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Fish fauna of the Sepik and Ramu River floodplain regions:
Summary of information on fish ecology, identification
of vacant niches and categories of species
suitable for stocking

A report prepared for project PNG/85/001:
Sepik River Fish Stock Enhancement Project

by

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This report was prepared during the course of the project identified on the title page. The conclusions and recommendations given in the report are those considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of the project.

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1. INTRODUCTION

This document summarises the information available on the habits of fishes in floodplain regions of the Sepik and Ramu River systems, Papua New Guinea, with respect to project PNG/85/001, and in particular to:

- (1) describe the recent evolutionary history of the fauna,
- (2) describe the floodplain fishery and present landings,
- (3) describe the ecology of the native species and presently existing introduced exotics,
- (4) explain why the present yield of these regions is considered to be low,
- (5) identify the niches occupied by the native species and identify those niches considered vacant and available for further species introductions, and
- (6) identify in what way the native species might be expected to be vulnerable to the introduction of further exotic species.

This document serves only to provide general background information leading to the conclusions on which types of fishes might be appropriate for introduction. The actual proposal to introduce a named species is a more complicated process which will need to follow the EIFAC/ICES code of practice on fish introductions (Turner 1988). This would need to include, amongst other matters, an in-depth consideration of conservation aspects, costs versus benefits and quarantine implications, together with proposed technical aspects of the method of stocking. For this reason, specific proposals for each species will be produced in later documents. I aim here only to explain the reasoning behind why certain categories of fish are thought suitable for consideration.

This document is based upon research on the ichthyofauna of the Sepik and Ramu Rivers from 1981 to 1989. In order to avoid lengthy and repetitive reference citations, details of information sources for the various species are summarised in Table 1.

Data and information on Sepik and Ramu tributary (lower order/hill) streams has been compiled by Van Zwieten (1989, 1989a, 1989b, 1989c).

The present document deals with floodplain regions of the Sepik and Ramu Rivers including floodplains, main river channels, ox-bow lakes and associated environments at lower altitudes in the Sepik and Ramu River catchment, i.e. all areas from 0 to 200 m elevation. The Sepik and Ramu rivers are interconnected and their fish faunas and fisheries are considered to be very similar, if not identical (Allen, Coates and Parenti, unpublished; Allen and Coates 1989). The term "floodplain region" refers to all habitats in this area, including higher order river channels, whereas "floodplain" is that habitat within this region comprising areas of low-lying land that are seasonally inundated with water as the river floods and drying out again as the river level falls towards the dry season.

This report excludes coastal streams which run directly into the sea. Such streams are small and insignificant in area. They also do not have floodplains. The fauna of such streams tends to be slightly different by the inclusion of an additional number of marine/estuarine species and the occasional freshwater endemic species. These streams will be covered in a second report dealing with tributary streams. Such streams are, in any case, outside the target area for stocking.

Within the Sepik River, the habitats covered by this report refer to the area from about the border with Irian Jaya, beyond which the river elevation rises up to the highlands, to the sea, a distance of about 1000 km by river, and laterally within this range up to an altitude of about 200 m, most of which is below 100 m. This is commonly referred to as the floodplain belt which varies between 5 and 70 km to either side of the main river channels within the meander belt. The equivalent area within the Ramu system is from Gusap Downs, where the river flows out of the Ramu Gorge on its course from the highlands, and similar areas of low altitude land in the meander belt between the Bismark and Finisterre Ranges to the mouth about 500 km downstream, see also Fig. 1.

Separate treatment of the lower altitudes in the Sepik catchment is justified in terms of:

(i) the lower altitude environments, where gradient is low, are quite different environments, in general, to those areas above about 200 m elevation which are characterised by steeper gradients, smaller, faster flowing rivers and the absence of lakes and swamps, and,

(ii) the fish species recorded within the catchment can be divided into two faunas, lowland and higher land, with very little overlap of the two groups. Of the species known from floodplain regions only the following also occur above 200 m:

- Zenarchopterus kampeni, occurs in floodplain regions but also in quieter portions of low gradient tributary rivers, e.g., pools, up to about 400 m.
- Arius velutinus, juveniles of which migrate from higher order rivers into tributary rivers up to about 800 m (Van Zwieten 1989c).
- Eels, Anguilla bicolor and A. marmorata, which migrate through lowlands into lower order streams which are their major habitat.
- Megalops cyprinoides, occasionally enters lower sections of tributary streams from its major higher order river and coastal habitat.

The gross difference in fauna of the two regions reflects their differences in environment. Consequently, species considered to be ecologically suitable for introduction into lower altitudes would be different to those considered for higher altitudes, although some overlap in the region 100 to 300 m might be expected.

2. GEOLOGICAL HISTORY OF THE FLOODPLAIN REGION AND RECENT EVOLUTIONARY HISTORY OF THE FLOODPLAIN FISH FAUNA

The native New Guinea freshwater fish fauna is well known to be devoid of primary and secondary freshwater fishes that form the conspicuous elements of riverine faunas from other regions (Roberts 1978, McDowall 1981, Coates 1985). During the process of continental drift, New Guinea (Fig. 1), being part of the Australasian landmass, split from Gondwanaland before major groups of freshwater fishes evolved. All fishes inhabiting New Guinea freshwaters, with the exception of Scleropages spp, which does not occur in the Sepik, are either diadromous or freshwater representatives of marine families. This accounts for the rather unusual nature of the fauna in comparison with other zoogeographic zones. None of the families of fish occurring in Sepik freshwaters form a major part of the freshwater ichthyofauna in other regions.

In addition to this gross geological factor affecting the basic composition of the fauna, the northern section of New Guinea has a recent geological history further determining the existing fauna. New Guinea and its associated smaller islands are situated between and are part of two major crustal elements, the continental, relatively stable land mass of Australia to the south and the deep ocean basin of the Pacific to the north (Löffler 1977). New Guinea has lain in the zone of interaction between the northward-moving Australian plate and the westward-moving Pacific plate. In simple terms, collision of these two plates has caused the uplifting of the central section of the

island, forming what is now referred to as the New Guinea highlands or the central cordillera. The cordillera separates northern and southern New Guinea into two distinct zoogeographic zones. This is witnessed by the division of the New Guinea freshwater fish fauna into two distinct groups. That in southern New Guinea is closely allied to the fauna of northern Australia, the two regions were previously joined across what is now the Torres Strait, whilst the northern region is characterised by a high degree of endemism of freshwater species (Allen and Coates 1989). All native Sepik/Ramu fish species restricted to freshwater are endemic to the Sepik/Ramu but belong to families occurring in southern New Guinea drainages, with one exception, a rainbowfish species occurring in both drainages (Allen and Coates 1989). The Sepik/Ramu basin is the largest faunal province of northern New Guinea, both in terms of its physical size and number of fish species. It extends from the Huon Gulf in Papua New Guinea to Geelvink Bay in Irian Jaya, encompassing the Markham, Ramu, Sepik and Mamberamo (Irian Jaya) river valleys. Although the two great systems, the Sepik and Mamberamo, are presently separated, they share a common geological history. There is a great similarity amongst the fish faunas of these drainages within this zone (Allen and Coates 1989), although only the Sepik and Ramu Rivers have been studied extensively.

Whilst the geological development of northern New Guinea helps a zoogeographic analysis of Australasian freshwater fishes, a further point is, however, more important in practical terms. Löffler (1977) considers the Sepik to have a more active and immature floodplain than the Fly, in southern New Guinea, as witnessed by its vigorously changing alluvial depositional system. The Sepik basin has probably been formed by down-warping due to compressional forces between the continental and Pacific plates. This, coupled with recent rises in sea-levels, has resulted only recently in rapid alluvial deposition in the present basin and the recent development of the existing floodplain. The precise timing of these events is conjectural but they are certainly recent. It is known that the present Sepik floodplains occupy an area that was, until very recently, an inland sea bordered by the Torricelli/Bewani mountains to the north and the central dividing range to the south. Recent archeological excavations at sites presently 70 to 600 km inland on existing floodplain confirm that such areas were marine/coastal habitats as little as 5,000 to 20,000 years ago (Swadling et al 1988).

A simplification of these points for the purposes of the present document are:

- (1) The Sepik is naturally devoid of primary and secondary freshwater fishes, in common with the rest of Australasia.

(2) The Sepik is much younger in geological terms compared with rivers in southern New Guinea, e.g., the Fly, and northern Australia. This accounts for the reduced species diversity in the Sepik compared with the Fly river (Allen and Coates 1989).

(3) The Sepik borders the deep Pacific plate whereas the rivers in southern New Guinea and northern Australian drainages discharge onto the continental plate. The Sepik, and other northern rivers, have no delta but drain via a single exit into deep water. This is in marked contrast to southern rivers which drain to shallow seas and are characterised by extensive deltas, estuarine and mangrove systems. In part, this factor may explain the absence from the Sepik of species belonging to New Guinea fish families dependent upon an extensive estuarine environment for their life-history (Allen and Coates 1989).

(4) Sepik floodplains are very young at between 5,000 and 20,000 years old. Although the "Sepik" as an independent area has existed for a longer period of time, the floodplain environment seen today, on a geological time scale, has only just appeared. To place this in perspective, Lowe-McConnell (1975), whilst discussing the evolution of fishes in the great African Lakes, refers to the younger Lake Victoria as being "only" 750,000 years old !

3. FISH AND FISHERIES

This report covers all fish species recorded from floodplain regions of the Sepik. Taxonomic descriptions for the species mentioned are provided by Allen and Coates (1989) together with references to specimens deposited in museums. Of 55 native fish species recorded from the whole Sepik catchment (i.e. including higher altitudes), 40 species are recorded from floodplain regions (Allen and Coates 1989). A list is provided in Table 1.

3.1 Yield of the floodplain fishery

The yield of the Sepik River floodplain fishery was estimated by Coates (1985) to be between 3,000 and 5,000 t yr⁻¹. This is approximately 10% of the yield predicted by comparison with African rivers. Coates also noted that about 50% of present landings were accounted for by the introduced tilapia, Oreochromis mossambicus. Therefore, the yield of the system based on native species is only about 5% of that expected. Coates (1985) concluded that, whilst increased fishing effort might produce modest improvements, the basic cause of the low yield was the impoverished fauna.

3.2 Comparisons with other regions by number of species

The whole Sepik catchment contains a known 55 native species compared with 89 species for the Fly (Allen and Coates 1989). Coates (1985) compared the number of species with data for rivers in other zoogeographic zones compiled by Welcomme (1979), resulting in figures of 59 species, by comparison with Africa, and 84 species, by comparison with Asia. However, it was also noted that such comparisons were unrewarding due to the predominance of diadromous and vagrant species in the Sepik which are normally excluded from species counts for other rivers. The Sepik is clearly depauperate in fish species even compared with the Fly river and certainly in comparison with rivers in other tropical regions, when diadromous species are excluded. Coates (1985) also noted that the habits of existing Sepik fishes were more important than the total number of species present, when attempting to explain the low fisheries yield.

3.3 Species important to the floodplain fishery

It should be noted that all fishes (Table 1) are eaten by people living in floodplain regions of the Sepik. The only exceptions would be those species too rare to be caught, and Redigobius bikolanus which is usually too small to be caught (maximum 35 mm SL, Allen and Coates 1989). There are, however, a very limited number of species important to the present fishery (Table 2); all being the larger, more common species. Of the native species, only the ariid catfishes, the two gudgeons and tarpon are important (Table 2). All other species are considered negligible in terms of fisheries landings. These data (Table 2) are, however, prior to common carp entering floodplain regions. Percentage landings are to be recalculated, but there will be no change in the relative importance amongst the native species.

Landings data alone do not fully represent the actual value of native species to the fishery since the nutritional value of fishes is also important. In this respect, Coates (1990) has noted the importance of fats obtained from ariid catfishes to the nutrition of people in the area.

4. ECOLOGICAL HABITS OF FLOODPLAIN FISH SPECIES

The following is a summary of the available information on the habits of all species encountered in the floodplain region of the Sepik river. All species of importance to the fishery have been covered in detail together with several lesser species where data exist (Table 1). There are limited data for some species which are all rare and not important to the present fishery. Neither do any represent an important part of the fauna in ecological terms and the lack of data is not considered important in order to give an overview of the important elements of the

fauna. Many of these lesser species are known only from single specimens.

4.1 Morphological adaptations of Sepik fishes

Morphological adaptations of New Guinea freshwater fishes are considered modest by comparison with those occurring in fishes from other regions (Roberts 1978). Whilst a degree of variation in body size and form occurs between Sepik fish species (Fig. 2) the most specialised fishes seen exhibit specialisations that are common to their respective families, not to the species themselves. There are no changes from the original familial body form that could be regarded as adaptations to riverine conditions. The exception to this would be the rainbowfishes, all members of the family being restricted to Australasian freshwaters but originally derived from the marine Atherinidae (Allen and Cross 1982).

The most morphologically specialised Sepik floodplain region fish is probably Zenarchopterus kampeni (Fig. 2). Its specialisations, however, are typical of its family and certainly did not evolve in freshwaters (Roberts 1978). A similar argument applies for all the other species recorded (Fig. 2). The most diverse family in floodplain regions are the ariid catfishes with five species present. These are typical of estuarine fork-tailed catfishes in general. Even amongst Sepik ariid species, although marked differences in habitats and ecology exist (Coates 1990), the species are difficult to separate on external characteristics alone.

Morphological adaptations would presumably have been limited, in evolutionary terms, by the fact that all species belong to essentially marine, not riverine, families and the comparative age of the river system. The latter factor, presumably, not allowing sufficient time for marked adaptations to evolve; even assuming that they would. In this respect it is notable that members of these families have never become markedly specialised in rivers in any region. In particular, Sepik fishes exhibit few morphological adaptations to floodplain conditions. They lack the prominent attributes of many floodplain dwellers from other regions, such as air-breathing apparatus, modified body and fin forms and the ability to withstand desiccation (e.g., Welcomme 1979).

In simple terms, based on morphology, Sepik fishes are typical of estuarine and marine groups which would be expected to be components of estuarine and mangrove habitats, not riverine and floodplain regions well inland.

4.2 Distribution of fishes within the river

A summary of locality collecting data is provided by Allen and Coates (1989). Of the species listed in Table 1 the following are restricted to the lower river, up to 100 km from the mouth, and are regarded as marine/estuarine intruders into the river: Chanos chanos, Microphis spinachoides, Ambassis buruensis, Mesopristes argenteus, Kuhlia rupestris, K. marginata, Pseudosciaena soldado, all three mullets (Liza spp), Eleotris melanosoma, Ophieleotris poracephala, Redigobius bikolanus and Brachamblyopus urolepis. In addition, the following species are recorded only as far as Ambunti, about 300 km upstream, and are also regarded as marine/estuarine vagrant species but intruding to a greater extent: Caranx sexfasciatus, Ambassis interrupta, Lutjanus goldiei. Of all of the aforementioned species only M. spinachoides is endemic, the others are recorded from either other New Guinea estuarine and/or riverine environments or more widely throughout the Indo-Pacific (full details in Allen and Coates 1989).

Only limited sampling has been undertaken in the upper reaches of the Sepik floodplain region. However, the following species are either known or presumed to occur throughout this region: Pristis microdon, Megalops cyprinoides, both eels (Anguilla spp), all five ariid catfishes (Arius spp), Tandanus novaeguineae, Zenarchopterus kampeni, Glossolepis multisquamatus, Glossamia gjellerupi (in marginal floodplain regions only), Eleotris aquadulcis, Oxyeleotris heterodon, Ophieleotris aporos, Glossogobius koragensis and the three introduced species tilapia, common carp, Cyprinus carpio, and Gambusia affinis. Most of these are freshwater breeders, many are endemic and only P. microdon, M. cyprinoides and eels are diadromous.

