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# Fisheries survey of the upper Purari River. Part 2 - Results and discussion.

A report prepared for the Sepik River Fish Stock Enhancement Project, PNG/85/001

by

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# 1. INTRODUCTION

This report provides results and discussion of data from a fisheries survey in lower order streams of the central Highlands of Papua New Guinea undertaken from August 1991 to August 1992. The survey can be considered as an extension of a similar survey of the Sepik/Ramu catchment undertaken by Van Zwieten as part of phase one of the Sepik River Fish Stock Enhancement Project (SRFSEP) (Van Zwieten 1990).

The freshwaters of Papua New Guinea are separated by the central highlands, into a southern and a northern catchment with only very few fish species shared between these two areas (Allen 1991).

The sampling stations in this study are all within the upper Purari River catchment, draining southwards from the central highlands to the Papuan Gulf. Thereby, a comparison between the higher altitude ichthyofauna of a southern river system and a northern (the Sepik/Ramu system) is attempted. The sampling stations are listed in a seperate report (Povlsen 1993a).

Stocking of higher altitude rivers and streams in the Sepik/Ramu catchment has been given high priority by SRFSEP, and several coldwater fish species have been recommended by the project (Coates 1991).

A follow-on project (FISHAID) dealing with stocking higher altitudes in the Sepik/Ramu commenced in March 1993 (Coates 1992). In that project, stocking of higher altitudes in the Purari catchment will be considered.

In the following, the objectives for this study in relation to the FISHAID project are given.

## 1.1. OBJECTIVES.

The objectives of the research project on which this report is based were:

1) to undertake a survey of the fish stock in the highland catchment area of a southern river, i.e. <u>outside</u> the Sepik/Ramu catchment.

2) to establish a relation between fish production/diversity and altitude in a southern river system.

3) to compare high altitude fish production/diversity in southern rivers (using Purari River as an example) with production/diversity in northern rivers (Sepik/Ramu catchment).

[the Fly River may have been a more obvious choice from a scientific point of view than the Purari for comparing a southern and a northern river system (Coates, in press). On the other hand, the upper Purari is more important from a fisheries point of view than the upper Fly (i.e. it covers a substantial part of the densely populated central highlands (see later)). The easier access to the upper Purari is a further advantage. These factors make the Purari a justifiable choice as sampling area].

4) following objectives 1, 2 and 3; to evaluate the need for stocking higher altitude rivers outside the Sepik/Ramu.

# 2. BACKGROUND.

## 2.1 THE PURARI.

This is the second-largest of the southern river systems in Papua New Guinea covering 33,670 $km^2$ and discharging 2607 $m^3/s$. Its headwaters comprise the basins of the Erave, Kaugel, Waghi, Asaro and Aure rivers, thereby occupying a considerable portion of the central highlands. The main divide between the northern and southern rivers runs along the Hagen Range, the Sepik-Waghi Divide and the Bismarck Range, and these ranges form part of the watershed of the Purari catchment (Pain 1983).

The major part of the Purari catchment (approximately 75 %) is situated within the highland zone above 1000 m.a.s.l., whereas the lowlands occupy a very limited area. This distinguishes the Purari from the other major river systems in Papua New Guinea. The huge floodplain areas, which occur in the Sepik/Ramu and in the Fly, are absent from the Purari.

Between 1,000,000 and 1,125,000 people live in the Purari catchment, most of whom live in the highland provinces with only 10-12,000 living in the lowland Gulf Province (1980 census + 25%). Except for Kainantu and Wabag, which is in the Sepik-Ramu catchment, all the major townships in the highlands are situated in the Purari catchment (i.e. Goroka, Kundiawa, Mount Hagen and Mendi).

Compared with the Sepik River, which covers an area of 78,000 $km^2$ with a mean annual discharge of 7663 $m^3/s$ (10,963 $m^3/s$ in May and 4363 $m^3/s$ in July (Allen and Coates 1990)), the Purari is considerably smaller. But more people live in the Purari catchment; especially in the highland zone. About 800,000 people live above 1000 m.a.s.l. in the Purari, whereas only 400,000 people live above 1000 m.a.s.l. in the Sepik/Ramu (Coates and Mys 1989). This makes the upper Purari potentially very important from a fisheries point of view.

## 2.2. GEOLOGY AND GEOMORPHOLOGY OF THE CENTRAL HIGHLANDS

The general geomorphology of Papua New Guinea has been described by Löffler (1977), Coates (1989) summarized the geology, geomorphology, climate and vegetation in the Sepik and Ramu River catchments, and Pain (1983) described the geology and geomorphology of the Purari River catchment.

The fundamental forces responsible for the creation of the present landmass of Papua New Guinea is the northward drift of the Australian continental plate and the westward drift of the Pacific plate. The interaction between these two forces has resulted in very complex geological events leading to upthrusting and folding and thereby creation of what today is the Central Highlands of Papua New Guinea.
The development of the Highlands started in the lower Miocene with the emergence of the New Guinea Mobile Belt, and this faulting belt is today the northern limit of the Highland area. The Papuan Fold Belt forms the southern limit of the Highlands. In between the two foldbelts is a more simple and stable structure, the Kubor

Anticline, a broad upward 140 km long and up to 65 km wide, covering a substantial part of the upper Purari River catchment (Löffler 1977).

