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CONTENTS

A FIELD KEY TO IDENTIFY SOME *RHINOCEROS* AND OTHER BEETLE LARVAE BREEDING IN COCONUT PALM HABITATS IN PAPUA NEW GUINEA

L. Beaudoin-Ollivier[1], R.N.B. Prior[2], and S. Laup[2]

ABSTRACT

A practical field key to rapidly distinguish third instar Scapanes australis *(Boisduval) and* Oryctes rhinoceros *(L.) larvae along with seven scarabaeoid species in Coconut Palm and similar habitats is devised. Drawings and photographs of the larvae in support of the key are also presented.*

Keywords: *Scarabaeoidea, rhinoceros beetle, identification, third instar, coconut.*

INTRODUCTION

A number of species of family Dynastidae commonly known as Rhinoceros beetles attack coconuts world wide. *Scapanes australis* and *Oryctes rhinoceros* are the worst pests of coconut palms in Papua New Guinea and particularly damaging during the first ten years of planting. These insects are common on the island regions (East New Britain Province, New Ireland) where severe damage is continuously observed and does not allow coconut rehabilitation. In either case, if attack by the rhinoceros beetles is associated with damage by *Rhynchophorus bilineatus* (Montrouzier) (Coleoptera: Curculionidae), this leads to the death of the palm. Investigations into the biological control of these pests were undertaken on the mainland of Papua New Guinea where the level of *Scapanes australis* population is quite low as well as in East new Britain which is a badly affected area.

The aim was to identify some pathogenic agents found in the field in a wide variety of breeding sites many of which are still not well known. A correct identification of the pest species larvae, amongst other white grubs found in very similar habitats, was needed.

During field studies, several larvae were discovered which were similar in external appearance but belonged to different species. Confusion could easily occur between at least 9 different white grubs of superfamily Scarabaeoidea which occupy similar feeding habitat *viz.* organic matter and decaying wood. The different larvae were identified as *Scapanes australis* (Boisduval), *Oryctes rhinoceros* (L.), *Oryctes centaurus* (Sternb.), *Xylotrupes gideon* (L.), *Trichogomphus vicinus* (Dechambre), *Oryctoderus latitarsis* (Boisd.) (Coleoptera, Scarabaeidae, Dynastinae), Cetoninae (Coleoptera, Scarabaeidae) and Lucanidae (Coleoptera, Scarabaeoidea).

The first six species are considered either as pests of coconut palm or occasionally attacking it. For many years a number of larvae of these species were unknown or subjected to misidentification. Although the adult beetles are quite distinct, there was an apparent absence of visible characters to distinguish the larvae of such beetles for inexperienced people such as farmers, extension workers or even scientists, not used to identify immature insects. The larvae of alll the 9 species are very much alike, being whitist-creamy curl grubs, typical of family Scarabaeidae (Waterhouse 1987).

During the past thirty years, a number of scientific papers have been published to distinguish the larvae to family, subfamily and genus (Richter 1966) level.

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[2] PNG Cocoa and Coconut Research Institute, P O Box 1846, Rabaul, Papua New Guinea.

Taxonomic works based on setation to distinguish six of these Dynastine species exist (Bedford 1974). Descriptions have also been provided for *Oryctes monoceros* from Seychelles (Bedford 1979) using the method of description developed for Dynastinae larvae by Richter (1944; 1966). Many of these keys can be used to distinguish the *Rhinoceros* species. However, such keys are difficult to use by non-specialists as well as field workers. Few authors have tried to provide descriptions of the white grubs from viable morphological characters which may be seen unaided or by the use of a low power hand lens and even these are far from practical.

The under surface of the last adominal segment, called the raster was described for some French Scarabaeidae (Hurpin 1961), for root-feeding beetle larvae (Goddyer 1977) and for *Oryctes elegans* (Hurpin and Fresneau 1969). The crawling of the larvae was discussed by Hurpin (1961). The size of the larva and the head capsule aspect was examined by O'Connor (1953) and Hurpin and Fresneau (1970). Other morphological characters such as the sclerite lateral plate of the first thoracic segment were used to distinguish *Oryctes elegans*, *O. rhinoceros*, *O. monoceros* and *O. nasicornis* (Hurpin and Fresneau 1969, 1970).

The present investigation provides descriptions, illustrations and drawings of the nine common scarabaeoid species, for the third instar larvae to rapidly differentiate them from one another in the field in live specimens and without a hand-lens.

MATERIALS AND METHODS

Field studies were carried out both on the mainland of Papua New Guinea during 1996 and 1997 and in East New Britain Province in 1996. On the mainland, Madang Province, including Karkar island and East Sepik Province were visited. In East New Britain, Keravat and Sigute sites were investigated. Inspections were centred around coconut plantations and inside the bush where felled trees, decaying logs, rotten wood and piles of organic matter are commonly used as breeding sites by *Rhinoceros* larvae. Third stage larvae were mostly hand-collected from their feeding habitat i.e from the medium they were found feeding on.

Field collected larvae were placed under ambient laboratory conditions (28-30^{0}C, 60-70% RH, natural photoperiod) inside different plastic buckets with their respective organic feeding medium. As the purpose of this paper is to provide a key to rapidly identify the larvae in the field, the live immature stages were studies first and then the dead specimen used for confirmation after additional observations and dissection.

At the time of collection and in the laboratory, the behaviour of live larvae and general aspect (colour and hairiness) was observed by placing various batches of larvae on the ground to observe their movement and photograph them. In the laboratory, the specimens were stored for about 20 minutes (depending on the size of the specimens, usually 70 mm on an average) in cool conditions to keep the specimen inactive to get clear macrophotographs. Three different parts of the larvae were photographed: the head capsule, the ventral and the dorsal surface of the last adominal segment.

The ventral part of the last adominal segment, the anal opening and the first thoracic sclerite were observed under a binocular microscope and sketched. From each different group of larvae, two specimens were dropped alive into KAA fixative, left overnight until fixed and preserved in 80% ethanol in plastic containers (Norris and Upon 1974). Fixation in KAA reduces shrinkage and avoids black discoloration by inhibiting enzymatic activity and prserves the larva in a life-like condition.

To confirm that the white grubs belonged to the families of Scarabaeoidea, especially Scarabaeidae and the subfamily of Dynastidae, the most valuable distinguishing characters were found on the head and mouthparts as described by Richter (1966) and Baraud and Paulian (1982). Dynastinae were confirmed using Bedford's (1974) key. As soon as a larva died, the head capsule was sliced with a razor blade and stored in 80% ethanol. For microscopic observation, the head capsule was plunged into 10% Potassium hydroxide for 5 minutes under a gentle flame until it became transparent. After cooling and rinsing in alcohol, the complex of the maxillae, labium, antenna and mandible were removed to observe the characters described by Richter (1966) and Baraud and Paulian (1982).

