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G. B. Whitlam. *Papua New Guin. agric. J.*, 27(1 & 2) : 1-10 (1976)

The application of multiple regression analysis to sample cross-section farm resource data resulted in the explanation of a statistically significant percentage of rubber production variance. The inclusion of a proxy variable representing management ability improved the fit of the Cobb-Douglas function. Significant and substantial resource productivity differences were found between management groups. Extension-induced technical change to increase farm output is likely to widen this gap and accelerate the degree of relative performance. Any improvement programme must, therefore, take cognizance of this fact particularly in the selection of farmers for smallholder settlement schemes, allocation of credit and the design of extension strategies.

CRYPTOPHLEBIA ENCARPA (MEYRICK) (LEPIDOPTERA:TORTRICIDAE) AS A PEST OF CACAO PODS IN THE NORTHERN PROVINCE OF PAPUA NEW GUINEA

G. L. Baker. *Papua New Guin. agric. J.*, 27(1 & 2) :11-17 (1976)

Cryptophlebia encarpa is a minor pest of cacao pods in the Northern Province of Papua New Guinea. The damage caused by this species has however become increasingly conspicuous in recent times following the control of other pod-damaging insects through the use of insecticides.

The larvae feed on the epicarp and less frequently penetrate the mesocarp and feed on the endocarp of the cacao pod. Death of an attacked pod may result from penetration of the mesocarp by the larvae and subsequent fungal infection of the endocarp and seeds.

High infestation levels are positively associated with increased abundance of large, maturing cacao pods, the abundance of which is characteristically seasonal.

Under laboratory conditions, the duration of the larval stage is 13 to 15 days and the pupal stage 8 to 11 days. Mean adult longevity is 4.3 days.

[*continued overleaf*]

INTRODUCTION AND DISTRIBUTION OF EXOTIC FISH IN PAPUA NEW GUINEA

G. J. West and J. Glucksman. *Papua New Guin. agric. J.*, 27(1 & 2):19-48 (1976)

Twenty species of exotic freshwater fish are known to have been introduced to Papua New Guinea. These introductions have been made for various reasons: for mosquito control, to establish sport fisheries, to improve the protein-deficient diet of inland people, to supply forage for introduced predatory fish, and for aquaculture. Nine of these species, including two that presumably escaped from ornamental aquaria, are now established in natural waters. *Salmo gairdneri* is, to date, the only species showing potential for intensive aquaculture, while two species originally intended for aquaculture, *Tilapia mossambica* and *Cyprinus carpio*, support fisheries in natural waters. The Department of Primary Industry has severely restricted the importation and distribution of most exotic fish, and the severity of the restrictions will probably increase.

ANALYSIS OF SOME FACTORS AFFECTING SMALLHOLDER RUBBER PRODUCTION

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ABSTRACT

The application of multiple regression analysis to sample cross-section farm resource data resulted in the explanation of a statistically significant percentage of rubber production variance. The inclusion of a proxy variable representing management ability improved the fit of the Cobb-Douglas function. Significant and substantial resource productivity differences were found between management groups. Extension-induced technical change to increase farm output is likely to widen this gap and accelerate the degree of relative performance. Any improvement programme must, therefore, take cognizance of this fact particularly in the selection of farmers for smallholder settlement schemes, allocation of credit and the design of extension strategies.

INTRODUCTION

It has been suggested (Yotopoulos 1968) that one approach to the analysis of economic development is through the micro-economic theory of production. In any production process, output depends on the flow of inputs and the proportions in which they are combined. The inputs involved are the productive factors conventionally defined as land, labour, capital and management. The economic development problem has to do, among other things, with increasing output per unit of input, i.e. resource productivity.

The purpose of this paper is to employ production function analysis (Heady and Dillon 1961) to show that a statistically significant percentage of interfarm variation in smallholder rubber production can be explained in terms of differences in farm resource structures and resource productivities. Such information can contribute to the definition of changes in the farm situation which may result in a more productive use of resources being attractive to individual farmers.

DESCRIPTION OF THE SURVEY AREA†

The data for the analysis were obtained from a sample of 32 of the 33 farmers producing rubber at the Murua Settlement Scheme (Gulf Province) during the year 1971. This work was the first in a programme of annual surveys designed to study resource productivity changes over time.

The settlement area lies on the southern bank of the Murua River (a tributary of the Matupi) approximately six miles from Kerema, the provincial capital. The topography and soils fall into two major groups. Bordering the river is a narrow flood plain with alluvial soils mainly of sandy loam. This area is flanked by a line of low hills where soils developed *in situ* are generally well-structured clay loams. The land was originally under coastal forest with limited areas of garden regrowth along the river and sago palm swamp in depressions between the low hills which form the dominant relief in the area.

In 1962, 36 blocks were allocated to settlers drawn, with the exception of one Kamea, from the coastal areas of the Gulf District. Block sizes of 8 to 25 ha provided a minimum of approximately 8 to 10 ha of cultivatable land. Development programmes for each block were planned on the basis of a DASF smallholder budget (Charles, unpublished) containing planting projections and cash flow analysis. The budget was adopted by the Native Loans Board as a basis for lending for personal needs and development expenditure of settlers. The minimum area of rubber per block, as determined by arbitrary labour input analysis, was 2.43 ha for a family supplying 1.5 units of labour for a total of 375 man days per year. The balance of the development on each block was not programmed. The blockholders were to be self-supporting and sufficient area was provided to allow for a permanent traditional garden with bush fallow cycle to be established.

Budgeted planting and income levels have not been achieved by the majority of the

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†Hartley 1972 and Irwin 1968.

growers. For example, only 16 of the 33 rubber producers had fulfilled the planting covenant and approximately the same number had not begun loan repayments by mid 1971. As there were no indications of agronomic difficulties, budget labour supply and productivity estimates appear to have been, on average, too high.

The following table shows Scheme rubber production and sales figures up to and including the period being studied. In 1971, 30 per cent of the producers sold 50 per cent of total output.

***Table* 1.—Rubber production and income**

Year	Production kg	Sales K	Average Price K/kg
1968-69	10 218	3 553	0.348
1969-70	24 545	10 928	0.445
1970-71	32 642	9 384	0.287
1971-72	33 274	7 885	0.237

Source: Marketing Branch, DPI, Konedobu

In all cases rubber was stated as the major source of cash income.

However, some money was earned from the sale of fresh vegetables to Kerema. The unreliability of data defining the vegetable activity restricts the following analysis to rubber enterprise input-output relations. It was found that the enterprises were not competing for resources. Cross-section farm information was collected on rubber output, land, labour, fixed capital and settler personal characteristic variables.

DESCRIPTION OF THE VARIABLES

The significance and content of any production function derived from empirical data depends on the way in which factors entering into the production relationship are defined. Problems of specification and of variability of individual farm situations are particularly acute.

Rubber output is measured in physical units—kilograms of rubber sold in 1971. There was little difference among farms in crop quality as reflected by the average price per block, so there was justification for treating the dependent variable as homogeneous. Average farm output was 955 kg with a coefficient of variation equal to 50 per cent.

Land is represented by the number of rubber trees that had been tapped as at the end of June, 1971. Average tapped trees per block was 542 (C.V. = 37 per cent). However, because tapped trees comprised only 70 per cent of the number of mature trees on the average farm and 54 per cent of total trees stocks, it could have been argued that rubber trees were not limiting and that the productivity of land is really the product of labour used in exploitation.

Labour was provided by members of the farm family. Because labour proved to be a constraint, particularly with respect to the tapping activity, the labour variable is included in the analysis by the number of "full-time" tappers on each block. Weights were allocated on the basis of the extent of participation by family members in the operation. The average farm had 2.6 tappers (C.V. = 38 per cent). Coagulation capacity could provide a daily constraint to output. Therefore the capital variable was represented by the number of coagulating pan equivalents owned by each blockholder. The average number equalled 22.6 (C.V. = 27 per cent).

The physical independent variables defined above have particular limitations. Specification errors relating to the use of stock concepts for inputs instead of service flows consumed by the production process, among other things, tend to limit the usefulness of the analysis. Nevertheless, the derived relationships are considered not as a quantitative definition of possible optimum input levels but rather as providing an indication of important variable inter-relationships and directions of change.

The remaining variable to be discussed is management ability. A comprehensive review of the literature on the importance of the human factor in the production process has been reported elsewhere (Muggen 1969). The conceptual and measurement problems of including management as an explicit variable in conventional economic models are considerable and only crude attempts seem possible (Minnesota Agric. Exp. Stn 1968). However, for a review of production function studies incorporating proxy variables for management in similar semi-traditional rural situations refer to Upton (1970). Theoretically, by incorporating management in the production function an estimate is made of its influence on farm output. Its inclusion should decrease specification bias in the estimated marginal productivities of physical factor inputs. The classification of farmers into relatively homogeneous groups is attempted in this study.

The Nielson (1962) management model was adopted as the conceptual framework for the "measurement" of management ability. The following figure (*Figure* 1) presents the essential elements of this model.

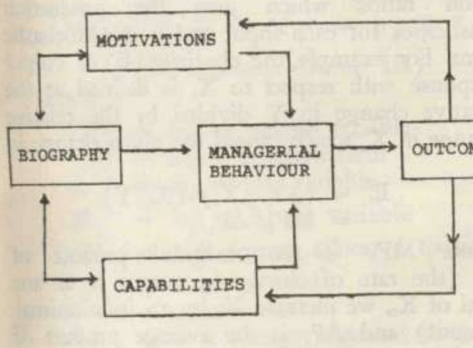

Figure 1.—Nielson Management Model

The manager is viewed as a goal-oriented system seeking to produce a desirable outcome. The manager possesses a biography of past experiences, motivations and capabilities which produce management behaviour and in turn generate an outcome. The model is completed by appropriate feedback from the outcome to the attributes where results may be used to influence future decisions. No allowance was made for reciprocal causation and the two-stage interaction between the behavioural antecedents (biography, capabilities and motivation) and management behaviour and managerial performance, in this application. In addition it is *assumed* that social structure variables as they relate to individual management ability remain constant over the sample, and that the four elements, as specified (refer Appendix 1) relate to the performance outcome—rubber production. It was considered that the rubber enterprise, although existing simultaneously with competing activities, and differing with respect to economic aims and social significance, was the relatively more modern activity and its outcome may be measured in physical units. The criterion problem remains: to what extent are the "measurements" of managerial ability inferences from performance?

A proxy management ability index is constructed from information given in response to personal characteristic questions relating to each of the four elements (variates) of the Nielson model. A dichotomous scoring system was adopted to obtain variate scores for each smallholder. Ranks were allocated on the basis of these results. The four variate ranks were summed to arrive at the total score for each farmer. These scores allowed the final ranking of farmers on the basis of managerial ability. The aim of the above procedure was to reduce the number of variables involved and to provide a ranking of farmers approximately according to the first principal component of the variates of the model, that is, the single factor which explains most variance generated by the data. Kendall (1965) states that such a method maximizes the average Spearman correlation between the final ranking and the ranking according to the four variates.

Because ordinal data may not be directly used in regression analysis without giving it a higher measurement status, cutting points were set to enable the allocation of farmers to three mutually exclusive management ability groups. The effect of the three management groups in the explanation of production variance was obtained by employing a dummy variable model (Massell 1967). The essence of the technique is that a dummy variable has the value one if the individual belongs to that management group and zero otherwise.

Table 2

Management Group	Dummy Variable		
	M_1	M_2	M_3
I	1	0	0
II	0	1	0
III	0	0	1

The two variables M_1 and M_2 are included in the production function analysis, but M_3 is excluded to prevent singularity of the moments matrix (Tomek and Ben-David 1965).

Table 3.—Average input and output per unit input for farms by management groups

Management Group	Output (kg)	Inputs			Output/Input		
		Trees	Tappers	Pans	Output per tree	Output per tapper	Output per pan
I (11)	1294	654	2.7	25.4	2.0	511.8	58.4
II (10)	1104	560	3.1	23.8	2.1	326.9	47.8
III (11)	480	414	1.9	18.6	1.2	264.2	27.7
SAMPLE (32)	955	542	2.55	22.56	1.76	268.9	44.5

Table 3 presents calculated summary data for the average farm in each management group.

It appears that both output and input are related to managerial ability; better managers tending both to use larger inputs and to obtain a larger output from a given set of inputs. A more recent survey (unpublished) of 23 of the 1971 rubber producers has supplied data to enable the construction of a scale of individual modernity (Appendix 2). Better managers tend to be more modern in their outlook. Seventy-five per cent of the relatively high management ability group (cutting point at the median) exhibited a high modernity outlook compared with 27 per cent of the low management group, giving a percentage difference of 48 per cent.