Volcanic activity has had a very important influence on the structure of the highland area. Several extinct vulcanoes are important characteristics in some parts of the present-day highlands landscape. Examples are Mount Giluwe, Mount Hagen and Mount Karimui. Volcanic activity disrupted a number of drainage systems leading to the formation of several intramontane basins (e.g. Waghi Basin). Other basins, like the Goroka and Aiyura basins, were caused by tectonic movements, formation of lakes and gradual filling of those lake basins with lacustrine deposits.

## 2.3. FRESHWATER ENVIRONMENT OF THE HIGHLANDS

The above geological events and geomorphological characteristics have created a diverse set of stream types in the Highlands, from the very torrential and steep mountain streams to the relatively turbid, moderate-flowing rivers on the intramontane basins (e.g. Asaro River and Waghi River).

Furthermore, the presence of the central Highlands has separated the freshwater environment of New Guinea into two catchment systems: a system of northflowing rivers, flowing from the mountains directly to the deep Pacific Ocean; and a system of southflowing rivers, flowing to the relatively shallow Papuan Golf.

As mentioned earlier the Purari catchment covers a considerable portion of the highlands and includes major highland rivers such as Asaro, Waghi, Tua, Mendi, Lai and Erave rivers.

Past the confluence with the Poru River, the Purari passes over a series of rapids and falls called Hathor Gorge. This forms a natural boundary between the highlands and the lower Purari. The rapids of Hathor Gorge have been considered an insurmountable barrier to most fishes moving upstream, but are probably no hindrance for downstream movement of fishes (Haines 1983).

The water chemistry of the highland streams is determined mainly by the underlying geological structure. Streams flowing through volcanic rocks are generally poor in calcium and therefore have a low alkalinity an low pH-value (soft water streams), and streams flowing through limestone geology are relatively rich in calcium and have a high alkalinity and high pH-value (hard water streams). An example of the first type is Kumi Creek, draining part of Mount Giluwe, with an alkalinity of 10 mg/l $CaCO_3$ and a pH-value of 6.9; an example of the second type is Lai River west of Mendi with an alkalinity of 88 mg/l $CaCO_3$ and a pH-value of 7.6 (Petr 1983).

The alkalinity (water hardness) is of relevance to fisheries. For salmonid fishes in temperate regions, the productivity of streams increases with increasing alkalinity (Whitworth and Strange 1983; Waters *et.al.* 1990). However, Geisler *et. al.* (1979) argue that in tropical waters higher alkalinities are not obligatory for higher fish production because many tropical fish species are "soft-water-fishes". But at least for exotic salmonid species in high-altitude streams the production potential might, to some extent, be effected by the alkalinity of the water.

## 2.4. ICHTHYOLOGY.

The fish fauna of lower order streams of the Sepik/Ramu catchment has been studied by van Zwieten (1990); the ichthyology of Sepik River has been studied by Allen & Coates (1990); the ichthyology of the Fly River has been studied by Roberts (1978); the fish fauna of the Purari River has been reviewed by Haines (1983), and Allen (1991) described the freshwater fish fauna of the whole island of New Guinea.

As mentioned earlier, the island of New Guinea is part of the Australian continental plate, which due to its long period of isolation at the vicinity of the Antarctica has a very different, and relatively poor, freshwater fish fauna compared to other continental areas.This is reflected in the fact that apart from one species, the Bony Tongue (*Scleropages jardinii*), all native freshwater fish species in Papua New Guinea are derived from marine families.

At present the freshwater fish fauna of New Guinea consists of 330 species of which 14 species are introduced and about 102 species are believed to have a marine larval stage (Allen 1991).

The separation by the central highlands of New Guinea into a southern and a northern region has created a distinct fish fauna for each area with only very few species shared between the two.

The Sepik River has a fish species diversity, which is only approximately half the diversity of the Fly River (Allen and Coates 1989). Coates (1990) outlined the reasons for this difference as follows:

(i) the Sepik River is geologically much younger than the Fly River;

(ii) the Sepik River has no delta in contrast to the extensive delta, mangrove and estuarine systems occurring in PNG's southern rivers; this in effect may have limited the entry into the river of several important groups of Fly River fishes requiring this environment for their life-cycle;

(iii) an analysis of recent geological history of the lower Sepik has shown that until very recent times, perhaps only 5000 years ago, what is now the Sepik lowlands or floodplain area was previously an inland sea which has only recently developed into an extensive freshwater habitat.

The young age of the Sepik and Ramu rivers is probably restricted to the lowland area. Consequently, the main difference in ichthyological diversity between the Fly and the Sepik/Ramu seems to be in the lowland floodplain area, whereas at higher altitudes, the two systems may have equal diversities (Coates, in press).