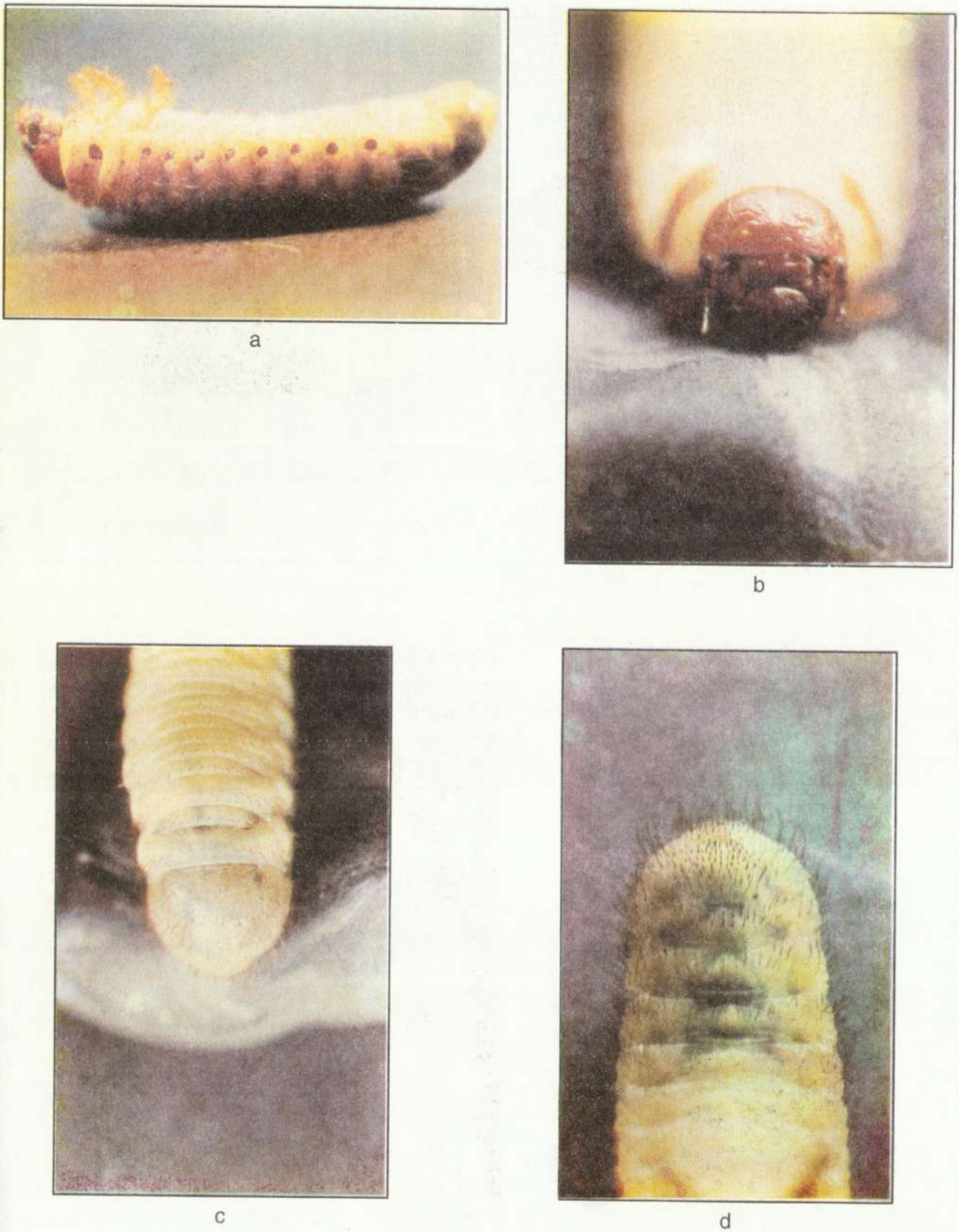


Plate 1. Larvae of Cetoninae

a

d

c

d

Plate 2. **Larvae of *Xylotrupes gideon***

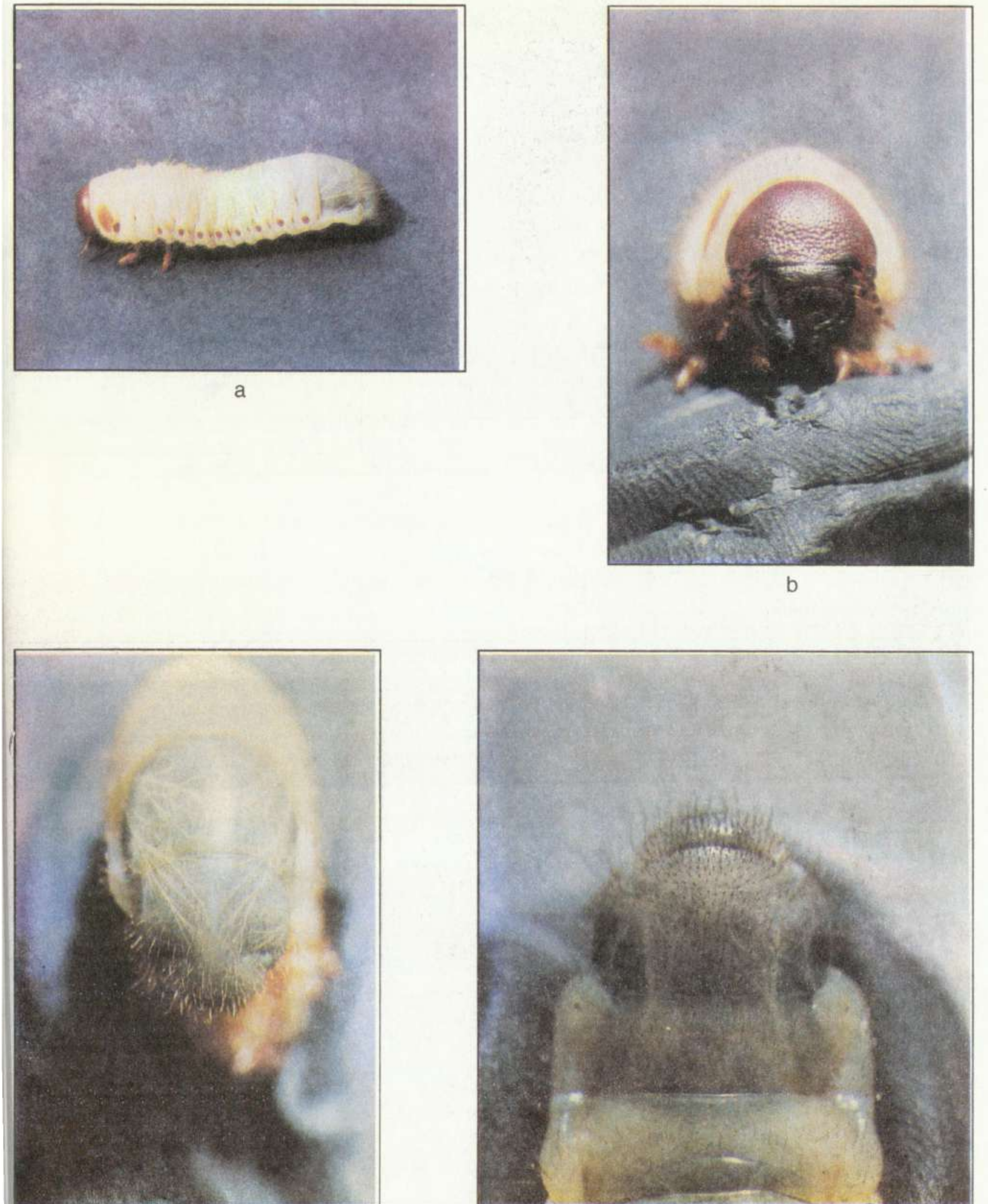


Plate 3. Larvae of *Oryctoderus latitarsis*

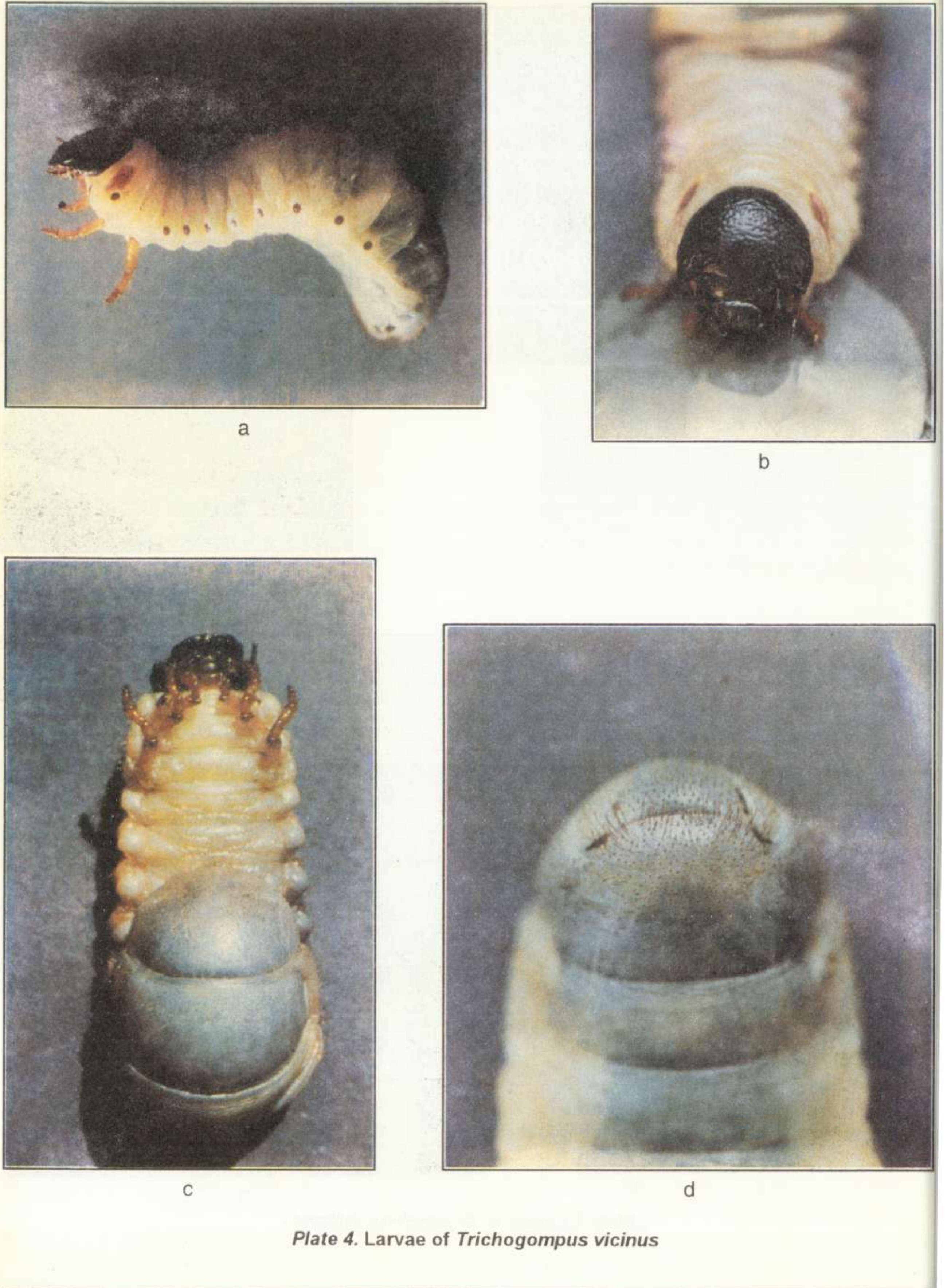


Plate 4. Larvae of *Trichogompus vicinus*

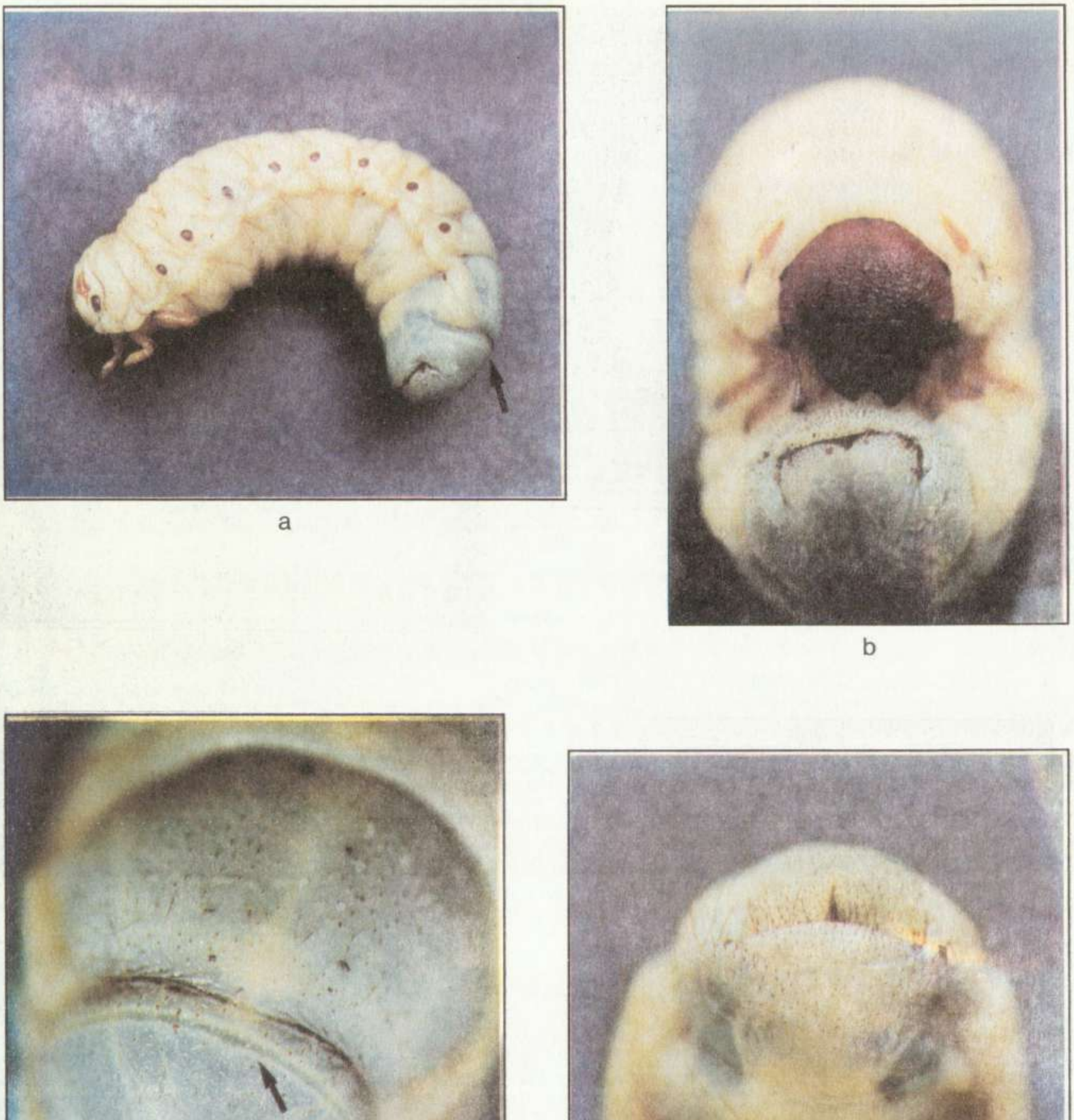


Plate 5. Larvae of *Oryctes rhinoreos*

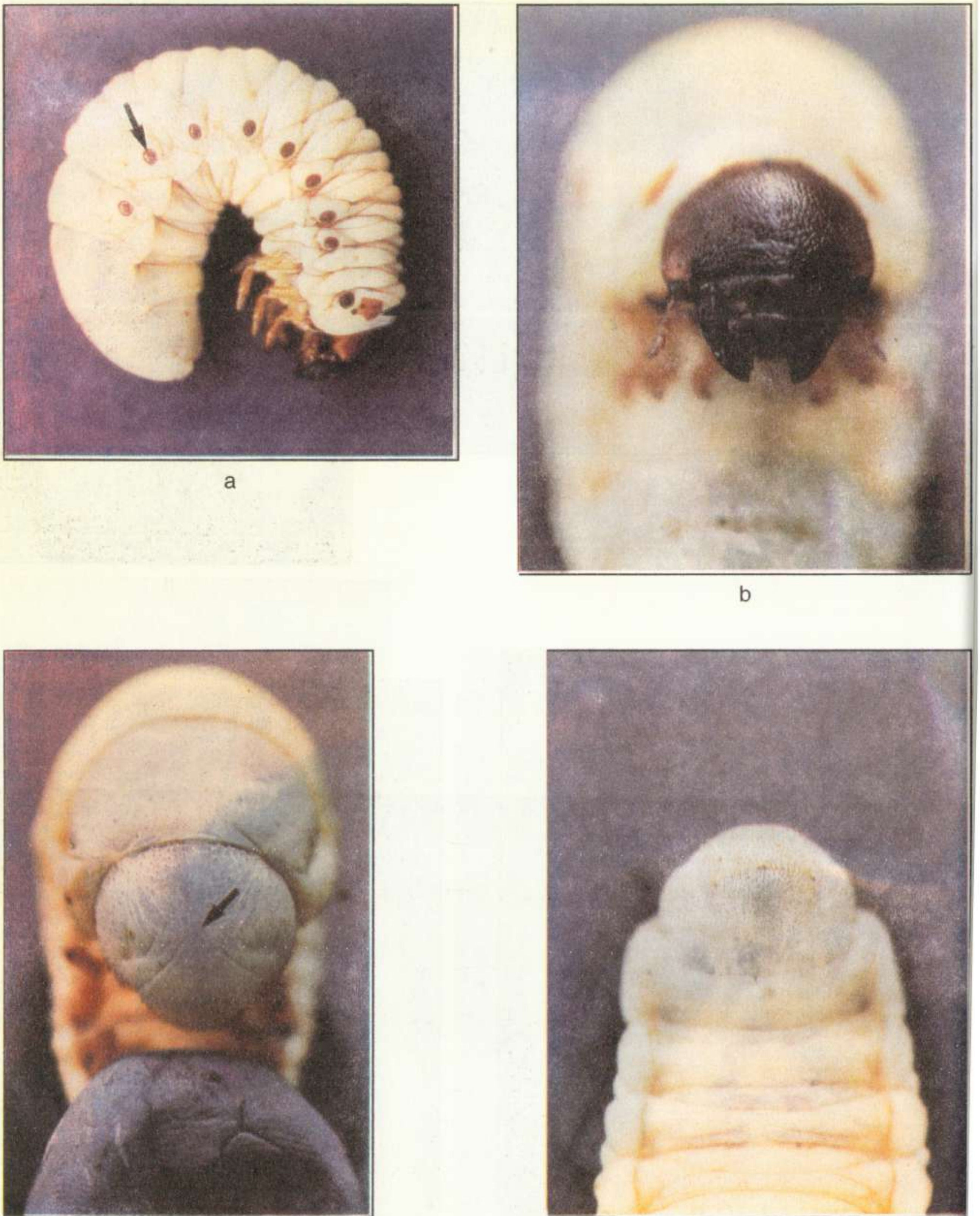


Plate 6. Larvae of ***Oryctes centaurus***

a

b

c

d

Plate 7.* Larvae of *Scapanes australis

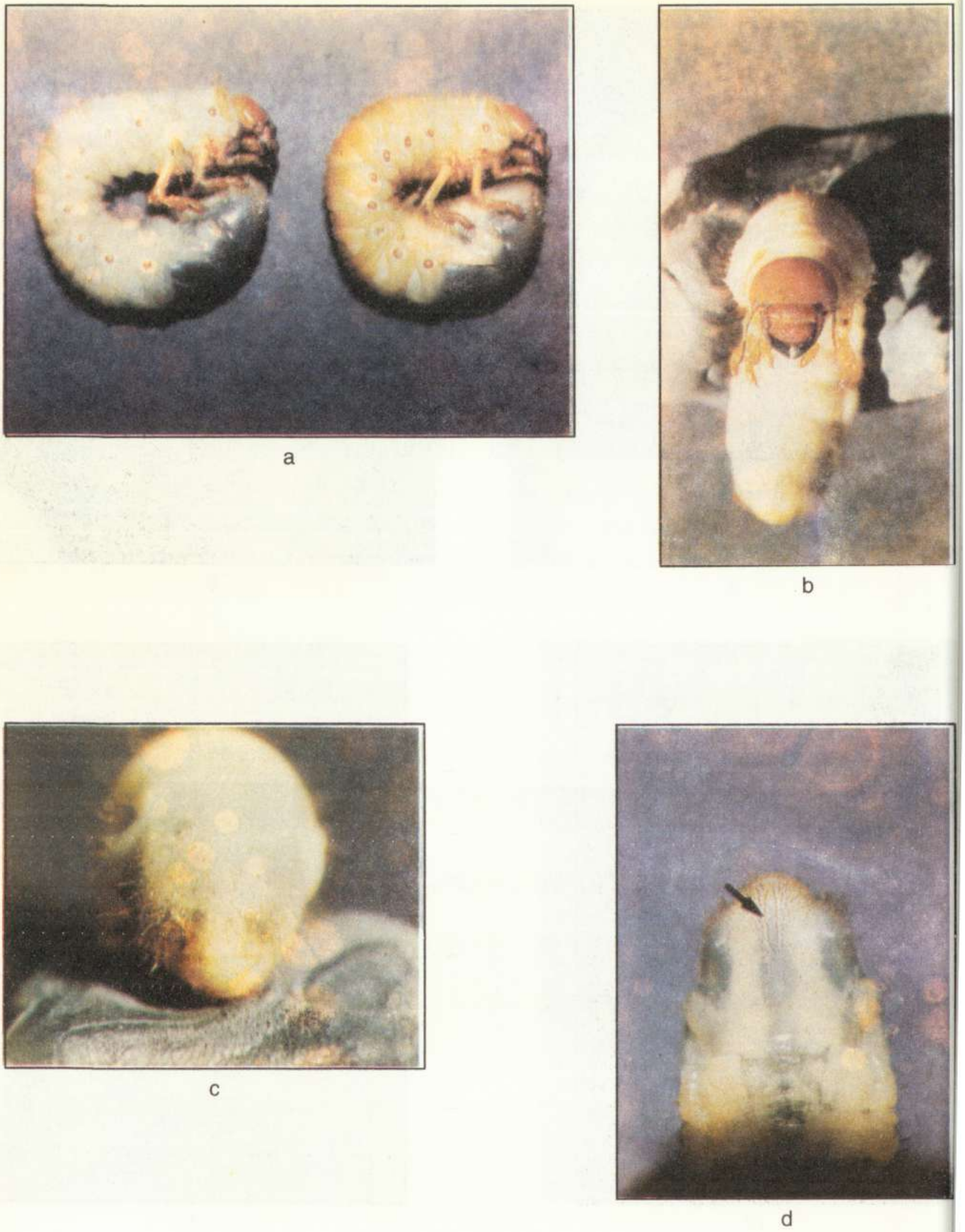


Plate 8. Larvae of *Dermolepida* spp.

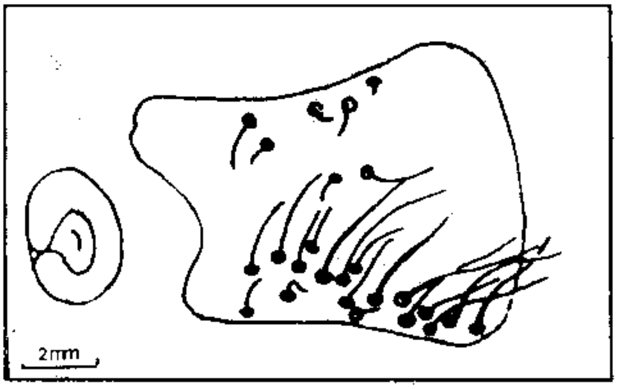
a

b

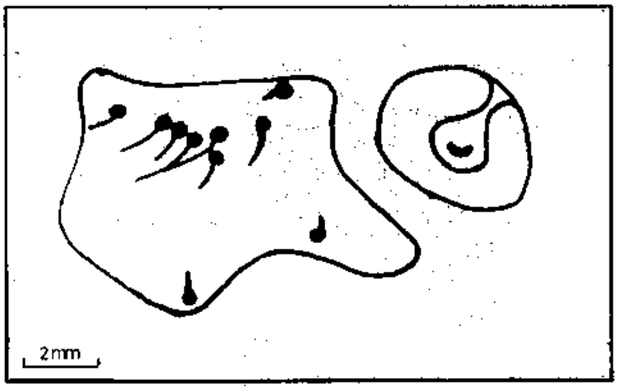
c

d

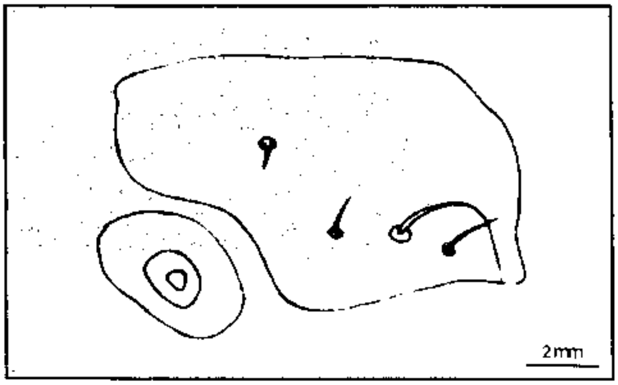
Plate 9. **Larvae of Lucanidae**



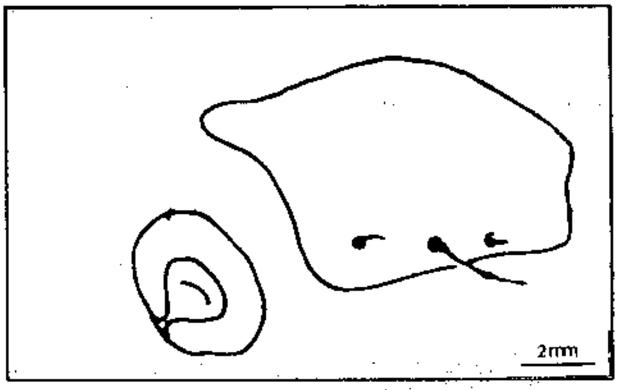
(a) *Xylotrupes gideon*



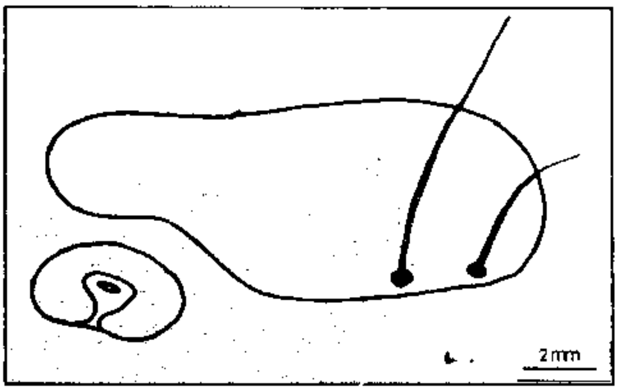
(d) *Oryctes rhinoreos*



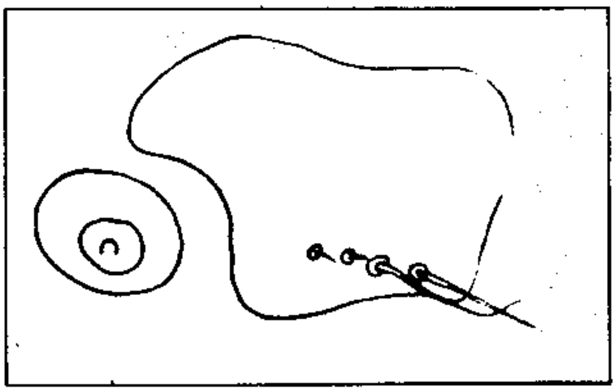
(b) *Oryctoderus latitarsis*



(e) *Oryctes centaurus*



(c) *Trichogompus vicinus*



(f) *Scapanes australis*

Figure 1. Thoracic sclerite plates and spiracles of various larvae.

RESULTS

At the beginning of the field work, it was observed that mixed collections of larvae behaved quite differently when placed live on flat ground. Any larvae which were not lying in a curled position were eliminated from the field collection. The rest were separable into three groups as soon as they moved.

1. The first group of larvae progress on their dorsal (back) surface (Plate 1 a) as previously described by Hurpin (1961) and Richter (1966). This character was sufficient to distinguish these Scarabaeidae from other larvae and to identify them as species of Cetoninae.

2. The second group of larvae progressed on their ventral (front) surface (Plates 2,3 a). These larvae could then be further separated into two different genera, mainly on the colour of the body hairs and head capsule colour (Plates 2 a, 2 b, 3 a, 3 b), and finally on the number and type of hairs on the first thoracic sclerite (Figure 1 a, 1 b). This group of larvae were identified as *Xylotrupes gideon* and *Oryctoderus latitarsis*.

3. The third group of larvae which were usually the most numerous in the field collections, only moved on their side, in a crab like progression (Plates 4,5,6,7,8 and 9 a). These were more difficult to separate using nothing more powerful than a pocket lens.

The examination of the head capsule colour and the anal (last segment) end in the third group reveals diagnostic features which are described and illustrated in the key. A black head capsule was observed for *Trichogomphus vicinus* (Plate 4 b). A ring, present as a dorsal impressed line on the last abdominal segment was found to be a characteristic of *Oryctes rhinoceros* (Plate 5 c). A depressed longitudinal line on the dorsal side of the last abdominal segment was observed for *Oryctes centaurus* (Plate 6 c). An arrangement of two rows of spines revealed Dermolepida (Melolonthinae) larvae (Plate 8 d) whereas two characteristic anal lobes with Y-shaped anal opening were features of the Lucanid species (Plate 9 d).

The length and number of setae on the first thoracic sclerite and the spiracles were also characteristic for species such as *Xylotrupes gideon, Oryctoderus latitarsis, Trichogomphus vicinus, Oryctes rhinoceros, Oryctes centaurus* and *Scapanes australis* (Figures 1 a, b, c, d, e, f). Using a combination of these characters, which can be seen using a hand lens, identification can be confirmed.

It is important to note that this key is designed to be used for the larger larval instars (3rd instar and beyond) and only those found, feeding on organic matter or in contact with the soil and lying in a curled position. When using the key, a larva that does not exactly fit the description given in the key, can be assumed to be another species not commonly found in the described situation, and probably not a scarabaeoid larva.

Field key to distinguish some third instar white grubs of Scarabaeoidea in PNG.

1. Live larvae, when placed on a flat surface, uncurl and move on their dorsal surface (plate 1 a.)..**Cetonidae**

1' Live larvae when placed on a flat surface, uncurl and move on their venral side (plates 2,3 a)..**2**

1" Live larvae when placed on a flat surface, uncurl and move on their side in a crab-like progression (plates 4, 5, 6, 7, 8, 9 a) **3**

2(1') First thoracic sclerite with 13-32 medium to long red setae. Body covered with red setae. Head capsule reddish brown (plates 2 a, b, fig. 1 a) ....***Xylotrupes gideon***

2' First thoracic sclerite with one long seta, one to two medium setae plus one to four short setae. Head capsule brown colour (plate 3 b, fig 1 b) ....***Oryctoderus latitarsis***

3(1") Head capsule black. First thoracic sclerite with 2 long setae (plate 4 b, fig 1 c)........................ ....***Trichogomphus vicinus***

3' Head capsule reddish brown (plates 5, 6, 7 b) **4**

3" Head capsule orange-reddish (plates 8, 9 b) **7**

4(3') Distinctive ring or saddle on anal segment. First thoracic segment with one long, 3-8 medium length setae, shorter than width of sclerite (plate 5 c, fig. 1 d)................................***Oryctes rhinoceros***

4' No distinctive ring or saddle on anal segment (plates 6, 7 c)..**5**

5(4') Presence or absence of a longitudinal depressive line in the middle of the dorsal anal segment. Thoracic spiracles more or less differentiated in their form and colour.

First thoracic sclerite with 1 to 2 prominent setae longer than width of sclerite. First thoracic sclerite with more than 2 prominent setae which are shorter than width of sclerite................................**6**

6(5) Presence of a longitudinal depressed line in the middle of the dorsal anal segment.
Thoracic spiracles well differentiated in their form and colour (fig. 6 a).

First thoracic sclerite with 1 prominent seta, longer than width of sclerite plus one or two short setae (fig. 1 e)..................................***Oryctes centaurus***

6' Absence of a longitudinal depressed line in the middle of the dorsal anal segment.
Thoracic spiracles uniformely dark brown in colour (fig. 7 a)
Thoracic sclerite with 2 prominent setae, longer than width of sclerite plus two minute setae or empty setal sockets (plate 7 c. fig. 1f) ....***Scapanes australis***

7(3") Characteristic design present on the ventral face of the raster (plate 8, 9 d)..............................**8**

8(7) Two rows of setae (plate 8 d)...***Dermolepida* spp.**

8' Two rows of setae and anal opening Y-shaped (plate 9 d)................................***Lucanidae.***

CONCLUSIONS

The results of our observations allow the use of simple characters to easily identify in the field the third stage of larvae similar morphologically and occupying similar breeding sites. This key does not require the use of complicated identification features as previously published. The first main character to observe in live specimens is the crawling movement of the larvae on a solid and flat surface. The readily visible characters are then compared. Colour of the head capsule (black for *Trichogomphus vicinus*), particularly important setation (*Xylotrupes gideon*), presence of a specific ring on the last ventral abdominal segment (*Oryctes rhinoceros*), design of the raster (*Demolepida* spp., Melolonthinae and Lucanidae), and characteristic spiracles and sclerite setation separate *Oryctes centaurus* and *Scapanes australis*.

In order to consider using biological control against coconut rhinoceros beetle pests, their numbers and distribution need to be determined. Collection of diseased larval specimens in the field requires identification and testing against other related species before any multiplication and introduction into the islands. This field key enables both experienced entomologists and the field staff to collect and identify the species being studies for biological control.

ACKNOWLEDGEMENTS

This work was carried out under an entomological project funded by the European Union to investigate the biological control of *Scapanes australis*. We would like to thank Miss Kalangpan Samai, Technician, Mr Roy Nanguai and Miss Thecla Nawai, assistant research officers at the PNG Cocoa and Coconut Research Institute for their assistance in preparing different specimens for observation and photography. We also acknowledge the continuing support of the PNG CCRI board and Director, Dr. John Moxon, and for their permission to publish this work. Professor R. Kumar read the manuscript critically.

REFERENCES

BARAUD J. and **PAULIAN R.** (1982). Faune des Coleopteres de France 2 Lucanoidea et Scarabaeoidea XIX pans Lechevallier 477p.

BEDFORD G.O. (1979). Description of the larva of *Oryctes monoceros* (Olivier) (Coleoptera, Scarabaedae, Dynastinae) from the Seychelles *Bull. Ent. Res.* 69:599-604.

BEDFORD G.O. (1974). Descriptions of the larvae of some rhinoceros beetles (Coleoptera, Scarabaeidae, Dynastinae) associated with coconut palms in New Guinea. *Bull. Ent. Res.* 63:445-472.

ENDRÖDI S. (1957). Rassenkreis von *Scapanes australis* Boisd. (Coleopt., Dynastinae) *Bonn zool Beitr* 8:71-74.