The attenuation of species with distance from the mouth is obvious from the above description. Fig. 3 places the data in graphical form. More systematic sampling in the Ramu system has confirmed this attenuation with distance from the river mouth. This reduction in species through the lower altitudes is due to the reduction in the marine/estuarine vagrant species with distance from the river mouth. A second attenuation of species with altitude occurs, i.e. irrespective of distance from the sea (Allen and Coates 1989; Van Zwieten 1989) and was also noted for the Fly by Roberts (1978), but this is outside the scope of the present report. The floodplain region referred to here is inhabited by a fairly uniform fauna throughout except for the predominance of vagrant species in the lower reaches. This is hardly surprising in view of the similarity of the environments within this region, and along its length, and the presumed ability of freshwater breeders to colonise them.

4.3 Adaptations to the floodplain

Within the floodplain region, the floodplain itself is regarded as being the habitat most different from the marine/estuarine, lacustrine or riverine environments from which present Sepik fishes are presumed to have arisen. The major difference is the gross seasonality of this habitat, being dry for six months a year, quickly inundated to a depth of only about 2.0 m for about six months and then suddenly becoming dry again at river draw-down (Coates et al. 1983). The floodplain environment is also normally the most productive in such river systems due to the inundation of large areas of shallow land that become available for fishes to colonise during appropriate times (Welcomme 1979). An analysis of the habits of Sepik fishes in response to flooding are fundamental to an explanation of why yield is low and for the identification of vacant niches.

Of the native species present, only Megalops cyprinoides, Arius nox, A. solidus, A. utarus, Tandanus novaeguineae, Zenarchopterus kampeni, Glossolepis multisquamatus, Oxyleotris heterodon and Ophieleotris aporos have been caught from the floodplain in any marked numbers. Ambassis interrupta, Glossogobius koragensis and Stenogobius laterisquamatus have been recorded on the floodplain only as the occasional single specimen, usually in marginal areas near rivers and lakes. Of these species only Oxyleotris heterodon, Ophieleotris aporos and Glossolepis multisquamatus produce significant populations on the floodplain. All other species in Table 1 are restricted to main river channels or permanent lakes.

Species inhabiting the floodplain are normally subject to great fluctuations in abundance in lakes and river channels as they migrate onto and off the floodplain at appropriate times. Investigations of seasonal changes in fish catches or landings of native Sepik fishes indicate that only Ox. heterodon, Op. aporos and G. multisquamatus exhibit marked migrations onto and off the floodplain in response to changes in river level. All three species also exhibit seasonal changes in feeding, condition, fat deposition and gonadosomatic index and gonad maturity stages in response to flooding, all factors increasing during the flood season. Only the two gudgeons, Ox. heterodon and Op. aporos, are important to the fishery. Even G. multisquamatus exhibits only modest affinity for floodplains as it appears to avoid clear water on floodplains and tends to prefer shallow but turbid areas.

The ariid catfishes, which account for about 50% of the landings of native species (Table 2), show a particular avoidance of the floodplain with the exception of A. nox. The latter species is the most highly specialised Sepik ariid which exhibits modest exploitation of the floodplain and modest seasonality in

its abundance and aspects of its biology. A. nox, however, is the smallest Sepik ariid and not significant in catches and landings. All other ariids tend to be restricted to lakes and/or river channels with little seasonality in their behaviour. Certain species even exhibit "reverse" seasonality by increasing feeding, condition and fat deposition in the dry season. Similar lack of seasonality is shown by M. cyprinoides and Ambassis interrupta whilst most of the other species are caught too infrequently to investigate this. The low abundance of these species is also taken to infer their lack of exploitation of the floodplain.

The introduced tilapia exhibits a marked affinity for the floodplain with great seasonal differences in catches and landings and in most aspects of its biology. The ability of tilapia to exploit floodplain conditions is regarded as being the major factor determining its relative success within the river. Common carp, a second inadvertent introduction, also exhibit an affinity for shallow recently flooded areas and are also influenced greatly by flood conditions, although there appear to be some differences in habitat preferences of these two exotics.

Landings and catch data (Table 2) clearly indicate that those species of importance to the fishery, which can be assumed to be those larger, more common species, exploit the floodplain with the exception of the ariids. This is expected since the floodplain is the major productive environment. Seasonality of floodplain fisheries is a common feature (Welcomme 1979) and due to the migration of fishes onto the more inaccessible productive floodplain during the flood and off again into lakes and channels where they are more readily caught during the dry season. The Sepik fishery is similarly seasonal. However, about 75% of the seasonal differences in catches are due to fluctuations in the abundance of the introduced tilapia, dry season catches of tilapia average perhaps 100 times flood season catches. The remainder of the seasonality of the fishery is accounted for almost entirely by only the two native gudgeons. In this respect, Coates (1990) noted the importance of ariid catfishes to the subsistence fishery since they are readily caught all year round, and particularly at times when tilapia and gudgeons are relatively unavailable.

4.4 Reproductive habits

A summary of knowledge on reproductive habits is provided in Table 3. It is likely that a number of species spawn in both freshwater and brackishwater, and/or marine environments, making a division into brackishwater, or marine, and freshwater species difficult. Out of the 40 species present in floodplain regions, 21 (53%) are either known to breed in brackishwater or the sea or are likely to do so. Only 19 species (47%) are known or likely to breed in freshwater. Of the freshwater breeders, a number may

also breed in brackishwater: five of the species are ariid catfishes, 4 are gudgeons (Eleotrididae) and 4 are gobies. One species, Pristis microdon, appears to only enter freshwater in order to breed and is actually a diadromous species. The breeding habits of Sepik fishes have a great bearing on their distribution within the region. All species where reproduction is known to be restricted to freshwater, without adults migrating to the sea, are species endemic to the Sepik, whereas those species with a brackishwater, or marine, phase of their life history tend to be distributed throughout New Guinea and nearby islands and those species where either adults or juveniles enter the sea are widely distributed within the nearby Indo-Pacific region (Allen and Coates 1989). Colonisation of the floodplain regions has been accompanied by endemism, in those species able to spend their full life cycle in freshwater.

Clearly, the majority of native fish species in floodplain regions are not freshwater species but dependent to varying degrees on the sea. It is interesting to note that all those species of importance to the fishery, i.e., the most abundant species, all have a fully freshwater life history, with the exception of Megalops cyprinoides which is of only modest importance to the fishery. In addition, Glossolepis multisquamatus is also abundant and a freshwater breeder. None of the species with a marine life history stage become abundant in the river or important to the fishery. On the other hand, the number of families and species that have evolved freshwater lifestyles is very limited.

The modes of reproduction amongst the species are regarded as being highly relevant to an understanding of the production from the floodplain region. Note is made of the preponderance of species within the river that have very low fecundities due to the production of large eggs. In the case of the ariids and Glossamia gjellerupi, this being due to their mouthbrooding habit. Fecundity in Sepik ariids was studied in detail by Coates (1988). Even the largest species, Arius coatesi, produces only a maximum of 170 eggs from a fish 625 mm standard length. Ariid eggs are between 9.30 and 13.8 mm in diameter. Large eggs are, however, not restricted to the mouthbrooders, although these are at the extreme of the trend. Many Sepik fishes produce large eggs and have low fecundity. A full appraisal of egg sizes in Sepik fishes is presently hindered by a lack of data on fishes in these families from other regions. Perhaps large egg production is a feature of the respective families involved. The precise situation is academic, the point is most species do tend to produce large eggs.

Dando (1984) notes the development of breeding specialisations amongst fishes associated with estuaries, particularly the occurrence of mouthbrooders. Such adaptations are understood to

be in response to the unusual instability of estuaries, in comparison with marine environments, and the existence of high levels of pathogenic microorganisms. Since Sepik fishes, and those in New Guinea freshwaters in general, are likely to have evolved from estuaries the occurrence of the breeding specialisations seen in existing freshwater species can be explained as arising from this source. Coates (1988) also discusses the biological significance of large egg production, concluding that a major advantage is to reduce predation on juveniles by producing young as large as possible before they become free-living. He also noted that such a phenomenon only makes ecological sense if the population of the species involved experiences relatively low mortality of adults.

Whatever the precise reason for large egg production in Sepik fishes, its existence is highly relevant. The theory that large eggs are in response to reduced mortality of adults agrees with knowledge of the Sepik fauna. None of the species producing large eggs, thus having low fecundities, are subject to predation on adults by other fishes. The only Sepik fish suffering high adult mortality through predation by other fishes is Op. aporos which has the highest reproductive rate of all Sepik species. It matures at a small size (young?), has very small eggs, relatively large gonads and is highly fecund. Its only predator is Ox. heterodon, which, although belonging to the same family, Eleotrididae, has a much reduced reproductive capacity: large eggs, small gonads, greater relative size/age at maturity. Significantly, Ox. heterodon does not suffer any predation on adults from other fishes. The relevance of fecundity etc. to predation within the system is mentioned in more detail later.

For the present purposes, low fecundities in Sepik fishes are regarded as being major constraints to their colonisation of the floodplain. This aspect was discussed in depth for the ariids by Coates (1988) who concluded that this was the major reason why ariids do not enter the floodplain. Floodplains, although productive environments, are also dangerous habitats. Mass mortalities normally occur with floodplain species through adults being trapped on the floodplain during river draw-down. Such mortalities have been recorded in the Sepik but limited almost entirely to tilapia. Swadling et al (1988) include a marvelous picture of a massive fish kill in Chambri Lake, a Sepik floodplain lake, which consists entirely of tilapia; although other species occur there it appears they either do not enter as deeply into the floodplain, or leave floodplain before tilapia at river draw-down.

Floodplain species are normally characterised by high reproductive rates, having high fecundity, low age of maturity etc. (Welcomme 1979). The argument is proposed that species with low fecundity, presumably offset by reduced juvenile mortality,

simply cannot "afford" high adult mortality by entering the floodplain. A major element of the Sepik fish fauna is, therefore, precluded from exploiting the floodplain by having a low reproductive capacity. Those species with high reproductive capacities, high fecundity, are generally limited within the river by being dependent upon the sea for reproductive purposes, e.g., eels, Megalops cyprinoides, many of the gudgeons and gobies, certain of the ambassids and Lutjanus goldiei. The theory is endorsed by the fact that the three native floodplain dwellers that produce large populations, Ox. heterodon, Op. aporos and G. multisquamatus, have much higher reproductive capacities due to the production of much smaller eggs than most of the other species breeding in Sepik freshwaters.

It would be interesting to take the above arguments further based on more quantitative data. For the present purposes, it is sufficient to note that although many Sepik species belong to families that are obviously pre-adapted to live within rivers, only the Eleotrididae and Melanotaeniidae have reproductive habits allowing significant colonisation of the floodplain. This is a major point since it suggests a likely reason why diversity amongst floodplain dwelling species is so low and production there is limited. The high reproductive abilities of introduced carp and tilapia are regarded as being a major factor allowing them to exploit floodplain conditions and produce large and productive populations within the river system.

4.5 Feeding habits

The available information on the diets of the native species are shown in Table 4. Diet data are obviously limited for the more rare species, most of these being known from one or two specimens. Of these, most are vagrant species that are more common in brackishwater, the sea or streams in coastal drainages; i.e., Chanos chanos, Ambassis buruensis, Mesopristes argenteus, Kuhlia rupestris, K. marginata, Liza spp, Ophieleotris porocephala, Eleotris melanosoma, Redigobius bikolanus and Brachyamblyopus urolepis. The only diet data for Pseudosciaena soldado are that one specimen was caught with a single B. urolepis in its mouth. The omission of diet data for these species is not considered important because they are not primarily river dwellers. The only Sepik endemic species where diet data are lacking are Microphis spinachoides, which presumably feeds on small crustaceans and other invertebrates, and Glossogobius spp 2, which presumably feeds on small invertebrates as for G. koragensis. The diet of Hypseleotris guntheri, non-endemic, is also unknown but presumably based on small invertebrates. Small eels do not feed in the floodplain regions whilst migrating to the upper reaches of the river and the stomachs of most eels migrating back down the river through this region were empty or contained vegetable debris. The main

habitat of eels is regarded to be outside the floodplain region. The diet of Glossamia gjellerupi is being studied in hill streams, its major habitat. Pristis microdon is presumably carnivorous if it feeds in the river at all. All Lutjanus goldiei investigated had empty stomachs but this fish is presumed to be a carnivore feeding on small fishes and molluscs, possibly also prawns.

The diets of the more common species, and all those of importance to the fishery, are reasonably well understood. There is much diet overlap amongst some species, both within and between families. No species are particularly specialised except Oxyeleotris heterodon, mentioned later, and Arius nox which filter feeds on small crustaceans and dipteran larvae. The following categories of food are of particular note amongst the native species:

(1) Prawns

Freshwater prawns, either small caridinid prawns or larger Macrobrachium spp, are fed on extensively by four species of ariid catfishes, Oxyeleotris heterodon and to a limited extent by Megalops cyprinoides.

(2) Piscivores

There is a remarkable lack of piscivorous fish within the river. Fish are eaten to a limited extent by Arius solidus and Arius coatesi but neither of these two species are considered predominantly piscivorous, in the case of A. solidus many of the fish in stomachs could have been scavenged from gillnets. The only truly piscivorous fish, at least amongst the known and common species, is Oxyeleotris heterodon. This species, however, feeds almost exclusively on Ophieleotris aporos despite the apparent availability of alternative species in its habitats.

(3) Small crustaceans, insects and insect larvae

Small crustaceans, i.e., excluding prawns, insect larvae (both small and large - see Table 4), together with adult insects from terrestrial sources feature prominently in the diets of a number of species including the ariids, Ophieleotris aporos, Megalops cyprinoides, Glossolepis multisquamatus and a number of the lesser species.

(4) Filamentous algae

This is only fed on only by Ophieleotris aporos which switches partly to this food in the dry season when its main food, insect larvae, becomes less abundant, and, strangely enough, in view of its general morphology, by Zenarchopterus kampeni.

(5) Coarse litter and aquatic macrophytes

This is eaten by a wide variety of species. However, all are considered to ingest such material incidentally together with target foods, especially insect larvae from amongst litter and aquatic vegetation.

(6) Detritus

Detritus is common within the stomachs of many species. However, with most it is again regarded as being ingested incidentally. Arius velutinus consumes large amounts of detritus but this, again, could be incidental since this species feeds predominantly on large insect larvae, especially Ephemeroptera, from river sediments. The mullets, Liza spp, are detritivorous but not considered a significant part of the river fauna, rarely entering from brackishwaters. Stenogobius laterisquamatus appears to feed extensively on coarse litter and especially detritus. However, the data for this species are limited as most stomachs examined were empty. Such food items could, again, be taken incidentally. It is unlikely that a goby would be a stenophagous detritivore. The species is also quite rare.

Further consideration of the feeding habits of Sepik fishes is presented later when niches are discussed.

The feeding habits of the introduced carp and tilapia are presently being studied in detail. Carp feed on small benthic invertebrates and detritus. Tilapia adults feed on "detritus", probably primarily surface algae and diatoms, whilst juveniles are predominantly insectivorous. The diet of Gambusia affinis in Sepik floodplain regions has never been studied but it is presumed to be mainly small invertebrates. The latter species is considered insignificant for the present purposes.

5. DISCUSSION

I will attempt to restrict my discussion to those points of direct relevance to the project.

