a large backwater area. In the next year's Early-wet season, Indium Billabong initially filled from local rainwater runoff. When the billabongs were receding during the Dry season, the shape and size of Georgetown Billabong changed very noticeably compared with Indium and Goanna billabongs, as it had more shallow, sloping banks rather than the steep-sided channel-forming clay banks of the latter two billabongs. Substrates in the deepest parts of these billabongs were usually mud, although sand substrates at Georgetown Billabong and gravel substrates at Indium and Goanna billabongs predominated in downstream sections where there were higher water velocities in the Wet season.

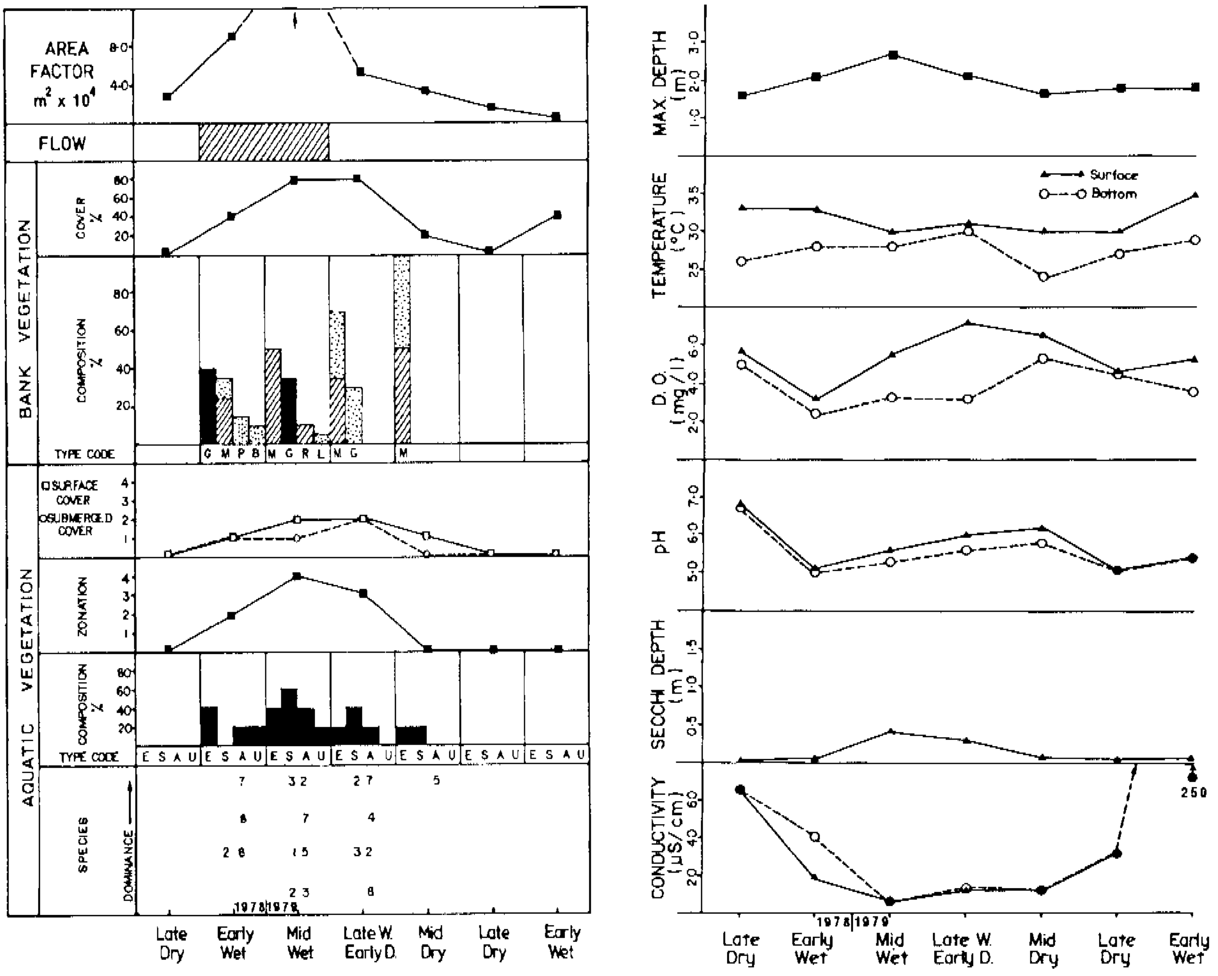



Figure 16. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland backflow billabong, Georgetown Billabong (GN). See Appendix 2 for a key to the habitat-structural variables.

There was maximum cover from bank vegetation at Georgetown and Indium billabongs over the Mid-wet and Late-wet-Early-dry seasons. At Goanna Billabong, however, there was most cover after this period, as over the Wet season the banks had been inundated up to a level of scant vegetation far beyond the trees and shrubs which normally fringed the billabong in the Dry season. *Melaleuca* sp., fallen timber (especially at Goanna Billabong) and grasses were the most important contributors to bank cover and grasses became very important during the Wet season. There was essentially no cover at Georgetown Billabong over both Late-dry seasons as the water level had receded about 100 m down the bare, shelving clay banks from a fringing *Melaleuca* forest. As the water level rose again in the Early-wet season, however, the recent grass growth over the normally bare (Dry season conditions) clay banks was inundated up to and into the *Melaleuca* forest.

Both surface and submerged cover from hydrophytes, which flourished in these billabongs in the Wet season, peaked during the Mid-wet at Georgetown and Indium billabongs. At Goanna Billabong, however, hydrophytes were present throughout the study and their contribution to cover peaked later in the Wet season. The zonation of hydrophytes was most complex at Georgetown Billabong in the Mid-wet season and most complex at Indium Billabong in the Late-wet-Early-dry season. At Goanna Billabong, zonational

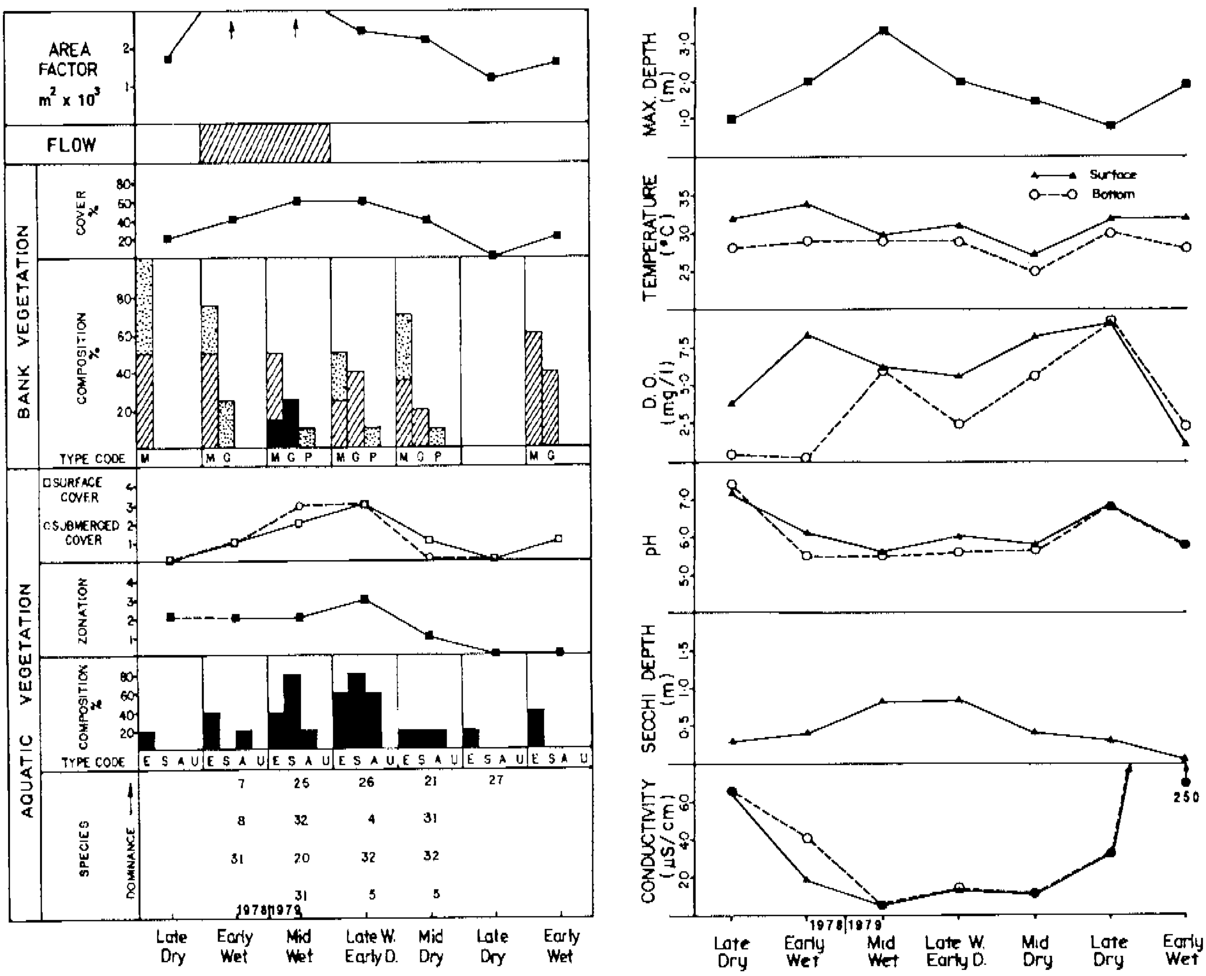



Figure 17. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland backflow billabong, Indium Billabong (IM). See Appendix 2 for a key to the habitat-structural variables.

complexity appeared to be lowest over the Late-wet-Early-dry season and the 1979 Late-dry season. *Pseudoraphis spinescens, Fimbristylis minima, Marsilea* sp. and *Nymphoides minima* were the first hydrophytes to appear at Georgetown and Indium billabongs in the Early-wet season and a diverse hydrophyte community including *Najas tenuifolia, Ceratophyllum* sp., *Nymphaea gigantea, Caldesia oligococca* and *Eleocharis dulcis* was later present for most of the Wet season. The hydrophyte community at Goanna Billabong was similar to that at Georgetown and Indium billabongs. *Utricularia stellaris, Aponogeton elongatus, Eriocaulon setaceum* and filamentous green algae, however, were also important community members at this site.

Georgetown, Indium and Goanna billabongs were deepest in the Mid-wet season, with maximum depths of 2.8, 3.4 and 2.8 m respectively. Depths were lowest in the Late-dry or Early-wet seasons at these three sites: 1.6 m at Georgetown Billabong and 0.8 m at Indium and Goanna billabongs. Surface water temperatures ranged from 30° to 35°C at Georgetown Billabong; from 27° to 34°C at Indium Billabong, and from 27° to 37°C at Goanna Billabong. They were generally lowest in the 1979 Mid-dry season and highest in the Late-dry and Early-wet seasons. Bottom water temperatures ranged from 24° to 30°C at Georgetown Billabong, from 25° to 30°C at Indium Billabong, and from 24° to 32°C at Goanna Billabong and were therefore generally 2-4°C cooler than surface tem-

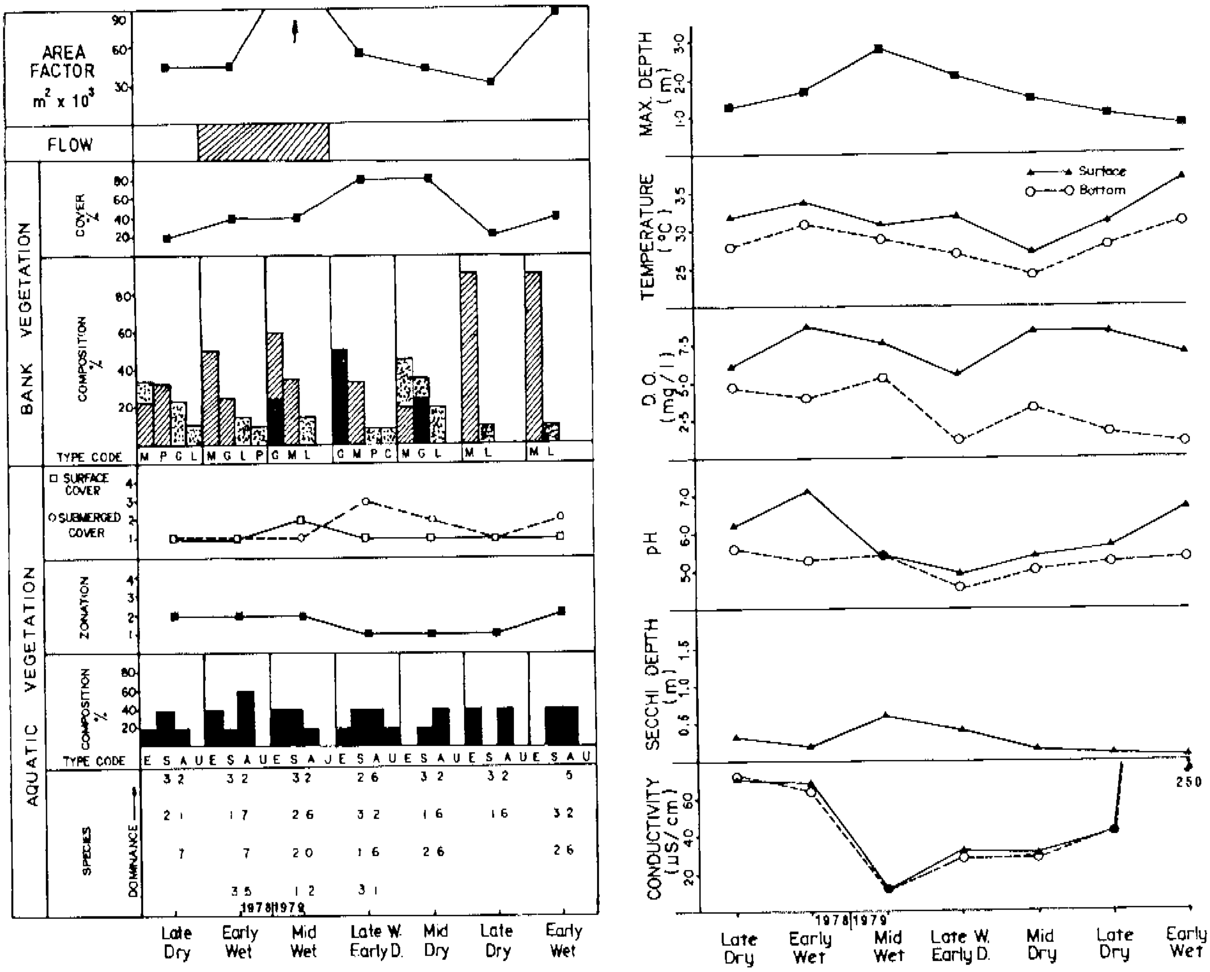


Figure 18. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland backflow billabong, Goanna Billabong (GA). See Appendix 2 for a key to the habitat-structural variables.

peratures. Bottom and surface temperatures were most similar in the Wet season and least similar in the Late-dry and Early-wet seasons.

Dissolved oxygen concentrations at the surface ranged from 3.2 to 7.2 mg/L at Georgetown Billabong, from 2.2 to 9.2 mg/L at Indium Billabong, and from 5.5 to 8.7 mg/L at Goanna Billabong. The surface dissolved oxygen concentrations was reduced to a minimum at Georgetown Billabong during the Early-wet seasons and then peaked in the Late-wet-Early-dry season. In contrast, surface dissolved oxygen concentrations at Indium and Goanna billabongs were at a minimum in the Late-wet-Early-dry seasons and peaked later in the Mid-dry to Late-dry and Early-wet seasons. Concentrations of dissolved oxygen at the bottom ranged from 2.4 to 5.0 mg/L at Georgetown Billabong; from 0.0 to 9.0 mg/L at Indium Billabong; and from 1.0 to 5.4 mg/L at Goanna Billabong. There was an extreme drop in the dissolved oxygen concentration at the bottom of Indium Billabong with anoxic conditions occurring during the 1978-79 Early-wet season when near-anoxic Dry season waters were enclosed by a surface layer of flowing waters. Surface and bottom dissolved oxygen concentrations were most dissimilar (3 to 4 mg/L lower in the bottom waters) at Georgetown Billabong towards the end of the Wet season and gradually converged over the Dry season when the billabong was becoming progressively shallower. At Indium Billabong dissolved oxygen concentrations were most similar in the Mid-wet and Late-dry seasons, and most dissimilar in the 1978-79 Early-wet season. At Goanna Billabong, dissolved oxygen concentrations generally followed similar trends throughout the study, although concentrations of dissolved oxygen for bottom waters were generally 3 to 6 mg/L less than those for surface waters.

Surface pH ranged from 5.1 to 6.7 at Georgetown Billabong, from 5.6 to 7.2 at Indium Billabong and from 4.9 to 7.1 at Goanna Billabong. The pH at the bottom of the billabongs ranged from 5.0 to 6.7 at Georgetown Billabong, from 5.5 to 7.4 at Indium Billabong and from 4.6 to 5.6 at Goanna Billabong. Surface and bottom pHs were generally similar at all sites, except at Goanna Billabong in both Early-wet seasons. Conductivities were initially reduced with the 1978 Early-wet season flow at Georgetown and Indium billabongs. Because water did not begin to backflow into Goanna Billabong until the evening after conductivity samples had been taken, the conductivity recorded for the 1978-79 Early-wet at this site was misleadingly high (Fig. 18b). Conductivities were reduced to low levels (6 to 30 μS/cm) during the Wet season, and then gradually increased into the Dry season. High (off-scale) conductivity readings were recorded at all sites in the following 1979-80 Early-wet season before flow began to dilute the concentrated Dry season waters again.

Turbidity in all the billabongs was generally high throughout the study and peaked at Georgetown, Indium and Goanna billabongs during the Wet season with Secchi depth readings of 0.4, 0.8 and 0.6 m respectively. The water at Indium Billabong was generally clearer than at the other sites, probably because this site was on an anabranch of Magela Creek in the Wet season and had sand and gravel substrates. Turbidity was high (Secchi depth < 1 cm) at Georgetown and Goanna billabongs in the Dry seasons.

**Fish communities.** Figure 19 summarises the total abundance, total weight, number of species, Shannon diversity and evenness indices for samples taken from Georgetown, Indium and Goanna billabongs. The total number of fish species collected by standard netting methods at these sites was 21 at Georgetown Billabong, 21 at Goanna Billabong and 20 at Indium Billabong. The most abundant species collected at these sites (Tables 11d-11f) were two *Ambassis* species, *M. splendida inornata, N. erebi* and *A. leptaspis* at Georgetown Billabong; *N. erebi*, two *Ambassis* species, *G. aprion* and *M. splendida inornata* at Goanna Billabong and *A. macleayi, P. rendahli, N. erebi, S. krefftii, M. splendida inornata* and *G. aprion* at Indium Billabong. Four of these species, therefore, were most abundant at all of the sites. Seasonal total abundance was maintained at a low but stable level throughout most of the study at the three sites but peaked during the Late-wet-Early-dry season. Catches of the two

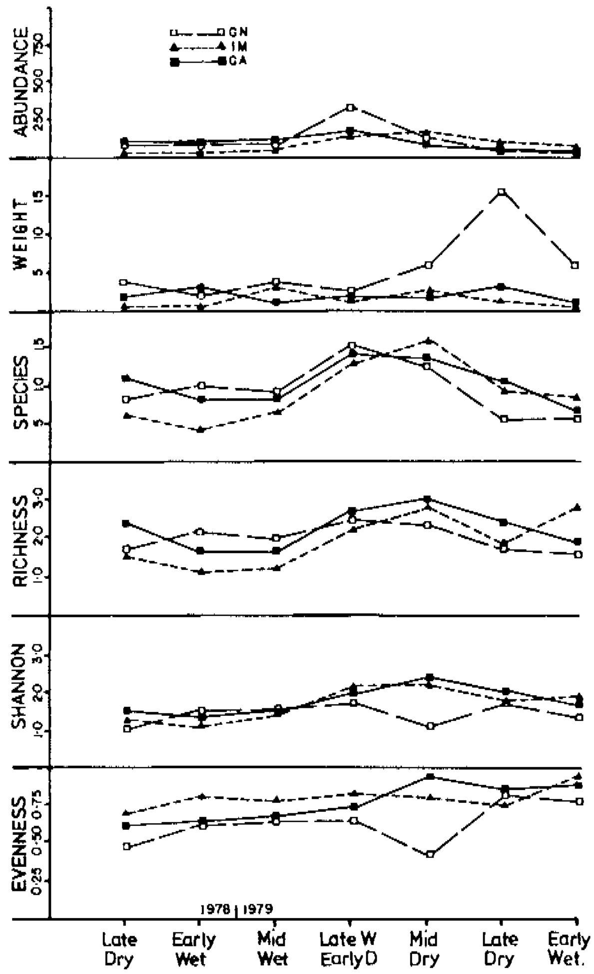



**Figure 19. Summary of seasonal abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken in the lowland backflow billabongs, Georgetown, Indium and Goanna billabongs**

**Catches were obtained using standard netting methods.**

*Ambassis* species contributed most to the total abundance throughout the greater part of the study and the peak in total abundance at all the sites after the 1978-79 Wet season resulted mainly from larger catches of these *Ambassis* spp., *M. splendida inornata* and *G. aprion*.

The total number of species at all sites was at a minimum between the 1978 Late-dry season and the 1978-79 Mid-wet season. Sampling efficiency may have been reduced in the Mid-wet season, as seining was at times restricted to littoral areas which had been recently inundated by rising flood-waters. During the Late-wet-Early-dry and Mid-dry seasons the total number of species at all sites increased to a maximum, but fell again to similar levels as those recorded in the previous year. The richness, Shannon diversity and evenness indices generally followed the same trends as the total number of species, although during the Mid-dry season the Shannon diversity and evenness indices were reduced at Georgetown Billabong owing to a large catch of *A. macleayi* and small numbers of other species. In the 1979-80 Early-wet season, all indices were elevated at Indium Billabong owing to relatively similar catches of all species.

The five fish species which contributed most to the total weight of fish captured over the sampling period were *A. leptaspis*, *N. erebi*, *L. calcarifer*, *O. lineolatus* and *T. ater* at Georgetown Billabong; *N. erebi*, *S. krefftii*, *P. rendahli*, *A. leptaspis* and *L. calcarifer* at Goanna Billabong; and *A. leptaspis*, *O. lineolatus*, *N. erebi*, *T. ater* and *P. rendahli* at Indium Billabong. These sites therefore shared species which contributed most to the total weight of the catches at each site. The total weight of the catches at Georgetown Billabong increased dramatically (Fig. 19) between the 1979 Mid-dry and 1979-80 Early-wet seasons, primarily due to large catches of *A. leptaspis*. The total weight at Goanna and Indium billabongs was generally lower than that at Georgetown Billabong, with the heaviest catches occurring at Goanna and Indium billabongs during the 1979 Late-dry and 1978-79 Mid-wet seasons respectively. The total weight of catches at Indium Billabong was lowest both before the 1978-79 Wet season, and during the 1979-80 Early-wet (pre-flow) season, when total weight was also at a minimum at Goanna Billabong. Catches of *A. leptaspis* were reduced during the Wet season at Goanna and Georgetown billabongs, although they remained high at Indium Billabong. *Nematalosa erebi*, *T. ater* and *L. calcarifer* also contributed greater weights to the catches in the Wet season at Georgetown Billabong. After this season, catches of *A. leptaspis* and *N. erebi* then contributed most to the total weight at Georgetown Billabong; *N. erebi* and *S. krefftii* contributed most to the total weight at Goanna Billabong and *O. lineolatus* and *N. erebi* contributed most to the total weight at Indium Billabong.

*Gulungul and Corndorl billabongs*

**Environment.** The habitat-structural and physico-chemical variables recorded at Gulungul Billabong are given in Fig. 20 and for Corndorl Billabong in Fig. 21.

Both of these billabongs backfilled from Magela Creek and had large surface areas with gently sloping, muddy banks. The surface area of Corndorl Billabong was approximately twice that of Gulungul Billabong during the Late-wet-Early-dry season. Water flowed through Corndorl Billabong in the Early-wet and Mid-wet seasons, but flow was only observed at Gulungul Billabong in the Mid-wet season, when it joined with the Magela Creek one week after the beginning of the Early-wet season during a flood peak which caused the creek to break its banks and inundate the billabong and adjoining lowlands. Following this backflow into the billabongs, the contribution of cover from bank vegetation peaked in the Mid-wet and Late-wet-Early-dry seasons, as *Melaleuca* spp., grasses and fallen timber at Gulungul Billabong, and *Pandanus aquaticus*, *Barringtonia acutangula*, grasses and fallen timber at Corndorl Billabong were inundated. As the water level fell at Gulungul Billabong, the billabong contracted approximately 100 m away from these forests, but at Corndorl Billabong the bank cover contribution from an island swamp forest persisted into the Dry season.

Surface and submerged hydrophyte cover increased into the Early-wet season and

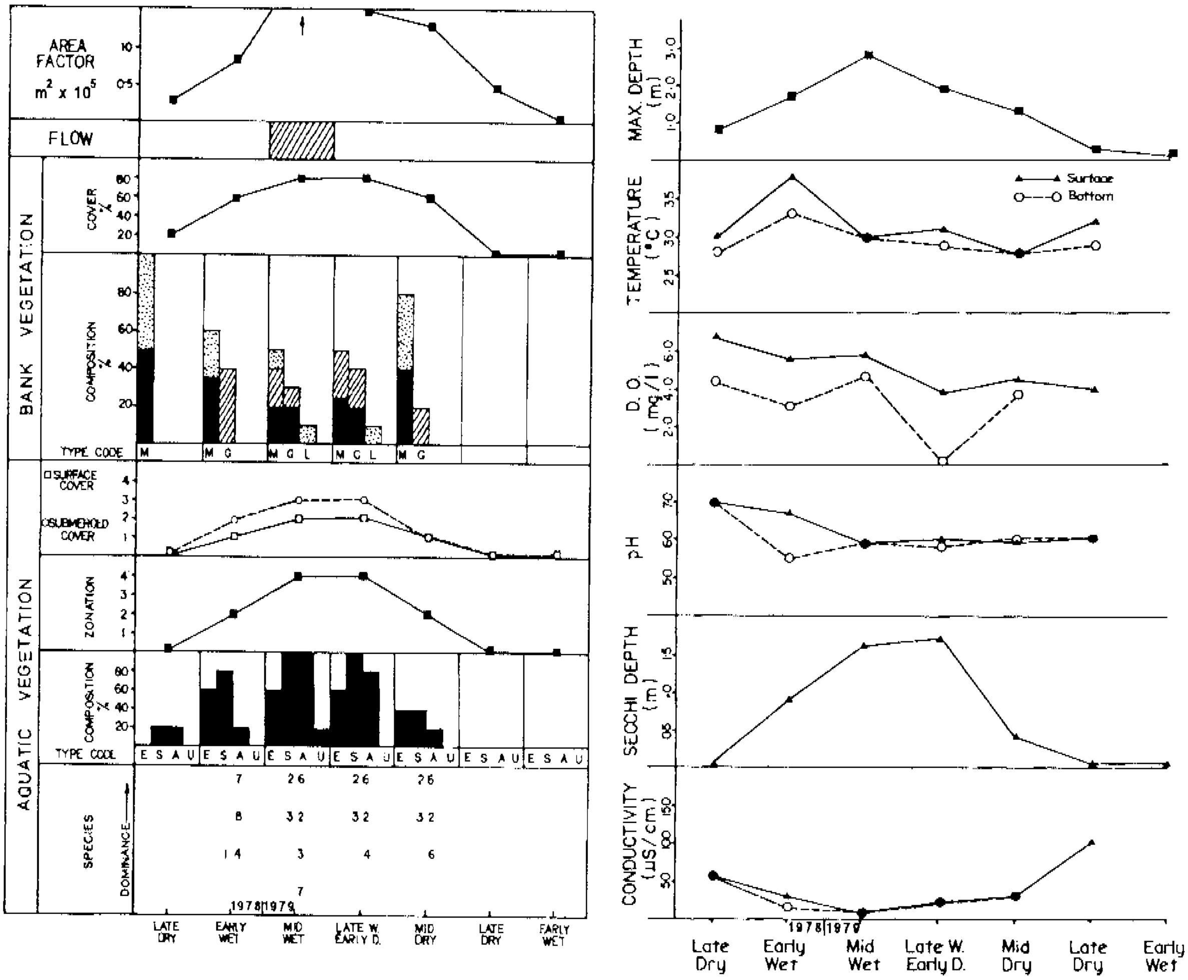



Figure 20. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland backflow billabong, Gulungul Billabong (GL). See Appendix 2 for a key to the habitat-structural variables.

peaked in the Mid-wet and Late-wet-Early-dry seasons at these sites. The zonational complexity of these hydrophyte communities also peaked during this period, and at Corndorl Billabong extended into the 1979 Mid-dry season. *Pseudoraphis spinescens* and *Fimbristylis minima* were important emergent hydrophytes, *Hydrilla verticillata* and *Najas tenuifolia* were important submergent plants, and *Nymphaea gigantea* and *Nymphoides minima* were the important floating attached plants. As the peak Mid-wet season flood levels subsided the littoral growths of *P. spinescens* and *N. tenuifolia* collapsed onto the clay substrates and formed a very thick mat, (a 2 m diameter 'cone' could be formed if this collapsed mat of vegetation was lifted at a given point). Understandably, enormous difficulties were encountered sampling fish in these areas.

Both billabongs were deepest in the Wet season, with maximum depths of 2.8 m at Gulungul Billabong and 2.9 m at Corndorl Billabong. However, maximum depths fell to below 1 m by the Late-dry seasons at both sites and the billabong at Gulungul Billabong had almost disappeared by the 1979-80 Early-wet season when a maximum depth of 0.1 m was recorded. Surface water temperatures, ranging from 28° to 38°C at Gulungul Billabong and from 29° to 34°C at Corndorl Billabong, reached a maximum during the 1978 Early-wet season and dropped to a minimum during the Mid-dry season at Gulungul Billabong and during the Late-wet-Early-dry season

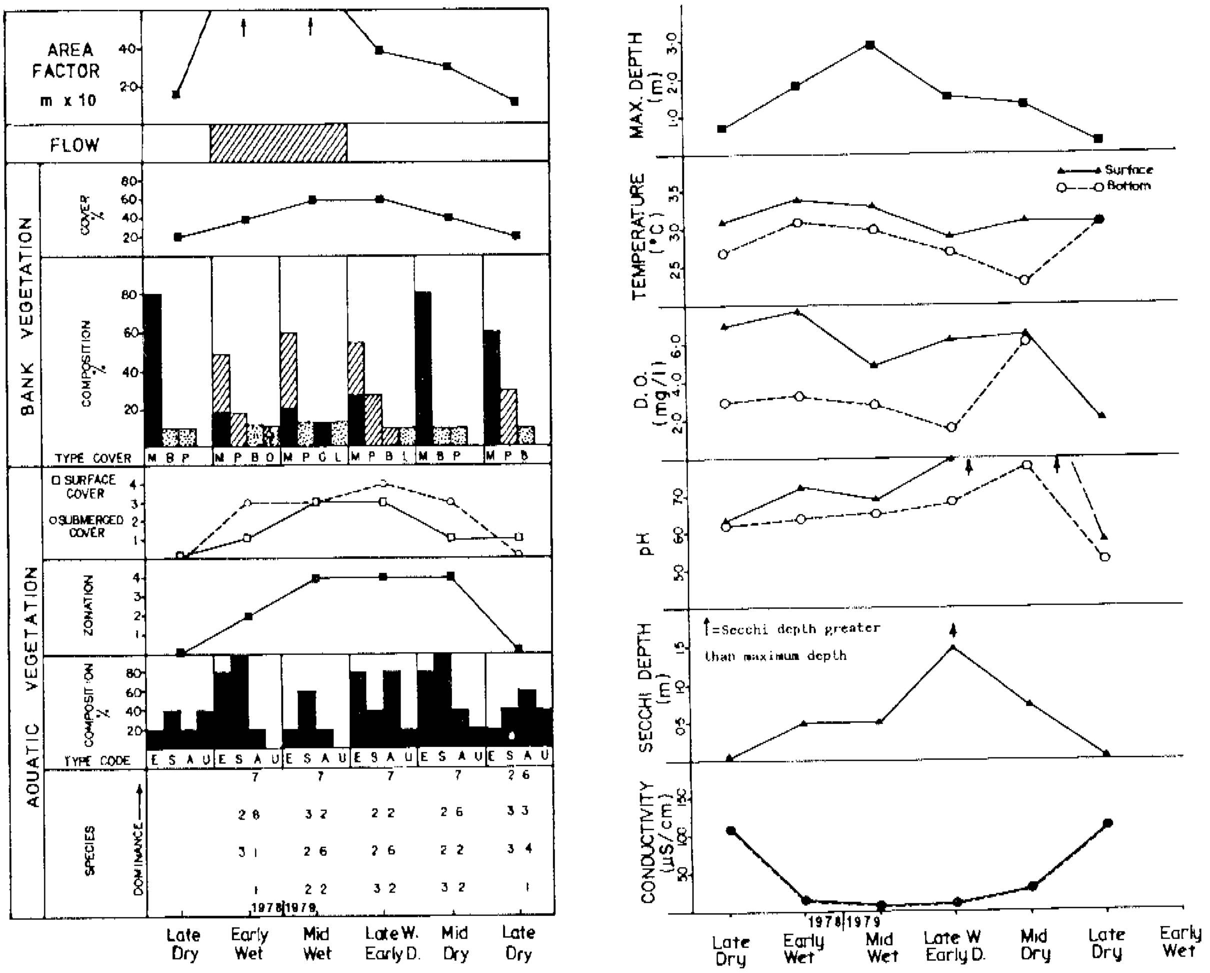


Figure 21. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland backflow billabong, Corndorl Billabong (CL). See Appendix 2 for a key to the habitat-structural variables.

at Corndorl Billabong. Bottom temperatures ranged from 28° to 33°C at Gulungul Billabong and from 23° to 31°C at Corndorl Billabong and were generally 2-4°C cooler than those of surface waters. Surface and bottom waters were most similar at Gulungul Billabong between the Mid-wet and the 1979 Mid-dry season and most dissimilar in the 1978-79 Early-wet season. At Corndorl Billabong the surface and bottom temperatures were most similar in the 1979 Late-dry season and most dissimilar in the Mid-dry season that preceded it.

Dissolved oxygen concentrations in the billabongs ranged from 3.8 to 6.8 mg/L at Gulungul Billabong and from 2.0 to 7.8 mg/L at Corndorl Billabong. Surface dissolved oxygen concentrations were highest at Gulungul Billabong in the 1978 Late-dry season and lowest from the end of the Wet season through to the following Dry season. Surface dissolved oxygen concentrations peaked at Corndorl Billabong in the 1978-79 Early-wet and the 1979 Mid-dry seasons, but then fell in both the Mid-wet and the 1979 Late-dry. Dissolved oxygen concentrations at the bottom ranged from 0.2 to 4.8 mg/L at Gulungul Billabong, and from 1.6 to 6.1 mg/L at Corndorl Billabong. Bottom concentrations were highest in the Mid-wet season at Gulungul Billabong and in the 1979 Mid-dry season at Corndorl Billabong, when they were most similar to those of surface waters. During the Late-wet-Early-dry seasons, dissolved oxygen concentrations at the bottom were lowest and most dissimilar to those of surface waters. Bottom dissolved oxygen samples were occasionally not taken at some shallow turbid sites owing to practical problems involved in sampling such habitats.

Surface pH levels ranged from 5.9 to 7.0 at Gulungul Billabong and from 5.8 to 9.9 at Corndorl Billabong, while bottom pH levels ranged from 5.5 to 7.0 at Gulungul Billabong and from 5.3 to 7.8 at Corndorl Billabong. Surface and bottom pH were very similar (except in the 1978-79 Early-wet season) at Gulungul Billabong, but at Corndorl Billabong bottom pH was usually 0.5 to 1.0 pH units less than that of the surface waters; this differential reached a maximum of 2.5 pH units in the 1979 Mid-dry season. Surface and bottom conductivities were very similar at both sites and showed a clear reduction in the Wet season and a build-up towards the end of the 1979 Late-dry season.

Turbidity was at a minimum during the Late-wet-Early-dry season with Secchi depth readings of 1.7 m at Gulungul Billabong and > 1.5 m at Corndorl Billabong. The turbidity increased during the Late-dry seasons (Secchi depth < 1 cm) at both sites.

**Fish communities.** Figure 22 summarises the total abundance, total weight, number of species, Shannon diversity and evenness indices for samples taken from Gulungul and Corndorl billabongs. Twenty-one fish species were collected during the study at Gulungul Billabong and 17 were collected at Corndorl Billabong by standard netting methods (Tables 11g-11h). A further four species were captured at Corndorl Billabong in a deep, sandy/muddy backwater which was isolated in the Dry season from the standard shallow muddy site (Corndorl Billabong was at times very difficult to sample owing to the muddy substrate). Extra species captured in this backwater included *Craterocephalus* nov. sp., *C. stercusmuscarum*, *A. macleayi* and *G. giurus*. The most abundant fish species collected at Gulungul Billabong were *A. agrammus*, *M. splendida inornata*, *D. bandata*, *G. aprion* and *P. rendahli* and the most abundant species at Corndorl Billabong were *A. agrammus*, *M. splendida inornata*, *P. tenellus*, *N. erebi* and *P. rendahli*. The abundance of three of these fish species peaked at both sites during the Late-wet-Early-dry season and *A. agrammus*, *M. splendida inornata* and *D. bandata* were mainly responsible for this peak. The total number of species was at a minimum during the 1978-79 Early-wet season but rose to peak during the Late-wet-Early-dry season and then fell again towards the Late-dry season. No fish were captured in the 1979-80 Early-wet season at Gulungul Billabong, which was then virtually reduced to a mudhole. The richness and Shannon diversity indices followed similar patterns throughout the study, as did the total number of species. Evenness was lowest, owing to large catches

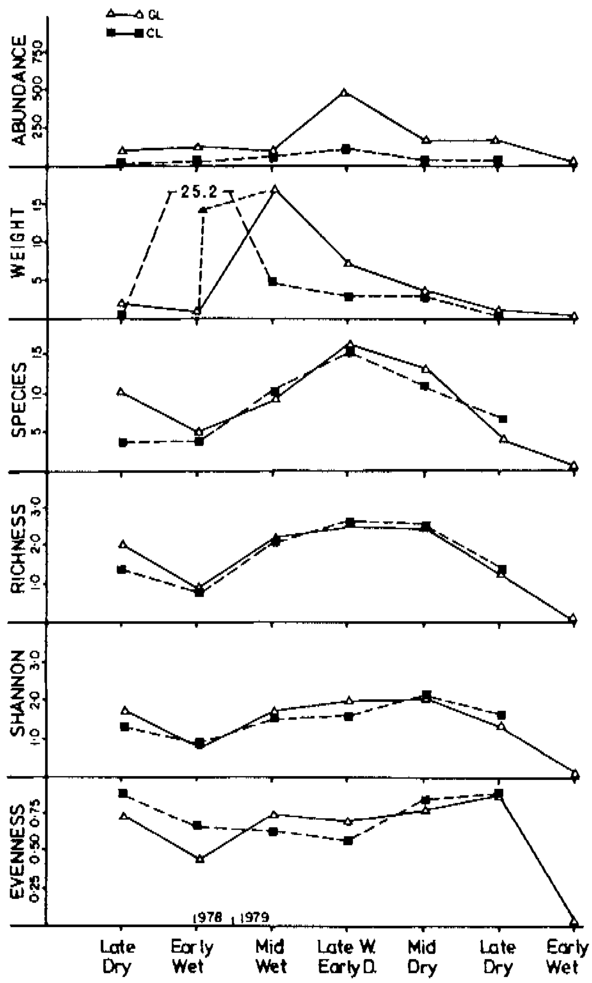



Figure 22. Summary of seasonal abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken in the lowland backflow billabongs, Gulungul and Corndorl billabongs

Catches were obtained using standard netting methods.

of *A. agrammus*, at Gulungul Billabong during the 1978-79 Early-wet and at Corndorl Billabong during the Late-wet-Early-dry season.

The five fish species which contributed most to the total weight of catches over the sampling period were *A. leptaspis, N. erebi, S. krefftii, P. rendahli* and *M. cyprinoides* at Gulungul Billabong and *A. leptaspis, N. erebi, M. cyprinoides, T. ater* and *T. chatareus* at Corndorl Billabong. Three of these species thus contributed most to the total weight of catches at both sites. Total weight peaked at Corndorl Billabong during the 1978-79 Early-wet season and at Gulungul Billabong during the Mid-wet season. Corndorl Billabong had already backfilled from the Magela Creek channel by the time of the Early-wet season sampling, but Gulungul Billabong had not. When Gulungul Billabong was re-sampled after it had backfilled from the main channel, the total weight had increased fifteen-fold compared with the previous sample. *Nematalosa erebi* at Gulungul Billabong and *P. rendahli* at Corndorl Billabong contributed most to the total weight before the 1978-79 Wet season. After flow commenced *M. cyprinoides, N. erebi, A. leptaspis, L. unicolor* and *T. chatareus* contributed most to total weight at both sites. After flow ceased, *S. krefftii, M. cyprinoides, N. erebi* and *P. rendahli* contributed most to the total weight of catches at Gulungul Billabong, and *A. leptaspis, N. erebi* and *A. percoides* at Corndorl Billabong.

*Malabanbandju Billabong, Anbangbang Billabong and Deaf Adder Creek*

**Environment.** The habitat-structural and physico-chemical variables recorded while sampling fish at the two billabong sites are summarised in Fig. 23 for Malabanbandju Billabong and in Fig. 24 for Anbangbang Billabong.

Malabanbandju Billabong filled from flow within its catchment during the 1978-79 Early-wet season, while Anbangbang Billabong backfilled from Nourlangie Creek. As Anbangbang Billabong had gently sloping, muddy banks, in contrast to the steep-sided clay banks at Malabanbandju Billabong, a much larger surface area resulted when Anbangbang Billabong was inundated during the Wet season. The Wet season flow was more noticeable at Malabanbandju Billabong. As Anbangbang Billabong contracted in the Dry season, it receded towards the size of Malabanbandju Billabong which was also decreasing in size. Bank vegetation cover increased following the Wet season inundation of these billabongs and peaked in the Mid-wet season when the fringing *Melaleuca* spp. forests were inundated. Grasses were particularly important cover at both sites in the Wet season during peak floods.

Surface and submergent hydrophyte cover increased over the 1978-79 Early-wet season at Anbangbang Billabong and towards the Mid-wet season at Malabanbandju Billabong to peak at both sites between the Mid-wet and Late-wet-Early-dry seasons. Hydrophytes persisted throughout the study at both sites (except during the 1979 Late-dry season at Anbangbang Billabong) and flourished during the Wet season. The zonational complexity of these hydrophyte communities peaked in the Wet season but this was gradually reduced into the 1979 Dry season. *Pseudoraphis spinescens* was an important emergent hydrophyte, *Najas tenuifolia* (especially at Anbangbang Billabong) was an important submergent, and important floating attached plants were *Caldesia oligococca, Marsilea* sp., *Nymphoides minima* and *Nymphaea gigantea*. There were also collapsed mats of *P. spinescens* and *N. tenuifolia* in the littoral zone, at the end of the Wet season at Anbangbang Billabong.

Malabanbandju Billabong had a much greater maximum depth (4.0 m at the fishing site), compared to that at Anbangbang Billabong (1.8 m) in the Wet season. Maximum depths had dropped to 1.0 m at Malabanbandju Billabong and 0.2 m at Anbangbang Billabong by the 1979 Late-dry season. Surface water temperatures, ranging from 28° to 35°C at Malabanbandju Billabong and from 26° to 34°C at Anbangbang Billabong, were highest at both sites in the 1978-79 Early-wet season and lowest by the 1979 Mid-dry season at Malabanbandju Billabong and the 1979 Late-dry season at Anbangbang Billabong. Water temperatures at the bottom of the

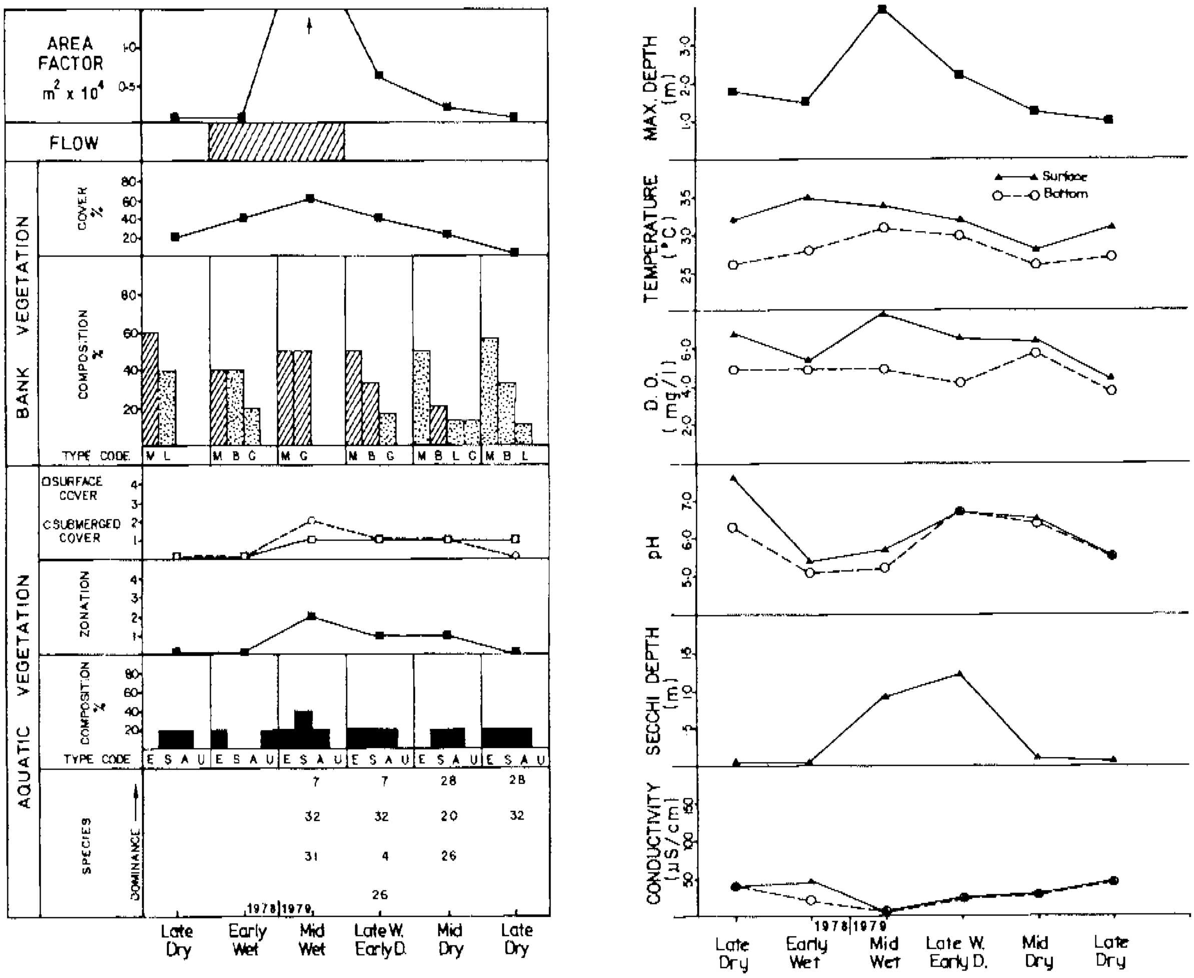



Figure 23. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland backflow billabong, Malabanbandju Billabong (BX). See Appendix 2 for a key to the habitat-structural variables.

billabongs ranged from 26° to 31°C at Malabanbandju Billabong and from 26°C to 30°C at Anbangbang Billabong. Bottom and surface water temperatures at Malabanbandju Billabong were most similar (only 2-3°C difference) in the 1979 Mid-dry season and was the same at Anbangbang Billabong during the 1979 Late-dry season. Bottom and surface temperatures were most dissimilar (4-7°C difference) during the 1978-79 Early-wet season.