METHOD OF ANALYSIS

The most commonly used form of aggregate function employed to analyse production relationships is the Cobb-Douglas function. The general form of this model is

$$Y = a X_1^{b_1} X_2^{b_2} \ldots\ldots\ldots X_n^{b_n} . u$$

which, if transformed into logarthms, reduces to the simple linear equation:

$$\log Y = \log a + b_1 \log X_1 + \cdots\cdots\cdots b_n \log X_n + \log u$$

where Y is the dependent variable (output), $X_1, X_2, \ldots\ldots X_n$ are the independent variables (inputs), a is a constant term, the exponents $b_1, b_2, \ldots\ldots b_n$ are the transformation ratios which give the production elasticities for each input and u is a stochastic term. For example, the elasticity (E) of output response with respect to X_1 is defined as the relative change in Y divided by the relative change in X_1 which caused the given change in Y.

$$E_1 = (\Delta Y/\Delta X_1)\ (X_1/Y)$$
$$= MP_1/AP_1$$

where MP_1 is the marginal product of X_1 (the rate of change in output if at any level of X_1, we increase X_1 by an infinitesimal amount) and AP_1 is the average product of X_1. The widespread use of the Cobb-Douglas function can be attributed to the relative ease in determining factor elasticities, marginal values and to its simple computational requirements. In the following analysis, it was found to give the best fit to the data relative to the linear model. In particular, the effect of management was proportional rather than additive. The log transformation assists to establish both additivity of effect and equality of variance between groups.

Given the Cobb-Douglas framework, the effect of management ability in the production process was conceptualized by two different specifications of the dummy variable model, as follows.

1. It is assumed that management directly affects factor elasticities. In particular, management is assumed to affect the elasticity of the labour input variable. Labour is selected given the problem of separating management and labour on a family farm. Data in *Table* 2 suggest that this is the appropriate specification. Further, the statistical advantage of pooling a limited number of observations through employing the dummy variable technique is

greatest if changes are permitted in one selected coefficient and *prima facie*, the labour variable seems the obvious choice. This regression model can be formulated:

$$Y^* = a^* + b_1 X_1 + b_2 X_2^* + c_1 X_2^* M_1 + c_2 X_2^* M_2$$

Thus,

$$Y^* = a^* + b_1 X_1^* + (b_2 + c_1) X_2^* \text{ (Management Group I)}$$

$$Y^* = a^* + b_1 X_1^* + (b_2 + c_2) X_2^* \text{ (Management Group II)}$$

$$Y^* = a^* + b_1 X_1^* + b_2 X_2^* \text{ (Management Group III)}$$

where

Y^* = log of output variable
a^* = log of constant term
X_1^* = log of tree variable
X_2^* = log of labour variable
M_1 = 1 if farmer allocated to management group I
= 0 otherwise
M_2 = 1 if farmer allocated to management group II
= 0 otherwise

2. It is assumed that management directly affects the elasticity of the labour variable and in addition is responsible for a vertical shift in the production function. This regression model can be written:

$$Y^* = a^* + b_1 X_1^* + b_2 X_2^* + c_1 X_2^* M_1 + c_2 X_2^* M_2 + d_1 M_1 + d_2 M_2$$

In this case we have:

$$Y^* = (a^* + d_1) + b_1 X_1^* + (b_2 + c_1) X_2^* \text{ (Management Group I)}$$

$$Y^* = (a^* + d_2) + b_1 X_1^* + (b_2 + c_2) X_2^* \text{ (Management Group II)}$$

$$Y^* = a^* + b_1 X_1^* + b_2 X_2^* \text{ (Management Group III)}$$

RESULTS AND DISCUSSION OF THE ANALYSIS

The results of the multiple regression analysis are reported in *Table* 4. Regression equations 1, 2 and 3 include only physical variables. Regression equation 4 includes management specified as a slope changing agent with respect to labour input (model one). Equation 5 represents the result of employing model two. All the regressions are significant at least at the 1 per cent level.

Table 5 shows analysis of variance results contributing to the exclusion of the capital regressor. Given the low level of rubber yields, it appears that production is limited not by daily coagulating capacity but rather by tapping frequency. The capital variable is not retained as the statistical results confirm a strong prior belief.

***Table* 5.—Analysis of variance**

Source of variation	Sum of squares	d.f.	Mean square	F	Prob. value for H_0
X_1 and X_2	1.327	2			
Add X_3	0.054	1	0.054	1.93	$p > 0.05$
	1.381	3			
Residual	0.800	28	0.028		
TOTAL	2.181	31			

The inclusion of the management factor in the production function leads to a significant increase (at least at the 1 per cent level) in explanation of rubber output variance—the coefficient of multiple determination increases from 63 to 75 per cent. Analysis of covariance results in *Table* 6 indicate the statistical superiority of model one in the specification of the management effect.

Timmer's (1970) suggestion that the impact of management in a production function would likely be through changes in factor elasticities rather than neutral shifts in the entire function is consistent with this analysis. Regression equation 4 is selected as the basis for the calculation of factor marginal value products. A Cobb-Douglas function does not give a single estimate of factor marginal productivities, for this varies according to the input level. *Table* 7 shows the estimated marginal productivities calculated for the geometric mean quantities of total sample input and output.

Conventional analysis emphasizes statements on the relative efficiency/inefficiency of resource allocation on the representative farm. This is determined on the basis of a comparison of marginal value productivities of inputs with

Table 4.—**Estimated production elasticities and related function statistics**

Regression equation No.	Regression coefficient								R^2 %	F	d.f.
	Const a	Land b_1	Labour b_2	Capital b_3	Management						
					c_1	c_2	d_1	d_2			
1	0.143	1.129	—	—	—	—	—	—	48	27.29	1/30
2	0.227	0.907	0.608	—	—	—	—	—	61	22.55	2/29
3	0.289	0.735	0.552	0.322	—	—	—	—	63	16.10	3/28
4 (model one)	1.363	0.512	0.138	—	0.841	0.692	—	—	75	20.26	4/27
5 (model one)	1.518	0.435	0.098	—	0.51	0.48	0.107	0.042	76	12.75	6/25

Table 6.—Analysis of covariance

Source of variation	Sum of squares	d.f.	Mean square	F	Prob. value for H_0
Residual	0.423	23	0.018		
Add M_1 and M_2 (differential slope vectors)	0.309	4	0.077	4.28	$p<0.01$
Residual	0.732	27	0.027		
Add M_1 and M_2 (differential intercepts)	0.122	2	0.061	2.25	$p>0.05$
TOTAL	0.854	29			

Table 7.—Estimated factor marginal products by management groups

Variable	Management group	Elasticity (b_i)	Average physical product (kg/unit)	Marginal physical product (kg/unit)	Marginal value product (K/unit)*
Land (trees)	I, II, III	0.512	1.6	0.82	0.22
Labour (tappers)	I	0.979	342.8	335.60	88.60
	II	0.830	342.8	284.52	75.11
	III	0.138	342.8	47.31	12.49

*Average rubber price received was equal to K0.264 per kilogram

Table 8.—Estimated factor marginal products by management groups

Variable	Management group	Elasticity (b_i)	Average physical product (kg/unit)	Marginal physical product (kg/unit)	Marginal value product (K/unit)
Land	I	0.512	1.90	0.97	0.26
	II	0.512	1.96	1.00	0.26
	III	0.512	1.12	0.57	0.15
Labour	I	0.979	492.2	481.8	127.19
	II	0.830	353.5	293.4	77.46
	III	0.138	233.5	32.2	8.50

their respective prices or opportunity costs. The absence of reliable opportunity cost data precludes such analysis. In the "transitional" type farm environment which we are investigating, the conceptual and measurement complexities of evaluating "returns" received from competing activities are considerable. Mellor (1969) argues that in the case of labour, the major input, its cost may be largely determined not by the rural minimum wage but by the subjective judgement of farmers concerning the utility they derive from purchased goods and services relative to the satisfaction generated by the range of competing activities, including leisure. Current capital expenditure is likewise provided from internal sources and its cost is determined by a subjective compromise between present and future consumption.

All that can be concluded is that the "return" to land and labour from competing activities is in fact higher than their estimated marginal value products. However, a comparison is possible between resource productivities for the three management categories. As well as substantial differences in resource structure, interfarm rubber output variation is influenced by variation in resource productivity between management groups. *Table* 8 shows marginal value product estimates relative to the mean input and output levels for each management category.

Estimated marginal resource productivities are substantially higher for management groups I and II compared with group III. Except for the case of the land (trees) input, management group I productivities exceed group II. For all groups, marginal values are less than their respective average equivalents, therefore marginal products must be falling. Given the production potential of the trees, a relatively low rate of tapping intensity and a production process characteristic of high resource divisibility, this phenomenon seems strange, unless specification errors have been made in the measurement of factor input. This seems likely, as no allowance was made for the age distribution of tree stocks in tapping, and the problem of assigning efficient weights for the aggregation of labour units over age groups differing markedly in their effective participation in the production process is most apparent.

Recent analysis (unpublished) has shown that the average Murua farmer exhibits a relatively high short-run price elasticity of supply. In this type of situation an increase in rubber output will be encouraged by an increase in resource marginal productivities. However, the critical question is not whether added labour would increase output, but whether the incremental increase in the value of output to the farmer is greater than the marginal opportunity cost of labour.

In the short term there are limited technically acceptable means by which resource productivities can be increased relative to their marginal physical cost. Pilot recommendations would include:

(1) Increase tapping intensity to between 60 and 70 per cent by adopting a full spiral tapping system particularly on tree panels C and D. A full spiral cut sixth or seventh daily system would increase both return per hectare and per man-day in spite of increased percentage of scrap rubber and possibly lower task size. The use of full spiral tapping on the virgin bark panels of A and B must be associated with a continuous check of dry tree incidence. Unfortunately, seedling planting material is most unreliable in its response to longer cut tapping systems.

(2) Initiate a programme of selective tapping. Eventual thinning of 30 per cent of lower producing trees (a decrease in tree density from 445 trees/hectare to 312) would increase average yield per tree and therefore per tapper by 20 to 25 per cent (Edgar 1958).

(3) Remove any daily output constraint provided by coagulating capacity by making available significantly cheaper coagulating containers. Such a product is currently being researched by A.C.I. (New Guinea) Pty Ltd.

In the long term the supply of high-yielding budgrafted clonal rubber planting material compatible with low labour input tapping systems would ensure a significant increase in resource productivities. Some of the budgrafted clones now being planted in Malaysia have shown that they can produce 2 000 to 3 000 kg per hectare. Yields of more than 6 000 kg/ha have been achieved in small-scale experimental plantings, and theoretical estimates indicate that the summit yield is much higher.

The maximum yield expected from the clonal seedling material planted at Murua would be in the vicinity of 1 300 kg per hectare.

It should be emphasized that changing the "technical" situation works only to the extent that farmers have a response structure appropriate to the perception, evaluation and action on the changed incentives (Nadkarni 1970). The marginal return to the above innovations must be sufficiently large to offset the non-material costs of adoption.

These costs will tend to be large where technical change is infrequent or when traditional values are strongly held, or both. Therefore, it is suggested that the response pattern may broadly reflect management group membership. The better managers (groups I and II) tending to increase resource productivity and output relative to group III. Extension induced technical change will, therefore, widen the gaps between the groups (Ashcroft 1973). Blanket advice can never "fit" the actual situation on every farm and in a wide range of circumstances, real improvement can only be made by modifying and tailoring the technique or practice to meet the individual circumstances. However, a substantial opportunity has been shown to exist to increase factor productivity and output by concentration of extension effort on the development of the smallholders' management resources.

CONCLUSIONS

The production function analysis indicates that a significant percentage of interfarm variation in rubber production can be explained in terms of differences in physical farm resource structures and productivities. The inclusion of a proxy variable set representing management ability was successful in improving the fit of the Cobb-Douglas function to the cross-section data and in reducing bias in the estimation of marginal productivities.

The adoption of technical innovations to increase resource marginal value products will more than likely parallel management group membership. Relatively better managers tending to be more modern in their outlook and possessing higher transactions demand for cash may be induced to increase factor supplies.

Extension programmes aimed to increase Scheme production should be explicitly designed to take into account variation in the management ability of farmers. Research should be initiated into the behavioural components of the management factor and the responsiveness of such components to different extension strategies. The potential implications of such research are substantial since more accurate measurement and prediction of the management factor would add a greatly needed element in economic analysis. There are obvious practical applications in the screening of applicants for smallholder blocks on capital intensive settlement schemes and rural credit.

APPENDIX 1

Personal characteristic question themes used as a basis for measuring management model component variates (*Muggen* 1969)

(1) *Biography* (6 *items*)
- (a) Age
- (b) Work experience
  - (i) location (urban/non urban)
  - (ii) type (skilled/unskilled)
- (c) Job mobility
- (d) Community responsibility
- (e) Education

(2) *Capabilities* (8 *items*)
- (a) Knowledge of crop
- (b) Knowledge of economic principles
- (c) Opinionatedness

(3) *Drives and motivation* (3 *items*)
- (a) Relative income aspiration
- (b) Attitude towards credit
- (c) Attitude to price changes

(4) *Management process* (5 *items*)
- (a) Planning and organizational practices
- (b) Plans for future
- (c) Use of information sources

APPENDIX 2

(A) *Minimum scale of individual modernity*: *Short form* 6 (Smith and Incheles 1966).