Native Sepik/Ramu fishes are all obviously derived from marine families. An important factor is the predominance of species that are diadromous or vagrant marine species briefly entering the river only occasionally from an essentially marine habitat. The latter species can be ignored for the present purposes. None are important to the fishery. Few species, or families, have developed fully freshwater life cycles within the river. These are limited to the ariids, plotosids, gobies, gudgeons and rainbowfish. Only the two gudgeons, Oxyleotris

heterodon and Ophieleotris aporos, and the single rainbowfish, Glossolepis multisquamatus, have colonised the floodplain to any significant extent. Of these, only the two gudgeons are large enough to be important to the fishery. The lack of species adapted to exploit floodplain conditions is considered a major factor leading to the low fisheries yield from native species (Coates 1985, 1987a). Such a conclusion is endorsed by the success of carp and especially tilapia within the river, both species exploiting this productive environment. Considering the recent development of the floodplains, the existing situation is hardly surprising. Existing Sepik/Ramu fishes presumably evolved from rivers, streams, estuaries and possibly permanent lakes within the older catchment before floodplains developed. Consequently, existing riverine species are more diverse whilst floodplain species have recently arisen, accounting for the low diversity and lack of appropriate adaptations to this environment.

The modes of reproduction of the native species, or at least their families, are considered to be a major factor limiting their colonisation of the floodplain.

5.1 Conservation of species in relation to further fish introductions

Vulnerability of native species to the introduction of further exotics will be discussed in detail when a separate report is produced on each exotic proposed. Whilst all species might, in theory, be vulnerable to the introduction of any new fish species, some discussion of some major points can be made. There are two main areas of concern here.

(i) conservation of species important to the present fishery

Introduced fishes might be expected to produce significant populations themselves, if they did not there might be less cause for concern over their effects. There is, therefore, in theory a play off through increased fish availability through introduction against any possible reduction in production from existing species. However, the basic aim of the project is to supplement existing stocks with minimal predicted impacts on existing species. Whilst a possible reduction in total yield is unlikely, if introduced species succeed ecologically they also presumably produce fishable populations, it is believed that, irrespective of increases in yield, existing stocks should, ideally, be maintained. In this respect vulnerability of any of the following species is important:

- any of the ariids (except A. nox)
- Oxyeleotris heterodon
- Ophieleotris aporos
- tilapia (itself an exotic)
- carp (itself an exotic)
- to a lesser extent Megalops cyprinoides (over which there is less concern as it is a large diadromous species)

Of particular note here is the present fisheries importance of the ariid catfishes (Coates 1988, 1990). Such fish, apart from being unique in themselves, are considered to be highly important for nutrition within the region since they contain large amounts of fat which is highly esteemed by local people. They are also available all year round. Species considered for introduction must be viewed very closely with respect to their effects on ariids. There need not be cause for too much alarm since the ariids are large, aggressive mouthbrooding species generally restricted to main river channels and lakes. Arius utarus, and to a lesser extent A. solidus, even feed on fish scales rasped from other species, including the much larger Lutjanus goldiei.

(ii) conservation of species per se

The conservation of species in their own right is a consideration in itself. Although the reasons for conserving many of the more obscure species could certainly be debated, most are insignificant for fish production and no use to local people, the possibility of them being affected should be considered.

A major point in the present respect is that the majority of native species found within the river are migrants from the sea and occur widely throughout the region, usually at least elsewhere within New Guinea and generally throughout the Indo-Pacific. It is the Sepik/Ramu endemic species which should be considered with the greatest attention. Sepik/Ramu endemic species in floodplain regions are (after Allen and Coates 1989):

- Arius nox, A. utarus, A. coatesi
- Microphis spinachoides
- Eleotris aquadulcis
- Glossogobius bulmeri
- Glossogobius koragensis
- Glossogobius sp 2

(Note that additional endemic species occur in hillstream areas).

The worst possible scenario of the obliteration of any of the other species from the Sepik would at least not be considered serious in species conservation terms as they at least occur, and are usually widespread, throughout other regions. A serious problem with the above list is that a number are known only from

single or a limited number of specimens providing limited information on their biology. Amongst the above list it should also be noted that many occur, or are likely to occur, in coastal drainages or other larger river systems in northern New Guinea, e.g., the Gogol river in PNG, which are not included as target areas for introductions under the project. In particular, many may occur in the Mamberamo system in Irian Jaya, although that system is already subject to fish introductions outside of the scope of this project.

In view of the importance placed especially on the ariid catfishes, both in fisheries and conservation terms, it is considered essential that the possible introduction of primary and secondary freshwater catfishes from other regions into the Sepik, or anywhere in New Guinea, should be viewed with extreme caution. This subject is discussed, with further justification, by Coates (1990).

5.2 The identification of niche availability and niches considered potentially appropriate for introductions

This is a difficult area since niches are defined by species inhabiting them not by scientists looking at systems ! I will presently work on the assumption that the Sepik is similar to other tropical floodplain systems in most respects other than its freshwater fish fauna. Note however that the limnology of the system is being studied intensively, the invertebrate fauna and related fish food availability has been studied by Dudgeon (1989, 1989a), and the geology, climate and vegetation of the catchment has been summarised by Coates (1989a). None of these activities or reports have given any indication that the Sepik is atypical in these respects.

The niches that are potentially available in a floodplain river system are best identified by looking at the habits and habitats of species of fish that are part of diverse and long-established faunas. General descriptions of such faunas are provided by Lowe-McConnell (1975) and Welcomme (1979). A list of major habitats available in floodplain regions is provided by Welcomme (1979), all of these occur in the Sepik. The major sources of food in floodplain regions are as follows (after Welcomme 1979):

Autochthonous:

Plankton community

- phytoplankton
- zooplankton

- Benthic community
- mud and associated micro-organisms
 - insects worms and small crustaceans
 - molluscs
 - larger decapod crustacea

Plants, including filamentous algae and submerged, floating and emergent vegetation

- "Aufuchs" community (including the root fauna and flora of floating vegetation)
- epiphytic and epilithic algae
 - associated animals

Neuston, including surface-living insects and larvae at the air/water interface

Fish, including eggs and larval stages

Allochthonous:

- Vegetable matter
- leaves, roots, flowers, fruit and seeds of plants growing near water which contribute to the surface drift and to the mud and detritus
- Animal matter
- insects, arachnids, worms etc. falling into the water

The majority of floodplain fish species are very flexible in their feeding habits (Lowe-McConnell 1975). Nevertheless, despite the variety of food taken in by any one species, it is generally possible to classify fish into broad categories according to their predominant feeding habits. Matthes (1964) distinguished several categories of feeding habits in the Zaire river basin which were summarised by Welcomme (1979) as:

Mud-feeders, which eat finely divided silt, together with the micro-organisms and organic decay products it contains.

Detritus-feeders, which ingest vegetable debris, leaf litter and the associated animal communities.

Omnivores, which are widely represented by all families and most genera.

Herbivores, which can be further separated to:

- (a) microherbivores which eat algae and diatoms,
- (b) macroherbivores which eat higher plants,

Plankton feeders, these are usually rare owing to the lack of plankton in the riverine environment.

Carnivores, the most important group which subdivides into:

- (a) meso-predators which feed mostly on insects and crustaceans and which are either:
 - (i) feeders on allochthonous matter or neuston,
 - (ii) bottom feeders which eat insects and molluscs, or
 - (iii) carnivorous browsers which inhabit floating vegetation and feed on the small insects and crustaceans found there.
- (b) macro-predators
 - (i) generalised predators which feed on fish and larger invertebrates such as decapod crustaceans or insect larvae,
 - (ii) piscivorous predators which feed only on fish, and
 - (iii) fin nippers and other specialised predators.

Amongst the native Sepik species it is interesting that few fit into any specialised category, most being generalised omnivores. This agrees with the theory that the fauna is young and originally derived from generalised estuarine dwellers.

In consideration of the above, together with data on the feeding habits of native species, I have the following conclusions about feeding niche availability. Obviously, an in depth analysis of all available feeding niches would be rather complicated. I propose to limit discussion to those obvious niches that are not presently occupied to any extent by native species and where suitable species with habits to fill those niches could be found. The following is also a summary of much thought concerning which feeding niches are "safest" to fill with regard to conservation of the existing native fauna.

Firstly, the following trophic niches should to be avoided in floodplain regions due to their importance to presently existing native species:

- freshwater prawns
- insects and insect larvae as a major food source

The following are feeding niches considered to be obviously presently vacant or under-utilised:

(1) Algal grazers

None of the native species feed extensively on algae, especially diatoms. This food source is, however, exploited by the introduced tilapia, Oreochromis mossambicus. Consideration of utilising this niche with further species will be discussed at length in a report dealing with specific species proposed.

(2) Macrophyte feeders

There is no macrophyte feeder within the river.

(3) Detritus feeders

Detritus is not consumed extensively, if at all on purpose, by any of the native species with the possible very minor exception of the rare Stenogobius laterisquamatus. This is a particularly interesting observation and potential trophic niche. Bowen (1983) regards detritivory in fishes to be a highly specialised habit due to the morphological adaptations required to deal with this food source, i.e., modified guts, and the behavioural adaptations needed in order to find detritus within the river system. It is, therefore, hardly surprising that detritivores are lacking in the Sepik with its young fauna recently evolved from estuarine/marine families. Bowen (1983) notes the importance of detritivores amongst commercial catches in several rivers in south America, e.g., a single detritivorous species, Prochilodus platensis, accounts for 60% of the total ichthyomass of the Rio Parana. It is also possibly one reason why carp and tilapia have succeeded so well in the Sepik as they consume, at least in part, this food source. The success of Oreochromis mossambicus in particular suggests that Sepik detritus is particularly rich, or under-exploited, or both. Detritivores are a definite for consideration for introduction. They are unlikely to compete for food with any important native species. However, possible competition with carp and tilapia will be discussed in a later report.

(4) Mud feeders

Mud, i.e., very fine detritus, is not fed on extensively by any native species. Arius velutinus ingests certain amounts of mud but perhaps incidentally with its major food source, insect larvae, taken from river sediments.

(5) Allochthonous fruits and seeds

Fruits and larger seeds from forest trees, and other plants, that fall into the water are not consumed by any Sepik species. This, again, is hardly surprising due to the highly specialised nature of this habit. Particularly in S. America, this habit is exhibited by a number of commercially important species, particularly the large characins, but also a number of catfish (e.g., Goulding et al 1988). This topic will be covered in more detail in a later report. Forest cover of Sepik/Ramu freshwater habitats is extensive (Coates 1989a, Coates and Mys 1989).

(6) Mollusc feeders

There are no fish in the Sepik/Ramu feeding extensively on molluscs, although small gastropods are consumed occasionally by a number of species. This is particularly interesting in view of the fact that two exclusively malocophagous species of ariids occur in the Fly (Roberts 1978). However, it is possible that mollusc abundance is low in the Sepik due to zoogeographic reasons (Dudgeon 1989b). In this respect, the introduction of mollusc feeders will not be proposed until more detailed information is available.

(7) Phytoplankton feeders

Phytoplankton is not consumed by any existing fish species. Although rivers are generally depauperate in phytoplankton, the Sepik floodplain lakes, and possibly the floodplain, do support phytoplankton stocks (Coates et al 1983). The extent of this resource, however, may need further evaluation. There is a problem here since the obvious candidate phytoplankton feeder might be Oreochromis niloticus. This was discussed in depth by Redding (1989) who concluded that the introduction of a second mouthbrooding tilapia is to be considered with caution because of possible interbreeding and competition for nesting sites with the existing O. mossambicus. It may be necessary to look outside of the tilapias if a phytoplankton feeder is considered desirable.

(8) Piscivores

There is an obvious paucity of piscivorous fish species in the river. Only one species, Oxyeleotris heterodon, is a piscivore but feeds exclusively on Ophieleotris aporos. None of the other fish species, including the introduced ones, are preyed on to any significant extent by any fish. By comparison, the Fly River has at least six major piscivores: seabass, Lates calcarifer, one ariid, Arius augustus, Thryssa scratchleyi, Strongylura kreffeti, Glossamia aprion, Glossamia narindica (Roberts 1978) and probably at least one of the larger gudgeons.

Although this is an "obvious" vacant niche, the introduction of a piscivorous predator is not considered appropriate for the following reasons:

- (i) amongst those exotic species where adverse effects of introductions are known, or suspected, predators feature conspicuously;
- (ii) the target prey species for a predator could never be predicted with accuracy; and,
- (iii) most importantly: low fecundities amongst native species are regarded as being, in part, a response to low predation pressure on adult stages from other fishes. Therefore, it has been argued that most Sepik species are not adapted to predation (see especially Coates 1988 and 1990). Consequently, Sepik fishes are regarded as being especially vulnerable to the introduction of predators.

It could not be over-emphasised how important it is that predominantly piscivorous species of exotic fishes are kept out of New Guinea freshwaters. This I regard as also applying to the often proposed transfer of the barramundi or seabass, Lates calcarifer, from southern to northern New Guinea. I believe the risks are simply too great with this particular fauna. In view of the aforementioned alternatives such risks are also not necessary to take.

(9) Forage fishes

It is interesting to note that, at present, there are limited amounts of forage fish for a predator. Were a predator to enter the river system there is a great danger that it would prey on a limited food base. Importantly, many smaller fishes are endemic and predation on juvenile ariid catfishes would be a particular cause for concern. Despite the fact that the purposeful introduction of a predator is firmly inadvisable, a piscivorous predator might enter the river system in the future via means outside the influence of the project, or PNG authorities. In such an event, predicted impacts might be lessened were the forage fish base broadened before its entry. Consideration might be given to stocking forage fishes, provided they were ecologically acceptable. Such would be particularly useful were they to also contribute to nutrient re-cycling within the river system. This possibility should be given further thought and might be regarded as a longer-term consideration.

(10) Other niches

In addition to the above trophic niches, note is made of the potential to introduce specialised species capable of withstanding anoxic, or at least reduced oxygen, conditions on floodplains. These fishes form a conspicuous feature of faunas from floodplains in other regions. Such adaptations are notably absent amongst the present fauna. Species considered, however, should also preferably have feeding habits amongst the acceptable categories listed above.

5.3 Species from southern New Guinea and northern Australia with potential for the Sepik

Comparisons of the freshwater fish faunas of northern and southern New Guinea were made by Allen and Coates (1989). Whilst the low species diversity amongst Sepik fishes, compared with, e.g., the Fly, are explained in terms of the comparative ages of the systems, the interesting feature is that whole families are absent from the Sepik. There are no Sepik families that do not also occur in the Fly and N. Australia. The following families are present in the Fly but absent from the Sepik:

- Osteoglossidae
- Moringuidae
- Clupeidae
- Engraulidae
- Belonidae
- Iriatherinidae
- Pseudomugilidae
- Atherinidae
- Centropomidae
- Lobotidae
- Sparidae
- Toxotidae
- Soleidae

The transfer of fishes from southern New Guinea into the Sepik might be more acceptable on ecological and conservation grounds due to the close similarity of the systems and the nearness of the faunas in question. It certainly makes sense to look first at regions near to the Sepik for possible species to introduce. The above families do already co-exist in the Fly with species of fishes from all Sepik families. In response to this factor attention has been given to this possibility.