Dissolved oxygen concentrations at the surface of the billabongs, ranging from 4.4 to 7.8 mg/L at Malabanbandju Billabong and from 5.1 to 8.0 mg/L at Anbangbang Billabong, were highest in the Mid-wet season at Malabanbandju Billabong and in the 1979 Mid-dry season at Anbangbang Billabong and lowest in the 1979 Late-dry season at both sites. Dissolved oxygen concentrations at the bottom ranged from 3.6 to 5.7 mg/L at Malabanbandju Billabong and from 0.6 to 3.2 mg/L at Anbangbang Billabong. Only two bottom dissolved oxygen samples were taken at this site owing to problems in sampling such shallow muddy habitats. Bottom dissolved oxygen concentrations were highest at Malabanbandju Billabong during the 1979 Mid-dry season and lowest during the Late-dry season. Surface and bottom dissolved oxygen concentrations were most dissimilar (2 to 3 mg/L less in bottom waters) at Malabanbandju Billabong during the Mid-wet and Late-wet seasons. A very low bottom dissolved oxygen (6 mg/L lower than in surface waters), was recorded at

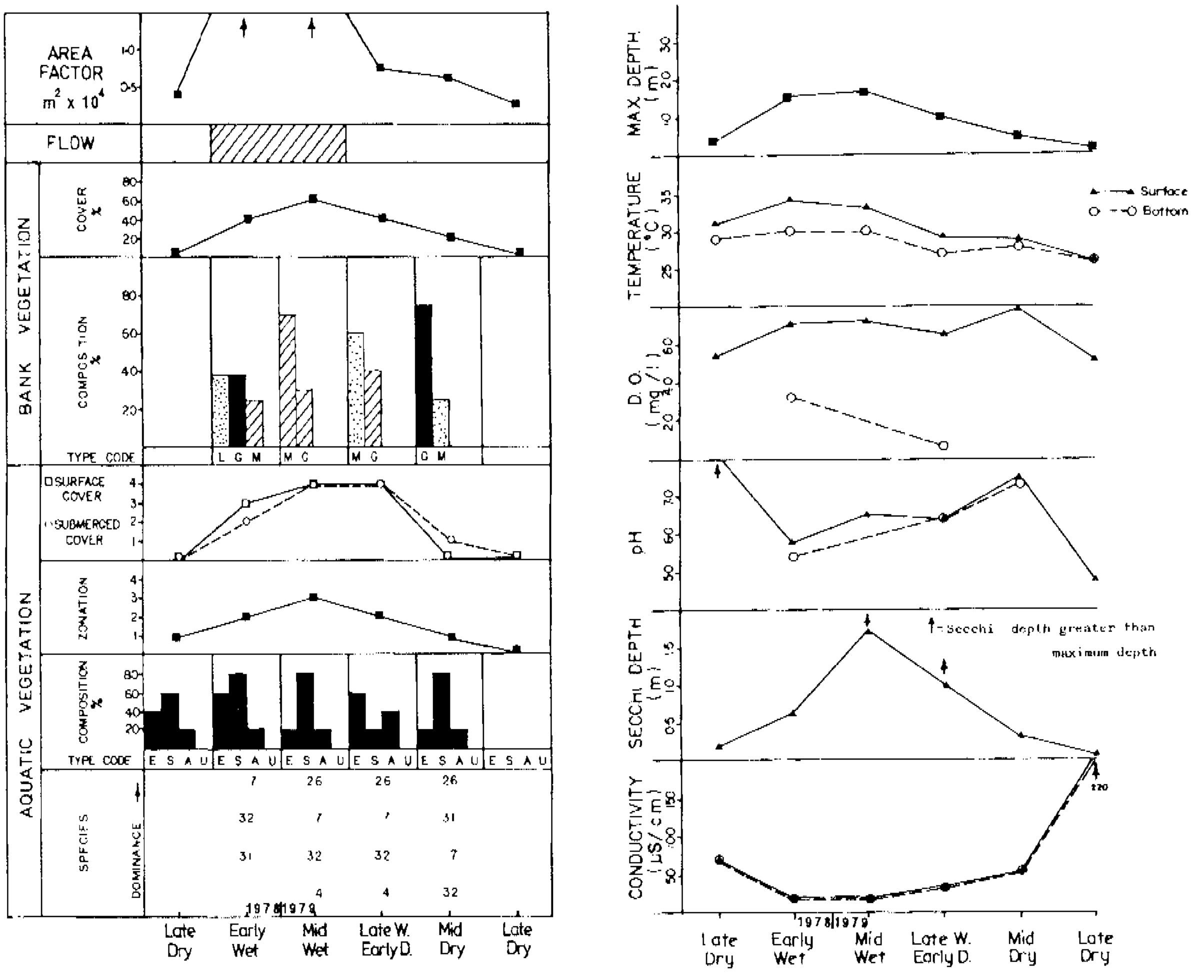


Figure 24. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a lowland backflow billabong, Anbangbang Billabong (NR). See Appendix 2 for a key to the habitat-structural variables.

Anbangbang Billabong during the Late-wet-Early-dry season.

Surface pH ranged from 5.4 to 7.6 at Malabanbandju Billabong and from 4.7 to 8.1 at Anbangbang Billabong and bottom pH ranged from 5.1 to 6.7 at Malabanbandju Billabong and from 5.4 to 7.3 at Anbangbang Billabong. Surface and bottom pH values were usually similar and were lowest in the Early-wet and Mid-wet seasons. Surface and bottom conductivities were generally similar and low (approx. 50 $\mu$S/cm throughout the study) and were at a minimum during the Mid-wet season. During the 1978-79 Early-wet season, the differences between the surface and bottom waters at Malabanbandju Billabong was possibly caused by the inflow of waters from the upstream parts of the catchment.

Surface and bottom conductivities at Anbangbang Billabong dropped to below 50 $\mu$S/cm between the 1978-79 Early-wet and the 1979 Mid-dry seasons, but as the billabong diminished in size in the 1979 Late-dry season the conductivities rose sharply to 220 $\mu$S/cm.

Turbidity at both sites was lowest during the Mid-wet and Late-wet-Early-dry seasons, with maximum Secchi depths of 1.4 m at Malabanbandji Billabong and 1.7 m at Anbangbang Billabong. Malabanbandju Billabong was usually a much more turbid site, with Secchi depth reading < 1 cm in the Dry season.

The Deaf Adder Creek site appeared to be superficially similar in character to the backflow Georgetown Billabong. In the Wet season, there were higher flow-through water velocities and so more sand and gravel substrates at the Deaf Adder site. The banks at Deaf Adder were vertical and clay-based in places and had fringing clumps of *Pandanus aquaticus*. As Deaf Adder was also deeper than Georgetown Billabong, water persisted there throughout the Dry seasons. Large populations of *Crocodylus johnstoni* were present in Deaf Adder Creek.

**Fish communities.** Figure 25 summarises the seasonal total abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken from Malabanbandju and Anbangbang billabongs. The total number of fish species collected from Malabanbandju Billabong was 23 species and that from Anbangbang Billabong was 21 species (Tables 11i-11j). No extra species were collected at either site by non-standard methods. The most abundant species collected at Malabanbandju Billabong were *A. agrammus*, *G. aprion*, *M. splendida inornata* and *C. stercusmuscarum*, and the most abundant species at Anbangbang Billabong were *A. agrammus*, *D. bandata*, *M. splendida inornata*, *N. erebi* and *P. rendahli*. Only two of these species, *A. agrammus* and *M. splendida inornata*, were among the most abundant at both sites. Total abundance at Malabanbandju Billabong peaked only during the Late-wet-Early-dry season. At Anbangbang Billabong, total abundance was initially high during the 1978 Late-dry season and then fell to a low level between the 1978-79 Early-wet and the Late-wet-Early-dry seasons. Sampling of this billabong was difficult in the Wet season because it was choked with hydrophytes. Total abundance at Anbangbang Billabong then peaked again during the Mid-dry season to fall by the following Late-dry season. Peaks in abundance were usually associated with large catches of *A. agrammus* and *M. splendida inornata* towards the end of the Wet season.

The total number of species in the samples taken at these sites generally followed opposite trends; e.g. over the Wet season, fewer fish species were captured at Anbangbang Billabong. At this time a maximum number of fish species was recorded at Malabanbandju Billabong. This anomaly was probably a result of difficulties in sampling Anbangbang Billabong, which had an extensive hydrophyte cover. Malabanbandju Billabong had only a medium hydrophyte cover at this time. The total number of species at Anbangbang Billabong fell to a minimum after the 1979 Mid-dry season peak. At Malabanbandju Billabong, richness followed similar trends to the total number of species throughout the sampling period, but at Anbangbang Billabong this parallel was not as obvious, although after the Wet season both indices rose, to fall again in the Late-dry. The Shannon diversity and

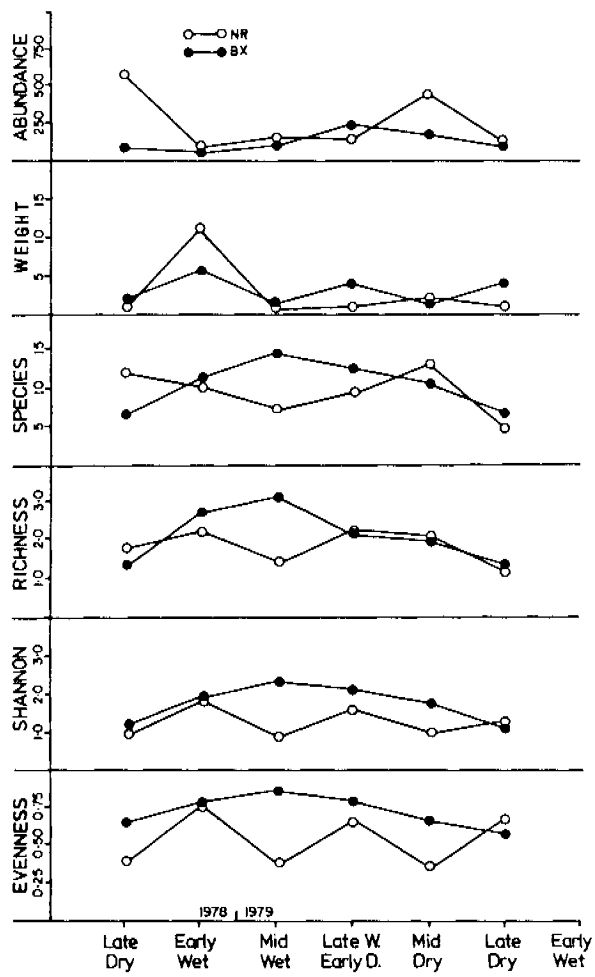



Figure 25. Summary of seasonal abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken in the lowland backflow billabongs, Malabanbandju and Anbangbang billabongs

Catches were obtained using standard netting methods.

evenness indices showed essentially the same features at both sites. At Malabanbandju Billabong the Shannon diversity and evenness indices were generally stable and peaked only once (during both the Mid-wet season), but at Anbangbang Billabong they fluctuated more widely, with minima occurring during the Mid-wet and Mid-dry seasons and usually resulting from large catches of *A. agrammus.*

The five species which contributed most to the total weight of fish captured over the total sampling period were *N. erebi, O. lineolatus, P. rendahli, A. dahli* and *A. leptaspis* at Malabanbandju Billabong and *N. erebi, T. ater, S. krefftii, T. chatareus* and *M. cyprinoides* at Anbangbang Billabong. Samples from these sites therefore, appeared to be relatively distinct in their weight composition. Total weight reached a maximum at both sites during the 1978-79 Early-wet season, when *N. erebi, T. ater, L. calcarifer, T. chatareus* and *M. cyprinoides* (at Anbangbang Billabong) entered during backfilling conditions. Total weight then remained low from the Mid-wet season to the end of the study, with *N. erebi* and *G. aprion* contributing most to the total weight at Malabanbandju Billabong and *P. rendahli* and *L. unicolor* contributing most to the total weight of the catches at Anbangbang Billabong in this period. *Arius proximus, A. dahli* and *T. lorentzi* were species characteristic of the Nourlangie Creek system samples, while *Liza alata* and *Hypseleotris compressa* were species usually characteristic of floodplain and corridor waterbody sample from Magela Creek catchment. *Arius graeffei* and *A. dahli* were captured at the Deaf Adder Creek site during the 1978 Late-dry season (Table 11i). Even though the Deaf Adder site was sampled on only one occasion, the composition of the community sample appeared to be similar to those found in Malabanbandju Billabong and Anbangbang Billabong.

*Cooper Creek waterbodies (Narbarlek Dam, Bullwidgi Billabong, Birraduk Creek)*

**Environment.** The Cooper Creek system billabongs were similar to the scoured channel backflow billabongs in the Magela Creek system (Indium and Goanna billabongs) in having relatively steep-sided clay banks. Bullwidgi Billabong was a deep (5.4 m in the 1978 Late-dry season), large (100 m x 20 m) billabong with banks thickly vegetated by *Pandanus aquaticus, Melaleuca* spp. and grasses. Birraduk Creek appeared to be very similar in character to Goanna Billabong. Nabarlek Dam was a waterbody created by the backflow from a dam supplying water for the Nabarlek mining camp. It was deep (approx. 7 m), and circular (60 m diameter), and had scant bank vegetation. The substrate was predominantly leaf litter, mud and, where the sandy creek entered the billabong, sand. Some hydrophytes were present in this upstream sandy section of the billabong.

**Fish commumities.** The fish communities present at these sites (Table 10) were similar, in terms of abundances and weights of fish species present, to other backflow billabong habitats examined. The main interesting differences in the fish present in samples from the Cooper Creek sites compared with the Magela and Nourlangie Creek System sites were the absence of *A. leptaspis* and the abundance of *A. percoides.* Bullwidgi Billabong, the site with the least diverse sample, contained large populations of *Crocodylus johnstoni.*

## 3.4 Corridor waterbodies

**Environment.** The habitat-structural and physico-chemical variables recorded at the corridor waterbody sites are summarised in Fig. 26 for Mudginberri corridor (MI, Map 2), Fig. 27 for Buffalo Billabong (BO, Map 2) and Fig. 28 for Island Billabong (ID, Map 2).

Water flowed through these billabongs between the 1978-79 Early-wet and the Late-wet-Early-dry seasons. Prior to the commencement of this water flow, these billabongs measured 80 × 800 m (Mudginberri corridor), 50 × 200 m (Buffalo Billabong) and 100 × 2000 m (Island Billabong). When the flow began early in the Wet season, the shape and surface area of the habitats with steep, well-vegetated banks at Mudginberri corridor and Buffalo Billabong did not change dramatically, but the well-vegetated, lower banks at Island Billabong became covered by water (particularly the

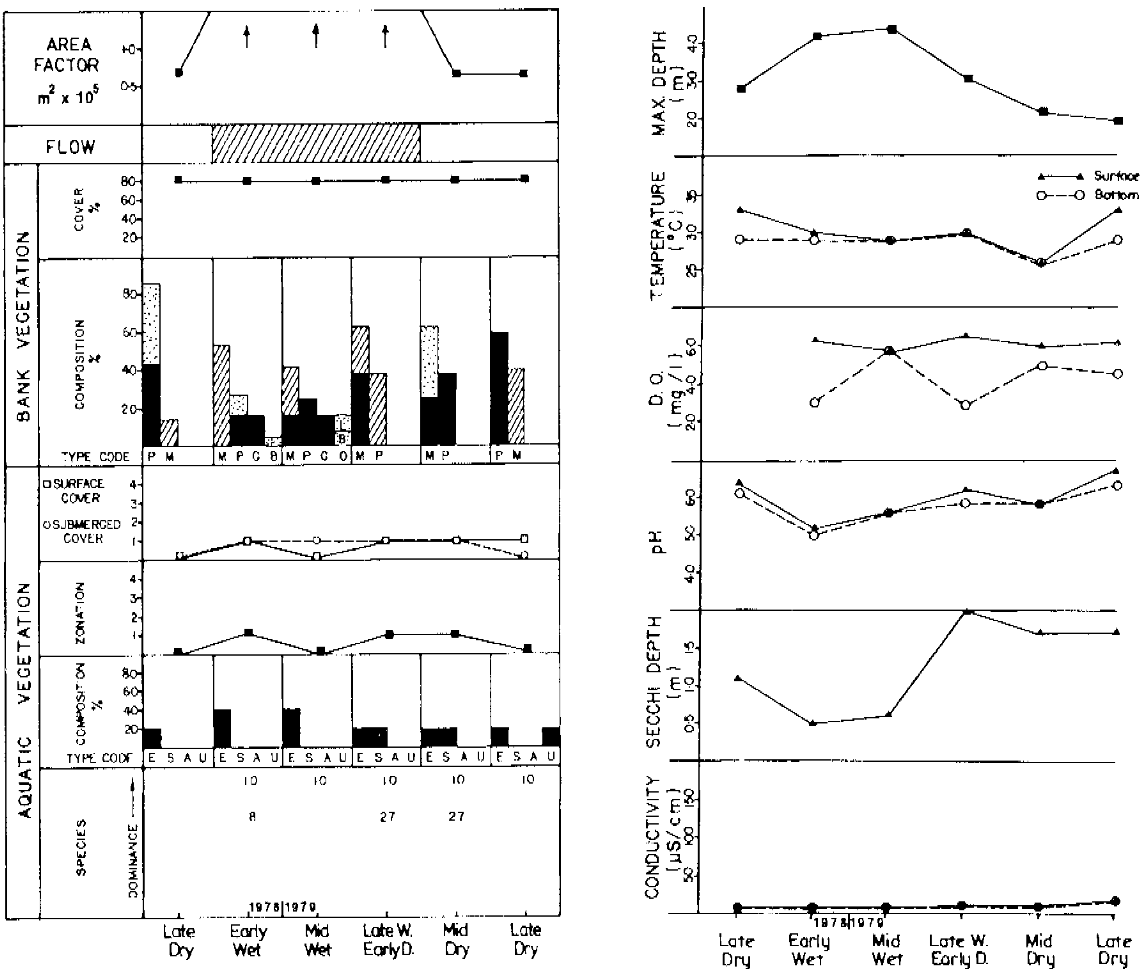



Figure 26. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a corridor billabong, Mudginberri corridor (MI). See Appendix 2 for a key to the habitat-structural variables.

western floodplain bank), along with nearby dry *Melaleuca* swamps. During the Mid-wet season, the floodwaters eventually broke the banks of Mudginberri corridor and Buffalo Billabong, covering large areas of grass (*Brachiaria mutica*), *Melaleuca* forests and the gravel road to Oenpelli near Buffalo Billabong. Cover from bank vegetation remained very high throughout the study at all sites with the bank vegetation communities being very dense and complex, especially at Buffalo Billabong. Large areas of inundated forests surrounded all sites by the Mid-wet season. In the Dry season, thick stands of *Pandanus aquaticus* fringed all the billabongs and *Barringtonia acutangula* was also present at Buffalo Billabong. As the season progressed, the supporting root systems of both these species gradually became the only parts of the trees which were submerged. As the water level rose again in the Wet season these plants were submerged to leaf level and stands, which in the Dry season had fringed the billabongs, became isolated towards the middle of the billabongs.

Hydrophytes were rare at Mudginberri corridor, hence the low contribution to surface and submerged cover and the low zonational complexity. This was possibly because of the scouring water velocities and sandy substrates, although hydrophytes flourished in slow-flowing muddy backwaters in the Mid-wet season. Next to the sandy sections of Mudginberri corridor there were thick growths of *Brachiaria mutica*, and occasionally of *Fimbristylis minima*, on the sun-exposed western banks and into the littoral waters throughout the

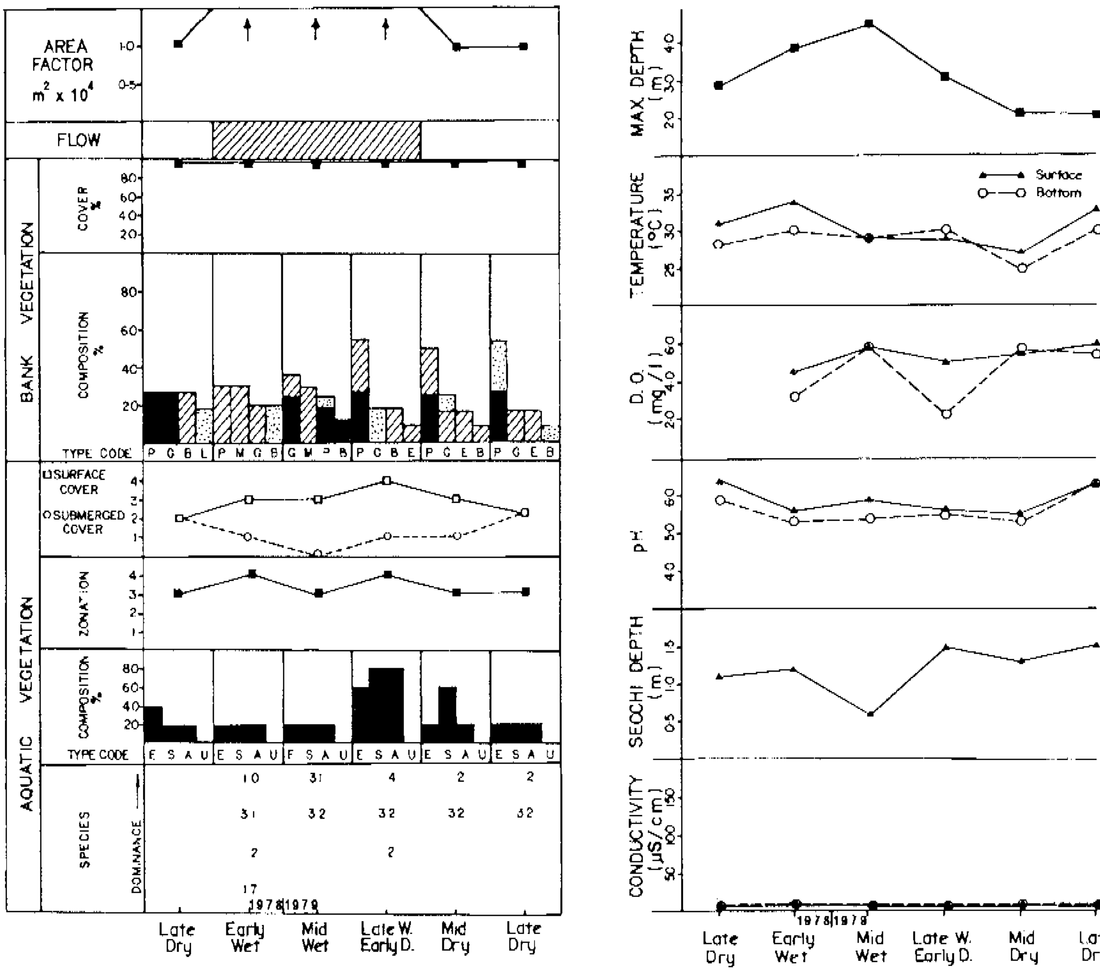



Figure 27. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at a corridor billabong, Buffalo Billabong (BO). See Appendix 2 for a key to the habitat-structural variables.

study. Filamentous green algae were also abundant over sandy substrates at Mudginberri corridor during the Late-wet-Early-dry and Mid-dry seasons. Hydrophytes were present at Buffalo and Island billabongs throughout the study. Mud substrates predominated at both of these sites, although at Buffalo Billabong there were sandy substrates in the upstream end of the billabong, near where a part of the discharge from Mudginberri corridor entered. *Brachiaria mutica*, *Polygonum* sp., *Utricularia* sp. and *Nymphoides minima* were present at Buffalo Billabong during the Late-dry season, although some of these plant species disappeared as flow commenced. *Nymphoides minima* and *Nymphaea gigantea* then became most abundant in the Wet season and after a peak in hydrophyte cover in the Late-wet-Early-dry season, *Polygonum* sp. became increasingly important into the Dry season. Zonation complexity remained high throughout the study at Buffalo Billabong, as did the hydrophyte surface cover, which peaked during the Late-wet-Early-dry season. Submergent hydrophyte cover at Buffalo Billabong was highest during the Late-dry seasons and lowest in the Mid-wet season; this may relate to water movement through the billabong over these seasons. At Island Billabong, surface and submergent hydrophyte cover and zonation complexity were generally high throughout the study. Both types of cover decreased in the Mid-wet season, however, to peak during the Late-wet-Early-dry season. In contrast, zonation complexity peaked during the Mid-wet season. Large floating meadows of *Ludwigia adscendens* with intertwined

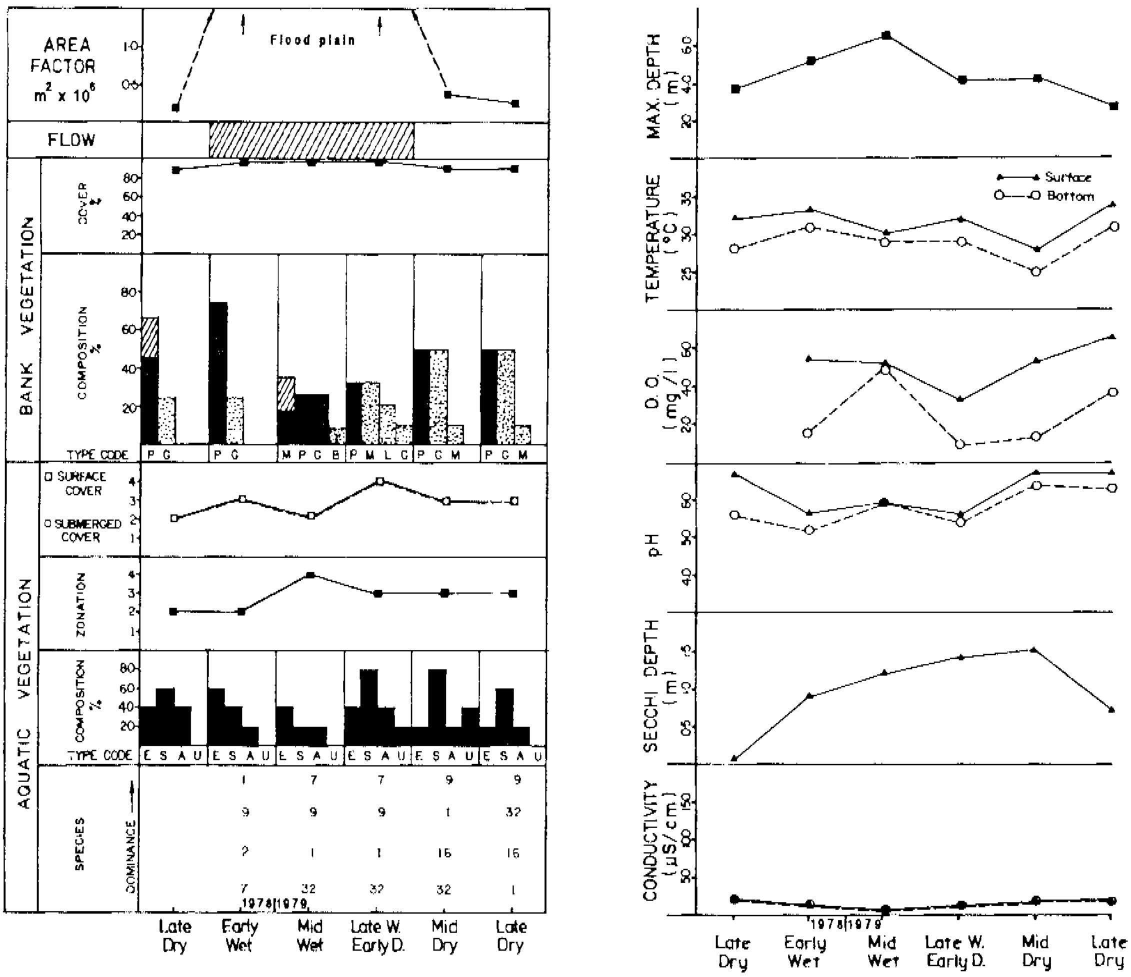



Figure 28. Summary of (a) habitat-structural and (b) physico-chemical variables recorded during fish sampling at a corridor billabong, Island Billabong (ID). See Appendix 2 for a key to the habitat-structural variables.

*Hymenachne acutigluma* and occasionally, *Pseudoraphis spinescens*, were present throughout the study. After the western bank of Island Billabong had been submerged by a thin sheet of water in the 1978-79 Early-wet season, *P. spinescens* flourished and covered this once bare area. Through the Wet season the dominant floating attached species was *Nymphaea gigantea*, and into the Dry season the main submergent species were *Utricularia stellaris* and *Najas tenuifolia*.

The maximum depths recorded in the Mid-wet season at Mudginberri corridor, Buffalo and Island billabongs were 4.4 m, 4.5 m and 6.5 m respectively, compared to maximum depths of 2.0 m, 2.1 m and 2.8 m in the 1979 Late-dry season. Surface water temperatures ranged from 26° to 33°C at Mudginberri corridor and from 27° to 34°C at both Buffalo and Island billabongs. Bottom water temperatures ranged from 26° to 30°C at Mudginberri corridor, from 25° to 30°C at Buffalo Billabong and from 25° to 31°C at Island Billabong. Surface and bottom water temperatures generally followed each other closely, especially between the 1978-79 Early-wet season and the Late-dry season. Highest temperatures were recorded in the Late-dry season and the lowest in the Mid-dry season.

Dissolved oxygen concentrations at the surface of the billabongs ranged from 5.6 to 6.6 mg/L at Mudginberri corridor; from 4.6 to 5.8 mg/L at Buffalo Billabong and from 3.4 to 6.6 mg/L at Island Billabong. Concentrations of dissolved oxygen at the bottom ranged from 3.0 to 5.8 mg/L at

Mudginberri corridor; from 2.2 to 5.8 mg/L at Buffalo Billabong and from 0.8 to 5.0 mg/L at Island Billabong. Surface dissolved oxygen concentrations varied only slightly at these sites, but fell to a minimum at Island Billabong during the Late-wet-Early-dry season. Surface and bottom dissolved oxygen concentrations were most similar at all sites in the Mid-wet season. During the previous (1978) Late-dry season, bottom dissolved oxygen concentrations at all the sites had generally been 4.0 mg/L less than surface dissolved oxygen concentrations (T.D. Walker, pers. comm). After the Wet season bottom dissolved oxygen concentrations fell dramatically relative to those of surface waters (3 to 4 mg/L less) and at Island Billabong remained low through the Dry season; at Mudginberri corridor and Buffalo Billabong they gradually increased through the Dry season (to be, respectively, 1.0 and 0.5 mg/L less than in surface waters).

Surface pH ranged from 5.2 to 6.7 at Mudginberri corridor; from 5.5 to 6.4 at Buffalo Billabong and from 5.6 to 6.7 at Island Billabong. Bottom pH ranged from 5.0 to 6.3 at Mudginberri corridor; from 5.3 to 6.3 at Buffalo Billabong and from 5.2 to 6.4 at Island Billabong. Surface and bottom pH levels were usually very similar and tended to be lower in the 1978-79 Early-wet and higher in the Late-dry seasons. Surface and bottom conductivities remained at a very stable low levels (5 to 20 $\mu$S/cm) at all the sites throughout the study.

Turbidity increased in the Dry seasons at Mudginberri corridor and Buffalo Billabong, the Secchi depth readings decreasing from a range of between 1.0 m to 2.0 m to ≈ 0.5 m, in the Early-wet and Mid-wet seasons. Secchi depths of < 1 cm were recorded at Island Billabong during the 1978 Late-dry season but, after flow commenced, the turbidity gradually decreased to reach a peak Secchi depth reading of 1.5 m during the Mid-dry season, before an increase in turbidity during the 1979 Late-dry season.

Other Nourlangie Creek system corridor waterbody sites at Nourlangie East (NE, Map 2) and Namandi (former name Skull Rock or Long Harry; SR, Map 2), most closely resembled the site at Mudginberri corridor on the Magela Creek system. The Nourlangie Creek sites Flying Fox (FX, Map 2) and the Nourlangie 3 site (N3, Map 2), resembled the Island Billabong site on the Magela Creek in many characteristics. Island Billabong appeared to be essentially a floodplain billabong (or at least transitional in character between corridor waterbodies and floodplain billabongs), while Flying Fox and the Nourlangie 3 site tended to be more similar in character to Nourlangie Creek upper flood plain billabongs.

**Fish communities.** The abundances and weights of those fish species captured at Mudginberri corridor, Buffalo Billabong and Island Billabong, using standard netting methods are shown in Tables 12a-12c. Figure 29 summarises the seasonal total abundance, total weight, richness, Shannon diversity and evenness indices for the fish communities at these sites.

The total number of fish species captured by standard netting methods during the study was 20 at Mudginberri corridor, 23 at Buffalo Billabong and 24 at Island Billabong. The use of non-standard methods at these sites demonstrated the presence of additional fish species: *Craterocephalus* nov. sp. (1.5 m deep seine net; 10 mm mesh), *L. calcarifer* (natural fish kills and underwater observation) and *L. alata* (underwater observation) at the Mudginberri corridor site bringing the total number of fish species at this site to 23; *Craterocephalus* nov. sp. (1.5 m deep seine net; 10 mm mesh) at Buffalo Billabong bringing the total number of fish species at this site to 24; and *L. calcarifer* (natural fish kills) at Island Billabong bringing the total number of fish species at this site to 25.

The five most abundant species over the whole sampling period were, *A. agrammus, C. stercusmuscarum, M. splendida inornata, G. giurus* and *D. bandata* at Mudginberri corridor; *A. macleayi, M. splendida inornata, A. agrammus, C. stercusmuscarum* and *D. bandata* at Buffalo Billabong and *M. splendida inornata, C. stercusmuscarum, A. macleayi, G. aprion* and *D. bandata* at Island Billabong. Four of these species, *A. agrammus, C. stercusmuscarum, M. splendida inornata* and *D. bandata* were therefore included among the most abundant species at all sites. Seasonal total abundance at Buffalo and Island billabongs followed similar trends, reaching a peak during the Late-wet-Early-dry season, which was associated with large catches of *M. splendida inornata* and *Ambassis* spp. Total abundance also peaked at Island Billabong during the 1978 and 1979 Late-dry seasons and was associated with large catches of *G. aprion, M. splendida inornata* and *D. bandata* in 1978, and *A. macleayi* and *M. splendida inornata* in 1979. Total abundance at Mudginberri corridor was much more variable than that recorded at the other two sites. A peak (Fig. 29), in total abundance occurred at this site during the 1978-79 Mid-wet season, caused by an extremely large catch of *A. agrammus* from the standard seine netting site which, in the Wet season, was the first area of near lentic shelter for small fish species below the input of the flood-swollen Magela Creek. There was also another peak in total abundance at Mudginberri corridor during the 1979 Mid-dry season, when large numbers of *C. stercusmuscarum, G. giurus* and *M. splendida inornata* were captured from a seasonally contracted, sandy backwater which was choked with algae (the standard sampling site was by then dry). Total abundance was at a minimum at Mudginberri corridor during both the 1978-79 Early-wet and the Late-wet-Early-dry season. The most dramatic changes in total abundance therefore occurred at this site.

The total number of species in the samples was at a maximum at both Buffalo and Island billabongs during the Late-wet-Early-dry season, and a minimum at both sites during the Mid-wet season (probably owing to difficulties in sampling the billabongs when they were flood-swollen). The total number of species in the sample then fell to another minimum at Island Billabong during the 1979 Mid-dry season. The total number of species at Mudginberri corridor was at a minimum during the 1978 Late-dry season and the number then gradually rose throughout the following Wet season, to reach a maximum during the 1979 Mid-dry season. The richness index followed a similar trend to the total number of species for Buffalo and Island billabongs; it fell, however, during the Mid-wet season at Mudginberri corridor (owing to the large catches of *A. agrammus*) but quickly rose to a peak in the following Late-wet-Early-dry season. The Shannon diversity index followed a similar trend to the richness index, although it showed that Buffalo Billabong appeared to be more seasonally stable than the other sites. The evenness index then followed similar trends to the Shannon diversity, although Buffalo Billabong showed a contrasting pattern to the other sites in having an elevated evenness during the Mid-wet season.

The total weight of catches in these corridor waterbodies was much higher than those recorded for the plateau, escarpment

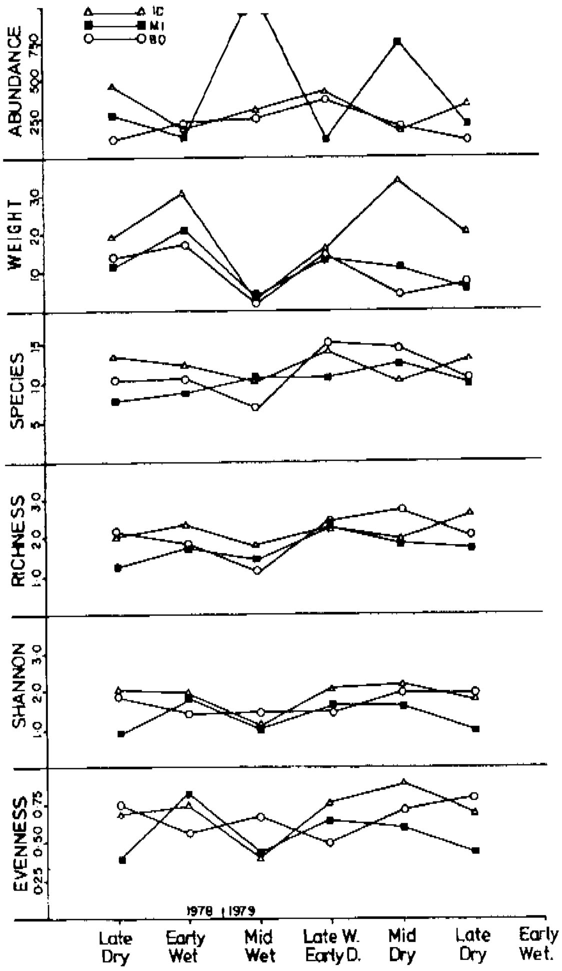



Figure 29. Summary of seasonal abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken in the corridor billabongs, Mudginberri corridor, Buffalo Billabong and Island Billabong

Catches were obtained using standard netting methods.

and lowland habitats studied. To accommodate this number on the graph, the scale on Fig. 29 has been adjusted to show a maximum of 40 kg compared with 10 kg in most of the other Figures. The five fish species which contributed most to the total weight of catches using standard sampling methods were *A. leptaspis, T. ater, S. butleri, N. erebi* and *S. jardini* at Mudginberri corridor; *A. leptaspis, T. ater, N. erebi, T. chatareus* and *L. alata* at Buffalo Billabong and *A. leptaspis, T. ater, M. cyprinoides, S. jardini* and *N. erebi* at Island Billabong. These sites therefore shared three species among those contributing most to the total weight of the catches. As well as being elevated by a particularly high weight contribution from the catches of *A. leptaspis*, the overall total weight of catches were generally higher at Island Billabong than at the other sites. The most noticeable feature of the seasonal total weight graph was that at all sites total weight fell to a minimum in the Mid-wet season, when it appeared that these sites had been evacuated by large fish species. At all the sites, there were increased weights of catches of *A. leptaspis* recorded from the 1978 Late-dry season to the 1978-79 Early-wet season. After the slump in total weight during the Wet season, there was another peak at Mudginberri corridor and Buffalo Billabong (mainly due to catches of *A. leptaspis* and *T. ater*) during the following Late-wet-Early-dry season. Later, during the Mid-dry season, there was an even greater peak in total weight at Island Billabong (due to catches of *A. leptaspis*). Total weight fell again towards the 1979 Late-dry season at Mudginberri corridor and Island Billabong.

At the Magela Crossing site (MX, Map 2), an occasional corridor site on the Magela Creek, only limited sampling was undertaken during the 1978-79 Mid-wet season. Magela Crossing is a shallow (less than 2 m), well-vegetated site, 200 m downstream from Mudginberri corridor and adjacent to the Oenpelli Road crossing, which was submerged during this season. Two species which are usually escarpment dwellers, *S. butleri* and *H. fuliginosus*, were found at this site. *Megalops cyprinoides, N. erebi, S. jardini, M. splendida inornata, C. stercusmuscarum, A. agrammus, D. bandata, L. calcarifer, A. percoides, G. aprion, T. chatareus, L. alata* and *G. giurus* were also present.

A summary of standard sampling in four occasional sites on Nourlangie Creek corridor waterbodies, showing abundances and weights with corresponding species diversity indices, is given in Table 13. Totals of 13, 12, 10 and 8 fish species were found during Dry season sampling at Nourlangie East, Flying Fox, Namandi and the Nourlangie 3 site respectively. These sites (in Table 13) are arranged in a series, going progressively downstream, and it is interesting to note that the number of species decreases in a downstream direction, as do all the species diversity indices and also the seasonal total abundance. Total weight, however, increases from site to site downstream. The most abundant species at the above sites were: *D. bandata, A. percoides, G. aprion, A. leptaspis* and *M. splendida inornata* at Flying Fox; *A. percoides, G. giurus, Craterocephalus* nov. sp., *A. dahli* and *A. graeffei* at Nourlangie East; *C. stercusmuscarum, A. graeffei, A. macleayi* and *M. splendida inornata* at Namandi; and *A. agrammus, A. leptaspis, M. mogurnda, A. proximus* and *T. ater* at the Nourlangie 3 site. The community samples at these sites appeared to be somewhat dissimilar; and may have been due to the variation in habitats present at each site, i.e. Nourlangie East and Namandi were typical sandy 'Mudginberri corridor-type' habitats, while Flying Fox and the Nourlangie 3 site were muddy, hydrophyte-choked habitats.

The fish species contributing most to the total weight of the catches at these sites were: *A. leptaspis, A. proximus, A. dahli, T. ater* and *S. jardini* at Flying Fox; *A. dahli, T. ater, A. graeffei, A. leptaspis* and *S. butleri* at Nourlangie East; *A. graeffei, A. leptaspis, A. dahli, T. ater* and *A. percoides* at Namandi; and *A. leptaspis, A. proximus, T. ater, S. jardini* and *M. cyprinoides* at the Nourlangie 3 site. The fish community samples at these sites resembled those of comparable corridor sites in the Magela Creek system (Nourlangie East being especially like Mudginberri corridor), although the presence of characteristic Nourlangie system species (i.e. *A. proximus, A. graeffei* and *A. dahli*) complicates this picture. The various

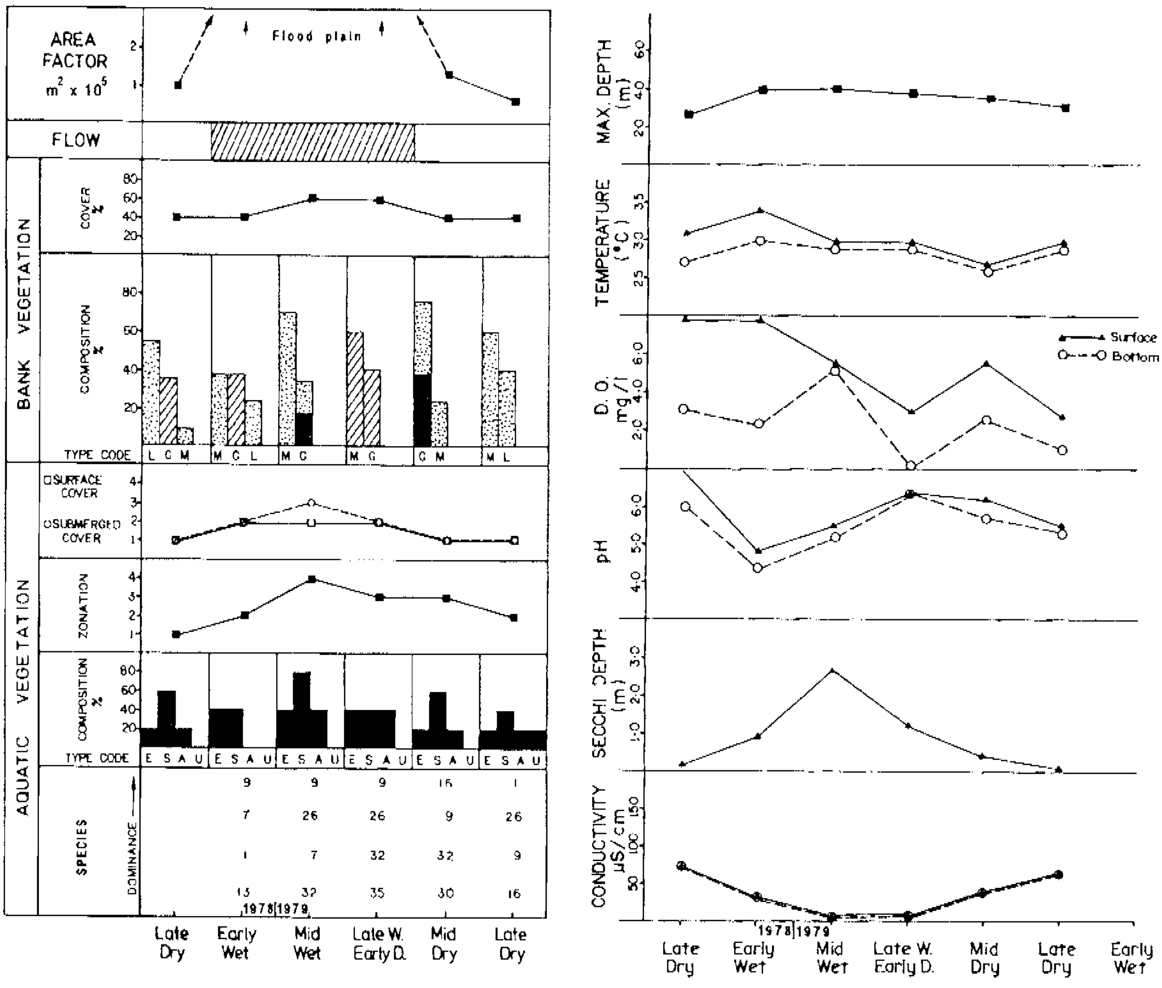


Figure 30. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at an upper floodplain billabong, Ja Ja Billabong (JJ). See Appendix 2 for a key to the habitat-structural variables.

species diversity indices were generally comparable with those of the Magela Creek corridor waterbodies samples during similar sampling periods.

## 3.5 Upper floodplain billabong habitats

**Environment.** A summary of habitat-structural and physico-chemical variables recorded at Ja Ja (JJ, Map 2), Leichhardt (LT, Map 2), Nankeen (NN, Map 2) and Jabiluka (JA, Map 2) billabongs is given in Fig. 30, Fig. 31, Fig. 32 and Fig. 33, respectively.