This scale provides a summary index of overall modernity—defined as a set of personal qualities which reliably cohere as a syndrome and which identify a type of man who may validly be described as fitting a reasonable conception of the modern man. Personal qualities central to this syndrome are:

(1) Openness to new experience;

(2) Assertion of increasing independence from the authority of traditional figures;

(3) Belief in the efficacy of science and medicine and a general abandonment of passivity and fatalism in the face of life's difficulties;

(4) Ambition for one's self and one's children to achieve high occupational and educational goals;

(5) Appreciation of punctuality and forward planning;

(6) Activity in community affairs; and

(7) Interest in national and international news.

(B) *Results*

Management ability	Modernity Low	High	TOTAL
High	3	9	12
Low	8	3	11
	11	12	23 = N

$P(3.5 \Sigma X^2 < \infty) = 6.5\%$

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CRYPTOPHLEBIA ENCARPA (MEYRICK) (LEPIDOPTERA:TORTRICIDAE) AS A PEST OF CACAO PODS IN THE NORTHERN PROVINCE OF PAPUA NEW GUINEA

G. L. Baker*

ABSTRACT

Cryptophlebia encarpa *is a minor pest of cacao pods in the Northern Province of Papua New Guinea. The damage caused by this species has however become increasingly conspicuous in recent times following the control of other pod-damaging insects through the use of insecticides.*

The larvae feed on the epicarp and less frequently penetrate the mesocarp and feed on the endocarp of the cacao pod. Death of an attacked pod may result from penetration of the mesocarp by the larvae and subsequent fungal infection of the endocarp and seeds.

High infestation levels are positively associated with increased abundance of large, maturing cacao pods, the abundance of which is characteristically seasonal.

Under laboratory conditions, the duration of the larval stage is 13 *to* 15 *days and the pupal stage* 8 *to* 11 *days. Mean adult longevity is* 4.3 *days.*

INTRODUCTION

Insect pod borers of *Theobroma cacao* recorded from Papua New Guinea include the lepidopterous tortricid borers *Laspeyresia* sp. (Froggatt 1938), *Olethreutes* sp. (Szent-Ivany 1961; DASF 1968; Anon. 1969) and *Cryptophlebia encarpa* (Meyrick). Other insects injurious to cacao pods include numerous species of cacao leaf-eating lepidoptera which at times may feed on the epiderm of cacao pods (Szent-Ivany 1961). The larvae of the cacao weevil borer, *Pantorhytes szentivanyi* Marsh. may attack cacao pods, penetrating the mesocarp and feeding on the pulpy layer around the seeds. Adults also may feed on the epiderm of cacao pods (Entwistle 1972). The tipulid *Limonia* sp. has also been recorded feeding within the cacao pod epicarp (DASF 1968).

In the Northern Province of Papua New Guinea cacao pods normally suffer extensive damage from the mirid *Helopeltis clavifer* Walk. and to a lesser extent from the coreid *Amblypelta theobromae* Brown. In recent years these pests have been effectively controlled by the use of insecticide sprays or dusts containing lindane. With the continued and prolonged use of lindane, *C. encarpa* has became increasingly conspicuous as a pest of cacao pods. Damage however continues to be of little economic importance and to date it has not warranted control.

Bradley (1960) lists the distribution of *C. encarpa* as South India, New Hanover Island, Sudest Island and Guadalcanal. The same, or closely related species of *Cryptophlebia*, has also been recorded from New Britain feeding on the epiderm of cacao pods (Szent-Ivany 1963; Entwistle 1972).

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DAMAGE

The larvae of *C. encarpa* damage cacao pods at all stages of development. The severity of the damage varies with the stage at which the pod is attacked, the depth of penetration by the larva (*Table* 1) and the number of larvae attacking individual pods (*Table* 2). The cacao pod invariably dies if the larvae penetrate the mesocarp and feed on either the endocarp or developing seeds.

Feeding on the epicarp does not harm the seeds of large cacao pods, but the damage to these tissues invariably leads to secondary fungal infection (*Plate* IA). This renders pods so attacked unsightly, and causes their neglect at the time of harvest because they resemble pods infected by black pod (*Phytophthora palmivora*).

In the case of young pods, feeding on the epicarp can lead to death of pods as secondary fungal infections can pass through the unhardened mesocarp and infect the seeds.

Penetration of the mesocarp by *C. encarpa* larvae usually only occurs in small pods in which the mesocarp has not hardened. The mesocarp at the distal end of the pod appears far easier for the larvae to penetrate for a longer period than the remainder of the mesocarp.

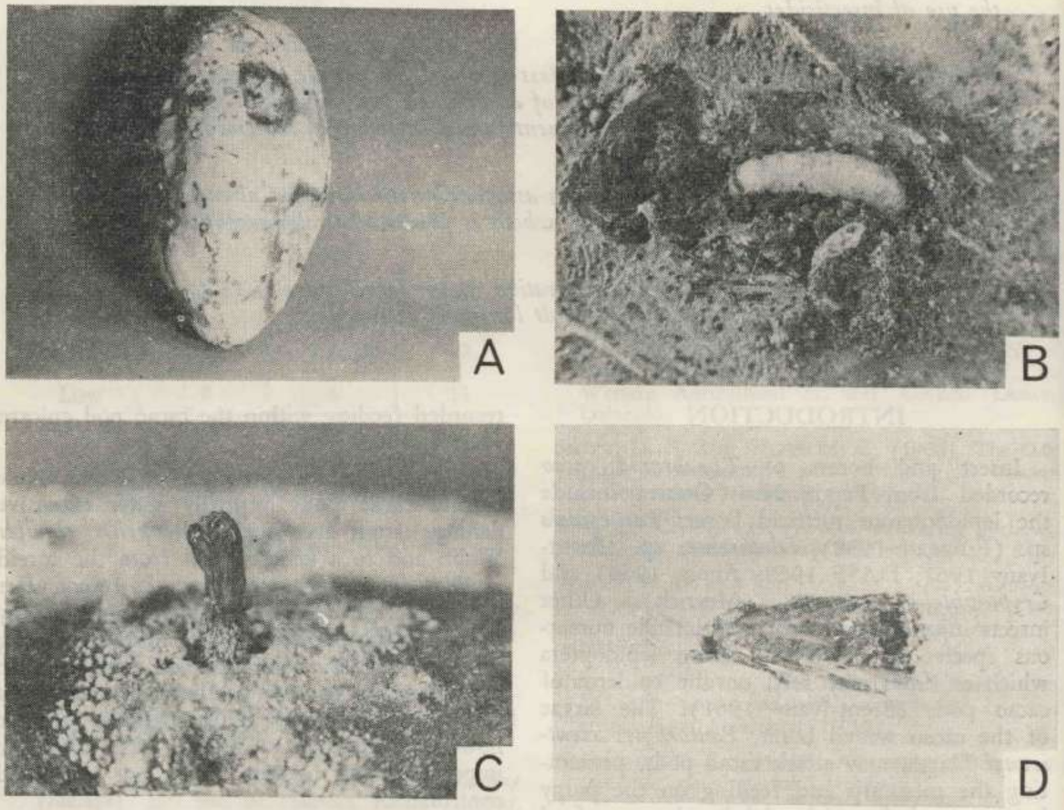

Plate I.—*Cryptophlebia encarpa*. A. Empty pupal case protruding from attacked cacao pod, and surrounded by tissue infected by secondary fungi. B. Final instar larva in channel in cacao pod epicarp. x 2. C. Empty pupal case protruding from cacao pod after emergence of adult. D. Adult female. x 2.5

Table 1.—**Number of cacao pods, with maximum penetration by C. *encarpa* larvae to tissue layer indicated**

Tissue layer penetrated	Epicarp	Mesocarp	Endocarp	Seeds	TOTAL
Pod size Small (< 10 cm)	29	3	2	9	43
Medium (10-15 cm)	35	0	0	9	44
Large (> 15 cm)	49	0	1	6	56
TOTAL	113	3	3	24	143
As %	79.0	2.1	2.1	16.8	

Table 2.—**Number of cacao pods attacked by varying numbers of C. *encarpa* larvae**

	Number of pods attacked					Total Pods	Total Larvae
	1	2	3	4	5 or more/no.		
Pod size:							
Small	24	17	6	2	2/11	51	95
Medium	29	23	18	11	10/72	91	245
Large	33	15	14	16	2/14	80	183
Total Larvae	86	110	114	116	97		523
As %	16.5	21.0	22.8	22.2	18.5		
Total Pods	86	55	38	29	14	222	
As %	38.73	24.8	17.1	13.1	6.3		

The maximum extent of tissue penetration by *C. encarpa* larvae in samples of pods of various sizes is shown in *Table* 1. It can be seen that the mesocarp was penetrated in only 21 per cent of cases, most of which were small or medium sized pods.

There is no obvious direct correlation between incidence of attack and crop loss. A conservative estimate would be that between 50 to 70 per cent of pods attacked fail to reach maturity and of the 30 to 50 per cent that do reach maturity, most are not harvested.

BIOLOGY OF *C. ENCARPA*

Eggs

The egg stage is unknown. Oviposition has taken place under laboratory conditions as larvae have been bred in cacao pods placed with females reared from field collected larvae and pupae. However, no eggs which could be confirmed as being those of *C. encarpa* were observed in these instances.

Larvae

Four adults which emerged from pupae on 22nd July, 1971 were placed in a breeding cage with mature cacao pods. All adults died over a period of seven days. Six days after the death of the last adult minute amounts of frass were found exuding from two larval channels in the cacao pods. The channels measured 4.3 and 5.9 mm in length and both were 0.5 mm in width. These larvae are believed to have been first instar larvae as no frass had been observed prior to the twelfth day after the introduction of the adults into the breeding cage.

The two larvae measured 1.46 and 1.61 mm in length and their head capsules both measured 0.25 mm in width. The body of the larvae was a pale yellow-lime whilst the head capsules were black in colour. There was a prominent though paler coloured prothoracic shield on the first thoracic segment.

The adfrontal area of the head capsule was very short with the lateral part of the head capsule posterior to the adfrontal suture flaring back to give the head capsule a distinctly heartshaped appearance.

Two days after being first observed the larvae underwent ecdysis to enter the second instar. The larvae were similar in appearance to first instars and measured 5.1 and 7.3 mm in length. Their head capsules measured 0.90 and 1.06 mm in width respectively.

The dorsal posterior border of the head capsule was much straighter, lacking the medial V-shaped border found in the first instar. The body remained yellow-green in colour.

The larval channels had been extended to 20 and 32 mm in length and had widened to 4 mm.

Ecdysis occurred six days later after which the larvae attained a size similar to that of field-collected final instar larvae.

The two larvae pupated after a further five and seven days respectively, giving a total larval development period of between 13 and 15 days. This excludes the small amount of development which would have occurred prior to the channels being first observed.

There is a marked change in the appearance of larvae between the second and third (final) instar.

In the final instar (*Plate* IB) the head capsule lightens in colour to a pale brown, whilst the prothoracic shield remains black. The body changes from a yellowish green to an orange colouration tinged with mauve. There is a pair of brown spots on the dorsal surface of each of the body segments.

The head capsule width of final instar larvae ranged from 1.2 to 2.0 mm (mean 1.75 mm: 17 larvae). Body length varied from 11.5 to 14.7 mm (mean 13.8 mm : 17 larvae).

Channels occupied by final instar larvae measure from 40 to 65 mm in length and vary between 10 and 28 mm in width. The channels, even when extensively broadened, remain relatively shallow and are usually no deeper than the thickness of the incumbent larva's body.

Pupation

Final instar larvae move towards the surface of the pod and enlarge the channel's entrance before spinning a cocoon within the channel and pupating. The outside of the cocoon is characteristically covered by small frass pellets and other debris from within the channel.

Spinning of the cocoon is usually completed within two hours. The larva remains as a pre-pupa within the cocoon for a further one to two days before pupating.

Adult Emergence

During emergence of the adult the pupa is drawn through the thin fabric of the cocoon by the semi-emerged adult and is dragged along the larval channel to the surface where the anterior third of the pupa remains protruding from the channel entrance after the adult has completed emergence (*Plate* IA and IC).

The pupal period lasts from 8 to 11 days (mean 9.9 days : 10 pupae).

Longevity of Adults

Adults bred from larvae in the laboratory were supplied with water and a sugar solution from the time of emergence. Their longevity, however, was very short and ranged from three to eight days (mean 4.3 days : 21 adults).

