ENVIRONMENT AND HEALTH IN A NEW GUINEA HIGHLANDS COMMUNITY

by

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Raiapu Enga boys sit on a limestone outcrop overlooking the sweet potato fields of the Saka Valley.

ABSTRACT

This thesis reports a 4 years' study into the environment and health of a small community of subsistence sweet potato growers in the Highlands of New Guinea. The community selected for study is the Tombeakini clan; a group of Raiapu Enga speakers who live in the Saka Valley, near Wapenamanda in the Western Highlands District. The thesis reports on some environmental influences on morbidity in the Saka Valley and focuses particularly on the inter-relationships between water use, faecal water pollution and morbidity. The thesis is divided into 5 parts. Part I introduces the ecological framework of the study, describes the environmental and cultural setting and gives details of the Tombeakini clan who are the subjects of this research. Part II presents information on water use and attitudes to water, in the Saka. It is shown that water use for drinking, cooking and hygiene is extremely low and that water is collected from the nearest stream which is not too warm or too turbid. Part III reports an extensive investigation of faecal water pollution in the streams of the Saka Valley. Data are given on the concentrations of faecal coliforms and faecal streptococci as well as on chemical properties, turbidity, water temperature and rainfall. All streams in the Saka are grossly polluted with faecal material and pigs are probably the source of most of this contamination. The associations between variations in the levels of faecal pollution and the physical parameters rainfall, temperature and turbidity are investigated. Part IV describes the medical services, both traditional and introduced, which are available to the people of the Saka and presents the findings of a 5 months' survey of morbidity among Tombeakini clansfolk. This morbidity is then related to various cultural and environmental factors and

particularly to the water use, and faecal water pollution, situation. It is concluded that the impact of strictly water-borne infection on the people of the Saka is negligible. Part V makes policy recommendations based on the findings of Parts I - IV and considers the problems of integrating the material in this thesis to produce a model of Raiapu medical ecology.

PREFACE

The work reported in this thesis was carried out between February 1970 and November 1973 during which time I held a fellowship under the Commonwealth Scholarship and Fellowship Plan. During this period I was based at the School of Civil Engineering of the University of New South Wales and, from there, I made three journeys to Papua New Guinea.

In August 1970 I visited Papua New Guinea and travelled through the Highlands from Kainantu to Wabag inspecting various locations for my proposed fieldwork. The primary requirement was a densely settled area where stresses in the man-environment system are likely to be greatest and thus most easily studied. In particular, I considered that a densely settled area would exhibit a high degree of faecal water pollution and thus facilitate the study of the relationships between faecally contaminated water and health. The Saka Valley, near Wapenamanda in the Western Highlands District, was selected as the study site for a number of reasons. It has dense populations of humans and pigs, it is the home of 10,000 Raiapu Enga speakers who form part of Papua New Guinea's largest ethno-linguistic group, it is fairly representative (culturally and environmentally) of many other parts of the Enga region, it has had limited contact with the white man since 1938 and many features of traditional Enga life and culture are found today, it is accessible by road from the Highlands Highway and it is a valley of great beauty. In addition, the Raiapu Enga who inhabit the Saka, and their neighbours the Mae Enga, have a salient position in the anthropological literature on New Guinea. This was invaluable in that it enabled me to become familiar with many aspects of Enga culture before returning to the field in 1971.

In February 1971 I returned to Papua New Guinea, accompanied by my wife, and we remained there until January 1972. Nine months of this period were spent living with the Tombeakini clan of the Saka Valley and it was during this residence with Tombeakini that the data, on which this thesis is based, were collected.

Between January 1972 and November 1973 I worked at the University of New South Wales writing this thesis and also preparing other material on the Raiapu Enga for publication. A list of publications arising from my work in the Saka will be found at the end of the thesis and copies of some of these publications are attached. In June and July 1973 I returned to Papua New Guinea, and revisited the Saka, to collect additional material and to observe what changes had taken place since 1971.

The execution of this research and the production of this thesis would not have been possible without the assistance and encouragement of a number of people. In 1969 and early 1970 I was greatly encouraged and aided by Professor O.H.K. Spate and this research would never have commenced without his early support. On first arriving at the University of New South Wales, my research plans were approved and encouraged by Professor E. Laurenson and Associate Professor D. Pilgrim, despite the fact that they represented a significant departure from the previous research interests of the School of Civil Engineering. Professor H.R. Vallentine took an early interest in my work and has been continually helpful thereafter. I am indebted to my supervisor, Associate Professor B.W. Gould, for his support over almost 4 years and for his prompt response to my appeals from New Guinea for additional equipment.