Water flowed through Ja Ja Billabong from the 1978-79 Early-wet through the Late-wet-Early-dry season, but flowed through Leichhardt Billabong only in the Mid-wet, and through Jabiluka and Nankeen billabongs only in the Mid-wet and Late-wet-Early-dry seasons. Flow commenced earlier at Ja Ja Billabong, as it was the site most upstream on the flood plain and so the closest to the corridor waterbodies. Leichhardt Billabong did not fill from the waters spreading across the flood plain until after the standard 1978-79 Early-wet sampling. Water velocities up to 0.25 m/s were recorded in Leichhardt, Jabiluka and Nankeen billabongs during peak flows in the Mid-wet season. Before the flow commenced, the approximate dimensions of Ja Ja, Leichhardt, Jabiluka and Nankeen billabongs were 100 × 1000 m, 50 × 1000 m, 100 × 1000 m and 60 × 2000 m respectively. As the flow commenced, the shape and surface area of these billabongs changed dramatically as the low level muddy banks were submerged and a sheet

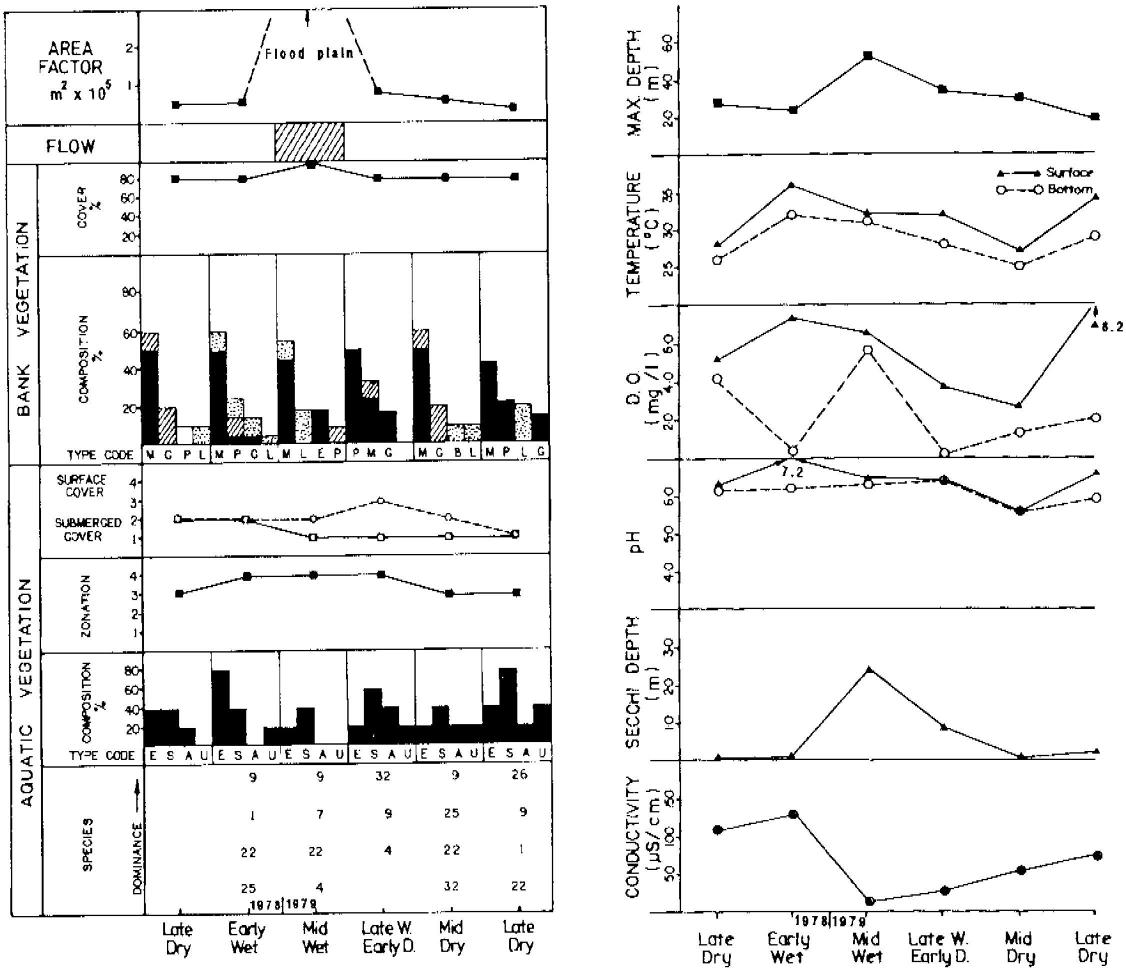


Figure 31. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at an upper floodplain billabong, Leichhardt Billabong (LT). See Appendix 2 for a key to the habitat-structural variables.

of water, reaching a depth of 2 m in the Mid-wet season, covered the surrounding flood plain. The flood plain was about 1 km wide at Ja Ja and Leichhardt billabongs and 2 to 3 km wide at Jabiluka and Nankeen billabongs. The banks of these billabongs were not as well vegetated as those of the corridor waterbodies. Leichhardt Billabong had the most bank cover because of its situation on the western edge of the flood plain, which is bordered by a very dense swamp of *Melaleuca* spp. There were also clumps of *Pandanus aquaticus*, *Eugenia* sp. and *Barringtonia acutangula* at Leichhardt Billabong as well as partially submerged fallen timber and thick growths of *Hymenachne acutigluma*. Clusters of these plants and timber were also present at Ja Ja Billabong. At Jabiluka and Nankeen billabongs there were only isolated clumps of *Pandanus aquaticus* (together with areas of fallen timber at Jabiluka Billabong) but, during the Mid-wet season, *Eucalyptus* (at Jabiluka Billabong) and *Melaleuca* (at Nankeen Billabong) forests fringing the flood plain contributed to bank cover, even though they were hundreds of metres from the shoreline in the Dry season.

There were hydrophytes in these billabongs throughout the study. The total number of hydrophyte species, however, and their total cover increased rapidly into the Wet season. Even the parched Dry season flood plain, when inundated, supported dense growths of *H. acutigluma* and *Pseudoraphis spinescens* to such an extent that they proved to be significant navigational hazards. Both surface and submerged hydrophyte cover generally increased in the Mid-

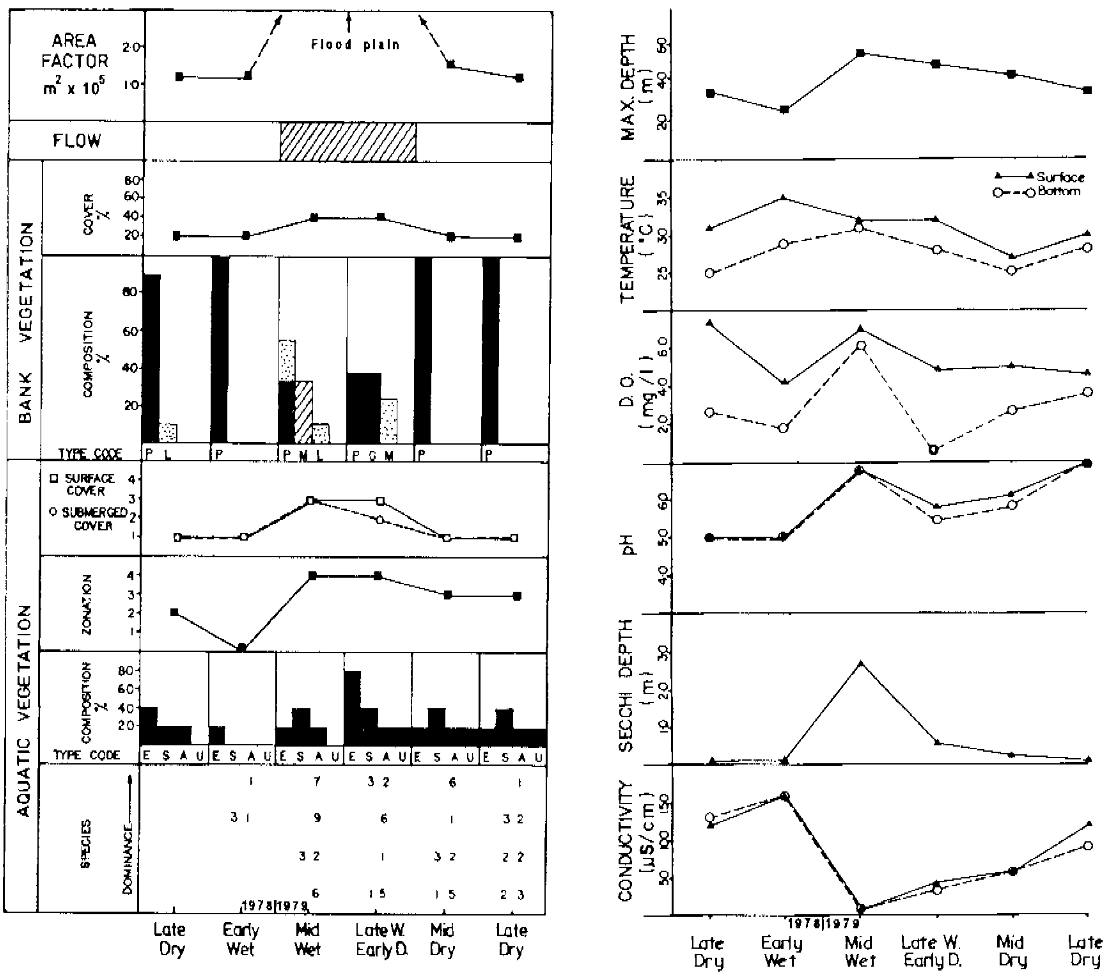



Figure 32. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at an upper floodplain billabong, Nankeen Billabong (NN). See Appendix 2 for a key to the habitat-structural variables.

wet or Late-wet-Early-dry seasons at all the billabongs except Leichhardt Billabong. High water velocities in the Mid-wet could have limited the distribution of some of the submergent hydrophytes that were normally present in the Dry season particularly at Leichhardt Billabong. Zonation complexity of the hydrophyte communities also increased in the Wet season. *Hymenachne acutigluma* was present throughout the study at Ja Ja and Leichhardt billabongs but only in the Wet season at Jabiluka and Nankeen billabongs. *P. spinescens* was present at all sites in the Mid-wet season, at Ja Ja Billabong in 1978-79 Early-wet and at Jabiluka Billabong in the Late-wet-Early-dry season. Floating meadows of *Ludwigia adscendens* were abundant in the 1978-79 Early-wet and the 1979 Late-dry seasons at Ja Ja and Leichhardt billabongs, and were also present during the Late-wet-Early-dry and the Mid-dry at Jabiluka and Nankeen billabongs. *Najas tenuifolia* was abundant at Ja Ja Billabong (also to a lesser extent, at Jabiluka Billabong) during and after the Mid-wet season and *Utricularia stellaris* appeared at these sites later in the 1979 Dry season. *Hydrilla verticillata* and *Lepilaena* sp. were important submergent species at Leichhardt Billabong; *Vallisneria spiralis* was important at Jabiluka Billabong and *Ceratophyllum* sp. at Nankeen Billabong. Thick swathes of *Eleocharis* sp. appeared during the Mid-wet season at Nankeen Billabong. Filamentous green algae were abundant at Ja Ja Billabong near the Pancontinental mining camp during the Late-wet-Early-dry season. The main flow channels of the flood plain in the Mid-wet season were characterised by *Aponogeton*

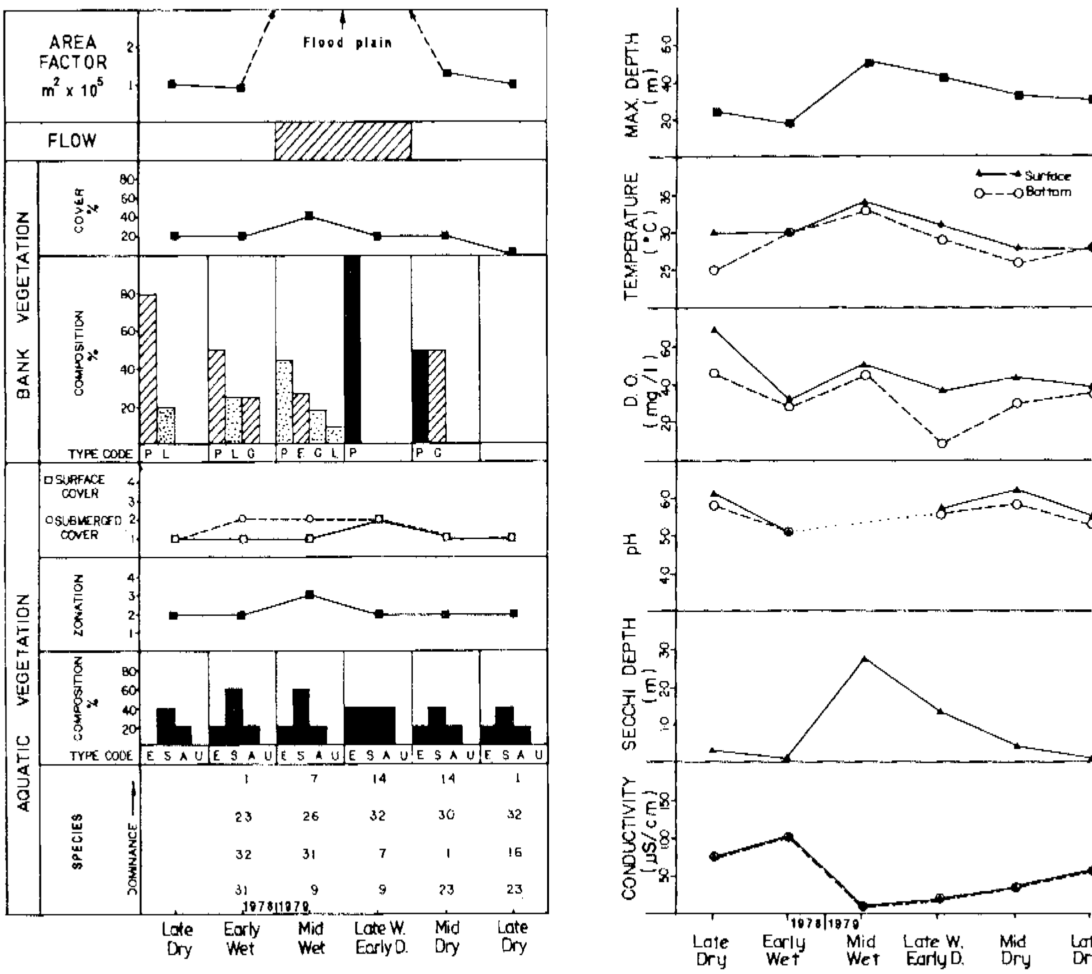


Figure 33. Summary of (a) habitat-structural, and (b) physico-chemical variables recorded during fish sampling at an upper floodplain billabong, Jabiluka Billabong (JA). See Appendix 2 for a key to the habitat-structural variables.

*elongatus*, *Caldesia oligococca*, *Eriocaulon setaceum*, *Limnophila indica* and *Triglochin procera* var. *dubia* (all of which are submergent or floating-leaf plants in faster flowing areas). The substrate at all of these billabongs was mud, but that at Leichhardt Billabong also contained patches of clay.

The maximum depth recorded in the Mid-wet season was 4.0 m Ja Ja Billabong, 5.2 m at Leichhardt Billabong, 5.0 m at Jabiluka Billabong and 5.5 m Nankeen Billabong. During the Dry season, the maximum depths recorded at these sites were 2.6 m at Ja Ja Billabong, 2.4 m at Leichhardt Billabong, 1.8 m at Jabiluka Billabong and 2.6 m at Nankeen Billabong. Surface water temperatures ranged from 27° to 34°C at Ja Ja Billabong, 28° to 36°C at Leichhardt Billabong, 27° to 34°C at Jabiluka Billabong and from 27° to 35°C at Nankeen Billabong. Daytime (1330 hrs) surface littoral zone (10 cm deep) water temperatures reached 44°C at Nankeen Billabong during the Mid-wet season. Bottom water temperatures ranged from 26° to 30°C at Ja Ja Billabong, 25° to 32°C at Leichhardt Billabong, 25° to 33°C at Jabiluka Billabong and from 25° to 32°C at Nankeen Billabong. At all the sites, except Ja Ja Billabong, the bottom temperatures were 2-4°C less than surface temperatures, with the most similar temperatures occurring in the Mid-wet season. At Ja Ja Billabong, bottom water temperatures were 4°C less than surface waters till the Mid-wet season and then for the rest of the study remained only 1°C cooler than surface waters. Highest overall water temperatures were recorded at Ja Ja, Leichhardt and

Nankeen billabongs during the 1978-79 Early-wet season and at Jabiluka Billabong during the Mid-wet season. Lowest overall water temperatures were recorded in the 1979 Mid-dry season at all sites.

Dissolved oxygen concentrations at the surface of the billabongs ranged from 3.0 to 7.8 mg/L at Ja Ja Billabong; from 2.8 to 8.2 mg/L at Leichhardt Billabong; from 3.2 to 7.0 mg/L at Jabiluka Billabong and from 4.0 to 7.4 mg/L at Nankeen Billabong. Concentrations of dissolved oxygen at the bottom ranged from 0.0 to 5.1 mg/L at Ja Ja Billabong; from 0.1 to 5.7 mg/L at Leichhardt Billabong; from 1.0 to 4.5 mg/L at Jabiluka Billabong and from 0.4 to 6.1 mg/L at Nankeen Billabong. Surface and bottom dissolved oxygen concentration were most similar at all sites in the Mid-wet season, but fell to near-anoxic levels (3 to 5 mg/L less than surface waters) during the Late-wet-Early-dry season at all sites. The water conditions at the bottom then more closely approached those at the surface as the 1979 Dry season progressed. Very low bottom dissolved oxygen concentrations were also recorded at Leichhardt Billabong, and to a lesser extent at Ja Ja and Nankeen billabongs, during the 1978-79 Early-wet season. Highest surface water dissolved oxygen concentrations were recorded during the 1978 Late-dry season at Ja Ja, Jabiluka and Nankeen billabongs and during the 1979 Late-dry at Leichhardt Billabong. Lowest surface dissolved oxygen concentrations were recorded during the Late-wet-Early-dry at Ja Ja Billabong, the 1979 Mid-dry at Leichhardt Billabong and the 1978-79 Early-wet season at both Jabiluka and Nankeen billabongs.

Surface water pH ranged from 4.8 to 7.1 at Ja Ja Billabong; from 5.6 to 7.2 at Leichhardt Billabong; from 5.1 to 6.1 at Jabiluka Billabong; and from 5.0 to 7.0 at Nankeen Billabong. Bottom water pH ranged from 4.3 to 6.3 at Ja Ja Billabong, 5.6 to 6.4 at Leichhardt Billabong, 5.1 to 5.8 at Jabiluka Billabong and from 5.0 to 7.0 at Nankeen Billabong. Bottom pH was usually slightly less than that of surface waters. The pH was usually higher at Leichhardt Billabong than at the other billabongs. Surface and bottom conductivities both followed very similar patterns throughout the study at all sites. Conductivities were high in the 1978-79 Early-wet (except at Ja Ja Billabong, where conductivity was low in the Early-wet as it filled from the corridor waterbodies), but fell to very low levels in the Mid-wet season. Conductivities then rose through the 1979 Dry season to reach high levels similar to those recorded in the Late-dry of the previous year.

Turbidity was generally high (Secchi depth < 10 cm), at all sites in the 1978 Late-dry season. As Ja Ja Billabong filled, the turbidity began to fall in the 1978-79 Early-wet season but remained high at the other billabongs until the Mid-wet season, when maximum Secchi depths of 2.7, 2.4, 2.7 and 2.7 m were recorded at Ja Ja, Leichhardt, Jabiluka and Nankeen billabongs respectively. After the Wet season, the turbidity at the sites increased again because of the disturbance of muddy substrates by buffalo and Magpie Geese and because of the effects of wind-generated water circulation currents.

**Fish communities.** The abundances and weights of those fish species captured at Ja Ja, Leichhardt, Jabiluka and Nankeen billabongs using standard netting methods are shown in Table 14a-14d. Figure 34 summarises seasonal total abundance, total weight, number of species, richness, Shannon diversity, and evenness indices at the fish communities at these sites.

The total number of fish species captured by standard netting methods during the study was 23 at Ja Ja Billabong, 22 at Leichhardt Billabong, 22 at Jabiluka Billabong and 22 at Nankeen Billabong. The use of non-standard sampling methods at these sites, demonstrated the presence of *A. percoides* at Ja Ja Billabong (daytime use of multiple-mesh-sized monofilament gillnet) bringing the total number of fish species present at this site to 24 and of *T. chatareus* at Jabiluka Billabong (underwater observation), bringing the total number of fish species present at this site to 23.

The most abundant species over the whole sampling period were: *A. agrammus*, *A. macleayi*, *M. splendida inornata*, *D. bandata* and *C. stercusmuscarum* at Ja Ja Billabong; *A. agrammus*, *M. splendida inornata*, *C. stercusmuscarum*, *A. leptaspis* and

*A. macleayi* at Leichhardt Billabong; *A. agrammus*, *C. stercusmuscarum*, *M. splendida inornata* and *D. bandata* at Jabiluka Billabong; and *A. agrammus*, *A. leptaspis*, *M. splendida inornata*, *P. tenellus* and *D. bandata* at Nankeen Billabong. These sites, excluding Leichhardt Billabong, thus shared three species among their most abundant, which had also been among the four most abundant in the corridor waterbodies. The most abundant species at Leichhardt and Nankeen Billabongs were normally small and able to be captured with a seine net. *Arius leptaspis*, however, was atypical of this group, being a large bodied species.

Total abundance at Nankeen Billabong was generally stable at a low level throughout most of the study, with a minor peak (due to catches of *A. agrammus*) occurring in the 1979 Mid-dry season and a low during the Mid-wet season, when catches changed markedly to include a predominance of *T. chatareus*, *A. agrammus* and *A. percoides*. Total abundance was also low at Ja Ja and Leichhardt billabongs during the Mid-wet season, when *C. stercusmuscarum*, *M. splendida inornata* and *A. agrammus* were the most abundant species at Ja Ja Billabong, and *M. splendida inornata* and *Ambassis* spp. (unidentified) were the most abundant at Leichhardt Billabong. During the 1978 Late-dry season, total abundances were at a maximum at Ja Ja and Leichhardt billabongs (Fig. 34), owing to very large catches of *A. agrammus*, but then dropped sharply in the Early-wet. By the 1979 Mid-dry season, the total abundance had peaked again at Leichhardt Billabong (owing mainly to catches of *C. stercusmuscarum* and *M. splendida inornata*), with the total abundance at Ja Ja Billabong increasing steadily from the Early-wet through to the 1979 Late-dry, when it appeared to be still on the increase (due mainly to catches of *A. agrammus*). In contrast to the other floodplain sites, Jabiluka Billabong showed peak total abundance in the Mid-wet season when large catches of *C. stercusmuscarum* and *A. agrammus* were made. By the following Late-wet-Early-dry sampling period, the total abundance at Jabiluka Billabong was at a minimum with mainly *M. splendida inornata* being captured. During the 1979 Dry season the total abundance increased again to the levels of the previous year with *D. bandata*, *M. splendida inornata* and *C. stercusmuscarum* being the main species captured.

The total number of species at Ja Ja, Leichhardt and Jabiluka billabongs was stable throughout most of the study, with a slight minimum in the Mid-wet season and a slight maximum in the 1979 Mid-dry. The total number of species at Nankeen Billabong varied more noticeably, with minima occurring during the 1978-79 Early-wet, Late-wet-Early-dry and 1979 Late-dry seasons, and with maxima occurring in the Mid-wet and Mid-dry seasons. The richness indices followed essentially

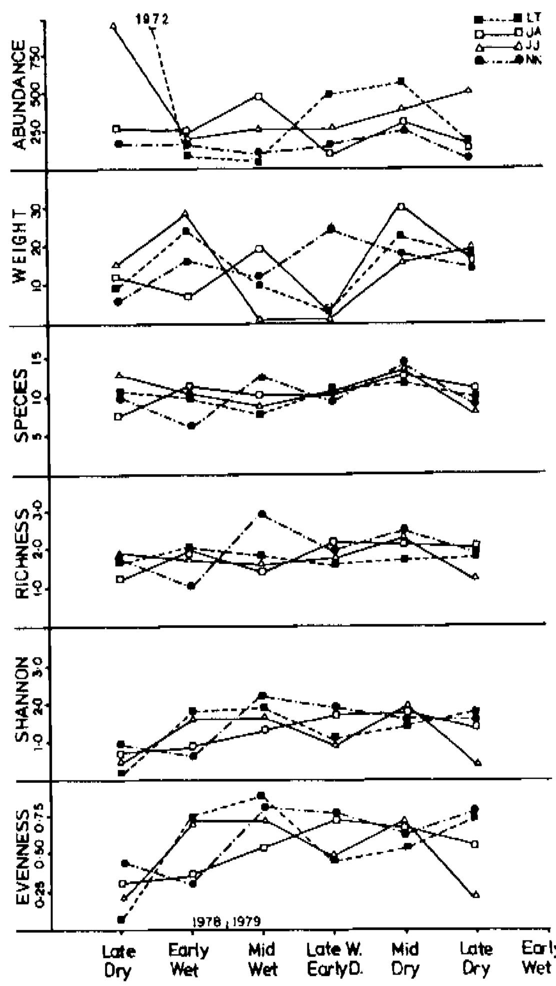



Figure 34. Summary of seasonal abundance, total weight, number of species, richness, Shannon diversity and evenness indices for samples taken in upper floodplain billabongs, Ja Ja, Leichhardt, Jabiluka and Nankeen billabongs

Catches were obtained using standard netting methods.

the same trends as total numbers of species, although at Leichhardt Billabong this index showed greater stability. The Shannon diversity and evenness indices showed the effects of large catches of a few species, i.e. these indices were strongly reduced at Ja Ja and Leichhardt billabongs during the 1978 Late-dry season and again in the 1979 Late-dry season at Ja Ja Billabong, owing to very large catches of *A. agrammus*. The Shannon diversity and evenness indices were at a peak at Ja Ja, Leichhardt and Jabiluka billabongs during the Early-wet to Mid-wet season and at Jabiluka Billabong during the early months of the 1979 Dry season (Ja Ja Billabong peaked again during the 1979 Mid-dry season).

The total weights of catches in these upper floodplain billabongs were at similar high levels to those of the corridor waterbodies; the scale on Fig. 34 has a maximum scale of 40 kg compared with the 20 kg maximum scale for the lowland and escarpment habitat figures. The fish species which contributed most to the total weight of catches, using standard methods were: *A. leptaspis, T. ater, L. calcarifer, A. agrammus* and *L. alata* at Ja Ja Billabong; *A. leptaspis, T. ater, M. cyprinoides, L. alata* and *S. jardini* at Leichhardt Billabong; *A. leptaspis, T. ater, N. erebi, M. cyprinoides* and *L. alata* at Jabiluka Billabong; and *A. leptaspis, T. ater, M. cyprinoides, N. erebi* and *A. percoides* at Nankeen Billabong. The majority of the weight of the catches from these sites was made up of *A. leptaspis* and *T. ater*. The weight of catches of *M. cyprinoides, L. alata* and *N. erebi* was minor in comparison with these two species. The presence of large numbers of some small fish species (*A. agrammus* and *G. aprion*) captured by seining contributed greatly to the total weight of catches from Ja Ja Billabong. Following the 1978 Late-dry season, the total weight of catches increased during the 1978-79 Early-wet season at Ja Ja, Leichhardt and Nankeen billabongs, mainly owing to increased catches of *A. leptaspis, T. ater* at Ja Ja Billabong, *A. leptaspis, T. ater* and *L. alata* at Leichhardt Billabong and *L. alata* at Nankeen Billabong. The total weight at these sites then fell during the Mid-wet season and dropped to a minimum at Ja Ja and Leichhardt billabongs in the Late-wet-Early-dry season. In contrast, total weight at Nankeen Billabong rose during this Late-wet-Early-dry season, mainly owing to catches of *A. leptaspis*, which also caused a later peak in total weight during the 1979 Mid-dry season at Ja Ja and Leichhardt billabongs. All sites returned to levels slightly higher than the previous year in the following 1979 Late-dry season. Seasonal changes in total weight at Jabiluka Billabong appeared to follow a dissimilar trend to the other sites; after reaching a minimum during the Late-wet-Early-dry season, the total weight increased to a maximum in the Mid-dry season (mainly owing to *A. leptaspis, M. cyprinoides* and *N. erebi*) and then fell to the level of the other sites by the 1979 Late-dry season.

## 3.6 Lower (riverine) floodplain billabong habitats

**Environment.** During the 1978 Late-dry season, Western Red Lily Billabong (WL, Map 2), measured ≈ 40 × 300 m and Cannon Hill Billabong (CH, Map 2), was ≈ 40 × 500 m. In the Late-dry and Mid-wet seasons, the maximum depths at Cannon Hill Billabong were 3.3 m and 5.3 m respectively and at Western Red Lily Billabong 2.4 m and 3.5 m respectively. Both of the billabongs were adjacent to escarpment outliers.

Clumps of *Pandanus spiralis* and *Melaleuca* spp. with thick growths of grasses bordered the Cannon Hill Billabong in the Dry season, but were inundated in the Wet season, when a fringing *Eucalyptus* forest became more important as bank vegetation. Bank vegetation at Western Red Lily Billabong was scant comprising only a few *Barringtonia acutangula, Livistona* sp. and terrestrial grasses. The substrate at Western Red Lily Billabong was mainly mud, while at Cannon Hill Billabong it was mud, in the deeper and slower (Wet season), flowing sections and sand in the swifter-flowing sections. In the waters adjacent to the escarpment outlier, bedrock was an important substrate. Hydrophytes were generally well developed throughout these billabongs. The major plant species present in the Dry season were *Elatine* sp., *Ceratophyllum demersum* and *Hydrilla verticillata* at Cannon Hill Billabong, and *Ipomoea aquaticus*, *C. demersum*, *H. verticillata* and *Nelumbo nucifera* at Western Red Lily Billabong. The major species present in the Wet season were: *C. demersum* and *H. verticillata* at both sites, with the addition of *I. aquaticus* and *Ludwigia adscendens* at Cannon Hill Billabong and *N. nucifera* and *L. adscendens* at Western Red Lily Billabong.

Surface water temperatures were identical at Cannon Hill and Western Red Lily billabongs: 31°C in the 1978 Late-dry and 33°C in the Mid-wet seasons respectively. The bottom water temperatures, however, differed between sites: 27°C during the 1978 Late-dry season and 29°C in the Mid-wet season at Cannon Hill Billabong and 28°C during the 1978 Late-dry season and 31°C in the Mid-wet season at Western Red Lily Billabong. The dissolved oxygen concentration at the surface of Cannon Hill Billabong was 5.1 mg/L in the 1978 Late-dry and 4.6 mg/L in the Mid wet seasons, while that at Western Red Lily Billabong was 7.5 mg/L in the 1978 Late-dry and 1.9 mg/L in the Mid-wet seasons. Bottom dissolved oxygen concentrations in the 1978 Late-dry were 3.9 mg/L at Cannon Hill Billabong and 1.7 mg/L at Western Red Lily Billabong. Near anaerobic conditions existed in the bottom waters at both sites during the Mid-wet season, 0.2 mg/L at Cannon Hill Billabong and 0.4 mg/L at Western Red Lily Billabong.

The surface pH value at Cannon Hill Billabong was 6.8 in the 1978 Late-dry and 6.3 during the Mid-wet season while that at Western Red Lily Billabong was a high 9.1 in the 1978 Late-dry and 6.6 in the Mid-wet season. Surface and bottom conductivities were both high at 200 μS/cm during the 1978 Late-dry season, but fell to 20 μS/cm in the Wet season.

During the 1978 Late-dry season, turbidity was at a maximum, with Secchi depth readings of 15 cm at Cannon Hill Billabong and 40 cm at Western Red Lily Billabong. Turbidity was lowest in the Mid-wet season at Cannon Hill Billabong (Secchi depth = 110 cm) and in the Late-dry season as Western Red Lily Billabong (Secchi depth = 80 cm).

**Fish communities.** The abundances and weights of those fish species captured during the 1978 Late-dry and 1978-79 Mid-wet seasons at Western Red Lily and Cannon Hill billabongs using standard netting methods are shown in Table 15.

The total number of fish species captured over both seasons was 9 at Western Red Lily Billabong and 14 at Cannon Hill Billabong. The main changes in the species composition of the fish community samples from the 1978 Late-dry to the 1978-79 Mid-wet season were the loss of *P. rendahli* and *A. leptaspis* and the gain of *M. splendida inornata* and *P. tenellus* at Western Red Lily Billabong; and at Cannon Hill Billabong, the loss of *A. leptaspis*, *A. graeffei*, *T. ater*, *A. percoides* and *O. lineolatus*, and the gain of only *T. chatareus* and possibly *A. macleayi* (as occurred in Nankeen Billabong in the upper flood plain habitats) and *Glossogobius aureus*. *Arius graeffei* had only been recorded previously from the Nourlangie Creek system in the Alligator Rivers Region and this was the first record of *G. aureus* in the East Alligator River catchment.

Total weight of the catch generally decreased into the Wet season. The fish community samples at Cannon Hill and Western Red Lily billabongs were essentially similar to the upper floodplain communities in that they were dominated in weight by *A. leptaspis*, *T. ater* and *M. cyprinoides*. In terms of species abundance, Cannon Hill Billabong was similar to the upper floodplain billabongs in having high abundances of *Ambassis* spp. and *C. stercusmuscarum*, whereas the most abundant species at Western Red Lily Billabong were *H. compressa*, *M. cyprinoides* and *P. rendahli*. Catches from Western Red Lily Billabong had greatest total weight and a lower abundance, than catches taken during the same sampling periods from Cannon Hill Billabong.

## 3.7 Estuarine upper reach habitats

**Environment.** Environmental descriptions of the two estuarine upper reach habitats sampled, Rock Hole (RH, Map 2) and Cahills Crossing (CC, Map 2), are given in Volume I (p. 7).

Both surface and bottom water temperatures were 32°C at Rock Hole Billabong during the Mid-wet season. Concentrations of dissolved oxygen at the surface and in the bottom water at this time were 6.1 and 5.7 mg/L respectively. Surface and bottom pH values were 6.8 and 7.0 and the conductivities were a low 10 μS/cm. During the 1979 Dry season, salinities at Rock Hole were 5 ppt. After the first freshwater flush in the 1979-80 Early-wet season, conductivities fell to below detectable levels. At both sites, the Secchi depth in the 1978-79 Mid-wet season was 100 cm. By the 1979 Late-dry season, the Secchi depth had decreased to 50 cm.

**Fish communities.** The abundances of fish species captured at Rock Hole and Cahills Crossing are shown in Table 16.

A total of 14 fish species were captured at Rock Hole and a total of 13 at Cahills Crossing. The apparent paucity of species in the samples at these sites probably reflects the limited sampling undertaken. More species were captured in the Mid-dry seasons than in either the Late-wet or Mid-wet seasons. The five most abundant species at Rock Hole were *Craterocephalus* nov. sp., *A. percoides, M. splendida inornata, Carcharhinus leucas* and *C. stercusmuscarum* and at Cahills Crossing were *Aseraggodes klunzingeri, Liza dussumieri, M. splendida inornata, L. calcarifer* and *Periophthalmus* sp. The fish community samples at Rock Hole quite closely resembled those present in lowland sandy creekbed habitats. The occurrence of the river whaler sharks (*C. leucas*), however, definitely gave this site a distinctive character. Approximately half of the species usually found in lowland or floodplain habitats (*A. leptaspis, T. ater, M. splendida inornata, A. agrammus, T. chatareus, G. aprion* and *G. giurus*), were present at Cahills Crossing, and *Acanthopagrus berda, Prionobutis microps* and *A. klunzingeri* were found exclusively at Cahills Crossing. A few large specimens of *L. calcarifer* were caught in the East Alligator River main channel, while large numbers of small specimens were captured in first-order tributary streams of the river in the Mid-dry season. Until sampling was carried out at this site, *A. graeffei* had only been found in the South Alligator River catchment of the Region.

## 3.8 Estuarine middle and lower reach habitats

**Environment.** Environmental descriptions of estuarine middle and lower reach habitats are given in Volume I (p. 8).

The tributary sampled during neap to falling tide at the Magela Mouth site MMb (Map 2), was approximately 40 m in length, 1 m wide, and 1 m deep. The tributary at the Magela Mouth Site MMa (Map 2) was approximately 300 m in length, 14 m wide and 2 m deep at high tide. Dense stands of mangroves bordered Magela Mouth site MMb, while at Magela Mouth site MMa the mangrove cover was more sparse and grasses were more important bank vegetation. Salinities at these sites were 29 ppt and 17.5 ppt respectively. Surface and bottom water temperatures were 28°C at both sites. The deep, muddy banks presented a sampling problem in most areas of the tidal rivers themselves. The small tributaries, however, could be sampled effectively from shore or canoe and the river mud on the undercut banks of the fast-flowing East Alligator River was stable enough to permit hauling of seine nets. (The possible threat from the abundant *Crocodylus porosus* to samplers and fishing nets must be considered when designing sampling procedures in such areas.)

**Fish communities.** The abundances of fish species captured in estuarine middle and lower reach habitats of the East Alligator River at Magela Mouth site MMa and Magela Mouth, site MMb are shown in Table 16.

A combined total of 11 fish species was captured from the two sites (7 species from each). The low number of species found at these sites probably reflects the limited sampling effort applied. The five most abundant species collected from the two sites combined were *Zenarchopterus caudovittatus*, *Collichthys lucidus*, *L. dussumieri*, *Periophthalmus* sp. and *T. chatareus*. The fish communities present at these sites appeared from these samples be quite distinctive, as only *T. chatareus* and *L. dussumieri* had been captured at other upstream sites. The numbers of *Periophthalmus* sp. present would have been underestimated by the netting methods used, as these fish could actively hop around or over nets when attempts were made to collect them.

Sampling was also undertaken in a small tributary of the South Alligator River estuary near the Arnhem Highway crossing, where *Kurtus gulliveri* (3), *C. lucidus* (1), *L. calcarifer* (1), *Ophichthys* sp. (1) and *Taenioides mordax* (1) were captured (abundances are shown in parentheses). The latter two species (an ophichthid eel and a gobiid) were not captured in the East Alligator River estuary.

## 3.9 Artificial waterbodies

**Environment.** The Retention Ponds, tailings dam, drainage channels and silt traps within the Ranger Uranium Project Area (Map 3), displayed soft mud/clay substrates and very turbid waters (Secchi depth < 1 cm). Virtually no hydrophytes were present during the 1979-80 Early-wet season as these newly-created waterbodies filled with water. During the 1979 Late-dry season, however, the hydrophytes *Najas tenuifolia*, *Utricularia* sp. and *N. minima* were found in the waters of the ten small, bulldozed muddy pools that were later to be inundated to form Retention Pond 1 (site RO, Map 3). Terrestrial grasses and *Fimbristylus minima* were present in all of these catchments before inundation in the 1979-80 Early-wet season. Essentially all bank vegetation had been cleared.

The surface water temperatures measured in the 1979-80 Early-wet season were 32°C in both the tailings dam (TD, Map 3) and the Retention Pond 1 site, with the bottom water temperatures being 29°C and 28°C respectively at both these sites. Concentrations of dissolved oxygen at the surface were 4.6 and 4.5 mg/L and pH was 5.9 at both sites. Conductivity in each was a low 10 μS/cm.

**Fish communities.** The abundances and weights of fish species collected during the 1979-80 Early-wet season along Coonjimba Creek (Ranger Uranium Project Area) from Coonjimba Billabong to below Retention Pond 1, at the site in the Retention Pond 1 itself, and in the tailings dam are shown in Table 17. Retention Pond 1 was also sampled during the 1979 Late-dry season and the results are shown in the same table.

A total of 9 fish species was collected during the 1979 Late-dry season from the ten small (3 x 10 m), muddy pools within the excavated area which became inundated in the following Wet season as Retention Pond 1 filled. The most abundant species in these pools were *P. tenellus*, *M. mogurnda*, *M. splendida inornata* and *A. agrammus*. During the following Early-wet season when the Retention Pond was filling, only four fish species were collected which, together with *P. rendahli* and *L. unicolor* which only appeared in this latter season, brought the total number of species captured in the pond area to 11. No fish were captured in the filling tailings dam (the lack of water in the dam during the Late-dry season explained the absence of fish at this site), although there were larvae of the anuran *Cyclorana australis* present. These tadpoles were the only aquatic vertebrate species present in the dam and in Retention Ponds 2, 3 and 4 (Map 3), during the following 1979-80 Early-wet season.

No fish were captured immediately below the Retention Pond 1 dam wall (sites C2 and C3, Map 3); these bulldozed sites may have been totally dry before the rains. A total of 6 species (*A. agrammus*, *G. aprion* and plotosids, which were the most abundant), were found at Coonjimba 3 and Coonjimba 4 (sites C3 and C4, Map 3), which was a lower fish species diversity than expected for these relatively deep (> 2 m) muddy sites during the Early-wet season. More diverse fish community samples were collected just downstream of these sites at Coonjimba Billabong (site CA, Map 3). The turbidity at these sites was extremely high owing to runoff from upstream earthworks associated with Retention Pond 1. Approximately 5 cm of silt had settled over the firm clay substrates of these sites since the Early-wet season runoff had begun. Another factor which may have caused the low species diversities recorded in these habitats was the fact that on the day before our standard sampling, visiting scientists had possibly oversampled these billabongs.

No fish were found in the artificial costean sampled (C1, Map 3). *Cyclorana australis* larvae were the only aquatic vertebrates found in silt traps and drainage channels adjacent to roadways in the Ranger Uranium Project Area during the 1979-80 Early-wet season.

No fish were found in recently excavated (sand mining) pits present in the sandy bed of Magela Creek near site MD during the 1979-80 Early-wet season. These pits were partially filled by seepage from underground waters.

# 4

# Synthesis and discussion

## 4.1 Environmental characteristics

The physico-chemical characteristics of waters are of major importance to aquatic organisms (Hynes 1970; Warren 1971). This is reflected in the recent emphasis by environmental protection agencies on attempts to reverse trends towards generally deteriorating water quality (Gorman & Karr 1978). There is a developing body of knowledge regarding minimum acceptable water quality characteristics (temperature, dissolved oxygen, etc.), for the survival and well being of fishes. No cohesive general set of theories relating habitat characteristics to stream fish community structure, however, has so far been developed. The definition, understanding and measurement of relevant habitat characteristics under the influence of seasonally dynamic physico-chemical environmental conditions may provide the key to understanding patterns of community structure among freshwater fishes.

### Seasonal changes in major characteristics

This synthesis is restricted to the environmental characteristics of escarpment, lowland, corridor and upper floodplain habitats, as adequate seasonal sampling was only undertaken in these habitats. Island Billabong has been grouped separately from corridor waterbodies as a transitional corridor/floodplain billabong.

The environmental characteristics of the sampling sites varied seasonally and also differed between the escarpment, lowlands and corridor zones, and the flood plains. In order to emphasise the dominant seasonal patterns, the following summary of seasonal trends is limited to the three most critical seasons studied, namely the 1978 Late-dry, 1978-79 Mid-wet and the 1979 Late-wet-Early-dry seasons. The Late-dry and Mid-wet seasons represent the two environmental extremes (i.e. the most 'unfavourable' and 'favourable' for fish survival) found in the ARR, while the Late-wet-Early-dry season was an important transitional period when conditions begin to deteriorate towards the following Late-dry season. Summaries of changes in the physico-chemical and habitat-structural variables are shown in Table 18.

#### 1978 Late-dry season

**Physico-chemical.** Surface water temperatures increased progressively downstream from the escarpment to the floodplain zone. Lowest surface water temperatures were recorded in the well-shaded seasonal escarpment stream, and the highest temperatures were recorded in the corridor waterbodies. Bottom water temperatures were generally 2°C less than those of surface waters in escarpment and lowland sandy creek bed pools, but from 3°C to 5°C less than surface temperatures in the more turbid and deep downstream habitats. The lowest bottom water temperatures were recorded in the floodplain habitats and the highest in the pools of lowland sandy creek beds.

Surface waters were oxygenated to approximately 80% saturation throughout the catchment during this season. Dissolved oxygen concentrations at the surface were generally greater in the large, wind-exposed corridor and floodplain billabongs. The highest surface dissolved oxygen concentrations were recorded in the seasonal escarpment streams. The lowest surface dissolved oxygen concentrations were found in lowland sandy creek bed pools. Dissolved oxygen concentrations at the bottom were very similar to those in the surface waters in all escarpment and lowland sandy creek bed pools. In the other deeper and more turbid downstream habitats, the dissolved oxygen levels in the bottom waters were 1 to 3 mg/L less than in the surface waters. The lowest bottom dissolved oxygen concentrations were recorded in the floodplain billabongs.

Downstream of the escarpment habitats the water became progressively more turbid. The corridor habitat sites at Mudginberri corridor and Buffalo Billabong, which were similar in character to the lowland sandy creek bed pools (i.e. they had areas of sandy substrate with underground water input from sandy aquifers), were an exception to this. The water clarity ensured that the bottom was clearly visible from the surface of the water in escarpment main-channel and perennial streams and lowland sandy creek bed pools, but phytoplankton populations increased the turbidity of the water in the seasonal escarpment pools. The highest turbidities (lowest Secchi readings), were recorded in lowland shallow backflow billabongs and floodplain billabongs.

The water was moderately acidic ($\approx$ pH 6), in the corridor, corridor/floodplain and floodplain billabongs, as well as in the escarpment main-channel waterbodies and seasonal streams. Very acidic conditions (pH = 4.2), were recorded at Noranda pools and in the perennial escarpment springs during this season. Neutral (pH = 7) conditions generally existed in both lowland habitat types. Conductivities were lowest in escarpment and corridor habitats during this season. The lowland shallow backflow billabongs and floodplain billabongs had the highest conductivities recorded during this season.

The corridor, corridor/floodplain and floodplain habitats had a maximum depth (at the fishing site) of > 3.0 m and were the deepest billabongs in the catchment during this season. The escarpment habitats averaged < 2 m maximum depth at the fishing sites, while the maximum depths of the lowland pools and backflow billabongs had been reduced to between 0.5 m and 1.0 m. Slow rates of flow were characteristic of the escarpment main-channel and perennial streams during this season. These flows persisted for only a few kilometres into the lowlands, downstream of these sites and so all the other waterbodies in the catchment were effectively isolated lentic habitats, although some of the corridor waterbodies appeared to receive seepage from sandy aquifers.

**Habitat-structural.** The substrate changed from one dominated primarily by rock, sand or leaf litter in the escarpment reaches, to mud and clay in the floodplain area of the lower reaches of the catchment. Some of the corridor waterbodies had mainly sandy substrates, as they were scoured by high water velocities in the Wet season. Characteristic of some of the backflow billabongs were areas of gravel and sand substrates where swift-flowing creek channel waters entered them in the Wet season. The leaf litter component of the substrate was high during the Dry season, especially in lowland sandy creek bed pools and escarpment habitats.

The highest densities of bank vegetation occurred in escarpment and corridor waterbodies. The floodplain billabongs had medium bank vegetation densities, while both types of lowland habitats had low densities, when their shorelines receded from normally fringing terrestrial plant communities. No hydrophytes were apparent in escarpment and lowland sandy creek bed habitats during this season. Hydrophytes were still present in some lowland backflow billabongs at this time. The complexity of the hydrophyte communities increased downstream towards the floodplain billabongs. Hydrophytes were generally absent from sandy corridor waterbodies, although some were present in the shallow, muddy backwaters. Surface cover was present, in the form of floating leaves shed by terrestrial plants and other plant material (not hydrophytes), in some escarpment habitats and lowland sandy creek bed pools. In the lowland backflow billabongs surface cover was minimal, but increased in sites further downstream, especially in the corridor/floodplain billabongs, where floating meadows of *Ludwigia adscendens* were present. Submerged hydrophytes were absent in the escarpment habitats and the lowland sandy creek bed pools. Submerged leaf litter was recorded as submerged cover in the latter pools. Traces of this cover were present in lowland backflow billabongs and became more important moving downstream to the floodplain billabongs.

### 1978-79 Mid-wet season

**Physico-chemical.** Surface water temperatures increased, the further they were downstream from the escarpment habitats. The lowest surface water temperatures were recorded in the seasonal escarpment feeder streams and the highest in habitats with slight water flow, such as lowland backflow billabongs and flood plains. Surface water temperatures were slightly reduced relative to those of the 1978 Late-dry season. Bottom water temperature patterns were similar to those of the surface waters. At sites with strong to medium flows such as escarpment, lowland sandy creek bed and corridor habitats, bottom water temperatures were the same as those at the surface. The water temperatures were slightly elevated relative to the 1978 Late-dry season.

Surface waters were well oxygenated throughout the catchment, with lower concentrations being recorded, together with higher water temperatures, towards the floodplain reaches. The concentrations of dissolved oxygen had slightly increased in the upper reaches and decreased in the lower floodplain reaches of the catchments, relative to the 1978 Late-dry season. The concentrations of dissolved oxygen of the bottom waters followed similar trends to those of surface waters. Bottom dissolved oxygen concentrations were the same as those for surface waters at sites with strong to medium flow. The lowest bottom dissolved oxygen concentrations relative to surface waters, were recorded in lowland backflow billabongs and in the deep floodplain channels. Dissolved oxygen concentrations were higher at most sites (especially in the corridor/floodplain and floodplain billabongs), than in the 1978 Late-dry season.

The turbidity was low in all habitats during this season and the bottom clearly visible from the surface at the sites fished in the escarpment area and in the lowland sandy creek beds. Highest turbidity was recorded in the corridor habitats. Turbidity was lower in all habitats, especially in the lower reaches of the catchments, than in the 1978 Late-dry season.

Readings for pH were generally the same in all habitats, except the perennial escarpment streams where lower readings were recorded. The pH was slightly lower than it had been in the 1978 Late-dry season. With the resumption of flow and dilution by rainwater, waterbodies throughout the catchments showed the low conductivities which, in the Late-dry season, typified the escarpment habitat water.

Greatest maximum depths occurred in the corridor and floodplain habitats, while the lowland backflow billabongs had maximum depths comparable with those of the escarpment habitats. Lowland sandy creeks were the shallowest habitats, but still averaged well over 1 m in maximum depth. Maximum depth rose most dramatically, relative to the 1978 Late-dry season, in lowland habitats and in the corridor and floodplain billabongs.