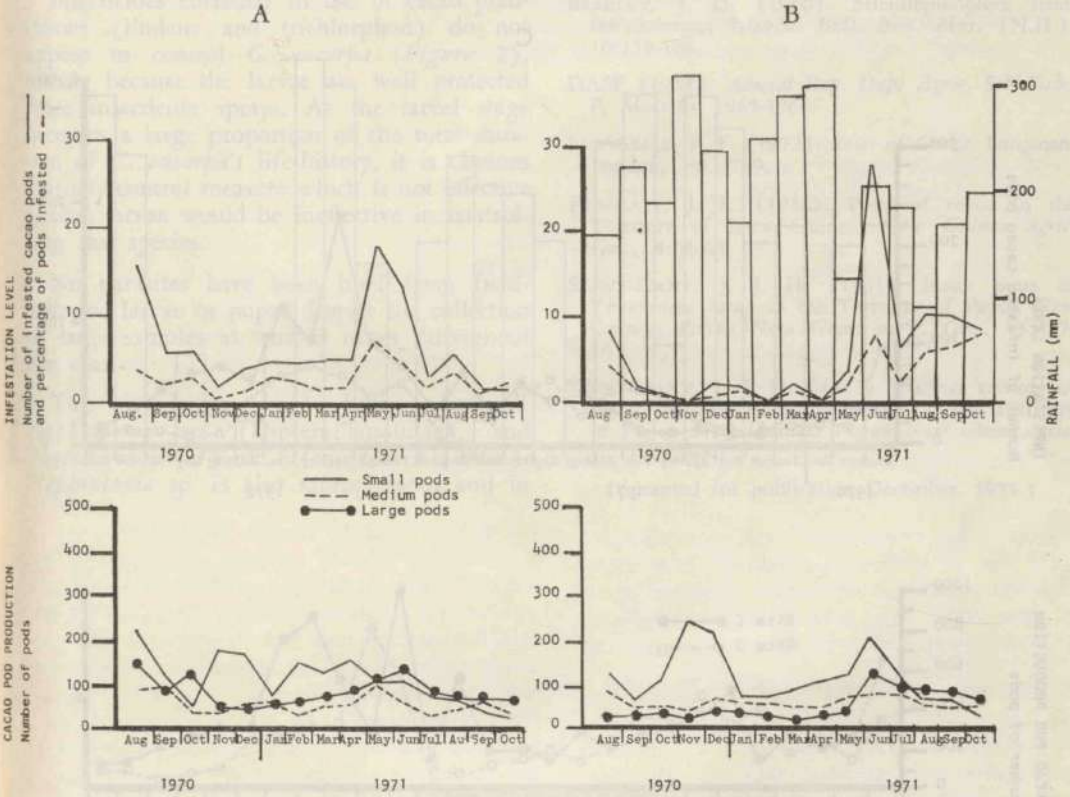

Figure 1.—Damage to cacao pods by *Cryptophlebia encarpa* in relation to pod production and rainfall at two sites. A. Cacao heavily infested by capsids; occupied by the non-predatory ant *Technomyrmex albipes;* grown under leucaena shade; B. Cacao with low level of capsid damage; occupied by the predatory ant *Anoplolepis longipes;* also grown under leucaena shade

SEASONAL ABUNDANCE

Recordings of *C. encarpa* damage levels were made at monthly intervals in four areas of cacao in conjunction with trials with unrelated aims.

It can be seen from the results (*Figures* 1 and 2), that there is a consistent tendency for the number of pods damaged and the proportion of total pods attacked to be greater during or immediately following a period of low rainfall.

However, this greater incidence of damage also corresponds with periods when a greater number of large pods are present. There does not appear to be any relationship between damage levels and the number of small or medium sized pods. The data shown in *Figure* 2 do not distinguish between pod sizes, however there are high levels of damage following a large increase in the number of pods which presumably coincides with maturation of pods following a period of flush.

The apparent relationship between high incidence of attack and low rainfall is incidental to changes in the number of large pods. Only two instances of an increase in the damage level corresponding to low rainfall without a concurrent change in the number of

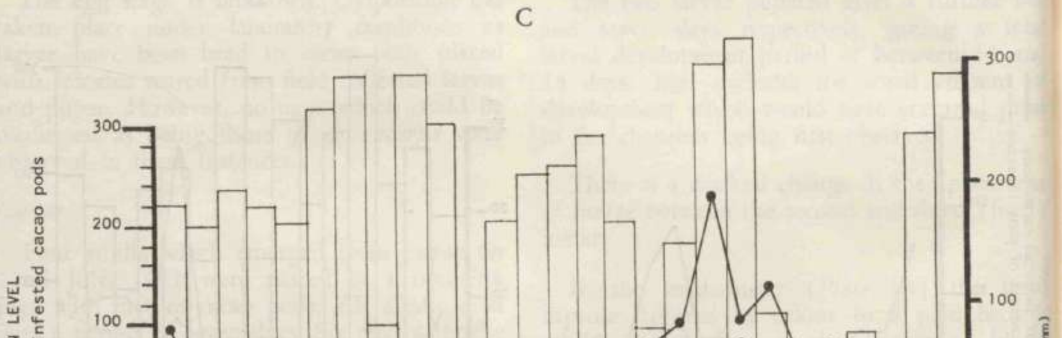

Figure 2.—Damage to cacao pods by *Cryptophlebia encarpa* in relation to pod production and rainfall at two sites. C. Unshaded cacao sprayed every third month with trichlorfon L.V.C.; D. Unshaded cacao—no insecticide treatment

large pods were recorded (August 1971, *Figures* IA and IB).

The seasonality of high damage levels may be due to a preference by the gravid female to oviposit on large pods. An alternative explanation is that it results from a gradual build up in the population of *C. encarpa* beginning soon after a flush, the population increasing to a maximum as the pods develop towards maturity.

CONTROL

As stated in the introduction, attack on pods by *C. encarpa* has not reached levels where it appears to warrant control measures.

Insecticides currently in use in cacao plantations (lindane and trichlorphon) do not appear to control *C. encarpa* (*Figure* 2), mainly because the larvae are well protected from insecticide sprays. As the larval stage occupies a large proportion of the total duration of *C. encarpa's* life-history, it is obvious that any control measure which is not effective against larvae would be ineffective in controlling the species.

No parasites have been bred from field-collected larvae or pupae despite the collection of large samples at various times throughout the year.

Two predators have been observed: *Nephrotoma* sp. (Diptera:Tipulidae), and *Physoderes azreal* Kirk. (Hemiptera:Aradidae). *Nephrotoma* sp. is also saprophagous and in many cases where it is encountered it has possibly only secondarily occupied the *C. encarpa* channel. Neither predator is host-specific, both attacking other cacao borers, e.g. *Pantorhytes szentivanyi*.

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INTRODUCTION AND DISTRIBUTION OF EXOTIC FISH IN PAPUA NEW GUINEA

G. J. West and J. Glucksman*

ABSTRACT

Twenty species of exotic freshwater fish are known to have been introduced to Papua New Guinea. These introductions have been made for various reasons: for mosquito control, to establish sport fisheries, to improve the protein-deficient diet of inland people, to supply forage for introduced predatory fish, and for aquaculture. Nine of these species, including two that presumably escaped from ornamental aquaria, are now established in natural waters. Salmo gairdneri *is, to date, the only species showing potential for intensive aquaculture, while two species originally intended for aquaculture,* Tilapia mossambica *and* Cyprinus carpio, *support fisheries in natural waters. The Department of Primary Industry has severely restricted the importation and distribution of most exotic fish, and the severity of the restrictions will probably increase.*

INTRODUCTION

THE first exotic fish to be introduced to Papua New Guinea was the mosquito fish *Gambusia affinis*† (Baird and Girard), brought in by Public Health authorities in 1930 as part of their malaria control programme.

Further interest in fish introductions was not evident until after the Second World War. A nutrition survey conducted in 1947 indicated that the diet of inland people was deficient in animal protein and it was recommended that supplies of fish be developed to the maximum possible extent (Anon. 1947).

In 1950, at the request of the Department of External Territories, W. H. Schuster, a fisheries specialist from Indonesia visited Papua New Guinea to advise on methods for increasing the fish harvest. His first recommendation was simply to intensify the coastal and brackish water fisheries. He realized, however, that problems in handling and transporting fresh fish would prevent this increased production from being distributed inland, where protein deficiency was most marked. For inland areas the aquaculture of *Cyprinus carpio* Linnaeus and *Tilapia mossambica* (Peters) was recommended, though Schuster noted that the people lacked any tradition of aquaculture (Schuster 1951).

Schuster also pointed out that the yield in many natural bodies of water would probably be below the potential indicated by primary production, because of a paucity of native plankton-eating species. He noted such a situation in the lower Sepik River, and suggested that if it became necessary to increase production, herbivores and omnivores such as *Trichogaster pectoralis* (Regan), *Helostoma temmincki* Cuvier and Valenciennes, and *Puntius gonionotus* (Bleeker) could be introduced. He emphasized that this should be done only after exhaustive ecological investigation.

Concerning the introduction of *Cyprinus carpio* and *Tilapia mossambica* to the highlands, Schuster considered that there could be no objections, as in this area there were no fish known to be of economic importance.

Whitley (1951), however, opposed the introduction of exotic fish and suggested that methods of preservation and distribution be improved so that existing fish populations could be more fully exploited, thus avoiding the almost inevitable ecological disruptions which follow introduction of exotic species.

In 1956, H. Van Pel, an inland fisheries specialist with the South Pacific Commission, visited Papua New Guinea and his report encouraged the introduction of exotic fish to natural waters (Van Pel 1956).

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†Common names are those in current use in Papua New Guinea.

The early attempts to develop freshwater fisheries followed the direction suggested by Schuster and Van Pel, although the recommendations of the former concerning methods of minimizing the possibility of ecological disruption were generally ignored.

The Department of Primary Industries has been responsible for the majority of the introductions, most of which were intended to increase the yield of inland fisheries. A brief summary of the first introductions of each species, with comments on their distribution and relative success, is given in *Table* 1, and a detailed histroy of the introduction of each of the twenty species is given to the following section.

HISTORY OF INTRODUCTIONS

Gambusia affinis (Baird and Girard)
MOSQUITO FISH

The mosquito fish was introduced to Rabaul in March 1930 when Public Health authorities obtained stocks of these fish from Sydney and placed them in a pond at the Rabaul Botanic Gardens (*Table* 2). When they began reproducing, stocks were transferred to numerous outstations (Anon. 1931). They were thought to have considerably reduced the mosquito population of the Lakunai Swamp, near Rabaul (Anon. 1932). Breeding continued in Rabaul and the fish were supplied free on request to all parts of the Trust Territory of New Guinea (Anon. 1936).

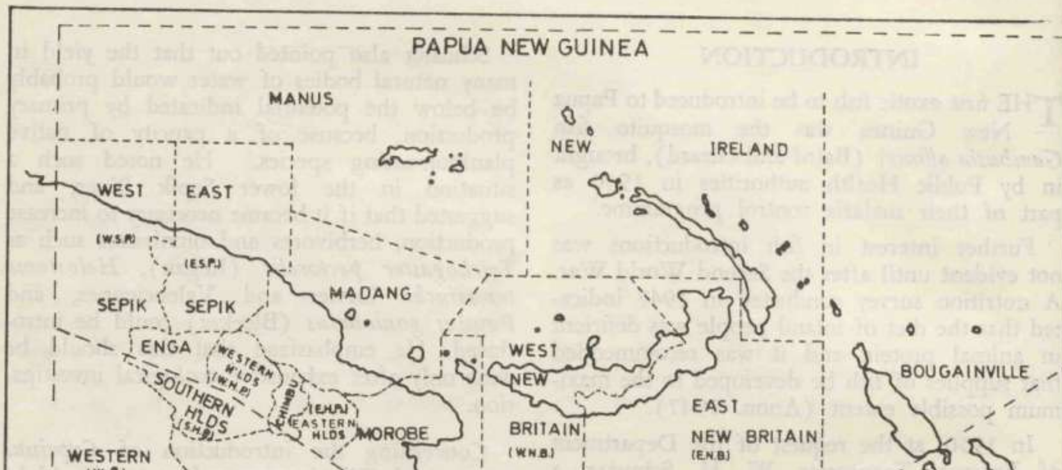

Figure 1.—Provinces of Papua New Guinea

Table 1.—Fish introductions in Papua New Guinea

Species	Date of first introduction	Present distribution	Comments
Gambusia affinis	1930	Very widespread	Of little value in malaria control, and possibly harmful to native fish.
Salmo trutta	1949	S.H.P. Chimbu, E.H.P.	Moderate potential for localized food source, aquaculture, and tourist incentive.
Salmo gairdneri	1952	E.H.P., S.H.P., W.H.P., Enga, Chimbu, W.S.P.	Similar, but better potential than *S. trutta*.
Tilapia mossambica	1954	Very widespread	Important as food, especially in Sepik and Central Provinces. Considerable potential.
Trichogaster pectoralis	1957	Very limited distribution; Central & Gulf Provinces	Of no value at present; possible potential in sewerage ponds and manure-methane digester systems.
Osphronemus goramy	1957	Small, widely scattered populations	Of little value, and low potential.
Cyprinus carpio	1959	In most suitable highland streams and lakes; isolated populations in lowlands	Of moderate value, potential probably realized.
Hypophthalmichthys molitrix	1961	Nil	Unsuccessful in pond culture trials.
Bidyanus bidyanus	1962	Nil	Intended for stocking in natural waters, but did not survive.
Tandanus tandanus	1963	Nil	Pond culture trials discontinued and stocks destroyed.
Carassiops klunzingeri	1963	Nil	Intended as forage fish, but did not survive.
Retropinna semoni	1963	Nil	Intended as forage fish for trout, but did not survive.
Ctenopharyngodon dellus	1964	Nil	Unsuccessful in pond culture trials. Stocks destroyed.
Plectroplites ambiguus	1966	Nil	Released in natural waters but did not survive.
Trachystoma petardi	1966	Nil	No information available.
Puntius gonionotus	1970	Experimental ponds. Aiyura, E. H. P.	Not to be distributed.
Poecilia reticulata	1967?	Port Moresby area	Escaped aquarium fish, possibly harmful.
Trichogaster trichopterus	1970?	Port Moresby area	Escaped aquarium fish, possibly harmful.
Salvelinus fontinalis	1974	Some fry released in streams in S.H.P.	Considerable mortality of ova during hatching.