GODDYER, G.J. (1977). Root-feeding beetle larvae-pests of crops and pastures. *Agricultural Gazette, New South Wales* 88:(5) 42-43.

HURPIN, B. (1961). Sachons distinguer entre les nombreuses espèces de vers blancs, *Ptytome*, 129: 11-16; 130:23-27.

HURPIN, B. and FRESNEAU, M. (1969). Contribution à l' étude des *Oryctes elegans* (Col. Dynastidae). *Ann. Soc. Ent. fr.* (N.S.) 5(3):595-612.

HURPIN, B. and FRESNEAU, M. (1970). Etude en labrtoire du dévelopement larvaire de *Oryctes monoceros* et Oryctes rhinoceros (Col. Scarabaeidae). *Ann. Soc. Ent. Fr.* (N.S.) 6(1): 193-214.

LEPESME, P. (1947). Les insectes des palmiers. Paris: Lechevallier. 903 p.

NORRIS, K.R. and **UPON, M.S.** (1974). The collection and preservation of insects. Brisbane: Australian Entomological Society. Miscellaneous Publication 3, 33pp.

O'CONNOR, B.A. (1953). The rhinoceros beetle (*Orycles rhinoceros* L.) in Fiji. *Fiji Agricultural Journal* 24(1-2):1-12.

RICHTER, P.O. (1966). White grubs and their allies. Corvallis; Oregon State University Press. 219 p.

PRODUCTION PERFORMANCE: AN ECONOMIC ANALYSIS OF SMALLHOLDER COFFEE PRODUCERS

Peter A. Manus[1]

ABSTRACT

Smallholder farms produce 70 percent of total national production. This study, which was undertaken in Nipa, Southern Highlands Province by a survey, aimed to examine the level of farm investment and factors affecting production. It was found that the sampled farms made, on an average, a net income of K129.86 with a net return of K2.54 per manday of labour. The production function fitted indicated diminishing returns to scale. Farm size and capital were significant at 1 percent and 10 percent levels of probability respectively. However, farm size, family labour and capital inputs were all used excessively due to high plant density, infrequent weeding and poor management of gardens.

Keywords: *Samllholder, coffee production, input valuation, farm investment, farm returns .*

INTRODUTION

Coffee is one of the most important agricultural industries in Papua New Guinea (PNG). Two types of coffee are grown: *Arabica* and *Robusta*. Arabica coffee, which is grown in the cooler Highlands Region, contributes about 85 percent of annual national production. *Robusta* and some *Arabica* coffee are grown on the lowlands.

Coffee is a monocultural cash crop grown mainly for export income. During the 1986 to 1992 period, coffee accounted for an average of 53 percent of total agricultural export income.

Earnings of this magnitude are made possible by a large number of smallholder producers who account for 70 percent of total annual production. The remaining balance is produced by the plantations and the blockholders. Smallholders see their high level of participation in the cash economy as necessary to improve their quality of living in the rural villages. In this regard, provision of physical and institutional infrastructure (such as roads, etc. and marketing information, etc.) is crucial in the development of agriculture (Longmire 1994).

Finney (1969), Arthur (1975) and Anderson (1976) studied the smallholder costs of production, levels of labour input use, and income. These studies found that small scale coffee farming was a remunerative farm activity. However, the studies showed that smallholders incurred very minimal cash cost inputs. Overfield (1994) found that smallholder production levels were positively related to labour input, implying that labour use may incrérase and/or decrease in proportion to changes in producer price.

The farmer's production level for a given unit area can be high or low depending upon the influences of (i) local environmental factors (such as local climate and pests and diseases), (ii) world coffee prices and (iii) the level of productive inputs committed in the production process. The former two are outside the farmer's sphere of influence. Gibson (1994) however, argued that providing subsidies to tree crop producers might create a high cost, inefficient industry that might not withstand competition on the world market. Nevertheless, institution of producer price stabilisation/subsidy policies during depressed world prices would ensure that the industry survives and also would enhance increased production. At the farm level, actual output is depen-

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dent on the level of quantity and quality of inputs incurred in production. Inputs include land, labour and capital.

Most smallholders are uneducated. Provision of extension education improves the farmer's management skills (such as allocation of inputs) and technical knowledge (such as correct pruning) in this situation. However, farmers often do not have complete information on changing management practices and coffee prices. Thus, the positive net incomes made by farmers during a given production season do not necessarily reflect better farmer's management performance nor efficient allocation of farm inputs.

Coffee was introduced to the Southern Highlands Province (SHP) in the late 1960s. About 3,000 families were involved in smallholder coffee production there by 1975 (French and Walter 1984) and by 1986 an estimated 24,176 more families were growing coffee (Department of Primary Industry 1986). In the 12 year period, this was an increase of 805 percent or an annual growth rate of 8 percent.

This study was undertaken in Nipa District, Southern Highlands Province. Agricultural extension is provided to the district's 3956 smallholder coffee producers by 3 extension officers or one extension officer is responsible for 1319 farmers on personal contact basis.

Given the small extension input, exactly which farm input variables (apart from environmental factors and changing world coffee prices) influence producer performance has not been the focus of any study. The objective of the paper is therefore, to examine the inputs that affect production and production decisions of the smallholder farmers.

The Data

The relevant input-output data and relative prices were collected from 30 farmers randomly selected from a list of 50 farmers obtained from the Nipa District's Department of Agriculture and Livestock (DAL) officers. A sample size larger than 50 farmers was not possible due to (i) non-existence of a smallholder coffee directory and (ii) time and money liminations. However, the average farm size found in this study is 0.21 of a hectare. This is comparable to the provincial estimate of 1.18 ha (Department of Primary Industry 1986) and 0.25 ha, the overall estimated average in the country (Underwood and Lahis 1986). Therefore, it is reasonable to believe that the sample finally selected is representative of Nipa coffee producers.

The data were generated by interviewing the farmers using a questionnaire prepared for the purpose of this study. The questions related to types and quantities of inputs used, purchased input prices, labour used in different farm tasks, output and output prices. Since one farmer was not available at the time of interview, 29 farmers were actually interviewed. All farms covered in the study were located within a 7 kilometre radius from the DAL district office. The study pertained to the 1986 production period. Since the farmers continue to operate on low input-low output philosophy and no significant improvements in world coffee prices over the past decade, it is less likely that significant changes may have occurred in smallholder production in the district.

METHODOLOGY

Two analytical tools were employed to analyse the data collected. They are the tabular and multiple regression analyses. The tabular method was used to analyse the costs and incomes of smallholder farms.

The multiple regrssion analysis was performed to study the input productivity of smallholder farms. The single equation model fitted was of the form:

$$(1)\ Y = AX_1{}^{a}X_2{}^{b}X_3{}^{c}X_4{}^{d}$$

To estimate the values of the parameters by ordinary least squares, equation (1) was transformed into logarithm of the form:

$$(2)\ LnY = LnB_0 + B_1\,LnX_1 + B_2\,lnX_2 + B_3\,LnX_3 + B_4\,LnX_4$$

where in the variables: Y is output and X_1, X_2, X_3, and X_4 are farm size (in hectares of land under mature coffee trees), family labour (in mandays), capital services (depreciation value of tools) and age of coffee trees (in number of years) respectively. A manday of labour is defined as the amount of work performed by an able bodied adult in eight hours. Plant density was highly correlated with farm size. It was therefore, dropped from the final equation fit-

Table 1. **Cost composition (in Kina) of smallholder farms.**

Item	Range	Average	% of total costs
Labour	96.37 - 205.64	130.10	95.30
Tools	1.26 - 12.08	3.71	2.72
Bags	0.60 - 3.20	1.38	1.01
Drying Mats	3.20	1.32	0.97

ted. The farm size of the sampled farms varied between 0.02 and 0.56 hectares with an average farm size of 0.21 of an hectare.

VALUATION OF INPUTS

Smallholder coffee farms occupied the most fertile land which was suitable for subsistence food production. There is a trade-off between coffee and food production in this situation. Sweet potato is the staple food crop in Nipa. The prices of land under coffee is therefore the value of sweet potato production foregone[1].

Similarly, family labour must be valued at its opportunity costs. Overfield (1994) noted the labour valuation problems involved in smallholder coffee production (for details, see his article). He implied that the net return to labour in coffee production could be used if no producer price support for a given production season existed. Since producer price support did not prevail during the study period (except December), family labour was valued using the sampled coffee farms' net return to labour[2].

Table 2. **Gross and net income (in Kina) of sampled farms.**

Description	Range	Average
Total gross income	30.88 - 333.52	136.26
Total cash costs*	3.72 - 42.26	6.41
Net farm income	26.72 - 321.02	129.86
Net return per manday	0.62 - 5.62	2.54

* Total cash costs excluding the imputed value of labour

RESULTS AND DISCUSSION

Costs Composition and Income of Sampled Farms

The results of smallholder farm investment situation are presented in Table 1. Family labour accounts for 95 percent of total cost of production. The value of family labour was inputed at K2.54, the net return to labour found in this study. In terms of actual cost of production, the farmers incurred minimal cash cost inputs. Family labour is therefore, the principal (non-cash cost input) input of smallholder farms. Similar studies (Finney 1969 and Anderson 1976) noted the same investment pattern, which imply that smallholder farm investment structure has not changed since the 1970s.

The yield of coffee depends upon producer price and management of gardens. For a given farm size, gross income can be affected by changes in either management and/or producer price. These changes would affect net income.

Given the yield levels and producer price, Table 2 shows the costs and returns of the sample farms. A representative farmer made a net profit of K129.86 with a net return of K2.54 per manday of labour. The return per manday of labour is comparable to the PNG rural minimum wages rate of K2.50 (prevailing in 1986) for an unskilled rural worker.

Despite the positive returns to smallholder coffee farming, average output of the sampled farms amounts to 0.9 tonnes per hectare which is less than 50 percent the plantation sectors' 2.2 tonnes per hectare.

Table 3. **Estimated regression and elasticity coefficients.**

Regression coefficient for No. of observations	constant	X1	X2	X3	X4	R^2	B_i
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
29	0.131 (0.15)	0.513*** (9.03)	0.085 (0.38)	0.120* (1.88)	0.176 (1.30)	0.86	0.894

* Significant at 10 percent level of probability
*** Significant at 1 percent level of probability
B is the sum of output elasticities
Figures in parentheses are "T" ratios

Table 4. **Marginal Value Products**

No. of observations	Marginal value product for X1	X2	X3
29	170.640	0.053	0.191

ELASTICITIES OF PRODUCTION

The coefficients of the log-linear function fitted directly measure the output elasticities. The elasticities are presented in Table 3. In view of the observed adjusted coefficient of multiple determination (R^2), all the explanatory variables contained in function (2) explained 86 percent of the variable in gross income. The high adjusted R^2 suggests that there is a good statistical fit for the underlying data used in the study.

The sum of output elasticities (B_i) of the production function was found to be less than one. This indicates decreasing returns to scale in smallholder coffee farming.

The elasticity coefficients with respect to farm size and capital inputs were positive and statistically significant at 1 percent and 10 percent levels of probability respectively. The elasticity of family labour and age of coffee trees were also positive but not significant. The non-significance of these variables (in particular labour) indicated that proportionate increases in family labour and age of coffee trees may not necessarily result in more than proportionate increase in gross income. The interesting feature noted was that the elasticity coefficient of family labour assumed a positive value. This may suggest excessive use of this input by the sampled smallhlder farms (an explanation is offered below).

MARGINAL VALUE PRODUCTS

Exposition of the extent of farm input use efficiency in smallholder coffee farms was accomplished by comparing the marginal value products calculated at the geometric mean levels with the respective input prices. The results are presented in Table 4.

The marginal value products of farm size family labour and capital services were all found to be less than the respective acquisition prices. This indicates that these inputs were excessively used. The over-utilisation of farm size, family labour and capital can be attributed to how the coffee gardens were managed.

Plant density of the sampled smallholder coffee farms were found to be higher by 358 trees per hectare than the most recently recommended plant density of 2478 trees per hectare in the plantation sector (Coffee Industry Board 1987). This over-planting would have the effect of reducing the potential bearing capacity of the coffee trees due to over-exploitation of space, intense competition for soil nutrients, and under-utilisation of sunlight. The effect would be even more dramatic under heavy shading.

The trees have grown taller than the manageable height in an attempt to reach sunlight. Apparently, most farmers did very little to control the trees' growth by proper pruning and/or cutting back the trees to make them manageable. The outcome of the lack of adequate management of the trees is that harvesting of cherries was done by either climbing into the trees or pinning the trees into the ground with anchors. These activities required more than the normal time required for harvesting.

Weeding of the coffee gardens is done on irregular basis using spades and bushknives. Most farmers tend to weed the coffee gardens when the weeds were bushy. This required the extensive use of spades and bushknives. It also required more labour than needed for more frequent weeding.

CONCLUSION

The sampled farms made positive net returns. The net return of labour of K2.54 is comparable to PNG rural minimum wages rate of K2.50 for an unskilled rural worker. However, average smallholder production is less than 50 percent of the plantation sector production of 2.2 tonnes per hectare. This reflected poor management of the coffee gardens due to ineffective extension input.

The production function estimate showed the existence of decreasing returns to scale. The decreasing returns suggest that average product is diminishing and an economic optimum will exist. This optimum may occur even with constant prices. Even so, there is a need for farmers to make some adjustment in resource allocation.

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[1] No land markets exist in the rural villages. In this context, land was valued at its opportunity cost, the value of sweet potato foregone.

[2] The December coffee support price of bounty payment was only K0.10 per kilogram which was outside the flush period.

REFERENCES

ANDERSON, D. (1976). An Economic Survey of Smallholder Coffee Producers. Department of Primary Industry, Port Moresby, Papua New Guinea.

ARTHUR, W. (1975). Returns to Smallholder Coffee Production. Department of Primary Industry, Port Moresby, Papua New Guinea.

COFFEE INDUSTRY BOARD, (1987). PNG Export Tree Crop Study, Largeholder Summary Report. Coffee Industry Board, Goroka, Papua New Guinea.

DEPARTMENT OF PRIMARY INDUSTRY, (1986). Statistical Report on Southern Highlands Provincial Smallholding Crop Survey - 1984/85. *Rural Statistical Bulletin*, No. 3.

FINNEY, B.R. (1969). New Guinea Entrepreneurs. *New Research Bulletin*, No. 17. Papua New Guinea.

FRENCH, W and **WALTER, A.H.B.** (1984). What's Worth Evaluation? *Monograph* 24. IASER, Port Moresby, Papua New Guinea.

GIBSON, J. (1994). The Price Elasticity of Demand for Papua New Guinea Export of Cocoa and Coffee. *PNG Journal of Agriculture, Forestry and Fisheries Vol. 37 NO 2. pp 67-75.*

LONGMIRE, J. (1994). Marketing Systems for Agriculture: Diagnosing Problems and Price and Marketing Analysis for Papua New Guinea. *PNG Journal of Agriculture, Forestry and Fisheries Vol. 37 NO 2. pp 67-75.*

OVERFIELD, D. (1994). The Smallholder Coffee System: Production costs, Grower returns, and Economic Sustainability. Coffee Discussion Paper, No. 15. Industry Affairs Division. Coffee Industry Corporation, Goroka, Papua New Guinea.

UNDERWOOD, D.J. and **LAHIS, S.B.** (1986). A study of Agricultural/rural Extension Experiences in Papua New Guinea. Department of Primary Industry, Papua New Guinea.

THE PERFORMANCE CHARACTERISTICS OF A TYPICAL PILOT-SCALE TRAY DRYER

Peter A. Sopade[1]

ABSTRACT

A pilot-scale tray dryer was assessed to relate the drying temperature (T,°C) and velocity ($V = ms^{-1}$) to the heater power (H_s) and fan speed (F_s) settings. K-thermocouples and an anemometer were used to measure these drying parameters for 121 setting combinations. Higher fan speed settings reduced the temperature in the drying chamber and multiple regression analyses gave the following relationships: $\ln T = 3.97 + 0.054 H_s - 0.061 F_s$; $r^2 = 0.9350$; $V = 0.4 \exp(0.129 F_s)$; $r^2 = 0.9897$. The relevance of the performance evaluation to downstream processing of PNG agricultural foods was highlighted.

Keywords: *dehydration, convective drying, air velocity, downstream processing.*

INTRODUCTION

The disparity between food supply and the number of people depending on it for survival is still topical. While declaring open the 1995 GASGA International Conference on Grain Drying in Asia at Bangkok, Thailand, the Assistant Director-General of the Food and Agriculture Organisation (FAO) noted that 800 million people go to bed hungry everyday. This was confirmed (Anon 1995) by the World Food Congress that was held in Hungary in its 'Budapest Declaration". Although not the only option, food science and technology has recognised the need to attend to post-harvest issues with a view to arresting pathological, chemical, physical, physiological, and microbiological spoilage factors. Moisture control by drying has proved (Brenndorfer *et al.* 1985; Hall 1989) to be quite effective and this is of particular relevance to Papua New Guinea because of the generally high humidity that prevails in the country.

Drying is often interchangeably used with dehydration in food processing to describe the unit operation in which nearly all the water present in a food is removed by evaporation or sublimation as a result of the application of heat under controlled conditions (Brennan *et al.* 1986). The methods for moisture removal can be conveniently classified (Strumillo and Kudra 1986) into four categories, amongst which is convective drying that passes heated air over the food. Although drying as a food preservation technique is as old as mankind, it continues to receive the attention of downstream processing experts because of the immense advantages it confers on its product. These advantages (and limitations) are well documented in the literature (Hall 1989; Singh 1994) and they have promoted a long-term research to generate drying data on PNG foods. Food dehydration is also a major component of the Food Technology program in the author's Department.

MATERIALS AND METHODS

The Tray Dryer

the schematic diagram of the tray dryer (UOP8-A) is shown in Figure 1. It has a 3 kW heater and four drying trays with each tray measuring 27.5 x 18.5 x 1.5 cm. The trays are not perforated but perforated trays can be fabricated locally to permit two-surface drying. The dryer weighs about 100 kg and its over-

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all dimensions (m) are height, 1.40; length, 2.95; depth, 0.73. The temperature in the drying chamber is controlled by the fan speed and heater power output, both of which are controlled by the settings of knobs. There are 11 settings (including position "0") per controller implying 121 possible combinations of fan speed and heater power output. Despite the controllers, the minimum and maximum temperatures (and relative humidity) obtainable are dependent on ambient conditions and these may vary from one pilot plant to another. Temperature regimes obtained elsewhere may only serve as a guideline and to minimise experimental error, it becomes imperative to assess the dryer's performance under the operating local conditions.

The Assessment

For each of the 121 combinations, four K (chromel-positive; alumel-negative) thermocouples were put on the drying trays and the termocouples were connected to a datalogger (Datataker DT50; Data Electronics (Aust.0 Pty Ltd., Rowville). The datalogger was competed to measure temperatures every 10 sec. and to log-in the average every 30 sec. for 10 min. The temperatures that were logged-in during the last 5 min. were used in the computation as it was assumed that the dryer would have stabilised during this period to reflect the true temperatures. The combinations were randomised and duplicated. The assessment was spread over 6 months (am and pm) to incorporate as much variations in ambient conditions as possible. The ambient temperature around the drier ranged from 22.2° - 30.4°C with a mean of 26.2° ± 2.4°C.

RESULTS AND DISCUSSION

Table 1 shows typical values that were obtained for the temperatures in the drying chamber. Generally, there was a temperature gradient in the drier with the top-most tray (tray 1) recording the highest temperature. The temperature gradient was possibly due to changes in the density of the air whereby hot air rises and cold air sinks. The gradient was more at high heater power ("10") and low fan speed ("0") settings and it was as little as 0.6° and a large as 35.8°C. Choosing any of the tray's temperature, as the drying temperature cold introduce substantial error in any drying study. An average of the four temperatures per combination was computed and the maximum coefficient of variation was 14.5%. Using the average temperature, the difference in the temperature on any tray was not more than 19.8°C. As expected, the average temperature is recommended for use as the temperature in the drying chamber.