There were strong rates of flow in all escarpment and lowland sandy creek bed habitats; medium rates of flow in corridor waterbodies; slight to medium flows in corridor/floodplain and floodplain habitats; and only slight flows in lowland backflow billabongs. The isolated and contracted billabongs and pools of the 1978 Late-dry season were, by the Mid-wet season, interconnected by creeks and channels. At this time the escarpment area was joined, through the lowlands and corridor waterbodies, to the flood plain. The total area of the aquatic environment had increased dramatically relative to the 1978 Late-dry season, as the peaking flood waters had swelled the billabongs and inundated both their banks and the surrounding low-level forested areas.

**Habitat-structural.** As the site localities moved further downstream of the escarpment habitats, the substrates changed from rock, sand and leaf litter to mud and clay, the dominant substrate of the floodplain waterbodies. The clay/grass component increased relative to the 1978 Late-dry season, as the billabong shores were inundated by peak Wet season water levels. The leaf litter component of the substrate fell at all sites, except in main-channel escarpment waterbodies, relative to the 1978 Late-dry season. The sand and gravel component of the substrate in the lowland backflow billabongs was derived from the channel-type billabongs which were scoured by Wet season flows. The high sand component in the corridor waterbodies is also attributed to high flow-through water velocities.

The percentage of bank vegetation, in relation to total cover increased in all habitats, except those of the escarpment, during this season as the more distant fringing vegetation of the 1978 Late-dry season was inundated by peak Wet season water levels. The greatest increase in bank vegetation occurred in the lowland and floodplain habitats. Hydrophytes generally appeared in many waterbodies during this season and existing communities became much more complex relative to the 1978 Late-dry season. The most complex hydrophyte communities occurred in the lower reaches of the catchments, especially in corridor/floodplain, floodplain and lowland backflow billabongs. The clay banks of the lowland sandy creek beds offered an adequate habitat for some less complex hydrophyte communities, but in escarpment habitats hydrophyte communities occurred only in the inundated, slow-flowing anabranches off the main-channel waterbodies. Surface cover showed similar trends to hydrophyte zonation. Floating leaf litter contributed to surface cover in escarpment habitats and had increased dramatically at sites in the lower reaches of the catchments relative to the 1978 Late-dry season. Submerged cover also followed similar trends to hydrophyte zonation. The lowest levels of submergent cover occurred in the corridor habitats with strong to medium flow rates. Submerged cover increased dramatically in the lowland backflow billabongs and floodplain billabongs relative to the 1978 Late-dry season.

### 1979 Late-wet-Early-dry season

**Physico-chemical.** Surface water temperatures increased in site localities further downstream of the escarpment. As in the 1978-79 Mid-wet season, the lowest surface water temperatures were recorded in the well-shaded seasonally flowing escarpment feeder streams and the highest temperatures in the corridor/floodplain and floodplain billabongs. Lowland sandy creek bed pool surface water temperatures were also higher during this season, as these habitats received a much reduced flow across the sun-exposed creekbeds. Surface water temperatures in the escarpment main-channel waterbodies had decreased by approximately 4°C relative to the Mid-wet season. temperatures of the bottom waters were approximately 1°C less than those of the surface waters in escarpment and lowland sandy creek bed pools and from 1° to 3°C less than the surface temperatures in the lower reach billabongs. Bottom water temperatures in the escarpment main-channel waterbodies had decreased by approximately 5°C relative to the Mid-wet season, but in lowland sandy creek bed habitats had increased by 1°C. In the deeper billabong habitats bottom temperatures were noticeably less than those of surface waters.

Surface waters upstream from the corridor waterbodies were generally well oxygenated, with the highest dissolved oxygen concentrations occurring at the sites with the lowest temperatures (i.e. escarpment main-channel and seasonal streams). The most dramatic change from the 1978-79 Mid-wet season and the 1978 Late-dry season was the drop in dissolved oxygen to < 5% saturation in the corridor/floodplain and floodplain billabongs. Dissolved oxygen concentrations in bottom waters were the same as those in the surface waters in the escarpment waterbodies and the lowland sandy creek bed pools, a result similar to that of the 1978-79 Mid-wet and the 1978 Late-dry seasons. These concentrations, however, began to fall dramatically at all other sites during this transitional season compared with the Mid-wet season, and conditions became nearly anoxic in most of the floodplain billabongs. Bottom dissolved oxygen concentrations in the lowland backflow billabongs and corridor waterbodies, however, were about 2 to 3 mg/L less than the concentrations in surface water.

The water clarity ensured that the bottom was clearly visible from the surface at the fishing sites in escarpment main-channel waterbodies and also in the lowland sandy creek bed pools. In the escarpment stream habitats, however, the turbidity increased relative to that of the Mid-wet and Late-dry seasons, as the phytoplankton populations increased in density with the drop in flow. Turbidity increased most noticeably in the lowland backflow billabongs and in the floodplain habitats during this season. As flow subsided in the corridor waterbodies, however, the turbidity decreased because there was less suspended sediment.

Readings for pH remained essentially the same as those in the Mid-wet season. The lowest pH values were again recorded in the escarpment perennial streams. Conductivities remained at the same, low, Mid-wet season levels in the escarpment waterbodies, the lowland sandy creek bed pools and the corridor waterbodies during this season. In the floodplain and lowland backflow billabongs, however, conductivities increased relative to the Mid-wet season levels.

By this time, the water levels had fallen at all sites. The escarpment main-channel waterbodies had decreased in depth by approximately 0.5 m, while the lowland backflow billabongs, corridor and floodplain billabongs, had fallen by more than 1 m. The corridor/floodplain billabong at Island Billabong had decreased by approximately 2.5 m since the Mid-wet season. Medium flows persisted in the escarpment main-channel waterbodies, and along the sandy creek beds to the corridor waterbodies. Owing to the size of the corridor waterbodies, however, the apparent flow in these waters was only slight. In this season the lowland backflow billabongs had become isolated from the sandy creek bed channels and had formed large areas of lentic water as in the previous Dry season. There was only very slight flow in the floodplain billabongs before the Magela flood plain became isolated from the East Alligator River.

**Habitat-structural.** Rock and sand substrates were less prevalent downstream, with mud and clay becoming increasingly predominant as a substrate towards the floodplain reaches. This trend was still apparent in this transitional sampling period. The leaf litter component of the substrate remained high in the escarpment main-channel waterbodies only. The importance of the inundated clay and grass-covered banks tended to decrease in this season as the water level receded. The density of bank vegetation generally remained the same as in the Mid-wet season, although it underwent a noticeable decrease in the lowland sandy creek beds and in floodplain habitats, where the water levels had receded from previously inundated bank vegetation.

The distribution and zonation of hydrophyte communities in this season, generally had not changed much from the Mid-wet season except for a slight reduction in zonation in the floodplain billabongs. Surface cover increased in the corridor, corridor/floodplain and floodplain billabongs, as well as in the lowland shallow backflow billabongs. Floating terrestrial plant material was recorded as surface cover in escarpment and lowland sandy creek bed pools. Submerged cover increased in lowland backflow billabongs, corridor and corridor/floodplain billabongs during this season. Submerged leaf litter was a significant component of cover in escarpment main-channel and lowland sandy creek bed habitats.

### Synthesis

From the headwaters and catchment to the mouths of the creek systems, the habitat-structural and physico-chemical variables presented a continuous gradient of conditions; cooler, clearer waters over rocky and sandy substrates in the headwaters moving downstream to hotter, more turbid waters over muddy and clayey substrates, with hydrophytes in the lower reaches of the creeks.

Superimposed on this gradient, were the extensive changes caused by the seasonal nature of waterflow in the creeks. During the Dry season, the physical and chemical variables were generally heterogeneous between the waterbodies of each creek system, with the most 'favourable' conditions existing in the escarpment main-channel waterbodies and varying 'unfavourable' conditions existing in the lowland and floodplain habitats. The Early-wet season heralded a rapidly expanding aquatic environment which by the Wet season had become more homogeneous between waterbodies within each creek system, as conditions tended towards and exceeded those recorded in escarpment habitats during the

Dry season. In the Late-wet-Early-dry season the aquatic environment slowly contracted, which led to the deterioration of conditions in the creek systems at varying rates in the different habitats and sites. This resulted in the reestablishment of the 'unfavourable' conditions observed in the previous Dry season, and a corresponding increase in the heterogeneity of conditions in the waterbodies.

## Catchment differences

Three independent drainage catchments were examined during the study: the Magela, Nourlangie and Cooper Creek systems. The Magela system was examined in most detail, while the Cooper system was examined only superficially.

The Magela and Nourlangie systems shared similar general zonation patterns, i.e. each system followed the escarpment, lowlands, corridor and flood plains scheme. The Nourlangie escarpment and lowlands were generally closer to the estuarine reaches than were the comparable zones in the Magela system, although some escarpment outliers bordered sections of the Magela upper flood plain near the site at Jabiluka Billabong (JA, Map 2). The catchment area of the escarpment perennial feeder stream, Baroalba Springs in the Nourlangie system, was greater than that of the comparable habitat, Radon Springs, examined in the Magela system. Anbangbang Billabong, the lowland backflow billabong sampled in the Nourlangie system, was located very close to an escarpment outlier and backfilled from a corridor waterbody, in contrast to similar lowland billabongs in the Magela system. The lowland sandy creek bed habitat in the Nourlangie system at the Nourlangie crossing 2 site had extensive hydrophyte cover for most of the study and was located just downstream of a gravel roadway between two large corridor waterbodies. The corridor waterbody zone of the Nourlangie system appeared to be much more complex and extensive than that of the Magela system. Billabongs with both mud and sand substrates existed in close proximity as a 25 km 'string' of waterbodies in the Nourlangie corridor zone, interspersed with areas of dense and extensive *Melaleuca* swamp.

Lowland sites in the Cooper Creek system were only examined in the vicinity of the Nabarlek uranium mine. These sites were four times as far upstream from estuarine reaches as similar sites in the Magela and Nourlangie systems. The zonation pattern of the Cooper Creek system differed from that of the other systems in having a second escarpment outlier zone (Mt Borradaile), 80 km downstream from the lowland habitats examined. No sites equivalent to those of the lowland shallow backflow billabongs of the Magela system could were located near Nabarlek on the Cooper system. Sites on Cooper Creek with some of the habitat characteristics common to the Magela lowland shallow backflow billabongs were associated with the channel systems, which gave them the characteristics of miniature transitional waterbodies.

## 4.2 Fish community structure

This synthesis and discussion is restricted to the characteristics of fish communities in escarpment, lowland, corridor and upper floodplain habitats, as adequate seasonal sampling was only undertaken in such habitats.

## Community summary-feature variables

### Total abundance

The total abundance of fish in the samples was shown to vary seasonally and between habitat types. A summary of seasonal trends in the mean total abundance of samples from the various habitat types is shown in Fig. 35.

Seining (10 m × 1.5 deep seine net; 10 mm mesh) and underwater observations consistently gave greater total abundances than gillnetting (35 m × 2 m multiple-mesh-sized gillnet), as gillnetting tended to capture fewer, but larger-bodied, fish. Total abundance trends at given sites or in different seasons, therefore, tend to reflect the capture and/or observation rates of the seining and/or underwater observations, rather than the gillnetting methods.

The highest total abundance occurred in the communities of the flood plain, corridor and corridor/floodplain waterbodies, and perennial escarpment streams. The lowest total abundances occurred in the lowland habitats, escarpment main-channel waterbodies and seasonal streams. The highest variations in total abundance occurred in floodplain, corridor/floodplain and corridor waterbodies, and escarpment main-channel waterbodies and perennial streams. The lowest variation in total abundances occurred in escarpment seasonal streams and

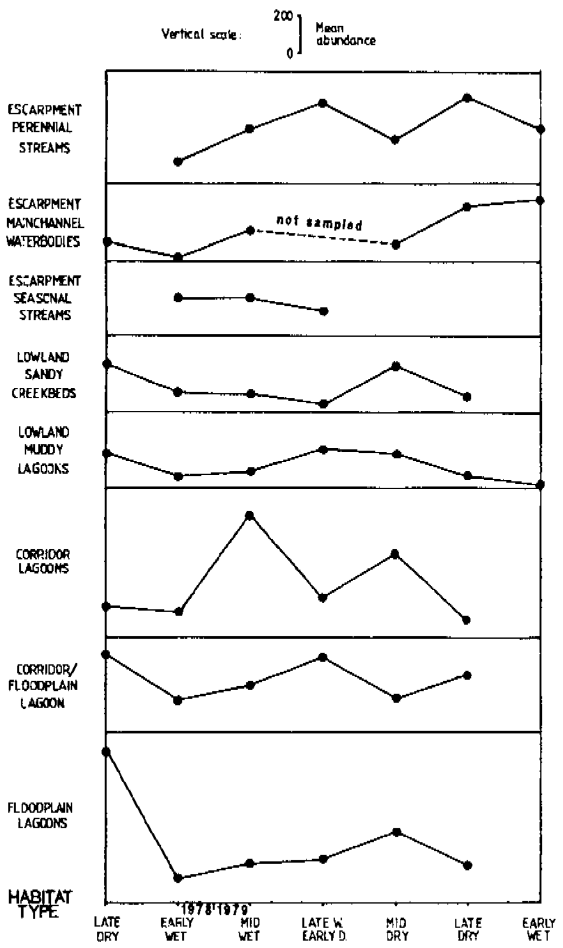



Figure 35. Summary of seasonal trends in the mean total number of fish collected or observed from a longitudinal array of habitats during the present study

Catches were obtained using standard netting methods. Mean abundance (vertical scale) = combined fish numbers for all species.

lowland habitats. Generally, habitats with a high total abundance also had the highest variations in total abundances.

Total abundance generally fell (especially in the floodplain habitats), after the 1978 Late-dry season and during the 1978-79 Early-wet season owing to dilution and dispersion effects. In the escarpment habitats, numbers increased into the 1978-79 Mid-wet season in perennial streams and main-channel waterbodies, but remained stable in seasonal streams. Total abundance decreased slightly after the Wet season in escarpment seasonal streams, but peaked in perennial streams in the same period. During the 1979 Mid-dry season, the total abundance decreased in the perennial streams and main-channel waterbodies and began to increase towards the 1979 Late-dry season. In the 1979 Early-wet season, total abundance remained stable in the main channels, but fell again in the perennial streams.

In the lowland sites total abundance remained low during the Mid-wet season, possibly due to sampling difficulties. Total abundance peaked in the 1979 Late-wet-Early-dry and 1979 Mid-dry seasons in the backflow billabongs, because the fish were concentrated as the waterbodies shrank. In the Late-wet-Early-dry season the total abundance fell in the sandy creek bed pools, only to peak again in the following season. In both habitats, total abundance then decreased into the 1979 Late-dry season and fell to near zero in some of the shallow backflow billabongs during the 1979 Early-wet season, as predation increased and environmental conditions deteriorated before the billabongs were flushed by Wet season flows.

Downstream of the lowlands, total abundance increased slightly during the 1978-79 Mid-wet season, after the slump in the Late-dry season, owing to the recolonisation of the floodplain and corridor/floodplain billabongs. In the corridor waterbodies, however, total abundance peaked during the Mid-wet season when many migrating fish species were concentrated into these billabongs just downstream of the torrential input of the lowland sandy creek channels. Total abundance fell equally dramatically after the Wet season in these corridor habitats, but increased in the 1979 Mid-dry season (possibly due to concentrating effects), to fall again during the following Late-dry season. Total abundance increased after the Wet season in the corridor/floodplain and floodplain billabongs to peak in the 1979 Late-wet-Early-dry and 1979 Mid-dry seasons respectively. Fish numbers in these downstream billabongs remained at a high level throughout the study with these habitats functioning as major Dry season refuges for various species. The escarpment main-channel and perennial streams also served as refuges during the Dry season.

### Total weight

The total weight of samples were shown to vary both seasonally and between habitat types. A summary of seasonal trends in the mean weight of the fish community samples from the various habitat types is shown in Fig. 36.

Gillnetting (multiple-mesh-sized monofilament gillnets) gave a consistently higher total weight of fish than seine netting (10 m long × 1.5 m deep with a 10 mm mesh), as seine netting tended to capture mainly smaller-bodied fish species. Total weight trends at given sites or in different seasons, therefore, tended to reflect the capture rates of the gillnet rather than the seine net method.

The escarpment main-channel waterbodies and both the lowland habitats maintained apparently much lower fish biomasses than did the corridor, corridor/floodplain and floodplain sites. Total weight decreased in the escarpment main-channel habitats during the 1978 Early-wet season but in the same season increased markedly in both lowland habitats after larger-bodied fish entered the sandy creek bed channels to colonise them and the backfilling backflow billabongs.

During the 1978-79 Mid-wet season, total weight remained stable in the escarpment main channels while decreasing slightly in the lowland backflow billabongs. This decrease in total weight was most noticeable in the swiftly flowing sandy creek beds; this was probably due to inherent sampling difficulties. Total weight then remained relatively stable throughout the rest of the study in the escarpment main channels, except for a slight fall during the 1979 Late-dry season and an increase in the following 1979 Early-wet season. In both lowland habitats, total weights fell to a minimum in the 1979 Late-wet-Early-dry season as large fish species moved out into Dry season refuge areas. Subsequently, the total weight remained at a low level in the sandy creek bed pools, and at a relatively higher level in the backflow billabongs, until the 1979 Late-dry season. After this time, during the 1979-80 Early-wet season,

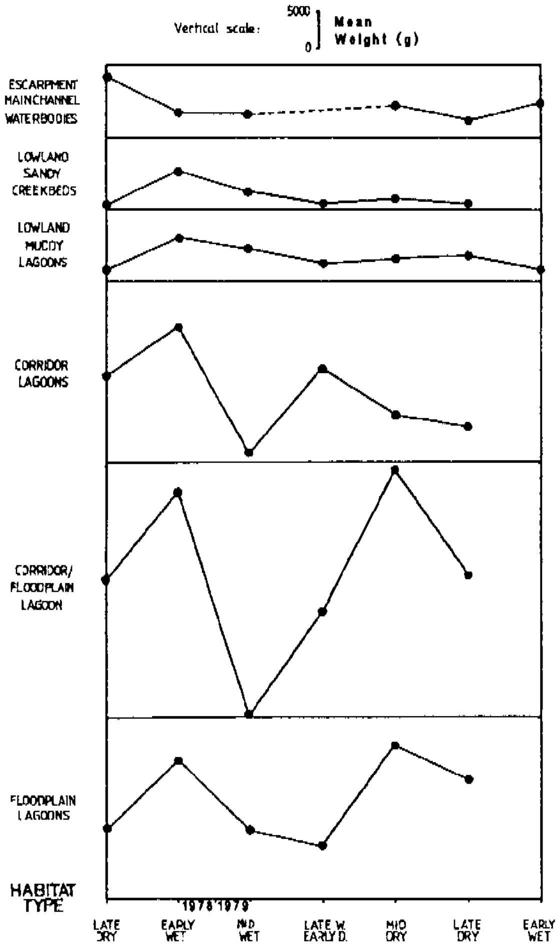



Figure 36. Summary of seasonal trends in the mean total weight of fish collected a longitudinal array of habitats during the present study

Catches were obtained using standard netting methods. Mean total weight (vertical scale) = combined fish weight (g) for all species.

a noticable decrease in the total weight occurred as predation increased and the environmental conditions deteriorated.

The corridor, corridor/floodplain and floodplain billabongs showed very large variations in total weight throughout the study with minima and maxima occurring essentially during the same seasons. Total weight peaked in these billabongs during the Early-wet season (especially in the corridor/floodplain billabong), possibly as a result of increased fish movement (mainly *A. leptaspis*, which were captured by gillnet). As the fish dispersed into the lowlands and across the flood plains during the following 1978-79 Mid-wet season, the total weight dropped to almost zero in the corridor and corridor/floodplain billabongs and to about half the Early-wet season level in the floodplain billabongs. During the Late-wet-Early-dry season, total weight recovered most rapidly in the corridor waterbodies but also increased in the corridor/floodplain billabongs, to peak in the following 1979 Mid-dry season as large fish species moved back into Dry season refuge areas. The near anoxic bottom water conditions in the floodplain billabongs were probably the main cause for the slight drop in total weight in the floodplain billabongs during the Late-wet-Early-dry season. Total weight later increased to peak in the following Mid-dry season but decreased during the 1979 Late-dry season in all of the downstream billabong sites as environmental conditions deteriorated.

The corridor, corridor/floodplain and floodplain waterbodies, and to a lesser extent the escarpment main-channel waterbodies, appeared to function as refuges for large-bodied fish species. In the escarpment main-channel habitats, total weight was mostly stable throughout the study. In contrast to this, the total weight in the lower reach billabongs varied considerably, with noticeable peaks in the Early-wet and Mid-dry seasons and a dramatic 'trough' during the Mid-wet season. Populations of larger fish species in the lowlands appear to depend on recruits from these previously mentioned refuges after the Dry season, as lowland populations would have either withdrawn to the refuges after the Wet season or deteriorated through the Dry season. The relative extent of input of larger fish species into the lowland habitats from either the upstream or the downstream refuges is unknown. The magnitude of the apparent 'biomass trough' in the corridor and corridor/floodplain waterbodies, however, indicates that a greater proportion of the fish species may migrate from the lower reaches upstream to the lowlands, once these zones are interconnected by flowing waters.

**Species diversity**

This summary is restricted to a description of changes in the 'number of species' found in community samples. This is the first, oldest and simplest concept of species diversity.

The number of species within fish communities in the study area was shown to vary seasonally and between habitat types. Other interrelated geographical and environmental phenomena were also shown to influence the total number of species collected at a given site.

**Habitats and seasons.** A summary of seasonal trends in the mean total number of fish species collected or observed along the water courses is shown in Fig. 37.

The escarpment main-channel, corridor, corridor/floodplain and floodplain waterbodies contained communities with relatively high numbers of species throughout the study. Fish communities appeared to have fewer species in the lower reach billabongs during the Wet season, probably owing to difficulties in sampling flood-swollen habitats. The number of species in these habitats, however, generally increased after the end of the Wet season and into the Dry season. The number of species remained high in the corridor/floodplain billabongs throughout the Dry season. In the floodplain billabongs, however, the number of species usually fell to a minimum towards the end of the Dry season and remained at this level into the Early-wet season, before the water flows reached these billabongs. In the escarpment main-channel waterbodies the number of species were highest in the 1978 Late-dry and lowest in the following 1979 Late-dry. This probably reflects variations resulting from insufficient sampling intensity, more than from instability of the fish communities.

Both lowland habitats contained unstable fish communities with greater variations in the number of species collected, although the number of species in the sandy creek bed communities was relatively more stable than that in the backflow billabongs. The backflow billabongs had the least number of species towards the end of the Dry season and even into the Early-wet season, depending on the timing of backfilling and the rate of colonisation via the inundated sandy creek bed channels. The number of species increased slightly into the Wet season, but did not peak until the Late-wet-Early-dry and Mid-dry seasons, when the billabongs contracted in size and the isolated communities were more easily caught. The high number of species decreased again towards the end of the 1979 Dry season.

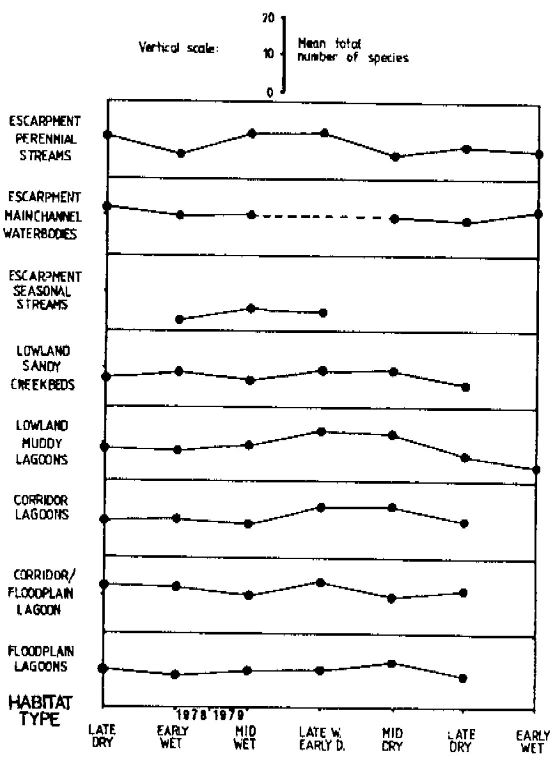



Figure 37. Summary of seasonal trends in the mean total number of species collected or observed from a longitudinal array of habitats during the present study

The vertical scale shows the mean total number of species

The lowland sandy creek bed pools had the least numbers of species, but were not as depauperate as some backflow billabongs in the Late-dry seasons. The number of species increased in the 1978 Early-wet season, as the pools were transformed into sections of rapidly flowing channels which were used both as migration routes and living space by various fish species. The number of species apparently fell in the Mid-wet season owing to difficulties inherent in collecting fishes from swift-flowing waterbodies. The number of species peaked during the Late-wet-Early-dry season owing to the influx of the more easily caught migrants and/or residents, and then fell again towards the Late-dry season.

The communities present in escarpment perennial streams appeared to be relatively unstable, with numbers fluctuating markedly. The most noticeable change in the number of species present occurred when the highly diverse 1978 Late-dry season community (especially that at Baroalba Springs), contained fewer species in the following Early-wet season. Underwater observations reinforced this finding. It was apparent that many members of the fish community had dispersed downstream during the period of initial water flow. The diversities peaked during the Mid-wet and Late-wet-Early-dry seasons as upstream migrants recolonised the upper reaches of these streams. The number of species slumped again in the 1979 Mid-dry season, to increase slightly once more in the 1979 Late-dry, as the fish were concentrated in the receding waters. Fish species number fell again in the 1979 Early-wet season.

The communities present in the plateau habitats, escarpment seasonal streams and escarpment terminal main-channel waterbodies contained the fewest species. Only the seasonal streams were sampled more than a few times because of access difficulties. Greater numbers of species occurred here during the Mid-wet season when migrants could move upstream over cascades which in the Dry season were steep rubble-strewn dry creek beds.

**Other factors.** Many published studies have shown increased community diversity in stream fishes from upstream to downstream areas (Shelford 1911; Thompson & Hunt

1930; Larimore & Smith 1963; Sheldon 1968). Most of these emphasise community expansion by species addition. Sheldon (1968) speculated that the primary factor in increased community diversity was increasing depth or volume of water available downstream. Kuehne (1962) showed a progressive increase in average numbers of species as stream order increased in a small catchment in Kentucky, North America, and Cadwallader (1979) showed a similar trend in the Seven Creeks system, Victoria (Aust.). Bishop (1979), however, noted that this relationship was not so straightforward in the Shoalhaven River, New South Wales, though 1st-order streams had the lowest and 7th-order streams had the highest species diversities. Gorman & Karr (1978) showed that along a stream order gradient in tropical Panama, the small amount of habitat change produced only a 25% change in the fish communities. They concluded that changes to the fish communities along a stream order gradient were due to changes in habitat characteristics or to increasing habitat heterogeneity with increasing stream order. Burton & Odum (1945) described elevational distribution in two small streams in North America where a distinct longitudinal change in fish species numbers and diversity was related to a very steep gradient of water temperature, water velocity and pH. Bishop (1979) indicated that difficulties encountered by migrating fish surmounting obstacles in the steep gradient escarpment zone between the upper and lower reaches of the Shoalhaven River were partly responsible for a reduction of species diversity recorded in the upper reaches of that catchment.

*Distance to estuarine reaches of the creek systems.* A scatter diagram of the total number of species collected at a given site during the study and its distance to the estuary is shown in Fig. 38.

No general relationship between fish community diversity and distance to estuarine reaches can be seen in this scatter diagram. Occasional sampling sites appear as 'low number of species anomalies', because of the low sampling effort involved. If the occasional sites are excluded, a pattern becomes apparent in the sites in the Magela Creek catchment. The most upstream sites (with the exception of Bowerbird Billabong), had low numbers of species, while the sites closer to the estuary (starting with Georgetown Billabong) had high numbers of species. The Nourlangie catchment sites, however, do not show such a pattern. The majority of the regular sampling sites in the lower reaches of both catchments appeared to cluster closely together, with 21 to 24 species. Thus although proximity to estuarine reaches may influence fish community diversity, other factors may be more important and therefore obscure the effect of this influence.

In studies of fish community diversity, ecologists have generally examined the classical, well-defined river channel type system, which is connected to the estuarine reaches throughout the year. The drainage systems of the Region do not conform to this classic model. The whole Magela Creek system could be viewed as a very large and intricate backflow 'lagoon' (Williams 1979) of the East Alligator River. In the Wet season, the fish in this system are free to range in all directions across the extensive flood plain (or 'lagoon') and, to a lesser extent, up to the inundated lowlands and into the 'micro-backflow' billabongs. During the Dry season the large 'wet season lagoon' fish community becomes fragmented into isolated subset communities of essentially similar structure; community diversity is not dependent on distance to estuarine reaches in such a system. In the Magela system, the fish communities should change upstream from the 'Wet season lagoon', near Island Billabong, as species would drop out according to their ability to migrate along the swift-flowing lowland sandy creek bed channel. This system is further complicated by the influence of some stable upstream main-channel escarpment fish communities and the heterogeneity of habitats present in the 'Magela lagoon' and the lowlands.

Welcomme (1970) studied the effects of abnormally high water levels on the ecology of fish in certain shallow regions at Lake Victoria, Africa. High water produced changes around the edges of the lake by forming lagoons cut-off from the main lake by differing widths of floating vegetation. The lagoons were occupied by characteristic groups of fishes with a species composition dependent on the degree of isolation from the main lake. The population changes associated with this isolation suggested that the mat of floating vegetation, by reason of the anoxic conditions that existed under it, acted as a form of 'biological filter'. This type of mechanism may to some extent influence the diversity of communities found in the lowland backflow billabongs of the present study area, i.e. varying degrees of isolation from sandy creek bed channels caused by direct distance, mouth width and vegetation type in mouth.

*Volume of waterbody.* The volume of water present at a particular site during the Late-wet-Early-dry season could reflect the diversity of the fish communities. A 'volume factor' was calculated for each site during this season as the product of estimated maximum depth, length and width of the waterbody, and these volume factors were then compared using a natural log scale. A scatter diagram of the number of species collected at a given site after the 1979 Late-wet-Early-dry season, plotted against the natural logarithm of its volume factor,

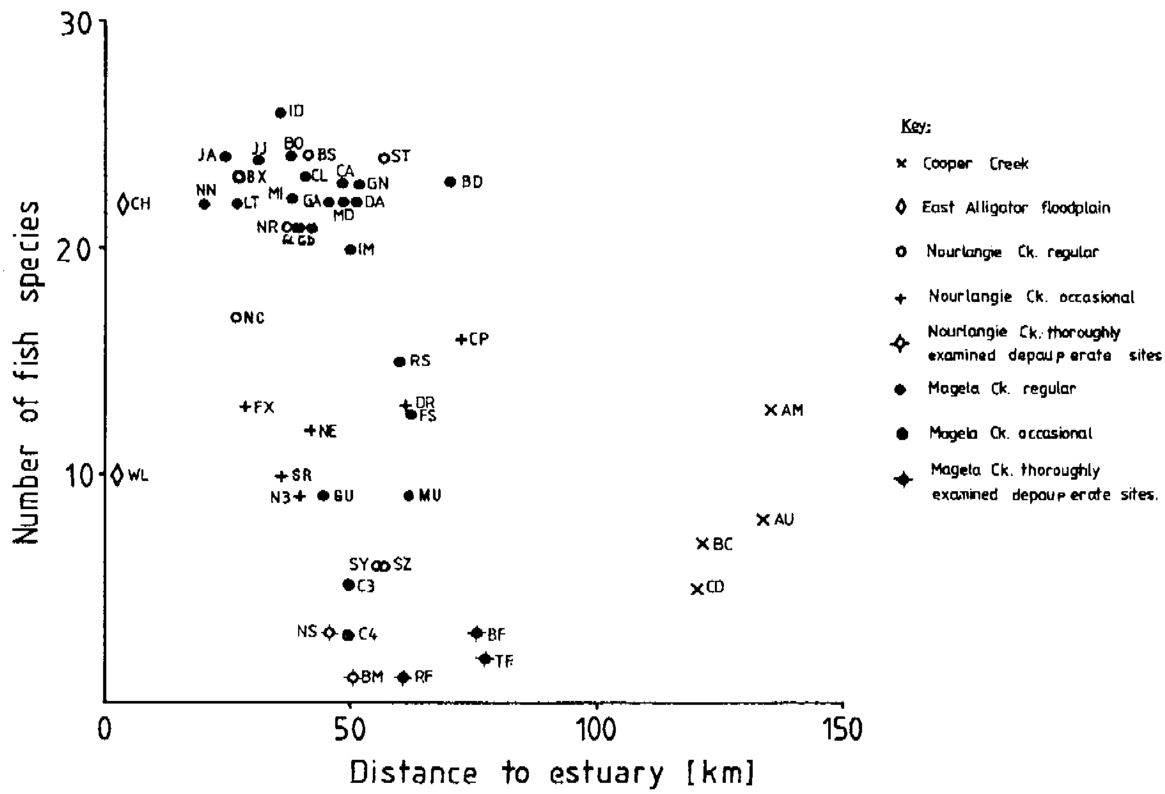



Figure 38. Scatter diagram of the total number of fish species collected at a given site during the study and its distance to the estuary

Sites in Cooper Ck: AM = Narbarlek Dam, AU = Adgibongololo Ck, BC = Birraduk Ck, CD = Bullwidgi Bb. Sites in the East Alligator floodplain: CH = Cannon Hill Bb., WL = Western Red Lily Bb. Regular sites in Nourlangie Ck: BS = Baroalba Springs, BX = Malabanbandju Bb., NC = Nourlangie crossing 2, NR = Anbangbang Bb., ST = Sawcut Gorge, SY = Hickey Ck tributary pool, SZ = Hickey Ck tributary pool. Occasional sites in the Nourlangie Ck: CP = Camp 1, DR = Deaf Adder, FX= Flying Fox, N3 = Noulangie 3, NE = Nourlangie East, SD = camp 2, SR = Namandi. Sites in Nourlangie Ck, thoroughly examined depauperate sites: AO = above Koolpin Gorge, BM = Mt Brockman, NS = Noranda pools. Midgley sites in Nourlangie Ck: AK = above Kolonjarluk (= Koolongjuluk) Falls, AJ = above Jim Jim Falls. Regular sites in Magela Ck: BD = Bowerbird Bb., BO = Buffalo Bb., CA = Coonjimba Bb., CL = Corndorl Bb., DA = Djalkmara Bb., FS = Fishless Bb., GA = Goanna Bb., GD = Magela Ck bed, GL = Gulungul Bb., GN = Georgetown Bb., ID = Island Bb., IM = Indium Bb., JA = Jabiluka Bb., JJ = Ja Ja Bb., LT = Leichhardt Bb., MD = Magela Ck bed, MI = Mudginberri corridor, MU = Magela upstream site, NN = Nankeen Bb., RS = Radon Springs. Occasional sites in the Magela Ck: C3 = Coonjimba 3, C4 = Coonjimba 4, GU = Magela Ck bed. Thoroughly examined depauperate sites in the Magela Ck: AT = above Twin Falls, BF = Magela Falls base, RF = Radon Falls, TF = Magela Falls top.

is shown in Fig. 39. This figure shows that the total number of fish species collected generally increased with the increasing log of the 'volume factor'. The sites with the least number of species were generally the smallest in volume and the site with most species had the largest volume. However, deviations from this relationship occurred, particularly with escarpment perennial streams (Baroalba Springs and Radon Springs), lowland sandy creek bed pools (Nourlangie crossing 2 and the Magela creek bed sites GD and MD) and lowland channel backflow billabongs (Indium Billabong and Goanna Billabong), which had unusually high numbers of species. The relationship between numbers of species and log 'volume factor' at occasional sampling sites, which had lower diversities overall, was similar to the relationship at regular sites.

These results suggest that the diversity of fish communities present at any particular site is influenced by the volume of water available; i.e. the diversity of the subset of a more widespread Wet season fish community retained in a billabong, after isolation in the Dry season, is influenced at least to some extent by the volume of water in this isolated waterbody. This result appears quite reasonable, considering the spatial requirements of many fish species. The occurrence of large numbers of species in a few sites with a small water volume, indicates that in places some other more important factors may override the influence of this factor (water volume or space available) on fish community diversity. Thus sites used as migration routes by fish (sandy creek bed channels, Nourlangie crossing 2 and the Magela creek bed sites GD and MD), refuge areas near migration routes (Indium and Goanna billabongs), and sites where blockages occur on such routes (e.g. below escarpment cascades, Baroalba Springs and Radon Springs) would be expected to have highly diverse fish communities, even though they contain relatively small volumes of water. Conversely, sites upstream of blockages (the base of Magela Falls, Twin Falls and Radon Falls) would be expected to have less diverse communities.

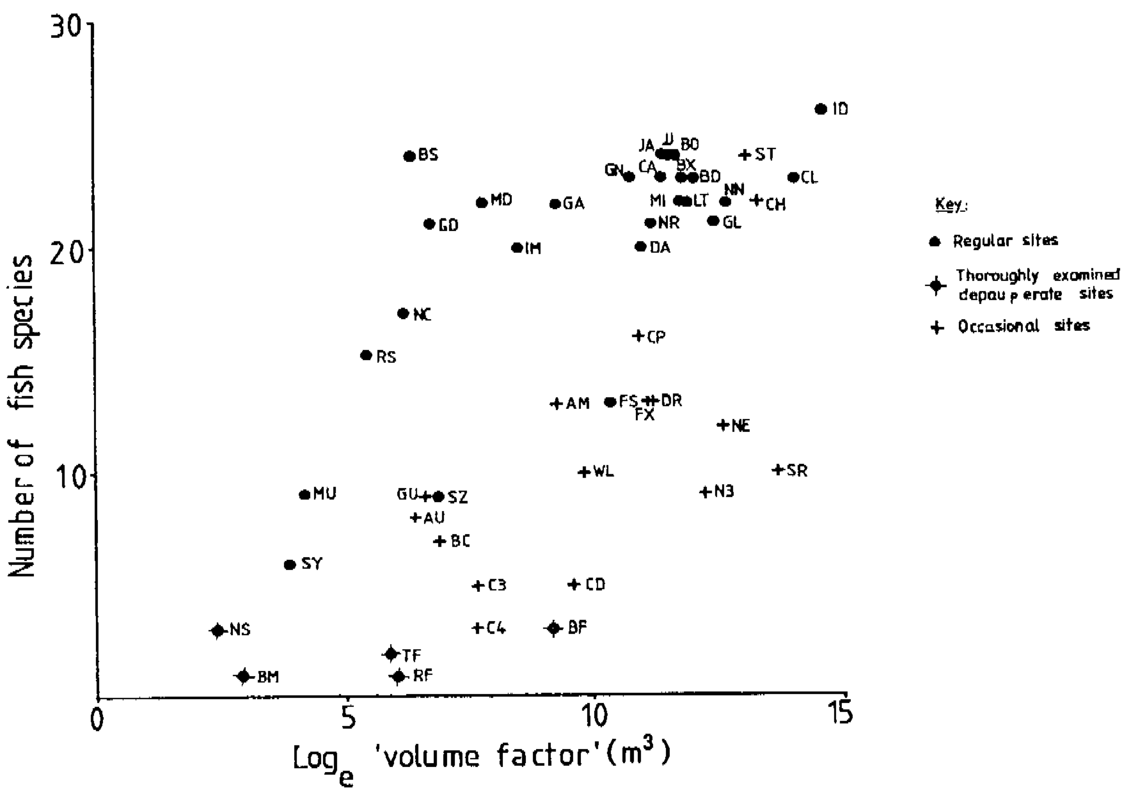



Figure 39. Scatter diagram of the total number of fish species collected at a given site after the 1979 Late-wet-Early-dry season and the natural logarithm of its 'volume factor'

Sites codes are given in Figure 38

*Stream order.* A scatter diagram of the total number of species collected at each site during the study against its stream order is shown in Fig. 40.

The number of fish species collected at regular sites selected along a stream order gradient appeared to be fairly similar for each order, and generally varied between 21 and 24 species. The sites with the fewest species were low order escarpment streams.

There were large variations in the number of fish species collected (1 to 24) in the 3rd-order regular sampling sites, indicating that other factors may override any influence of stream order on the number of species collected. The drainage systems in the Region do not conform to the classical stream order systems defined by earlier workers, such as Abell (1961) and Kuehne (1962). There were problems in defining stream order from season to season and from habitat to habitat; these streams dry up into a series of isolated waterbodies for most of the year and in the Wet season a vast sheet of water inundates the entire flood plain and the lowland areas near the sandy creek channels (which backfill into tributary creeks). Many of the streams in the Region commence, not as well-defined channels, but rather as sheet runoff from their upper reaches in the Wet season. These streams may therefore become interconnected in their upper reaches in periods of heavy rainfall. In the lower reaches of the streams the channels become more clearly defined, but anastomose into complex networks during the Wet season. Such networks are most complex around the lower corridor and upper floodplain billabongs. The fish communities retained in the billabong areas during the Dry season are usually subsets of a well-mixed, widespread, Wet season community and are independent of the stream order of the creeks flowing through them.

Some species, such as *M. nigrans* and *M. mogurnda* in the escarpment zone and

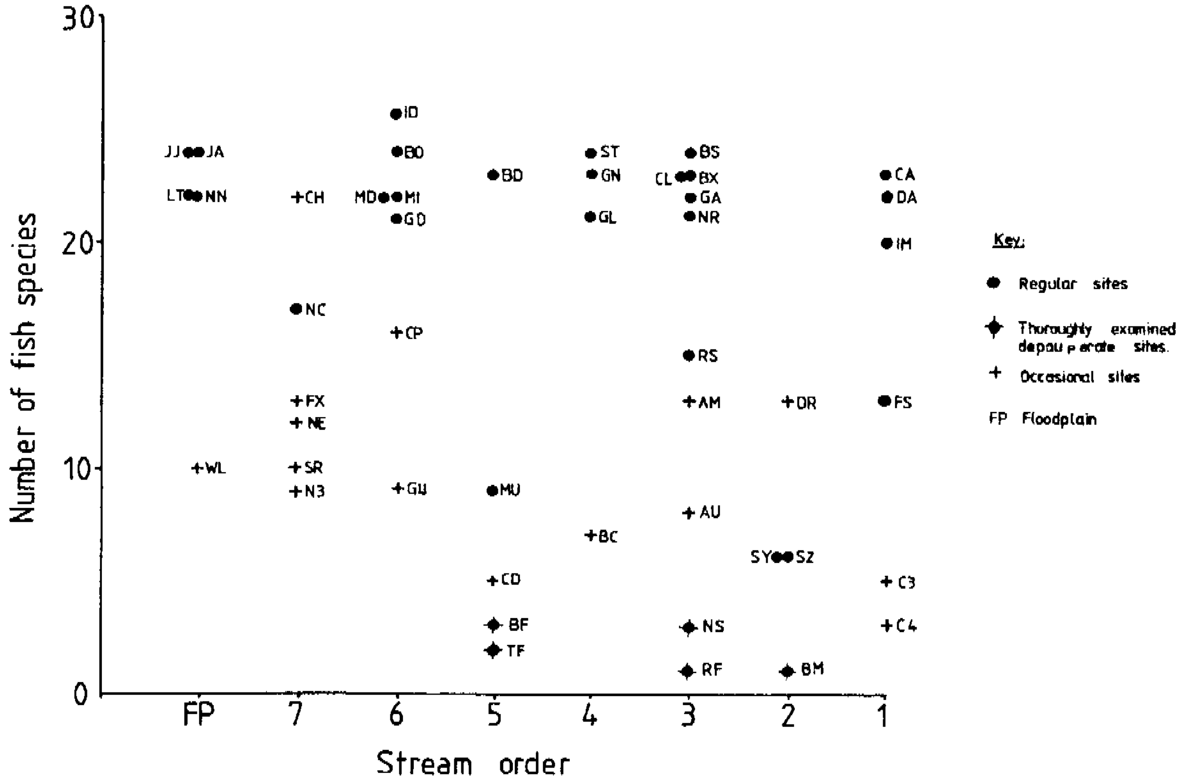



Figure 40. Scatter diagram of the total number of fish species collected at a given site during the study and its stream order

Site codes are given in Figure 38

*P. tenellus* and again *M. mogurnda* in the lowland zone, are characteristically found even at the sources of 1st-order streams in the Mid-wet and Late-wet seasons. *M. mogurnda* has also been found in artificial waterbodies: in costeans on the Ranger Uranium Project Area (Pollard 1974), in roadside drainage channels in the Jabiru East township, in the related sewage treatment works during the 1978-79 Mid-wet season (pers. obs.), and even in cattle drinking troughs on Mudginberri Pastoral Station (M. Giles, pers. comm.).

*Elevation.* A scatter diagram of the total number of species collected at a given site during the study against its elevation above sea level is shown in Fig. 41

An obvious relationship between the decreasing numbers of species and increasing elevation of regular sampling sites existed. Occasional sampling sites are excluded from this discussion. The relationship between the number of species collected and elevation was not obvious from the flood plains upstream to the lower reaches of lowlands, as the sites were clustered closely together owing to the flat terrain in these areas. A sharp decrease in the number of species present occurred, however, between the upper reaches of the lowland creeks and the escarpment perennial and seasonal streams. The escarpment main-channel waterbodies, however, maintained high numbers of species although in the upper reaches of the escarpment the higher elevation terminal main-channel waterbodies contained few species. The most obvious cause of this increasing depauperacy with increasing elevation would be species dropping out during upstream movements because of an inability to surmount obstacles in escarpment cascades during the Wet season. This effect is well illustrated in escarpment perennial springs (Tables 7b and 8) where *M. mogurnda* and then *L. unicolor*, *H. fuliginosus*, *M. nigrans* and sometimes some plotosids were the only species which appear to be able to negotiate such obstacles to reach higher elevation sites.

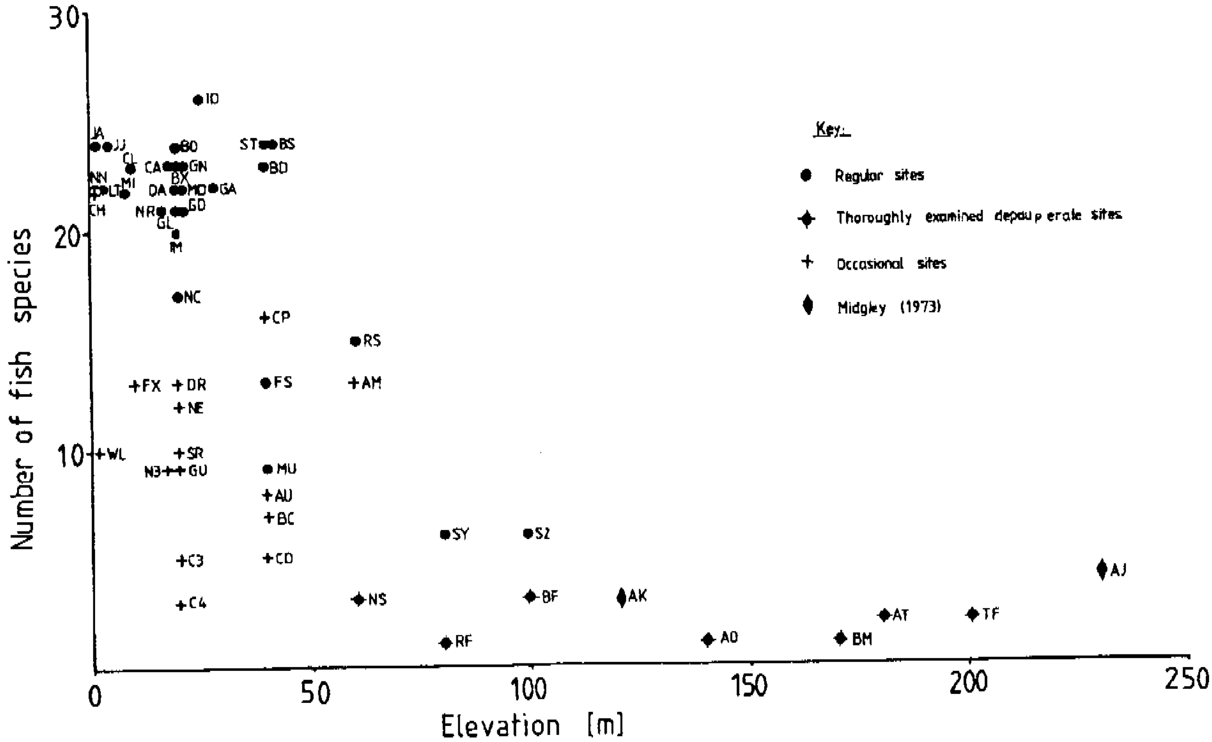



Figure 41. Scatter diagram of the total number of fish species collected at a given site during the study and its elevation above sea level

Site codes are given in Figure 38

The low number of species collected (even though these were only occasionally sampled sites) in the Cooper Creek system near the Nabarlek Uranium Mine may likewise have resulted from the possible occurrence of escarpment cascades (at Mt Borradaile) some 80 km downstream, which may effectively block migration routes. This possibility is supported by the fact that no *A. leptaspis* were captured in these sites and local Aborigines (Solomon, pers. comm.) indicated that *L. calcarifer*, a well known diadromous species, has never been captured in this section of the Cooper Creek catchment.