Mosquito fish were first introduced to the Territory of Papua in 1933, when Public Health authorities in Port Moresby received a shipment from Rabaul. They were placed in rainwater storage tanks and a billabong near the Laloki River, 20 km from Port Moresby. Subsequent floods gave the fish access to the Laloki River and adjacent swamps. Studies at the time indicated that the fish showed promise for the control of mosquito larvae (Giblin 1936). Distribution continued well into the Second World War, when demand declined with the advent of DDT (Anon. 1950).

Whitley (1951) considered that the mosquito fish might be no more effective in controlling mosquito larvae than many native freshwater fish, and that its introduction might offer the native species serious competition.

The Department of Health no longer considers larvivorous fish to be effective in malaria control and the distribution of any fish for this purpose is now discouraged (Venters 1973, unpublished report).

Salmo trutta Linnaeus BROWN TROUT

Salmo gardneri Richardson RAINBOW TROUT

Salvelinus fontinalis (Mitchill) BROOK TROUT

Trout were first introduced in 1949, when Sir Edward Hallstorm imported 20 000 brown trout fingerlings from Oberon, N.S.W., and released them in streams in the Nondugl area and in a pond at the Hallstrom Fauna Trust

Table 2.—**Introduction of *Gambusia affinis***

Year	Date	Source	Place of introduction	Place of Discovery	Comments
1930	March	Sydney	Rabaul		Successfully bred in pond in Botanic Gardens. Distributed to outstations.
1930-31		Rabaul Botanic Gardens	Lakunai Swamp, Rabaul		
1933	July	Rabaul	Port Moresby ponds near Laloki River, S.D.A. Mission Mirigeda		Spread into Laloki River system.
1934-37		Rabaul	New Guinea, Samarai, Solomon Is., Gilbert & Ellice Is.		Widespread introductions.
1942-44		Port Moresby	Sogeri, Lakekamu, Lae, Milne Bay		
1944-45		Port Moresby	Wewak, Madang		
1950 (?)			Manus I.		Introduced by DASF
1954				Nondugl	In ponds at Hallstrom Fauna Trust.
1955	20 August			Laloki R. swamps	Abundant.
1956	24 August			Lae Botanic Gardens	Moderate population reported.
1958			Irian Jaya		sent by DASF
1961	July			Minj area	Found in many ponds.
1962		Aua I.	Uvulu I.		Have since become abundant.
1972	October			Chambri Lake	Moderate population reported.
1972	December			Mendi area	Found in streams.

(Rapson, unpublished) (*Table* 3). The area was inspected in 1950, but there was no evidence of their survival, due probably to the turbid conditions during violent floods in the wet season (Schuster 1951).

The next introduction involved eyed eggs, which were much cheaper to transport by air than fingerlings. Bulolo Gold Dredging Ltd successfully hatched 10 000 rainbow trout ova in a raceway in the Upper Buane Creek, a tributary of the Bulolo River, in 1952. The company continued hatching eggs and distributing fry in the Bulolo River and its tributaries for several years, and the fish apparently survived until about 1964.

Private introductions continued until 1959, but as with the earlier releases, the streams to which they were introduced apparently were not suitable for long term survival or reproduction. The reasons for the introductions do not appear in the records, but it was the opinion of one visiting fisheries consultant that "From the point of view of local food resources, trout is not very important and its interest lies more in providing sports fishing for the European population" (Van Pel 1956).

The Division of Fisheries first became involved in importing trout in 1964, when 2 000 rainbow trout fry were released in the Baiyer and Gumanch Rivers near Mount Hagen. The release sites were evidently more suitable than those of earlier private introductions, for the fish survived and reproduced. Further introductions of small numbers of fingerlings were made in 1968 and 1970. In 1971 a small hatchery was established at Mendi, and by the end of the 1973 hatching season approximately 180 000 rainbow trout had been distributed throughout the highlands (*Table* 4). The growth rates exhibited by these trout have been very encouraging and they are heavily fished by the highlands people. Now that it has become economically feasible to periodically stock waters unsuitable for natural reproduction, it is felt that trout will not only make a contribution to the diet of the people, but that they will have some value in encouraging tourism. During the severe famine in 1972, caused by drought and frost, considerable quantities of trout were caught in some of the worst affected areas and served as a very welcome addition to the people's diet (Blichfeldt 1974, unpublished report).

There has been little objection to trout introductions because the native fish fauna in the highlands is sparse and trout are a far more attractive food item. In addition, because trout can survive only in cold highland streams, they offer no threat to the valuable lowland native fish fauna.

Commercial trout farming was first begun in 1973 by two private individuals, David Hunter and Ian Holder, who organized the Kotuni Trout Farm in conjunction with the landowners along Kotuni Creek. To date 250 000 eggs have been hatched and the resulting trout are being reared for market.

In August 1974 the Mendi Local Government Hatchery received a trial shipment of 50 000 eyed ova of the brook trout, *Salvelinus fontinalis* (Mitchill) from New South Wales State Fisheries. Hatching was not successful, and only 4 000 fry were released in the Margarima River.

Tilapia mossambica (*Peters*) TILAPIA or MAKAU

In December 1954, 250 tilapia fry from Malaya arrived in Port Moresby. Most of them were forwarded to Goroka, from where further distributions were made.

Experiments with tilapia, as well as other species under consideration for highlands pond culture, were carried out by the Division of Fisheries at the Dobel experimental ponds, Mount Hagen, where tilapia were first introduced in October 1955. Tilapia proved disappointing in pond culture trials in the highlands. The fish bred rapidly, ponds quickly became overcrowded, and the maximum size attained fell to about 15 cm.

In the lowlands, the first record of tilapia occurring in natural waters was in 1956, when tilapia were noticed in a stream near Port Moresby (Van Pel 1956). Van Pel encouraged the introduction of new species into natural waters, and it was only shortly after that that extensive distributions of tilapia commenced (*Table* 5). Claims were made at the time that tilapia were effective in controlling mosquito larvae, and since they grow to what was considered a more desirable size for human consumption, they were distributed in preference to *Gambusia affinis*.

Table 3.—Introduction of trout

Year	Province	Species	Date	Source		Number and life stage	Place of introduction	Comments
				External	Internal			
1949	W.H.P.	Brown	30 Nov.	Oberon, N.S.W.		20 000 fingerlings	Arl River, near Nondugl; pond at Nondugl.	Imported by Hallstrom Fauna Trust. Did not survive.
1952	Morobe	Rainbow	1 Oct.	New Zealand		10 000 ova	Bulolo River and tributaries, Wau area.	Imported by Bulolo Gold Dredging Ltd. Hatching successful.
1954	Morobe	Rainbow	6 Oct.			20 000 ova	Bulolo River and tributaries, Wau area.	Imported by Bulolo Gold Dredging Ltd. Hatching successful.
1955	Morobe	Rainbow				20 000 ova	Bulolo River and tributaries, Wau area.	Bulolo Gold Dredging Ltd. No trout sighted since 1964.
	Morobe	Brown	30 June			20 000 ova	Bulolo River and tributaries, Wau area.	Bulolo Gold Dredging Ltd. High mortality before release.
	E.H.P.	Rainbow			Bulolo Gold Dredging Ltd.	fry	Streams around Goroka.	Organized by Farmers and Settlers Association. Established and reproducing in Kotuni Creek.
1956	E.H.P.					50 000 ova		Imported by Farmers and Settlers Association. Total mortality during hatching.
	W.H.P.		Mar. ?				Minj River at Minj, Mumbul River at Banz, Kayne River at Kudjip, Aviamp River at Aviamp, Limil River at Kinjip.	Stocked by Banz Farmers and Settlers Association. Apparently not successful, possibly due to wet season floods, from November to March, at the time the fish were released.
1959	Morobe	Rainbow		Ballarat, Victoria*		500 fry	Komo and Ove Rivers, Kokoda	Organized by Kienzle Bros. Did not survive. Rivers subject to torrential flooding.
1964	W.H.P.	Rainbow		Jindabyne, N.S.W.†		2 000 fry	Baiyer and Gumanch Rivers, near Mt Hagen	Introduced by DASF. Subsequent natural reproduction.

Table 3.—continued

Year	Province	Species	Date	Source: External	Source: Internal	Number and life stage	Place of introduction	Comments
1968	W.H.P.	Rainbow			Gumants River	Fingerlings	Nebilyer River, near Mt Hagen	Transplanted by private individuals T. Kinkuy and P. Lovell.
	Chimbu	Brown	13 Dec.	Ballarat, Victoria		Approx. 200 fry	Aunde Lake, Mt Wilhelm	Good growth, some mortality of large fish. Subsequent natural reproduction.
	E.H.P.	Brown	13 Dec.	Ballarat, Victoria		Approx. 1 000 fry	Streams around Goroka	Introduced by DASF. Apparently unsuccessful.
	S.H.P.	Brown	13 Dec.	Ballarat, Victoria		Approx. 300 fry each	Mangani River, Mendi and Iaro River, Ialibu	Introduced by DASF. Good growth, subsequent natural reproduction.
	W.H.P.	Brown	13 Dec.	Ballarat, Victoria		Approx. 400 fry	Nebilyer River, Mt Hagen	Introduced by DASF. Apparently unsuccessful.
1970	W.H.P.	Brown Rainbow	27 Oct.	Hume Weir Trout Farm Albury		70 yearlings and 500 fry		Introduced by DASF. Intended for Kaugel River, Tambul, but all died in transit.
	S.H.P.	Rainbow	24 Nov.	Hume Weir Trout Farm		400 fry	Iaro River at Kagua	Introduced by DASF. Subsequent natural reproduction.
			8 Dec.	Hume Weir Trout Farm		400 fry	Piwa River at Tari	Introduced by DASF.
1971-74	See *Table* 4 for hatching and release details of Rainbow Trout from Mendi Local Government Hatchery.							
1973	E.H.P.	Rainbow	Aug.	Hume Weir Trout Farm		50 000 ova	Kotuni Trout Farm	Hatched and reared for market.
	E.H.P.	Rainbow	Sept.	Silver Stream Trout Farm, Buxton, Vic.		200 000 ova	Kotuni Trout Farm	Hatched and reared for market.
1974	E.H.P.	Rainbow	Sept.				Kotuni Trout Farm	

*Ballarat Fish Acclimatisation Society.
†New South Wales State Fisheries.