Van Zwieten (1990b) described the distribution and abundance of fish species in lower order streams of the Sepik-Ramu catchment and found that fish species diversity decreased exponentially with increasing altitude. Above 1000 m he found virtually no native species except two species of migrating anguillid eels. A replacement of species longitudinally, as is found in other areas, for example in southflowing rivers in Papua New Guinea (Roberts 1978; Haines 1983), did not appear to occur in the Sepik and Ramu Rivers.

Roberts (1978) noted that highland tributaries of the Fly basin have fewer fish species than tributaries of comparable size in the lowlands. Lowland tributaries equivalent in size to highland tributaries with only 2 species are inhabited by 12 or 13 species.

Robertson and Baidam (1983) noted that the number of fish species in the upper Ok Tedi River (above Ok Menga junction) in the Fly River catchment is low compared to the lower Ok Tedi (downstream Tabubil), but they didn't determine any productivity/biomass values for that area.

It is probably a general characteristic that the number of fish species increases with decreasing altitude, i.e. physical and chemical conditions are more stable and feeding niches more complex at lower altitudes (Lowe-McConnell 1987). For southern rivers in Papua New Guinea there seems to be little doubt that fish diversity and production decrease with increasing altitude. However, no work has so far been done on estimating the fish production in lower order streams at higher altitudes of rivers draining southwards in Papua New Guinea.

The extensive study of the Sepik/Ramu fish fauna has revealed a very poor fish stock in that system, and in consequence, the need for fish stocking in the Sepik/Ramu was emphasized and justified (Coates 1990a). Stocking higher altitude rivers was given high priority due to the almost lack of fish resources in these environments and the large proportion of people living there.

This study aimed at clarifying the need for stocking high altitude rivers and streams in the upper Purari catchment, the most densely populated area in Papua New Guinea.

## 3. RESULTS AND DISCUSSION OF SAMPLING DATA

Results from sampling in the Upper Purari are listed in Table 1. In this table, only the sampling stations where fish occurred are listed.

***Table 1. Results from rotenone sampling in upper Purari. (Refer to Povlsen (1993a) for River Number and date of sampling).***

***Ch.ca = Chilatherina campsi; Cy.ca = Cyprinus carpio; Ga.af = Gambusia affinis; Gl.br = Glossogobius brunnoides; Me.pi = Melanotaenia pimaensis; Ne.eq = Neosilurus equinus; On.my = Oncorhynchus mykiss; Ox.fi = Oxyeleotris fimbriata.***

| River | Altitude (m) | Species | Weight (g) | Number | Biomass (kg/ha) | Density (no/ha) |
|---|---|---|---|---|---|---|
| 1 | 1380 | Cy.ca | 1005 | 6 | 44.7 | 267 |
| 6 | 1840 | On.my | 728 | 10 | 69.3 | 952 |
| 7 | 1520 | Gl.br | 9.26 | 1 | - | - |
| 9 | 1560 | Gl.br | 156 | 199 | 7.63 | 9707 |
| 10 | 1480 | Cy.ca | 7.07 | 2 | - | - |
| 15 | 2280 | On.my | 1432 | 9 | 46.3 | 290 |
| 18 | 1500 | Cy.ca | 282 | 31 | 5.99 | 660 |
| | | Ga.af | 2 | 4 | 0.04 | 85 |
| | | TOTAL | 284 | 35 | 6.03 | 745 |
| 20 | 1720 | Gl.br | 67.9 | 8 | 2.32 | 274 |
| 21 | 1560 | Ch.ca | 2.48 | 6 | 0.13 | 306 |
| 24 | 1000 | Me.pi | 241 | 76 | 17.9 | 5630 |
| | | Ox.fi | 118 | 15 | 8.7 | 1111 |
| | | TOTAL | 359 | 91 | 26.6 | 6741 |
| 24 | 1000 | Me.pi | 162 | 41 | 7.78 | 1952 |
| | | Ox.fi | 131 | 9 | 6.22 | 429 |
| | | TOTAL | 293 | 50 | 14.0 | 2381 |
| 27 | 1040 | Cy.ca | 176 | 4 | 8.10 | 185 |
| | | Ne.eq | 195 | 3 | 9.10 | 139 |
| | | TOTAL | 371 | 7 | 17.2 | 324 |
| 28 | 1120 | Me.pi | 67 | 8 | 15.2 | 1818 |
| | | Ox.fi | 68 | 6 | 15.4 | 1364 |
| | | TOTAL | 135 | 14 | 30.6 | 3182 |

Stations where no fish were caught are listed in Table 2.