However, the presence of a fish species on the plateau does not necessarily mean that it can surmount obstacles such as 100 m high waterfalls. *M. mogurnda* is the only species that might be able to surmount such obstacles. Such observations have recently been made by Bishop on Howard Springs dam wall on 6.7.85, other eleotrids (e.g. *Gobiomorphus coxii*; Bishop, 1979) have been observed ascending vertical wet cliff faces. Theories which may explain the presence of particular species on the plateau include:

- the species were present in the area when it was accessible to fish from the lowlands before the escarpment zone was formed by erosional forces;
- the species were present in more accessible eastern drainages and were introduced to the plateau through river capture;
- fish eggs adhering to birds' legs were introduced from the lowlands onto the plateau; and
- fish eggs adhering to aquatic vegetation and other plant material were swept skyward and transported to the plateau by fierce 'willy willys' which are frequent in the Region in the Late-dry season (such winds were observed to remove aquatic vegetation and submerged plant material from sandy creek bed pools during the 1978 Late-dry season).

*Dissolved oxygen.* Very low bottom and surface dissolved oxygen concentrations have been considered responsible for the near-zero (gillnet sampled) numbers of fish which occurred at times during the study. Such examples occurred at Indium Billabong during the 1978 Early-wet season and in a few of the floodplain billabongs during the 1979 Late-wet-Early-dry season.

Many other habitat-structural and physico-chemical variables in the aquatic systems could also affect the numbers of fish in community samples taken from the study area. As habitat complexity is frequently correlated with fish species diversity (Gorman & Karr 1978), it would be useful if some general measure of habitat diversity be developed in the future so that predictions can be made of fish community diversities. The relevance of this approach to the management of aquatic ecosystems is outlined in detail by Karr & Schlosser (1977).

## Community composition variables

### Combined seasons analysis

**Sites with similar community composition.** The reciprocal averaging ordination of sites was examined only for the first two factors (or axes), as they accounted for a considerable proportion (47.5%) of the total variation within the community data matrix. The third factor accounted for only another 6.2% of variation. (A similar approach was taken in the 'species with similar abundance distributions across sites' and the 'analysis of seasonal changes' sections.)

Three site groups are apparent in the ordination (Fig. 42). Group 1 contains all the escarpment seasonal and perennial stream sites. The Baroalba Springs site (BS), within this group, usually has a much more diverse community than the other three sites. This may be explained by the easy accessibility of this site for fish from the lowland and floodplain billabong habitats, which would also explain why Baroalba Springs is closer to the lowland and floodplain sites in Fig. 42, reflecting similarity in species composition. This is discussed further below.

Group 2 contains the escarpment main-channel sites and two of the three sandy creek bed sites. The excluded sandy creek bed site (Nourlangie crossing 2 site, NC in Goup 3) is notable for its atypical community, where *M. splendida inornata* are usually more abundant than *Craterocephalus* nov. sp., and its location within the corridor zone rather than the lowland zone.

All the lowland backflow billabongs, corridor waterbodies and floodplain billabongs are in Group 3. Most of the sites in Group 3 are tightly clustered, but two sites (Mudginberri corridor, MI, and Indium Billabong, IM) are located on its periphery facing Groups 1 and 2. The Mudginberri corridor site is a sandy corridor waterbody which is essentially the downstream 'terminus' of the Magela Creek lowland sandy creek bed habitat. Indium Billabong is located contiguous to the lowland sandy creek bed habitat of the Magela Creek system. During flood peaks in the Mid-wet season this billabong loses its identity and becomes an active channel of Magela Creek. Outside flood peaks, migrating fish in the sandy creek channels use the billabong to shelter from high water velocities.

The clustering of sites produced by this ordination analysis thus appears to have resulted from similarity of habitat; this was largely independent of whether the sites were located in the Magela or Nourlangie catchment. This indicated that the influence of habitat characteristics on community composition extends past catchment boundaries and is therefore a regional phenomenon.

The two-way indicator species classification analysis (Fig. 43) showed similar results to the reciprocal averaging analysis. In this analysis four groups were formed.

Group A comprised the two escarpment seasonal streams (Noranda pools, NS, and Hickey Creek tributary pool site, SZ) and only one (Radon Springs, RS) of the escarpment perennial streams. The site at Baroalba Springs (BS), showed only marginal preference away from Group A, for reasons described in the reciprocal

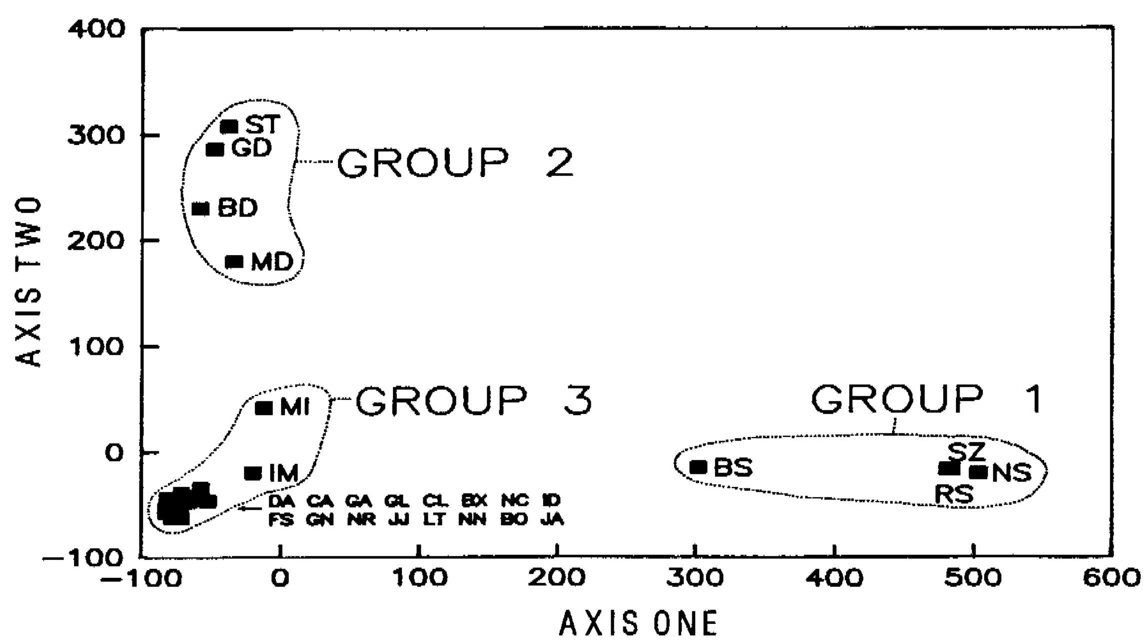



Figure 42. Reciprocal averaging ordination analysis of regular sites for combined seasons

Site codes are given in Figure 38

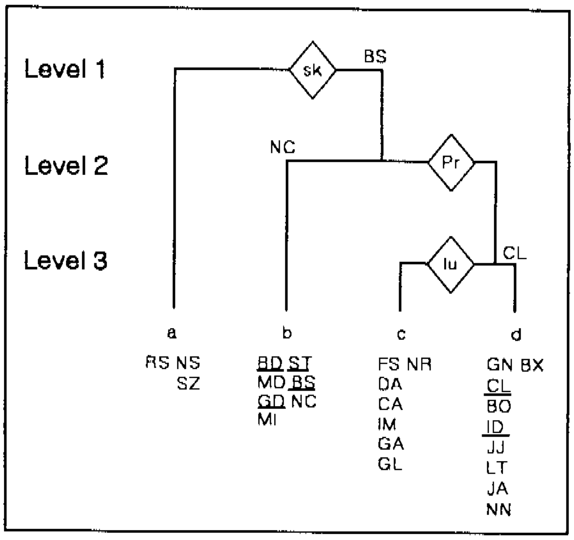



Figure 43. Dendrogram of two-way indicator species analysis (TWINSPAN) of regular sites for combined seasons

Horizontal lines between site codes divide the sites according to habitats. Where the site appears on the dendrogram itself, the site is only marginally included in the group indicated. Magela Creek sites are shown on the left and Nourlangie Creek sites are shown on the right in each group. Site codes are given in Figure 38.

A diamond represents the indicator species for each division; the position of the diamond indicates which group the species is associated with. The codes used for the indicator species are: LU = *Leiopotherapon unicolor*, PR = *Porochilus rendahli*, SK = *Strongylura krefftii*.

averaging ordination discussion. *S. krefftii* was the indicator species separating Groups B, C, and D from group A.

Group B comprised the escarpment main-channel waterbodies (Bowerbird Billabong, BD, and Sawcut Gorge, ST), the other escarpment perennial stream site (Baroalba Springs, BS) and all of the lowland and sandy creek bed sites (though the Nourlangie crossing 2 site, NC was only marginally included for the reasons mentioned above) and a sandy corridor waterbody (Mudginberri corridor, MI). This group, therefore, includes an upstream 'terminus', the escarpment main-channel waterbodies, interconnecting channels (the lowland sandy creek beds) and the downstream 'terminus' of the lowland sandy creek bed habitats (sandy corridor waterbody). *Porochilus rendahli* was the indicator species separating Groups C and D from Group B.

Groups C and D correspond to divisions of Group 3 described in the reciprocal averaging analysis.

Group C comprised only the lowland backflow billabongs. These billabongs, when compared to the Magela Creek backflow billabongs in Group D, are generally smaller and have less permanent water available in the Late-dry season. The indicator species for this Group is *L. unicolor*. This species is more typical of lowland billabongs as opposed to floodplain billabongs and the remaining corridor waterbodies.

Group D comprised the remaining backflow billabongs (Corndorl Billabong (CL), only marginally preferring this Group), non-sandy corridor waterbodies and all the floodplain billabongs. The lowland billabong, Malabanbandju Billabong (BX), would be expected to be grouped with floodplain billabongs as it is located on the edge of the Nourlangie Creek flood plain. The remaining corridor waterbodies would also be expected to be grouped with floodplain billabongs because of their similar habitat characteristics, i.e. the Buffalo Billabong (BO) site is on a muddy anabranch within the corridor zone and Island Billabong (ID), is located in a transition zone between the corridor and floodplain zones.

The fishes' preferential response to habitat characteristics, as judged by changes in community composition, is illustrated with the use of the analysis technique discussed below.

**Species with similar abundance distributions across sites.** The species reciprocal averaging ordination (Fig. 44) shows a core group with two lobes running out in the direction of each axis.

The core group has a nucleus of centropomids, eleotrids, ariids, *P. rendahli* and *G. aprion*. These species are typical of muddy habitats with fringing beds of aquatic plants such as billabongs and anabranch and transition zone corridor waterbodies. This core group corresponds to Group 3 of the site ordination. On the periphery of this core group, facing away from the two lobes are two species (*L. alata* and *Ophisternon gutturale*) which are typical of very weedy areas. On the periphery, on the other side of the core group, are species which are regularly found away from muddy-weedy areas in sandy creek beds and escarpments habitats. On the periphery facing lobe 1 are *P. tenellus* and *M. mogurnda* which are frequently found in escarpment seasonal and perennial streams. Facing lobe 2 are *M. cyprinoides, N. erebi, C. stercusmuscarum* and *M. splendida inornata* which are frequently found in lowland sandy creek bed habitats as well as escarpment main-channel waterbodies.

Lobe 1 corresponds to the escarpment seasonal and perennial stream group, Group 1 of the site ordination. *H. fuliginosus, M. nigrans, N. hyrtlii* and *P. midgleyi* sp. are characteristics of these habitats. Moving down the lobe towards the core group, *T. lorentzi, L. unicolor* and then *S. jardini* are found in these habitats as well as in the billabongs.

Lobe 2 corresponds to the escarpment main-channel waterbodies, lowland sandy creek bed habitats, and to a lesser extent sandy corridor waterbodies, Group 2 of the site ordination. *Craterocephalus* nov. sp., *A. dahli* and *S. butleri* are characteristic of these habitats. *S. butleri* is situated closer to lobe 1 than the others because it is occasionally found in escarpment perennial streams. Moving down the lobe towards the core group, *A. percoides, G. giurus* and then *T. ater, T. chatereus* and *S. krefftii* are found in these habitats as well as in billabongs. Lobe 2 is less distinct from the core group than is lobe 1.

**Factors contributing to community composition differences.** The major physiographic variable complexes which were identified (Table 19), relate to longitudinal changes occurring in the creeks, up the water courses from the flood plains, through the lowland sandy creek bed channels to the escarpment habitats. For example, as the distance from the estuary and the elevation

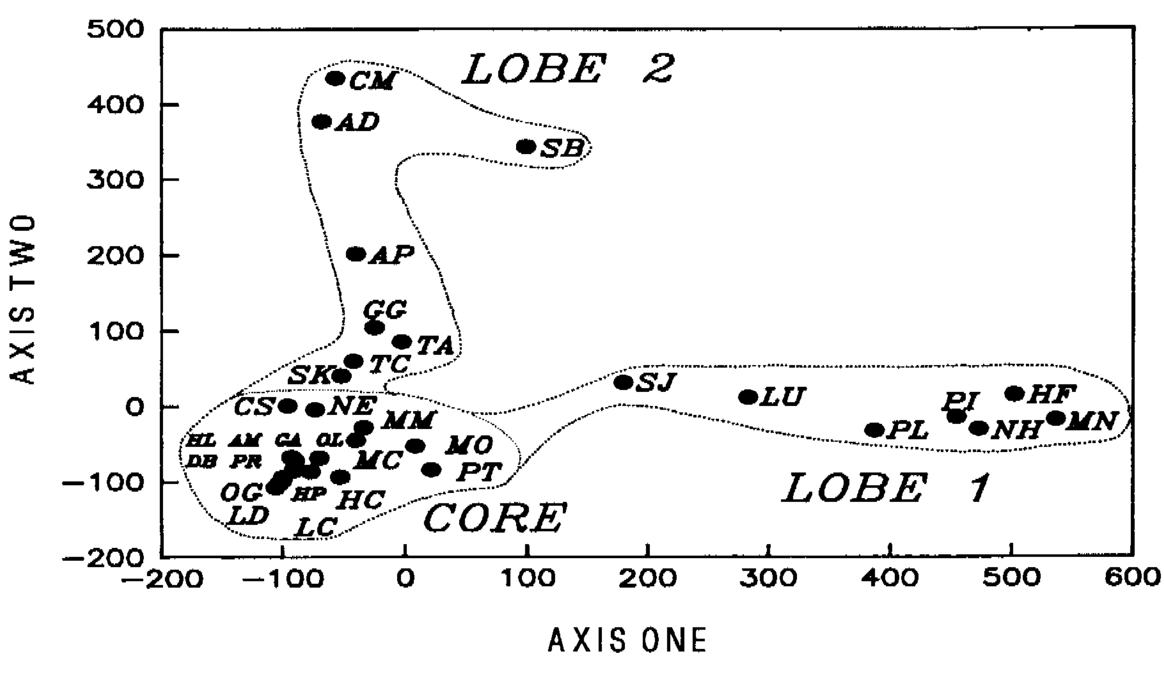



**Figure 44. Reciprocal averaging ordination analysis of fish species for combined seasons**

Species codes: AD = *Anodontiglanis dahli*, AM = *Ambassis* sp., AP = *Amniataba percoides*, CM = *Craterocephalus* nov. sp., CS = *Craterocephalus stercusmuscarum*, DB = *Denariusa bandata*, GA = *Glossamia aprion*, GG = *Glossogobius giurus*, HC = *Hypseleotris compressa*, HF = *Hephaestus fuliginosus*, HL = *Arius leptaspis*, HP = *Arius proximus*, LC = *Lates calcarifer*, LD = *Liza alata*, LU = *Leiopotherapon unicolor*, MC = *Megalops cyprinoides*, MM = *Melanotaenia splendida inornata*, MN = *Melanotaenia nigrans*, MO = *Mogurnda mogurnda*, NE = *Nematalosa erebi*, NH = *Neosilurus hyrtlii*, OG = *Ophisternon gutturale*, OL = *Oxyeleotris lineolatus*, PI = *Pingalla midgleyi*, PL = *Toxotes lorenzi*, PR = *Porochilus rendahli*, PT = *Pseudomugil tenellus*, SB = *Syncomistes butleri*, SJ = *Scleropages jardini*, SK = *Strongylura krefftii*, TA = *Tandanus ater*, TC = *Toxotes chatareus*.

increase, the gradient also increases slightly, while the stream order decreases (due to the branching of the creek) and the volume of the waterbodies also tends to decrease. In escarpment areas there was a rapid increase in gradient corresponding to increased elevation; in these high gradient areas, the volume of the waterbody was generally less than in other areas. The general lack of significance of the stream order correlations suggests that this concept is of little use ecologically in the Region.

In summary, there appeared to be two sets of variables operating inversely towards each other, namely volume and stream order (Set 1), versus elevation, gradient and distance to the estuary (Set 2).

The correlations between the first two ordination axes and the five physiographic variables are shown in Table 20. Axis 1 correlates highly significantly with increased elevation and gradient and decreased waterbody volume. This axis also relates to increased distance from the estuary but bears no relationship to stream order. The correlations between these variables and this axis, indicate that fish community composition is significantly changed in the higher gradient reaches of the escarpment zone (especially seasonal and perennial streams), by factors related to the physiographic variables measured. A similar point was made in an earlier part of this section which discussed the influence of site elevation on the diversity of the communities found. Reduced accessibility to floodplain, corridor and lowland communities in the form of near-insurmountable escarpment cascades is likely to be the main factor influencing community composition. The species found in the escarpment seasonal and perennial streams are thus likely to have specialised swimming abilities which allow them to endure high water velocitites and surmount obstacles. Other correlated variables (e.g. presence of boulder substrates, low pH and oligotrophic conditions), may influence their preference for and survival in these habitats. Such an analysis is not within the scope of this volume though it will be broached in further studies.

Axis 2 correlates significantly with distance to the estuary and to a lesser extent stream order. Elevation, gradient and volume factor bore no influence on this axis.

This indicates that the community composition changed moving upstream from the floodplain and corridor zones along the higher order lowland creek beds (e.g. Magela, Nourlangie and Hickey creeks) into escarpment main-channel areas. As axis 2 accounts for much less of the variation in the community data matrix than does axis 1, it may be assumed that the community composition changes are less marked in the higher order escarpment-draining creeks that had high values on axis 2 (see Fig. 42). This will be the case if no significant gradient, and hence elevation changes, exist in the reaches leading up to the escarpment area.

Accessibility problems faced by floodplain, corridor and backflow billabong species are thus much less for the reaches separated out on axis 2, than they are for the high gradient escarpment seasonal and perennial streams separated out on axis 1. Nevertheless the communities found in the escarpment main-channel waterbodies are characteristic, though these waterbodies impose less need for specialised swimming abilities than do the high gradient escarpment streams. It must be pointed out that other correlated variables (e.g. dominance of sand substrates, presence of thick *Pandanus* bank cover and greater overall depth), may help determine which species are found in these habitats.

#### Analysis of seasonal changes

**Habitats with similar community composition in the seasons.** Three site groups are apparent in the ordination (Fig. 45). These groups correspond to Groups 1 to 3 in the combined-seasons ordination of sites (Fig. 42) and therefore the axis interpretation remains similar. The groups remain relatively intact during the three seasons, but there are some obvious trends in the community composition changes. The escarpment stream group (escarpment seasonal streams ESS and escarpment perennial streams, EPS) changed least through the seasons, followed by the billabong and corridor waterbody group (lowland backflow billabongs LBB, floodplain billabongs FB and corridor waterbodies CW), then the more labile escarpment main-channel waterbodies (EMW) and lowland sandy creek bed group (LSC).

The escarpment stream habitats show relatively small seasonal shifts in community composition. This is probably because of the inaccessibility of these habitats and the limited range of species adapted to reach and survive in them. The main seasonal trend from the Late-dry through the Mid-wet to the Late-wet-Early-dry season (denoted from now on by 'through the seasons'), is the movement of the habitat points to the left-hand side of axis one. This means that in the Wet season the escarpment streams become more similar in composition to the other habitats than they were at the end of the Dry season. This can happen primarily through recruitment of species which are characteristic of the other habitats, i.e. the arrival of upstream migrants into the escarpment streams. Typical migrant species which appear in these streams in the Wet season are *M. cyprinoides*, *S. krefftii*, *A. percoides*, *G. aprion* and *T. chatareus*.

The escarpment main-channel waterbodies and lowland sandy creek bed habitats undergo greatest seasonal community composition change. The change through the seasons for both habitats is one of greatly increased similarity to billabong and corridor communities in the Mid-wet season followed by a return toward Late-dry season community composition in the Late-wet-Early-dry season. This reversion in community composition is most obvious in escarpment main-channel waterbodies at the end of the Wet season. Community changes in these habitats, as in escarpment streams, would be mainly caused by the recruitment of species migrating upstream from billabong and corridor habitats, as these sites are easily accessible once creek flow recommences and relinks all of these habitats. The sandy creek bed channels are of course the link. Typical migrant species include those most mentioned for the escarpment streams as well as the small species such as *M. splendida inornata*, *C. stercusmuscarum*, *Ambassis* spp. and *D. bandata*. Larger species would include *A. leptaspis* and possibly *T. ater*. The latter species is only 'possibly' included, as an upstream migrant, because in the sandy

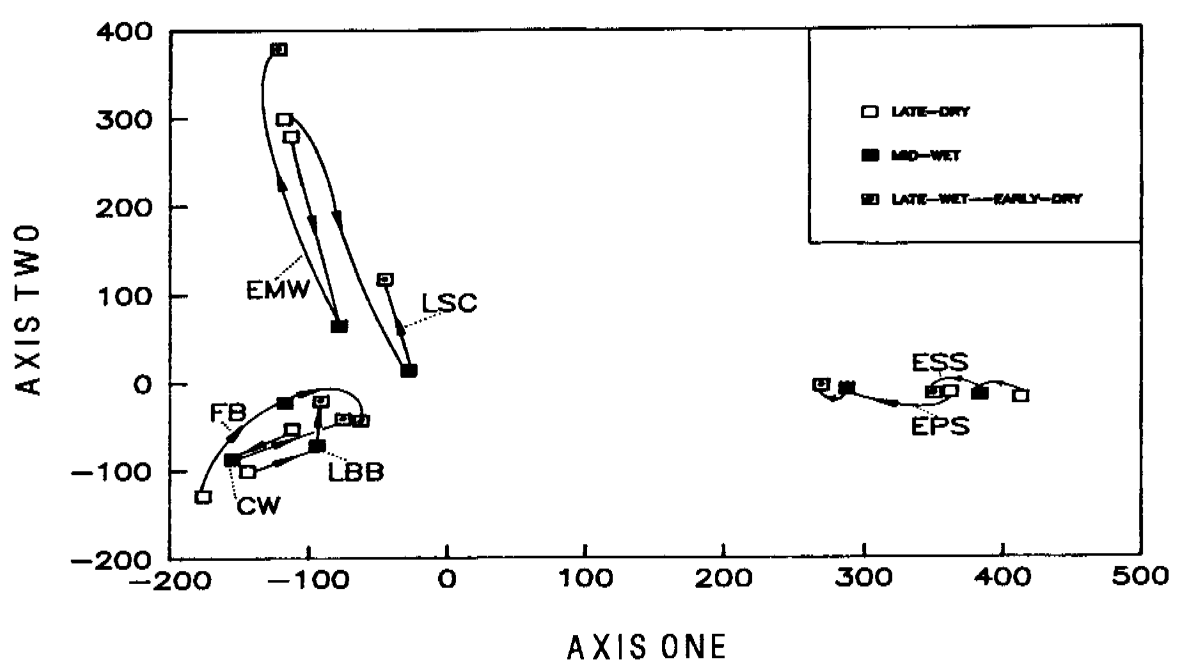



**Figure 45.** Reciprocal averaging ordination analysis of all habitats, showing seasonal changes

Habitat codes: CW = corridor waterbodies, EMW = escarpment main-channel waterbodies, EPS = escarpment perennial streams, ESS = escarpment seasonal streams, FB = floodplain billabongs, LBB = lowland backflow billabongs, LSC = lowland sandy creek bed group.

creek bed habitat it could well be a downstream migrant; large populations of *T. ater* take refuge in escarpment main-channels in the Dry season.

To a lesser extent, community change through the seasons might also be caused by species departing from the escarpment main channels and sandy creek bed channels once creek flow recommences. This would cause the Wet season communities of these habitats to become similar to the communities of other habitats, if the departing species were characteristic of these habitats in the Dry season and the species which remain are those which are more widely distributed during the Dry season. This circumstance occurs in the Early-wet season when *S. butleri* and *H. fuliginosus* migrate downstream from the escarpment main channels towards the lowland and corridor zones and *L. unicolor* and *A. percoides*, inhabitants of the sandy creek bed habitats, move towards the billabong habitats. An additional, though minor factor, which may cause apparent community change is not related to fish movement but to an artefact in the sampling methods employed; with changing conditions in the habitat, a fish species might remain in the habitat but become more difficult to catch. For example, the virtual loss of a characteristic species of the escarpment main-channel waterbodies and sandy creek bed channels, *Craterocephalus* nov. sp., from community samples taken in the Wet season, could be because it had moved to a microhabitat which was difficult to sample. This hypothesis is in part disproved by the observation of this species migrating up the sandy creek beds towards the end of the Wet season.

The strong and rapid return to the community composition typical of the Late-dry season in the escarpment main-channel waterbodies (EMS) and the lowland sandy creek habitats (LSC), at the end of the Wet season, suggests that the returning migration of characteristic species is an

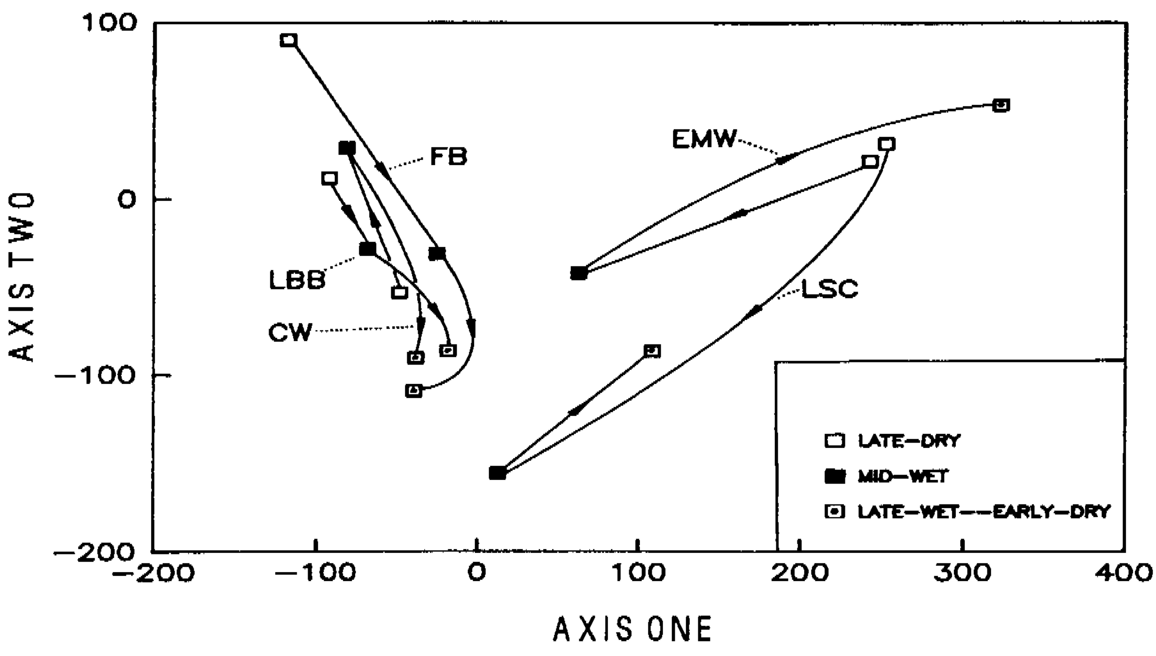



Figure 46. Reciprocal averaging ordination analysis of habitats other than escarpment streams, showing seasonal changes

Habitat codes: CW = corridor waterbodies, EMW = escarpment main-channel waterbodies, FB = floodplain billabongs, LBB = lowland backflow billabongs, LSC = lowland sandy creek bed group.

important factor in this change. Escarpment main-channel waterbodies show a stronger swing back to the Late-dry season community structure at the end of the Wet season, than do the communities in the sandy creek beds. This probably reflects the importance of the escarpment main-channel waterbodies as a Dry season refuge area as well as their greater overall distance from billabongs and corridor waterbodies. The sandy creek beds possibly still provide a linking function as their water level drops towards the end of the Wet season.

The seasonal composition of the backflow (lowland backflow billabongs, LBB) and floodplain billabongs (FB) habitats differs from that of the habitats already discussed, by displaying diametrically opposite trends. Through the seasons, the community composition of backflow and floodplain billabongs shifts towards that of the escarpment main-channel waterbodies and sandy creek bed habitats (up axis 2, Fig. 45), as well as towards the escarpment streams (across axis 1, Fig. 45). This shift is most conspicuous in floodplain billabongs, the obvious cause being the migration of characteristic species into these habitats from escarpment main-channel waterbodies, sandy creek bed habitats and possibly corridor waterbodies. Migration of characteristic species away from these habitats (lowland backflow billabongs, LBB and floodplain billabongs, FB) also occurs, but has little effect on community composition because the populations that refuge in these habitats are large and diverse; this is particularly true of the flood plains in the Dry season. The typical change from the Dry season to the Wet season in these billabongs is from a dominance of *Ambassis* spp., *D. bandata, O. lineolatus, H. compressa, P. rendahli, N. erebi* and possibly *A. leptaspis* and *G. aprion* in the Dry season to a dominance of *M. splendida inornata, T. chatareus, S. krefftii, T. ater* and *A. percoides* in the Wet season. Species in the latter group appear to be active migrants in the Wet season and some are characteristic of upstream habitats or have substantial populations that refuge in these habitats during the Dry season.

Corridor waterbodies (CW), though similar in community composition to the billabongs, show quite different seasonal trends from the billabongs. Their community composition undergoes a shift (to the left and down, Fig. 45) in the Mid-wet season towards a composition more typical of billabongs in the Dry season. The Late-wet-Early-dry season composition, however, follows the trend of pattern of the billabongs and clearly departs from a Dry season character. In the Mid-wet season, this contrary trend was caused by the capture of large numbers of migrants moving upstream through the corridor billabongs, presumably from the flood plains, into the lowlands and possibly further. A particularly large catch of *Ambassis* spp. and *D. bandata* was made in the Mid-wet at the upstream end of a corridor waterbody (Mudginberri corridor, MI), where high water velocity restricted their movement further upstream. This trend for corridor waterbodies in the Mid-wet to take on the community composition character of Dry season billabongs suggests that corridor waterbodies are important migration routes in the Wet season when fish from the flood plains are funnelled through to the lowlands.

The overall changes in community composition throughout the catchment can be determined by examining the statistics (mean and standard deviation) of the axes for all habitats together in each of the three seasons (Table 21). The changes in position of the mean indicates the overall trends in community composition from one season to another. The magnitude of the standard deviation indicates how different the compositions of the communities in the various habitats are in a given season; the smaller the standard deviation (SD) the more similar are the compositions of the communities in different habitats and conversely, the larger the standard deviation, the more dissimilar are the compositions of communities in different habitats. In other words, a catchment with well mixed communitites will have a smaller standard deviation than a catchment with poorly mixed communities.

For axis 1 (Table 21), the mean shows a small, though steady increase through the seasons. This indicates that the communitites shifted slightly towards escarpment stream community composition during the Wet season. The escarpment stream habitats themselves showed a reverse shift, but this was outweighed by the shift upwards towards the escarpment stream community composition for the other habitats. The standard deviation decreased through the seasons, indicating that the communitites in the different habitats were increasing in similarity. This trend corresponds to the increasing homogeneity of the aquatic environment during the Wet season and the increased mixing of communities allowed by better access between habitats.

Axis 2 (Table 21), shows a large drop in mean and standard deviation during the Mid-wet season. The reduction in the mean reflects the considerable community composition changes which occurred in the escarpment main-channel waterbodies and the sandy creek bed habitats owing to extensive fish migration. The billabong and corridor waterbody communities show a tendency to take on the compositional character of the escarpment main-channel waterbodies and sandy creek bed habitats. The increase in the mean caused by this trend is greatly outweighed by a decrease due to the changes described above. The relatively stable composition of the billabong and corridor waterbody community and its strong influence on the communities of upstream habitats, probably reflects the extensive area of Dry season refuge available in such habitats (especially the flood plains and the corridor waterbodies; the extensive and 'influentual Magela lagoon' community of Williams, 1979). The strong reduction of the standard deviation in the Mid-wet season (Table 21), reflects once again the greatly enhanced mixing of the communities in this season.

As shown in Fig. 45 and Table 21, community compositions in the Dry season reflect the preferences of different fish species for different refuges in this season (the sample points for the different habitats occupy different positions on the periphery of the ordination plane). In the Wet season, migration between habitats occurred and the communitities become more similar; hence the points for the various communitities are closer to the centre of the ordination plane (Fig. 45). This effect is confirmed by examination of the means and standard deviations for axes 1 and 2 (Table 21). It is expected that this pattern will prove to be a regular annual cycle.

**Habitats other than escarpment streams with similar community composition.** With the removal of the escarpment streams (i.e. escarpment perennials streams, EPS and escarpment seasonal streams, ESS) from the ordination more detailed changes in seasonal community composition may be demonstrated (Fig. 46). Separation on axis 1 of the ordination now corresponds to the separation depicted on axis 2 of the previous ordination, i.e. billabongs and corridor waterbodies (left) *vs* escarpment main-channel waterbodies and lowland sandy creek beds (right). The statistics for axis 1 (Table 21), also demonstrates seasonal trends similar to the statistics for axis 2 of the previous ordination.

Axis 2 of this ordination (Fig. 46), represents another factor influencing community composition in the habitat sample matix, which was masked by the presence of the escarpment stream habitat samples in the previous ordination (Fig. 45). This axis appears to depict the seasonal community changes occurring in each habitat. Downward shifts for most habitats (except corridor waterbodies), are obvious from the Late-dry to the Mid-wet season (see means in Table 21). Returning shifts are apparent in the Late-wet-Early-dry season for the escarpment main-channel waterbodies and sandy creek beds; the billabongs maintain a downward shift towards this season. The contrary trend noted in the corridor waterbodies in the previous ordination is very obvious in this ordination. The standard deviation for axis 2 (Table 21), shows no decrease through the seasons, but rather a very slight increase. This small change (if any), in the standard deviation does not infer that there are only small changes in community composition homogeneity between habitats through the seasons. This concept is irrelevant for this axis (2), because the axis describes a temporal factor (seasonality) rather than a spatial factor (longitudinal gradients). It is unlikely that standard deviations would vary to any great extent from season to season on this axis because, by the seasonal definition of axis, the Late-dry season samples are grouped to the top of the axis and the Wet season samples are grouped to the bottom of the axis. The axis therefore equalises the variation between the habitat samples per season.

## Classification of river zones and habitats.

The classification of river or stream zones, besides being helpful in comparing results of studies on the ecology of different river systems, is also of practical value in fishery and river management (Whitton 1975). In the field of water quality and pollution control, more attention needs to be given to the river zones involved, as not only do organisms in the different river zones often show different degrees of tolerance to pollution, but the environmental changes induced by a polluting discharge may differ between zones.

Most workers agree that it is desirable to classify river zones, but there is less agreement on whether such a classification is possible, as difficulties arise when attempts are made to define zones in ecological terms and refine the system (Whitton 1975). Marlier (1951) considered that a synecological rather than an autoecological approach was needed and Carpenter (1928) stressed the need for adopting a flexible scheme.

From the results of surveys of fish species in the rivers of different countries it is evident that, in general, there is a longitudinal distribution, with successions of different fish communities along the length of the river from its source to its mouth. Bishop (1979) recognised three broad geographic zones (lower reaches, steep intermediate escarpment area, and the upper reaches to the headwaters) which contained three characteristic associated fish communities in the Shoalhaven River catchment, New South Wales.

In the present study we found that the structure of fish communities in the Alligator Rivers Region did indeed change according to the environmental conditions in the different habitats. This confirms the ideas of W.C. Purdy (a plankton specialist with the US Public Health Service) who, in 1923, stated that 'if it were true that biological life of a stream is distinctly affected by the numerous factors which form the environment, it follows that the organisms in a stream [would] constitute, in a general way, a reflection of the prevailing environmental conditions of the stream'.

In the tropical ecosystem of the ARR, however, seasonal changes in environmental conditions were so marked that they often obscured the effects of environmental gradients along a watercourse and differing environmental conditions characteristic of different types of waterbody. Hence it may not be entirely satisfactory to define environmental zones in these catchments based on overall environmental conditions through the whole seasonal cycle, because changes in any one such zone between seasons result in very marked changes in the fish communities of habitats in that zone.

Nevertheless, many fish species in the study area were found to be associated with particular habitats, in part because of unchanging environmental features such as the escarpment cascades that exclude many species from the upper reaches of catchments and the characteristic substrates and vegetation of particular habitats. A tentative listing of zone and habitat types is therefore presented in Table 22. We hope that when the aquatic ecosystems of this Region are better understood, these zone and habitat types will be able to be defined more precisely, allowing a classification key to be produced. This would be of great value in developing policies for aquatic environmental management.

## Catchment differences.

The most noticeable difference between fish communities in the Magela and the Nourlangie Creek systems was that a number of species were exclusive to the Nourlangie system, i.e. *T. lorentzi* in escarpment and lowland backflow billabongs; *A. dahli* in escarpment main channels, lowland backflow billabongs and corridor waterbodies; and *A. proximus* and *A. graeffei* in lowland backflow and corridor waterbodies. Some of the species such as *L. alata* and *H. compressa*, typically found in the lower reaches of the Magela Creek system, were also captured in lowland habitats towards the Nourlangie system escarpment zone (these areas are located relatively closer to the estuarine reaches of the main river of the Nourlangie system). During this study, *M. splendida australis* was found only in Twin Falls Creek, a tributary (like Nourlangie Creek) of the South Alligator River.

Even though sites in the Cooper Creek system were sampled on only one occasion during the study, it was surprising that *A. leptaspis* was absent from catches in that area as this species was found commonly throughout the Magela and Nourlangie Creek systems during all seasons.

# REFERENCES


Abell, D.L. (1961). The role of drainage in biological work on streams. *Verh. int. Verin. theor. angew. Limnol.* **14**, 533-537.

Bishop, K.A. (1979). Fish and aquatic macroinvertebrate communities of a coastal river (Shoalhaven River, New South Wales) during the development of a water diversion scheme. MSc thesis, Macquarie University

Beumer, J.P. (1976). The fishes of a tropical river with emphasis on the spangled perch, *Therapon unicolor* Gunther, 1859 and the east Queensland rainbowfish, *Nematocentris splendida* Peters, 1866. PhD thesis, James Cook University of North Queensland.

Burton, G.W. & Odum, E.P. (1945). The distribution of stream fish in the vicinity of Mountain Lake, Virginia. *Ecology* **26**, 182-194.

Cadwallader, P.L. (1979). Native and introduced fishes of the Seven Creeks (Goulbourn River system), Victoria. *Aust. J. Ecol.* **4**, 361-385.

Cairns, J. & Dickson, K.L. (1980). The ABCs of biological monitoring, *in* C.H. Hocutt & J.R. Stauffer (eds), 'Biological Monitoring of Fish'. Lexington, Toronto.

Carpenter, K. E. (1928). Life in inland waters. Sidgwick and Jackson, London.

Fox, R.W., Kelleher, C.G. & Kerr, C.B. (1977). Ranger Uranium Environmental Inquiry, Second Report. AGPS, Canberra.

Gorman, O.T. & Karr, J.R. (1978). Habitat structure and stream fish communities. *Ecology* **50**, 507-515.

Green, R.H. (1979). Sampling design and statistical methods for biologists. John Wiley and Sons, New York.

Hellawell, J.M. (1978). Biological surveillance of rivers. Water Research Centre, Stevenage, England.

Hill, M.O. (1973). Reciprocal averaging: an eigenvector method of ordination. *Journal of Ecology* **61**, 237-249.

Hill, M.O. (1979*a*). DECORANA - A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Cornell University, Ithaca, N.Y.

Hill, M.O. (1979*b*) Twinspan - A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University, Ithaca, N.Y.

Hynes, H.B.N. (1970). The ecology of running waters. University Press, Liverpool.

Karr, J.R. & Schlosser, I.J. (1977). Impact of nearstream vegetation and stream morphology on water quality and stream biota. Ecological Research Series EPA-600/ 3-77-097. United States Environmental Protection Agency, Athens, Georgia, USA.

Krebs, C.V. (1972). Ecology, the experimental analysis of distribution and abundance. Harper & Row, New York.

Kuehne, R.A. (1962). A classification of streams, illustrated by fish distribution in an Eastern Kentucky Creek. *Ecology* **43**, 608-614.

Larimore, R.W. & Smith, P.W. (1963). The fishes of Champaign County, Illinois, as affected by 60 years of stream changes. *Bull. Ill. St. Nat. Hist. Surv.* **28**, 299-382.

Marlier, G. (1951). La biologie d'un ruisseau de plaine. Le Smohain. *Mem. Inst. R. Sci. Nat. Belg.* **114**, 1-98.

Midgley, S.H. (1973). Freshwater fish inventory and associated habitat information. Alligators Rivers Region Environmental Fact Finding Study. Department of the Northern Territory, Canberra.

Odum, E.P. (1971). Fundamentals of ecology. Philadelphia, W.B. Saunders.

Peet, R.K. (1974). The measurement of species diversity. *Ann. Rev. Ecol. Syst.* **5**, 285-307.

Pollard, D.A. (1974). The freshwater fishes of the Alligator Rivers 'Uranium Province' area (Top End, Northern Territory) with particular reference to the Magela Creek catchment (East Alligator River System). Report 1, *in* P.J.F. Newton (ed.), 'Alligator Rivers area fact finding study, four AAEC Reports'. Report E305, Australian Atomic Energy Commission. AAEC, Sydney.

Sheldon, A.L. (1968). Species diversity and longitudinal succession in stream fishes. *Ecology* **49**, 193-198.

Shelford, V.E. (1911). Ecological succession I. Stream fishes and the method of physiographic analysis. *Biol. Bull. Mar. Biol. Lab. (Woods Hole)* **21**, 9-35.

Stauffer, J.R. & Hocutt, C.H. (1980). Inertia and recovery: an approach to stream classification and stress evaluation. *Wat. Res. Bull.* **16**, 72-78.

Taylor, W.R. (1964). Fishes of Arnhem Land, *in* 'Records of the American-Australian Scientific Expedition to Arnhem Land, Vol. IV: Zoology'. Melbourne University Press, Melbourne.

Thompson, D.H. & Hunt, F.D. (1930). The fishes of Champaign County; a study of the distribution and abundance of fishes in small streams. *Bull. Ill. St. Nat. Hist. Surv.* **19**, 5-101.

Warren, C.E. (1971). Biology and Water Pollution Control. W.B. Saunders, Philadelphia.

Welcomme, R.L. (1970). Studies on the effects of abnormally high water levels on the ecology of fish in certain shallow regions of Lake Victoria. *J. Zool. Lond.* **160**, 405-436.

Whitton, B.A. (ed.) (1975). River Ecology. Blackwell Scientific Publications, London.

Williams, A.R. (1979). Vegetation and stream pattern as indicators of water movement on the Magela floodplain, Northern Territory. *Aust. J. Ecol.* **4**, 239-247.

Wilhm, J.L. & Dorris, T.C. (1968). Biological parameters for water quality criteria. *Bioscience* **18**, 477-481.