Table 4.—**Introduction of rainbow trout hatched at Mendi, 1971-1974**

Date	Place of introduction	Province	Number	Origin of ova	Comments
4.8.71	Andel River	S.H.P.	1 700	Hume Weir Trout Farm, Albury	Original shipment of 2 000 eggs arrived on 22-7-71.
30.8.71	Upper Mangani River	"	1 500	" " " " "	25 000 ova arrived 5-8-71; 16 500 fry released.
1.9.71	Upper Tongo River, Komia	"	5 000	" " " " "	Subsequent reproduction.
2.9.71	Lake Egari	"	200	" " " " "	
2.9.71	Lake Pipak	"	200	" " " " "	
6.9.71	Upper Kaugel River	"	5 000	" " " " "	Subsequent reproduction.
6.9.71	Hydro-dam, Mendi	"	100	" " " " "	
21.9.71	Aip River	"	500	" " " " "	
22.9.71	Upper Margarima	"	3 750	" " " " "	Unconfirmed reports of reproduction.
30.9.71	Tributary of Upper Mangani River	"	400	" " " " "	
6.12.71	Tongo River, Komiakul	"	800	Gaden Hatchery, Jindabyne, N.S.W. State Fisheries	50 000 ova arrived 2-11-71; 10 500 fry released.
7.12.71	Tongo River, Komia	"	2 400	" " " " "	Subsequent reproduction.
7.12.71	Tongo River, Egari	"	3 300	" " " " "	
9.12.71	Kompian via Wabag	W.H.P.	4 000	" " " " "	
18.8.72	Upper Andabare	"	3 000	Hume Weir Trout Farm, Albury	
18.8.72	Waga River, Kandep-Laiagam	"	3 000	" " " " "	
19.8.72	Tinj River, Kandep-Laiagam	"	2 000	" " " " "	
19.8.72	Marient River, Kandep-Laiagam	"	2 000	" " " " "	
24.8.72	Poru River, Pangia	S.H.P.	1 000	" " " " "	
24.8.72	Nama River	"	1 000	" " " " "	

Table 4.—continued

Date	Place of Introduction	Province	Number	Origin of ova	Comments
24.8.72	Luma River	S.H.P.	1 000	Hume Weir Trout Farm, Albury	
24.8.72	Ibei River	"	1 000	" " " " "	
31.8.72	Lake Egari, Mendi	"	2 000	" " " " "	
4.9.72	Aweta River, Kopiago	"	1 000	" " " " "	Have appeared in Lake Kopiago.
4.9.72	Paga River	"	1 000	" " " " "	
5.9.72	Iaro River	"	4 000	" " " " "	Brown trout previously established.
5.9.72	Konju River	"	1 000	" " " " "	
6.9.72	Sau River	"	2 000	" " " " "	
6.9.72	Kai River	"	2 000	" " " " "	
7.9.72	Wagaba River, Komo	"	1 000	" " " " "	
7.9.72	Tamaria River	"	1 000	" " " " "	
9.9.72	Aiyena River, Tari	"	3 000	" " " " "	
9.9.72	Aura	"	3 000	" " " " "	
9.9.72	Wambip Creek	"	2 000	" " " " "	
9.9.72	Wapu Creek	"	2 000	" " " " "	
10.9.72	Arkim River, Mendi	"	1 000	" " " " "	
10.9.72	Anga River	"	3 000	" " " " "	
12.9.72	Andabare River	W.H.P.	3 000	" " " " "	
12.9.72	Lai River	"	1 500	" " " " "	
12.9.72	Yangi River	"	3 000	" " " " "	
12.9.72	Kera River	"	1 500	" " " " "	
13.9.72	Ambum River (Wabag-Kampian)	"	2 000	" " " " "	
13.9.72	Leima River	"	2 000	" " " " "	

Table 4.—continued

Date	Place of introduction	Province	Number	Origin of ova	Comments
15.9.72	Andawe River, Ialibu	S.H.P.	2 000	Hume Weir Trout Farm, Albury	
15.9.72	Iaro River	,,	1 000	,, ,, ,, ,, ,,	
15.9.72	Linengi River	,,	1 000	,, ,, ,, ,, ,,	
15.9.72	Lake Iviva (Ipea)	W.H.P.	2 000	,, ,, ,, ,, ,,	
15.9.72	Ailee River	,,	2 000	,, ,, ,, ,, ,,	
16.9.72	Korman River, Mt Hagen	,,	2 000	,, ,, ,, ,, ,,	
16.9.72	Tuman River, Angalimp	,,	2 000	,, ,, ,, ,, ,,	
17.9.72	Upper Mendi River	S.H.P.	6 000	,, ,, ,, ,, ,,	
18.9.72	Mambo River Kagua	,,	3 000	,, ,, ,, ,, ,,	
18.9.72	Sugu River, Kagua	,,	2 000	,, ,, ,, ,, ,,	
20.11.72	Kiburu River (Longo)	,,	2 000	Gaden Hatchery, Jindabyne, N.S.W. State Fisheries	
4.12.72	Sol River, Telefomin	W.S.P.	1 000	,, ,, ,, ,, ,,	
9.12.72	Catholic Mission Dam, Pangia	S.H.P.	100	,, ,, ,, ,, ,,	
12.12.72	Ankura River	,,	5 000	,, ,, ,, ,, ,,	
13.12.72	Pino River	,,	2 000	,, ,, ,, ,, ,,	
13.12.72	Anga River	,,	2 000	,, ,, ,, ,, ,,	
13.12.72	Biano River	,,	1 000	,, ,, ,, ,, ,,	
16.12.72	Nebilyer River, Mt Hagen	W.H.P.	1 000	,, ,, ,, ,, ,,	
20.12.72	Kolba Creek, Lai Valley	S.H.P.	1 500	,, ,, ,, ,, ,,	
9.1.73	Aip River	,,	1 500	,, ,, ,, ,, ,,	
9.1.73	Enep Creek, Upper Mangani	,,	2 250	,, ,, ,, ,, ,,	

Table 4.—continued

Date	Place of introduction	Province	Number	Origin of ova	Comments
10.1.73	Lower Mangani	S.H.P.	3 400	Gaden Hatchery, Jindabyne, N.S.W. State Fisheries	
30.8.73	Kum River, Mt Hagen	W.H.P.	1 000	Hume Weir Trout Farm, Albury	50 000 ova arrived 29-7-73; 20 400 fry distributed.
30.8.73	Kuna River	"	5 000	" " " " "	
31.8.73	Kagua River, Kagua	S.H.P.	1 000	" " " " "	
4.9.73	Minj River, Minj	W.H.P.	3 000	" " " " "	
4.9.73	Arl River, Nondugl	"	3 000	" " " " "	First stocked in 1949 with brown trout.
7.9.73	Piwa River, Tari	S.H.P.	2 000	" " " " "	
7.9.73	Huria River, Tari	"	4 000	" " " " "	
1.10.73	Korn River, Mendi	"	1 400	" " " " "	
3.10.73	Rivers near Kompiam	Enga	5 000	" " " " "	65 000 ova arrived 28-8-73; 37 000 fry distributed.
3.10.73	Noka River, Wapenamanda	"	2 000	" " " " "	
4.10.73	Arou River, Kopiago	S.H.P.	1 000	" " " " "	
10.10.73	Minamp River, Wapenamanda	Enga	3 000	" " " " "	
10.10.73	Tobak River, Wapenamanda	"	2 000	" " " " "	
10.10.73	Tale River, Wapenamanda	"	3 000	" " " " "	
11.10.73	Megabo River, Henganofi	E.H.P.	2 000	" " " " "	
11.10.73	Dunatina River, Henganofi	"	3 000	" " " " "	
11.10.73	Akuitana River, Kainantu	"	3 000	" " " " "	
11.10.73	Ibauta River, Kainantu	"	2 000	" " " " "	
15.10.73	Nali River, Pangia	S.H.P.	2 000	" " " " "	
16.10.73	Tekin River, Telefomin	W.H.P.	2 000	" " " " "	
16.10.73	Lutap-Feramin Rivers	"	2 000	" " " " "	
16.10.73	Iram River, Tifalmin	W.S.P.	2 000	" " " " "	
17.10.73	Bernaria River, Tari	S.H.P.	1 000	" " " " "	
17.10.73	Tebi River	"	1 000	" " " " "	
19.10.73	Nembi River, Nipa	"	3 000	" " " " "	
24.10.73	Rivers near Ialibu	"	4 000	Gaden Hatchery, Jindabyne, N.S.W. State Fisheries	50 000 ova arrived 4-10-73; 33 600 fry distributed.
25.10.73	Kolba River, Mendi	"	2 000	" " " " "	
7.11.73	Rivers near Ialibu	"	4 000	" " " " "	
8.11.73	Nijo River, Laiagam	Enga	2 000	" " " " "	

Table 4.—continued

Date	Place of introduction	Province	Number	Origin of ova	Comments
8.11.73	Lake Iviva	Enga	1 000	Gaden Hatchery, Jindabyne, N.S.W. State Fisheries	
8.11.73	Lagaip River	"	5 000	" " " " "	Previous stocking of 2 000 failed to reproduce.
8.11.73	Kinduli River, Kandep	"	1 000	" " " " "	
8.11.73	Yenat River	"	1 000	" " " " "	
8.11.73	Sais River	"	1 000	" " " " "	
8.11.73	Yakwat River	"	1 000	" " " " "	
8.11.73	Kuliak River	"	1 000	" " " " "	
13.11.73	Poru River, Pangia	S.H.P.	1 000	" " " " "	
13.11.73	Ioropini River, Pangia	"	1 000	" " " " "	
13.11.73	Ombrey River, Pangia	"	3 000	" " " " "	
14.11.73	Ingish River, Mendi	"	1 000	" " " " "	50 000 ova arrived 24-10-73; 34 400 fry distributed.
15.11.73	Wiwi River, Pangia	"	2 000	" " " " "	
15.11.73	Lua River, Pangia	"	1 000	" " " " "	
15.11.73	Nali River, Pangia	"	1 000	" " " " "	
19.11.73	Nomandi River, Kerowagi	Chimbu	2 000	" " " " "	
21.11.73	Nipa River, Mendi	S.H.P.	2 000	" " " " "	
27.11.73	Tilipa River, Mendi	"	1 000	" " " " "	
29.11.73	Kegan River, Kandep	Enga	1 000	" " " " "	
29.11.73	Labai River, Kandep	"	2 000	" " " " "	
29.11.73	Ko River, Kandep	"	1 000	" " " " "	
29.11.73	Moi River, Kandep	"	2 000	" " " " "	
5.12.73	Mubi River, Kutubu	S.H.P.	2 000	" " " " "	
11.12.73	Enep River, Mendi	"	1 000	" " " " "	
11.12.73	Mangani River, Mendi	"	2 000	" " " " "	Brown trout previously established.
12.12.73	Lake Kopiago, Koroba	W.H.P.	1 000	" " " " "	
12.12.73	Paga River, Kopiago	"	500	" " " " "	
12.12.73	Hembe River, Kopiago		500	" " " " "	
17.12.73	Tongo River, Mendi	S.H.P.	2 000	" " " " "	

Table 5.—**Introduction of *Tilapia mossambica***

Year	Province	Date	Source: External	Source: Internal	Place of introduction	Place of discovery	Comments
1954	Central	10 Dec.	Malaya		Bomana ponds		50 sent to Bomana.
	E.H.P.	"	Malaya		Goroka ponds		200 sent to Goroka.
1955	"	6 June		Goroka	Goroka area		
	W.H.P.	20 July		Goroka	Korn Farm, Mt Hagen		
	"	17 Aug.		Goroka	Nondugl, Minj		
	Chimbu	29 Aug.		Goroka	Chimbu Catholic Mission		
	Central	31 Aug.		Goroka	Port Moresby		
	"	1 Sept.		Goroka	Sogeri		Reproducing readily (1960). Largest fish 0.2 kg (July 1961).
	W.H.P.	20 Sept. Oct.		Goroka	Baiyer River Dobel Fish Ponds		
1956	Central	15 Jan. Feb.		Bomana	Port Moresby	Port Moresby	To ponds behind Jackson's airstrip. Observed in a stream near Port Moresby, (Van Pel 1956).
	W.N.P.	2 May		Bomana	Kandrian		
	Morobe	4 May		Bomana	Bulolo		To Bulolo Gold Dredging Ltd.
	Central	7 June		Bomana	Waigani Swamp		Established in Waigani Swamp and Laloki River by 1959.
	E.H.P.	8 July		Bomana	Aiyura		To ponds at H.A.E.S. Aiyura.
	Central	12 Sept.		Bomana	Laloki R. Agric. Station		
	Morobe	12 Sept.		Bomana	Wau		To Mr A. L. Hurrell and Mr Dix.

Table 5—continued

Year	Province	Date	Source External	Source Internal	Place of introduction	Place of discovery	Comments
1956	Morobe	Sept.		Goroka	Bulolo		Sent by Highlands Farmers and Settlers Association to Bulolo Gold Dredging Ltd. By 1961 tilapia had become established in Bulolo River. Considered by local people as inferior to catfish as food.
		3 Oct.	Singapore				No data on place of introduction.
	Morobe	23 Oct.			Lae		To ornamental ponds, Lae Botanical Gardens.
	S.H.P.	?			L. Kutubu		Date uncertain. Apparently did not survive.
1957	Madang	27 May				Madang	Caught in DASF station dam.
		10 June		Bomana	Maprik		Natural pond stock.
	E.H.P.	27 Nov.		Kainantu	Aiyura		To ponds at H. A. E. S. Aiyura.
1958	W.N.B.	27 May		Bomana	Talasea		To Mr Searle. No further information.
	Central	July		Bomana	Bisianumu		To Agriculture Station pond.
	"	19 Sept.		Bomana	Koitaki		To Mr Sefton, Sogeri area.
	Northern	30 Sept.		Bomana	Kokoda		To Mr Kienzle at Yodda.
	"	10 Oct.		Bomana	Kokoda		To Mamba Plantation.
	Central					Bolegila River, Rigo	Tilapia reported.
1959	Northern	Jan.		Lae	Awala Plantation		Later released in Sohu River from where they moved into the Kumusi River. Plentiful by 1963.
	Central	24 July				Waigani Swamp	Tilapia caught with 3¼ inch gill net averaged 0.4 kg. First noticed for sale at Koki Market on 28 June, 1961.
	"	Aug.			Kemp Welch River		Numerous by 1962.
	Bougainville	20 Aug.			Tauu (Mortlock) I.		No further information.
	"				Arawa Plantation		Spread to Jaba-Panguna system.