***Table 2. Sampling stations where no fish were caught. Station No. refers to number of station as given in Povlsen (1993b).***

| Station No. | Station Name | Altitude (m) |
|---|---|---|
| 2 | Wara Ngumi | 1780 |
| 3 | Wattabung | 1800 |
| 4 | Sokozoi River | 1440 |
| 5 | small creek | 1320 |
| 7 | Kintinu Creek | 1520 |
| 8 | Henganofi 1 | 1480 |
| 11 | Keglsugl | 2300 |
| 12 | Mondia Bridge | 2320 |
| 13 | Simbu River | 2320 |
| 14 | Gembogl River | 2200 |
| 16 | Pamba Creek | 1640 |
| 17 | Rur Creek | 1640 |
| 19 | Kwiena Creek | 1880 |
| 22 | Yu Creek | 1800 |
| 23 | Asaro Village | 1560 |
| 25 | Karenda River | 2220 |

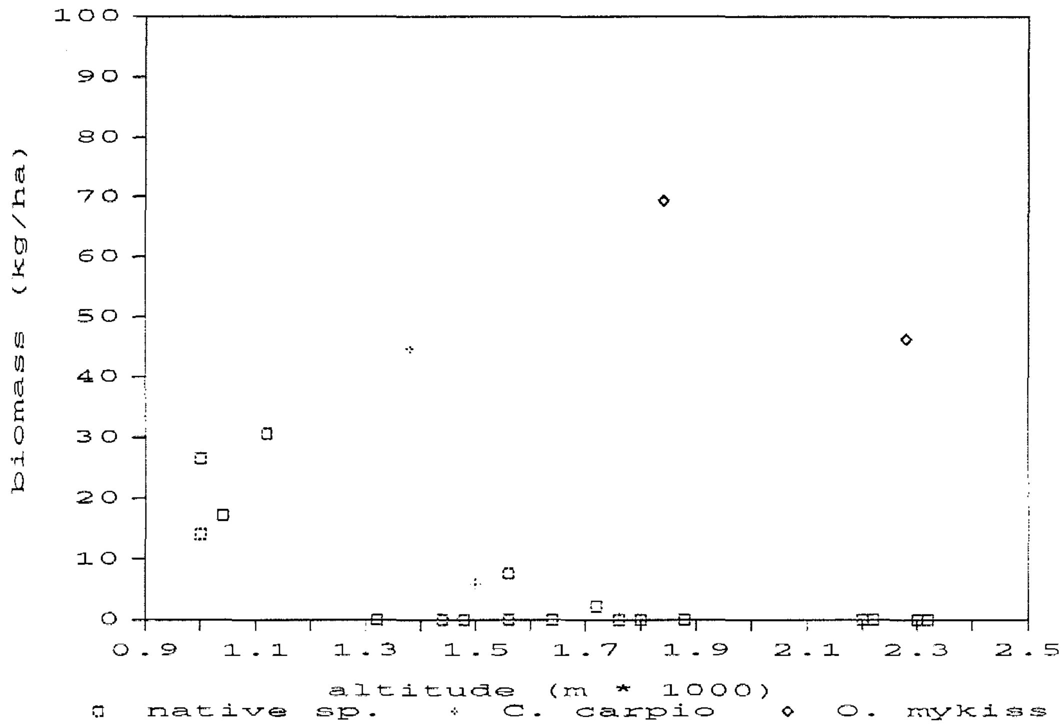
In general, the fish fauna of the upper Purari (above 1000 m.a.s.l.) can be described as very poor. For example, in 54 % of the sampling stations, no fish were caught at all. And in 75 % no native fish species were caught.

Six native species were caught: *Glossogobius brunnoides*, *Mogurnda sp.3* (see: Allen 1991), *Oxyeleotris fimbriata*, *Chilatherina campsi*, *Melanotaenia pimaensis* and *Neosilurus equinus*. Of these, the eeltailed catfish (Plotosidae), *Neosilurus equinus*, is the only species to reach a good fishing size with a maximum length of 300 mm (Allen 1991). All species inhabit relatively fast-flowing, rocky streams in hilly or mountainous terrain.

The families represented by the six species (i.e. Gobiidae, Eleotrididae, Melanotaeniidae and Plotosidae) are mainly carnivorous, feeding on aquatic and terrestrial insects and their larvae, crustaceans, molluscs, worms and, to a lesser extent, fish (Allen 1991).

Biomass (standing stock) of native species decreases with increasing altitude (Fig. 1). This is also seen in other river systems and is probably a general characteristic of riverine environments (Lowe-McConnell 1987). Interestingly, where exotic species have established, biomass is increased dramatically and there is no decrease in biomass with increasing altitude. In the case of rainbow trout, an increase in biomass from almost zero to almost 60 kg/ha is indicated (based on two successful rotenone samplings of trout).

***Figure 1. Biomass of fish vs altitude in the upper Purari.***




Van Zwieten (1990a,b) sampled the Sepik and Ramu rivers and didn't catch any fish species above 800 m.a.s.l. Compared with my data, this suggests that the upper Purari has a more diverse fish fauna than the upper Sepik/Ramu.

The relationship between biomass and altitude in the Sepik/Ramu, based on van Zwieten's data, is (native species only):

$$Y = e^{(5.19-0.0078X)}$$

where Y=Biomass and X=Altitude.