There are, however, certain problems with this approach. All fully freshwater Sepik species are different to their Fly counterparts. The converse argument is that introductions from

the Fly could be regarded as equally "exotic" as those from other regions. A further problem is that Fly species, in common with those from the Sepik, are also either diadromous or freshwater representatives of marine families. None are known to produce productive floodplain populations in the Fly, although several support significant riverine stocks there. Unfortunately, few Fly species occupy niches in the Fly identified above to be vacant in the Sepik. The transfer to Fly species to the Sepik should also be restricted to those families absent from the Sepik. There would be a great danger of loss of genetic diversity if Fly species that were closely related to, and could cross-breed, with Sepik species were to be transferred.

Of the above Fly families, of particular note are the Clupeidae, Engraulidae and Centropomidae, which produce fishable populations in the Fly. In particular, the barramundi or seabass, Lates calcarifer (Centropomidae) forms the basis of an important commercial fishery in the Fly. Fly clupeids feed on ostracods and insects and insect larvae (Roberts 1978). However, the Fly engraulid (Thryssa scratchleyi) and barramundi are piscivorous. The possible introduction of these into the Sepik, therefore, should be viewed with caution for the reasons already outlined.

A major problem with this approach is the consideration of why these families are absent from the Sepik. Allen and Coates (1989) proposed that many families may be absent from the Sepik because they are estuarine spawners or at some stage have a brackishwater life history phase. This particularly applies to the clupeids, engraulids and barramundi. Sepik brackishwaters are very limited in comparison to the extensive delta and estuarine zone of the Fly system. It is possible, therefore, that species in such families may not survive Sepik conditions if introduced; which may be why they do not already occur there.

Introductions into the Sepik from elsewhere within New Guinea, or from northern Australia, might be regarded by the international community as less controversial and preferable to more "exotic" species. However, an in depth understanding of the situation might suggest that such an overview is over-simplified. In view of the fact that New Guinea species do not fit the main target niches, the possibility of them not surviving Sepik conditions and the predatory habits of many of them I feel that this approach offers less scope than might, at first sight, be expected. In addition, certain species from other zoogeographic regions, being specialised in certain habits, may actually be safer since they might occupy vacant niches and have more predictable, stenophagous habits. Provided appropriate species are chosen, the arguments for exotic transfers, as opposed to translocations with Australasia, may be stronger on ecological/biological grounds, depending upon the species in question.

There are some species within southern New Guinea and northern Australia that might be of interest for introduction into the Sepik. For example, the Fly River bony bream (Nematolosa sp) offers an interesting possibility as it is a riverine dweller feeding on insects and detritus. Other species, for example, archerfishes (Toxotidae) may have potential for transfer to tributary stream environments but these will be discussed further elsewhere. It is not the purpose of this document to name species appropriate for introduction, but to outline the types of fishes thought suitable for stocking. Due attention to possibilities from the Fly and northern Australia will be given at a later stage. If appropriate, they should be given serious consideration.

5.4 Constraints on the development of the existing fishery in floodplain regions

Coates (1987a) has already outlined considerable constraints on increasing yield from floodplain regions based on existing stocks. In particular, the predominance of native ariid catfishes in present landings is a major problem. Due to their extremely low reproductive rate it is hypothesised that they would be quickly over-fished in any attempt to improve landings based on these fish (Coates 1988). This has already occurred in several areas where semi-commercial fisheries have developed with a subsequent rapid reduction in ariid landings. The ariids account for 25% of present landings; 50% of the landings of native species. The reproductive rate of Oxyeleotris heterodon is thought to be limited by its dependence on Ophieleotris aporos and the lack of predation on adults (Coates 1989). Increased landings based on Op. aporos might be expected to adversely affect the fishery for Ox. heterodon.

As fish populations begin to be exploited it is well known that the older, slower growing fishes with low reproductive rates, "k - selected communities", see, e.g., Lowe McConnell (1975) begin to be replaced by faster growing species with higher reproductive rates, "r - selected communities". The problem in the Sepik is that there are no, or few, native "r-selected" fishes to form the basis of a more intensive fishery. Any longer-term increases in landings must be based on the existing two exotics, common carp and tilapia, or further introduced species. Redding (1989) has, however, noted that existing tilapia stocks are more limited than previously thought, and they have already showed tendencies to become over-exploited, even at modest levels of fishing-pressure.

An interesting point arises here in that the introduction of the correct species of exotics may well help to preserve native fishes if fish landings are to increase in the future, as they

might be expected to do, irrespective of stocking. Any increases in fishing effort may, however, be expected to place additional pressure on native species. The most vulnerable group, the ariids, occur in areas, main river channels, that may not be target fishing areas for the present or future introduced exotics. If landings are to increase anyway, such species would in any case be vulnerable. The provision of alternative species might assist in the preservation of vulnerable species by giving the fishing community an alternative stock. This aspect provides a possible beneficial conservation aspect to exotic introductions. Although speculative, this illustrates just how complicated the issue of conservation is.

6. CONCLUSIONS

On ecological grounds, there is clearly potential for stocking fishes to exploit the following trophic niches within floodplain regions of the Sepik River:

- algal grazers, including diatoms
- macrophyte feeders
- allochthonous fruit and large seed feeders, in forest regions
- detritivores
- mud feeders
- phytoplankton feeders

In addition to these trophic niches it appears that there is considerable potential for introducing species able to withstand anoxic, or reduced oxygen, conditions on floodplains, provided they comply with the above requirements.

The actual proposal to introduce such species is a more lengthy subject and requires consideration of costs versus potential benefits, possible interactions with existing species, both native and introduced, quarantine implications and socio-economic justification. As such, a separate report dealing with each proposed species will deal with these matters. This present report serves only to identify those important niches considered to be the more logical and "safer" ones to consider for fish stocking purposes.

It is important that species considered for introduction should have, amongst other things, fairly stenophagous and, therefore, predictable feeding habits. They should also fill the

above niches. Attention should be given to possible transfers from southern New Guinea and northern Australia where possible.

Species feeding extensively on aquatic insects, small crustaceans and prawns should not be considered for floodplain regions.

Exotic riverine dwelling catfishes and especially any piscivorous predators should be considered for introduction with extreme caution.

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Table 1. List of fish species recorded from floodplain regions of the Sepik River (from Allen and Coates, 1989). Also indicated are information sources for the various species. Where no references are given refer to Allen and Coates (1989).

Pristidae	Kuhliidae
<u>Pristis microdon</u>	<u>Kuhlia rupestris</u>
	<u>K. marginata</u>
Megalopidae	Apogonidae
<u>Megalops cyprinoides</u> Coates 1987	<u>Glossamia gjellerupi</u> ¹
Anguillidae	Carangidae
<u>Anguilla marmorata</u> Coates 1983	<u>Caranx sexfasciatus</u> Coates 1983
<u>A. bicolor pacifica</u> Coates 1983	
Chanidae	Lutjanidae
<u>Chanos chanos</u>	<u>Lutjanus goldiei</u> Coates 1983 (as <u>L. argentimaculatus</u>)
Cyprinidae*	Sciaenidae
<u>Cyprinus carpio</u> Coates 1984, Ulaiwi 1989	<u>Pseudosciaena soldado</u>
Ariidae (all spp in Coates 1988, Coates 1990)	Cichlidae
<u>Arius (Brustiarius) nox</u>	<u>Oreochromis mossambicus</u> Redding 1989
<u>A. (B.) solidus</u>	
<u>A. velutinus</u>	Mugilidae
<u>A. utarus</u>	<u>Liza macrolepis</u>
<u>A. coatesi</u>	<u>L. melinoptera</u>
	<u>L. tade</u>
Plotosidae	Eleotrididae
<u>Tandanus novaeguineae</u> Coates 1983	<u>Butis amboinensis</u>
Hemirhamphidae	<u>Eleotris aquadulcis</u> Coates 1989b
<u>Zenarchopterus kampeni</u> Coates 1983	<u>E. melanosoma</u>
	<u>Hypseleotris guntheri</u>
	<u>Ophieleotris aporos</u> Coates 1989
	<u>Op. porocephala</u>
	<u>Oxyeleotris heterodon</u> Coates 1989

(Table 1 continued)

Poeciliidae*

Gambusia affinis

Melanotaeniidae

Glossolepis multisquamatus Coates 1990a

Sygnathidae

Microphis spinachoides

Ambassidae

Ambassis buruensis

A. interrupta Coates 1990b

Parambassis confinis

Teraponidae

Mesopristes argenteus

Gobiidae

Glossogobius koragensis

Glossogobius sp 2

Mugilogobius fuscus

Redigobius bikolanus

Stenogobius laterisquamatus

Gobioididae

Brachyamblyopus urolepis

* - introduced

1 - enters floodplain from tributary streams

Table 2. The approximate composition (by weight) of fish catches from floodplain regions (from Coates 1985).

Family/species	%
Tilapia (introduced)	50
Fork-tailed catfishes (Ariidae - 5 species)	25
Gudgeons (Eleotrididae) (<u>Oxyeleotris heterodon</u> and <u>Ophieleotris aporos</u>)	20
Tarpon (Megalopidae) (<u>Megalops cyprinoides</u>)	<5
All other species together	<5

Table 3. Summary of the reproductive habits of fishes occurring in floodplain regions of the Sepik and Ramu Rivers.

PRISTIDAE

Pristis microdon

Ovo-viviparous. Very low fecundity. Adults migrate from the estuary and young are produced in main river channels in the upper Sepik and Ramu Rivers (Allen and Coates 1989).

MEGALOPIDAE

Megalops cyprinoides

Breeds in coastal regions (Coates 1987)

ANGUILLIDAE

Anguilla marmorata and A. bicolor

Juveniles migrate to the upper reaches of the catchment where they grow and descend again to spawn in the sea (Coates 1983, Allen and Coates 1989).

CHANIDAE

Chanos chanos

Marine spawner (Allen and Coates 1989)

ARIIDAE

Arius nox, A. solidus, A. utarus, A. velutinus, A. coatesi

All species freshwater breeders. Males mouthbrood. Fecundity very low due to large eggs. (Coates 1988, 1990).

PLOTOSIDAE

Tandanus novaeguineae

Presumed to be a freshwater breeder which builds nests although not confirmed for this species (Coates 1983, Allen and Coates 1989).

HEMIRHAMPHIDAE

Zenarchopterus kampeni

Freshwater breeder (Coates 1983, Allen and Coates 1989). Has large eggs (2 to 3 mm diameter) and low fecundity. Breeder and

Rosen (1966) state that marine/estuarine species are egglayers whilst freshwater species tend to become ovo-viviparous. The exact situation in the Sepik species is not known. Coates has never observed ovo-vivipary in this species in the river but more extensive investigations are being undertaken by Van Zwieten in tributary streams.

MELANOTAENIIDAE

Glossolepis multisquamatus

Freshwater, on or near the floodplain in marginal vegetation (Coates 1990a). Relatively small eggs (1 to 2 mm diameter) with fecundity of between 50 and 300 eggs per fish.

SYGNATHIDAE

Microphis spinachoides

Males carry large eggs in their brood pouch (Duncker 1985). It is not known if breeding occurs in the estuary or river. Due to this species being endemic (Allen and Coates 1989) it is likely that it breeds in the lower, freshwater, sections of the river.

AMBASSIDAE

Ambassis buruensis

Breeds in coastal regions (Allen and Coates 1989).

Ambassis interrupta

Heavily dependent upon the estuary and considered to be primarily a marine/estuarine spawner (Coates 1990b).

Parambassis confinis

Freshwater breeder (Allen and Coates 1989).

TERAPONIDAE

Mesopristes argenteus

Marine/estuarine spawner (Allen and Coates 1989).

KUHLIDAE

Kuhlia rupestris, K. marginata

Presumably a marine/estuarine spawner with marine/coastal larvae - young enter coastal streams and mangroves (Allen and Coates 1989).

APOGONIDAE

Glossamia gjellerupi

Freshwater - oral brooders. Presumably brooding occurs by males (Breder and Rosen 1966) but there are insufficient observations on this species in the Sepik. Very large eggs and very low fecundity.

CARANGIDAE

Caranx sexfasciatus

Marine/coastal spawner (Allen and Coates 1989).

LUTJANIDAE

Lutjanus goldiei

Definitely spawns near the estuary. Juveniles only found in the lower river. Adults migrate upstream. It is not known if spawning occurs in freshwater or more saline areas. The species is recorded from southern New Guinea drainages and is therefore likely to have a marine/brackishwater life history phase (Allen and Coates 1989).

SCIAENIDAE

Pseudosciaena soldado

Marine spawner (Coates 1983, Allen and Coates 1989).

MUGILIDAE

Liza macrolepis, L. melinoptera, L. tade

All marine/estuarine spawners (Coates 1983, Allen and Coates 1989)

ELEOTRIDIDAE

Butis amboinensis

Presumed to breed in mangroves and estuaries but possibility of freshwater breeding not confirmed (Allen and Coates 1989).

Eleotris aquadulcis

Probably breeds in freshwater. Very high fecundity due to large ovaries and small eggs (mean 0.27 mm diameter) (Coates 1989b).

Eleotris melanosoma

Breeds in mangroves/estuaries or coastal regions (Allen and Coates 1989).

Hypseleotris guntheri

Not confirmed to breed in freshwater but due to its widespread distribution it can be assumed to have a marine/coastal life history at some stage (Allen and Coates 1989).

Ophieleotris aporos

Freshwater breeder with very high fecundity amongst the native species breeding within the river due to small eggs (mean diameter 0.297 mm) and large ovaries. Matures at an early age and has a very high reproductive rate (Coates 1989).

Ophieleotris poracephala

Presumed to breed in mangroves and estuaries (Allen and Coates 1989).

Oxyeleotris heterodon

Freshwater breeder. However, has low fecundity for its size due to large eggs (mean 0.46 mm diameter) and small gonad size compared with Op. aporos (Coates 1989).

GOBIIDAE

Glossogobius koragensis

Presumably a freshwater breeder but not confirmed (Allen and Coates 1989).

Glossogobius sp 2

Highly likely to be a freshwater breeder as it is endemic to the Sepik (Allen and Coates 1989).

Mugilogobius fuscus

Freshwater breeder (Allen and Coates 1989).

Redigobius bikolanus

Presumably breeds in brackishwater since it has a wide regional distribution and only adults enter the lower river (Allen and Coates 1989).

Stenogobius laterisquamatus

Presumably a freshwater breeder but not confirmed - possibly enters brackishwater and may also breed there (Allen and Coates 1989).

GOBIOIDIDAE

Brachyamblyopus urolepis

Brackishwater or coastal breeder (Allen and Coates 1989).

Introduced species:

CYPRINIDAE

Cyprinus carpio

Freshwater spawner. Very high fecundity (Coates 1984, Ulaiwi 1989).

CICHLIDAE

Oreochromis mossambicus

Freshwater. Females mouthbrood, males build nests in shallow areas of more permanent water close to floodplain but not on it (Redding 1989).

POECILIIDAE

Gambusia affinis

Ovo-viviparous in freshwater.

Table 4. A summary of the feeding habits of native fishes from the floodplain region of the Sepik River system. Where no references are given the data are to be found in Allen and Coates 1989.

? - refers to numbers examined not known or percentage composition not known (see Allen and Coates 1989).