An analysis of variance (not shown) revealed that both heater power (H_s) and fan speed (F_s) settings significantly ($p<0.05$) affected the average temperature (T) in the drying chamber. A multiple regression analysis, which was done using Lotus 1-2-3 statistical software, showed that the dependence can be represented by an equation of the form:

$$\ln T = 3.97 + 0.054\, H_s - 0.0061\, F_s \quad \text{.......................(1)}$$

$r^2 = 0.9350$

% standard error of T-estimate (se) = 6.9

In addition to regression parameters, the mean relative deviation modulus, D_m, is recommended (Sopade and Ajisegiri 1995) in food processing as being valuable in assessing the goodness of fit of an equation.

$$DM = \frac{100}{n} \cdot \sum \frac{T_1 - T_{pi}}{T_1} \quad \text{..............................(2)}$$

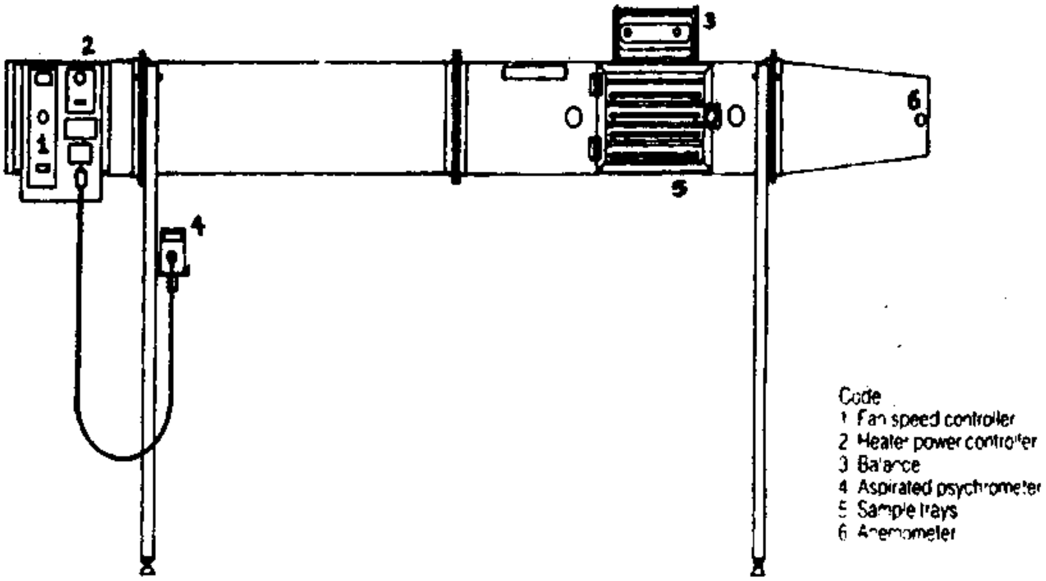
where n = number of experimental data, T_1 and T_{pi} = experimental and predicted temperatures respectively, A D_m of 5.7 was obtained for equation (1). This shows that equation (1) can be used with a reasonable accuracy to obtain the drying temperature when both heater power and fan speed settings are known. Alternatively, both settings can be computed to obtain a pre-determined drying temperature.

The practical importance of this mathematical analysis is that the dryer can be used to obtain drying data at temperatures and airflow within its regime that are representative of local PNG conditions. This will assist the design of an appropriate drier that is representative of the prevailing local conditions. Despite the desirability of dehydration as a downstream processing technique, a trial-and-error approach that arises in the absence of relevant drying data has culminated in a number of failures. Such failures have projected dehydration as unsuitable while neglecting the inaccuracy at the onset of the design.

Table 1. **Typical temperatures in the dryer at different settings.**

Heater Power Setting	Fan Speed Setting	Temperature (°C)				
		Tray 1	Tray 2	Tray 3	Tray 4	Average
0	0	51.1	52.7	48.2	44.2	49.8
0	1	57.4	57.0	55.5	52.1	55.5
0	5	41.1	41.6	41.6	40.8	41.3
1	6	38.4	38.7	38.7	38.0	38.5
1	7	39.1	39.4	39.4	38.6	39.1
1	9	30.4	30.5	30.6	29.8	30.3
1	10	33.7	33.9	33.8	33.1	33.6
2	4	45.1	46.3	46.2	45.1	45.7
2	7	41.3	41.6	41.7	40.8	41.3
2	8	35.0	35.3	35.3	34.5	35.0
3	2	53.2	52.9	52.5	51.1	52.4
3	3	46.0	47.4	47.3	45.9	46.7
3	5	49.4	50.1	50.1	49.0	49.6
4	0	73.7	70.1	63.4	56.4	65.9
4	1	71.1	68.8	65.3	60.0	66.3
4	2	56.2	55.9	55.4	53.7	55.3
4	10	38.4	38.7	38.6	38.0	38.4
5	0	80.5	76.1	68.4	59.7	71.2
5	1	76.0	73.7	69.6	63.6	70.7
5	2	59.9	59.5	58.7	56.8	58.7
5	5	56.6	57.4	57.4	56.0	56.9
6	7	51.2	51.8	51.9	50.8	51.4
6	8	43.6	44.2	44.1	43.2	43.8
6	10	42.4	42.8	42.8	41.9	42.5
7	0	92.3	86.5	77.3	65.5	80.4
7	5	64.5	65.6	65.4	63.7	64.8
7	10	43.8	44.3	44.3	43.3	43.9
8	0	97.7	91.2	81.4	68.1	84.6
8	2	71.2	71.0	69.7	66.3	69.5
8	10	45.7	46.3	46.2	45.4	45.9
9	4	66.9	69.6	69.4	67.2	68.3
9	5	55.9	57.3	50.6	45.3	52.3
9	6	60.6	61.4	61.4	60.1	60.9
9	7	59.6	60.5	60.5	59.2	59.9
10	0	109.1	100.9	89.0	73.3	93.1
10	1	103.0	98.6	91.6	80.9	93.5
10	9	48.4	49.0	48.8	48.2	48.6
10	10	49.5	50.0	49.8	48.8	49.5

Figure 1. **Schematic diagram of the tray dryer.**



It can be observed from equation (1) and as shown in Figure 2 that an increase in the heater power setting increased the drying temperature, which got reduced when the fan speed setting was increased. The air velocity was measured with an anemometer at the outlet of the dryer (position 6 in Figure 1), which is of a smaller flow area than the drying chamber. Applying the continuity equation which states (Earle 1983) that the product of flow area and velocity is a constant, the actual flow velocity ($V = ms^{-1}$) in the drying chamber was related to the fan speed setting as shown in equation (3):

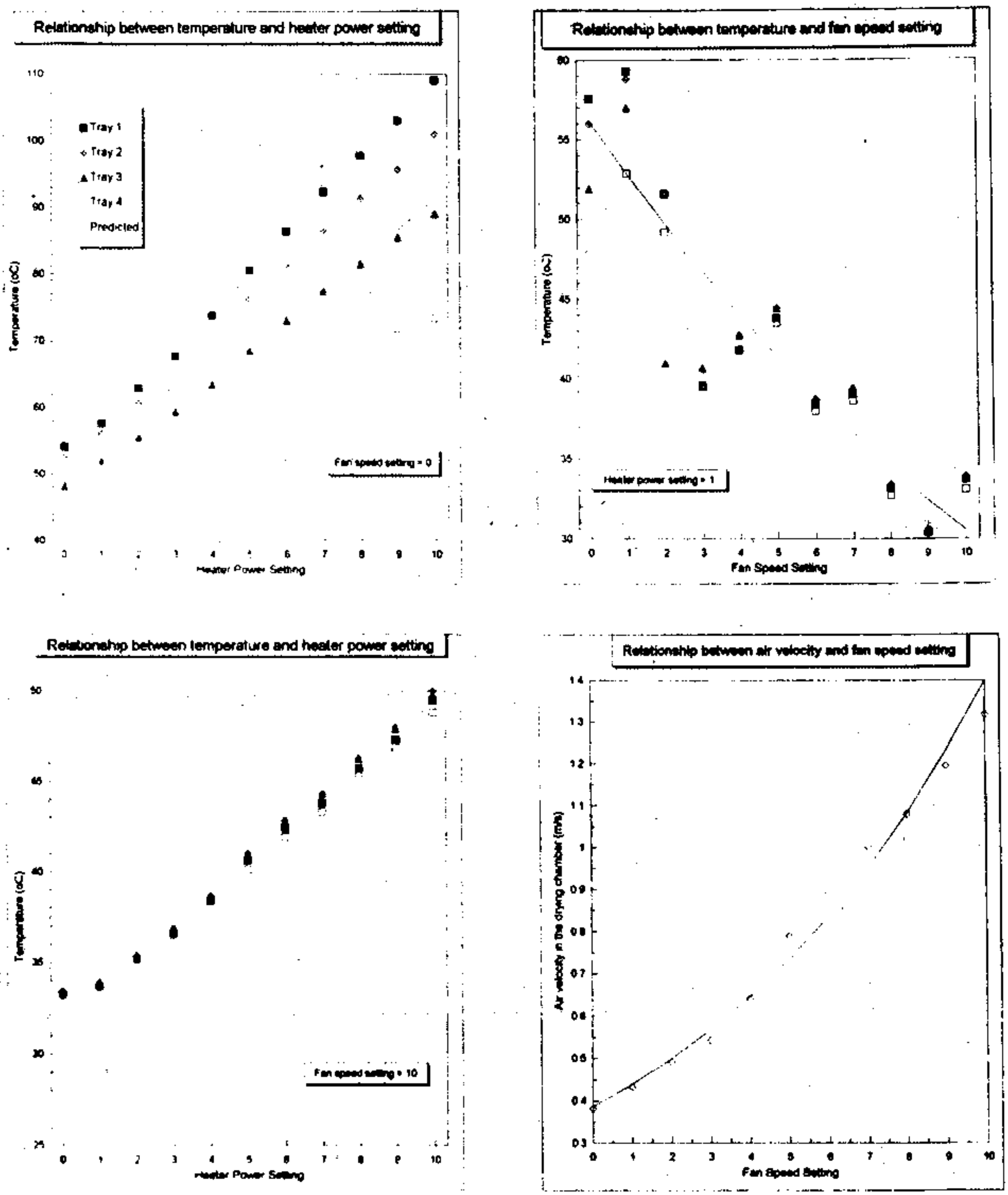
$$V = 0.4 \exp (0.129 F_s) \quad (3)$$
$$r^2 = 0.9897$$
$$se = 4.6$$
$$D_m = 3.4$$

The velocity of the air determines as the driving force for moisture evaporation and its residence time in the drying chamber. Although it is desirable to remove the evaporated moisture with the drying air as fast as possible. The resulting reduction in drying temperature prolongs drying. A balance needs to be struck, therefore, between air velocity and drying temperature for an acceptable drying rate. Apart from the economic implications, slow-drying results in a quality deterioration while too rapid a drying enhances the formation of a hard surface (case-hardening) that inhibits moisture migration from the interior of the food to the surface. The consequence is that the food is not uniformly dried.

CONCLUSIONS

The tray dryer under the local conditions in Lae, is capable of generating a drying temperature of 30° - 90°C with a air velocity that ranges from 0.4 - 1.4 $V = ms^{-1}$. These regimes appear to accommodate conditions in PNG and it is possible to simulate convective drying in different parts of the country once the local conditions are specified. This information should interest academics and entrepreneurs who are using or proposing to use dehydration. They will also find the evaluation valuable as a small scale study of their drying requirements can be conducted to maximise the benefits of dehydration. Relative humidity of the air plays a major role in dehydration as it determines the moisture removing ability (evaporative capacity) of the air. There is no humidity controller on the dryer. When air is heated, the

Figure 2. **Dependence of drying temperature and air velocity on heater power and fan speed settings of the dryer.**



relative humidity decreases but the reduction id dependent on the air's final temperature. A humidity as low as 10% was obtained in this study from an ambient relative humidity that averages 85%. For further reduction in humidity particularly at low drying temperature, it is possible to pass the air through a re-usable desiccant prior to heating. The cost benefit of this option will, however, need to be properly worked out.

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REFERENCES

ANONYMOUS (1995). The Budapest Declaration. *Food Australia* 47 (12): 571.

BRENNAN, J.G., BUTTERS, J.R., COWELL, N.D. and **LILLY, A.E.V.** (1986). *Food engineering Operations.* 3rd edn. Appl. Sci. Publ., London.

BRENNDORFER, B., KENNDRY, L., OSWIN-BATEMAN, C.O., TRIM, D.S., MRENA, G.C. and **WEREKO-BROBBY, C.** (1985). *Solar Dryers -Their Role in Post-Harvest Processing.* Commonwealth Science Council, London.

EARLE, R.L. (1983). *Unit Operations in Food Processing.* 2nd edn. Pergamon press, Oxford.

HALL, C.W. (1989). *Drying and Storage of Agricultural Crops.* 2nd edn. Farming Press, Ipswich.

SINGH, K.K. (1994). Development of a small capacity dryer for vegetables. *Journal of Food Engineering* 21(1): 19-30.

SOPADE, P.A. and **AJISEGIRI, E.S.** (1995). Moisture sorption characteristics of bambara groundnut (*Voandzeia subterranea* L. Thouars). *Food Australia* 47(10): 465-469.

STRUMILLO, C. and **KUDRA, T.** (1986). *Drying: Principles, Applications and Design* (Topics in Chemical engineering Vol. 3). Gordon and Breach Sci. Publ.; Switzerland.

METHODS OF ASSESSING LOSSES IN STORED FOOD PRODUCTS

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ABSTRACT

The need for reliable estimates of losses in stores due to insect pests is emphasized. Situations in which losses occur are outlined. Major categories of losses are considered. Sampling framework and methods of estimating losses are discussed.

Keywords: *loss category, loss estimation, loss methodology.*

INTRODUCTION

This paper is written to draw attention at all levels of government departments, officials, farmers and the public to the great importance of losses in food due to insect pests and that reliable estimates of losses in store are required. Figures commonly quoted have ranged from a 10 percent worldwide loss of cereals in store, 35 percent for grain losses in India after harvest to 46 percent for sorghum losses in Nigeria (Scrimshaw 1978). Such figures, according to Spensley (1982), often quoted and requoted, are usually little more than guesses. Reliable assessment techniques might prove these figures to be over-estimates rather than under-estimates. A number of recent studies at subsistence farmer level (see Boxall and Gillett 1984. Tyler and Boxall 1984 and Evans 1987 for references) point to levels of loss of the order of about 5 percent or less. The report of the First Regional Grain Conservation Seminar held in 1978 in Lusaka, Zambia stressed an urgent need for more precise studies on losses during and after harvest in terms of their magnitude, nature, and point of occurrence. The methods of measuring losses during and after harvest and during the various processes of marketing need to be standardised, at least regionally. Such studies are essential for the development of rational and viable post-harvest loss management programmes. The term pest used in this paper refers to insect pests.

Detecting Insects in Stored Produce

Before starting loss assessment studies, it is necessary to have a knowledge of the pest species occurring in the produce. the following stages may be present in the commodity:

1. Living adults
2. Dead adults
3. Living larvae
4. Dead larvae
5. Living pupae
6. Dead pupae
7. Eggs

The identification of pest species requires specialist knowledge. With the correct name, it should be possible to know its biology and behaviour and whether or not secondary pests will be able to infest the produce in store. Methods for detecting insects in stored produce have been described by Ashman *et al.* (1970).

Detection of insects may be combined with a preliminary survey, which may often help to clarify pest problems and give information on where most losses occur (Freeman 1978).

Situations in Which Losses Occur

This has been discussed by Harris (1978). Post harvest grain losses are caused by insects, rodents and birds, during harvesting, transport, storage and processing of the produce, on government and commercial farms, during distribution, wholesale and retail handling and in the household itself.

Harris and Lindblad (1978), in their manual on Post-Harvest Grain Loss Assessment Methods, rec-

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ommend a three-step procedure for making loss assessments and decisions on the feasibility of intervention, control or prevention:

1. Obtain an overview of the whole post-harvest system.

2. Make a rapid on-site appraisal that will focus on the potentially significant losses, the "peaks" in the system.

3. Study specific losses and methods of loss reduction and prevention.

The factors to be considered in any rapid on-site appraisal are as follows:

(a) Moisture content of the produce and outside.
(b) Length of time and temperature of holding.
(c) Local quality and quality control.
(d) Type of bins or other storage structure.
(e) Standard of sanitation in the store.
(f) Presence or absence of any trading quality factors.
(g) Use of pesticides and the technical standard of their use.
(h) Evidence of insect and rodent damage in grain: the kinds and amounts of insects, their frass and webbing exit holes and rotten kernels, or kernels damaged by rodents and presence of their excrements.

Mechanical Losses in Handling or Processing

In the tropics, storage over extended periods of time without reasonable control of temperature and moisture and without sound rotation of the produce in store may result in serious losses due to pests.

The Nature of Loss

Attempts to categorise losses have been reviewed by Howe (1965). Parkin (1956) divided losses into two categories: (a) a general estimate, or an informed expert guess; (b) an estimate based on actual measurements, however crude, of loss in weight or quality of produce.

Hall (1970) recognized the following major categories of loss:

(i) Weight Loss

This is a physical loss of substance, as shown by loss of weight or volume, caused by insects, rodents or other pests. Such a loss can easily be accounted for and quantified. However the following points ought to be noted:

a. Where there is sale by volume, especially in rural areas, such a loss may remain undetected.

b. In large scale trading, when there is adulteration with inert materials, weight loss may appear greater.

c. Increase in moisture content due to the activity of some insect pests may also show as a loss when dried.

(ii) Loss in Quality

Various commodity and marketing boards, for example the Cocoa marketing Boards in West Africa, have specific criteria which permit values to be placed on certain aspects of quality. The presence of insects, their remains, their excreta, damage and moulds obviously lower the quality of the produce.

(iii) Nutritional Loss

Feeding by pests may reduce the nutritional value of the produce. For example, fungal damage and the consequent production of toxins, such as aflatoxin, will make the product unfit for human consumption. The presence of insects and their remains may cause customers to reject the produce for fear of nutritional hazards.

(iv) Loss of Seed

Seeds are usually stored with extra care because they affect future food supplies. However losses due to pest infestation, excessive respiration, fungal diseases and inadequate or inappropriate control measures may still occur.

METHODOLOGY

De Lima (1979) stated that the scope of any loss assessment studies should be clearly defined. It should be decided whether all the stored produce or part, some section, category (some kind of it) is to be sampled to measure the extent of losses. The actual process of assessing losses will vary according to the individual situation but usually involves the following.

The Survey

An initial survey should be carried out to select an area in which to measure losses, and to select farmers and stores from whom the samples of produce will be taken. Such surveys usually provide a general idea of the problems involved.

The Sampling Framework

Sampling Stores

For the choice of farmers and stores recognised statistical procedures should be followed. De Lima (1979) suggested the use of a 7 x 7 Latin Square, superimposed over a map of the area surveyed to select sample stores. Area and cluster techniques (De Lima 1973, 1978) are more appropriate in cases where villages do not exist and each farmer lives on his own holding. Where cost does not even permit the use of these techniques, a line sampling technique may be employed (De Lima 1978) using a vehicle and stopping at fixed distances along a road. Sampling and its limitations are discussed by Zarkovich (1965, 1966) and others (e.g. Harris and Lindbald 1978).

Sampling of Grain

For sampling grain, Adams and Harman (1977) recommended intense sampling programmes such as taking samples regularly from the grain that the farmer is actually going to consume until the store is empty. However, where such a programme cannot be undertaken it may be necessary to divide the contents of the store into sampling units in such a way that every unit has an equal opportunity of being selected (De Lima 1979).

As practical examples given by De Lima (1979), when maize is stored on the cob or sorghum on the head, each cob or head forms a convenient sampling unit. If beans are stored in the pod or shelled, or wheat, maize, sorghum, millet and other grains are stored in a shelled or threshed condition, a way has to be found of dividing the produce into convenient units. However, if grain is stored in bulk, is completely accessible, and a sample divided or similar device can be used, there will be no need to divide the bulk into smaller units.

The Estimation of Loss

Although it would be ideal to base losses on the reduction in weight, nutritional or other quality, loss of seed or in practice, it may be necessary to confine studies to weight loss only, if facilities are limited.

The methods used to determine the loss have been classified by Adams and Harman (1977) as follows:-

i Volumetric
ii Gravimetric
iii Indirect methods

They suggest that the volumetric method, involving the weighing of a standard volume of sample and comparing it with the same volume of visibly damaged grains, was the most appropriate in the small farmer situation. However, De Lima (1978) criticized this method.

i. The method is too variable and requires a great deal of base-line data.

ii. The bulk density of a cereal varies with the variety moisture content, and whether or not an insecticidal dust or ash has been added.

iii. The extent and type of damage due to insects or fungi affect the weight/volume ratio of the sample.

iv. Without the use of standard instruments, variations in bulk density readings occur due to 'packing'.

De Lima (1978) advocated the intensive examination of each sample by dissecting individual grains to determine the loss caused by each pest species in order to establish a loss profile.

The Thousand Grain Mass (TGM) Method

The basic principle of this method considers that when an entire lot of grain is weighed before and after being attacked by insect pests or some other causative agent, the percentage loss of mass is easily calculated by using the formula:

$$\frac{m_1 - m_x}{m_1} \times 100 = \%$$

where m is the grain mass before attack and m is the grain mass after attack. Mass is the dry matter weight.

In this method the sample taken from the lot must be representative. This means that if a lot consists of 30% large grains, 50% medium and 20% small grains, these properties should be found in a representative sample. Similarly if 10% of the grains in the lot are damaged this percentage of damaged grains should also be found in the representative sample. The authors of this method (Proctor and Rowley 1983) believe that the method is based on sounder principles than any methods previously developed.

Synthesis of the Data

De Lima (1979) stressed that the estimates of loss made for each sample in the laboratory must be related to losses in the farmer's store from which the sample was taken. Information from the samples of farmers in each stratum have to be brought together to provide overall loss estimates for the district province or region and finally at the national level for the whole country. Clearly there is a need for further research on loss assessment methodology and practical methods allowing rapid appraisals to be made at the farm level are required (ECA and ICIPE 1988). Location specific studies also need to be carried out (Gahukar 1994).