Assuming that there is also an exponential relationship between biomass and altitude in the Purari, my data gives the following relationship (native species only):

$$Y = e^{(7.41-0.0069X)}$$

This indicates that the biomass is higher for a given altitude in the Purari. However, this comparison is not strictly valid, since I only sampled at altitudes above 1000 m.a.s.l., whereas van Zwieten only sampled 6 stations above 800 m.a.s.l. Neither of these two surveys can be regarded as complete.

Table 3 lists species occurring at altitudes above 600 m.a.s.l. ("Type 4" rivers, as defined by Van Zwieten, 1989) in the three main river systems in Papua New Guinea. Anguillid eels are excluded. This is based on data from Allen (1991), the most complete list of New Guinea freshwater fishes.

*Table 3. Fish species occurring at altitudes above 600 m in the three main river systems in Papua New Guinea (based on: Allen 1991).*

| SPECIES | SEPIK/RAMU | FLY RIVER | PURARI |
|---|---|---|---|
| **PLOTOSIDAE** | | | |
| *Neosilurus equinus* | | + | + |
| *N. gjellerupi* | + | | + |
| *N. idenburgi* | + | | |
| **MELANOTAENIIDAE** | | | |
| *Chilatherina campsi* | + | | + |
| *Glossolepis maculosus* | + | | |
| *Melanotaenia affinis* | + | | |
| *M. herbertaxelrodi* | | | + |
| *M. iris* | | + | |
| *M. monticola* | | | + |
| *M. pimaensis* | | | + |
| **ATHERINIDAE** | | | |
| *Craterocephalus nouhuysi* | | + | |
| *C. pimatuae* | | | + |
| **TERAPONTIDAE** | | | |
| *Hephaestus transmontanus* | + | | |
| *H. habbemai* | | + | |
| *H. fuliginosis* | | + | + |
| **ELEOTRIDIDAE** | | | |
| *Mogurnda aurofodinae* | + | | |
| *M. cingulata* | | + | |
| *M. sp.1* | | | + |
| *M. sp.3* | | | + |
| *Oxyeleotris fimbriata* | + | + | + |
| **GOBIIDAE** | | | |
| *Glossogobius bulmeri* | + | | + |
| *G. brunnoides* | | | + |
| *G. torrentiis* | + | | |
| *G. concavifrons* | | + | |
| *G. sp.3* | | | + |
| *G. sp.6* | | | + |
| *G. sp.13* | | | + |
| *G. sp.14* | + | | |
| **TOTAL** | 11 | 8 | 16 |

As can be seen, the Purari contains 16 species (8 genera) above 600 m compared to 11 (8) in the Sepik/Ramu and only 8 (7) in the Fly. At the family level, the hardyheads, Atherinidae, do not occur in the upper Sepik/Ramu. However, excluding atherinid species still gives a higher diversity in the upper Purari (15/7).

The low species number in the upper Fly may be due to the fact that this area is relatively smaller than the upper Sepik/Ramu and upper Purari (although a lower sampling intensity in the remote upper Fly may also be a contributing factor).

The upper Purari is inhabited by the highest number of species of the three systems in spite of the fact that the total species number in the whole Purari catchment is smaller than in both Sepik/Ramu and Fly (42 species in the Purari, 48 in Sepik/Ramu, 89 in Fly; excluding diadromous and coastal/brackishwater species (Allen 1991)). This supports the theory that diversity is higher in upper Purari compared to upper Sepik/Ramu, as indicated by my findings.

There may be several explanations for this. According to Goulding *et.al.* (1988) a difference in diversity among systems may be based on either geological or ecological factors (or a combination of the two).

In this case, geological events (i.e. volcanic activity) may have disrupted parts of the upper Sepik/Ramu causing them to drain into the Purari. This may explain the occurrence in the Purari of the melanotaenid *Chilatherina campsi,* a genus otherwise restricted to northern river systems (Allen 1991).

Another explanation, based on the ecological factor, is that the habitat diversity is higher in the upper Purari. This is supported by the fact that a number of major intermountane basins are situated within the Purari catchment. These basins create low-gradient, slow flowing rivers (e.g. in Asaro and Waghi valleys) in addition to the typical torrential mountainous rivers, thereby increasing the number of habitat-types. In comparison, the upper Sepik/Ramu contains few major intermountane basins and, therefore, few low-gradient rivers.

Of the 16 species in the upper Purari 8 are endemic. These are: two rainbow fishes (Melanotaenidae) of the genus *Melanotaenia*, three gobies (Gobiidae) of the genus *Glossogobius*, two gudgeons (Eleotrididae) of the genus *Mogurnda* and one Atherinid species of the genus *Craterocephalus*. The endemics belonging to the first 3 genera are all relatively small species which mainly live in small forest creeks. The atherinid species, *Craterocephalus pimatuae*, has so far only been recorded from the junction between Pima and Tua rivers at an altitude of 823 m, where it inhabits deeper pools and quiet backwaters of an otherwise fast-flowing gravel-bottom river (Allen 1991).