* - most stomachs empty (caution - feeding data biased)

Food categories:

- a - filamentous algae
- b - aquatic plant tissue
- c - Salvinia root hairs
- d - coarse litter (wood, fallen leaves etc)
- e - detritus (fine particulate organic matter)
- f - small Crustacea (excluding adult prawns)
- g - caridinid prawns
- h - Macrobrachium spp prawns
- i - gastropod molluscs
- j - large insect larvae (e.g. Ephemeroptera, Odonata, Lepidoptera)
- k - small insect larvae (e.g. Coleoptera, Diptera)
- l - insects from terrestrial sources
- m - Hirudinea
- n - oligochaetes
- o - unidentified eggs
- p - fish scales
- q - whole fish or large parts of fish bodies

Table 4. Continued:

[illegible]

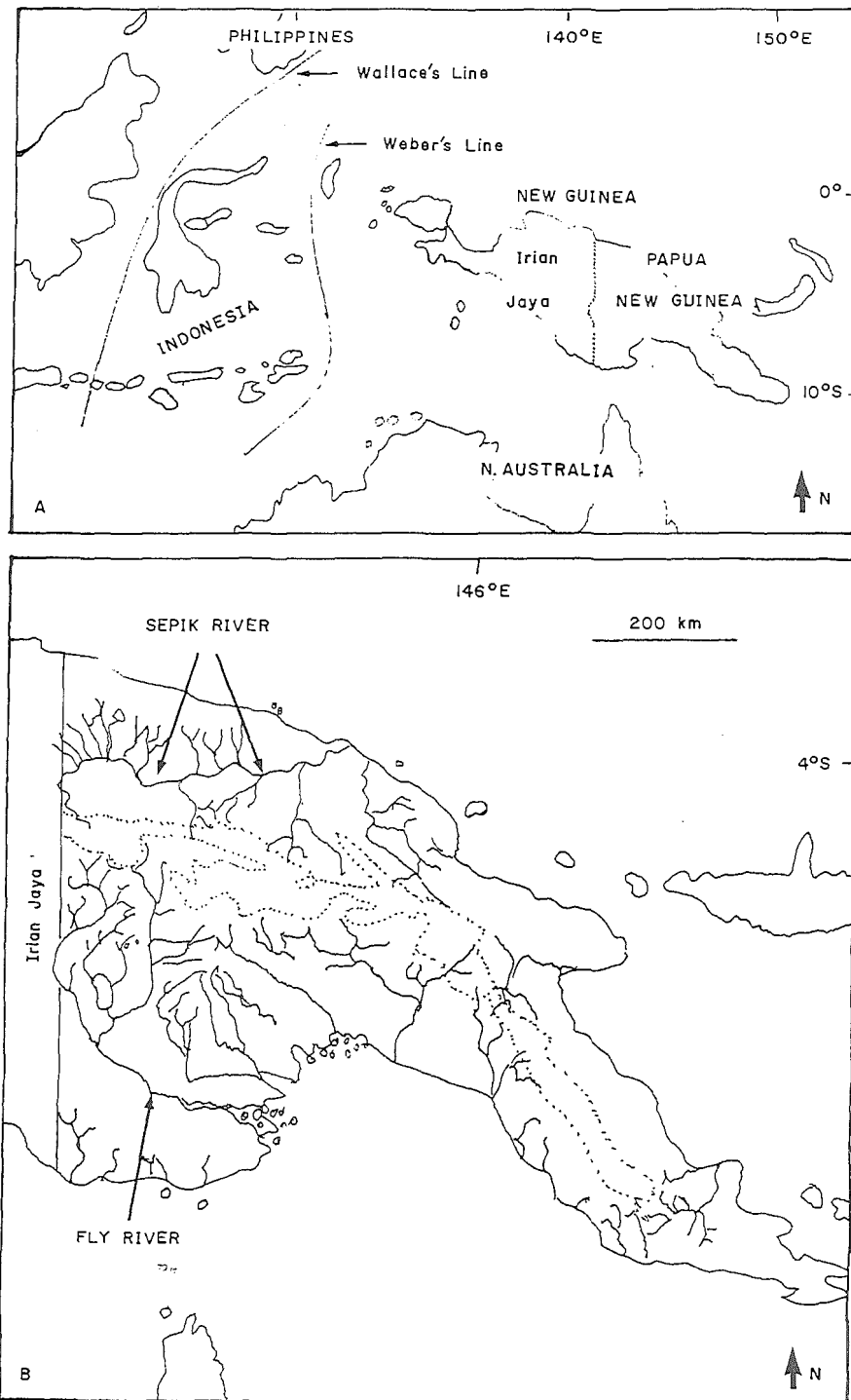
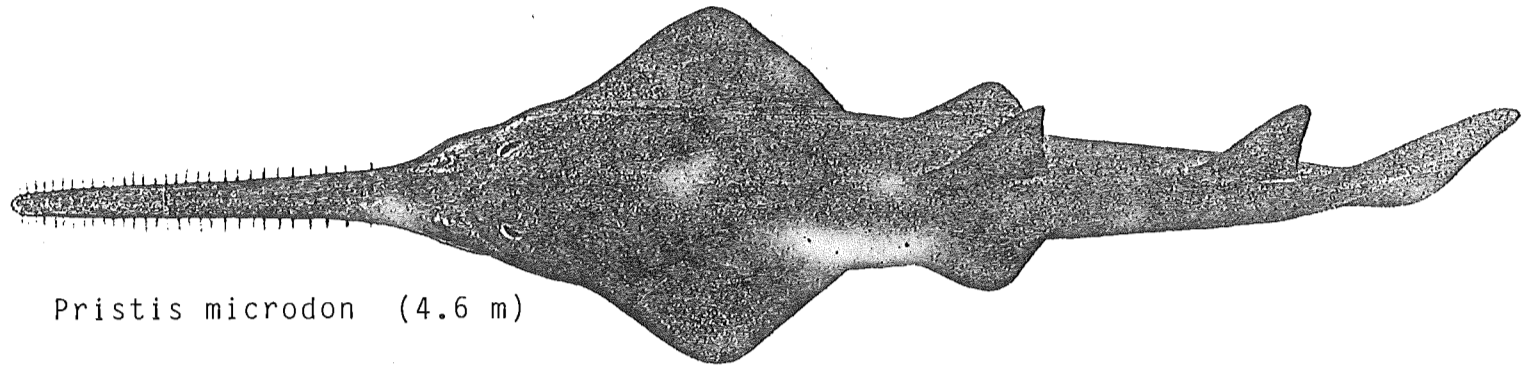


Figure 1. A — Sketch map of the region showing the island of New Guinea and Wallace's and Weber's Lines which represent zoogeographic boundaries between Australasia and Asia (to the west). B — Sketch map of Papua New Guinea showing the location of the Sepik River System. The stippled area represents the central dividing range separating rivers in the north from those in the south.

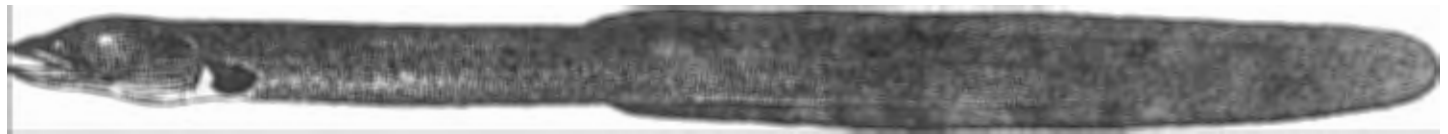
Fig. 2. Copies of drawings of Sepik River fishes, from original paintings by Roger Swainston. In brackets are maximum standard lengths achieved by the species in the Sepik River.

Continued over.

Fig. 2 continued



Pristis microdon (4.6 m)

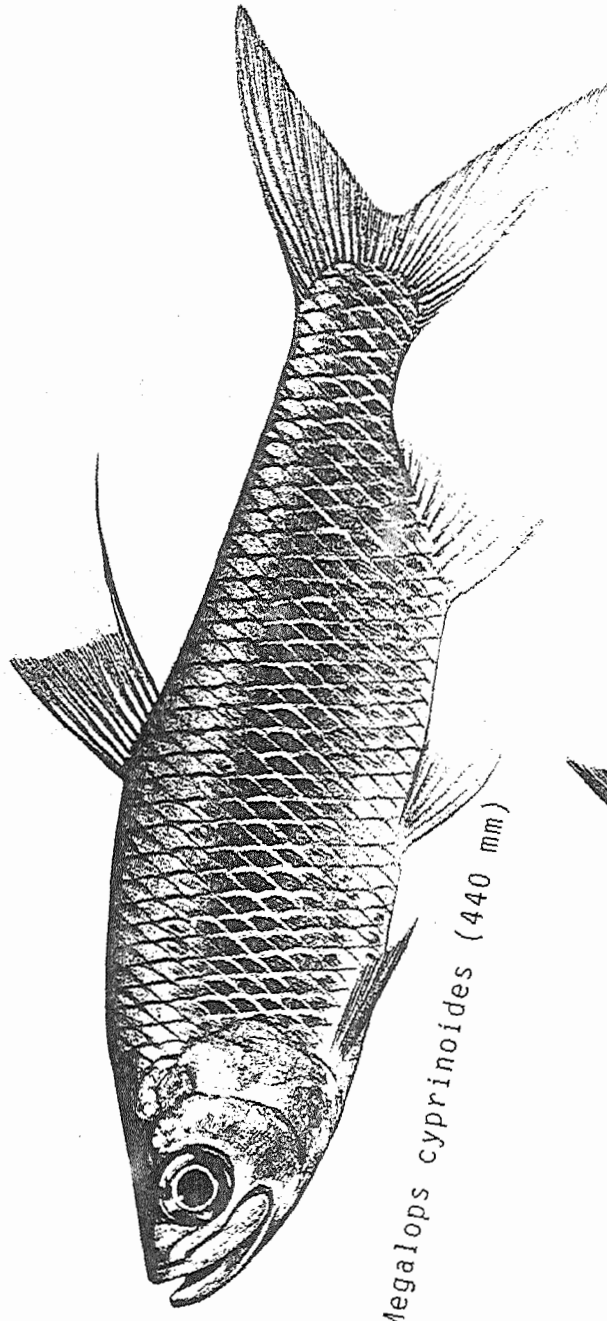


Anguilla bicolor pacifica (1.0 m)

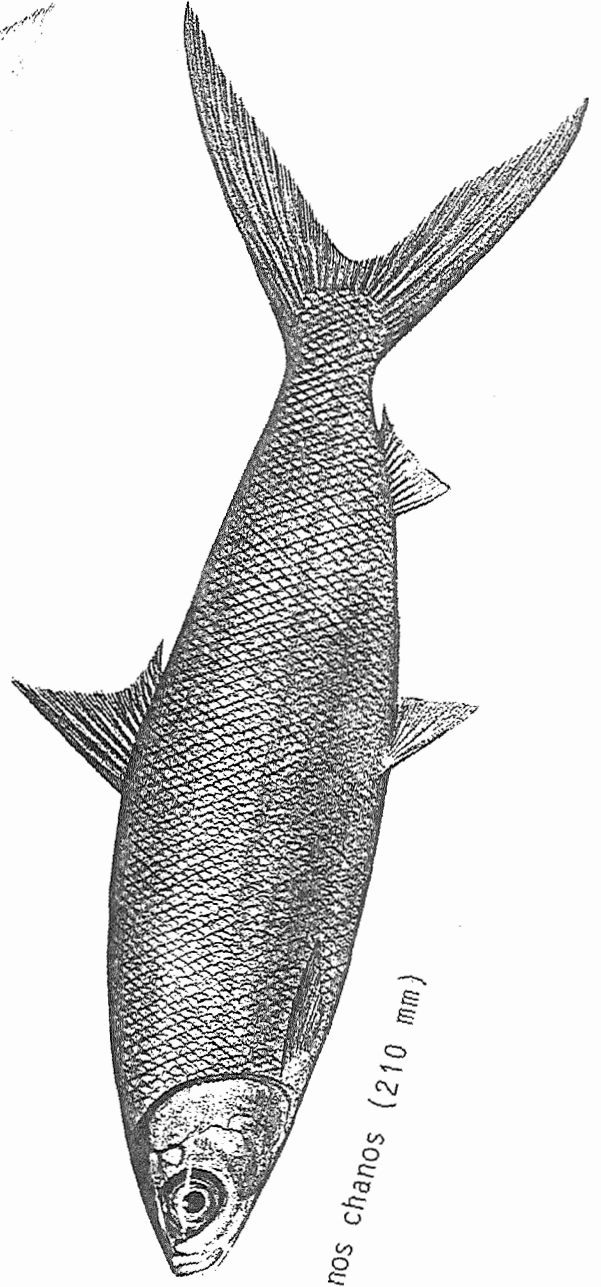


Anguilla marmorata (1.8 m)

Fig. 2 continued



Megalops cyprinoides (440 mm)



Chanos chanos (210 mm)

Fig. 2 continued

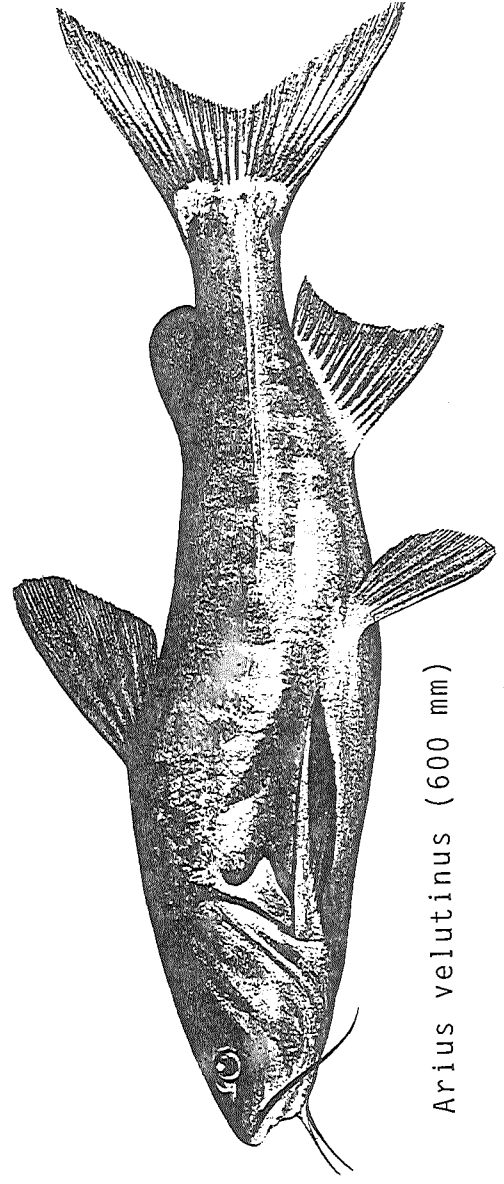
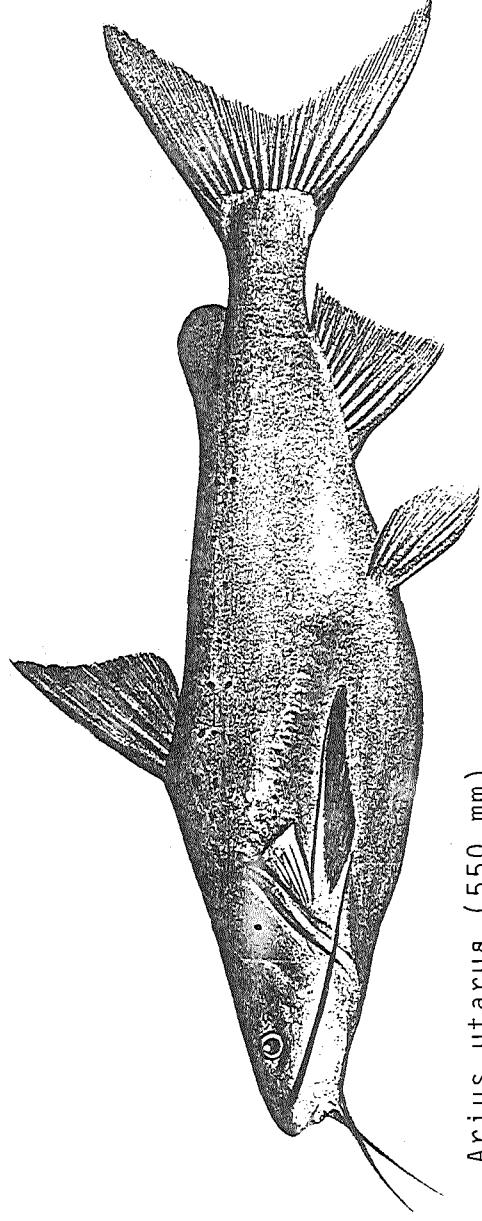