REFERENCES

ADAMS, J.M. and **HARMAN, G.W.** (1977). The evaluation of losses in maize stored on a selection of small farms in Zambia with particular reference to the development of methodology. *Rep. Trop. prod. Inst.* (now TDRI, London). G 109, xi + 149.

ASHMAN, F., ELIAS, D.G., ELLISON, J.F. and **SPARTLEY, R.** (1970). Ashman-Simon infestation detector, an instrument for detecting insects within food grains. *TROP. STORED PROD. INF.* 19: 15-19.

BOXAL, R.A. and **GILLET, R.** (1984). Farm level storage losses in Eastern Nepal. *TROP. STORED PROD. INF.* 50: 20-25.

DE LIMA, C.P.F. (1973). A technical report on twenty-two grain storage projects at the subsistence farmer level in Kenya. Report of the Kenya Ministry of Agriculture, National Agriculture Laboratories. PROJ/RES/AG21, cyclostyled. 23 pp + supplementary reports. No. 1. 41 pp. No 2. 16 pp. No 3. 12 pp, No 4. 17 pp, No 5. 16 pp, No 6. 9 pp, No 7. 25 pp, No 8. 17 p, No 9. 5 pp.

DE LIMA, C.P.F. (1978). A study of the bionomics and control of *Sitophilus zeamais* (Motschulsky) and *Sitotroga cerealella* (Oliver) and associated fauna in stored maize under laboratory and field conditions in Kenya. Unpublished Ph D Thesis, University of London. 241 pp.

DE LIMA, C.P.F. (1979). The assessment of losses due to insects and rodents in maize stored for subsistence in Kenya. *TROP. STORED PROD. INF.* 38: 21-25.

ECA (United Nations Economic Commission For Africa) and ICIPE (The International Centre of Insect Physiology and Ecology) (1988). Study workshop on on-farm and post-harvest losses of cereal crops in Africa due to pests and diseases. AMREF Nairobi, Kenya - 106 pp.

EVANS, D.E. (1987). Stored Products. p 425461. *In* Burn A.J., Coaker T.H. and Jepson P.C. (ed.) 1987. Integrated Pest Management Academic Press, London. 474 pp.

FREEMAN, G.H. (1978). Surveys in relation to the stages in the post-harvest system. *TROP. STORED PROD. INF.* 36: 8-9.

GAHUKAR, R.T. (1994). Storage of food grains and insect control in developing countries. *Insect Sci. Applic.* 15: 383-400.

HALL, D.W. (1970) Handling and storage of food grains in tropical and subtropical areas. *FAO Agric. Dev. Paper* 90. 350 pp.

HARRIS, K.L. (1978). Situations where losses occur. *TROP. STORED PROD. INF.* 36: 6.

HARRIS, K.L. and **LINDBLAD, C.J.** (Compliers) (1978). Post-harvest grain loss assessment methods. *American association of Cereal Chemists.* St. Paul Minnesota. 193 pp.

HOWE, R.W. (1965). Losses caused by insects and mites in stored foods and feeding stuffs. *Nutr. Abstr. Rev.* 35: 285-293.

PARKIN, E.A. (1956). Stored product entomology (the assessment and reduction of losses caused by insects to stored food-stuffs). *Ann: Rev. Ent.* 1: 223-239.

PROCTOR, D.L. and **ROWLEY, J.Q.** (1983). The Thousand Grain Mass (TGM). A basis for better assessment of weight losses in stored grain. *TROP. STORED PROD. INF.* 45: 19-23.

SCRIMSHAW, N.S. (1978). Global use of the instruments of scholarship for the conquest of hunger. The World Hunger Programme of the United Nations University. *Food and Nutrition Bulletin*. **1**(1): 6-14.

SPENSLEY, P.C. (1982). Wither the post-harvest sector? p. 1111-130. *In* Post-harvest improvements for the eighties and nineties. *Ed* G.G.M. Schulten. Communication 72 of Department of Agriculture Research, Konikklijk Institut Voor de Tropen, Amsterdam.

TYLER, P.S. and **BOXALL, R.A.** (1984). Post harvest loss reduction programmes: a decade of activities - what consequences" *TROP. STORED PROD. INF.* 50: 4-13.

ZARKOVITCH, S. (1965). Sampling methods and causes. Rome: United Nations, Food and Agricultural Organization. 213 pp.

ZARKOVITCH, S. (1966). The quality of sample statistics. Rome: United Nations. Food and Agricultural Organization. 395 pp.

EFFECT OF MIXED PLANTING OF TARO LEAF BLIGHT RESISTANT VARIETIES ON THE DISEASE AND YIELD OF A PREFERRED SUSCEPTIBLE TARO VARIETY

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ABSTRACT

Five combinations of susceptible and resistant varieties were used to determine the best combination that had 30% susceptible and 70% resistant plants and gave significantly higher yield and lower disease incidence. The coefficient of disease index and level of susceptibility or resistance showed a linear relationship with yield. The inclusion in the cropping system of a Taro leaf blight (TLB) resistant variety does have an effect on the incidence of the disease and the yield of the susceptible variety.

Keywords: Colocasia esculenta, Phytophthora colocasiae, *Leaf blight resistance.*

INTRODUCTION

Taro leaf blight (TLB) caused by *Phytophthora colocasiae* Racib. has been considered a major constraint on taro (*Colocasia esculenta* L. Schott) production in Asia and the Pacific region. The pathogen was first described by Raciborsici in 1900 in Java (Ooka 1983). It was recorded in Papua New Guinea (PNG) by Anon in 1953 and Shaw in 1963 (Shaw 1984). The A2 mating type is found in PNG (Arentz 1986).

All the above ground parts may be affected by this disease. Its spread can be fast and incidence very high on susceptible varieties during favourable weather conditions (Trujillo 1965). At Bubia, plants were seen to be severely blighted in a few days and destroyed in less than two weeks. The disease reduced leaf number which has a direct effect on the biomass production of the crop, reducing the corm yield (Cox and Kasimani 1990). Yield reductions of more than 20% have been reported by Trujillo and Aragaki (1964) and Kay (1973), Jackson and Gollifer (1974), Cox and Kasimani (1988), Sahu *et al.* (1989) and Vasquez (1990).

The disease is controlled by spraying of fungicides, by cultural practices, and by using resistance varieties. Until resistant varieties are developed, chemical control of the disease is seen as the most effective practice. Many reports are available on effective *in vivo* and *in vitro* control of the pathogen by fungicides, although effective fungicides are expensive and pose health risks to farmers when not handled properly. In view of these problems a safer, inexpensive and appropriate control strategy is needed.

From our observation in farmer fields, the incidence and spread of TLB on susceptible varieties under conditions of mixed cropping is lower than under monocropping. The other crop species grown together with taro act as a buffer or barrier by restricting the movement of *P. colocasiae* inoculum in the field. When a resistant taro variety is grown in a mixture with a susceptible variety the TLB resistant variety may act as the barrier crop. Higher yields of susceptible varieties were reported by Paiki (1996) under mixed cropping situations in Biak Island of Irian Jaya, Indonesia. No accurate estimates on yields of susceptible varieties under mixed cropping are available in PNG.

This study was conducted to determine the best combination(s) of a susceptible taro variety and TLB resistant varieties that will significantly reduce the disease incidence and lead to higher yields. This combination could be adopted by farmers who wish to grow their preferred susceptible variety without major TLB control activities. The TLB resistant taro varieties (Ph 15, Ph 19 and Ph 21) used in this

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study were identified by Kokoa and Darie (pers.comm).

MATERIALS AND METHOD

The trial was conducted within the months of May and November in 1995 and repeated at the same time in 1996 at the Bubia Agriculture Research Centre, outside Lae, in the Morobe Province of PNG. Both trials were conducted on different sites closer to each other on a block of land that had high percentage of gravel.

The land was ploughed with a disc plough and then disc harrowed just before planting on flat land. The susceptible variety Numkovi, normally produces one large corm and 6 - 8 suckers, depending on the growing conditions. The three resistant varieties (Ph 15. Ph 19 and Ph 21) are semi-wild and normally produce more than 10 suckers. Their corms are not edible as they weigh less than 100 g and usually associated with high concentration of oxalate. Setts of about the same size (25 - 30 cm high and 3 - 4 cm base diameter) were selected and used for planting. The setts consisted of the top part of the corm and the bases of petioles.

In both experiments plant spacing was 0.8 x 1.0 m and each plot consisted eight rows of ten plants. Five combinations of the susceptible and resistant varieties were used as treatments with the resistant plants being interspaced among the susceptible plants as much as possible (Table 1). Blocks were separated by paths, 2 m wide. The treatments were arranged in a randomized complete block design (RCBD) and replicated four times.

Infection of *P. colocasiae* was by naturally occurring inoculum. From previous observations TLB disease pressure was very high on taro during July and August which is the wettest months of the year in the area. Thus taro planted in May reached peak leaf production at this stage, providing optimal time for TLB assessment. Assessment of the disease incidence and severity on fully expanded leaves of 10 plants of the susceptible variety per plot was done eight weeks after planting and continued weekly for three months and was discontinued two months before harvest. Disease incidence was measured as the percent of plants infected by TLB. The disease severity rating ranged from 0 to 6, with 0 being no infection and 6 being most severe disease (91 - 100% blighted leaf area) using the field assessment key of Gollifer and Brown (1974). The Coefficient of Disease Index (CODEX) was calculated using the following formula of Datar and Mayee (1981).

$$\text{CODEX} = \frac{\text{PDI X PDS}}{100}$$

PDI = Percent Disease Incidence = the number of affected compared to the total number of leaves.

PDI = Percent Disease Severity = the relative extent of disease on affected leaves based on the above assessment scale (0-6).

***Table 1.* Treatment code and combination of TLB susceptible and resistant varieties planted in each plot.**

Treatment code	Number of susceptible plants per plot (var. Numkovi)	Number of resistant plants per plot (vars Ph 15, Ph 19, Ph 21)	Total plants in plot
A	80(100)	0(0)	80
B	48(60)	32(40)	80
C	40(50)	40(50)	80
D	32(40)	48(60)	80
E	24(30)	56(70)	80

Note: Figures in brackets are percentages

Figure 1. **Corm yield (g/plant) of the susceptible variety against ratio of resistant/susceptible plants (1995, 1996).**

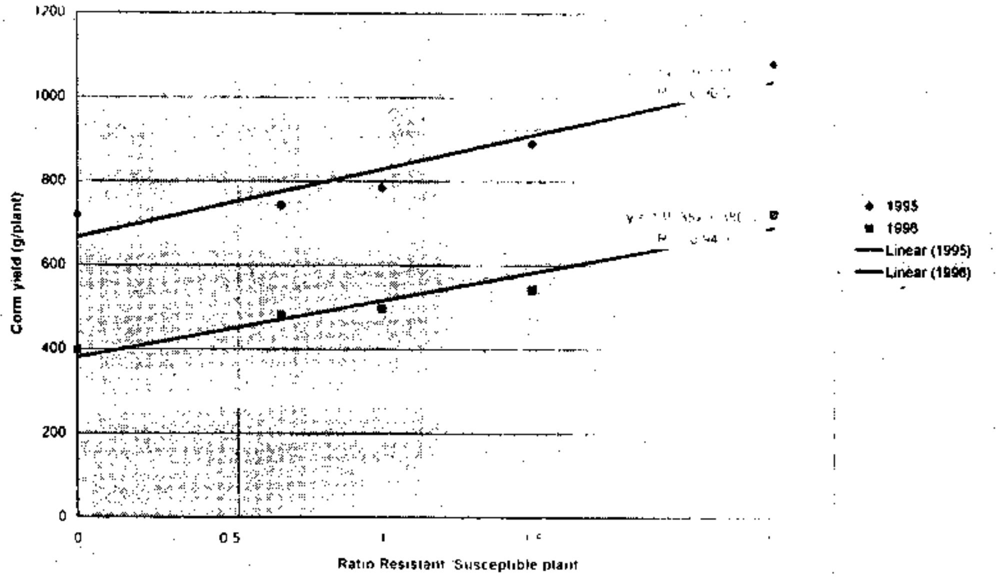
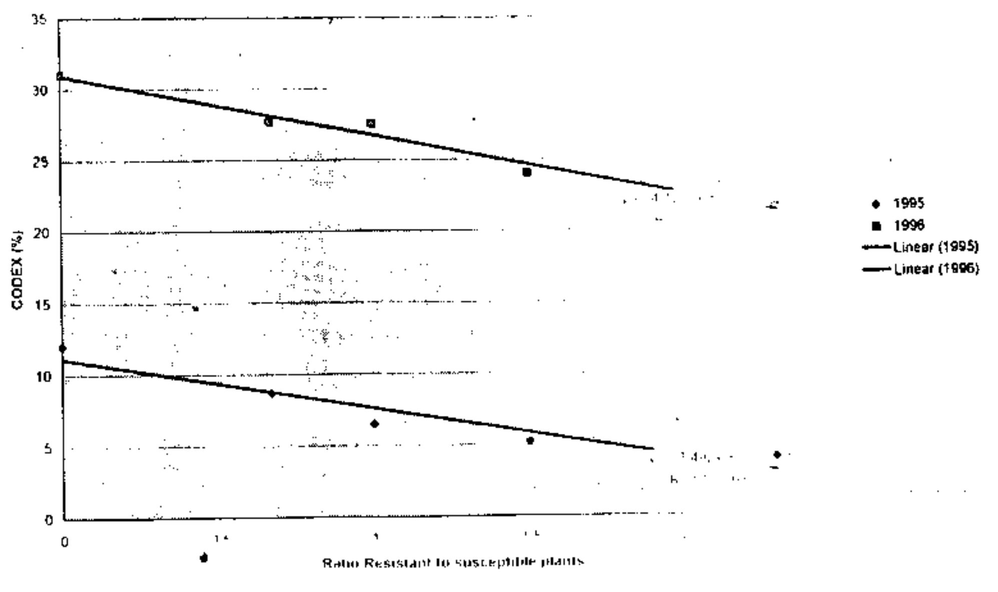


Figure 2. **CODEX (%) of the susceptible variety against the ratio of resistant/susceptible plants (1995, 1996).**



At harvest the corms and suckers of the susceptible variety were carefully lifted with a digging stick. The main corms were weighed after the tops were removed. Sample plants were used to test the relationship between CODEX, level of resistance or susceptibility and yield and was analysed using linear regression and simple correlation analysis.

RESULTS

The yield and CODEX of the five treatments is shown in table 2. There was a positive correlation (r = 0.95 for 1995 and r = 0.97 for 1996) between corm yield of the susceptible variety and the proportion of resistant plants in each plot, with maximum yield in the susceptible variety occurring when the ratio of susceptible plants in the plot was 30/70 (Figure 1). The increase in yield in the susceptible variety was associated with a decrease in disease incidence, disease severity and CODEX in the susceptible variety. Generally, yield recorded for the susceptible variety was higher in 1995 than in 1996 (Table 2).

Simple linear regression analysis showed a positive correlation between corm yield and the ratio of resistant to susceptible plants and a negative correlation on CODEX in both years (see Figure 1). The relationship between CODEX and ratio of Resistant/Susceptible plants showed a negative correlation (see Figure 2).

DISCUSSION

Treatment E which had 24 susceptible plants grown among 56 resistant plants escaped severe infestation of TLB and had the highest corm yield in the susceptible variety. It is seen that the yield of the susceptible variety has an indirect relationship with CODEX. The resistant plants, which mimick other crop plants, prevented *P. colocasiae* inoculum from spreading rapidly between susceptible plants. Apparently resistant taro plants have the same canopy height as the susceptible plants and therefore are effective barriers to *Phytophthora colocasiae* spread. Higher yield and lower disease incidence on a susceptible taro variety were observed under mixed cropping on Biak Island (Paiki 1996).

It is apparent that incorporation of a TLB resistant variety does have an effect on the disease incidence and yield of the susceptible variety. Although treatment E gave the highest yield of the susceptible variety, 70% of the plants in the plot were the lower yielding resistant variety. This tends to decrease

Table 2. **Effect of different ratios of susceptible to resistant taro varieties on corm yield, disease incidence, disease severity and CODEX in the susceptible variety measured in two field trials (1995, 1996).**

Treatment	Ratio suscep./ resist. plants	Mean corm yield (g/plant) of suscep. var. 1995	Mean corm yield (g/plant) of suscep. var. 1996	Disease incidence (%) 1995	Disease incidence (%) 1996	Disease severity* (%) 1995	Disease severity* (%) 1996	CODEX 1995	CODEX1996
A	10/0	721	397.7	30.25	57.8	39.68	53.6	12	31
B	60/40	742.2	480.5	21.49	56.2	40.48	49.29	8.7	27.7
C	50/50	784.6	497.1	15.42	53.58	42.14	51.32	6.5	27.5
D	40/60	890.6	542.3	13.79	49.74	37.71	48.25	5.2	24
E	30/70	1081.4	723.1	11.92	45.71	33.56	46.97	4.0	21.5

* Disease severity rating on a scale of 0 (no disease) to 6 (91 - 100% leaf area affected)

the total yield. If the resistant variety had useful corms, this would increase the overall yield of the plot. Local farmers will benefit more when desired resistant taro plants are developed and made available which they could use together with preferred susceptible local varieties.

REFERENCES

ARENTZ, F. (1986). A Key to *Phytophthora* species found in Papua New Guinea with notes on the distribution and morphology. *PNG Journal of Agriculture, Forestry & Fisheries.* 34(1-4): 9-19.

COX, P.G. and **C.K. KASIMANI** (1988). Control of taro leaf blight using metalayxl. *Tropical Pest Management* 34 (1): 81-84.

COX, P.G. and **C.K. KASIMANI** (1990). Effect of taro leaf blight on leaf number. *PNG Journal of Agriculture, Forestry and Fisheries.* 35 (Nos 1-4): 43-48.

DATAR, V.V. and **C.D. MAYEE** (1981). Epidemiology of early blight of tomato caused by *Alternaria solani. Indian Phytopathology* 35(4): 434-437.

GOLLIFER, D.E. and **BROWN, J.F.** (1974). *Phytophthora* leaf blight of *Colocasiae esculenta* in the British Solomon Islands. *PNG Agricultural Journal 25(123): 6-11.*

JACKSON, G.V.H. and **GOLLIFER, D.E.** (1975). Diseases and Pest problems of taro (*Colocasia esculenta*) in the British Solomon Islands. *Pest Articles and News Summaries.* 21(1): 45-53.

KAY, D.E. (1973). Root Crops. TPI Crop and Product Digest Tropical Product Institute Publication. London, UK. pp. 168-179.

OOKA, J.J. (1983). Taro Diseases. pp. 236-257 in Jay - Kay Wang & Hign S. (eds). Taro a review of *Colocasia esculenta* and its potential. University of Hawaii Press Honululu.

PAIKI, F.R. (1996). Symptoms of taro leaf blight disease (*Phytophthora colocasiae*) and relationship with yield components in Biak, Irian Jaya. *Science in New Guinea.* 21(3): 153-157.

SAHU, M.P., P. SINGH and **J.R.P. SINGH** (1989). Control of blight disease of taro. *Indian Farming*, p: 22-29.

SHAW, D.E. (1984. Micro-organisms in Papua New Guinea. DPI, PORT MORESBY, RESEARCH BULLETIN. NO. 38 PP. 344.

TRUJILLO, E.E. and **ARAGAKI, M.** (1964). Taro blight and its control. *Hawaii Farm Sci.* 13: 11-13.

TRUJILLO, E.E. (1965). The effect of humidity and temperature on *Phytophthora* blight of taro. *Phytopathology.* 55: 183-188.

VASQUEZ, E.A. (1990). Yield loss in taro due to *Phytophthora* leaf blight. *Journal of Root Crops.* 16(1): 48-50.

URBAN DEMAND FOR FOOD, BEVERAGES, BETELNUT AND TOBACCO IN PAPUA NEW GUINEA

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ABSTRACT

Data from household surveys conducted between 1985 and 1990 were used in a regression model to estimate the impact that changes in household incomes have on the demand for each of 36 major foods, beverages, betelnut and tobacco within urban areas of Papua New Guinea. Locally produced crops that should be in high demand in future, if urban incomes rise, include betelnut, fresh vegetables, sweet potato, and fresh fruits. All else the same, the higher value of future demand for these crops may justify extra research spending, as opposed to spending on crops whose demand will not respond strongly to rising urban incomes.

***Keywords**: Demand, income elasticity, Papua New Guinea, research priorities, urban consumers.*

INTRODUCTION

In recent years Papua New Guinea (PNG) agriculturalists have begun to pay more attention to market opportunities for supplying food to the local market. This switch in attention has been caused both by low world prices for the traditional export crops and local market growth, especially within urban areas. Although precise data on the value of local food production for the urban market are unavailable, informed estimates suggest that this industry rivals the main tree crop industries as an income source for rural producers (Shaw 1985).