In conclusion, the native fish fauna in the upper Purari, although here assumed to be more diverse than the upper Sepik/Ramu, is not able to support any significant fisheries. It mainly consists of small fish with a limited distribution. In more than half the streams covered in this study, no fish were caught at all; and where exotic species have already been introduced, they have increased fish production dramatically. Therefore, introductions of ecologically suitable, exotic fishes could undoubtedly increase the fisheries potential significantly in the upper Purari.

Furthermore, the assumption made here that the habitat-diversity is high in the upper Purari, is of importance with regards to fish introductions: a high habitat-diversity creates better opportunities for any future fish introductions to succeed.

# 4. FISHERIES IN THE UPPER PURARI

## 4.1. TRADITIONAL FISHERIES IN THE UPPER PURARI

The limited native fish fauna in the highlands area has traditionally restricted the fishing habits of the local people, but even these limited fish resources, e.g. eels, catfishes, gobies, gudgeons and rainbowfishes, have been subject to exploitation.

At Henganofi in Eastern Highlands Province the only native fish is the goby *Glossogobius brunnoides*, a small fish with maximum size of 100 mm. The local people call this species "colpis", which is a commonly used name for gobies and gudgeons throughout the Highlands. They catch it with their bare hands. Although small in size, this fish is very much appreciated by the local people. Some people reported that it had decreased in numbers since the arrival of introduced common carp (see later). Others stated that they didn't bother catching gobies anymore, but preferred to catch common carp in Dunantina River nearby. The habitat of *G. brunnoides* is mountainous, fast-flowing headwater streams with gravel or rocky bottoms (Allen 1991), very different from the habitat of common carp. It seems that, if at all, the two species only overlap marginally.

At Anggura River in Southern Highlands Province people originally caught the Highlands Gudgeon, *Mogurnda sp.3* (see Allen 1991) for consumpsion; the only native species in that area. As for the goby at Henganofi, people catch this species by grabbing the fish while it is hiding under stones. Since trout was introduced in the early seventies, people have concentrated their fishing effort on this species. According to the local people the gudgeon (also named "colpis" in Tok Pisin) has declined since the introduction of trout, but it is still present after 20 years of co-existence with trout. A juvenile gudgeon-specimen was caught on the same spot where several trout-specimens were taken during my one-hour visit at Anggura River.

Eeltailed catfish (Plotosidae) seem to have been the most important fish for fisheries purposes before exotic species were introduced. This is one of the few fish to reach a "good fishing" size in the highlands. At Bomai, Simbu Province, and Erave, Southern Highland Province, which are both at about 1000 m.a.s.l. eeltailed catfish was originally the only fish to be exploited regularly. According to villagers at Bomai, this has resulted in a decrease in numbers in nearby streams. At both places it was highly prized and the preferred fish for eating.

Eeltailed catfish, probably *Neosilurus equinus*, was by the local people reported to occur in Asaro River, Eastern Highlands and Waghi River, Simbu and Western Highlands. It was reported to have declined in recent years, and according to local fishermen it is difficult to catch. This species is also reported to occur in Lai River, Southern Highlands Province (ca. 1800 m.a.s.l.).

Finally, eels are caught occasionally in several places. In many places at higher altitudes they were (and still are) the only fishery resource. Traditionally, they were caught in traps made of different kinds of bush material (e.g. tree bark, bamboo etc.), and often taboos and customary obligations accompanied the eel fishing (Yalu 1984). Now, hook and line is taking over, and in many places it is only elder people, who know how to make eel traps.

In the upper Sepik/Ramu, eels (Anguillidae) are the most important native fish for consumption. Van der Heijden (personal communication) estimated the consumption of eels in that area to approximately 1 kg/person/year. In the Purari, this figure is probably lower, i.e. there are less eels and more people.

In general, the native species in the Purari highlands account for only a negligible part of the total catch. They have probably never played a significant role in the diet, although socio-economic data are needed to confirm this. Currently, the main part of the catch consists of introduced common carp and rainbow trout.

## 4.2. INTRODUCED FISH SPECIES AND THEIR IMPORTANCE IN FISHERIES

As mentioned in the previous section, exotic fish species have been introduced into highland streams of Papua New Guinea. They were introduced for various reasons, and their introduction and distribution were reviewed by West and Glucksman (1976). In the following, the exotic species occuring in the highland part of the Purari catchment are listed with a short description of their status.

Rainbow trout, *Oncorhyncus mykiss.*

This species is discribed in a separate report, also based on the findings of the work on which this report is based (Povlsen 1993b).