Fig. 2 continued

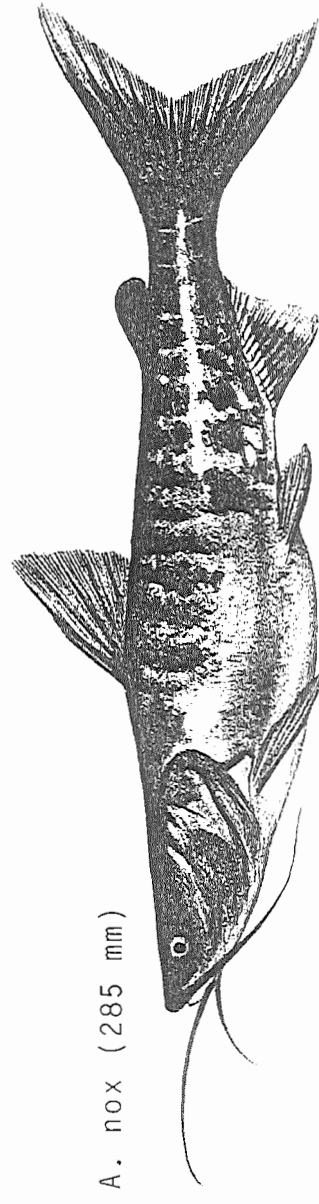
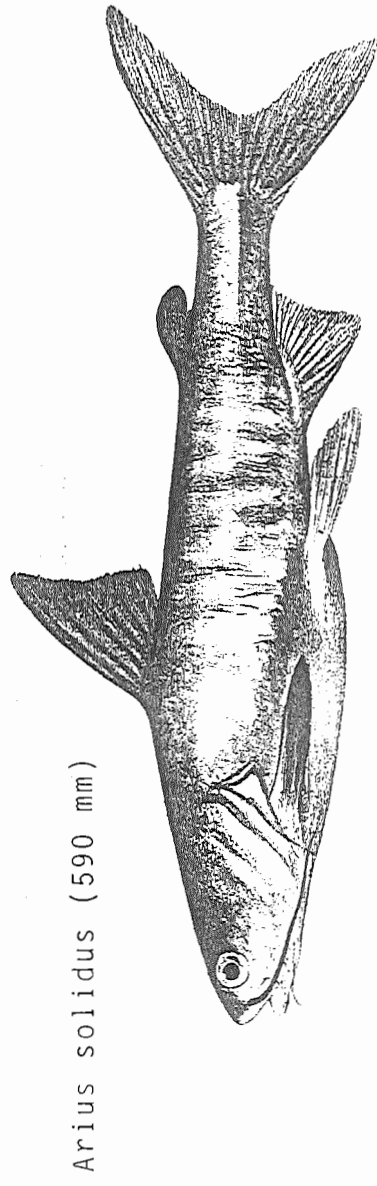
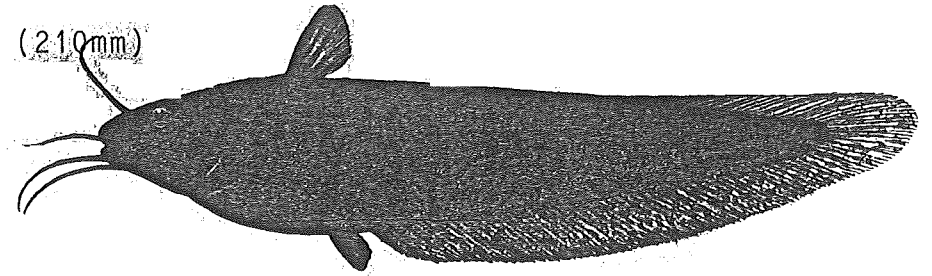


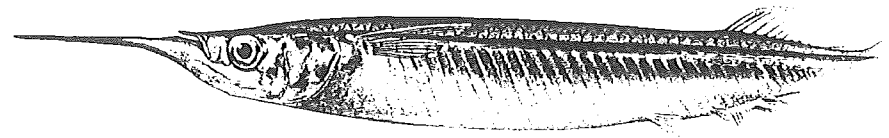
Fig. 2 continued

T. novaeguineae (210 mm)



T. novaeguineae

Zenarchopterus kampeni (195 mm)



Kuhlia rupestris (172 mm)

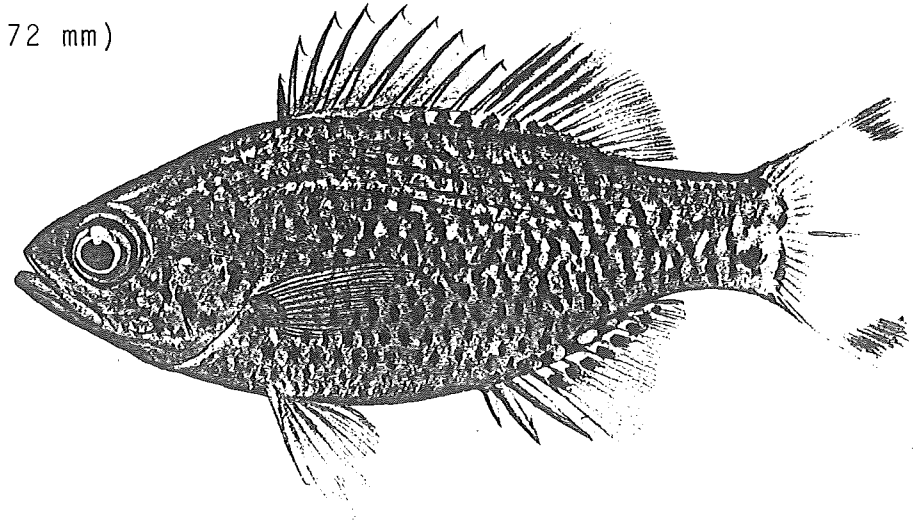
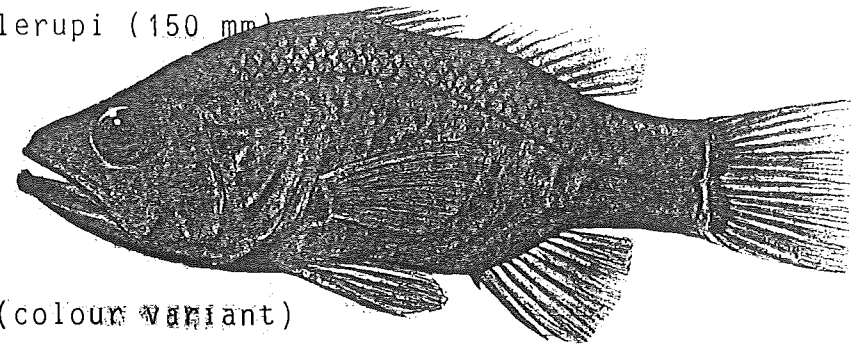
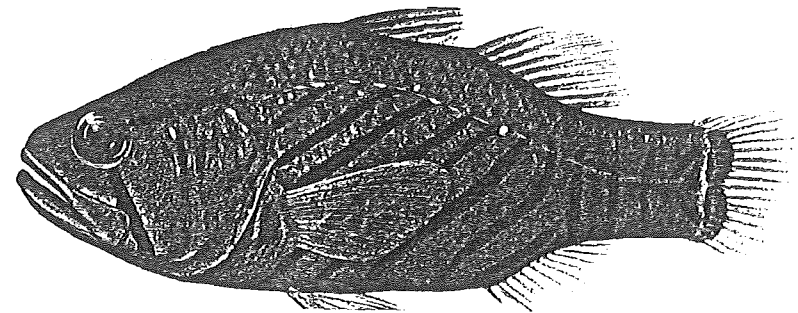


Fig. 2 continued

Glossamia gjellerupi (150 mm)



G. gjellerupi (colour variant)



Caranx sexfasciatus (to about 500 mm)

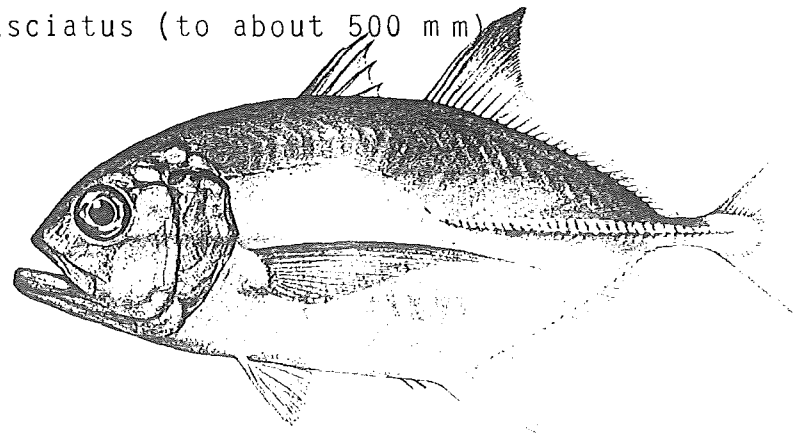
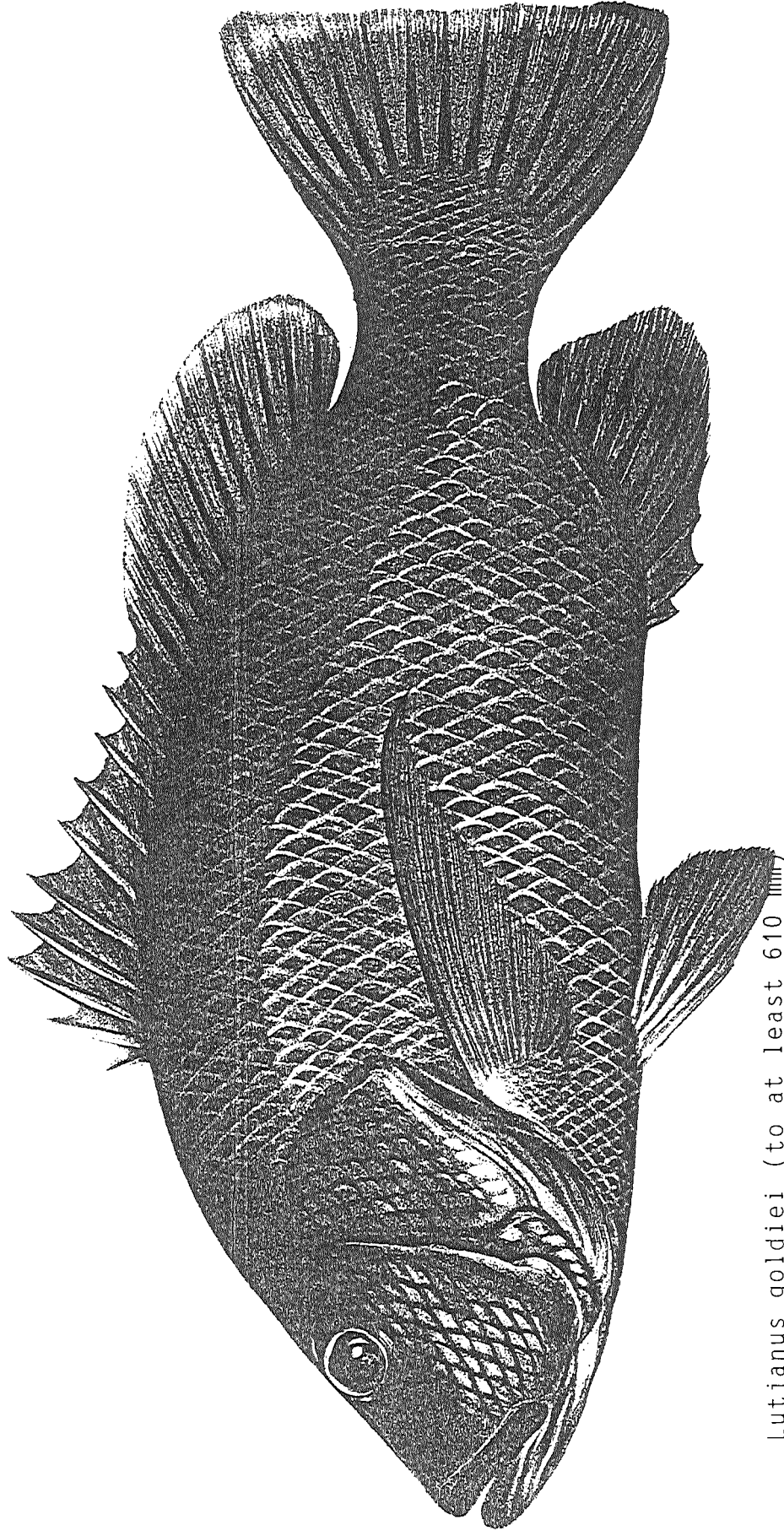
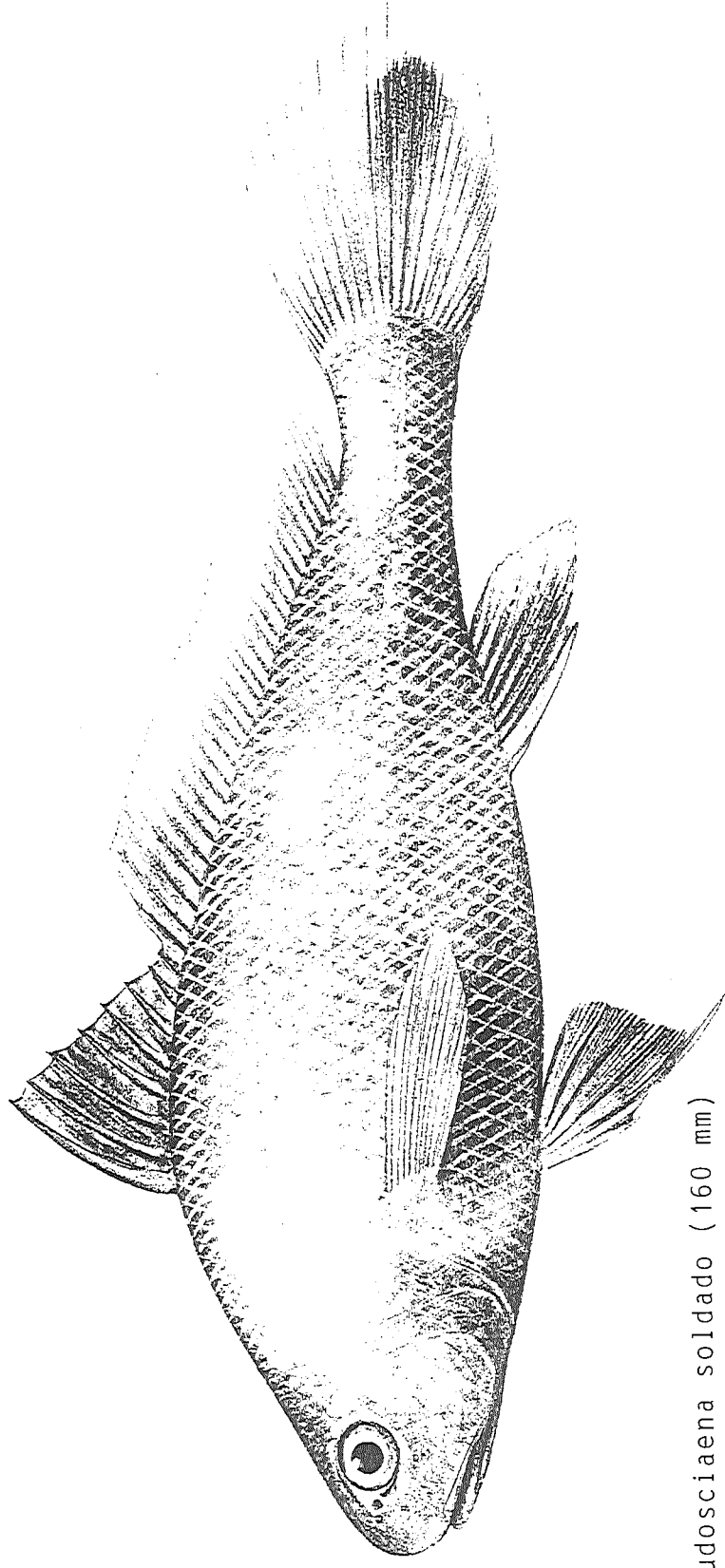