# TABLES

Table 1. Relative abundances of fish species captured or observed in plateau habitats during present study and by Midgely (1973)

R = rare; C = common; A = abundant

| Species | Sites and dates | | | | | |
|---|---|---|---|---|---|---|
| | Baroalba Ck (BM) 24.3.79 | Above Magela Falls (TF) 28.9.79 | Above Twin Falls[b] 8.11.79 | Above Jim Jim[b] Falls 13.10.72 | Above Kolondjarluk[b] Falls 19.7.73 | Above Kooplin Gorge[a] 10.10.78 |
| *Neosilurus* sp. | - | - | - | C | - | - |
| *Melanotaenia* sp. | - | - | - | A | - | - |
| *M. nigrans* | - | A | - | - | - | - |
| *M. splendida australis* | - | - | A | - | C | - |
| *Ambassis* (unidentifiable) | - | - | - | C | C | - |
| *Leiopotherapon unicolor* | - | C | - | C | - | - |
| *Mogurnda mogurnda* | C | - | C | R | C | C |
| Total number of species | 1 | 2 | 2 | 5 | 3 | 1 |

[a]Near El Sharana on the South Alligator River System
[b]Midgley 1973

Table 2. Relative numbers and size ranges (LCF) of fish observed in various main-channel escarpment waterbodies

R = relative numbers (A > 50, C = 5-50, R < 5, - = absent); LCF = length to caudal fork in mm; nd = not determined. Site codes: BD = Bowerbird Billabong, BF = Magela Falls (base), TWa = Twin Falls waterbody, TW = Twin Falls (base), JD = Jim Jim Falls (base), KD = Kolondjarluk Falls (base), CP = Camp 1 billabong, lower Kolondjarluk Creek.

| | East Alligator River catchment | | | | South Alligator River catchment | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sites | BD 26.7.79 | | BF 28.9.79 | | TWa 8.12.79 | | TW 8.12.79 | JD 9.12.79 | KD 10.10.78 | CP 10.10.78 |
| Species | No. | LCF | No. | LCF | No. | LCF | R | R | R | R |
| *Megalops cyprinoides* | - | - | - | - | C | 180-200 | - | - | - | R |
| *Nematalosa erebi* | 1 | 300 | - | - | R | 250 | - | - | - | C |
| *Scleropages jardini* | 1 | 600 | - | - | R | 500-600 | - | - | - | R |
| *Arius leptapis* | 1 | 350 | - | - | R | 340 | - | - | - | R |
| *Anodontiglanis dahli* | - | - | - | - | - | - | - | - | - | C |
| *Tandanus ater* | 5 | 350-400 | - | - | - | - | - | - | - | - |
| *Neosilurus hyrtlii* | - | - | - | - | - | - | - | - | - | C |
| *Strongylura kreffiii* | 1 | 250 | - | - | R | 300 | - | - | - | R |
| *Melanotaenia nigrans* | 4 | 20-35 | 4 | 45-55 | C | 15-60 | C | - | - | R |
| *M. splendida inornata* | 40 | 20-55 | - | - | R | 20-55 | - | - | - | - |
| *M. splendida australis* | - | - | - | - | A | 15-60 | C | - | - | - |
| *Pseudomugil tenellus* | 40 | 20-25 | - | - | - | - | - | - | - | - |
| *Craterocephalus* nov. sp. | 100 | 15-40 | - | - | C | 20-50 | - | - | - | A |
| *C. stercusmuscarum* | 8 | 25-45 | - | - | R | 20-40 | - | - | - | R |
| *Ambassis agrammus* | 70 | 50-60 | - | - | A | 10-70 | - | - | - | - |
| *A. macleayi* | - | - | - | - | - | - | - | - | - | A |
| *Amniataba percoides* | 200 | 60-120 | - | - | A | 15-110 | - | - | - | C |
| *Hephaestus fuliginosus* | 14 | 200-300 | 50 | 25-350 | A | 25-280 | R | A | C | C |
| *Leiopotherapon unicolor* | 300 | 70-170 | 100 | 16-90 | R | 15-120 | C | A | A | C |
| *Syncomistes butleri* | 8 | 90-250 | - | - | C | 100-250 | - | C | C | C |
| *Pingalla midgleyi* | 3 | 60-90 | - | - | C | 40-120 | - | - | A | C |
| *Glossamia aprion* | - | - | - | - | R | nd | - | - | - | - |
| *Toxotes lorentzi* | - | - | - | - | - | - | - | - | - | R |
| *T. chatareus* | 5 | 220-250 | - | - | C | 10-220 | - | - | - | C |
| *Glossogobius giurus* | 2 | 30-40 | - | - | C | 25-30 | C | C | - | C |
| Total number of species | 18 | | 3 | | 19 | | 5 | 4 | 4 | 19 |

Table 3(a). Numbers and weights of fish species captured in Bowerbird Billabong (BD), a main-channel escarpment waterbody
Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Mid-wet | | Mid-dry | | Late-dry 1979 | | Early-wet | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Nematalosa erebi* | 1 | 300.0 | 0 | - | 0 | - | 2 | 613.0 | 4 | 1211.5 | 7 | 2124.5 |
| *Scleropages jardini* | 1 | 800.0 | 0 | - | 0 | - | 1 | 633.0 | 0 | - | 2 | 1433.0 |
| *Arius leptapis* | 3 | 1256.0 | 0 | - | 0 | - | 0 | - | 0 | - | 3 | 1256.0 |
| *Tandanus ater* | 9 | 3344.0 | 0 | - | 7 | 2591.0 | 0 | - | 12 | 2219.2 | 29 | 8154.2 |
| *Strongylura krefftii* | 2 | 364.0 | 4 | 447.1 | 0 | - | 0 | - | 0 | - | 6 | 811.1 |
| *Melanotaenia nigrans* | 0 | - | 0 | - | 0 | - | 2 | 0.7 | 0 | - | 2 | 0.7 |
| *M. splendida inornata* | 0 | - | 71 | 136.3 | 4 | 1.4 | 2 | 0.6 | 10 | 6.0 | 87 | 144.3 |
| *Craterocephalus* nov. sp. | 83 | 45.3 | 15 | 19.0 | 232 | 44.8 | 54 | 20.4 | 197 | 92.3 | 581 | 221.8 |
| *C. stercusmuscarum* | 9 | 1.7 | 47 | 28.4 | 55 | 9.2 | 18 | 4.2 | 45 | 8.6 | 174 | 52.1 |
| *Ambassis macleayi* | 0 | - | 73 | 200.1 | 1 | 5.1 | 0 | - | 58 | 22.8 | 132 | 228.0 |
| *Ambassis* (unidentifiable) | 1 | 0.1 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 0.1 |
| *Amniataba percoides* | 15 | 1110.0 | 0 | - | 18 | 966.3 | 4 | 314.7 | 3 | 94.5 | 40 | 2485.5 |
| *Hephaestus fuliginosus* | 0 | - | 1 | 2.9 | 0 | - | 0 | - | 0 | - | 1 | 2.0 |
| *Leiopotherapon unicolor* | 0 | - | 0 | - | 0 | - | 0 | - | 3 | 136.3 | 3 | 136.3 |
| *Syncomistes butleri* | 0 | - | 1 | 368.0 | 1 | 256.9 | 1 | 392.0 | 5 | 765.9 | 8 | 1782.8 |
| *Pingalla midgleyi* | 0 | - | 4 | 54.4 | 1 | 7.1 | 0 | - | 0 | - | 5 | 61.5 |
| *Glossamia aprion* | 0 | - | 11 | 24.0 | 1 | 0.2 | 0 | - | 5 | 9.8 | 17 | 34.0 |
| *Toxotes chatareus* | 1 | 100.0 | 1 | 193.0 | 1 | 98.2 | 1 | 158.0 | 1 | 204.5 | 5 | 753.7 |
| *Glossogobius giurus* | 2 | 0.5 | 0 | - | 0 | - | 0 | - | 1 | 1.5 | 3 | 2.0 |
| Total | 127 | 7321.6 | 228 | 1473.2 | 321 | 3980.2 | 85 | 2136.6 | 340 | 4772.9 | 1101 | 19684.5 |

Table 3(b). Numbers and weights of fish species captured in Sawcut Gorge (ST), a main-channel escarpment waterbody

Catches were obtained using standard netting methods.

| Species | Late-dry 1978 | | Early-wet | | Mid-wet | | Mid-dry 1979 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 0 | - | 3 | 985.0 | 3 | 985.0 |
| *Nematalosa erebi* | 5 | 1715.0 | 0 | - | 0 | - | 0 | - | 5 | 1715.0 |
| *Arius leptaspis* | 2 | 2425.0 | 4 | 1930.0 | 0 | - | 0 | - | 6 | 4355.0 |
| *Anodontiglanis dahli* | 1 | 450.0 | 1 | 430.0 | 0 | - | 0 | - | 2 | 880.0 |
| *Tandanus ater* | 14 | 3082.0 | 3 | 705.0 | 0 | - | 1 | 260.0 | 18 | 4047.0 |
| *Strongylura krefftii* | 2 | 1233.0 | 0 | - | 0 | - | 0 | - | 2 | 1233.0 |
| *Melanotaenia nigrans* | 0 | - | 0 | - | 3 | 1.2 | 0 | - | 3 | 1.2 |
| *M. splendida inornata* | 1 | 0.2 | 2 | 0.7 | 9 | 60.0 | 17 | 29.0 | 29 | 89.9 |
| *Craterocephalus* nov. sp. | 37 | 13.1 | 1 | 0.1 | 38 | 38.6 | 243 | 324.1 | 319 | 375.8 |
| *C. stercusmuscarum* | 5 | 1.7 | 5 | 1.0 | 1 | 1.0 | 0 | - | 11 | 3.7 |
| *Ambassis agrammus* | 11 | 0.7 | 5 | 1.1 | 0 | - | 0 | - | 16 | 1.8 |
| *A. macleayi* | 0 | - | 0 | - | 1 | 5.1 | 1 | 5.8 | 2 | 10.9 |
| *Amniataba percoides* | 8 | 482.3 | 1 | 1.0 | 24 | 580.4 | 19 | 355.3 | 52 | 1418.2 |
| *Hephaestus fuliginosus* | 1 | 68.0 | 0 | - | 5 | 778.8 | 1 | 75.0 | 7 | 921.8 |
| *Leiopotherapon unicolor* | 0 | - | 0 | - | 2 | 28.7 | 1 | 17.7 | 3 | 46.4 |
| *Syncomistes butleri* | 0 | - | 0 | - | 6 | 1951.0 | 5 | 1825.0 | 11 | 3776.0 |
| *Toxotes chatareus* | 1 | 255.0 | 3 | 461.5 | 6 | 1304.4 | 1 | 245.0 | 11 | 2265.9 |
| *Glossogobius giurus* | 2 | 0.9 | 1 | 1.6 | 1 | 1.0 | 0 | - | 4 | 3.5 |
| Total | 90 | 9726.9 | 26 | 3532.0 | 96 | 4750.2 | 292 | 4121.9 | 504 | 22130.1 |

Table 4. Numbers and weights of fish species collected in Noranda Pools (NS), on Noranda Creek (off Koongara Creek) a seasonal escarpment stream, during the 1978 Late-dry and 1978-79 Early-wet seasons

| | Late-dry | | Early-wet | |
|---|---|---|---|---|
| Species | No. | Wt (g) | No. | Wt (g) |
| *Melanotaenia nigrans* | 89 | 42.9 | 30 | 23.4 |
| *Leiopotherapon unicolor* | 2 | 14.9 | 0 | - |
| *Mogurnda mogurnda* | 6 | 28.6 | 1 | 1.3 |
| Total | 97 | 86.4 | 31 | 2.47 |

Table 5. Numbers and size ranges (LCF) of fish species observed at site SZ, off Sawcut Gorge (ST), a seasonal escarpment feeder stream pool

LCF = length to caudal fork in mm

| | Sampling period | | | | | |
|---|---|---|---|---|---|---|
| | Early-wet | | Mid-wet | | Mid-dry | |
| Species | No. | LCF | No. | LCF | No. | LCF |
| *Megalops cyprinoides* | - | - | 1 | 400 | - | - |
| *Melanotaenia nigrans* | 200 | 30-90 | 150 | 30-60 | 100 | 15-60 |
| *M. splendida inornata* | - | - | 10 | 30-60 | 20 | 20-50 |
| *Hephaestus fuliginosus* | - | - | 3 | 35-100 | 1 | 120 |
| *Leiopotherapon unicolor* | 1 | 100 | 30 | 50-70 | 12 | 40-130 |
| *Pingalla midgleyi* | 2 | 100 | 3 | 45-70 | 5 | 30-60 |
| Number of species | 3 | | 6 | | 5 | |

Table 6. Numbers and size ranges (LCF) of fish species observed along a seasonal escarpment feeder stream (between sites SZ, SY) off Sawcut Gorge, during the 1978-79 Mid-wet season

None of the following species were present at a sampling site below a large waterfall (elevation 130 m).
P/A = presence (+), absence (-); E = elevation in metres; LCF = length to caudal fork in mm

| | Longitudinal array of sampling sites | | | | | |
|---|---|---|---|---|---|---|
| | Above standard pool E = 110 | | Standard pool E = 100 | | Shallow sandy pool below standard pool E = 80 | |
| Species | P/A | LCF | No. | LCF | No. | LCF |
| *Megalops cyprinoides* | - | - | 1 | 400 | - | - |
| *Melanotaenia nigrans* | - | - | 150 | 30-60 | 5 | 25-35 |
| *M. splendida inornata* | - | - | 10 | 30-60 | 20 | 25-50 |
| *Hephaestus fuliginosus* | + | 50-100 | 3 | 35-100 | 4 | 30-35 |
| *Leiopotherapon unicolor* | + | 60-70 | 30 | 50-70 | 20 | 45-60 |
| *Pingalla midgleyi* | - | - | 3 | 45-70 | 4 | 35-50 |

Table 7(a). Numbers and size ranges (LCF) of fish species observed in Radon Springs (RS), a perennial escarpment pool

LCF = length to caudal fork in mm; absent -

| | Sampling period | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Early-wet 1978 | | Mid-wet | | Late-wet-Early-dry 1979 | | Mid-dry | | Late-dry | | Early-wet | | Total |
| Species | No. | LCF | No. | LCF | No. | LCF | No. | LCF | No. | LCF | No. | LCF | No. |
| *Scleropages jardini* | - | - | 1 | 400 | 2 | 600-800 | - | - | - | - | - | - | 3 |
| *Tandanus ater* | - | - | - | - | 60 | 80-120 | - | - | 2 | 120-180 | - | - | 62 |
| *Neosilurus hyrtlii* | - | - | - | - | 120 | 80-120 | 124 | 140-180 | 100 | 100-150 | 15 | 120-150 | 359 |
| *Melanotaenia nigrans* | 200 | 7-70 | 200 | 15-40 | 80 | 20-60 | 200 | 25-60 | 200 | 15-50 | 300 | 6-48 | 1180 |
| *M. splendida inornata* | 3 | 30-80 | - | - | - | - | - | - | - | - | - | - | 3 |
| *Craterocephalus stercusmuscarum* | - | - | - | - | - | - | - | - | 5 | 5-25 | - | - | 5 |
| *Hephaestus fuliginosus* | 5 | 100-250 | 11 | 60-200 | 9 | 40-250 | 6 | 60-70 | 24 | 60-300 | 16 | 40-250 | 71 |
| *Leiopotherapon unicolor* | 17 | 40-110 | 23 | 25-30 | 23 | 30-130 | 25 | 70-260 | 50 | 30-120 | 30 | 40-250 | 168 |
| *Pingalla midgleyi* | 15 | 50-100 | 7 | 40-70 | 8 | 60-100 | 3 | 80-90 | 25 | 40-80 | 23 | 50-100 | 81 |
| *Mogurnda mogurnda* | 1 | 30 | - | - | - | - | - | - | 5 | 20-30 | 10 | 15-40 | 16 |
| Total number of species | 6 | | 5 | | 7 | | 5 | | 8 | | 6 | | 1948 |

Table 7(b). Numbers and size ranges (LCF) of fish species observed in Baroalba Springs (BS), a perennial escarpment pool

LCF = length to caudal fork in mm; present +, absent -; nd = not determined

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | Early-wet | | 1978-79 Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Early-wet | | Total |
| Species | No. | No. | LCF | No. | LCF | No. | LCF | No. | LCF | No. | LCF | No. | LCF | No. |
| *Megalops cyprinoides* | + | - | - | 2 | 200 | 1 | 200 | - | - | 2 | 150-200 | - | - | 5 |
| *Scleropages jardini* | + | - | - | 1 | 800 | 1 | 800 | 1 | 550 | 1 | 650 | 1 | 400 | 5 |
| *Tandanus ater* | - | - | - | 5 | 400-450 | 10 | 400-450 | - | - | 10 | 250-350 | 6 | 230-300 | 31 |
| *Neosilurus hyrtlii* | + | - | - | - | - | - | - | - | - | 200 | 40-70 | - | - | 200 |
| *Porochilus rendahli* | - | - | - | - | - | 10 | 100-120 | - | - | 150 | 20-80 | - | - | 160 |
| *Strongylura krefftii* | - | - | - | 5 | nd | 1 | 250 | - | - | - | - | - | - | 6 |
| *Melanotaenia nigrans* | + | 9 | 60 | 100 | 20-60 | 100 | 20-60 | 100 | 30-70 | - | - | 80 | 20-50 | 389 |
| *M. splendida inornata* | + | 6 | nd | 120 | 20-75 | 150 | 30-75 | - | - | - | - | 55 | 14-80 | 331 |
| *Craterocephalus stercusmuscarum* | + | - | - | 1 | 30 | - | - | - | - | - | - | - | - | 1 |
| *Pseudomugil tenellus* | - | - | - | 10 | 5-10 | - | - | - | - | 40 | 15-20 | - | - | 50 |
| *Ambassis agrammus* | - | - | - | - | - | - | - | 1 | 30 | - | - | - | - | 1 |
| *A. macleayi* | - | - | - | - | - | 1 | 40 | - | - | - | - | - | - | 1 |
| *Lates calcarifer* | - | - | - | 1 | 800 | - | - | - | - | - | - | - | - | 1 |
| *Amniataba percoides* | + | - | - | 3 | 45-130 | 9 | 45-130 | 1 | 100 | 2 | 40-60 | 1 | 80 | 16 |
| *Hephaestus fuliginosus* | + | 6 | 250 | 7 | 120-350 | 4 | 350-450 | 1 | 150 | 20 | 100-350 | 10 | 180-350 | 48 |
| *Leiopotherapon unicolor* | + | - | - | 25 | 40-180 | 10 | 60-120 | 10 | 60-120 | 30 | 40-150 | 20 | 50-180 | 95 |
| *Syncomistes butleri* | - | - | - | 8 | 120-280 | 1 | 250 | - | - | 2 | 150-200 | - | - | 11 |
| *Pingalla midgleyi* | + | 5 | nd | 55 | 80-120 | 45 | 80-120 | 21 | 50-120 | 50 | 60-130 | 40 | 60-130 | 216 |
| *Glossamia aprion* | + | 1 | 20 | 5 | 60-110 | 3 | 60-130 | 7 | 150-170 | 12 | 25-130 | 6 | 25-160 | 34 |
| *Toxotes lorentzi* | - | - | - | 10 | 80-90 | 10 | 80-90 | - | - | - | - | - | - | 20 |
| *T. chatareus* | - | - | - | 2 | 40-80 | 3 | 40-120 | 2 | 70-150 | 4 | 70-80 | - | - | 11 |
| *Mogurnda mogurnda* | - | 1 | 30 | 1 | 45 | - | - | - | - | - | - | - | - | 2 |
| Total number of species | 11 | 6 | | 18 | | 17 | | 9 | | 13 | | 9 | | 1634 |

Table 8. Numbers and size ranges (LCF) of fish species observed along a perennial escarpment spring-fed stream, Baroalba Creek, during the 1979 Mid-dry season

LCF = length to caudal fork in mm; E = elevation; N = numbers observed; P = presence (+, present; -, absent)

| | Longitudinal array of sites in Baroalba Creek | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mt Brockman Plateau (BM) E = 170 | Above standard pool E = 45 | Standard pool E = 40 | | Shallow sandy pool (0.5 km below standard pool) E = 39 | | Deep sandy pool (1.5 km below standard pool) E = 35 | |
| Species | P | P | N | LCF | N | LCF | N | LCF |
| *Megalops cyprinoides* | - | - | - | - | - | - | 40 | 200-450 |
| *Scleropages jardini* | - | - | 1 | 500 | 2 | 250-300 | 10 | 250-550 |
| *Neosilurus hyrtlii* | - | + | - | - | 100 | 120-200 | 300 | 120-400 |
| *Strongylura krefftii* | - | - | - | - | - | - | 1 | 300 |
| *Craterocephalus* nov. sp. | - | - | - | - | - | - | 50 | 30-50 |
| *Ambassis agrammus* | - | - | 1 | 30 | - | - | - | - |
| *Amniataba percoides* | - | - | 1 | 100 | 3 | 40-50 | 4 | 40-50 |
| *Hephaestus fuliginosus* | - | + | 1 | 150 | - | - | 2 | 120-250 |
| *Leiopotherapon unicolor* | - | + | 10 | 60-120 | 10 | 60-80 | 50 | 60-180 |
| *Syncomistes butleri* | - | - | - | - | - | - | 1 | 250 |
| *Pingalla midgleyi* | - | + | 21 | 50-120 | 10 | 50-100 | 50 | 60-150 |
| *Glossamia aprion* | - | - | 7 | 150-170 | - | - | 10 | 170 |
| *Toxotes lorentzi* | - | - | - | - | 8 | 150-170 | - | - |
| *T. chatareus* | - | - | 2 | 70-150 | - | - | 3 | 80-300 |
| *Mogurnda mogurnda* | + | - | - | - | - | - | - | - |
| Total number of species | 1 | 5 | 9 | | 7 | | 13 | |

Table 9(a). Numbers and weights of fish species captured at the Magela Creek bed site MD, a lowland sandy creekbed pool

Catches were obtained using standard netting methods; nd = not determined

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early dry | | Mid-dry | | Late-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 1 | 410.0 | 0 | - | 0 | - | 0 | - | 1 | 410.0 |
| *Nematalosa erebi* | 0 | - | 13 | 2860.0 | 0 | - | 3 | 99.4 | 18 | 517.3 | 2 | 144.9 | 36 | 3621.6 |
| *Scleropages jardini* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | nd | 1 | nd |
| *Arius leptaspis* | 0 | - | 0 | - | 4 | 3830.0 | 0 | - | 0 | - | 0 | - | 4 | 3830.0 |
| *Tandanus ater* | 0 | - | 17 | 5090.0 | 1 | 250.0 | 0 | - | 0 | - | 0 | - | 18 | 5340.0 |
| *Neosilurus hyrtlii* | 2 | 75.0 | 0 | - | 0 | - | 0 | - | 11 | 300.7 | 1 | 29.3 | 14 | 434.3 |
| *Strongylura krefftii* | 11 | 851.0 | 1 | 1.0 | 2 | 42.5 | 3 | 79.3 | 6 | 322.2 | 5 | 904.4 | 28 | 2199.4 |
| *Melanotaenia splendida inornata* | 49 | 22.7 | 14 | 13.2 | 128 | 179.0 | 0 | - | 0 | - | 3 | nd | 194 | 215.4 |
| *Craterocephalus* nov. sp. | 143 | 189.0 | 0 | - | 6 | 6.9 | 26 | 26.0 | 117 | 12.8 | 106 | 49.2 | 398 | 283.9 |
| *C. stercusmuscarum* | 18 | 4.1 | 25 | 14.3 | 14 | 5.7 | 14 | 0.4 | 2 | 0.4 | 2 | 0.7 | 75 | 25.6 |
| *Ambassis agrammus* | 3 | 2.2 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 3 | 2.2 |
| *A. macleayi* | 0 | - | 7 | 2.4 | 1 | 3.8 | 1 | 4.2 | 0 | - | 0 | - | 9 | 10.4 |
| *Amniataba percoides* | 4 | 17.9 | 4 | 195.5 | 0 | - | 22 | 478.5 | 21 | 385.1 | 8 | 118.1 | 59 | 1195.1 |
| *Leiopotherapon unicolor* | 2 | 87.6 | 0 | - | 3 | 42.5 | 2 | 150.9 | 17 | 975.3 | 3 | 83.6 | 27 | 1339.9 |
| *Syncomistes butleri* | 0 | - | 1 | 750.0 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 750.0 |
| *Glossamia aprion* | 0 | - | 0 | - | 0 | - | 1 | 18.0 | 0 | - | 0 | - | 1 | 18.0 |
| *Toxotes chatareus* | 0 | - | 2 | 410.0 | 6 | 680.0 | 1 | 17.2 | 0 | - | 0 | - | 9 | 1107.2 |
| *Mogurnda mogurnda* | 1 | 1.4 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 1.4 |
| *Oxyeleotris lineolatus* | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 130.7 | 0 | - | 1 | 130.7 |
| Total | 233 | 1250.9 | 84 | 9335.4 | 166 | 5450.4 | 73 | 873.9 | 193 | 2644.5 | 131 | 1330.7[a] | 880 | 20885.8[a] |

[a]excluding *Scleropages jardini* and *M. splendida inornata*

Table 9(b). Numbers and weights of fish species captured at the Magela Creek bed site GD, a lowland sandy creekbed pool Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Early-wet | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Nematalosa erebi* | 0 | - | 24 | 1472.3 | 1 | 0.1 | 1 | 28.3 | 3 | 81.5 | 1 | 33.3 | 0 | - | 30 | 1615.5 |
| *Arius leptaspis* | 0 | - | 0 | - | 1 | 700.0 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 700.0 |
| *Tandanus ater* | 0 | - | 13 | 3290.0 | 1 | 1.8 | 0 | - | 4 | 109.4 | 0 | - | 0 | - | 18 | 3401.2 |
| *Strongylura kreffii* | 0 | - | 0 | - | 0 | - | 1 | 16.7 | 1 | 33.4 | 0 | - | 0 | - | 2 | 50.1 |
| *Melanotaenia splendida inornata* | 29 | 13.7 | 5 | 2.6 | 24 | 45.4 | 8 | 31.4 | 0 | - | 2 | 1.4 | 0 | - | 68 | 94.5 |
| *Craterocephalus* nov. sp. | 324 | 126.4 | 1 | 0.4 | 0 | - | 0 | - | 376 | 146.7 | 217 | 59.2 | 0 | - | 918 | 332.7 |
| *C. stercusmuscarum* | 24 | 5.9 | 21 | 12.5 | 9 | 2.3 | 2 | 0.1 | 0 | - | 3 | 0.5 | 0 | - | 59 | 21.3 |
| *Ambassis agrammus* | 28 | 11.0 | 27 | 29.6 | 0 | - | 0 | - | 3 | 1.0 | 0 | - | 0 | - | 58 | 41.6 |
| *A. macleayi* | 0 | - | 0 | - | 0 | - | 4 | 2.7 | 0 | - | 0 | - | 0 | - | 4 | 2.7 |
| *Ambassis (unidentifiable)* | 0 | - | 0 | - | 28 | 15.7 | 0 | - | 0 | - | 0 | - | 0 | - | 28 | 15.7 |
| *Denariusa bandata* | 0 | - | 0 | - | 0 | - | 10 | 2.8 | 0 | - | 0 | - | 0 | - | 10 | 2.8 |
| *Amniataba percoides* | 2 | 15.8 | 1 | 7.6 | 1 | 2.5 | 8 | 337.9 | 7 | 100.6 | 2 | 38.5 | 0 | - | 21 | 502.9 |
| *Leiopotherapon unicolor* | 0 | - | 15 | 7.3 | 4 | 141.2 | 6 | 358.2 | 6 | 187.5 | 10 | 317.9 | 0 | - | 41 | 1012.1 |
| *Syncomistes butleri* | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 33.7 | 0 | - | 0 | - | 1 | 33.7 |
| *Pingalla midgleyi* | 0 | - | 1 | 12.2 | 0 | - | 1 | 7.7 | 2 | 19.6 | 1 | 9.5 | 0 | - | 5 | 49.0 |
| *Glossamia aprion* | 0 | - | 2 | 13.3 | 0 | - | 1 | 11.4 | 3 | 71.2 | 0 | - | 0 | - | 6 | 95.9 |
| *Toxotes chatareus* | 0 | - | 7 | 1089.1 | 0 | - | 1 | 2.9 | 4 | 80.7 | 0 | - | 0 | - | 12 | 1172.7 |
| *Glossogobius giurus* | 9 | 17.1 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 9 | 17.1 |
| *Mogurnda mogurnda* | 6 | 11.8 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 6 | 11.8 |
| *Oxyeleotris lineolatus* | 0 | - | 0 | - | 0 | - | 2 | 63.3 | 1 | 0.4 | 0 | - | 0 | - | 3 | 63.7 |
| Total | 422 | 201.7 | 117 | 5936.9 | 69 | 909.0 | 45 | 863.4 | 411 | 865.3 | 236 | 406.3 | 0 | - | 1894 | 9236.6 |

Table 9(c). Numbers and weights of fish species captured at the Nourlangie crossing 2 site (NC), a lowland sandy creekbed pool
Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet[a] | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Tandanus ater* | 0 | - | 0 | - | 1 | 1.0 | 0 | - | 0 | - | 0 | - | 1 | 1.0 |
| *Strongylura krefftii* | 0 | - | 0 | - | 0 | - | 2 | 63.2 | 0 | - | 0 | - | 2 | 63.2 |
| *Melanotaenia nigrans* | 1 | 0.7 | 0 | - | 0 | - | 1 | 0.5 | 0 | - | 0 | - | 2 | 1.2 |
| *M. splendida inornata* | 36 | 25.9 | 0 | - | 11 | 30.7 | 11 | 44.5 | 69 | 116.4 | 4 | 3.0 | 131 | 220.5 |
| *Craterocephalus* nov. sp. | 3 | 0.4 | 1 | 1.4 | 0 | - | 0 | - | 0 | - | 0 | - | 4 | 1.8 |
| *C. stercusmuscarum* | 30 | 27.4 | 52 | 12.2 | 0 | - | 1 | 0.2 | 2 | 2.5 | 0 | - | 33 | 42.1 |
| *Pseudomugil tenellus* | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 0.1 | 0 | - | 1 | 0.1 |
| *Ambassis agrammus* | 22 | 23.6 | 0 | - | 0 | - | 0 | - | 188 | 183.3 | 0 | - | 210 | 206.9 |
| *A macleayi* | 0 | - | 54 | 44.2 | 0 | - | 0 | - | 0 | - | 7 | 8.6 | 61 | 52.8 |
| *Denariusa bandata* | 0 | - | 0 | - | 11 | 3.4 | 3 | 0.7 | 67 | 36.2 | 0 | - | 81 | 40.3 |
| *Amniataba percoides* | 0 | - | 2 | 0.8 | 0 | - | 3 | 36.2 | 0 | - | 0 | - | 5 | 37.0 |
| *Leiopotherapon unicolor* | 1 | 0.1 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 0.1 |
| *Glossamia aprion* | 0 | - | 1 | 1.2 | 0 | | 1 | 6.0 | 16 | 42.9 | 0 | - | 18 | 48.9 |
| *Toxotes chatareus* | 0 | - | 1 | 0.4 | 0 | - | 1 | 11.3 | 0 | - | 0 | - | 2 | 11.7 |
| *Glossogobius giurus* | 0 | - | 1 | 0.5 | 0 | - | 1 | 3.6 | 0 | - | 0 | - | 2 | 4.1 |
| *Mogurnda mogurnda* | 0 | - | 1 | 0.2 | 0 | - | 0 | - | 2 | 15.7 | 14 | 85.6 | 17 | 101.3 |
| *Oxyeleotris lineolatus* | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 8.3 | 0 | - | 1 | 8.3 |
| Total | 93 | 78.0 | 113 | 62.2 | 23 | 35.1 | 24 | 166.2 | 346 | 405.4 | 25 | 97.2 | 511 | 844.1 |

[a]NC inaccesible at this time, data from site NY, Nourlangie crossing 1 (see Map 2)

Table 9(d). Numbers and weights of fish species captured at site MJ in the Magela Creek bed, a lowland sandy creekbed pool

Catches were obtained using standard netting methods; nd = not determined

| | Sampling period | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Early-wet 1978-79 | | Late-wet-Early-dry 1979 | | Early-wet 1979-80 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Tandanus ater* | 4 | 1383 | 0 | - | 0 | - | 4 | 1383 |
| *Melanotaenia nigrans* | 0 | - | 1 | 0.3 | 0 | - | 1 | 0.3 |
| *M. splendida inornata* | 1 | 0.4 | 0 | - | 136 | 164.1 | 137 | 164.5 |
| *Craterocephalus* nov. sp. | 0 | - | 10 | 24.9 | 2 | 2.8 | 12 | 27.7 |
| *C. stercusmuscarum* | 16 | 9.8 | 2 | 0.4 | 0 | - | 18 | 1.02 |
| *Lates calcarifer* | 1 | nd | 0 | - | 0 | - | 1 | nd |
| *Amniataba percoides* | 0 | - | 0 | - | 52 | 30.0 | 52 | 30.0 |
| *Leiopotherapon unicolor* | 0 | - | 0 | - | 3 | nd | 3 | nd |
| *Toxotes chatareus* | 0 | - | 6 | 99.9 | 0 | - | 6 | 99.9 |
| *Mogurnda mogurnda* | 1 | 0.9 | 0 | - | 0 | - | 1 | 0.9 |
| Total | 23 | 1394.1[a] | 19 | 125.5 | 193 | 196.9[a] | 235 | 1716.5[a] |

[a] excluding *L. calcarifer, L. unicolor*

Table 9(e). Numbers and weights of fish species captured at site GU in the Magela Creek bed, a lowland sandy creekbed pool

Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet 1978-79 | | Later-wet-Early-dry 1979-80 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Nematalosa erebi* | 0 | - | 1 | 0.7 | 0 | - | 1 | 0.7 |
| *Strongylura kreffiii* | 22 | 1356 | 0 | - | 0 | - | 22 | 1356 |
| *Melanotaenia splendida inornata* | 3 | 0.5 | 2 | 2.5 | 0 | - | 5 | 3.0 |
| *Craterocephalus* nov. sp. | 604 | 32.3 | 0 | - | 3 | 0.1 | 507 | 33.3 |
| *C. stercusmuscarum* | 23 | 3.3 | 2 | 0.6 | 0 | - | 25 | 3.9 |
| *Ambassis agrammus* | 2 | 0.5 | 0 | - | 0 | - | 2 | 0.5 |
| *A. macleayi* | 0 | - | 2 | 1.8 | 0 | - | 2 | 1.8 |
| *Amniataba percoides* | 0 | - | 0 | - | 3 | 28.9 | 3 | 28.9 |
| *Glossogobius giurus* | 25 | 4.9 | 0 | - | 0 | - | 25 | 4.9 |
| Total | 679 | 1397.6 | 7 | 5.6 | 6 | 29.0 | 692 | 1432.1 |

Table 9(f). Numbers and weights of fish species captured at site MU in the Magela Creek bed, a lowland sandy creekbed pool
Catches were obtained using standard netting methods.

| | Sampling period | | | | | |
|---|---|---|---|---|---|---|
| | Mid-wet 1978-79 | | Mid-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Melanotaenia nigrans* | 3 | 0.6 | 8 | 6.6 | 11 | 7.2 |
| *M. splendida inornata* | 4 | 4.4 | 0 | - | 4 | 4.4 |
| *Craterocephalus* nov. sp. | 15 | 11.1 | 16 | 9.5 | 31 | 20.6 |
| *C. stercusmuscarum* | 2 | 1.2 | 11 | 7.8 | 13 | 9.0 |
| *Ambassis agrammus* | 3 | 1.3 | 0 | - | 3 | 1.3 |
| *Leiopotherapon unicolor* | 0 | - | 2 | 46.9 | 2 | 46.9 |
| Total | 27 | 18.6 | 37 | 70.8 | 64 | 89.4 |

Table 10. Summary of standard fish sampling near Nabarlek (6.9.78-7.9.78) showing numbers and weights with corresponding species diversity indices

Site codes: AU = Adgibongololo Creek, AM = Narbarlek dam, CD = Bullwidgi Billabong, BC = Birraduk Creek.

| | Sampling site | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | AU | | AM | | CD[a] | | BC | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Nematalosa erebi* | 0 | - | 6 | 1151.0 | 14 | 988.0 | 3 | 728.0 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 1 | 337.0 |
| *Porochilus rendahli* | 2 | 24.6 | 11 | 2031.0 | 0 | - | 0 | - |
| *Strongylura kreffiii* | 0 | - | 2 | 963.0 | 0 | - | 0 | - |
| *Melanotaenia splendida inornata* | 2 | 2.2 | 1 | 0.5 | 2 | 5.0 | 2 | 4.6 |
| *Craterocephalus* nov. sp. | 91 | 51.9 | 0 | - | 0 | - | 0 | - |
| *C. stercusmuscarum* | 5 | 2.4 | 2 | 0.9 | - | 0 | 6 | 3.1 |
| *Ambassis agrammus* | 0 | - | 3 | 1.9 | 0 | - | 13 | 10.2 |
| *A. macleayi* | 0 | - | 2 | 12.4 | 35 | 38.7 | 0 | - |
| *Amniataba percoides* | 9 | 690.0 | 6 | 142.1 | 3 | 28.8 | 2 | 183.0 |
| *Leiopotherapon unicolor* | 2 | 22.8 | 0 | - | 0 | - | 0 | - |
| *Pingalla midgleyi* | 1 | 7.6 | 0 | - | 0 | - | 0 | - |
| *Glossamia aprion* | 1 | 12.8 | 4 | 2.5 | 0 | - | 1 | 2.7 |
| *Toxotes chatareus* | 0 | - | 5 | 363.1 | 10 | 1448.0 | 0 | - |
| *Glossogobius giurus* | 0 | - | 1 | 0.6 | 0 | - | 0 | - |
| Total | 113 | 814.3 | 43 | 4669.0 | 64 | 2508.5 | 28 | 1268.6 |
| Number of species | 8 | | 11 | | 5 | | 7 | |
| Shannon | 0.81 | 0.66 | 2.16 | 1.37 | 1.20 | 0.81 | 1.54 | 1.04 |
| Richness | 1.48 | 0.78 | 2.66 | 0.93 | 0.96 | 0.40 | 1.80 | 0.64 |
| Evenness | 0.39 | 0.32 | 0.90 | 0.57 | 0.75 | 0.51 | 0.79 | 0.53 |

[a] a large population (n > 50) of *Crocodylus johnstoni* present in this pool

Table 11(a). Numbers and weights of fish species captured in Fishless Billabong (FS), a lowland backflow billabong

Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Mid-wet | | Mid-dry | | Late-dry 1979 | | Early-wet | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Tandanus ater* | 0 | - | 3 | 10.5 | 1 | 47.8 | 0 | - | 0 | - | 4 | 58.3 |
| *Neiosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 5 | 107.6 | 0 | - | 5 | 107.6 |
| *Porochilus rendahli* | 2 | 13.5 | 0 | - | 19 | 286.9 | 64 | 784.5 | 0 | - | 85 | 1084.9 |
| *Strongylura krefftii* | 0 | - | 1 | 9.8 | 0 | - | 3 | 250.5 | 0 | - | 4 | 260.3 |
| *Melanotaenia splendida inornata* | 71 | 48.6 | 28 | 33.1 | 18 | 30.9 | 37 | 96.2 | 0 | - | 154 | 208.8 |
| *Craterocephalus stercusmuscarum* | 3 | 0.9 | 0 | - | 0 | - | 0 | - | 0 | - | 3 | 0.9 |
| *Ambassis agrammus* | 362 | 305.4 | 100 | 35.2 | 0 | - | 0 | - | 0 | - | 462 | 340.6 |
| *A. macleayi* | 0 | - | 0 | - | 93 | 65.8 | 487 | 650.1 | 2 | 2.5 | 582 | 718.4 |
| *Denariusa bandata* | 75 | 45.5 | 55 | 11.5 | 10 | 3.7 | 0 | - | 0 | - | 140 | 60.7 |
| *Leiopotherapon unicolor* | 1 | 20.4 | 15 | 230.5 | 6 | 159.5 | 6 | 151.6 | 0 | - | 28 | 562.0 |
| *Glossamia aprion* | 11 | 48.8 | 8 | 22.6 | 7 | 70.9 | 14 | 118.4 | 0 | - | 40 | 260.7 |
| *Mogurnda mogurnda* | 22 | 45.2 | 8 | 5.3 | 1 | 4.8 | 7 | 42.1 | 0 | - | 38 | 97.4 |
| *Oxyeleotris lineolatus* | 1 | 3.6 | 2 | 1.0 | 1 | 1.1 | 3 | 26.4 | 0 | - | 7 | 32.1 |
| Total | 548 | 531.9 | 220 | 359.5 | 156 | 671.4 | 626 | 2227.4 | 2 | 2.5 | 1552 | 3792.7 |

Table 11(b). Numbers and weights of fish species captured in Djalkmara Billabong (DA), a lowland backflow billabong

Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Early-wet | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 1 | 480.0 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 480.8 |
| *Nematalosa erebi* | 0 | - | 2 | 723.0 | 4 | 692.5 | 16 | 556.0 | 9 | 381.6 | 0 | - | 0 | - | 31 | 2353.1 |
| *Scleropages jardini* | 0 | - | 0 | - | 0 | - | 1 | 52.0 | 0 | - | 0 | - | 0 | - | 1 | 52.0 |
| *Arius leptaspis* | 0 | - | 1 | 730.0 | 1 | 1300.0 | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 2030.0 |
| *Tandanus ater* | 0 | - | 0 | - | 2 | 600.0 | 2 | 355.0 | 0 | - | 0 | - | 0 | - | 4 | 955.0 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 10 | 181.0 | 1 | 46.9 | 0 | - | 0 | - | 11 | 227.9 |
| *Porochilus rendahli* | 4 | 47.1 | 1 | 18.7 | 0 | - | 9 | 137.6 | 2 | 340.0 | 2 | 206.3 | 0 | - | 18 | 749.7 |
| *Strongylura kreffiii* | 0 | - | 1 | 569.0 | 1 | 146.0 | 0 | - | 2 | 200.0 | 0 | - | 0 | - | 4 | 915.0 |
| *Melanotaenia nigrans* | 0 | - | 0 | - | 0 | - | 1 | 0.4 | 0 | - | 0 | - | 0 | - | 1 | 0.4 |
| *M. splendida inornata* | 17 | 5.1 | 16 | 18.1 | 32 | 36.1 | 100 | 165.0 | 48 | 61.7 | 0 | - | 0 | - | 213 | 286.0 |
| *Craterocephalus stercusmuscarum* | 0 | - | 1 | 0.7 | 3 | 4.4 | 0 | - | 45 | 7.5 | 0 | - | 1 | 0.1 | 50 | 12.6 |
| *Pseudomugil tenellus* | 0 | - | 0 | - | 1 | 0.1 | 0 | - | 3 | 0.2 | 0 | - | 0 | - | 4 | 0.3 |
| *Ambassis agrammus* | 42 | 45.6 | 8 | 8.8 | 15 | 7.0 | 0 | - | 164 | 97.0 | 0 | - | 0 | - | 229 | 158.4 |
| *A. macleayi* | 0 | - | 0 | - | 1 | 4.9 | 1 | 5.3 | 0 | - | 14 | 6.7 | 0 | - | 16 | 16.9 |
| *Ambassis* (unidentifiable) | 0 | - | 0 | - | 0 | - | 104 | 52.6 | 0 | - | 0 | - | 0 | - | 104 | 52.6 |
| *Denariusa bandata* | 9 | 4.2 | 0 | - | 0 | - | 38 | 10.5 | 66 | 18.5 | 0 | - | 0 | - | 113 | 33.2 |
| *Amniataba percoides* | 0 | - | 0 | - | 1 | 0.1 | 1 | 10.1 | 0 | - | 0 | - | 0 | - | 2 | 10.2 |
| *Leiopotherapon unicolor* | 0 | - | 1 | 144.0 | 0 | - | 11 | 461.5 | 26 | 1082.8 | 12 | 302.2 | 0 | - | 50 | 1990.5 |
| *Glossamia aprion* | 2 | 3.3 | 0 | - | 0 | - | 7 | 41.2 | 14 | 108.9 | 0 | - | 0 | - | 23 | 153.4 |
| *Toxotes chatareus* | 0 | - | 5 | 873.0 | 3 | 6.0 | 7 | 63.9 | 1 | 5.1 | 0 | - | 0 | - | 16 | 948.0 |
| *Mogurnda mogurnda* | 1 | 1.1 | 0 | - | 0 | - | 0 | - | 1 | 1.3 | 0 | - | 0 | - | 2 | 2.4 |
| *Oxyeleotris lineolatus* | 18 | 12.6 | 0 | - | 0 | - | 1 | 3.0 | 2 | 7.8 | 2 | 29.8 | 0 | - | 23 | 53.2 |
| Total | 93 | 119.0 | 36 | 3085.3 | 65 | 3277.0 | 309 | 1775.6 | 384 | 1853.3 | 30 | 545.0 | 1 | 0.1 | 932 | 10655.2 |

Table 11(c). Numbers and weights of fish species captured in Coonjimba Billabong (CA), a lowland backflow billabong
Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Early-wet | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 0 | - | 1 | 11.7 | 1 | 219.2 | 0 | - | 0 | - | 2 | 230.9 |
| *Nematalosa erebi* | 7 | 448.0 | 1 | 333.0 | 6 | 851.7 | 20 | 1136.3 | 9 | 567.4 | 12 | 1057.2 | 0 | - | 55 | 4393.9 |
| *Scleropages jardini* | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 140.0 | 0 | - | 0 | - | 1 | 140.0 |
| *Arius leptaspis* | 0 | - | 4 | 4100.0 | 2 | 3550.0 | 0 | - | 1 | 52.6 | 0 | - | 0 | - | 7 | 7702.6 |
| *Tandanus ater* | 0 | - | 1 | 260.0 | 0 | - | 2 | 33.6 | 1 | 63.5 | 0 | - | 0 | - | 4 | 357.1 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 2 | 30.8 | 3 | 187.8 | 0 | - | 1 | 63.0 | 6 | 281.6 |
| *Porochilus rendahli* | 0 | - | 1 | 16.5 | 0 | - | 2 | 70.8 | 2 | 41.7 | 7 | 99.4 | 3 | 41.2 | 15 | 269.6 |
| *Strongylura krefftii* | 1 | 60.0 | 0 | - | 1 | 10.9 | 1 | 69.6 | 0 | - | 4 | 153.6 | 0 | - | 7 | 294.1 |
| *Melanotaenia splendida inornata* | 5 | 4.4 | 15 | 0.8 | 32 | 39.5 | 106 | 151.8 | 62 | 104.6 | 3 | 6.1 | 0 | - | 223 | 307.2 |
| *Craterocephalus stercusmuscarum* | 5 | 1.3 | 4 | 2.5 | 9 | 0.9 | 7 | 2.8 | 1 | 0.1 | 0 | - | 0 | - | 26 | 7.6 |
| *Pseudomugil tenellus* | 1 | 0.1 | 0 | - | 2 | 0.3 | 0 | - | 1 | 0.1 | 0 | - | 0 | - | 3 | 0.5 |
| *Ambassis agrammus* | 234 | 130.2 | 33 | 2.0 | 1 | 0.6 | 0 | - | 39 | 29.5 | 3 | 2.7 | 0 | - | 310 | 165.0 |
| *A. macleayi* | 0 | - | 0 | - | 0 | - | 0 | - | 22 | 37.6 | 13 | 23.4 | 0 | - | 35 | 61.0 |
| *Ambassis* (unidentifiable) | 0 | - | 0 | - | 0 | - | 15 | 25.4 | 0 | - | 0 | - | 0 | - | 15 | 25.4 |
| *Denariusa bandata* | 62 | 23.3 | 1 | 0.3 | 0 | - | 4 | 1.4 | 4 | 1.6 | 0 | - | 0 | - | 71 | 26.6 |
| *Amniataba percoides* | 1 | 22.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 22.0 |
| *Leiopotherapon unicolor* | 0 | - | 7 | 0.6 | 0 | - | 6 | 412.4 | 1 | 47.4 | 3 | 109.4 | 2 | 65.2 | 19 | 635.0 |
| *Glossamia aprion* | 0 | - | 1 | 39.3 | 0 | - | 8 | 167.1 | 11 | 71.2 | 8 | 86.9 | 1 | 1.2 | 29 | 365.7 |
| *Toxotes chatareus* | 1 | 25.0 | 14 | 2870.0 | 1 | 2.3 | 1 | 8.0 | 0 | - | 4 | 46.6 | 1 | 8.8 | 22 | 2960.7 |
| *Glossogobius giurus* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 8 | 3.8 | 8 | 3.8 |
| *Mogurnda mogurnda* | 4 | 14.6 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 9.4 | 0 | - | 5 | 24.0 |
| *Oxyeleotris lineolatus* | 1 | 375.0 | 0 | - | 0 | - | 1 | 3.4 | 0 | - | 0 | - | 2 | 104.9 | 4 | 483.3 |
| Total | 322 | 1103.9 | 82 | 7625.3 | 54 | 4456.2 | 176 | 2125.1 | 159 | 1564.2 | 58 | 1594.7 | 18 | 288.1 | 869 | 18757.5 |

Table 11(d). Numbers and weights of fish species captured in Georgetown Billabong (GN), a lowland backflow billabong

Catches were obtained using standard netting methods; nd = not determined

| | Sampling period | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Early-wet | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 0 | - | 2 | 178.2 | 0 | - | 0 | - | 0 | - | 2 | 178.2 |
| *Nematalosa erebi* | 1 | 400.00 | 0 | - | 5 | 1247.7 | 34 | 1701.1 | 2 | 681.4 | 0 | - | 1 | 374.8 | 43 | 4405.0 |
| *Arius leptaspis* | 4 | 3450.0 | 0 | - | 0 | - | 7 | 41.2 | 5 | 4396.2 | 14 | 14201.4 | 9 | 5702.9 | 39 | 27791.7 |
| *Tandanus ater* | 0 | - | 3 | 735.0 | 0 | - | 2 | 101.8 | 1 | 875.0 | 0 | - | 0 | - | 6 | 1711.8 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 1 | 46.0 | 0 | - | 2 | 91.2 | 0 | - | 3 | 137.2 |
| *Porochilus rendahli* | 2 | 46.8 | 2 | 22.4 | 0 | - | 1 | 1.0 | 0 | - | 1 | 2.7 | 0 | - | 6 | 72.9 |
| *Strongylura krefftii* | 0 | - | 0 | - | 0 | - | 3 | 88.2 | 0 | - | 0 | - | 0 | - | 3 | 88.2 |
| *Melanotaenia splendida inornata* | 7 | 1.1 | 31 | 22.2 | 6 | 4.6 | 24 | 32.1 | 2 | 0.2 | 3 | 1.5 | 0 | - | 73 | 61.7 |
| *Craterocephalus stercusmuscarum* | 0 | - | 1 | 0.9 | 9 | 3.4 | 13 | 1.1 | 2 | nd | 0 | - | 0 | - | 25 | 5.4 |
| *Ambassis agrammus* | 75 | 35.5 | 32 | 24.2 | 50 | 25.2 | 0 | - | 0 | - | 10 | 3.9 | 0 | - | 170 | 88.8 |
| *A. macleayi* | 0 | - | 0 | - | 0 | - | 0 | - | 97 | 20.3 | 0 | - | 0 | - | 97 | 20.3 |
| *Ambassis* (unidentifiable) | 0 | - | 0 | - | 0 | - | 168 | 93.1 | 0 | - | 0 | - | 2 | 0.3 | 170 | 93.4 |
| *Denariusa bandata* | 3 | 0.7 | 0 | - | 1 | 0.6 | 25 | 4.0 | 1 | 0.3 | 0 | - | 0 | - | 30 | 5.6 |
| *Lates calcarifer* | 0 | - | 1 | 675.0 | 1 | 2100.0 | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 2775.0 |
| *Amniataba percoides* | 1 | 5.2 | 0 | - | 1 | 0.4 | 3 | 0.2 | 1 | 0.7 | 1 | 0.9 | 0 | | 7 | 7.4 |
| *Leiopotherapon unicolor* | 0 | - | 1 | 62.5 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 62.5 |
| *Glossamia aprion* | 0 | - | 2 | 1.5 | 4 | 3.2 | 26 | 56.5 | 2 | 1.3 | 0 | - | 1 | 0.7 | 35 | 63.2 |
| *Toxotes chatareus* | 0 | - | 0 | - | 2 | 14.4 | 1 | 4.4 | 0 | - | 0 | - | 0 | - | 3 | 18.8 |
| *Glossogobius giurus* | 3 | 1.5 | 0 | - | 0 | - | 0 | - | 1 | 7.9 | 0 | - | 0 | - | 4 | 9.4 |
| *Mogurnda mogurnda* | 0 | - | 1 | 2.1 | 0 | - | 0 | - | 1 | 1.4 | 0 | - | 0 | - | 2 | 3.5 |
| *Oxyeleotris lineolatus* | 0 | - | 1 | 360.0 | 0 | - | 3 | 2.8 | 7 | 8.7 | 15 | 1361.9 | 2 | 1.2 | 28 | 1734.6 |
| Total | 96 | 3940.8 | 75 | 1905.8 | 79 | 3399.5 | 313 | 2351.7 | 122 | 5993.4[a] | 46 | 15663.5 | 15 | 6079.9 | 746 | 39334.6 |