Tilapia, *Oreochromis mossambicus.*

Tilapia was first introduced to Papua New Guinea in 1954, and in 1955 the species was introduced to Dobel experimental ponds at Mount Hagen for consideration as a suitable species for highlands pond culture (West & Glucksman, 1976). The trials proved unsuccessful, and tilapia pond culture never established in the highlands. In some parts of the highlands populations in natural waterways apparently established. During my sampling in the highlands I have recieved several reports from local people that tilapia still occur in a few small ponds and lakes in Western and Eastern Highlands. At Henganofi village it was reported that tilapia used to occur in Dunantina River, but had disappeared after the common carp established in the area.

No specimens of tilapia were caught during my sampling in highland streams. Redding (1989) described the biology and ecology of *Oreochromis mossambicus* in the lowland Sepik River, where it is currently the most important fish species from a fisheries point of view (Coates 1985).

Common carp, *Cyprinus carpio*

The common carp is quantitatively the most important species for fisheries purposes in the Highland area. Due to the distribution by the governmental Highlands Aquaculture Development Center (HAQDEC) at Aiyura of carp fingerlings to local pond farmers all over Papua New Guinea, including the Highlands, this species is very widespread. It is likely that it will continue to extend its range in the future, as it is doing in the Sepik River. Ulaiwi (1990) described the occurrence and spread of common carp in the lowland Sepik River, and estimated the species to spread 40-60 km per year.

According to reports from villagers it seems that common carp has a detrimental effect on other species, including the tilapia as mentioned above. In some places (i.e. villages at Asaro River) concern was expressed over the effect of carp on native species such as catfish and gobies.

It has been indicated that common carp may have some deleterious effects on the aquatic environment, although the nature and extent of this has not been established (Morison and Hume 1990).

However, because of the poor native fish fauna in the highlands it has definitely improved fisheries in that area, and in many places it is the only species with any significance to fisheries. While driving along the Highlands Highway, a very common sight is boys or women selling carps caught in a stream nearby.

Mosquitofish, *Gambusia affinis*

The mosquitofish was the first exotic fish to be introduced in Papua New Guinea, as it was introduced by Public Health authorities in 1930 as part of their malaria control programme (West and Glucksman 1976). Today it occurs all-over Papua New Guinea in lakes and stagnant parts of rivers. The fish has probably no significant value for fisheries purposes (although, during a fisheries survey at the Yonki Dam, Eastern Highlands, a woman was seen catching mosquitofish to be used for cooking soup (van der Heijden, personal communication)).

## 4.3. FISHING METHODS

People have been very quick in developing different methods of catching fish since the first introduced fish species occurred. The most widespread method is hook and line, which is used for both carp and trout throughout the Highlands. An example is the people from Kireni village in Southern Highlands, who fish for trout in Anggura River. Using hook and line, and small aquatic insects as bait, they have in a short period of time become very dedicated and skilled trout-fishermen. It is mainly boys and young men who catch trout, and they actually call themselves "fishermen", indicating they consider the activity important.

Spears in different varieties are also very widespread, produced out of whatever is available (wire, nails, knives, pig- and cassowary-claws etc.). More simple methods include chasing fish on land or chasing them into primitive chicken wire fishtraps; and damming of small streams for catching gobies, gudgeons and rainbow fish.

The use of Derris root for poisoning fish is very widespread, also in areas where it wasn't used before exotic fishes occurred. At Waghi River near Mount Hagen the fishing of common carp with Derris root has become a kind of ceremonial event, where people arrange a singsing and dress up in traditional costumes (Ulaiwi, personal communication).

Probably the most recent method is using dive-mask and speargun, which I have seen used for catching carps in Asaro River and catfish at Bomai, Simbu Province.

The variety of fishing methods developed over a relatively short period of time is quite impressive considering that the highlands people have limited fishing tradition. But at the same time it reflects the popularity and needs of fish as a source of protein in the Highlands.

## 5. CONCLUSIONS

Fisheries in the upper Purari can without doubt be improved significantly through further fish introductions for the following reasons:

1) In 54 % of the streams sampled in this study, no fish were caught at all. Those streams appeared to be suitable for fish production.

2) In 75 % of the streams sampled, no native species were caught.

3) Except for eels and eeltailed catfishes, the native fish species occurring in the upper Purari are small species of very little importance to fisheries (and eels and eeltailed catfishes, although much appreciated, are rare).

4) Where exotic species have already been introduced (i.e. common carp and rainbow trout), they have boosted the fishery significantly.

5) The native fish species are mainly carnivorous, exploiting aquatic and terrestrial insects and crustaceans, i.e. exotic species that feed on plant matter and detritus would not compete for food with the native fishes.

6) The upper Purari has a varied aquatic environment with both low-gradient and high-gradient rivers and streams.

Adding to those arguments, the upper Purari is the most densely populated region in Papua New Guinea, inhabiting more people than the whole Sepik/Ramu (where fish stocking has already been justified by SRFSEP).

From a conservational point of view, introduction of exotic fishes is usually regarded as a constraint to conservation. However, in this case there is an important conservational advantage: introduction of new species will reduce the fishing pressure on native species. This has already happened with the introduction of common carp and rainbow trout. According to reports from local people at Henganofi, Eastern Highlands, and at Anggura River, Southern Highlands, they almost exclusively fish for the introduced species. This has reduced the fishing pressure on the native *Glossogobius brunnoides* and *Mogurnda sp.3.*, small species which were the only fisheries resource before exotic species were introduced.