For agricultural planners to allocate scarce research and extension funds amongst the many foods that can be grown for the urban market, information about the demand prospects for those foods is required. In particular, it would be helpful to identify the crops that will be in high local demand in the future, so that farmers can be encouraged to produce these crops. Examining the demand patterns of urban households can help agricultural planners identify market opportunities by showing (i) which foods have large existing markets, and (ii) which foods will be most heavily demanded in future as urban incomes change.

There are several examples of demand analysis being used to inform agricultural research priorities in the international literature. For example, Sarma and Gandhi (1990) used demand analysis to forecast future consumption patterns of food grains in India, under alternative scenarios of economic growth and development. Pinstrup-Andersen *et al.* (1976) used data on demand patterns to see how reallocating the agricultural research budget would affect the nutritional status of the urban poor in Colombia. However, these types of analyses have not previously been possible in PNG because of the lack of information on consumer demand patterns for foods and agricultural crops.

Various concepts can be used to measure existing market demand. Two of these are:

1. The average share of the household budget spent on an item.
2. The proportion of households who consume the item.

Items with a large average share in household budgets will generate more revenue for producers because of the large expenditures that households make. However, the average budget share can be

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inflated when a minority of the population have an intense demand for an item, while the remaining households do not consume it at all. In this case, demand may be vulnerable to what happens to this small group of consumers. Foods consumed heavily by expatriate households would be a relevant example for PNG. Therefore, it is valuable to know what proportion of households consume a particular food, so that the stability of its demand can be assessed.

Two economic concepts for predicting future market demand under changing incomes are:

1. The income elasticity of demand.
2. The marginal budget share.

The income elasticity of demand measures the percentage by which the quantity demanded of an item increases following a one percent increase in household income. When the demand increases by more than one percent, an item is known as a "luxury good", and when the demand increases by between zero and one percent, it is a "normal good", and when the demand goes down as incomes rise, it is an "inferior good" (Sadoulet and de Janvry 1995). The marginal budget share measures how a household allocates any additions to its budget, in contrast to the existing division of the budget. For example, if a household's income rose by K100 per year, the marginal budget share for a particular food shows how many Kina or toea from that K100 would be spent on the food. Hence, the marginal budget share is a good measure of the value of future demand.

The paper provides estimates for PNG urban areas of these four different measures of market demand for 36 major foods, beverages, betelnut and tobacco. The implications of these demand estimates for agricultural research priorities are then discussed.

METHODS AND DATA SOURCES

There are two important requirements for the functional forms that are used to estimate income elasticities of food demand. They should be 'flexible', by allowing income elasticities to differ between rich and poor households, because the usual pattern is for income elasticities of food demand to fall as income rises (Timmer *et al.* 1983). The functional form also should be able to be estimated even when a household has zero consumption of particular foods; otherwise those households have to be dropped from the sample, which can cause sample selection bias (Deaton 1989).

The "share-log" function form, where the budget share of the *i*th food (w_i) regressed on the logarithm of household income (x) meets these requirements. In addition to income, other variables affecting the budget share of particular foods need to be included in the model. These variables include the size of the household, its age, gender and ethnic composition, and dummy variable for the town the household is located in. This gives the following regression model:

$$w_i = \alpha_i + \beta_i \ln x + \Theta_{ij} z_j + U_i \qquad (1)$$

where Z_j is the vector of control variables, α_i, β_i and Θ_{ij} are parameters to be estimated, and U_i is a random error term. The coefficient β_i gives the rate at which the budget share for the *i*th food changes as the logarithm of income changes, $\partial w_i/\partial \ln x$, and this can be transformed into the elasticity of the budget share with respect to income, $\partial w_i/\partial \ln x$ by dividing by w_i (because $\partial \ln w_i = \partial w_i/w_i$). The fact that the budget share is the product of price, p_i and quality, q_i divided by income, x (and hence $\ln w_i = \ln p_i + \ln q_i - \ln x$) allows the income elasticity of the quantity demanded of the *i*th food, ε_i to be derived from the formula:

$$\varepsilon_i = \frac{\beta_i}{w_i} + 1 \qquad (2)$$

Because budget shares vary by household, the income elasticity calculated with equation (2) also varies. For example, the estimated rice demand of rich households can be less income elastic than the rice demand of poor households, because rice has a bigger budget share for poor household. This is consistent with the usually occurring empirical pattern (Timmer *et al.* 1983).

The marginal budget share was estimated by multiplying the income elasticity of demand for the food by the average share that food *i* has in household budgets. These marginal budget shares must obey the "adding-up" condition that they sum to one. In other words, the value of all extra demands, following a rise in income, must exactly equal the value of the extra income (Deaton and Muellbauer 1980). This condition provides a cross-check on the plausibility of the estimates.

Data

Household income and expenditure data were obtained from urban household surveys conducted by the National Statistical Office between 1985 and 1990[2]. These surveys were carried out in nine PNG urban areas: Port Moresby, Goroka, Wewak, Ambunti, Kieta, Arawa, Panguna, Lae, and Rabaul. In all, over 1400 households were surveyed, and complete data were available for 1095 households (Gibson 1995). This is the largest household expenditure survey ever carried in PNG.

The survey collected information on purchases, gifts, production, and sales of food within a two week period, as well as changes in household food stocks. From these components, the value of each household's consumption of 36 food items was estimated. Although the survey collected information on household wage and business income, the actual income variable used in this study is total household expenditure. Total expenditure is less affected by transitory components (e.g. extra overtime pay) and is more closely related to the concept of permanent income, which is what economists believe influences demand (Deaton and Muellbauer 1980). The total expenditure variable includes the value of consumption of all goods and services, including imputed rent. Households were surveyed at different points in time so the effects of inflation were accounted for by using a price index calculated for each town. Full details of the construction of variables and the quality control procedures that the data were subjected to are contained in Gibson (1995).

RESULTS AND DISCUSSION

The four different measures of market demand are reported in Table 1 for 36 foods, beverages, betelnut and tobacco. Measures for the aggregate non-food group (containing all other goods and services) are provided for comparison. The items with the largest average share of household budgets are rice, alcohol, tinned meat, tobacco products, tinned fish, poultry, bread and biscuits. These items make up over one quarter of the total budget for the average household.

The items that are consumed most commonly by households are rice, bread and biscuits, tinned fish, soft drinks, and fresh vegetables. At least 90 percent of households consumed these within the two week period. Hence it is likely that these items have very stable demand. In contrast, alcohol has a high average share of the budget but only 40 percent of the households consumed alcohol. The food item consumed by the smallest proportion of households was pork, with less than 10 percent of households consuming within the two week period. Pork is sometimes regarded as the national meat so this low consumption seems surprising but it may reflect the high price of pork in urban areas and the fact that pork is consumed during celebrations and ceremonial events rather than as an everyday meal.

The income elasticities for demand, and associated standard errors, are reported in the third and fourth column of Table 1. These were estimated using Ordinary Least Squares, with heteroscedastically consistent standard errors being calculated (White 1980). There were only three foods whose income elasticities were not statistically significant (cassava, dried and other fish, and other roots and tubers). The luxury goods, with income elasticities greater than one, were alcohol, eggs, English potatoes, poultry, beef and veal, and fresh fruit (except bananas). For example, if the income of an urban household rose by one percent, its demand for fresh fruit should rise by 1.04 percent (±0.096).

No inferior goods were identified but some important foods had income elasticities that were fairly low, e.g., tinned fish (0.15±0.055); rice (0.30±0.048); and sugar (0.33±0.076). Rising urban incomes will not lead to big percentage increases in the demand for these three basic foods. In contrast, most of the foods produced by rural households and sold in urban areas had income elasticities in the 0.50 to 0.75 range, thus sales of these items should benefit strongly from rising urban incomes.

The final column of Table 1 gives the marginal budget share for each item. This is the amount of extra spending on an item if the household had an extra K100 income available. The "adding-up" condition that the sum of extra expenditures exactly equals K100 holds, and confirms the plausibility of the results.

The marginal budget share gives the best overall

***Table 1.* Demand characteristics for foods, beverages, betelnut and tobacco in urban areas of Papua New Guinea (ranked by marginal shares of total expenditure).**

	Average share of total expenditure %	Households who consume%	Income elasticity of demand*	Marginal share of total expenditure %
Alcohol	4.83	40.3	1.48±0.087	7.15
Poultry	2.89	61.5	1.23±0.060	3.54
Takeaways and Meals	2.74	81.8	0.93±0.078	2.55
Tinned Meat	3.11	84.6	0.78±0.048	2.42
Soft Drinks	2.72	90.9	0.87±0.050	2.37
Bread and Biscuits	2.78	93.5	0.75±0.044	2.09
Tobacco	3.09	70.6	0.61±0.052	1.87
Rice	5.62	96.2	0.30±0.048	1.67
Lamb and Mutton	1.66	48.0	0.84±0.082	1.40
Betelnut	2.32	75.1	0.57±0.055	1.32
Fresh/Frozen Fish	1.36	41.1	0.93±0.114	1.26
Fresh Vegetables	1.83	90.1	0.66±0.056	1.21
Other Dairy Fats & Oils	1.26	78.2	0.95±0.056	1.20
Sweet Potatoes	2.06	72.9	0.54±0.080	1.11
Processed Food n.e.s.	0.94	59.9	0.83±0.107	0.78
Bananas	1.29	70.7	0.56±0.083	0.72
Other Fresh Fruit	0.63	57.7	0.04±0.096	0.65
Sugar	1.78	89.1	0.33±0.076	0.60
Beef and Veal	0.50	20.0	1.18±0.144	0.58
Milk (all forms)	0.67	62.3	0.87±0.072	0.58
Coffee, Tea, Hot Beverages	0.85	67.1	0.64±0.070	0.55
Other Cereal Products	0.58	61.8	0.93±0.076	0.54
Spreads & Sugared Foods	0.48	66.4	0.97±0.062	0.47
Processed Meats n.e.s.	0.54	24.7	0.82±0.240	0.44
Tinned Fish	3.04	92.0	0.15±0.055	0.44
Flour	0.66	45.0	0.55±0.097	0.36
Taro	0.69	36.7	0.52±0.117	0.36
Pork	0.31	9.8	0.99±0.297	0.30
Coconuts	0.36	54.1	0.74±0.115	0.27
Eggs	0.15	14.1	1.39±0.140	0.21
Other Nuts and Seeds	0.29	51.8	0.63±0.153	0.18
Sago	0.32	13.9	0.50±0.217	0.16
English Potatoes	0.06	10.0	1.26±0.148	0.08
Cassava	0.20	17.4	0.22±0.285	0.04
Dried and Other Fish	0.19	13.4	0.20±0.224	0.04
Other Roots and Tubers	0.28	12.0	0.03±0.329	0.01
Non-Food	46.92	100.0	1.29±0.018	60.45

n e s = not elsewhere specific.

* Estimated from a regrssion model with 1095 observations and 1077 degrees of freedom. Standard errors are heteroscedastically consistent.

[2] I am grateful to the National Statistical Office for allowing access to these data.

estimate of the future value of a crop because it combines the income elasticity with a measure of the item's monetary importance. For example, English potatoes are a luxury food (e=1.26±0.148), which farmers should grow because their demand will rise with increases in urban incomes. However, English potato is such a minor budget item, a household with an extra K100 to spend would allocate only eight toea to extra purchases of this item. Even though sweet potato has a lower income elasticity, the same household would allocate K1.11 to extra sweet potato purchases. Hence, the research payoff would be greater, *ceteris paribus*, from sweet potato than from English potato.

The items in Table 1 are ranked by the value of their marginal budget share (the final column). The items that would gain the biggest share of increased spending by urban consumers include alcohol, poultry, takeaway meals, tinned meat, soft drinks, and bread and biscuits. Amongst the items produced by rural households and sold in urban markets, betelnut, fresh vegetables, and sweet potato would see the biggest increase in demand if urban household incomes increased.

The marginal budget share for alcohol is twice as large as for any other item and this may be a source of social concern, because of the problems that excessive alcohol consumption can create. Several of the control variables in the vector z_j of equation (1) were important influences on the demand for alcohol, especially the proportion of the household that was male and aged between 15 and 50 years, and whether the household head was from the Highlands. All else the same, the budget share for alcohol would be two percentage points higher in a household where men between the age of 15 and 50 comprised one-half of the dwellers, compared with a household where they were only one-fifth of the dwellers.

DISCUSSION

This ordering of food crops may be helpful in guiding research priorities, because it has been suggested that some crops have gained more research attention that others of greater economic importance (Shaw 1985). The publication of the elasticity and budget share estimates provides one economic criterion for ranking food crop research, although other factors, such as compatibility with existing farming systems and environmental suitability of the crop play a role as well.

One food crop that has received considerable research attention over many years in PNG is rice (Shaw 1985; Fereday 1993). The results in Table 1 show that the marginal budget share for rice is lower than the marginal budget share for foods that are produced from wheat, which is the other major cereal import. Hence, agricultural research that helps local farmers to increase their share of the inputs used in the production of bread and biscuits may give a higher payoff than research into the local production of rice. One example of research that might help local farmers increase their share of the inputs used in bread and biscuit manufacture is the question of blending sweet potato flour with wheat flour (Berrios 1992).

The results also help to disprove the hypothesis that imported cereals are seen by local households as superior foods to the traditional starchy staples (Kannapiran 1993). If this hypothesis were true, the income elasticity of demand for cereals would be greater than for the local root crops, implying that consumers switch to cereals as urban incomes rise. Although bread and biscuits have a greater income elasticity of demand (0.75±0.044) than the major root crops, this is not the case for rice (0.30±0.048), which is the cereal with the largest budget share. To further compare the income elasticities of cereals versus local starchy staples, foods were grouped into (i) cereals, (ii) meats and fish, (iii) fruits, vegetables and nuts, and (iv) root crops and the share-weighted income elasticities of demand for each group were calculated (Table 2).

Table 2.* Income elasticities of demand for major food groups

Food group	Share-weighted income elasticity of demand
Cereals	0.48
Meats, poultry and fish	0.77
Fruits, vegetables and nuts	0.67
Root crops	0.49

* Derived from data in Table 1.

The income elasticity of demand for the cereals group is 0.48, indicating a ten percent increase in urban household income would cause cereals demand to rise by 4.8 percent. The income elasticity of demand for the root crops is slightly higher, at 0.49, so demand for the root crops benefits slightly more from rising urban incomes than does demand for the cereals. Other locally produced fruits, vegetables, and nuts also have demands that rise by more than those of cereals when urban incomes rise. Thus, rising urban incomes do not signal a dietary transition away from locally produced foods. Instead, the demand profile for food items associated with rising urban incomes indicates an important market opportunity for rural producers to supply food into the local urban market.

CONCLUSIONS

Income elasticities of demand and marginal budget shares were estimated for 36 food items in urban Papua New Guinea markets. The ranking of items according to income elasticities and marginal budget shares gives one economic criteria for the setting of research and extension priorities. Locally produced crops that should be in high demand in future, if urban incomes rise, include betelnut, fresh vegetables, sweet potato, and fresh fruits. All else the same, the higher future demand for these crops may justify increased research spending, as opposed to research spending on crops whose demand will not respond strongly to rising urban incomes. The results also suggest that urban demand for wheat products will eventually exceed demand for rice, if urban incomes rise, so research into the replacement of imported cereals with local crops may give a higher payoff if it is directed at finding substitutes for wheat flour.

REFERENCES

BERRIOS, D. (1992). Sweet potato bread in Burundi: An update *CIP Circular.* 19(1): 9.

DEATON, A. (1989). Household survey data and pricing policies in developing countries. *The World Bank Economic Review.* 3(2): 183-210.

DEATON, A. and **MUELLBAUER, J.** (1980). *Economics and Consumer Behavior.* Cambridge University Press, New York.

FEREDAY, N. (1993). Rice production in Papua New Guinea: The experiences of the Bereina and Maprik rice projects. *Policy Working Paper No. 4,* Programming, Planning and Budgeting Division, Department of Agriculture and Livestock, Konedobu, Papua New Guinea.

GIBSON, J. (1995). *Food Consumption and Food Policy in Papua New Guinea.* Institute of National Affairs, Port Moresby.

KANNAPIRAN, C. (1993). Food security: Rice production policy in Papua New Guinea. *Policy Discussion Paper,* Department of Agriculture and Livestock, Papua New Guinea.

PINSTRUP-ANDERSEN, P., DE LONDONO, N. and **HOOVER, E.** (1976). The impact of increasing food supply on human nutrition: implications for commodity priorities in agricultural research and policy. *American Journal of Agricultural Economics.* 58(1): 131-142.

SADOULET, E. and **DE JANVRY, A.** (1995). *Quantitative Development Policy Analysis.* John Hopkins University Press, Baltimore.

SARMA, J. and **GANDHI, V.** (1990). *Production and Consumption of Food grains in India: Implications of Accelerated Economic Growth and Poverty Alleviation.* International Food Policy Research Institute. Washington, D.C.

SHAW, B. (1985). *Agriculture in the Papua New Guinea Economy.* Institute of National Affairs, Port Moresby.

TIMMER, P., FALCON, W. and **PEARSON, S.** (1983). *Food Policy Analysis.* John Hopkins University Press, Baltimore.

WHITE, H. (1980). A heteroscedastically-consistent covariance matrix and a direct test for heteroscedasticity *Econometrica* 48(4): 817-838.

FIELD STUDIES OF THE DEPTH DISTRIBUTION OF RECRUIT-SIZED PRAWNS, *PENAEUS MERGUIENSIS* AND *P. MONODON*, IN THE GULF OF PAPUA: IMPLICATIONS FOR MANAGEMENT

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ABSTRACT

During 25th March to 11th April 1996, transects and commercial operations covering the fishing grounds, from 8 to 30 m depth indicated that catch per unit of fishing effort (CPUE) of recruit-sized banana prawns was highest in 8 to 12 m depth. Relative abundance decreased with increasing depth ($p = 0.031$, single-tail test for negative correlation). Similarly, the CPUE of recruit-sized black tiger prawns decreased with depth from 8 to 30 m ($p = 0.046$). The percentage catch (by weight) of recruit-sized banana prawns and black-tiger prawns were similarly each negatively correlated with depth ($p = 0.018$ and $p = 0.012$ respectively). The permanent closure of the 3-mile zone, i.e. trawl-able areas extending seawards 3 miles from the mean low-water mark, to industrial trawling, is supported by these findings. Extension of the eastern boundary of the area closure for 1997 (and subsequent years) eastward from Cape Cupola to the fishing grounds as far south-east as Iokea village is recommended in order to include and protect the mangrove nursery areas and adjacent offshore recruitment areas located in 4 to 8 m depth in Freshwater Bay (Lesi Creek, Lakekamu Estuary and Mopu inlet) during the principal recruitment season, January through April. There is increasing interest from resource owners to develop the nearshore prawn resources within the 3-mile zone in a sustainable manner, by opening the 3-mile zone to small-scale, beam trawling, i.e. a limited number of relatively small beam trawls towed by dory. The nets used should be of relatively large mesh sizes in the net body and cod-end, because the results of the present study indicate that, particularly during January through June each year, a large proportion of the catch in the 3-mile zone will probably be new recruits which have not realised their growth potential. Studies to assess the impact of beam trawls should ideally be conducted prior to allowing this kind of fishery to develop. From the transect studies (25th March - 2nd April) alone, the average CPUE (the recruitment index) of banana prawns was 8.23 +/- SE 2.30 kg of tails/ trawl-hour. Similarly, for black tiger prawns the recruitment index was 1.53 +/- SE 0.34 kg (head-on)/trawl-hour. The average depth trawled during the transect studies was 17.7 m (SD 6.39 m). Similar field transect studies to determine comparable recruitment indices in future years could be undertaken.