[a]excluding *C. stercusmuscarum*

Table 11(e). Numbers and weights of fish species captured in Indium Billabong (IM), a lowland backflow billabong Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Early-wet | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 0 | - | 1 | 118.0 | 0 | - | 0 | - | 0 | - | 1 | 118.0 |
| *Nematalosa erebi* | 0 | - | 3 | 0.4 | 0 | - | 28 | 1112.0 | 10 | 553.8 | 24 | 691.4 | 0 | - | 65 | 2357.6 |
| *Arius leptaspis* | 0 | - | 0 | - | 6 | 5350.0 | 0 | - | 0 | - | 0 | - | 1 | 102.9 | 7 | 5452.9 |
| *Tandanus ater* | 0 | - | 0 | - | 5 | 1440.0 | 0 | - | 1 | 44.7 | 0 | - | 0 | - | 6 | 1484.7 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 0 | - | 12 | 267.1 | 15 | 231.1 | 1 | 18.9 | 28 | 517.1 |
| *Porochilus rendahli* | 15 | 333.0 | 0 | - | 0 | - | 30 | 654.3 | 22 | 313.0 | 4 | 40.9 | 1 | 26.0 | 72 | 1367.2 |
| *Strongylura krefftii* | 0 | - | 0 | - | 0 | - | 1 | 56.8 | 7 | 639.1 | 2 | 471.7 | 0 | - | 10 | 1167.6 |
| *Melanotaenia splendida inornata* | 0 | - | 1 | 1.7 | 24 | 34.1 | 27 | 70.3 | 1 | 0.6 | 0 | - | 1 | 0.5 | 54 | 107.2 |
| *Craterocephalus* nov. sp. | 6 | 0.8 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 6 | 0.8 |
| *C. stercusmuscarum* | 0 | - | 0 | - | 3 | 1.0 | 3 | 0.4 | 1 | 0.1 | 0 | - | 0 | - | 7 | 1.5 |
| *Ambassis agrammus* | 1 | 0.1 | 0 | - | 0 | - | 5 | 3.7 | 3 | 0.6 | 0 | - | 0 | - | 9 | 4.4 |
| *A. macleayi* | 3 | 17.9 | 9 | 9.2 | 0 | - | 7 | 36.9 | 45 | 199.6 | 45 | 201.1 | 3 | 12.4 | 112 | 477.1 |
| *Ambassis* (unidentifiable) | 0 | - | 0 | - | 12 | 8.7 | 0 | - | 0 | - | 0 | - | 0 | - | 12 | 8.7 |
| *Denariusa bandata* | 0 | - | 0 | - | 0 | - | 18 | 4.4 | 0 | - | 0 | - | 0 | - | 10 | 4.4 |
| *Amniataba percoides* | 0 | - | 0 | - | 0 | - | 28 | 359.6 | 6 | 49.9 | 1 | 13.5 | 0 | - | 35 | 423.0 |
| *Leiopotherapon unicolor* | 0 | - | 3 | 0.3 | 0 | - | 8 | 366.1 | 19 | 567.8 | 9 | 128.3 | 2 | 26.3 | 41 | 1088.8 |
| *Glossamia aprion* | 1 | 0.8 | 0 | - | 1 | 4.6 | 4 | 224.5 | 28 | 224.5 | 7 | 229.7 | 1 | 26.2 | 42 | 485.8 |
| *Toxotes chatareus* | 0 | - | 0 | - | 0 | - | 5 | 37.8 | 3 | 26.1 | 0 | - | 0 | - | 8 | 63.9 |
| *Mogurnda mogurnda* | 1 | 0.1 | 0 | - | 0 | - | 0 | - | 2 | 17.0 | 0 | - | 0 | - | 3 | 17.1 |
| *Oxyeleotris lineolatus* | 0 | - | 0 | - | 0 | - | 0 | - | 5 | 2075.5 | 1 | 26.2 | 1 | 314.0 | 7 | 2415.7 |
| Total | 27 | 351.7 | 16 | 11.6 | 51 | 6834.6 | 165 | 2824.9 | 164 | 4979.4 | 108 | 2033.9 | 11 | 527.2 | 542 | 17563.3 |

Table 11(f). Numbers and weights of fish species captured in Goanna Billabong (GA), a lowland backflow billabong

Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Early-wet | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 0 | - | 2 | 202.0 | 0 | - | 1 | 188.0 | 0 | - | 3 | 390.0 |
| *Nematalosa erebi* | 7 | 808.0 | 46 | 2771.7 | 29 | 1932.9 | 1 | 37.9 | 9 | 1853.2 | 9 | 1265.1 | 0 | - | 101 | 8668.8 |
| *Arius leptaspis* | 1 | 119.0 | 0 | - | 0 | - | 8 | 416.6 | 6 | 412.1 | 5 | 1003.8 | 0 | - | 20 | 1951.5 |
| *Tandanus ater* | 0 | - | 3 | 181.9 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 3 | 181.9 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 0 | - | 7 | 208.0 | 2 | 53.4 | 7 | 166.2 | 16 | 427.6 |
| *Porochilus rendahli* | 3 | 197.0 | 3 | 238.1 | 2 | 151.6 | 6 | 344.8 | 8 | 130.8 | 1 | 26.2 | 4 | 25.2 | 25 | 2743.7 |
| *Strongylura krefftii* | 3 | 1076.4 | 11 | 1667.3 | 1 | 70.0 | 3 | 573.9 | 6 | 563.9 | 8 | 2894.1 | 1 | 517.5 | 33 | 7363.1 |
| *Melanotaenia splendida inornata* | 7 | 1.7 | 0 | - | 6 | 5.8 | 31 | 60.1 | 0 | - | 0 | - | 0 | - | 44 | 67.6 |
| *Craterocephalus* nov. sp. | 4 | 0.7 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 4 | 0.7 |
| *C. stercusmuscarum* | 0 | - | 0 | - | 0 | - | 3 | 0.1 | 1 | 0.3 | 1 | 0.1 | 0 | - | 5 | 0.5 |
| *Ambassis agrammus* | 0 | - | 13 | 5.6 | 33 | 18.7 | 0 | - | 2 | 0.9 | 0 | - | 0 | - | 48 | 25.2 |
| *A. macleayi* | 5 | 8.6 | 0 | - | 0 | - | 42 | 65.7 | 5 | 14.8 | 14 | 29.6 | 5 | 22.3 | 71 | 141.0 |
| *Ambassis* (unidentifiable) | 55 | 24.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 55 | 24.0 |
| *Denariusa bandata* | 0 | - | 0 | - | 0 | - | 8 | 3.3 | 0 | - | 0 | - | 0 | - | 8 | 3.3 |
| *Lates calcarifer* | 1 | 1200.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 1200.0 |
| *Amniataba percoides* | 0 | - | 1 | 22.9 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 22.9 |
| *Leiopotherapon unicolor* | 1 | 83.0 | 0 | - | 0 | - | 3 | 379.5 | 8 | 373.1 | 0 | - | 2 | 162.4 | 14 | 998.0 |
| *Glossamia aprion* | 1 | 0.1 | 1 | 2.1 | 4 | 18.4 | 26 | 142.5 | 8 | 130.4 | 7 | 173.0 | 1 | 22.1 | 48 | 488.6 |
| *Toxotes chatareus* | 0 | - | 1 | 0.9 | 2 | 11.9 | 1 | 88.0 | 2 | 50.2 | 0 | - | 0 | - | 6 | 151.0 |
| *Mogurnda mogurnda* | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 4.8 | 0 | - | 0 | - | 1 | 4.8 |
| *Oxyeleotris lineolatus* | 0 | - | 0 | - | 1 | 2.3 | 1 | 415.7 | 2 | 345.1 | 1 | 66.0 | 0 | - | 5 | 829.1 |
| Total | 88 | 3518.5 | 79 | 4890.5 | 78 | 2211.6 | 135 | 2730.1 | 65 | 4087.6 | 49 | 5699.3 | 18 | 915.7 | 512 | 24053.3 |

Table 11(g). Numbers and weights of fish species captured in Gulungul Billabong (GL), a lowland backflow billabong
Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 0 | - | 3 | 614.4 | 0 | - | 0 | - | 3 | 614.4 |
| *Nematalosa erebi* | 7 | 1317.0 | 0 | - | 21 | 1967.9 | 8 | 611.7 | 11 | 1464.0 | 1 | 141.5 | 48 | 5502.1 |
| *Arius leptaspis* | 0 | - | 0 | - | 13 | 14000.0 | 4 | 258.0 | 9 | 408.6 | 0 | - | 26 | 14666.6 |
| *Tandanus ater* | 0 | - | 0 | - | 1 | 600.0 | 0 | - | 0 | - | 0 | - | 1 | 600.0 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 4 | 68.5 | 4 | 119.7 | 0 | - | 8 | 188.2 |
| *Porochilus rendahli* | 4 | 117.0 | 18 | 220.6 | 0 | - | 47 | 603.5 | 4 | 37.3 | 3 | 38.8 | 54 | 1017.2 |
| *Strongylura krefftii* | 0 | - | 0 | - | 1 | 409.0 | 7 | 768.7 | 6 | 141.4 | 3 | 80.0 | 17 | 1399.1 |
| *Melanotaenia splendida inornata* | 3 | 0.8 | 0 | - | 26 | 27.1 | 100 | 175.7 | 1 | 0.4 | 0 | - | 130 | 204.0 |
| *Craterocephalus* nov. sp. | 4 | 0.9 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 4 | 0.9 |
| *C. stercusmuscarum* | 0 | - | 0 | - | 1 | 1.8 | 4 | 5.4 | 0 | - | 0 | - | 5 | 7.2 |
| *Pseudomugil tenellus* | 0 | - | 0 | - | 1 | 0.2 | 0 | - | 0 | - | 0 | - | 1 | 0.2 |
| *Ambassis agrammus* | 39 | 24.6 | 79 | 90.1 | 11 | 3.6 | 0 | - | 37 | 4.3 | 6 | 2.9 | 172 | 125.5 |
| *A. macleayi* | 1 | 7.1 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 7.1 |
| *Ambassis* (unidentifiable) | 0 | - | 0 | - | 0 | - | 148 | 59.2 | 0 | - | 0 | - | 148 | 59.2 |
| *Denariusa bandata* | 6 | 2.4 | 0 | - | 2 | 0.5 | 95 | 24.2 | 16 | 3.7 | 0 | - | 119 | 30.8 |
| *Amniataba percoides* | 0 | - | 0 | - | 0 | - | 19 | 263.8 | 1 | 17.1 | 0 | - | 20 | 280.9 |
| *Leiopotherapon unicolor* | 0 | - | 0 | - | 6 | 218.5 | 2 | 102.7 | 0 | - | 0 | - | 8 | 321.2 |
| *Glossamia aprion* | 3 | 18.0 | 2 | 47.2 | 0 | - | 18 | 99.9 | 34 | 165.7 | 0 | - | 57 | 330.8 |
| *Toxotes chatareus* | 0 | - | 0 | - | 2 | 6.4 | 4 | 48.0 | 0 | - | 0 | - | 6 | 54.4 |
| *Mogurnda mogurnda* | 14 | 33.2 | 2 | 4.5 | 0 | - | 1 | 6.0 | 1 | 3.0 | 0 | - | 18 | 46.7 |
| *Oxyeleotris lineolatus* | 1 | 325.0 | 1 | 13.1 | 0 | - | 2 | 6.0 | 6 | 18.7 | 0 | - | 10 | 362.8 |
| Total | 82 | 1846.0 | 102 | 375.5 | 83 | 17235.0 | 466 | 3471.8 | 132 | 3113.9 | 13 | 324.6 | 878 | 25739.3 |

Table 11(h). Numbers and weights of fish species captured in Corndorl Billabong (CL), a lowland backflow billabong

Catches were obtained using standard netting methods; nd = not determined

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet[a] | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 1 | 400.0 | 1 | 750 0 | 0 | - | 1 | 131.7 | 0 | - | 3 | 1281.7 |
| *Nematalosa erebi* | 0 | - | 19 | 2795.0 | 3 | 16.3 | 11 | 355.9 | 3 | 157.7 | 0 | - | 36 | 3324.9 |
| *Arius leptaspis* | 0 | - | 26 | 21405.0 | 2 | 2790.0 | 2 | 1638.5 | 2 | 1058.1 | 0 | - | 32 | 26831.6 |
| *Tandanus ater* | 0 | - | 0 | - | 2 | 720.0 | 1 | 68.4 | 0 | - | 0 | - | 3 | 788.4 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 0 | - | 5 | nd | 0 | - | 5 | nd |
| *Porochilus rendahli* | 1 | 12.9 | 0 | - | 0 | - | 2 | 3.0 | 19 | 437.8 | 11 | 159.5 | 33 | 613.2 |
| *Strongylura kreffiii* | 0 | - | 0 | - | 0 | - | 2 | 79.3 | 0 | - | 0 | - | 2 | 79.3 |
| *Melanotaenia splendida inornata* | 0 | - | 0 | - | 11 | 10.9 | 41 | 32.9 | 0 | - | 0 | - | 52 | 43.8 |
| *Pseudomugil tenellus* | 0 | - | 0 | - | 28 | 3.4 | 9 | 0.9 | 3 | 0.3 | 0 | - | 40 | 4.6 |
| *Ambassis agrammus* | 4 | 1.6 | 0 | - | 42 | 15.1 | 110 | 38.8 | 5 | 1.2 | 0 | - | 161 | 56.7 |
| *Ambassis* (unidentifiable) | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 8 | 4.4 | 8 | 4.4 |
| *Denariusa bandata* | 3 | 0.8 | 0 | - | 0 | - | 2 | 0.3 | 0 | - | 4 | 2.5 | 9 | 3.6 |
| *Amniataba percoides* | 0 | - | 0 | - | 1 | 3.6 | 7 | 175.6 | 5 | 171.6 | 0 | - | 13 | 350.8 |
| *Leiopotherapon unicolor* | 0 | - | 0 | - | 0 | - | 1 | 9.5 | 3 | 140.3 | 0 | - | 4 | 49.8 |
| *Glossamia aprion* | 1 | 7.2 | 0 | - | 1 | 16.6 | 1 | 18.6 | 4 | 31.7 | 3 | 1.4 | 10 | 75.5 |
| *Toxotes chatareus* | 0 | - | 2 | 600.0 | 0 | - | 2 | 22.9 | 1 | 7.2 | 0 | - | 5 | 630.1 |
| *Mogurnda mogurnda* | 0 | - | 0 | - | 0 | - | 4 | 3.7 | 0 | - | 15 | 60.0 | 19 | 63.7 |
| *Oxyeleotris lineolatus* | 0 | - | 0 | - | 1 | 7.6 | 2 | 2.0 | 0 | - | 3 | 32.5 | 6 | 42.1 |
| Total | 9 | 22.5 | 48 | 25200.0 | 92 | 4333.5 | 197 | 2450.3 | 51 | 2641.6[b] | 44 | 260.3 | 441 | 34908.2[b] |

[a]Seine net catches were not included in Early-wet season results
[b]excluding *T. ater*

Table 11(i). Number and weights of fish species captured in Malabanbandju Billabong (BX) and Deaf Adder Creek (DR), which are lowland backflow billabongs
Catches were obtained using standard netting methods. Data from Deaf Adder Creek is included to the right of the Table; nd = not determined

| | Sampling period | | | | | | | | | | | | | | DR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | | Late-dry 1978 | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 1 | 30.8 | 0 | - | 0 | - | 0 | - | 1 | 30.8 | 0 | - |
| *Nematalosa erebi* | 4 | 1349.7 | 8 | 3390.0 | 2 | 485.7 | 21 | 3146.5 | 3 | 791.8 | 5 | 2401.1 | 43 | 11564.7 | 13 | 313.2 |
| *Arius leptaspis* | 1 | 234.0 | 1 | 230.0 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 464.0 | 1 | 1300.0 |
| *A. proximus* | 0 | - | 1 | 7.7 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 7.7 | 0 | - |
| *A. graeffei* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 5 | 1823.0 |
| *Anodontiglanis dahli* | 0 | - | 1 | 500.0 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 500.0 | 1 | 975.0 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 2 | 138.3 | 0 | - | 0 | - | 2 | 138.3 | 0 | - |
| *Porochilus rendahli* | 0 | - | 1 | 620.0 | 0 | - | 2 | 17.1 | 0 | - | 0 | - | 3 | 637.1 | 0 | - |
| *Stronglyura krefftii* | 0 | - | 0 | - | 7 | 204.6 | 2 | 125.0 | 1 | 41.5 | 0 | - | 10 | 371.1 | 0 | - |
| *Melanotaenia splendida inornata* | 2 | 0.3 | 5 | 1.2 | 8 | 8.1 | 37 | 19.8 | 8 | 3.9 | 2 | 1.9 | 62 | 35.2 | 5 | 4.2 |
| *Craterocelphalus stercusmuscarum* | 0 | - | 1 | 0.1 | 11 | 13.7 | 35 | 5.5 | 10 | 0.6 | 0 | - | 57 | 19.9 | 4 | 1.1 |
| *Pseudomugil tenellus* | 0 | - | 1 | 0.2 | 13 | 1.5 | 0 | - | 0 | - | 0 | - | 14 | 1.7 | 0 | - |
| *Ambassis agrammus* | 35 | 14.5 | 0 | - | 12 | 3.6 | 29 | 13.5 | 71 | 35.3 | 0 | - | 147 | 66.9 | 13 | 15.1 |
| *A. macleayi* | 0 | - | 0 | - | 2 | 6.0 | 6 | 14.8 | 32 | 18.2 | 0 | - | 40 | 39.0 | 0 | - |
| *Ambassis* (unidentifiable) | 0 | - | 14 | 9.6 | 0 | - | 0 | - | 0 | - | 42 | 21.0 | 56 | 30.6 | 0 | - |
| *Denariusa bandata* | 0 | - | 0 | - | 2 | 0.6 | 22 | 2.4 | 1 | 0.3 | 0 | - | 25 | 3.3 | 0 | - |
| *Lates calcarifer* | 0 | - | 1 | 430.0 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 430.0 | 0 | - |
| *Amniataba percoides* | 0 | - | 0 | - | 3 | 105.1 | 1 | 20.6 | 3 | 15.8 | 1 | 1.8 | 8 | 143.3 | 7 | 45.1 |
| *Leiopotherapon unicolor* | 0 | - | 0 | - | 1 | nd | 0 | - | 0 | - | 0 | - | 1 | nd | 1 | 9.9 |
| *Glossamia aprion* | 12 | 4.3 | 1 | 0.5 | 4 | 26.7 | 46 | 42.7 | 14 | 51.7 | 7 | 17.0 | 84 | 142.9 | 1 | 0.1 |
| *Toxotes lorenzti* | 0 | - | 0 | - | 1 | nd | 0 | - | 0 | - | 0 | - | 1 | nd | 0 | - |
| *T. chatareus* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 124.0 |
| *Liza alata* | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 35.3 | 0 | - | 1 | 35.3 | 0 | - |
| *Mogurnda mogurnda* | 2 | 0.2 | 0 | - | 0 | - | 0 | - | 2 | 4.7 | 0 | - | 4 | 4.9 | 0 | - |
| *Oxyeleotris lineolatus* | 0 | - | 5 | 1.5 | 0 | - | 0 | - | 0 | - | 2 | 1310.5 | 7 | 1310.5 | 0 | - |
| Total | 56 | 1602.9 | 39 | 5183.1 | 68 | 894.1[a] | 203 | 3546.2 | 145 | 999.1 | 59 | 3753.3 | 571 | 15978.7[a] | 64 | 4631.6 |

[a]excluding weights for *L. unicolor* and *T. lorenzti*

Table 11(j). Numbers and weights of fish species captured in Anbangbang Billabong (NR), a lowland backflow billabong
Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 2 | 620.0 | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 620.0 |
| *Nematalosa erebi* | 2 | 157.9 | 18 | 7025.0 | 0 | - | 1 | 8.6 | 0 | - | 0 | - | 21 | 7191.5 |
| *Arius leptaspis* | 0 | - | 1 | 300.0 | 0 | - | 1 | 36.0 | 0 | - | 0 | - | 2 | 336.0 |
| *Tandanus ater* | 0 | - | 5 | 2180.0 | 0 | - | 1 | 11.2 | 0 | - | 0 | - | 6 | 2191.2 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 2 | 28.3 | 1 | 18.2 | 0 | - | 3 | 46.5 |
| *Porochilus rendahli* | 3 | 99.5 | 0 | - | 0 | - | 1 | 12.6 | 16 | 157.7 | 0 | - | 20 | 269.8 |
| *Strongylura kreffiii* | 1 | 175.0 | 3 | 700.0 | 0 | - | 0 | - | 5 | 371.8 | 0 | - | 9 | 1247.5 |
| *Melanotaenia splendida inornata* | 7 | 1.2 | 2 | 0.7 | 2 | 4.7 | 26 | 169.0 | 7 | 40.1 | 9 | 1.4 | 53 | 217.1 |
| *Craterocephalus* nov. sp. | 0 | - | 0 | - | 1 | 0.1 | 0 | - | 0 | - | 0 | - | 1 | 0.1 |
| *C. stercusmuscarum* | 14 | 4.8 | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 0.1 | 16 | 4.9 |
| *Pseudomugil tenellus* | 0 | - | 7 | 2.0 | 1 | 0.1 | 0 | - | 3 | 0.3 | 0 | - | 11 | 2.4 |
| *Ambassis agrammus* | 144 | 100.2 | 22 | 17.7 | 85 | 17.7 | 0 | - | 347 | 227.8 | 22 | 12.4 | 620 | 397.9 |
| *Denariusa bandata* | 369 | 137.3 | 0 | - | 14 | 4.1 | 0 | - | 11 | 4.5 | 1 | 0.4 | 395 | 146.3 |
| *Amniataba percoides* | 2 | 32.0 | 0 | - | 0 | - | 7 | 52.2 | 4 | 44.3 | 0 | - | 13 | 128.5 |
| *Leiopotherapon unicolor* | 2 | 102.1 | 0 | - | 0 | - | 4 | 40.6 | 12 | 168.1 | 0 | - | 18 | 310.8 |
| *Glossamia aprion* | 5 | 16.5 | 1 | 1.9 | 1 | 0.5 | 0 | - | 6 | 114.2 | 0 | - | 13 | 133.1 |
| *Toxotes chatareus* | 0 | - | 3 | 810.0 | 0 | - | 2 | 18.5 | 2 | 17.5 | 0 | - | 7 | 846.0 |
| *Liza alata* | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 213.2 | 0 | - | 2 | 213.2 |
| *Hypseleotris compressa* | 1 | 0.4 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 0.4 |
| *Mogurnda mogurnda* | 3 | 5.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 3 | 5.0 |
| *Oxyeleotris lineolatus* | 0 | - | 0 | - | 1 | 2.5 | 0 | - | 2 | 2.8 | 0 | - | 3 | 5.3 |
| Total | 553 | 831.9 | 64 | 11658.0 | 105 | 51.7 | 45 | 377.0 | 418 | 1380.5 | 34 | 14.3 | 1219 | 14313.4 |

Table 12(a). Numbers and weights of fish species captured in Mudginberri corridor (MI), a corridor billabong
Catches were obtained using standard netting methods.

| Species | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 0 | - | 1 | 352.0 | 0 | - | 2 | 559.5 | 3 | 911.5 |
| *Nematalosa erebi* | 0 | - | 8 | 611.2 | 75 | 104.6 | 2 | 754.0 | 3 | 992.0 | 2 | 520.5 | 90 | 2982.8 |
| *Scleropages jardini* | 0 | - | 0 | - | 0 | - | 1 | 1550.0 | 0 | - | 0 | - | 1 | 1550.0 |
| *Arius leptaspis* | 4 | 4100.0 | 25 | 19469.2 | 1 | 800.0 | 6 | 6589.0 | 2 | 2523.0 | 0 | - | 38 | 33481.2 |
| *Tandanus ater* | 20 | 6255.0 | 3 | 662.0 | 0 | - | 8 | 2712.0 | 10 | 3752.4 | 7 | 2656.0 | 48 | 16037.4 |
| *Neosilurus hyrtlii* | 0 | - | 1 | 280.0 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 280.0 |
| *Strongylura krefftii* | 0 | - | 0 | - | 11 | 960.0 | 2 | 68.0 | 2 | 476.4 | 0 | - | 15 | 1504.4 |
| *Melanotaenia splendida inornata* | 1 | 0.3 | 14 | 4.0 | 80 | 51.8 | 42 | 161.0 | 92 | 37.5 | 22 | 5.7 | 251 | 260.3 |
| *Craterocephalus stercusmuscarum* | 2 | 0.3 | 26 | 50.0 | 7 | 1.6 | 25 | 3.6 | 324 | 59.5 | 0 | - | 384 | 70.0 |
| *Ambassis agrammus* | 204 | 57.6 | 0 | - | 801 | 489.6 | 0 | - | 57 | 8.7 | 151 | 87.5 | 1213 | 643.4 |
| *A. macleayi* | 0 | - | 24 | 14.5 | 0 | - | 2 | 11.3 | 0 | - | 0 | - | 26 | 25.8 |
| *Denariusa bandata* | 0 | - | 0 | - | 157 | 36.8 | 0 | - | 2 | 0.8 | 0 | - | 159 | 37.6 |
| *Amniataba percoides* | 2 | 129.0 | 0 | - | 0 | - | 1 | 0.1 | 36 | 708.3 | 6 | 422.9 | 45 | 1260.2 |
| *Leiopotherapon unicolor* | 0 | - | 0 | - | 2 | 71.3 | 0 | - | 0 | - | 2 | 65.6 | 4 | 136.9 |
| *Syncomistes butleri* | 0 | - | 2 | 650.0 | 0 | - | 0 | - | 3 | 1820.0 | 1 | 789.0 | 6 | 3259.0 |
| *Glossamia aprion* | 0 | - | 2 | 1.9 | 1 | 34.7 | 0 | - | 10 | 15.7 | 1 | 7.1 | 14 | 59.4 |
| *Toxotes chatareus* | 5 | 1025.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 5 | 1025.0 |
| *Glossogobius giurus* | 20 | 4.9 | 0 | - | 2 | 1.4 | 1 | 0.1 | 189 | 48.7 | 5 | 3.8 | 217 | 58.8 |
| *Mogurnda mogurnda* | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 4.9 | 0 | - | 1 | 4.9 |
| *Oxyeleotris lineolatus* | 0 | - | 0 | - | 1 | 287.0 | 0 | - | 0 | - | 0 | - | 1 | 287.0 |
| Total | 258 | 11572.1 | 105 | 21697.8 | 1138 | 2838.8 | 91 | 12200.9 | 731 | 10448.4 | 199 | 5117.6 | 2522 | 63875.6 |

Table 12(b). Number and weights of fish species captured in Buffalo Billabong (BO), a corridor billabong
Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 0 | - | 1 | 155.0 | 0 | - | 1 | 142.0 | 2 | 297.0 |
| *Nematalosa erebi* | 1 | 275.0 | 13 | 1.1 | 0 | - | 3 | 709.6 | 2 | 878.8 | 5 | 1487.5 | 26 | 3352.0 |
| *Scleropages jardini* | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 750.0 | 0 | - | 1 | 750.0 |
| *Arius leptaspis* | 9 | 7450.0 | 24 | 16583.0 | 0 | - | 4 | 5295.0 | 0 | - | 0 | - | 37 | 29328.0 |
| *Tandanus ater* | 11 | 4850.0 | 0 | - | 0 | - | 15 | 6927.0 | 2 | 812.8 | 7 | 2594.0 | 35 | 15183.8 |
| *Porochilus rendahli* | 0 | - | 1 | 20.1 | 0 | - | 1 | 14.0 | 0 | - | 0 | - | 2 | 34.1 |
| *Strongylura krefftii* | 0 | - | 0 | - | 0 | - | 2 | 146.4 | 0 | - | 0 | - | 2 | 146.4 |
| *Melanotaenia splendida inornata* | 10 | 7.6 | 4 | 0.3 | 20 | 30.8 | 192 | 165.5 | 48 | 56.3 | 13 | 6.9 | 287 | 267.4 |
| *Craterocephalus stercusmuscarum* | 43 | 13.6 | 21 | 4.2 | 51 | 29.5 | 1 | 1.6 | 2 | 0.6 | 9 | 1.2 | 127 | 50.7 |
| *Pseudomugil tenellus* | 0 | - | 0 | - | 0 | - | 10 | 1.7 | 3 | 0.6 | 0 | - | 13 | 2.3 |
| *Ambassis agrammus* | 9 | 3.1 | 0 | - | 97 | 41.8 | 0 | - | 24 | 14.6 | 0 | - | 130 | 59.5 |
| *A. macleayi* | 0 | - | 124 | 27.7 | 33 | 76.9 | 92 | 60.9 | 22 | 18.2 | 33 | 19.0 | 304 | 202.7 |
| *Denariusa bandata* | 5 | 2.1 | 2 | 0.8 | 2 | 0.2 | 12 | 3.3 | 40 | 18.2 | 0 | - | 61 | 24.6 |
| *Lates calcarifer* | 1 | 350.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 350.0 |
| *Amniataba percoides* | 0 | - | 0 | - | 1 | 19.8 | 4 | 124.3 | 1 | 101.2 | 4 | 121.0 | 10 | 366.3 |
| *Leiopotherapon unicolor* | 0 | - | 1 | 0.1 | 0 | - | 0 | - | 0 | -.1 | 0 | - | 1 | 0.1 |
| *Glossamia aprion* | 3 | 1.5 | 0 | - | 0 | - | 3 | 1.8 | 28 | 179.8 | 4 | 8.3 | 38 | 191.4 |
| *Toxotes chatareus* | 0 | - | 3 | 0.6 | 1 | 3.2 | 1 | 46.1 | 2 | 612.8 | 5 | 991.0 | 12 | 1653.7 |
| *Liza alata* | 0 | - | 0 | - | 0 | - | 1 | 783.0 | 0 | - | 0 | - | 1 | 783.0 |
| *Glossogobius giurus* | 4 | 1.0 | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 1.1 | 6 | 2.1 |
| *Hypseleotris compressa* | 1 | 1.2 | 3 | 2.1 | 0 | - | 0 | - | 0 | - | 0 | - | 4 | 3.3 |
| *Mogurnda mogurnda* | 0 | - | 0 | - | 0 | - | 1 | 2.9 | 1 | 0.6 | 0 | - | 2 | 3.5 |
| *Oxyeleotris lineolatus* | 0 | - | 1 | 0.1 | 0 | - | 0 | - | 2 | 6.1 | 0 | - | 3 | 6.2 |
| Total | 97 | 12955.1 | 197 | 16640.1 | 205 | 202.2 | 343 | 14438.1 | 179 | 3450.6 | 83 | 5372.0 | 1104 | 53058.1 |

Table 12(c). Numbers and weights of fish species captured at Island Billabong (ID), a corridor billabong

Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 1 | 31.3 | 0 | - | 10 | 2377.3 | 9 | 646.0 | 20 | 4708.4 |
| *Nematalosa erebi* | 1 | 5.4 | 16 | 2704.6 | 2 | 29.8 | 1 | 152.0 | 0 | - | 11 | 1416.6 | 40 | 4308.4 |
| *Scleropages jardini* | 1 | 1550.0 | 0 | - | 0 | - | 0 | - | 1 | 3000.0 | 0 | - | 2 | 4550.0 |
| *Arius leptaspis* | 11 | 9950.0 | 33 | 26200.0 | 0 | - | 24 | 11068.5 | 21 | 21258.1 | 12 | 13630.0 | 101 | 82106.6 |
| *Tandanus ater* | 12 | 6750.0 | 6 | 2170.0 | 0 | - | 7 | 3043.0 | 16 | 7963.5 | 2 | 2196.4 | 48 | 22122.9 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 2 | 123.2 | 0 | - | 0 | - | 2 | 123.2 |
| *Porochilus rendahli* | 0 | - | 0 | - | 1 | 67.0 | 0 | - | 1 | 5.9 | 0 | - | 2 | 73.9 |
| *Strongylura krefftii* | 0 | - | 1 | 0.2 | 2 | 56.5 | 0 | - | 0 | - | 0 | - | 3 | 56.7 |
| *Melanotaenia splendida inornata* | 109 | 105.2 | 2 | 0.8 | 31 | 72.9 | 126 | 152.1 | 23 | 22.0 | 46 | 43.1 | 337 | 396.1 |
| *Craterocephalus stercusmuscarum* | 33 | 11.4 | 14 | 4.5 | 192 | 56.6 | 15 | 19.9 | 24 | 13.2 | 6 | 3.5 | 284 | 109.1 |
| *Pseudomugil tenellus* | 0 | - | 0 | - | 0 | - | 5 | 0.4 | 0 | - | 0 | - | 5 | 0.4 |
| *Ophisternon gutturale* | 0 | - | 0 | - | 0 | - | 1 | 0.1 | 0 | - | 0 | - | 1 | 0.1 |
| *Ambassis agrammus* | 0 | - | 62 | 39.3 | 0 | - | 79 | 30.1 | 0 | - | 0 | - | 141 | 69.4 |
| *A. macleayi* | 5 | 18.2 | 0 | - | 0 | - | 37 | 44.5 | 44 | 100.0 | 167 | 122.1 | 253 | 284.8 |
| *Ambassis* (unidentifiable) | 20 | 13.2 | 0 | - | 20 | 23.0 | 0 | - | 0 | - | 0 | - | 40 | 36.2 |
| *Denariusa bandata* | 84 | 42.1 | 2 | 1.5 | 2 | 0.3 | 51 | 11.7 | 19 | 9.1 | 20 | 7.9 | 178 | 72.6 |
| *Amniataba percoides* | 6 | 270.4 | 2 | 0.4 | 1 | 157.0 | 0 | - | 0 | - | 17 | 867.3 | 26 | 1295.1 |
| *Leiopotherapon unicolor* | 0 | - | 1 | 0.2 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 0.2 |
| *Glossamia aprion* | 137 | 116.5 | 20 | 12.4 | 0 | - | 53 | 286.0 | 18 | 80.0 | 19 | 40.7 | 247 | 535.6 |
| *Toxotes chatareus* | 1 | 154.0 | 1 | 0.4 | 1 | 2.6 | 0 | - | 0 | - | 3 | 910.5 | 6 | 1067.5 |
| *Glossogobius giurus* | 0 | - | 0 | - | 0 | - | 5 | 3.6 | 0 | - | 0 | - | 5 | 3.6 |
| *Hypseleotris compressa* | 1 | 1.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 1.0 |
| *Mogurnda mogurnda* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 4 | 0.3 | 4 | 0.3 |
| *Oxyeleotris lineolatus* | 0 | - | 0 | - | 0 | - | 3 | 12.4 | 0 | - | 0 | - | 3 | 12.4 |
| Total | 421 | 18987.4 | 160 | 31134.3 | 253 | 497.0 | 409 | 14947.5 | 177 | 34829.1 | 321 | 19884.4 | 1741 | 120279.6 |

Table 13. Summary of standard fish sampling in Nourlangie Creek corridor habitats showing numbers and weights with corresponding species diversity indices

Site codes: FX = Flying Fox, NE = Nourlangie East, SR = Namandi, N3 = Nourlangie 3

| | Sampling sites and dates | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | FX 10.9.79 | | NE 6.10.78 | | SR 6.5.79 | | N3 15.9.78 | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 0 | - | 2 | 1130.0 |
| *Scleropages jardini* | 1 | 785.0 | 0 | - | 0 | - | 1 | 2100.0 |
| *Arius leptaspis* | 10 | 6803.0 | 3 | 2760.0 | 4 | 4245.0 | 37 | 28980.0 |
| *A. proximus* | 3 | 1018.0 | 0 | - | 0 | - | 5 | 6100.0 |
| *A. graeffei* | 0 | - | 12 | 2884.0 | 20 | 10378.0 | 0 | - |
| *Anodontiglanis dahli* | 3 | 924.0 | 13 | 6875.0 | 5 | 3038.0 | 0 | - |
| *Tandanus ater* | 1 | 792.0 | 6 | 3700.0 | 1 | 786.0 | 5 | 3475.0 |
| *Strongylura kreffii* | 1 | 371.0 | 0 | - | 0 | - | 0 | - |
| *Melanotaenia splendida inornata* | 8 | 4.1 | 1 | 1.2 | 7 | 10.5 | 0 | - |
| *Craterocephalus* nov. sp. | 0 | - | 17 | 39.0 | 0 | - | 0 | - |
| *C. stercusmuscarum* | 4 | 2.9 | 0 | - | 100 | 10.2 | 0 | - |
| *Ambassis agrammus* | 0 | - | 1 | 0.6 | 0 | - | 153 | 86.4 |
| *A. macleayi* | 0 | - | 0 | - | 130 | 45.0 | 0 | - |
| *Ambassis* (unidentifiable) | 2 | 0.1 | 0 | - | 10 | 4.0 | 0 | - |
| *Denariusa bandata* | 25 | 13.4 | 0 | - | 0 | - | 4 | 1.6 |
| *Amniataba percoides* | 23 | 425.5 | 28 | 301.3 | 5 | 117.1 | 0 | - |
| *Syncomistes butleri* | 0 | - | 1 | 500.0 | 0 | - | 0 | - |
| *Glossamia aprion* | 16 | 50.7 | 1 | 6.7 | 0 | - | 0 | - |
| *Toxotes chatareus* | 1 | 201.0 | 2 | 191.2 | 0 | - | 0 | - |
| *Glossogobius giurus* | 0 | - | 20 | 16.4 | 0 | - | 0 | - |
| *Mogurnda mogurnda* | 0 | - | 0 | - | 1 | 0.2 | 7 | 4.0 |
| Total | 98 | 11390.6 | 105 | 17275.4 | 166 | 18634.0 | 214 | 41877.0 |
| Number of species | 13 | | 12 | | 10 | | 8 | |
| Shannon | 2.03 | | 1.99 | | 1.43 | | 0.97 | |
| Richness | 2.62 | | 2.36 | | 1.76 | | 1.31 | |
| Evenness | 0.79 | | 0.80 | | 0.62 | | 0.47 | |

Table 14(a). Numbers and weights of fish species captured in Ja Ja Billabong (JJ), an upper floodplain billabong
Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 1 | 152.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 152.0 |
| *Nematalosa erebi* | 3 | 309.0 | 23 | 3.1 | 13 | 78.8 | 0 | - | 0 | - | 1 | 122.4 | 40 | 513.3 |
| *Arius leptaspis* | 8 | 12325.0 | 30 | 22720.0 | 0 | - | 0 | - | 22 | 11829.4 | 16 | 17885.2 | 76 | 64759.6 |
| *Tandanus ater* | 0 | - | 18 | 6280.0 | 3 | 798.5 | 0 | - | 4 | 953.6 | 0 | - | 25 | 8032.1 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 0 | - | 3 | 117.3 | 0 | - | 3 | 117.3 |
| *Porochilus rendahli* | 0 | - | 0 | - | 0 | - | 7 | 48.4 | 7 | 62.2 | 1 | 8.7 | 15 | 119.3 |
| *Strongylura krefftii* | 2 | 352.0 | 0 | - | 0 | - | 1 | 25.1 | 1 | 19.2 | 0 | - | 4 | 396.3 |
| *Melanotaenia splendida inornata* | 5 | 5.6 | 9 | 4.9 | 67 | 33.0 | 20 | 25.8 | 56 | 92.7 | 0 | - | 157 | 162.0 |
| *Craterocephalus stercusmuscarum* | 9 | 1.9 | 10 | 1.7 | 92 | 12.1 | 1 | 0.1 | 10 | 2.7 | 6 | 0.9 | 128 | 19.4 |
| *Pseudomugil tenellus* | 5 | 0.6 | 0 | - | 10 | 1.0 | 1 | 0.1 | 0 | - | 0 | - | 16 | 1.7 |
| *Ophisternon gutturale* | 1 | 1.5 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 1.5 |
| *Ambassis agrammus* | 819 | 480.9 | 0 | - | 43 | 6.9 | 0 | - | 110 | 66.0 | 495 | 209.9 | 1467 | 763.7 |
| *Ambassis macleayi* | 0 | - | 2 | 0.5 | 0 | - | 172 | 157.1 | 109 | 112.7 | 0 | - | 283 | 270.3 |
| *Ambassis* (unidentifiable) | 0 | - | 85 | 43.8 | 0 | - | 0 | - | 0 | - | 0 | - | 85 | 43.8 |
| *Denariusa bandata* | 66 | 14.0 | 3 | 1.7 | 20 | 5.6 | 24 | 9.1 | 23 | 10.3 | 5 | 1.3 | 141 | 42.0 |
| *Lates calcarifer* | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 3208.0 | 0 | - | 2 | 3208.0 |
| *Leiopotherapon unicolor* | 0 | - | 0 | - | 0 | - | 2 | 32.2 | 1 | 39.3 | 0 | - | 3 | 71.5 |
| *Glossamia aprion* | 9 | 28.0 | 0 | - | 0 | - | 11 | 105.7 | 56 | 363.3 | 1 | 0.2 | 77 | 497.2 |
| *Toxotes chatareus* | 0 | - | 5 | 2.0 | 1 | 6.0 | 0 | - | 0 | - | 0 | - | 6 | 8.0 |
| *Liza alata* | 3 | 610.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 3 | 610.0 |
| *Hypseleotris compressa* | 1 | 0.3 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 0.3 |
| *Mogurnda mogurnda* | 1 | 2.5 | 0 | - | 1 | 0.6 | 2 | 0.7 | 1 | 2.1 | 0 | - | 5 | 5.9 |
| *Oxyeleotris lineolatus* | 0 | - | 1 | 0.1 | 0 | - | 1 | 12.5 | 0 | - | 2 | 0.2 | 4 | 12.8 |
| Total | 933 | 14283.3 | 186 | 29057.7 | 250 | 942.5 | 242 | 416.8 | 405 | 16878.8 | 527 | 18228.8 | 2543 | 79807.9 |

Table 14(b). Numbers and weights of fish species captured in Leichhardt Billabong (LT), an upper floodplain billabong
Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 3 | 1065.0 | 0 | - | 4 | 1895.0 | 2 | 885.0 | 3 | 649.0 | 10 | 1956.0 | 22 | 6450.0 |
| *Nematalosa erebi* | 0 | - | 1 | 360.0 | 0 | - | 0 | - | 0 | - | 1 | 107.8 | 2 | 467.8 |
| *Scleropages jardini* | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 1130 | 0 | - | 1 | 1130.0 |
| *Arius leptaspis* | 5 | 5175.0 | 21 | 18740.0 | 7 | 7115.0 | 1 | 1102.0 | 31 | 20070.0 | 18 | 12872.2 | 83 | 65074.2 |
| *Tandanus ater* | 1 | 650.0 | 4 | 3205.0 | 0 | - | 0 | - | 5 | 993.4 | 5 | 2208.2 | 15 | 7056.6 |
| *Porochilus rendahli* | 1 | 3.5 | 0 | - | 0 | - | 11 | 7.4 | 3 | 4.0 | 0 | - | 15 | 14.9 |
| *Strongylura kreffiii* | 0 | - | 0 | - | 1 | 41.2 | 2 | 80.7 | 0 | - | 1 | 41.1 | 4 | 163.0 |
| *Melanotaenia splendida inornata* | 6 | 7.1 | 26 | 19.3 | 12 | 3.7 | 317 | 232.6 | 114 | 50.4 | 34 | 43.2 | 509 | 356.3 |
| *Craterocephalus stercusmuscarum* | 1 | 0.3 | 0 | - | 4 | 0.2 | 8 | 0.7 | 355 | 21.1 | 0 | - | 368 | 22.3 |
| *Pseudomugil tenellus* | 0 | - | 8 | 1.2 | 0 | - | 0 | - | 0 | - | 1 | 0.2 | 9 | 1.4 |
| *Ambassis agrammus* | 1925 | 937.0 | 0 | - | 0 | - | 0 | - | 26 | 6.3 | 0 | - | 1951 | 943.3 |
| *A. macleayi* | 0 | - | 0 | - | 0 | - | 0 | - | 23 | 10.5 | 58 | 29.4 | 81 | 39.9 |
| *Ambassis* (unidentifiable) | 0 | - | 0 | - | 10 | 3.6 | 112 | 36.0 | 0 | - | 0 | - | 122 | 39.6 |
| *Denariusa bandata* | 14 | 43 | 6 | 2.6 | 0 | - | 16 | 5.8 | 25 | 8.2 | 18 | 5.3 | 79 | 26.2 |
| *Lates calcarifer* | 2 | 928.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 928.0 |
| *Amniataba percoides* | 0 | - | 0 | - | 4 | 410.0 | 0 | - | 0 | - | 0 | - | 4 | 410.0 |
| *Glossamia aprion* | 8 | 53.9 | 0 | - | 0 | - | 5 | 11.5 | 0 | - | 2 | 11.6 | 15 | 77.0 |
| *Toxotes chatareus* | 0 | - | 2 | 680.0 | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 680.0 |
| *Liza alata* | 0 | - | 2 | 1445.0 | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 1445.0 |
| *Hypseleotris compressa* | 6 | 6.7 | 0 | - | 0 | - | 1 | 2.0 | 0 | - | 0 | - | 7 | 8.7 |
| *Mogurnda mogurnda* | 0 | - | 1 | 0.2 | 1 | 0.3 | 0 | - | 1 | 1.4 | 0 | - | 3 | 1.9 |
| *Oxyeleotris lineolatus* | 0 | - | 2 | 0.6 | 0 | - | 3 | 11.2 | 0 | - | 0 | - | 5 | 11.8 |
| Total | 1972 | 8830.8 | 73 | 24453.9 | 43 | 9469.0 | 478 | 2374.9 | 587 | 22980.4 | 148 | 17275.0 | 3300 | 85384.0 |

Table 14(c). Numbers and weights of fish species captured in Jabiluka Billabong (JA), an upper floodplain billabong

Catches were obtained using standard netting methods.