The Plotosid catfish, *Neosilurus equinus*, is the most important native fish to be exploited in many places in the highlands. At Bomai, Simbu Province, this has resulted in a decline in numbers in the nearby stream (report from Bomai villagers). The Bomai area is a sparsely populated area. In more densely populated areas like the Asaro and Waghi valleys, where this species also occur, the fishing pressure is, consequently, much higher. Introduction of ecologically suitable new fish species into rivers in those valleys will reduce the fishing pressure on this native catfish.

Furthermore, with the expected growth in the human population, this aspect of fish introductions will become increasingly important in the future.

SRFSEP has recommended 4 species for stocking higher altitudes in the Sepik/Ramu catchment (Coates 1991). Those are: *Schizothorax richardsonii* (Gray), *Tor putitora* (Hamilton), *Acrossocheilus hexagonolepis* (McClelland) and *Labeo dero* (Hamilton). All are cyprinid species with native range in the Himalayan region. They have been evaluated for their suitability for stocking Sepik/Ramu by the project and its advisory group and all were approved as ecologically suitable.

These species would without doubt also be able to improve fisheries in the upper Purari, i.e. the same arguments would be applicable as for the Sepik/Ramu. The environmental issues are also very much the same as for the Sepik/Ramu: the recommended species have different feeding habits from the native species, and they are not predatory. However, there are two major concerns regarding this:

1) the potential predatory nature of *Tor putitora.*

As noted by Coates (1991), there have been several reports that *Tor* feeds on fish. Shrestha (1990) noted that in Nepalese rivers, this species feeds on fish (e.g. *Barilius sp.* and *Garra sp.*) in its adult stages. Obviously, this should be further investigated prior to any introduction of *Tor putitora* into the upper Purari.

2) effects of the introductions on endemic species.

As mentioned earlier, there are at least 8 endemic species in the upper Purari. All are small species, and 7 of them live mainly in small mountainous rainforest creeks. These are: *Melanotaenia herbertaxelrodi, M. pimaensis, Mogurnda sp.1, Mogurnda sp.3, Glossogobius brunnoides, G. sp.3* and *G. sp.13* (Allen 1991). The proposed himalayan carp species are much bigger and are not expected to enter those small creeks (at least not in their adult stages). Consequently, apart from the fact that the proposed species will not compete for food with these endemic species, they are not likely to compete for habitats either. The atherinid endemic, *Craterocephalus pimatuae*, has so far only been reported from a collection near the junction of the Pima and Tua rivers (823 m.a.s.l.), where it occurs in quiet backwaters of an otherwise fast-flowing river (Allen 1991). To the extent that any of the proposed species will establish at that altitude, they may compete for habitat with this species.

Furthermore, it should be noted that there is no need for fish stocking at lower altitudes in the Purari. This is a sparsely populated area, and the native fish fauna is more diverse than the upper Purari fish fauna.

Consequently, an optimal species for introduction into the Purari would be one that will be productive and reproductive in highland streams and rivers (mainly above 800-1000 m) and would have minimal implications for the fish assemplage at lower altitudes.

Based on this, the snowtrout, *Schizothorax richardsonii*, is environmentally the most suitable of the four recommended species. In the Himalayas, it occurs above 500 m, and the optimal altitudinal range is 1100-3000 m.a.s.l. (Shrestha 1990). This species would not establish at lower altitudes under PNG-conditions.

*Tor putitora* is reported to occur between 80 and 1400 m.a.s.l. in the Himalayas, with main preferences for the higher altitudes; *Acrossocheilus hexagonolepis* between 100 and 600 m.a.s.l. (with an optimum temperature range of 15-18°C) and *Labeo dero* between 150 and 1000 m.a.s.l. (Shrestha 1990). Consequently, these 3 species will establish at lower altitudes than *Schizothorax richardsonii*, as also noted by Coates (1991). However, their preferences are for the higher altitudes. For example, the optimum temperature range of 15-18°C for *Acrossocheilus* corresponds to an altitudinal range of 1200-1500 m in the Purari (see: Povlsen 1993a).

In conclusion, and based on the above information, *Schizothorax richardsonii*, is recommended for stocking high altitude rivers in the upper Purari.

*Acrossocheilus hexagonolepis, Tor putitora* and *Labeo dero* are not recommended at this stage due to the possibility that they will approach lower altitudes. Further investigations regarding their biology and ecology (including the potential predatory nature of *Tor putitora*) should be undertaken before their introduction into the Purari is considered.

Finally, it should be emphasized that this study only covers the Purari catchment. Other southern catchments like the Kikori and the Fly are not included. Therefore, fish introductions should not take place in those areas, at least not until the native fauna in their upper reaches has been surveyed and a need for fish stocking established.

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