Fig. 2 continued



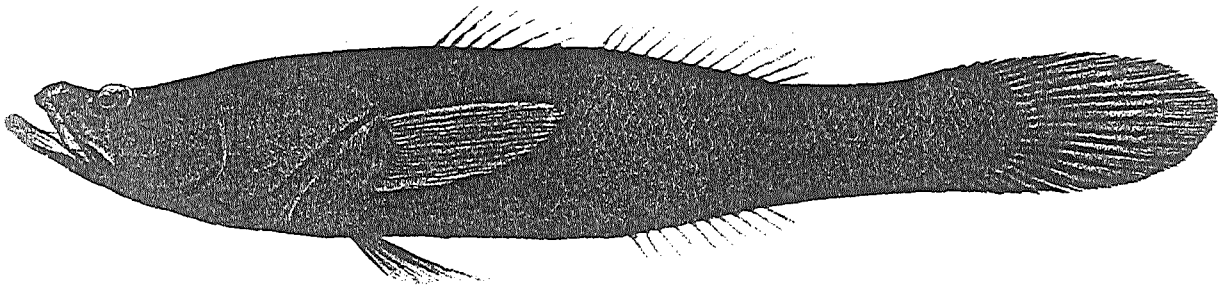
Lutjanus goldiei (to at least 610 mm)

Fig. 2 continued

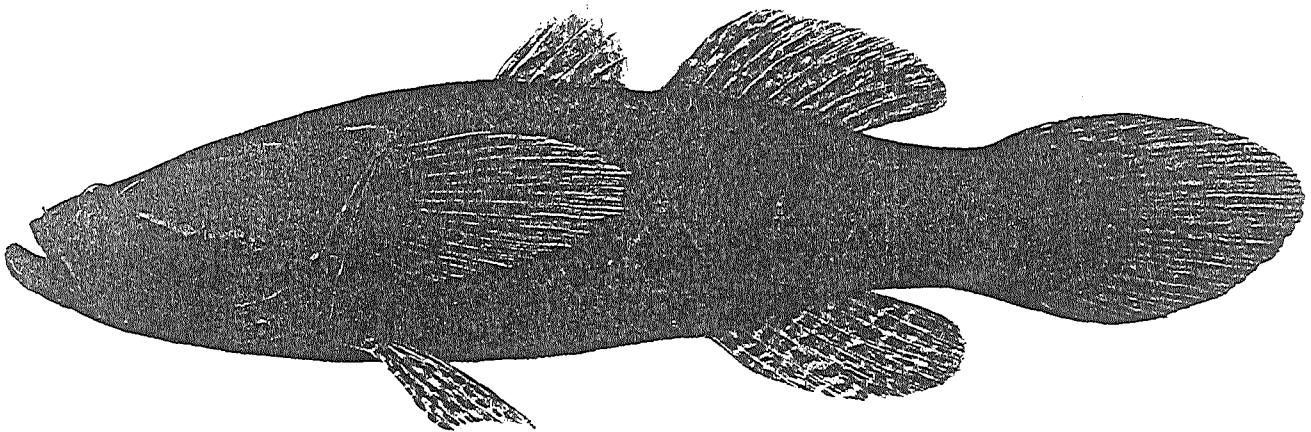


Pseudosciaena soldado (160 mm)

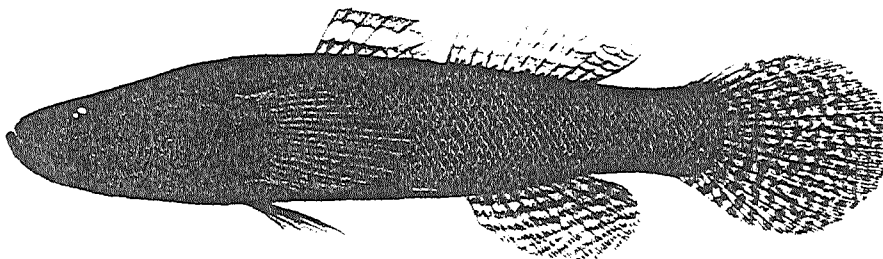
Fig. 2 continued



Oxyeleotris heterodon (404 mm)

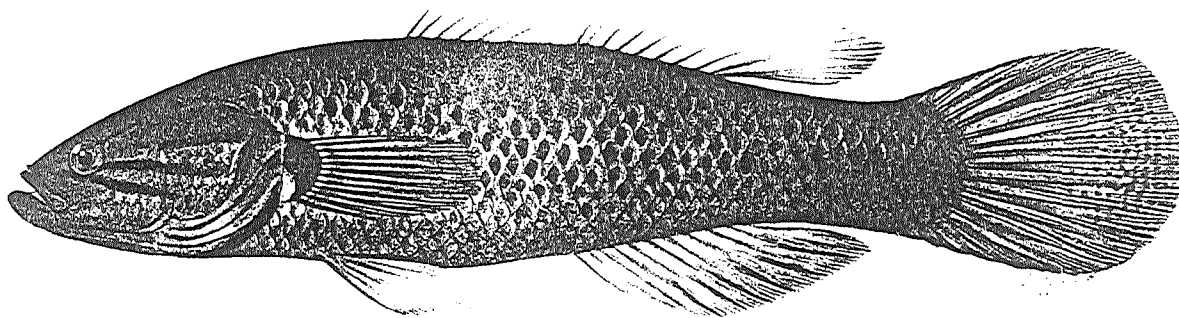


Eleotris aquadulcis (266 mm)

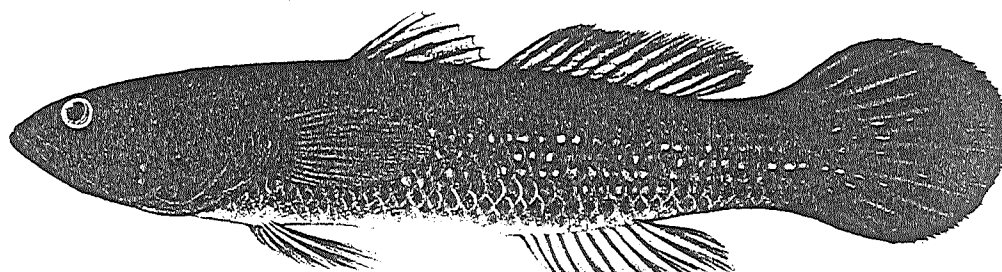


Eleotris melanosoma (117 mm)

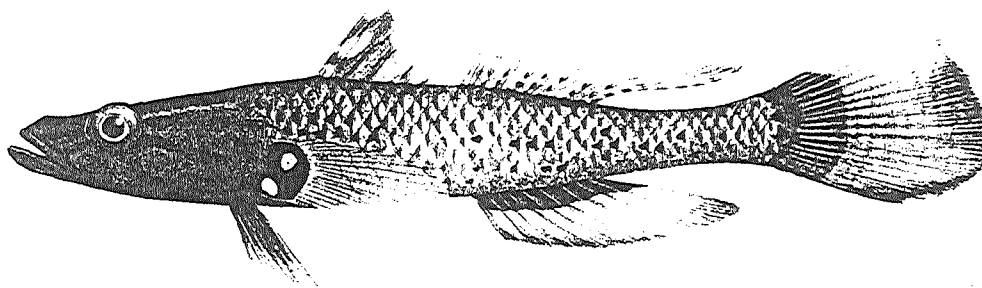
Fig. 2 continued



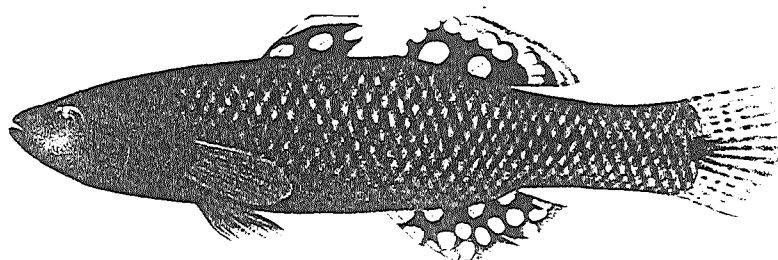
Ophieleotris aporos (196 mm)



Ophieleotris poracephala (109 mm)

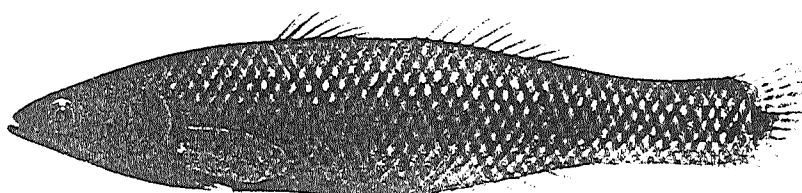


Butis amboinensis (84 mm)



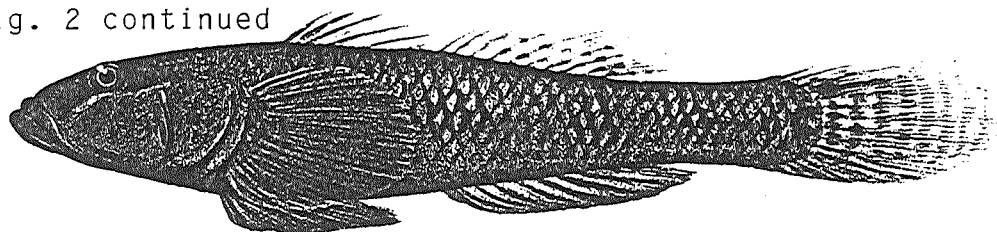
male

Hypseleotris gunteri (60 mm)

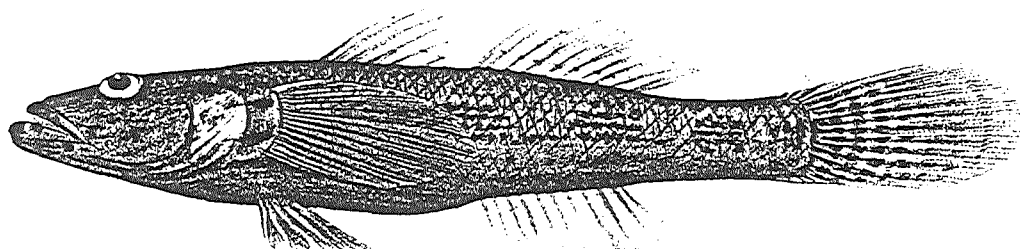


female

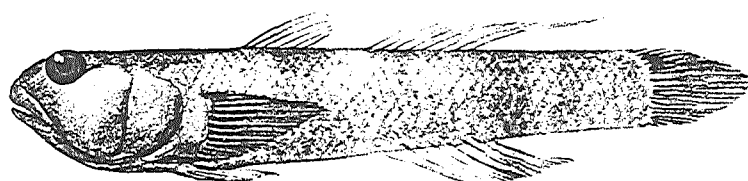
Fig. 2 continued



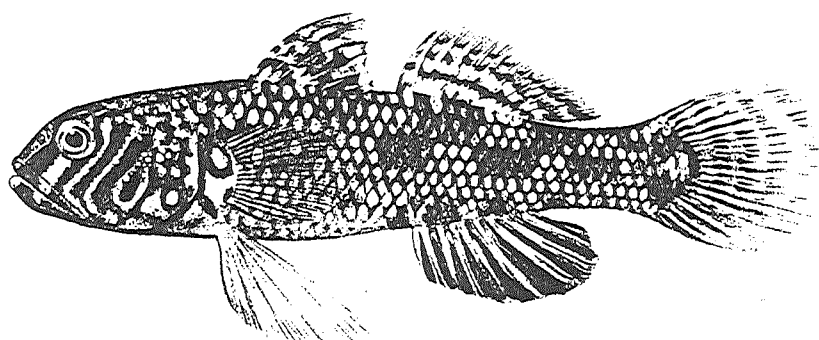
Glossogobius sp (76 mm)



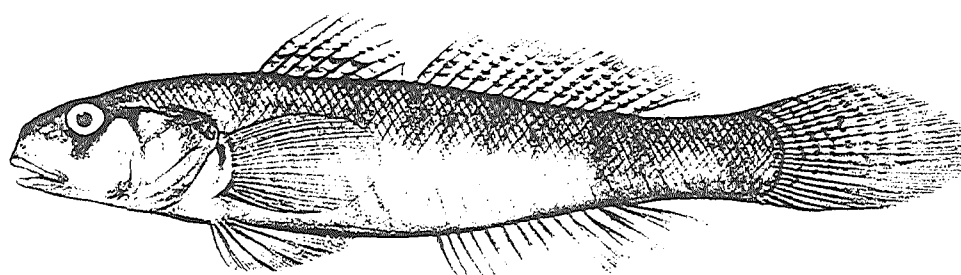
Glossogobius koragensis (126 mm)



Mugilogobius fuscus (31 mm)

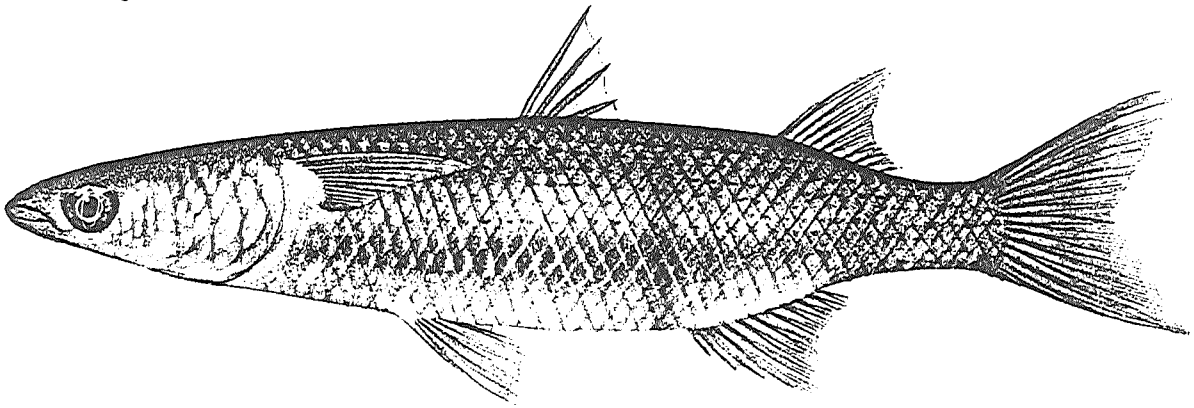


Redigobius bikolanus (27 mm)