Keywords: *Penaeid-prawns, recruitment-index, -monitoring, depth-distribution, Gulf-of-Papua.*

INTRODUCTION

The fishery for banana (*Penaeus merguiensis*), black tiger (*P. monodon*) and endeavour (*Metapenaeus* spp) prawns in the Gulf of Papua is currently the largest domestic fishery in Papua New Guinea. The catch consists chiefly of *P. merguiensis* (over 50% by weight), and secondly of *P. monodon* with lesser amounts of *Metapenaed* Prawns. Approximately 700-1000 t of prawn tails per year are caught by 13-14 otter trawl vessels, either quad-rigged or double-rigged and of not more than 28 m overall length. Only companies with more than 50% ownership by PNG citizens are permitted in the fishery. A 3-mile conservation (prohibited trawl) zone was estimated in the 1980s to protect young prawns in the inshore

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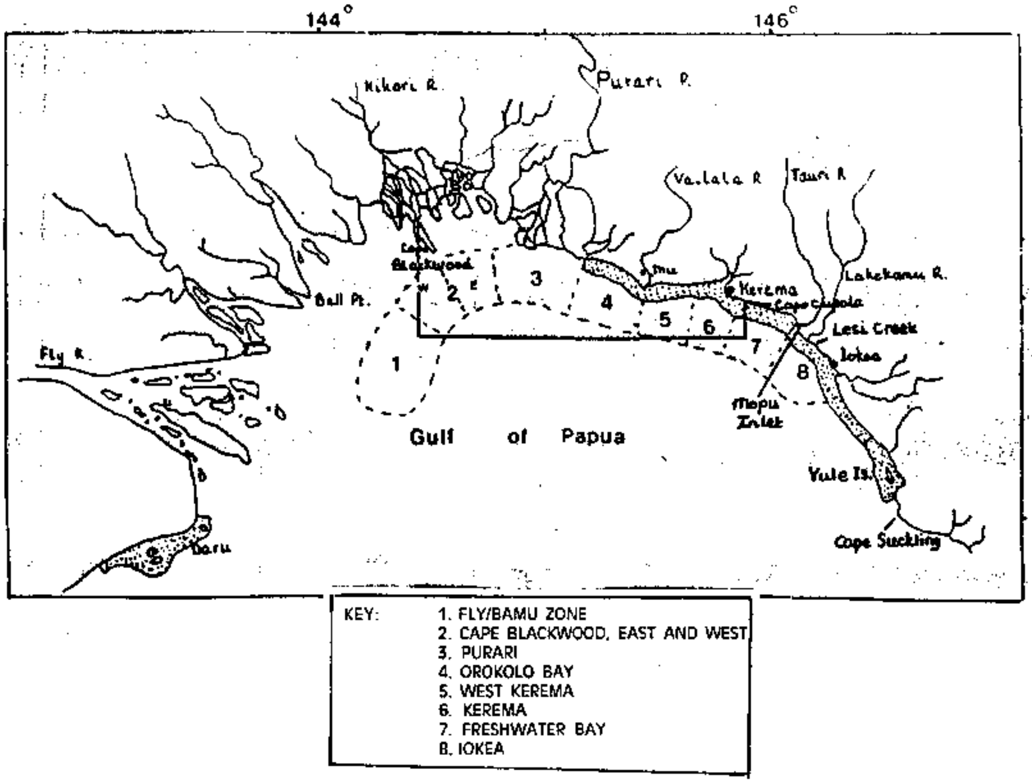
Figure 1. **Gulf of Papua prawn fishing zones, capes, large villagesand towns, and the 3-mile zone (stippled).**



areas from trawling.

The principal risk and concern in recent years has been growth of over-fishing with trawler captains targeting new recruits as they enter the fishery in the northern areas adjacent to extensive nursery areas for *P. merguiensis* and *P. monodon* (the mangrove swamps of the Rivers Fly, Kikori and Purari, and as they enter the fishery in the south-eastern areas adjacent to other similar nursery areas of lesser extent associated with the Vailala River mouth, Kerema Bay and Inlet and the Lakekamu Estuary/ Mopu Inlet). There has also been suspected growth over-fishing from illegal fishing of the 3-mile conservation zone.

Management in 1995 and 1996 has featured (i) a 6-week closed season 1st February to 15th March (1995) (Opnai and Evans 1994) and (ii) a 14 week area closure of the fishing zones East Cape Blackwood, Purari, Orokolo Bay, West Kerema and Kerema Bay (which are the principal recruitment windows), from 1st January to 15th April 1996 (Evans *et al.* 1995; Evans *et al.* 1995 a; Kare *et al.* 1995). Prawn operators have generally respected and understood the area closure measure and there have been only minor incursions into areas near the boundary. However, the provision of surveillance in the prawn industry is insufficient because of a shortage of manpower. The trawl grounds are large and distant from the National Capital District, surrounding Port Moresby, which lies off map to the south-east (Figure 1). In recent years, 1993-96, there have been many reported, and a few prosecuted cases, of illegal trawling within the established 3-mile conservation zone (Figure 1). These included citizens' arrests and vessel seizures by resource owners, sightings by airline pilots with navigational fixes and a boarding by staff of the Research Branch of the National Fisheries Authority.

The Lakekamu Estuary, the Kikori River Delta, and the small channels of the lower Purari River and of the Vailala river mouth are the major nursery areas for banana prawns that migrate and recruit into the grounds of ten south-eastern area (Frusher 1980; Gwyther 1980 a). The Fly River Estuary is the principal nursery area for juveniles that recruit into the offshore fishing areas associated with the Fly River (Ursula Kolkolo), (PNG Department of Fisheries and Marine Resources, pers. comm. 1995).

Gwyther (1980 a) found that the percentage of female prawns in the Gulf of Papua having ripe or ripening ovaries is greatest in the months of March-April and July-November. Catch per unit effort (CPUE) of commercial grades of *P. merguiensis* showed a progression through the year according to mean monthly data 1978-87 (Polovina and Opnai 1989). From this, Polovina and Opnai inferred that postlarval *P. merguiensis* settle in the estuaries mainly during November and recruit to the fishery in February.

Earlier studies of the distribution of new prawn fishery recruits from January to August (Gwyther 1980 b) suggested a migration of new recruits from the area around C. Blackwood to Kerema Bay. Recruit-sized prawns occur in temporal-spatial sequence, from C. Blackwood in January to Kerema Bay in June (Frusher 1980; Gwyther 1980 b).

Based upon the results of these studies, a recruitment monitoring field study was carried out during the 1995 closure of the Gulf of Papua fishery (1st February to 15th March) (Evans *et al.* 1995 b). The East Cape Blackwood, Purari, Fly/Bamu, West Cape Blackwood and Kerema Bay zones (ranked in that order in CPUE of 41-50+51-60 grade prawns caught) were found to be the chief recruitment areas of *P. merguiensis* during this period in 1995, which was in an El Nino with low rainfall (Evans *et al.* 1995 b). Evans and Kare (1996) found evidence that the beginning of the chief recruitment pulse to the northern fishing zones near Cape Blackwood coincides with the onset of monsoon rains in the upper Kikori Basin, and occurs on an average during mid-February to mid March.

The primary objective of the present study was to document the depth distribution of recruit-sized banana prawns (*Penaeus merguiensis*) and black tiger prawns *(P. monodon)* by depth, in a year of reasonable rainfall, in order to determine if the populations of these species in inshore areas (i.e. the 3-mile prohibited trawl zone) would be endangered by illegal fishing inside the 3-mile limit.

The second objective of the study was to estimate a mean catch per unit effort (CPUE) for recruit-sized banana prawns and for black tiger prawns by transect surveys, in the entire fishing grounds during the period of peak recruitment to the northern fishing zones (approximately late March to early April: Evans and Kare 1996).

Such a survey could be undertaken annually to provide data on the approximate level of fishery recruitment of *Penaeus merguiensis* and *P. monodon.*

MATERIALS AND METHOD

The study consisted of two parts: phase 1, systematic transect studies in all the fishing zones, from 25th March to 2nd April, 1996 and phase 2, normal commercial operations, from 2nd to 11th April, 1996.

The quad-rigged *Delta Seafoods* industrial prawn trawl vessel *Leremori* with four 7 fathom nets of 2 inch mesh in the cod-end was *chartered* for the survey.

During phase 1, in each fishing zone, from Fly/Bamu in the west to lokea in the east, one main shot was made in each of 3 differing depth categories, by day and by night. These categories were wherever possible 8-12 m, 12-20 m and 20-30 m. The 3-mile zone was generally shallower than 8 m depth, so no trawling with main nets was carried out inside the 3-mile limit, for conservation purposes and so as to prevent upsetting local communities of resource owners and to reduce the potential for vessel seizure.

The number of cartons of each grade of banana and black tiger prawns caught were recorded along with carton weight. The time winched down, time winched up, and the position down and the position up were also recorded. During each man net shot, echosounder depth measurements were made at 30 minute intervals, so that the mean depth trawled during the shot could be calculated.

During phase 2, the normal commercial operations were adopted so that the trawler could have an economic return from the charter. Search across depth contours with the try net was followed by trawling along contours with the main net once commercial quantities of prawns were located. Number of cartons by grade of prawns caught, mean depth trawled, and time and positions were recorded, as for phase 1.

Table 1. **CPUE of recruit-sized prawns in the Gulf of Papua. A. Cruise 1, Transect Studies, 25th March to 2nd April (WB = banana prawns, *Penaeus merguiensis* chiefly, with minor proportion of < 5% of *P. indicus*; BT = black tiger *P. monodon*; % = percentage of new recruits in total catch of the species, by weight)**

Date	Day or night	Fishing area	mean depth (m)	WB-CPUE (kg/hr)	%WB	BT-CPUE (kg/hr)	%BT
25/03/96	D	F/BAM	29.5	0	-	0	-
26/03/96	N	F/BAM	18.0	5.8	100	0	-
26/03/96	N	F/BAM	9.4	0.96	22	0	-
26/03/96	D	F/BAM	13.8	2.9	32	0	-
26/03/96	D	F/BAM	21.7	4.0	55	0	-
26/03/96	D	F/BAM	19.7	0.45	33	6.8	19
27/03/96	N	WCB	20.1	0	0	0	-
27/03/96	N	WCB	18.2	1.5	43	0	-
27/03/96	D	ECB	18.5	1.3	50	0	-
27/03/96	N	ECB	29.3	0	-	0	-
28/03/96	N	ECB	25.5	2.5	38	0	0
28/03/96	N	ECB	26.5	0.91	38	0.96	34
28/03/96	D	P	8.0	1.7	100	0	-
28/03/96	D	P	14.5	12.0	69	1.1	50
28/03/96	D	P	25.3	2.6	38	1.8	51
28/03/96	N	P	27.7	1.7	50	0	0
28/03/96	N	P	15.3	18	50	4.0	57
28/03/96	N	P	8.4	9.1	80	0	-
29/03/96	N	WK	24.9	18	50	5.1	26
29/03/96	D	WK	24.1	45	53	1.2	27
29/03/96	D	WK	12.3	45	85	1.4	100
29/03/96	D	WK	8.7	26	78	3.7	40
29/03/96	D	WK	9.3	18	53	4.0	67
29/03/96	D	WK	20.6	46	43	7.4	29
29/03/96	N	KB	9.7	1.9	54	2.7	27
30/03/96	D	KB	11.4	9.4	37	3.1	27
30/03/96	D	KB	11.4	1.5	17	1.1	21
30/03/96	N	I	14.5	0.96	40	0.72	33

A. Cruise 1, Transect Studies, 25th March to 2nd April continued.

Date	Day or night	Fishing area	mean depth (m)	WB-CPUE (kg/hr)	%WB	BT-CPUE (kg/hr)	%BT
31/03/96	N	I	20.9	0	-	1.1	45
31/03/96	D	FWB	18.3	0	0	1.5	38
31/03/96	N	FWB	19.7	0.4	20	1.4	66
01/04/96	N	FWB	17.5	0	-	0.38	18
01/04/96	N	CC	12.6	1.9	22	1.8	39
01/04/96	N	CC	17.3	0.48	11	0.72	21

Key to fishing areas:

KB = Kerema Bay.
FWB = Freshwater Bay.
F/Bamu = Fly Bamu.
CC = Cape Cupola.
I = Iokea.
WK = West Kerema
P = Purari.
WCB = West Cape Blackwood.
ECB = East Cape Blackwood.

B. Cruise 2, Commercial Operations, 2nd to 11th April.

Date	Day or night	Fishing area	mean depth (m)	WB-CPUE (kg/hr)	%WB	BT-CPUE (kg/hr)	%BT
11/04/96	N	KB	9.0	29	63	0	-
10/04/96	D	KB	11.3	27	65	27	49
10/04/96	D	KB	12.3	27	58	3.9	27
10/04/96	D	KB	10.9	2	50	0.5	30
10/04/96	N	KB	13.7	2.7	11	4.6	44
08/04/96	N	KB	14.7	1.8	15	6.7	28
07/04/96	D	KB	14.0	0.57	17	1.6	37
07/04/96	D	KB	11.3	0	-	0.68	18
07/04/96	N	KB	14.9	5.3	28	7.9	48
07/04/96	N	KB	14.2	9.1	36	7.5	40
05/04/96	N	KB	14.0	11	42	2.5	35
04/04/96	D	KB	11.4	2.1	13	2.7	34
04/04/96	D	KB	14.9	6.8	33	4.8	48

B. Cruise 2, Commercial Operations, 2nd to 11th April Continued.

Date	Day or night	Fishing area	mean depth (m)	WB-CPUE (kg/hr)	%WB (kg/hr)	BT-CPUE	%BT
04/04/96	N	KB	14.9	4.1	39	1.7	42
03/04/96	N	KB	15.5	5.2	34	1.9	27
03/04/96	D	KB	10.2	1.6	18	3.7	57
03/04/96	D	KB	8.9	8.8	34	5.1	39
03/04/96	N	KB	9.8	4.5	39	0.68	31
03/04/96	N	KB	11.6	30	71	2.4	41
03/04/96	N	KB	11.0	31	85	2.7	47
02/04/96	D	KB	10.8	16	68	5.7	53
02/04/96	D	KB	10.3	31	62	4.3	47
06/04/96	D	P	13.2	26	66	2.8	36
06/04/96	N	P	12.7	7.0	58	0	0
06/04/96	D	P	14.2	15	52	2.9	44
09/04/96	D	Ak	12.4	15	80	3.7	65
09/04/96	D	Ak	13.0	15	90	2.4	53
09/04/96	D	Ak	12.0	21	44	1.2	28
08/04/96	N	Ak	9.5	19	73	4.5	24
08/04/96	D	Ak	10.0	47	64	13	54
10/04/96	N	KK	12.7	5.4	53	1.7	41
08/04/96	N	KK	12.9	0	-	2.7	53
08/04/96	N	KK	19.9	10	35	4.4	40
05/04/96	N	CC	14.0	9.0	32	3.3	35
05/04/96	N	CC	14.5	12	32	5.6	48

Key to fishing areas:

KB = Kerema Bay,
CC = Cape Cupola,
I = Iokea,
KK = Kea Kea, West Kerema,
P = Purari,
Ak = Akoma, boundary of Purari and West kerema zones.

Carton weights of head-less b/tiger prawns were transformed to head-on weights. A conversion factor of 1.33 x head-less weight was used to transform carton weights of head-less black-tiger prawns to estimated carton weights of head-on black tiger prawns, where necessary (the majority of black tiger prawn cartons were packed with head-on prawns).

RESULTS

Depth distribution

The CPUE for recruit-sized banana prawns (*Peneaus merguiensis*) and for recruit-sized black tiger prawns (*P. monodon*) in the Gulf of Papua in March/April 1996 were each negatively correlated with the mean depth of individual main net trawls ($p = 0.031$ and $p = 0.046$ respectively, by a single tail test for negative correlation) (Figures 2-3, based upon Tables 1 A-B, and Table 2).

Recruit-sized prawns were defined as follows:-

1) banana prawns: the lowest 2 grades combined: 41-50 and 51-60 prawn tails to the pound weight, corresponding to approximately 24-28 mm carapace length (CL).

2) black-tiger prawns: 16-20 (head-on) + 21-25 (head-on) + 26-30 (head-less) + 31-35 (head-less) grades (to the pound weight), corresponding to 33-37 mm CL, approx.

Percentage catch (by weight) of recruit-sized banana prawns and black-tiger prawns were similarly each negatively correlated with mean depth ($p = 0.018$ and $p = 0.012$ respectively, single tail test) (Figures 4-5, based upon Tables 1 A-B, and Table 3).

Indices of recruitment

A t-test on the day-time CPUE and night-time CPUE of banana prawns caught during the transect studies (25th March to 2nd April) indicated that there was no statistical difference between day and night-time CPUE (p=0.34, 32 df).

The descriptive statistics of the CPUE of recruit-sized banana prawns caught during the transect studies indicate that the mean CPUE (recruitment index) was 8.23 +/- SE 2.30 kg of tails/trawl-hr (96% CI 3.56 to 12.91 kg of tails/trawl-hr) (Table 4A; and Figure 6, Appendix I).

The descriptive statistics of the CPUE of recruit-sized black tiger prawns caught during the transect studies indicate that the mean CPUE (recruitment index) was 1.53 +/- SE 0.34 kg (head-on)/trawl-hour (95% CI 0.84 to 2.22 kg (head-on)/trawl-hour) (Table 4 B; and Figure 7, Appendix II).

Descriptive statistics of the mean depth of main shots during the transect studies showed the mean depth trawled was 17.73 m (SD 6.39 m) (Table 4 C; Figure 8 Appendix III). During March/April, 1996 recruit-sized banana prawns were found in greatest abundance in 8 to 12 m depth, based upon catch per unit of fishing effort (CPUE), from transects and commercial operations covering the whole of the fishing grounds, from 8 to 30 m depth. CPUE decreased with depth from 8 to 30 m (correlation/regression, p = 0.031, single-tail test).

Similarly, the CPUE of recruit-sized black tiger prawns decreased with depth from 8 to 30 m (correlation/regression, $p = 0.046$, single-tail test).

DISCUSSION, INCLUDING IMPLICATIONS FOR MANAGEMENT

This study documents the association between the CPUE of recruit-sized prawns (*Penaeus merguiensis* and *P. monodon*) and depth and the results support the conservation value of the 3-mile zone. The associations found are negative correlations, statistically significant at the 5% level. The high catch rates of recruit-sized banana prawns at about the 10 m depth contour (up to 46 kg/trawl-hr) and black tiger prawns (up to 29 kg/trawl-hr) suggest that the 1996 seasonal spatial closure (from Cape Blackwood to Cape Cupola, from 1st January to 15th April 1996) and/or the more substantial rains of the 1996 monsoon season have had good effect.

The results indicate that the value of the 3-mile zone as a conservation measure for the protection and growth of recruit-sized banana and black tiger prawns (and the protection and growth of finfish) cannot be over-emphasised. Even smaller individuals of these prawn species were found and measured in a try shot survey of the 4-10 m depth band made during

Table 2. **Correlation of CPUE of recruit-sized prawns and depth (including slope and intercept for equations of the associations).**

A. Spearman rank correlation of CPUE of recruit-sized banana prawns on mean depth.

R_s	t	df	p
-0.3630	-3.189	67	0.0022

B. Correlation/regression of CPUE of recruit-sized banana prawns on mean depth.

r	t	df	p(single-tail*)
-0.2265	1.904	67	0.0307

	Value	se	95% CI
Slope	-0.53	0.28	-1.09 to 0.03
Intercept	18.74	4.48	9.79 to 27.68

C. Spearman rank correlation of CPUE of recruit-sized b/tiger prawns on mean depth.

R_s	t	df	p
-0.1847	-1.539	67	0.1286

D. Correlation/regression of CPUE of recruit-sized b/tiger prawns on mean depth.

r	t	df	p(single-tail*)
-0.2044	1.709	67	0.0461

	Value	se	95% CI
Slope	-0.15	0.09	-0.32 to 0.02
Intercept	5.09	1.37	2.35 to 7.83

* Single-tail test for negative correlation.

Table 3. **Correlation of percentage of recruit-sized prawns (by weight) an depth, Gulf of Papua (including slope and intercept for equations of the associations).**

A. Spearman rank correlation of percentage of recruit-sized banana prawns on mean depth.

R_s	t	df	p
-0.3412	-2.835	61	0.0062

B. Correlation/regression of percentage of recruit-sized banana prawns on mean depth.

r	t	df	p(single-tail*)
-0.2641	2.138	61	0.0183

	Value	se	95% CI
Slope	-1.26	0.59	-2.44 to 0.08
Intercept	64.79	9.08	46.63 to 82.95

C. Spearman rank correlation of percentage of recruit-sized b/tiger prawns on mean depth.

R_s	t	df	p
-0.1847	-1.394	55	0.1690

D. Correlation/regression of percentage of recruit-sized b/tiger prawns on mean depth.

r	t	df	p(single-tail*)
-0.2975	2.311	55	0.0123

	Value	se	95% CI
Slope	-1.06	0.46	-1.97 to -0.14
Intercept	53.78	7.08	39.59 to 67.98

* Single tail test for negative correlation.