Year	Province	Date	Source External	Source Internal	Place of introduction	Place of discovery	Comments
1959	Morobe				Mumeng		Escaped from dams into natural waters.
	,,				Bulolo		To ponds of Golden Pines Sawmilling Co. Ltd. Had stunted by 1961.
	E.S.P.				Screw River		Subsequently moved into Sepik River where they were plentiful by 1966.
1960	Bougainville	25 Feb.		Bomana	Sohano		Released in airport bomb craters.
	E.N.B.	16 Mar.		Bomana	Warangoi		To Mr Morris. Tilapia reported to be plentiful in Warangoi River, 12 Oct., 1971.
	New Ireland	16 Mar.			Kavieng		No further information.
	Western	2 May		Bomana	Balimo		Intended for mosquito control.
	,,	12 Oct.			Balimo, Lake Murray		Apparently did not survive.
	Gulf				Kerema		In pond near district office; reported still present.
1961	Western	2 June		Bomana	Balimo		To Awaba Mission.
	Central	2 June			Bereina		About 200 sent for planting in backwaters.
	,,	10 July				Inauaia (Bereina District)	
	Northern	10 July				Popondetta	
	W.S.P.	10 July				Lumi	Tilapia reproducing in ponds in Somoro area.
	W.H.P.	10 July				Kerowagi, Henganofi, Banz, Bena Bena, Wahgi River near Minj	Tilapia known to be present.
	,,	Aug.			Natural waters near Mt Hagen		Tendimbuga and Ambra areas.
1963	Northern						Tilapia being introduced to slow-moving streams in the province.
1964	Morobe	May				Kabwum	Tilapia breeding well.
	W.S.P.	July			Miliom, Wigotei, Rautei, Eretei		Ponds stocked with tilapia.
	,,	Nov.		Wewak	Amanab		200 fish introduced.

Table 5—continued

Year	Province	Date	Source External	Source Internal	Place of introduction	Place of discovery	Comments
1965	Central	1 June			Bereina		
1966	Gulf	30 Nov.			Terapo		
1967	"	1 Feb.			Kukipi		
1968	Central	15 Mar.			Cape Rodney		
	Madang				Tung		Bogia area. Introduced by F. Beale.
	"				Ramu River backwaters		Introduced by J. McKinnon.
1969	"	27 Mar.			Ramu River at Aiome		**By DASF. Apparently** unsuccessful.
	"				Ramu River backwaters near Annaberg		By Catholic Mission, Annaberg.
1970	"	15 Dec.			Ramu River backwaters near Annaberg		**By DASF. Tilapia** caught in same area in April 1972.
1971	Morobe	7 Sept.				Boana area	Approximately 200 ponds previously stocked.
	Gulf					Tauri River backwaters	Originally transplanted from pond at Kerema.
1972	W.H.P.	18 May				Baiyer River	
	E.H.P.	29 Aug.				Ramu River backwaters, Arona	
1972	Bougainville	Oct.		Arawa Plantation		Tributary of Jaba River, B.C.L. Jaba pump station	Washed out of ponds at headwaters of Jaba **River. These are descndents of** Arawa stock transported by ex-labourers.
1974	E.H.P.	May				Pond at Okapa	Poisoned to begin culture of carp.
	Bougainville	May				Billabong at Pagana River	Probably intentionally introduced by local inhabitants, from Jaba stocks.

Table 6.—Introduction of Trichogaster pectoralis

Year	Province	Date	Source		Place of introduction	Place of discovery	Comments
			External	Internal			
1957	Central	2 Oct.	Malaya		Bomana		300 imported.
1959	W.H.P.	24 July		Bomana	Dobel Ponds		5 fish transferred. Did not breed at Dobel.
1960	Central	June	Malaya		Waigani Swamp		20 fish survived out of shipment of 300.
	Central	21 Dec.	Singapore		Waigani Swamp		150 fish released.
1962		Nov.	Malaya				1 000 fish sent, but only 500 survived.
1963	Central	13 Jan.	Malaya		Bomana		120 fish released.
	,,	21 May		Bomana	Sirinumu Dam		700 fish released. Very rare by 1969.
1972	Gulf					Gulf Province	Snake-skinned goramy reported in eastern coastal areas, as far west as Moviavi.

Table 7.—Introduction of *Osphronemus goramy*

Year	Province	Date	Source		Place of introduction	Place of discovery	Comments
			External	Internal			
1957	Central	2 Oct.	Malaya		Bomana		30 fish arrived.
1959	W.H.P.	3 July		Bomana	Dobel ponds		2 fish transferred.
1960	Central	16 June	Sydney		Bomana		96 fish.
	"	5 July	Sydney		Bomana		140 fish.
	Western	25 July		Bomana	Balimo		
	W.H.P.	20 July		Bomana	Dobel Ponds		A further 10 fish introduced.
	E.N.B.	July		Bomana	Rabaul		25 fish sent to G. Morris, Warangoi. Growth excellent.
1961	W.H.P.	20 Oct.		Dobel	Golf course pond, Mt Hagen		All fish transferred. Survival improbable.
		July	Malaya				400 fish.
1962	E.S.P.	Nov.	Jayapura Irian Jaya		Wewak		1 000 fish.
	Madang			Wewak	Dumpu, Bogia		Released in lake near Dumpu, and at Bogia. No information on survival.
1963	W.S.P.	Aug.		Kreer ponds, Wewak	Amanab		20 fish transferred, reproducing (1972).
	E.S.P.	Mar.			Lake Imbia near Maprik		85 fish introduced—still present at Jan. 1973.
	Morobe	14 Sept.				Lae	Present at Botanical Gardens and Animal Industry Section.
1966	Central	2 Nov.		Wewak	Sirinumu impoundment		28 fingerlings introduced; no evidence of survival.
	Morobe				Lake Wanum		Some doubt about species—possibly *Trichogastre pectoralis*. No goramy caught in survey of 1975.
1970	Central	6 May		Bomana	Iarowari High School		30 fish placed in a pond with access to Laloki River. Pond subsequently destroyed.

Table 7—continued

Year	Province	Date	Source		Place of introduction	Place of discovery	Comments
			External	Internal			
1971	Manus	12 Jan.		Bomana	Lake Puwan, Tong I.		62 fish introduced.
	E.N.B.	Aug.			Vudal Agricultural College		
1972	"					Kerevat River	Report of giant goramy in Kerevat River.
1973	E.S.P.	8 Jan.				Lake Imbia	A 4 kg fish caught by handline.

Table **8.—Introduction of *Cyprinus carpio***

Year	Province	Date	Variety	Source External	Source Internal	Place of introduction	Place of discovery	Comments
1959	Central	Aug.	Golden	Taronga Park, Sydney		Bomana ponds		26 fish
	"	Aug.	"	Taronga Park, Sydney		Dobel ponds		10 fish
1960	E.H.P.	Dec.	"		Dobel	Goroka		6 fish to I. Downs
	W.H.P.	Dec.	"			Mt Hagen		6 fish to G. Broomhead
1961	E.H.P.	Jan.	.		Dobel	Aiyura H.A.E.S.		6 fish
	"	Jan.	"		"	Goroka		6 fish to I. Downs
	W.H.P.	Jan.	"		"	Banz		6 fish
	Madang	Jan.	"		"	Madang		6 fish to Agriculture Office
	Morobe	Jan.	"		"	Lae		6 fish to 3-mile Agriculture station
	S.H.P.	Mar.	"			Mendi		12 fish to District Commissioner
	W.H.P.	Mar.	"		Dobel	Wapenamanda		6 fish
	"	Mar.	"		"	Catholic Mission, Mt Hagen		6 fish
	Morobe	Mar.				Wau		6 fish to H. Fleck
	E.H.P.	21 April	"			Aiyura		12 fish to W. Larner
	"	21 April	"			Aiyura H.A.E.S.		23 fish
	W.H.P.	6 May	"			Mt Hagen		17 fish to golf course pond; subsequently reproduced
	S.H.P.	17 June	"			Kandep		12 fish for release in Kandep lakes; now very common
	W.H.P.	20 June	"			Mt Hagen		6 fish
	"	4 July	"	Lake Sentani, Irian Jaya		Dobel ponds, Mt Hagen		6 fish brought by A. Tubb
	"	8 July	Mirror	Singapore		Dobel ponds		325 fish

Table 8—continued

Year	Province	Date	Variety	Source External	Source Internal	Place of introduction	Place of discovery	Comments
1961	Central	8 July	Mirror	Singapore		Bomana ponds		25 fish.
	E.N.B.	8 July	"	"		Warangoi		25 fish to G. Morris.
	E.H.P.	8 July	"	"		Arau Plantation Aiyura		25 fish to W. Larner. Dam burst in 1966; carp established in Wanton and O'awa Rivers.
						Korgua		6 fish to D. Leahy.
	W.H.P.	17 July	Golden					
	Morobe	7 Aug.					Lae Botanical Gardens	Carp present.
	W.H.P.	25 Aug.	Mirror			Wabag		15 fish to station pond.
	"	24 Sept.	Golden			Golf course pond, Mt Hagen		6 fish.
	"	18 Oct.	Mirror			Minj		To Swiss Mission and private individuals.
	"	18 Oct.	"			Nondugl		To Hallstrom Trust.
	"	20 Oct.	Cantonese			Mt Hagen		20 fish to golf course pond.
	E.H.P.	25 Oct.	"			Goroka		17 fish to DASF piggery pond.
						Dobel ponds		200 fish.
	W.H.P.	26 Oct.	Golden					
	Morobe	26 Oct.	"			Lae Botanical Gardens		6 fish.
	S.H.P.	1 Nov.	Mirror			Mendi		20 fish to station pond.
	Central	17 Nov.				Tapini		On 5th May 1962 dam burst and carp escaped.
	W.H.P.	27 Nov.	Cantonese			Minj		45 fish to Swiss Mission and private individuals.
	"	27 Nov.	"			Nondugl		25 fish to Hallstrom Trust.
	"	1 Dec.	"			Wapenamanda		15 fish to Lutheran Mission.
	E.H.P.	6 Dec.	"			Aiyura		100 fish to H.A.E.S.
	"	6 Dec.	"			Goroka		60 fish to 4 plantations.

Table 8—continued

Year	Province	Date	Variety	Source External	Source Internal	Place of introduction	Place of discovery	Comments
1961	W.H.P.	22 Dec.	Golden			Nondugl		20 fish to Hallstrom Trust.
1962	S.H.P.	Jan.	Golden, Cantonese, Mirror				Mendi	Golden, cantonese and mirror carp held in DASF ponds.
	Central	7 June			Dobel	Tapini and Kosipi Swamps		50 fish, 40 for release in swamps.
	Northern	13 June			Dobel	Kokoda		To Mamba Plantation.
	Chimbu	29 Sept.			Dobel	Kerowagi		5 carp sent.
	E.S.P.	Oct.			Mt Hagen	Wewak		120 fish to Boram Corrective Institute.
1963	W.H.P.	20 Feb.	Golden and Cantonese		Dobel	Lake Kopiago		9 Golden, 24 Cantonese carp introduced. Have since become abundant.
	E.S.P.	June	Golden		Mt Hagen	Wewak		25 fish to Kreer Ponds.
	W.H.P.	Aug.				Western Highlands		200 carp distributed.
	E.S.P.	Aug.	Golden		Goroka	Wewak		10 fish to Kreer Ponds.
	W.S.P.	Dec.	"			Ponds in Somoro area		Fish grew well.
1964	E.N.B.	7 May	Cantonese		Aiyura, H.A.E.S.	Rabaul		20 fish.
	Bougainville	7 May	"		Aiyura, H.A.E.S.	Buin		30 fish.
	Morobe	May	"		Aiyura, H.A.E.S.	Lae		100 fish.
	Central	May	Golden			Bomana pond		17 fish stocked.
	S.H.P.	May				Tari and Pangia		Released in natural waters.
	E.H.P.	July	Golden			Bena Bena, Henganofi Kamano area		Ponds stocked with small number of fish.
	Morobe	July	"			Lake near Boana		Lake thought to have no native fish; no outlet.
	S.H.P.	Nov.	"			Egari area		Fish ponds stocked.
	"	Dec.	Cantonese			Kagua		15 fish for pond project.