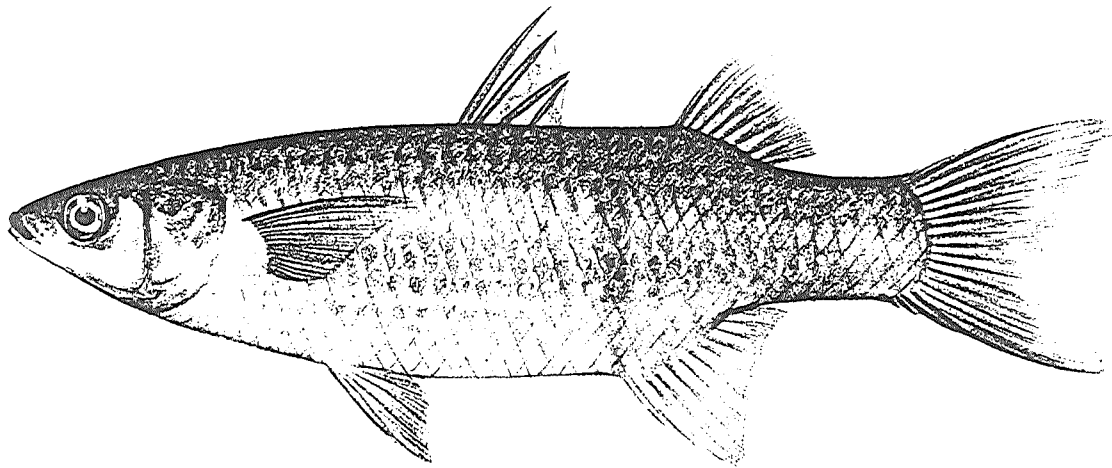


Stenogobius laterisquamatus (215 mm)

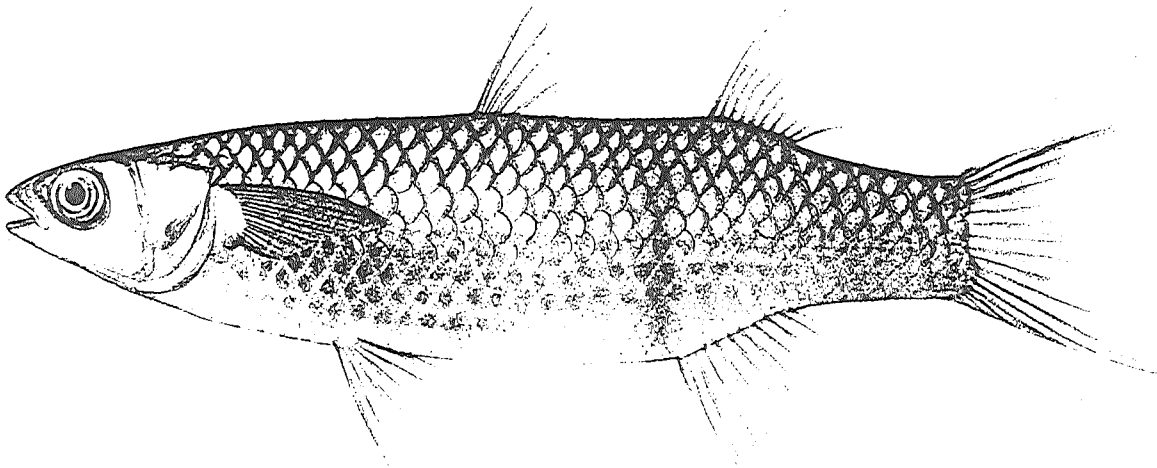
Fig. 2 continued



Liza tade (84 mm)

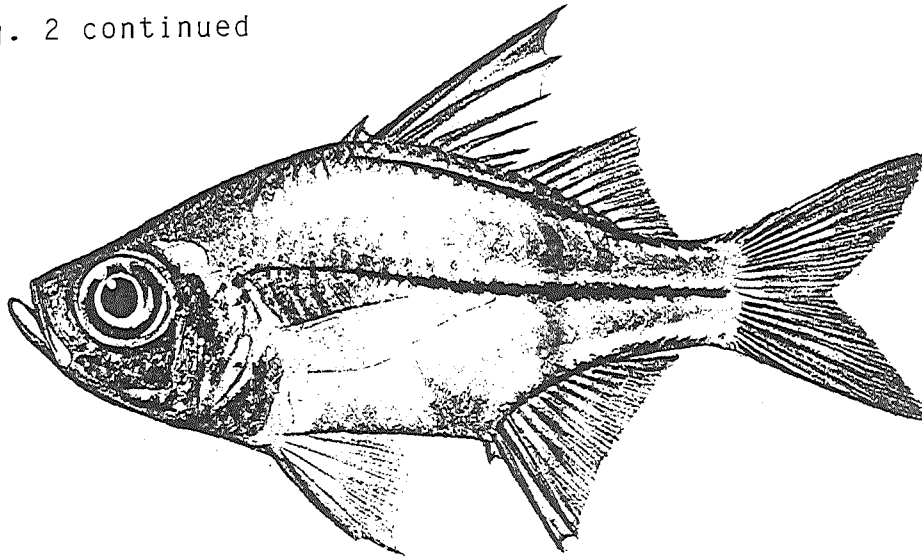


Liza melinoptera (150 mm)

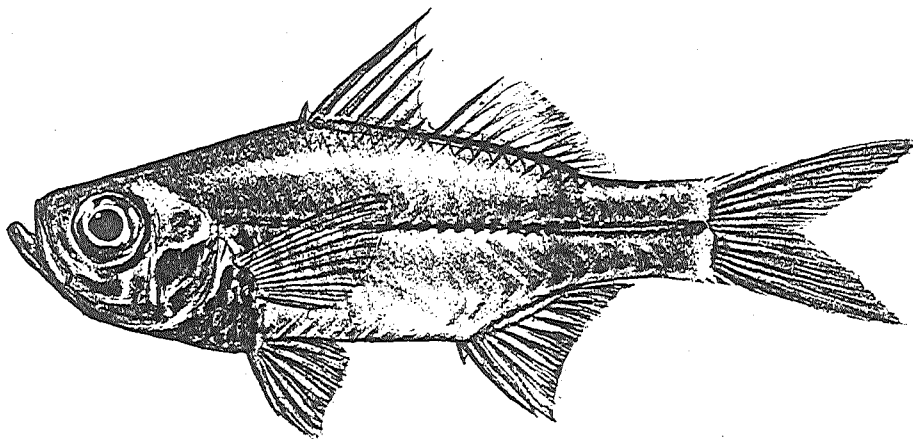


Liza macrolepis (300 mm)

Fig. 2 continued

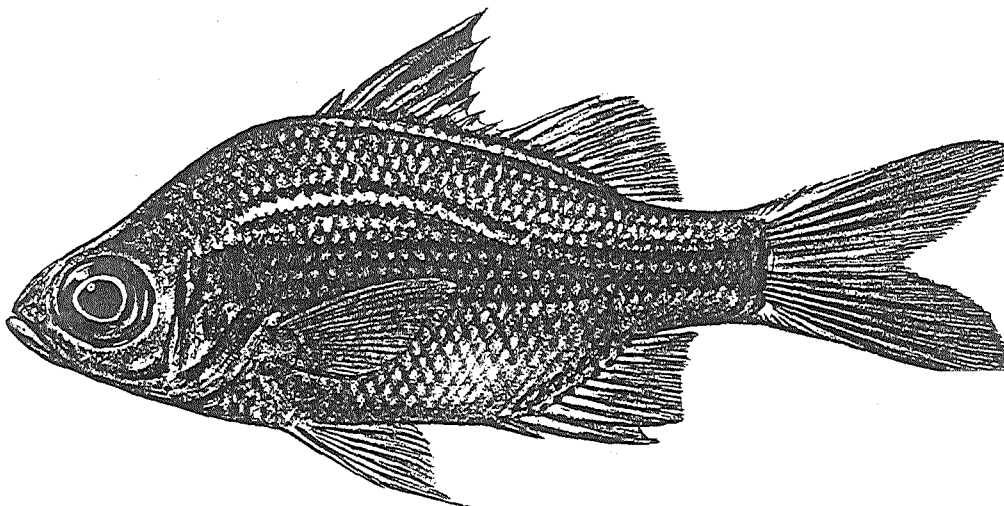


Ambassis interrupta (115 mm)



Ambassis buuensis (50 mm)

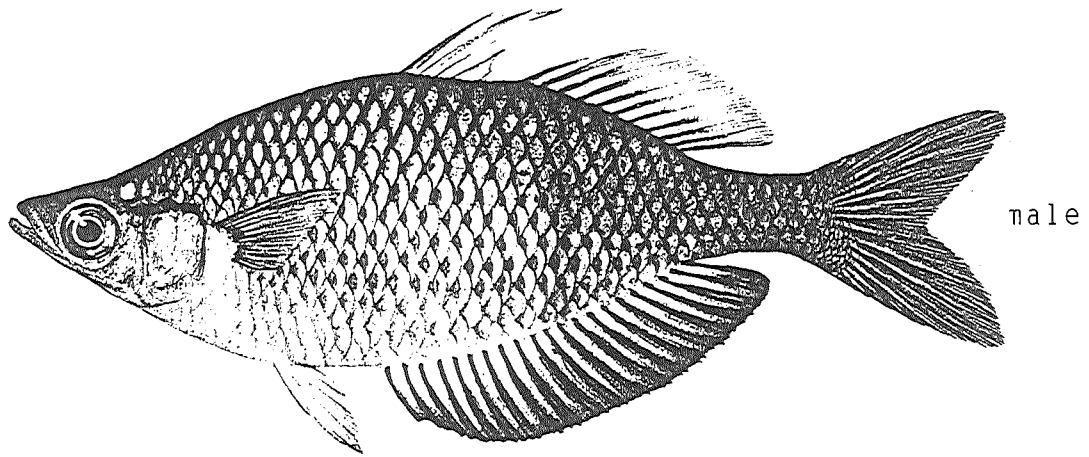
Ambassis buuensis ?



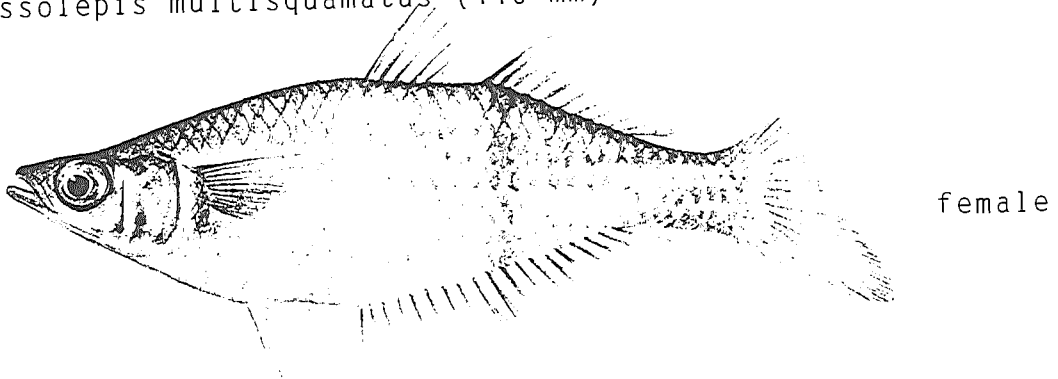
Parambassis confinis (100 mm)

Parambassis confinis

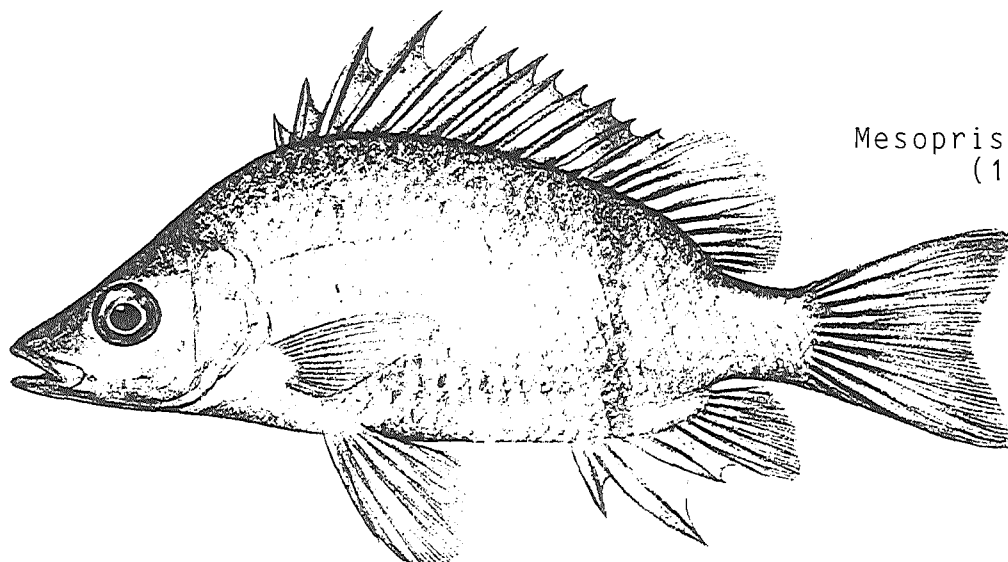
Fig. 2 continued



Glossolepis multisquamatus (110 mm)

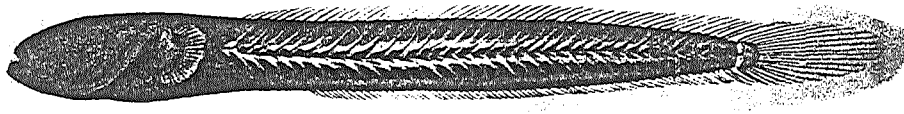


female



Mesopristes argenteus
(160 mm)

Fig. 2 continued



Brachyamblyopus urolepis (84 mm)



Microphis spinachoides (150 mm)

spinachoides

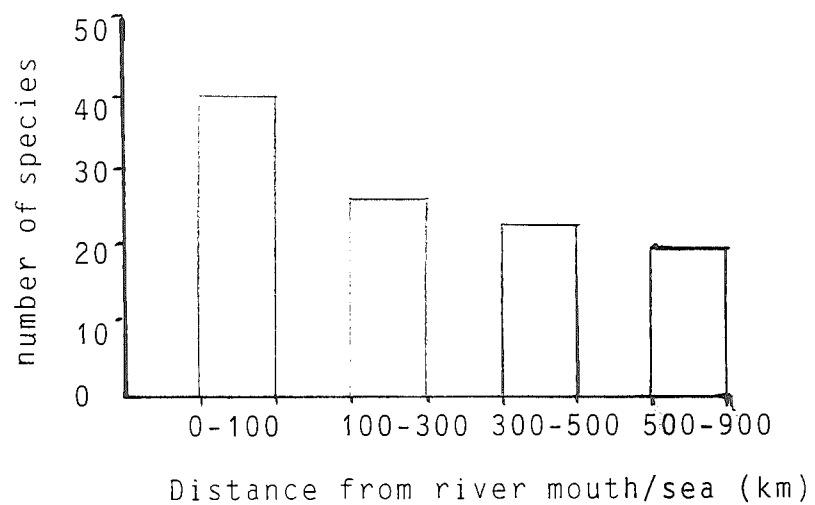


Fig. 3. Numbers of fish species recorded in the Sepik River against distance from the sea. (Note: from 0 to 200 m elevation only).