Figure 2. **Association of CPUE of recruit-sized banana prawns (41-50 + 51-60 grades combined) and mean depth for individual main-net trawl shots (quad-rig) in the Gulf of Papua, March/April 1996. Trawler *Laremori*. Depths shallower than 8.0 m were not trawled, in the interests of conservation and safety.**

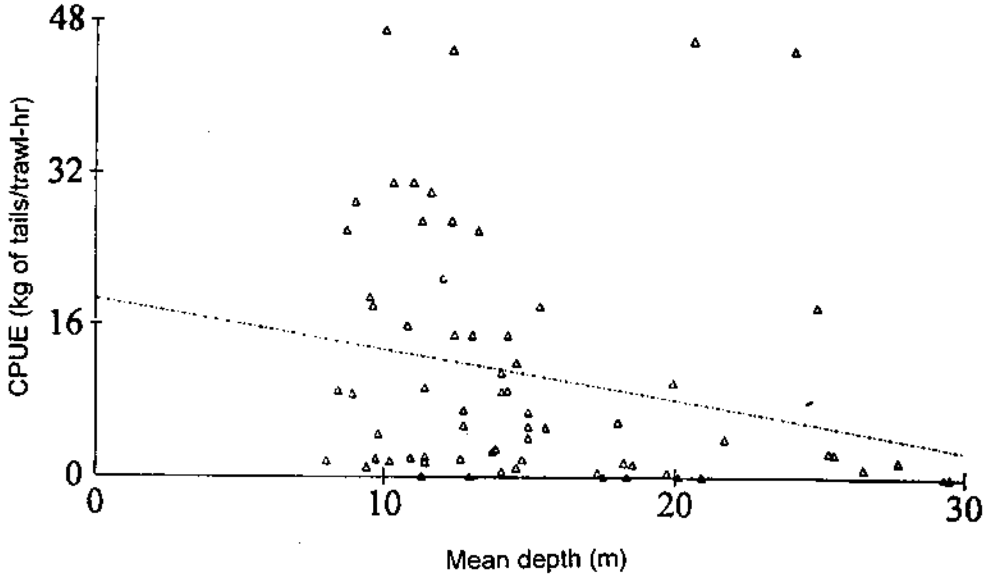


Figure 3. **Association of CPUE of recruit-sized black tiger prawns, comprised of 16-20 (head-on) + 21-25 (head-on) + 26-30 (head-less) + 31-35 (head-less) grade, and mean depth for individual main-net trawl shots (quad-rig) in the Gulf of Papua, March/April 1996. Trawler Laremori. It should be noted that (i) depths shallower than 8.0 m were not trawled, and (ii) a conversion factor of 1.33 x head-less weight was used to transform carton weights of head-less prawns to estimated carton weights of head-on prawns.**

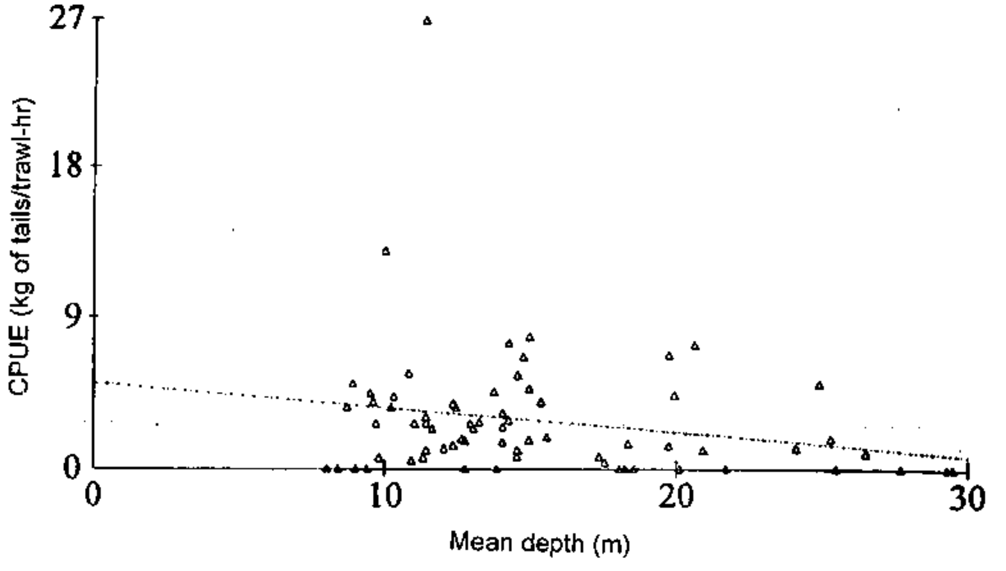


Figure 4. **Association of the percentage catch (by weight) of recruit-sized banana prawns and mean depth for individual main-net trawl shots (quad-rig) in the Gulf of Papua, March/April 1996. Trawler Laremori (Depths shallower than 8.0 m were not trawled).**

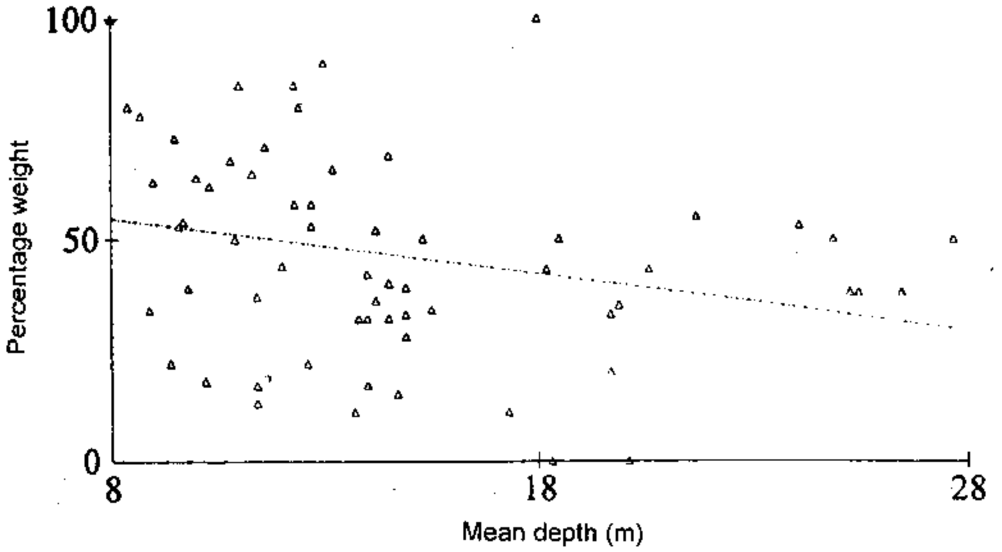
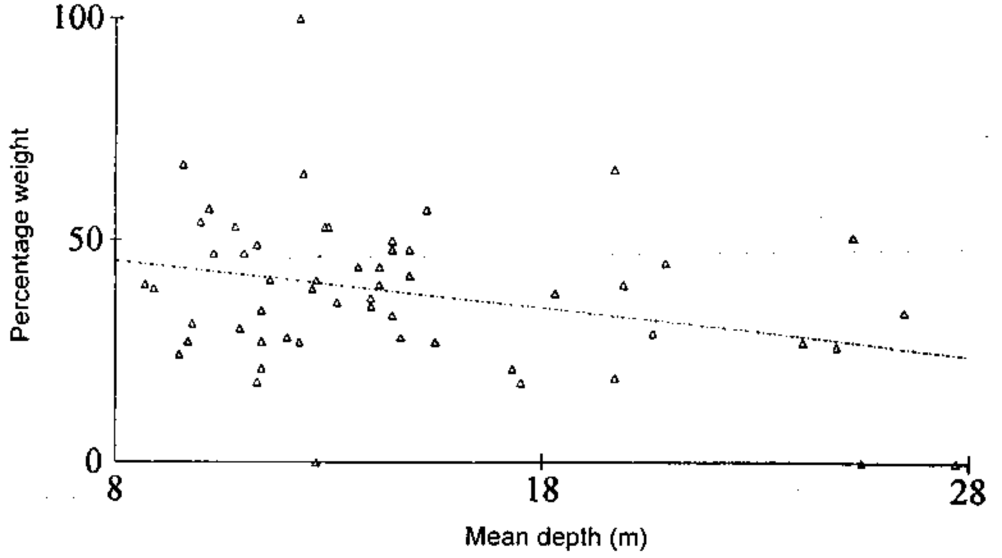


Figure 5. **Association of the percentage catch (by weight) of recruit-sized black tiger prawns and mean depth for individual main-net trawl shots (quad-rig) in the Gulf of Papua, March/April 1996. Trawler laremori (Depths shallower than 8.0 m were not trawled; a conversion factor of 1.33 x head-less weight was used to transform carton weights of head-less prawns to carton weights of head-on prawns).**



the transect study period from Lesi Creek, Freshwater Bay, to Cape Cupola, Kerema Bay (Kare *et al.* 1996). Finfish were also smaller (personal observations). The results of Kare *et al.* (1996) study inferred that Lesi Creek, Lakekamu estuary and Mopu inlet were prawn nursery areas.

KEY RECOMMENDATIONS FOR MANAGEMENT

It is likely that industrial-scale prawn trawl operators will continue to illegally fish the 3-mile zone until a vessel tracking (transponder) system is established. However, operators do understand, respect and support the concept of a seasonal spatial closure (personal communications, Lady Morauta, November 1995 and July 1996).

Considering the findings of the present study, 2 key recommendations emerge:-

(1) The 3-mile conservation zone should remain in place; and

(2) The eastern boundary of the seasonal area closure for 1997 and subsequent years should be extended eastward from Cape Cupola to the fishing grounds as far south and east as lokea village, so that the mangrove nursery areas and adjacent offshore recruitment areas located in 4-8 m depth in Freshwater Bay (Lesi Creek, Lakekamu Estuary and Mopu In-let) are included in the seasonal spatial closure and will thus be protected during the principal season of recruitment (January through April). Prawn trawl operators would be forced to fish the established seasonal grounds of West Cape Blackwood and Fly/Bamu and the newly opened grounds from Cape Suckling to lokea (including the prawn resource associated with Yule Island, outside the 3-mile limit). Resource owners in this southern area near Yule Island are protective of their inshore fishery resources (as at Orokolo Bay) so incursion may not be a problem there.

Five further important points relating to conservation of the prawn fishery resources are the following:-

(3) There is mounting interest from resource owners to develop the nearshore prawn resources within the 3-mile zone in a sustainable manner, by opening the 3-mile zone to small-scale beam trawling, i.e. a limited number of relatively small beam trawls towed by dory (draft Gulf of Papua prawn fishery plan for 1997, Research & Management Branch, NFA). The nets used should be of relatively large mesh sizes in the net body and cod-end, because the results of the present study indicate that, particularly during January through June each year, a large proportion of the catch in the 3-mile could be new recruits which have not realised growth potential. It should be noted that even with this preventative measure many juveniles passing through the net may still die.

(4) Studies to assess the impact of beam trawls should ideally be conducted prior to allowing this kind of fishery to develop (pers. comm. from Referee 2, 24th April, 1998).

(5) Studies on artisanal trawl fisheries in Mexico indicate that they compete directly with the offshore fishery and that overall production would be increased by removing the artisanal trawl component of their prawn fisheries (per.comm. Referee 2, 24th April).

(6) Establishment of a vessel monitoring (i.e. tracking) system (VMS) would provide much needed surveillance capability for both the seasonal spatial closure and the 3-mile conservation zone.

(7) A prawn observer programme during April through November each year would assist surveillance until a vessel tracking system is established and provides important data on secondary recruitment pulse(s) during the latter half of the year.

ACKNOWLEDGEMENTS

We would like to thank Lady R. Morauta and Sir M. Morauta of Delta Seafoods for their assistance and logistical support of this research, including Skipper and crew of the trawler *Laremori* who accommodated and assisted us in every way, both with the transect studies (phase 1) and with the second phase of the study. We would also like to thank Mr. Joe Opnai, Executive Manager, Fisheries Management and Industry Support, NFA, an Mr. G. Lubang, Gulf Provincial Fisheries Officer, for approving and facilitating these studies despite a lack of funding, and Mr. M. Brownjohn, Head of the Fishing Industry Association, for advice on juvenile prawn escapement. Mr. Graham Lubang and his officers assisted us by recording the grades and depths trawled during the 2nd phase.

REFERENCES

EVANS, C.R., OPNAI, L.J. and **KARE, B.D.** (1995 a). The Gulf of Papua Prawn Fishery: Management Recommendations for 1996. Report in: 'The results of prawn recruitment research in the Gulf of Papua in 1995: management recommendations for 1996', Research Bulletin 95. 01, National Fisheries Authority, PO Box 165, Konedobu, PNG.

EVANS, C.R., KUMORU, L., KUMILGO, K., KARE, B.D., TATAMASI, M. and **BAULE, L.** (1995 b). A survey of the distribution and abundance of recruit-sized prawns *Penaeus merguiensis* and *P. monodon* in the Gulf of Papua, during the 1995 closed season, 1st February to 15th March. Report in Research Bulletin 95, 01, National Fisheries Authority, P.O. Box 165, KONEDOBU, NCD, Papua New Guinea. Background Paper Number 29, pp 6-16 in 'Manuscript Collection of country Statements and Background papers, Vol. 11. South Pacific Commission and Forum Fisheries Agency Workshop on the Management of South Pacific Inshore Fisheries'. South Pacific Commission, Noumea.

EVANS, C.R. and **KARE, B.D.** (1996). Observations on the seasonality of the prawns *Penaeus merguiensis* and *P. monodon* in the Gulf of Papua: implications for the timing of a seasonal closure. *Science in New Guinea* 22(2): 83-93.

FURSHER, S. (1980). The distribution and abundance of juvenile penaeid prawns in the northern Gulf of Papua, Papua New Guinea, with particular reference to *P. merguiensis* (De Man). Department of Primary Industry, Port Moresby. Res. rep. No. 84-06, 28 pp.

GWYTHER, D. (1980 a). Commercial and biological aspects of the Gulf of Papua prawn fishery. Department of Primary Industry, Port Moresby, Research Bulletin No. 21, 72 pp.

GWYTHER, D. (1980 b). The Gulf of Papua offshore prawn fishery in relation to the Wabo hydro-electricity scheme. Technical Report, Kanudi, Fisheries Research Station, Department of Primary Industry, Papua New Guinea, 22 pp.

KARE, B.D., EVANS, C.R., BAULE, L., KUMORU, L., KUMILGO, K. and **TATAMASI, M.** (1995). Size frequencies of white banana prawns (*Panaeus merguiensis*) and black tiger prawns (*P. monodon*) in the Gulf of Papua, by sex, area and depth during the closed season, 1st February to 15th March 1995: juvenile recruitment and implications for management. Report in: 'The results of prawn recruitment research in the Gulf of Papua in 1995: management recommendations for 1996', Research Bulletin 95. 01, National Fisheries Authority, PO Box 165, Konedobu, NCD, Papua New Guinea.

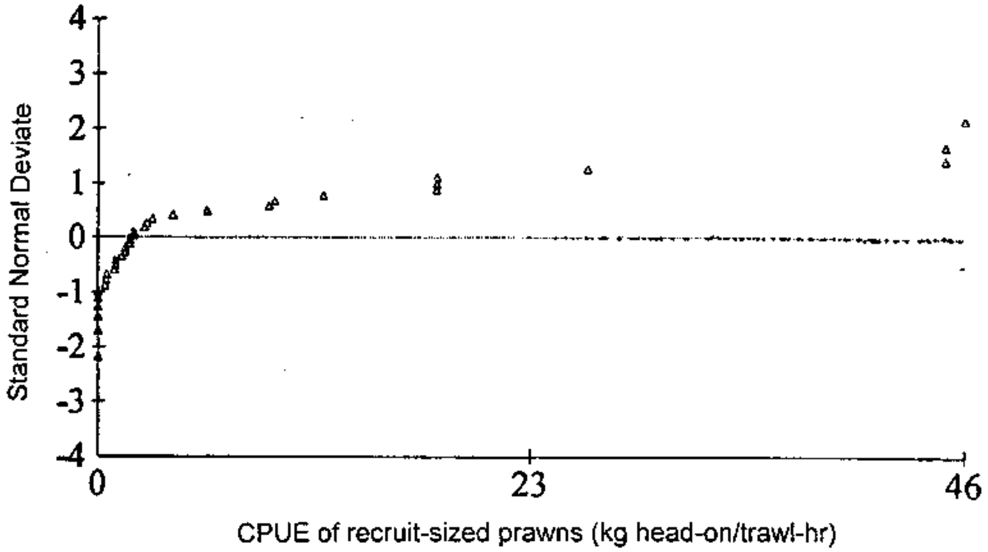
KARE, D.B., EVANS, C.R. and **BAULE, L.** (1996). Size frequency distribution of the prawns *Penaeus merguiensis* and *P. monodon* by depth in the Gulf of Papua: implications for management. Technical Report 96. 05, National Fisheries Authority, PO Box 165, Konedobu, NCD, Papua New Guinea.

OPNAI, L.J. and **EVANS, C.R.** (1994). A comprehensive management plan for the Gulf of Papua Prawn Fishery. Department of Fisheries and Marine Resources, PO Box 165, Konedobu, NCD, Papua New Guinea. Occasional Technical Report, December 1994.

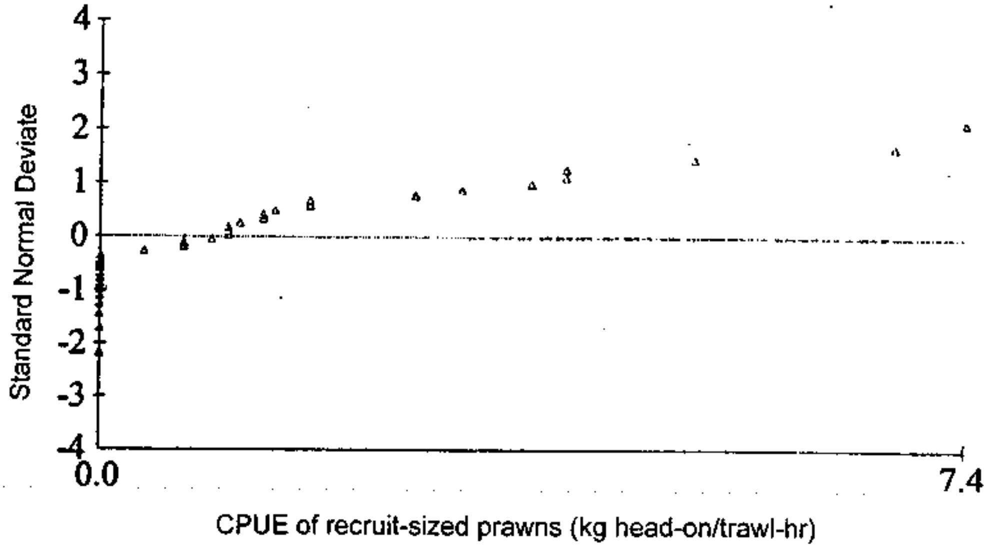
POLOVINA J.J. and **OPNAI, L.J.** (1989). Assessment of the Gulf of Papua Prawn Fishery. Department of Fisheries and Marine Resources. Papua New Guinea. Occasional Technical Report. 1989. 34 pp.

Appendices

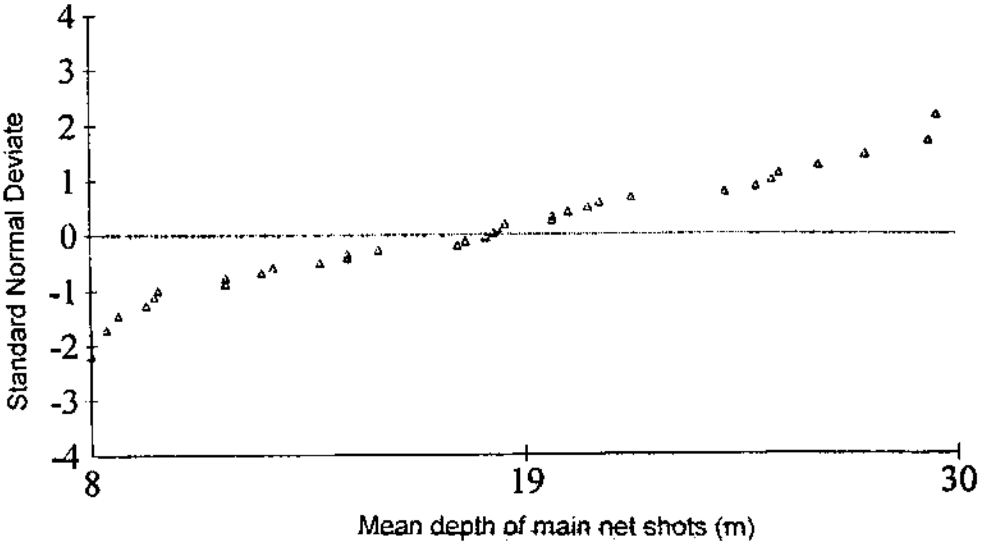
Appendix I: Figure 6. **Descriptive statistics of CPUE of recruit-sized banana prawns, Gulf of Papua, during transect studies 25th March to 2nd April 1996.**



Appendix II: Figure 7. **Descriptive statistics of CPUE of recruit-sized black tiger prawns, Gulf of Papua, during transect studies 25th March to 2nd April 1996.**



Appendix III: Figure 8. **Descriptive statistics of mean depth of main net shots in the Gulf of Papua, during transect studies 25th March to 2nd April 1996.**



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TROBEN, M.M. (1973). Genetic fine structure in *Drosophila. Department of Primary Industry Research Bulletin* No. 102: 196-197.

VANCE, P.N. (1976). Maize in the Markham Valley. pp. 215-220. *In: 1975 Papua New Guinea Food Crops Conference Proceedings.* K. Wilson and R.M. Bourke (Ed.). Department of Primary Industry, Port Moresby.

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l	- litre
ml	- millilitre
ha	- hectare
mm	- millimetre
cm	- centimetre
m	- metre
a.s.l.	- above sea level
yr	- year
wk	- week
h	- hour
min	- minute
s	- second
K	- kina
n.a.	- not applicable or not available
n.r.	- not recorded
var	- variance
s.d.	- standard deviation
s.e.m.	- standard error of difference
d.f.	- degrees of freedom

Levels of significance

n.s.	- not significant
*	- $0.01 \leq p < 0.05$
**	- $0.001 \leq p < 0.01$
***	- $p < 0.001$

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