Table 8—continued

Year	Province	Date	Variety	Source		Place of introduction	Place of discovery	Comments
				External	Internal			
1965	S.H.P.	Feb.	Golden			Lake Kutubu		Subsequent unconfirmed sightings.
	W.H.P.					Lake Iviva (Ipea)		50 fish stocked. Present in 1970 survey.
1966	E.H.P.					Henganofi		Carp escaped from burst pond into Kamanotina and Kafetina Rivers.
1967	W.H.P.	Jan.			Dobel		Wahgi River	Fish escaped into Wahgi River.
	Morobe	Oct.				Lake Trist		Have since become abundant.
	Madang					Ponds at Simbai		Approx. 80 ponds had previously been stocked.
1970	W.H.P.	13 May				Lake Iviva (Ipea)		68 carp introduced.
		May					Lake Birip	Established.
	Central	July					Laloki River, Port Moresby	Established.
	W.H.P.	Oct.	Cantonese				Lagaip River, Laiagam	Carp abundant in backwaters.
	S.H.P.	Oct.					Haliabadia Creek, Komo.	Carp escaped from burst dam into tributary of Waguba River.
	Madang	21 Nov.	Golden				Simbai	Ponds flooded during heavy rain and carp lost.
1971	S.H.P.	Feb.					Lakes Egari, Pipiak and Walolo	Established.
	W.S.P.	Feb.					Vanimo Vocational School	Established.
	W.H.P.	20 Aug.					Wahgi River near Mt Hagen, and Lai River near Wabag.	Established.
	"	5 Nov.				Banz		500 fish to Lutheran Agricultural Training School.

Table 8—continued

Year	Province	Date	Variety	Source: External	Source: Internal	Place of introduction	Place of discovery	Comments
1971	S.H.P.	10 Nov.			Dobel	Tomba		80 fish.
	W.H.P.	19 Nov.			Dobel	Minj		450 fish to D.A.S.F.
1972	Western	13 Jan.	Golden				Aramia River, Balimo area	Established.
	E.H.P.	Aug.					Ramu River, Kainantu	Established.
1973	Distribution of fish from Dobel and Aiyura restricted to approved aquaculture projects in highlands.							

Although tilapia were first introduced to the highlands, it is only in lowland waters with their warmer temperatures and more abundant food supply that tilapia have become of economic importance.

In Port Moresby, tilapia caught in Waigani Swamp were first noticed for sale at Koki Market in June 1961. During the season of the south-easterly trade winds they are one of the most common species at the market, and by 1969 the annual sale there was estimated at 70 tonnes, worth approximately K60 000.

It is in the Sepik River system that the impact of tilapia (called "makau" in this area) has been greatest. It was noted by Schuster as an area where the fish production could be greatly increased by the introduction of suitable species. Tilapia were introduced first to a natural pond at Maprik in June 1957, from where, apparently as a result of a flood in 1959, they entered the Screw River, a tributary of the Sepik. By 1966 they were abundant in the Sepik River system, and the stock is considered sufficiently large that, if it could be suitably processed locally, it might largely displace imported low-priced canned fish.

Tilapia introduction and natural dispersal have been extensive. There is insufficient information to assess their effect on the native fish fauna, but subjective observations suggest that, to date, there have been no ill effects.

Trichogaster pectoralis (Regan) SNAKE-SKINNED GORAMY

The introduction of this fish to waters containing no species capable of directly exploiting primary production was suggested by Schuster (1951). Limited trials at Dobel Ponds indicated that, as expected, the fish were unsuitable for the highlands, and all subsequent releases were in lowland natural waters or ponds (*Table* 6). There is no record of how this fish became established in the Gulf Province, the only area where its utilization for food is reported. Except in sewerage ponds and manure-methane digestor systems, there is little interest in the pond culture of this relatively small fish.

Osphronemus goramy Lacepède GIANT GORAMY

Van Pel (1956) suggested this species for lowland pond culture, an activity previously given low priority by Schuster (1951). The fish first arrived from Malaya in 1957 and were released in a billabong at Bomana Gaol, where they subsequently bred. They are still present at Bomana, and some individuals as large as 40 cm are occasionally caught. These fish have been the source of various introductions throughout Papua New Guinea (*Table* 7). A small number were sent to Dobel for trials in pond culture, but the growth rate was poor, and they failed to reproduce.

In 1962 *Osphronemus goramy* were obtained from Dutch officials in Hollandia (now Jayapura) and placed in ponds at Amanab and Wewak. There followed some distributions to natural waters in the Sepik and Madang areas, but little is known of the success of these introductions.

Cyprinus carpio Linnaeus COMMON CARP

Although the introduction of carp had been recommended in 1951 by Schuster and again in 1956 by Van Pel, the Division of Fisheries was somewhat reluctant to introduce this fish, which was already considered a noxious species in several countries. However, when tilapia proved unsuccessful in highland pond culture the introduction of carp was deemed necessary, and the first stocks were secured in 1959 (*Table* 8).

Of the three varieties introduced, Golden, Cantonese and Mirror, only the Cantonese and Golden survived past 1969. They proved amenable to highland conditions, breeding readily in ponds at Dobel, and later at the Highlands Agricultural Experimental Station at Aiyura. The first stocks of fingerlings for distribution were ready at Dobel in 1961 and Aiyura in 1963. From then on extensive stocking of artificial ponds (most of which were improperly constructed), rivers and lakes took place, and now nearly every body of water in the highlands even marginally suitable for carp has been stocked.The wisdom of some of these stockings has subsequently been questioned, particularly that of Lake Kutubu in

1965, which had a unique and plentiful fish and invertebrate fauna (Rapson 1967).

Under proper management, the yield from the pond culture of carp can be very considerable. For example, experiments with supplemental feeding of local pig rations consisting of 10 per cent fishmeal and 90 per cent cooked sweet potato (*Ipomoea batatas*), resulted in production equivalent to 1 600 kg/ha/annum. Another experiment with a specially formulated pellet feed produced 3 000 kg/ha/annum (Glucksman 1973, unpublished report). However, even from the inception of the carp distribution programme, doubts were expressed about the economic viability of carp culture, based mainly on the high cost of fish food (Van der Meulen 1962). In addition, problems of capital, labour, expertise, preservation and transport prevented the indigenous small-holder from achieving yields even approaching this magnitude, or marketing the bulk of lesser harvests.

In a Department of Agriculture, Stock and Fisheries survey in October 1973 it was found that fish constituted a negligible portion of the animal protein marketed in the highland centres of Mendi, Mount Hagen, Kundiawa and Goroka, and that what fish were marketed were almost invariably taken from wild populations (Glucksman 1974, unpublished report).

In the lowlands, carp are economically important only in Port Moresby. Individual carp, taken from surrounding swamps, first appeared in Koki Market in 1971. Since then their numbers have increased steadily and in 1974 they amounted to between 5 and 10 per cent of the tilapia catch.

Hypophthalmichthys molitrix (Cuvier & Valenciennes) SILVER CARP

Ctenopharyngodon idellus (Cuvier & Valenceinnes) GRASS CARP

Puntius gonionotus (Bleeker) JAVANESE CARP

These fish were introduced at various times for highland pond culture because they were thought to be superior to common carp in that they required less supplemental feeding, particularly of protein, and were amenable to multi-species culture in chemically fertilized ponds.

The early introductions of silver and grass carp did little to establish their usefulness in pond culture, due mainly to difficulties in obtaining seed stock, and a lack of research facilities. There were some introductions to natural waters, both deliberate and accidental, but it appears that there has been no survival (*Table* 9).

After 1970, when the contribution of highlands aquaculture began to be questioned, carp other than *Cyprinus carpio* were restricted to experimental ponds. There has been little success in the culture of these species except for *Puntius gonionotus*. Individuals reared in a pond fertilized at the rate of 360 kg/ha/annum of calcium triple superphosphate have reproduced.

Australian Freshwater Fish Introductions

Seven species of Australian freshwater fish have been introduced to Papua New Guinea (*Table* 10). *Bidyanus bidyanus* (Mitchell), the silver perch, and *Carrassiops klunzingeri* Ogilby, the western carp-gudgeon were released together in Sirinumu Dam near Port Moresby, the carp-gudgeon being intended as a forage species. However, the number of fish involved was small, and the introduction was unsuccessful.

The freshwater catfish *Tandanus tandanus* (Mitchell), was introduced to test its suitability for highland pond culture, but all the fish were destroyed when it was decided to discontinue the experiment.

The Australian smelt *Retropinna semoni* (Weber), was released in streams which had previously been stocked with trout. It was intended as a forage species but it apparently did not survive.

There is little information available about the introduction of *Percalates colonorum* (Gunther), the estuary perch, and *Trachystoma petardi* (Castlenau), the freshwater mullet, to a pond at Mageri Agricultural Station, Sogeri, but apparently neither species survived.

The last introduction was that of the golden perch, *Plectroplites ambiguus* (Richardson).

Table 9.—Introduction of *Hypophthalmicthys molitrix*, *Ctenopharyngodon idellus* and *Puntius gonionotus*

Year	Date	Source: External	Source: Internal	Place of introduction	Comments
Hypophthalmichthys molitrix—Silver carp					
1961	8 July	Singapore		Bomana	25 fish.
				Dobel	190 fish.
				Aiyura	Sent to W. Larner. Washed into Wanton and O'awa Rivers in 1966. Check in 1970 revealed no survivors.
	25 Oct.		Dobel ?	Mt Hagen	10 fish to golf course pond.
	1 Nov.			Mendi	20 fish to station pond. Survived until about 1964.
	9 Nov.		Dobel ?	Minj	20 fish to P. Maxtone-Graham. No further record.
1963	June		Mt Hagen	Kreer ponds, Wewak	21 fish, no further record.
1965	22 Oct.	Hongkong		Bomana, Dobel, Goroka	Unsuccessful.
1972	21 Feb.	Japan		Dobel	15 fish, subsequently destroyed by vandals in 1973.
Ctenopharyngodon idellus—Grass carp					
1964	Dec.	Hongkong		Bomana	No records.
				Dobel	1 surviving at present.
				Goroka	No records.
1965	22 Oct.	Hongkong		Waigani	Apparently unsuccessful.
1972	21 Feb.	Japan		Dobel	12 fish, destroyed by vandals 1973.
Puntius gonionotus—Javanese carp					
1970	15 Dec.	Kuala Lumpur		Aiyura H.A.E.S.	200 fish, surviving and reproducing.

Table 10.—Introduction of native Australian freshwater fish

Species	Date	Province	Place of introduction	Comments
Bidyanus bidyanus	1963 May	Central	Sirinumu impoundment	No evidence of survival.
Carassiops klunzingeri	1963 May	"	" "	
Tandanus tandanus	1963 May	W.H.P.	Dobel Ponds	Stocks subsequently destroyed.
Retropinna semoni	1963 May			Died in transit.
	1968 Mar.	S.H.P.	Mangani River	Approx. 300 fish introduced. Apparently unsuccessful.
		W.H.P.	Nebilyer River	Approx. 400 fish introduced. Apparently unsuccessful.
Plectroplites ambiguus	1966	Central	Pond at Mageri Agricultural Station	No evidence of survival.
Percalates colonorum	1966	Central	" " " " "	" " " "
Trachystoma petardi	1966 8 July	"	Pond near Waigani Swamp	12 fish. No evidence of survival.
	1968 27 June	"	Pond at Bisianumu Agricultural Station	Apparently unsuccessful, checked 1969.
		W.H.P.	Dobel Ponds	4 remaining 1972, probably all dead by 1974
		Madang	Usino	30 fish released in natural waters—no further reports.
			Aiome	40 fish released in natural waters—no further reports.
		Morobe	Wau	20 fish to ponds of H. McKenzie and O. Kadletz. No further reports.
		S.H.P.	Mendi	No further record.

Many of the 500 fish introduced in 1968 died because of transport and handling difficulties, but a small number were released in ponds and natural waters. Several of the release sites have not been investigated since, but it appears unlikely that these fish have become established.

Freshwater Aquarium Fish

The guppy, *Poecilia reticulata* Peters, and the three-spot goramy, *Trichogaster trichopterus* (Pallas), are both established in natural waters around Port Moresby (West 1973). The guppy is present in drains and streams leading into Waigani Swamp, and the three-spot goramy is commonly found in backwaters of the Laloki River. At times guppies are so numerous in drains in the suburb of Boroko that they are collected for food. A single specimen of another aquarium fish, *Puntius semifasciolatus* (Gunther) was reported from Waigani Swamp in January 1966 (Filewood, pers. comm.).

To reduce the risk of further species becoming established in natural waters the Department of Agriculture, Stock and Fisheries banned the importation of aquarium fish in 1975.

DISCUSSION

Nine of the twenty species of fish introduced to Papua New Guinea have established naturally reproducing populations. Two of them, tilapia and carp, have not become the basis of an aquaculture industry as originally intended, but are components of large inland commercial or subsistence fisheries. At present, rainbow trout is the only species showing potential for successful intensive aquaculture. The brown trout, snake-skinned and giant goramys are of value in extremely localized areas, and may prove to be so in others, while the mosquito fish, guppy and three-spot goramy are essentially valueless.

Because of the uncontrolled and inevitable movement of fish by private individuals, or natural dispersal, the distributions are probably greater than reported in this paper, and at any rate may be considered to be expanding.

The importation by individuals of exotic fish other than trout, and the transplanting of existing introduced fish, except for trout, to areas where they are not presently established, was prohibited in 1975. The authors are in wholehearted agreement with this policy. The Department of Primary Industry may import freshwater fish for research purposes, but has not done so since 1972, and in keeping with the world-wide reaction against the introduction of exotic fish, probably will not in the future.

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