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 0 | - | 1 | 1200.0 | 1 | 314.5 | 1 | 2140.0 | 3 | 3654.5 |
| *Nematalosa erebi* | 8 | 553.3 | 7 | 1710.3 | 1 | 6.9 | 0 | - | 8 | 94.7 | 1 | 1580.0 | 25 | 3945.2 |
| *Scleropages jardini* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 1900.0 | 1 | 1900.0 |
| *Arius leptaspis* | 9 | 8825.0 | 3 | 2340.0 | 11 | 17155.0 | 1 | 1300.0 | 29 | 28158.6 | 8 | 8600.0 | 61 | 66378.6 |
| *Tandanus ater* | 4 | 2200.0 | 2 | 1250.0 | 3 | 1670.0 | 0 | - | 1 | 39.2 | 1 | 1100.0 | 11 | 6259.2 |
| *Porochilus rendahli* | 0 | - | 0 | - | 0 | - | 3 | 17.5 | 12 | 130.7 | 0 | - | 15 | 148.2 |
| *Strongylura krefftii* | 0 | - | 0 | - | 0 | - | 1 | 47.0 | 0 | - | 0 | - | 1 | 47.0 |
| *Melanotaenia nigrans* | 0 | - | 0 | - | 0 | - | 4 | 1.2 | 0 | - | 0 | - | 4 | 1.2 |
| *M. splendida inornata* | 0 | - | 0 | - | 30 | 23.1 | 29 | 13.5 | 83 | 62.2 | 5 | 1.7 | 147 | 100.5 |
| *Craterocephalus stercusmuscarum* | 3 | 0.3 | 7 | 1.3 | 262 | 29.2 | 9 | 1.4 | 67 | 11.4 | 12 | 2.0 | 360 | 45.6 |
| *Pseudomugil tenellus* | 3 | 0.2 | 1 | 0.1 | 14 | 1.7 | 0 | - | 0 | - | 10 | 0.4 | 28 | 2.4 |
| *Ambassis agrammus* | 217 | 105.6 | 179 | 95.8 | 150 | 40.9 | 4 | 2.0 | 6 | 2.0 | 0 | - | 556 | 246.3 |
| *A. macleayi* | 0 | - | 0 | - | 0 | - | 0 | - | 3 | 2.9 | 0 | - | 3 | 2.9 |
| *Ambassis* (unidentiable) | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 86 | 32.7 | 86 | 32.7 |
| *Denariusa bandata* | 4 | 0.8 | 2 | 0.7 | 8 | 1.6 | 2 | 0.7 | 85 | 33.9 | 0 | - | 101 | 37.7 |
| *Amniataba percoides* | 0 | - | 1 | 0.1 | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 0.1 |
| *Glossamia aprion* | 1 | 2.7 | 6 | 4.4 | 0 | - | 4 | 20.4 | 2 | 13.5 | 0 | - | 13 | 41.0 |
| *Liza alata* | 0 | - | 2 | 1470.0 | 0 | - | 0 | - | 1 | 505.1 | 0 | - | 3 | 1975.1 |
| *Glossogobius giurus* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 0.4 | 1 | 0.4 |
| *Hypseleotris compressa* | 0 | - | 1 | 0.9 | 1 | 2.8 | 0 | - | 0 | - | 0 | - | 2 | 3.7 |
| *Mogurnda mogurnda* | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 1.5 | 1 | 1.1 | 2 | 2.6 |
| *Oxyeleotris lineolatus* | 0 | - | 5 | 1.2 | 1 | 1.9 | 0 | - | 0 | - | 0 | - | 6 | 3.1 |
| Total | 249 | 11687.9 | 216 | 6874.8 | 481 | 18933.1 | 58 | 2603.7 | 299 | 29370.2 | 127 | 15358.3 | 1430 | 84828.0 |

Table 14(d). Numbers and weights of fish species captured in Nankeen Billabong (NN), an upper floodplain billabong

Catches were obtained using standard netting methods; nd = not determined

| | Sampling period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late-dry 1978 | | Early-wet | | Mid-wet | | Late-wet-Early-dry | | Mid-dry | | Late-dry 1979 | | Total | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 0 | - | 0 | - | 1 | 660.0 | 5 | 1352.0 | 1 | 234.0 | 0 | - | 6 | 2246.0 |
| *Nematalosa erebi* | 1 | 650.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 1 | 650.0 |
| *Arius leptaspis* | 3 | 3200.0 | 19 | 15665.0 | 8 | 7858.0 | 22 | 22812.0 | 11 | 14803.0 | 15 | 14499.8 | 78 | 78837.8 |
| *Tandanus ater* | 1 | 925.0 | 1 | 550.0 | 1 | 1115.0 | 2 | 10.8 | 1 | 974.0 | 1 | 782.1 | 7 | 4356.9 |
| *Neosilurus hyrtlii* | 0 | - | 0 | - | 0 | - | 9 | 9.1 | 0 | - | 0 | - | 9 | 9.1 |
| *Porochilus rendahli* | 0 | - | 0 | - | 0 | - | 2 | 6.5 | 4 | 12.0 | 1 | 9.0 | 7 | 27.5 |
| *Strongylura kreffiii* | 0 | - | 0 | - | 1 | 11.0 | 0 | - | 0 | - | 0 | - | 1 | 11.0 |
| *Melanotaenia splendida inornata* | 2 | 0.7 | 1 | 0.2 | 3 | 11.4 | 16 | 9.3 | 30 | 21.6 | 5 | 2.3 | 57 | 45.5 |
| *Craterocephalus stercusmuscarum* | 1 | 0.1 | 0 | - | 4 | 0.3 | 0 | - | 29 | 1.4 | 0 | - | 34 | 1.8 |
| *Pseudomugil tenellus* | 11 | 1.3 | 2 | 0.4 | 0 | - | 0 | - | 25 | 2.5 | 16 | 1.2 | 54 | 5.4 |
| *Ophisternon gutturale* | 0 | - | 0 | - | 0 | - | 1 | 0.6 | 0 | - | 0 | - | 1 | 0.6 |
| *Ambassis agrammus* | 99 | 45.0 | 143 | 72.7 | 13 | 6.0 | 52 | 28.6 | 130 | 64.1 | 0 | - | 437 | 216.4 |
| *Ambassis* (unidentifiable) | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 7 | 2.7 | 7 | 2.7 |
| *Denariusa bandata* | 6 | 1.3 | 0 | - | 3 | 2.2 | 19 | 6.3 | 9 | 2.9 | 0 | - | 37 | 12.7 |
| *Amniataba percoides* | 0 | - | 0 | - | 11 | 360.6 | 0 | - | 0 | - | 0 | - | 11 | 360.6 |
| *Leiopotherapon unicolor* | 0 | - | 0 | - | 1 | 77.6 | 0 | - | 1 | nd | 0 | - | 2 | 77.6 |
| *Glossamia aprion* | 1 | 1.5 | 0 | - | 2 | 18.6 | 4 | 5.1 | 2 | 4.2 | 0 | - | 9 | 29.4 |
| *Toxotes chatareus* | 0 | - | 0 | - | 15 | 147.1 | 0 | - | 0 | - | 0 | - | 15 | 147.1 |
| *Liza alata* | 0 | - | 2 | 202.8 | 0 | - | 0 | - | 2 | 68.4 | 0 | - | 4 | 271.2 |
| *Hypseleotris compressa* | 6 | 3.1 | 0 | - | 0 | - | 0 | - | 5 | 4.7 | 1 | 0.2 | 12 | 8.0 |
| *Mogurnda mogurnda* | 0 | - | 0 | - | 0 | - | 0 | - | 2 | 0.3 | 1 | 0.1 | 3 | 0.4 |
| *Oxyeleotris lineolatus* | 0 | - | 0 | - | 1 | 2.3 | 0 | - | 0 | - | 0 | - | 1 | 2.3 |
| Total | 131 | 4828.0 | 168 | 16491.1 | 64 | 10305.1 | 132 | 24240.3 | 252 | 16193.1[a] | 47 | 15297.4 | 794 | 87355.0 |

[a]excluding *L. unicolor*

Table 15. Summary of standard fish samplings in lower riverine floodplain billabongs showing numbers and weights with corresponding species diversity indices

Site codes: WL = Western Red Lily Billabong, CH = Cannon Hill Billabong

| | Sampling site | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | WL | | | | CH | | | |
| Season | Late-dry 1978 | | Mid-wet | | Late-dry 1978 | | Mid-wet | |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) |
| *Megalops cyprinoides* | 6 | 2370.0 | 13 | 4365.0 | 0 | - | 0 | - |
| *Arius leptapis* | 5 | 13200.0 | 0 | - | 5 | 3305.0 | 0 | - |
| *A. graeffei* | 0 | - | 0 | - | 4 | 2300.0 | 0 | - |
| *Tandanus ater* | 0 | - | 0 | - | 3 | 1575.0 | 0 | - |
| *Porochilus rendahli* | 9 | 618.2 | 0 | - | 0 | - | 0 | - |
| *Melanotaenia splendida inornata* | 0 | - | 2 | 1.1 | 2 | 0.5 | 2 | 2.5 |
| *Craterocephalus stercusmuscarum* | 0 | - | 0 | - | 3 | 1.4 | 48 | 21.6 |
| *Pseudomugil tenellus* | 0 | - | 1 | 0.1 | 0 | - | 5 | 0.8 |
| *Ambassis agrammus* | 3 | 2.6 | 0 | - | 0 | - | 0 | - |
| *A. macleayi* | 0 | - | 0 | - | 0 | - | 75 | 69.7 |
| *Ambassis* (unidentifiable) | 0 | - | 5 | 2.3 | 162 | 75.1 | 0 | - |
| *Amniataba percoides* | 0 | - | 0 | - | 1 | 6 | 0 | - |
| *Glossamia aprion* | 0 | - | 0 | - | 1 | 14.8 | 5 | 16.3 |
| *Toxotes chatareus* | 0 | - | 0 | - | 0 | - | 3 | 24.8 |
| *Glossogobius aureus* | 0 | - | 0 | - | 0 | - | 3 | 2.7 |
| *Hypseleotris compressa* | 6 | 10.0 | 16 | 29.8 | 18 | 18.3 | 1 | 8 |
| *Oxyeleotris lineolatus* | 1 | 525.0 | 1 | 830.0 | 2 | 1.9 | 0 | - |
| Total | 30 | 16725.8 | 38 | 5228.3 | 201 | 7297.6 | 142 | 139.2 |
| Number of species | 6 | | 6 | | 10 | | 8 | |
| Shannon | 1.65 | | 1.34 | | 0.83 | | 1.20 | |
| Richness | 1.47 | | 1.38 | | 1.70 | | 1.41 | |
| Evenness | 0.92 | | 0.75 | | 0.36 | | 0.58 | |

Table 16. Numbers of fish species captured during the study period in estuarine habitats and tidal habitats of the East Alligator River
Site codes: MMa = Magela Mouth, MMb = tidal creek, CC = Cahills Crossing, RH = Rock Hole.

| Habitat | Estuarine | | Tidal | | | |
|---|---|---|---|---|---|---|
| Distance to river mouth (km) | 60 | 70 | 95 | 95 | 100 | 100 |
| Site | MM(a) | MM(b) | CC | CC | RH | RH |
| Season | Mid-dry | Mid-dry | Mid-dry | Late-wet-Early-dry | Mid-dry | Mid-wet |
| Species | | | | | | |
| Carcharhinidae | | | | | | |
| *Carcharhinus leucas* | 0 | 0 | 0 | 0 | 8 | 0 |
| Clupeidae | | | | | | |
| *Nematalosa erebi* | 0 | 0 | 0 | 0 | 3 | 0 |
| Dorosomatidae | | | | | | |
| *Stoleophorus* sp. | 3 | 0 | 0 | 0 | 0 | 0 |
| Ariidae | | | | | | |
| *Arius leptaspis* | 0 | 0 | 0 | 1 | 3 | 0 |
| *A. graeffei* | 0 | 0 | 1 | 0 | 0 | 0 |
| Plotosidae | | | | | | |
| *Tandanus ater* | | | | | | |
| Hemirhamphidae | | | | | | |
| *Zenarchopterus caudovittatus* | 1 | 18 | 0 | 0 | 0 | 0 |
| Melanotaeniidae | | | | | | |
| *Melanotaenia splendida inornata* | 0 | 0 | 2 | 5 | 1 | 8 |
| Atherinidae | | | | | | |
| *Craterocephalus* nov. sp. | 0 | 0 | 0 | 0 | 32 | 0 |
| *C. stercusmuscarum* | 0 | 0 | 0 | 0 | 2 | 6 |
| Centropomidae | | | | | | |
| *Ambassis agrammus* | 0 | 0 | 4 | 0 | 0 | 0 |
| *A. macleayi* | 0 | 0 | 0 | 0 | 0 | 3 |
| *Lates calcarifer* | 3 | 0 | 7 | 0 | 3 | 3 |
| Teraponidae | | | | | | |
| *Amniataba percoides* | 0 | 0 | 0 | 0 | 9 | 6 |
| Apogonidae | | | | | | |
| *Glossamia aprion* | 0 | 0 | 3 | 0 | 0 | 0 |
| Sparidae | | | | | | |
| *Acanthopagrus berda* | 0 | 0 | 1 | 0 | 0 | 0 |
| Sciaenidae | | | | | | |
| *Collichthys lucidus* | 0 | 17 | 0 | 0 | 0 | 0 |
| *Nibea* sp. | 1 | 0 | 0 | 0 | 0 | 0 |
| Toxotidae | | | | | | |
| *Toxotes chatareus* | 0 | 4 | 5 | 0 | 1 | 5 |
| Polynemidae | | | | | | |
| *Polydactylus sheridani* | 1 | 0 | 0 | 0 | 0 | 0 |
| Mugilidae | | | | | | |
| *Liza dussumieri* | 3 | 13 | 9 | 1 | 3 | 0 |
| Gobiidae | | | | | | |
| *Oxuderces dentatus* | 0 | 4 | 0 | 0 | 0 | 0 |
| *Glossogobius giurus* | 0 | 0 | 0 | 1 | 1 | 1 |
| Eleotridae | | | | | | |
| *Mogurnda mogurnda* | 0 | 0 | 0 | 0 | 0 | 1 |
| *Prionobutis microps* | 0 | 0 | 0 | 1 | 0 | 0 |
| Periophthalmidae | | | | | | |
| *Periophthalmus* sp. | 6 | 5 | 5 | 2 | 0 | 0 |
| Kurtidae | | | | | | |
| *Kurtus gulliveri* | 0 | 2 | 0 | 0 | 0 | 0 |
| Belonidae | | | | | | |
| *Strongylura krefftii* | 0 | 0 | 0 | 0 | 1 | 0 |
| Soleidae | | | | | | |
| *Aseraggodes klunzingeri* | 0 | 0 | 9 | 24 | 0 | 0 |
| Total number of species | 7 | 7 | 10 | 8 | 12 | 8 |

Table 17. Summary of fish samplings along Coonjimba Creek and in Retention Pond 1 and the Tailings dam during the 1979-80 Early-wet season showing numbers and weights with corresponding species diversity indices

Site codes: CA = Coonjimba Billabong, C4 = Coonjimba 4 site, C3 = Coonjimba 3 site, LC = Little Coonjimba, C2 = Coonjimba 2 site, RO = Retention Pond 1, TD = Tailings dam; present = +

| | Longitudinal array of sites in Coonjimba Creek | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Natural sites | | | | | | | | Artificial sites | | |
| | CA 11.12.79 | | C4 5.12.79 | | C3 5.12.79 | | LC 5.12.79 | C2 5.12.79 | RO 6.10.79 | RO 29.11.79 | TD 6.11.79 |
| Species | No. | Wt (g) | No. | Wt (g) | No. | Wt (g) | No. | No. | No. | No. | No. |
| *Nematalosa erebi* | 0 | - | 0 | - | 3 | 124.6 | 0 | 0 | 0 | 0 | 0 |
| *Neosilurus hyrtlii* | 1 | 63.0 | + | + | 10 | 107.7 | 0 | 0 | 2 | 0 | 0 |
| *Porochilus rendahli* | 3 | 31.2 | 5 | 129.2 | 1 | 27.5 | 0 | 0 | 0 | 2 | 0 |
| *Melanotaenia nigrans* | 0 | - | 0 | - | 0 | - | 0 | 0 | 7 | 0 | 0 |
| *M. splendida inornata* | 0 | - | 0 | - | 0 | - | 0 | 0 | 25 | 0 | 0 |
| *Craterocephalus stercusmuscarum* | 0 | - | 0 | - | 0 | - | 0 | 0 | 2 | 0 | 0 |
| *Pseudomugil tenellus* | 0 | - | 0 | - | 0 | - | 0 | 0 | 75 | 0 | 0 |
| *Ambassis agrammus* | 0 | - | 17 | 23.3 | 0 | - | 0 | 0 | 22 | 0 | 0 |
| *A. macleayi* | 0 | - | 0 | - | 0 | - | 0 | 0 | 3 | 0 | 0 |
| *Ambassis* (unidentifiable) | 0 | - | 0 | - | 0 | - | 0 | 0 | 0 | 7 | 0 |
| *Denariusa bandata* | 0 | - | 0 | - | 0 | - | 0 | 0 | 0 | 0 | 0 |
| *Leiopotherapon unicolor* | 2 | 65.2 | 0 | - | 1 | 17.5 | 0 | 0 | 0 | 1 | 0 |
| *Glossamia aprion* | 1 | 1.2 | 1 | 3.9 | 9 | 127.5 | 0 | 0 | 0 | 0 | 0 |
| *Toxotes chatareus* | 1 | 8.8 | 0 | - | 0 | - | 0 | 0 | 0 | 0 | 0 |
| *Glossogobius giurus* | 8 | 3.8 | 0 | - | 0 | - | 0 | 0 | 0 | 0 | 0 |
| *Mogurnda mogurnda* | 0 | - | 0 | - | 0 | - | 0 | 0 | 28 | 3 | 0 |
| *Oxyeleotris lineolatus* | 2 | 104.9 | 0 | - | 0 | - | 0 | 0 | 1 | 0 | 0 |
| Total | 18 | 278.1 | 24 | 156.4 | 24 | 474.4 | 0 | 0 | 165 | 13 | 0 |
| Number of species | 7 | | 3 | | 5 | | 0 | 0 | 9 | 4 | 0 |
| Shannon | 1.63 | | 0.69 | | 1.26 | | 0 | 0 | - | 1.16 | 0 |
| Richness | 2.08 | | 0.44 | | 1.26 | | 0 | 0 | - | 1.17 | 0 |
| Evenness | 0.84 | | 0.64 | | 0.78 | | 0 | 0 | - | 0.84 | 0 |

Table 18. Summary of seasonal mean values for habitat-structural and physico-chemical variables recorded from a longitudinal array of habitats in the study area

Sites sampled: perennial streams - Radon Springs (RS) & Baroalba Springs (BS); main-channel - Bowerbird Bb. (BD) & Sawcut Gorge (ST); seasonal stream - a tributary pool on Hickey Creek (SZ); sandy creekbed - sites MD and GD in the Magela Creek bed & Nourlangie crossing 2 (NC); backflow billanongs - Fishless Bb. (FS), Georgetown Bb. (GN), Indium Bb. (IM), Goanna Bb. (GA), Djalkmara Bb. (DA), Coonjimba Bb. (CA), Corndorl Creek (CL), Gulungul Bb. (GL), Malabanbandju Bb. (NX), Anbangbang Bb. (NR); corridor - Buffalo Bb. (BO) & Mudginberri corridor (MI); corridor/floodplain - Island Bb. (ID); floodplain - Ja Ja Bb. (JJ), Leichhardt Bb. (LT), Jabiluka Bb. (JA), Nankeen Bb. (NN).

| Zone | Escarpment | | | Lowlands | | | | |
|---|---|---|---|---|---|---|---|---|
| Habitat | Perennial stream | Main-channel | Seasonal stream | Sandy creekbed | Backflow billabongs | Corridor | Corridor/ floodplain | Floodplain |
| **(a) 1978 Late-dry season**[a] | | | | | | | | |
| Temperature (° C): Surface | 28.5 | 29.5 | 28 | 30 | 31.7 | 32.5 | 32 | 30.5 |
| Bottom | 26 | 27.0 | 26 | 28.3 | 27.9 | 28 | 28 | 25.7 |
| Dissolved oxygen (mg/L): Surface | 5.15 | 6.0 | 7.2 | 5.0 | 5.85 | 6.15 | 6.6 | 6.85 |
| Bottom | 5.0 | 5.8 | 7.2 | 5.9 | 4.0 | 5.0 | 3.7 | 3.65 |
| Visibility (m) | 1.8 (max) | 2.2 (max) | 1.5 | 0.6 (max) | 0.09 | 1.1 | 0.1 | 0.13 |
| pH (mean of surface and bottom) | 5.0 | 6.1 | 6.2 | 7.1 | 6.7 | 6.2 | 6.2 | 6.0 |
| Conductivity (μs/cm) (mean of surface and bottom) | 18 | 11 | 5 | 36 | 80 | 10 | 20 | 96 |
| Maximum depth (m) | 1.8 | 1.8 | 2.0 | 0.6 | 0.8 | 2.85 | 2.8 | 2.85 |
| Substratum (%): Rock/gravel | 45 | 36 | 50 | - | 7 | - | - | - |
| Sand | 43 | 51 | 33 | 67 | 4 | 89 | 33 | - |
| Leaf litter | 12 | 13 | 17 | 33 | 2 | 6 | - | 1 |
| Clay/grass | - | - | - | - | 21 | - | - | 44 |
| Mud | - | - | - | - | 65 | 4 | 67 | 54 |
| Bank vegetation (% density) | 90 | 94 | 80 | 27 | 16 | 90 | 80 | 40 |
| Hydrophytes: Zonation | 0 | 0 | 0 | 0 | 0.7 | 1.5 | 2.0 | 2.0 |
| Surface cover | 2.0 | 1.0 | 0 | 0.3 | 0.2 | 1.0 | 2.0 | 1.3 |
| Submergent cover | 0 | 0 | 0 | 0.3 | 0.2 | 1.0 | 2.0 | 1.3 |
| Flow | Slight | Slight | Lentic | Lentic | Lentic | Lentic | Lentic (seepage) | Lentic (seepage) |
| **(b) 1978-79 Mid-wet season** | | | | | | | | |
| Temperature (° C): Surface | 28 | 29 | 23 | 29.7 | 31.5 | 29 | 30 | 32 |
| Bottom | 28 | 29 | 23 | 29.7 | 29.4 | 29 | 29 | 31 |
| Dissolved oxygen (mg/L): Surface | 6.7 | 6.2 | 7.2 | 6.1 | 6.5 | 5.7 | 5.1 | 6.1 |
| Bottom | 6.7 | 6.1 | 7.2 | 6.1 | 3.7 | 5.7 | 4.9 | 5.3 |
| Visibility (m) | 2.25 (max) | 2.3 (max) | 2.5 (max) | 1.4 (max) | 1.8 | 0.6 | 1.2 | 2.6 |
| pH (mean of surface and bottom) | 4.75 | 5.8 | 6.2 | 6.3 | 5.8 | 5.75 | 5.8 | 5.8 |
| Conductivity (μs/cm) (mean of surface and bottom) | 9 | 11 | 5 | 11 | 9 | 10 | 10 | 10 |
| Maximum depth (m) | 2.75 | 2.3 | 2.5 | 1.7 | 2.7 | 4.45 | 6.4 | 4.9 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Substratum (%): Rock/gravel | 67 | 36 | 67 | - | 5 | - | - | - |
| Sand | 33 | 32 | 33 | 67 | 9 | 14 | - | - |
| Leaf litter | - | 32 | - | - | - | - | - | - |
| Clay/grass | - | - | - | 33 | 54 | 86 | 2 | 14 |
| Mud | - | - | - | - | 32 | - | 98 | 87 |
| Bank vegetation (% density) | 90 | 94 | 80 | 73 | 67 | 90 | 100 | 65 |
| Hydrophytes: Zonation | 0 | 1 | 0 | 1.7 | 3.0 | 1.5 | 4 | 3.8 |
| Surface cover | 1.5 | 1 | 2 | 1.3 | 2.3 | 1.5 | 2 | 1.75 |
| Submerged cover | 0 | 0.5 | 0 | 1.0 | 2.5 | 0.5 | 2 | 2.5 |
| Flow | Strong | Strong | Strong | Strong | Slight | Medium | Slight to Medium | Slight to Medium |
| **(c) 1979 Late-wet-Early-dry season** [b] | | | | | | | | |
| Temperature (°C): Surface | 27.5 | 25 | 23 | 31.3 | 30.4 | 30 | 32 | 31.2 |
| Bottom | 27.5 | 24 | 23 | 30.7 | 28.0 | 29.5 | 29 | 28.5 |
| Dissolved oxygen (mg/L): Surface | 5.5 | 7.4 | 7.2 | 6.7 | 5.7 | 5.7 | 3.2 | 3.9 |
| Bottom | 5.5 | 7.4 | 7.2 | 6.7 | 1.9 | 2.6 | 1.0 | 0.3 |
| Visibility (m) | 1.25 | 2.75 (max) | 1.5 | 1.5 (max) | 0.9 | 1.75 | 1.4 | 0.96 |
| pH (mean of surface and bottom) | 5.0 | 6.2 | 6.2 | 6.1 | 6.0 | 5.8 | 5.5 | 6.0 |
| Conductivity ($\mu$s/cm) (mean of surface and bottom) | 10 | 5.5 | 5 | 8 | 20 | 10 | 10 | 26 |
| Maximum depth (m) | 2.0 | 1.8 | 2.0 | 1.2 | 1.64 | 3.05 | 4.0 | 4.0 |
| Substratum (%): Rock/gravel | 83 | 18 | 67 | - | - | - | - | - |
| Sand | 17 | 57 | 33 | 97 | - | 52 | - | - |
| Leaf litter | - | 26 | - | 3 | - | 4 | - | - |
| Clay/grass | - | - | - | - | 43 | 29 | 67 | 46 |
| Mud | - | - | - | - | 57 | 15 | 33 | 54 |
| Bank vegetation (% density) | 90 | 95 | 80 | 60 | 67 | 90 | 100 | 50 |
| Hydrophytes: Zonation | 0 | 0 | 0 | 1.3 | 2.8 | 2.5 | 3.0 | 3.3 |
| Surface cover | 1.0 | 1.0 | 2 | 1.0 | 2.4 | 2.5 | 4.0 | 2.0 |
| Submerged cover | 0.5 | 0 | 0 | 1.0 | 3.0 | 2.5 | 4.0 | 2.25 |
| Flow | Slight | Medium | Slight | Medium | Lentic | Slight | Slight | Slight |

[a] The seasonal stream, SZ, was not sampled until the Early-wet season but, as flow had not yet begun, the data are considered to be representative of the Late-dry season.
[b] No data are available for one of the main-channel sites, ST, in this season.

Table 19. Pearson's product moment correlation coefficients between physiographic variables for 26 regular sampling sites

| Variable | [DE] | [SO] | [EL] | [VF] | [GR] |
|---|---|---|---|---|---|
| Distance to estuary [DE] | 1.000 | | | | |
| Stream order [SO] | -0.519** | 1.000 | | | |
| Elevation [EL] | 0.507** | -0.367 | 1.000 | | |
| Volume factor [VF] | 0.218 | 0.208 | -0.522** | 1.000 | |
| Gradient [GR] | 0.311 | -0.275 | 0.894** | -0.417 | 1.000 |

** significant ($p < 0.01$)

Table 20. Pearson's product moment correlation coefficients between physiographic variables and the first two axes of the reciprocal averaging site ordination for combined seasons

| | Ordination axes | |
|---|---|---|
| Variable | Axis one | Axis two |
| Distance to estuary | 0.328 | 0.419* |
| Stream order | -0.032 | 0.247 |
| Elevation | 0.858** | 0.096 |
| Volume factor | -0.731** | -0.062 |
| Gradient | 0.735** | 0.057 |

*significant ($0.01 < p < 0.05$);
**highly significant ($p < 0.01$)

Table 21. Seasonal changes in community composition analysed by reciprocal averaging analysis ordination for all habitats in each of three critical seasons

| | Season | | |
|---|---|---|---|
| Grouping | Late-dry | Mid-wet | Late-wet-Early-dry |
| All habitats | | | |
| Axis 1: mean | 16.3 | 28.3 | 32.0 |
| SD | 255 | 214 | 183 |
| Axis 2: mean | 38.1 | -18.0 | 53.0 |
| SD | 177 | 51 | 153 |
| All habitats except escarpment streams | | | |
| Axis 1: mean | 47.2 | -19.6 | 67.4 |
| SD | 184 | 59 | 156 |
| Axis 2: mean | 20.2 | -45.6 | -63.6 |
| SD | 51 | 68 | 66 |

Table 22. Tentative list of zonational and habitat types developed during the study period based on fish community and environmental characteristics

| Zone type | Habitat type | Examples of sites |
|---|---|---|
| Plateau | Plateau rocky streams | BM, TF |
| Escarpment valleys | Terminal main-channel rock pools | KD, BF, JD |
| Escarpment valleys | Main-channel waterbodies | BD, ST, TW, CP, SD |
| Escarpment valleys | Seasonal feeder streams (shallow) | NS, BY |
| Escarpment valleys | Seasonal feeder streams (deep) | SZ, SY |
| Escarpment valleys | Perennial rocky streams (isolated) | RF |
| Escarpment valleys | Perennial rocky streams | BS, RS |
| Lowlands | Sandy creekbed pools (temporary) | MJ, MU, MG, GU |
| Lowlands | Sandy creekbed pools (permanent in average years) | MD, GD, NC, AU |
| Lowlands | Backflow billabongs (large size, shallow) | CL, GL, NR |
| Lowlands | Backflow billabongs (medium size, shallow) | DA, CA, FS |
| Lowlands | Backflow billabongs (channel type) | IM, GA, GN, BX, DR, CD, AM, BC |
| Corridor | Sandy main channel | MI, NE, SR |
| Corridor | Muddy anabranch | BO, FX |
| Corridor | Transitional with flood plain | ID, N3 |
| Upper flood plains | Billabongs with heavy mortality in Late-dry-Early-wet | JJ, LT |
| Upper flood plains | Billabongs with slight mortality in Late-dry-Early-wet | JA, NN |
| Lower riverine flood plains | Lower riverine floodplain billabongs | CH, WL |
| Estuarine | Main channel (muddy) | CC |
| Estuarine | Sandy anabranch | RH |
| Estuarine tributaries | Estuarine tributaries | MM a & b |

# APPENDIX 1

## Genus species card (type B)

The following variables are recorded on the genus species card. Columns on data card (80 columns wide) are shown in parentheses.

**Sample reference code (1-17)**

Date, time, sampling site, sampling method and mesh size.

**Genus and species (18-54)**

Generic and specific names follow the usage of the Australian Museum.

**Total number (55-58)**

Total number of fish per species per sample.

**Total weight (59-64)**

Total weight (in g x $10^{-1}$) of fish per species per sample.

**Length: minimum (65-68), maximum (69-72)**

Minimum and maximum length (mm, TL or LCF) of fish per species per sample.

**Species code (73-77)**

Australian Museum fish family codes are used for fish captured during the study or recorded from 'freshwater' habitats. These codes are:

| *Code* | *Family* | *Genus and species* | *Common name* |
|---|---|---|---|
| 00801 | Carcharhinidae | *Carcharhinus leucas* | River whaler shark |
| 02301 | Pristidae | *Pristis leicchardtii* | River sawfish |
| 03501 | Dasyatidae | *Dasyatis fluviorum* | Brown river stingray |
| 05402 | Megalopidae | *Megalops cyprinoides* | Tarpon or ox-eye herring |
| 08501 | Clupeidae | *Nematalosa erebi* | Bony bream |
| 08502 | Clupeidae | *Nematalosa come* | Bony bream |
| 08503 | Clupeidae | *Hilsa kelee* | Black spotted bream |
| 08801 | Osteoglossidae | *Scleropages jardini* | Saratoga |
| 18801 | Ariidae | *Arius leptaspis* | Lesser salmon catfish |
| 18803 | Ariidae | *Arius leptaspis* ( = *Hexanematichthys* sp. A) | Forktailed catfish |
| 18804 | Ariidae | *Arius proximus* ( = *Hexanematichthys* sp. B) | Forktailed catfish |
| 18805 | Ariidae | *Arius graeffei* ( = *Hexanematichthys* sp. C = *Arius australis*) | Forktailed catfish |
| 19201 | Plotosidae | *Anodontiglanis dahli* | Toothless catfish |
| 19202 | Plotosidae | *Neosilurus* sp. A | Eel-tailed catfish |

| Code | Family | Genus and species | Common name |
|---|---|---|---|
| 19203 | Plotosidae | *Neosilurus* sp. B | Eel-tailed catfish |
| 19204 | Plotosidae | *Porochilus obbesi* | Obbes catfish |
| 19205 | Plotosidae | *Neosilurus* sp. C | Eel-tailed catfish |
| 19211-3 | Plotosidae | *Tandanus ater* (3 colour types) | Narrow-fronted tandan |
| 19214-6 | Plotosidae | *Neosilurus hyrtlii* (3 colour types) | Hyrtl's tandan |
| 19217-9 | Plotosidae | *Porochilus rendahli* (3 colour types) | Rendahl's tandan |
| 23401 | Hemirhamphidae | *Zenarchopterus caudovittatus* | Garfish |
| 24501 | Melanotaeniidae | *Melanotaenia nigrans* | Black-banded rainbow fish |
| 24502 | Melanotaeniidae | *Melanotaenia splendida inornata* ( = *Melanotaenia maculata*) | Chequered rainbow fish |
| 24503 | Melanotaeniidae | *Melanotaenia splendida australis* ( = *Melanotaenia australis*) | Red-tailed rainbow fish |
| 24600 | Atherinidae | *Craterocephalus* sp. | Hardyhead |
| 24601 | Atherinidae | *Craterocephalus* nov. sp. ( = *Craterocephalus marjoriae*) | Marjorie's hardyhead |
| 24602 | Atherinidae | *Craterocephalus stercusmuscarum* | Fly-specked hardyhead |
| 24603 | Atherinidae | *Pseudomugil tenellus* | Dainty blue eye |
| 28501 | Synbranchidae | *Ophisternon gutturale* | One-gilled eel |
| 31001 | Centropomidae | *Ambassis agrammus* | Sail-fin perchlet |
| 31002 | Centropomidae | *Ambassis macleayi* | Reticulated perchlet |
| 31003 | Centropomidae | *Denariusa bandata* | Penny fish |
| 31004 | Centropomidae | *Lates calcarifer* | Silver barramundi |
| 31005 | Centropomidae | *Ambassis elongatus* | Yellow-fin perchlet |
| 31006 | Centropomidae | *Ambassis* sp. | Perchlet |
| 32101 | Teraponidae | *Amniataba percoides* | Black-striped grunter |
| 32102 | Teraponidae | *Hephaestus fuliginosus* | Black grunter or bream |
| 32103 | Teraponidae | *Leiopotherapon unicolor* | Spangled grunter |
| 32104 | Teraponidae | *Syncomistes butleri* | Sharp-nosed grunter |
| 32105 | Teraponidae | *Pingalla midgleyi* ( = *Pingalla* sp.) | Black-blotched anal-fin grunter |
| 32701 | Apogonidae | *Glossamia aprion* | Mouth almighty |
| 35901 | Toxotidae | *Toxotes lorentzi* | Primitive archer fish |
| 35902 | Toxotidae | *Toxotes chatareus* | Common archerfish |
| 35903 | Toxotidae | *Toxotes jaculator* | Archerfish |
| 36301 | Scatophagidae | *Scatophagus* sp. | Butter fish |
| 38101 | Mugilidae | *Liza alata* ( = *Liza diadema*) | Ord River mullet |
| 38102 | Mugilidae | *Liza dussumieri* | Green-backed mullet |
| 38103 | Mugilidae | *Squalomugil nasutus* | Mud mullet |
| 38104 | Mugilidae | *Liza macrolepis* | Mullet |
| 42801 | Gobiidae | *Glossogobius giurus* | Flat-headed goby |
| 42802 | Gobiidae | *Glossogobius aureus* | Goby |
| 42901 | Eleotridae | *Hypseleotris compressa* ( = *Hypseleotris compressus*) | Northern carp gudgeon |
| 42902 | Eleotridae | *Mogurnda mogurnda* | Purple-spotted gudgeon |

| *Code* | *Family* | *Genus and species* | *Common name* |
|---|---|---|---|
| 42903 | Eleotridae | *Oxyeleotris lineolatus* | Sleepy cod |
| 42904 | Eleotridae | *Prionobutis microps* | Small-eyed sleeper |
| 42905 | Eleotridae | *Oxyeleotris* sp. | Black-banded gauvina |
| 45101 | Belonidae | *Strongylura krefftii* | Long tom |
| 46201 | Soleidae | *Aseraggodes klunzingeri* | Tailed sole |
| 46202 | Soleidae | *Brachirus salinarum* | Salt-pan sole |
| 46301 | Cynoglossidae | *Cynoglossus heterolepis* | Tongue sole |

Estuarine species (uncoded)

| | |
|---|---|
| Dorosomatidae | *Stoleophorus* sp. |
| Sparidae | *Acanthopagrus berda* |
| Sciaenidae | *Collichthys lucidus* |
| Sciaenidae | *Nibea* sp. |
| Periophthalmidae | *Periophthalmus* sp. |
| Kurtidae | *Kurtus gulliveri* |

**Card type (80)**

Genus species card coded as **B**.

# APPENDIX 2

## Key to summary figures of habitat-structural variables

### Area factor

Area factor is calculated as the product of estimated length and width. The symbol † indicates that the waterbody is continuous with creek or flood plain and therefore the area cannot be defined. Area factors for escarpment sites are for pools within the perennial creek.

### Flow

- present
- absent

### Bank vegetation

**Cover.** Percentage of bank adjacent to water covered by terrestrial vegetation.

**Composition.** Percentage contribution of each cover type:

B = *Barringtonia*; E = *Eucalyptus*; G = grass or sedge; L = logs; M = *Melaleuca*; P = *Pandanus*; R = *rainforest*; S = rocks/ boulders;

Density code:

- thick
- medium
- sparse

### Aquatic vegetation

**Surface and submerged cover.** The amount of cover over the surface or beneath the water, respectively, ranked as follows:

0 = absent; 1 = slight ( < 1/3); 2 = moderate (1/2 to 2/3); 3 = extensive ( > 2/3 but less than complete); 4 = complete cover of waterbody.

**Zonation.** The diversity of habitats formed by aquatic vegetation, ranked as follows:

0 = absent; 1 = present but not well marked; 2 = marked zonation into two zones in at least one section of the waterbody; 3 = marked zonation into 3 zones in at least one section of the waterbody; 4 = marked zonation into 4 zones in at least one section of the waterbody.

**Composition.** The percentage breakdown into aquatic vegetation types:

E = emergent; S = submergent; A = floating attached; U = floating unattached

The four most dominant species are listed in decreasing order of dominance. (This numbering code differs from that given in volume I, in appendix 2.)

Numbering code for aquatic vegetation:

1 *Ludwigia adscendens*
2 *Polygonum* sp.
3 *Limnophila* sp.
4 *Caldesia oligococca*
5 *Eleocharis dulcis*
6 *Eleocharis* sp.
7 *Pseudoraphis spinescens*
8 *Fimbristylis minima*
9 *Hymenachne acutigluma*
10 *Brachiaria mutica*
11 *Cyperus javanicus*
12 Reed A
13 Herb A
14 Grass A
15 *Ceratophyllum* sp.

16 *Utricularia stellaris*
17 *Utricularia* sp.
18 *Myriophyllum* sp.1
19 *Myriophyllum* sp.2
20 *Aponogeton elongatus*
21 *Eriocaulon setaceum*
22 *Hydrilla verticillata*
23 *Vallisneria spiralis*
24 *Vallisneria* sp.
25 *Lepilaena* sp.
26 *Najas tenuifolia*
27 Green filamentous alga 1
28 *Marsilea* sp.
29 *Nymphoides furculifolia*
30 *Nymphoides indica*
31 *Nymphoides minima*
32 *Nymphaea gigantea*
33 *Azolla pinnata*
34 Floating weed A
35 Surface red and green algae

# APPENDIX 3

## Sampling sites

The following sampling sites are listed alphabetically by site code. Sites AJ, AK, AO and AT, those sampled by Midgley (1973) and referred to in the figures and tables of this Volume, are included here.

Further site details are given in tables 4 and 5 of volume I (vol. I, table 4, pp. 16-18; vol. I, table 5, p. 19). Table 4 (vol. I) lists the sampling sites by catchment and includes associated information in zone, stream order, map references, grid references, latitude and longitude, elevation above sea level and the distance from the estuary. The classification of sites according to their use for regular or occasional sampling, is give in table 5 (vol. I). This table (vol. I, table 5, p. 19) groups the sites by drainage system and habitat type.

| Code | Site Name | Code | Site Name |
|---|---|---|---|
| AJ | above Jim Jim Falls | DA | Djalkmara Bb. |
| AK | above Kolondjarluk Falls | DR | Deaf Adder |
| AM[1] | Nabarlek Dam | | |
| AT | above Twin Falls | FS | Fishless Bb. |
| AO | above Koolpin Gorge | FX | Flying Fox |
| AU | Adgibongololo Ck | | |
| | | GA | Goanna Bb. (on Baralil Ck) |
| BC | Birraduk Creek | GD | Magela bed |
| BD | Bowerbird Bb. | GL | Gulungul Bb. |
| BF | Magela Falls base | GN | Georgetown Bb. |
| BM | Mt Brockman | GU | Magela bed |
| BO | Buffalo Bb. | | |
| BS | Baroalba Springs | ID | Island Bb. |
| BX | Malabanbandju Bb. | IF[1] | Magela riffle |
| BY | Baroalba stream | II[1] | Surshar Bb. |
| | | IM | Indium Bb. |
| C1[1] | Costean 1 | | |
| C2 | Coonjimba 2 | | |
| C3 | Coonjimba 3 | JA | Jabiluka Bb. |
| C4 | Coonjimba 4 | JD | Jim Jim Falls base |
| CA | Coonjimba Bb. | JJ | Ja Ja Bb. |
| CC | Cahills Crossing | | |
| CD | Bullwidgi Bb. | KD | Kolondjarluk (on Kolondjarluk Ck) |
| CH | Cannon Hill Bb. (on anabranch) | | |
| CL | Corndorl Bb. | LC | Little Coonjimba |
| CP | Camp 1 (on Kolondjarluk Ck) | LT | Leichhardt Bb. |

[1] artificial structure

| Code | Site Name | Code | Site Name |
|---|---|---|---|
| MA | Muriella Park | RF | Radon Falls |
| MD | Magela bed | RH | Rock Hole |
| MG | Magela bed | RO[1] | Retention Pond 1 |
| MI | Mudginberri corridor | RS | Radon Springs |
| MJ | Magela bed | RT[1] | Retention Pond 2 |
| MMa | Magela mouth | SD | Camp 2 (on Kolondjarluk Ck) |
| MMb | Tidal creek | SR | Namandi |
| MU | Magela upstream | ST | Sawcut Gorge |
| MX | Magela Crossing | SY | Tributary pool (on Hickey Ck) |
| MY | Maybangul Bb. | SZ | Tributary pools (on Hickey Ck) |
| | | TD[1] | Tailings dam |
| N2 | Nourlangie 2 | TF | Magela Falls top |
| N3 | Nourlangie 3 | TW | Twin Falls |
| NC | Nourlangie crossing 2 | | |
| NE | Nourlangie East | UU | Magela upstream |
| NN | Nankeen Bb. | | |
| NR | Anbangbang Bb. | WL | Western Red Lily Bb. (on anabranch) |
| NS | Noranda pools (on Noranda Ck) | | |
| NY | Nourlangie crossing 1 | ZZ[1] | Bore site |

[1]artificial structure

# SUPERVISING SCIENTIST FOR THE ALLIGATOR RIVERS REGION RESEARCH PUBLICATIONS

Alligator Rivers Region Research Institute Research Report 1983-84
Alligator Rivers Region Research Institute Annual Research Summary 1984-85
Alligator Rivers Region Research Institute Annual Research Summary 1985-86
Alligator Rivers Region Research Institute Annual Research Summary 1986-87
Alligator Rivers Region Research Institute Annual Research Summary 1987-88
Alligator Rivers Region Research Institute Annual Research Summary 1988-89 (in press)

*Research Reports (RR) and Technical Memoranda (TM)*

| | | |
|---|---|---|
| RR 1 | The macroinvertebrates of Magela Creek, Northern Territory. April 1982 (pb, mf - 46 pp.) | R. Marchant |
| RR 2 | Water quality characteristics of eight billabongs in the Magela Creek catchment. December 1982 (pb, mf - 60 pp.) | B.T. Hart & R.J. McGregor |
| RR 3 | A limnological survey of the Alligator Rivers Region. I. Diatoms (Bacillariophyceae) of the Region. August 1983 (pb, mf - 160 pp.) | D.P. Thomas |
| | *A limnological survey of the Alligator Rivers Region. II. Freshwater algae, exclusive of diatoms. 1986 (pb, mf - 176 pp.) | H.U. Ling & P.A. Tyler |
| RR 4 | *Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory. Volume I. Outline of the study, summary, conclusions and recommendations. 1986 (pb, mf - 63 pp.) | K.A. Bishop, S.A. Allen, D.A. Pollard & M.G. Cook |
| | Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory. Volume II. Synecology. 1990 (pb - 155 pp.) | K.A. Bishop, S.A. Allen, D.A. Pollard & M.G. Cook |
| | Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory. Volume III. Autocology. (in press) | K.A. Bishop, S.A. Allen, D.A. Pollard & M.G. Cook |
| RR 5 | Macrophyte vegetation of the Magela Creek flood plain, Alligator Rivers Region, Northern Territory. March 1989 (pb - 41 pp.) | C.M. Finlayson, B.J. Bailey & I.D. Cowie |
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| TM 2 | Transport of trace metals in the Magela Creek system, Northern Territory. II. Trace metals in the Magela Creek billabongs at the end of the 1978 Dry season. December 1981 (pb, mf - 23 pp.) | S.H.R. Davies & B.T. Hart |
| TM 3 | Transport of trace metals in the Magela Creek system, Northern Territory. III. Billabong sediments. December 1981 (pb, mf - 24 pp.) | P.A. Thomas, S.H.R. Davies & B.T. Hart |
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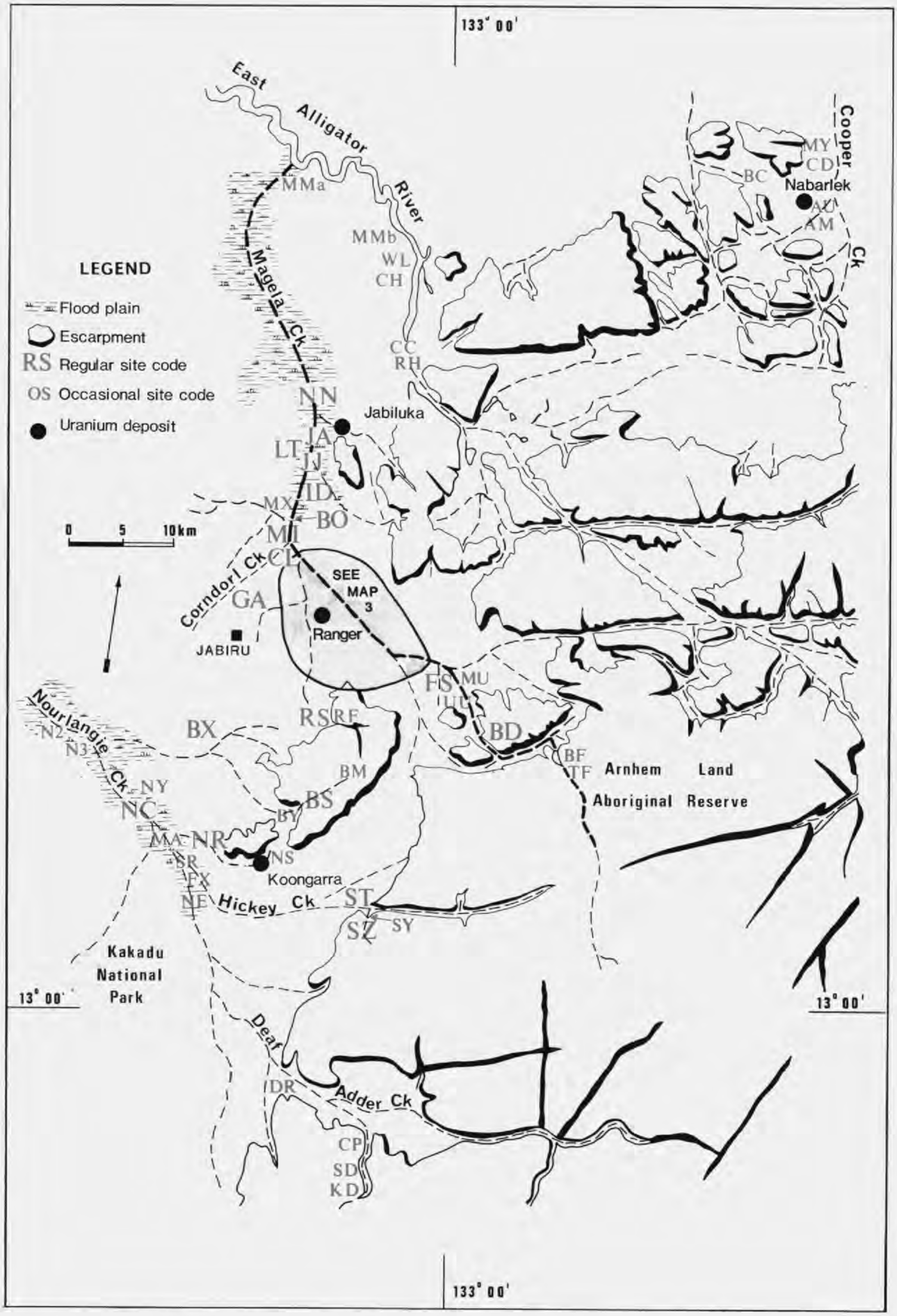


Map 2. Location of regular and occasional sampling sites. Sites JD and TW are further south than the coverage of this map. Sites CA, C1, C2, C3, C4, DA, GD, GL, GN, GU, IF, II, IM, LC, MD, MG, MJ, RO, RT, TD and ZZ are shown on Map 3.