In Papua New Guinea I was greatly assisted by Professor D. Lea in Port Moresby and Professor E. Laurenson in Lae. The staff of the New Guinean Lutheran Mission gave unstinting hospitality and support and in particular I am grateful for the many kindnesses shown to my wife and myself by Mark and Priscilla Heidorn and Elwyn and Phyllis Ewald. The staff of the Lutheran Hospital at Mambisanda gave both personal and technical assistance and I acknowledge especially the help of Dr. C. Binns and Mr. D. Weinhold.

I am indebted to those who have given such valuable guidance and advice in the many academic disciplines which are represented in this study. In the field of anthropology I am grateful to Professors P. Lawrence, M. Meggitt and A. Strathern; in tropical medicine to Drs. R. Hornabrook, T. Murrell, A. Radford and Professor R. Walsh; in bacteriology to Dr. E. Geldreich; in computing to Mr. D. Doran and Mr. I. Fisher; in linguistics to Dr. R. Lang; in acarology to Dr. P. Robertson; and in statistics to Dr. C. McGilchrist. I owe a special debt to Professor Meggitt who originally suggested that I should inspect the Saka Valley as a possible fieldwork location.

Many others have assisted me over the past 4 years and I would like in particular to acknowledge my debt to the following: Professor D. Anderson, Timothy Bayliss-Smith, Dr. D. Bradley, Professor H. Brookfield, Dr. W. Clarke, Dr. I. Cordery, Dr. G. Feachem, Professor E.P. George, Roderick Lacey, Harold and Elizabeth Levine, David Potter, Jeremy and Leela Smith, Roger Southern, Dr. W. Symes, Dr. N. Wace, Professor G. White, and Dr. G. Woodfield. The maps and figures in this thesis were all drawn by Mrs. V. Murphy and I am grateful for the great co-operation of Mrs. A. Bailey, who did the typing.

This research would not have been possible without generous financial support from a number of quarters. The Australian Government, through the Commonwealth Scholarship and Fellowship Plan, have met my personal living costs and also provided additional funds for research expenses. Most of the bacteriological equipment which I employed in the Saka was paid for by the School of Civil Engineering of the University of New South Wales and I am grateful to Professor H. Vallentine and Associate Professors B. Gould and D. Pilgrim for authorising these expenditures. The cost of fieldwork in New Guinea was covered by generous support from the Nuffield Foundation, the Wenner-Gren Foundation (grant No. 2731) and the Frederick Soddy Trust. I am also grateful to the Australian and New Zealand Association for the Advancement of Science, who paid for my first visit to Papua New Guinea in 1970. The New Guinea Research Unit of the Australian National University were generous in assisting me with transport in 1970 and with accommodation in Mount Hagen in 1970, 1971 and 1973.

Finally, I wish to acknowledge 2 special debts. Firstly to Zuzana Feachem, who shared with me the experience of living with Tombeakini and who has given me so much assistance and encouragement in my work. Secondly, to the Tombeakini clansfolk with whom we lived and who were almost invariably helpful, hospitable and patient. In particular I am grateful for the friendship of Liangau, my adopted father, and of Tetepe, who acted as my interpreter and companion throughout our residence in the Saka. I also remember with special gratitude Nyio the student, Ambi the kamóngo, Pakao the "enemy" from Pindakini clan, and our neighbours, Pato and Neteme. I can only hope that these Tombeakini clansfolk found our visit half as pleasurable and rewarding as Zuzana and I found our stay amongst them.

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GLOSSARY

A) English Glossary. Certain words with specific meanings to the anthropologist are used in this thesis. Readers not familiar with the technical vocabulary of anthropology will find the following explanations useful. Technical medical vocabulary is also used and the reader is referred to any medical dictionary for clarification.

AFFINES: Relatives through marriage.

AGNATES: Kinsmen related patrilineally.

BIG MAN: A leader in a Melanesian society.

CLAN: In the Enga case, refers to a named, exogamous, localised, patrilineal descent group. It is a segment of a phratry and is composed of sub-clans and patrilineages.

CLAN TERRITORY: In the Enga case, a precisely delimited area of land which is owned and occupied by a single clan.

EXOGAMY: Prohibition of marriage within a group or amongst a category of relatives.

MATRILATERAL KIN: Kinsmen related through the mother, including her brothers and their children.

NON-AGNATE: A kinsman who is related by means other than agnatic descent - may be an affine.

PATRILINEAGE: In the Enga case, a named patrilineal descent group which is a segment of a sub-clan.

PATRILINEAL: Relationship or descent in the male line, as from father to son.

PHRATRY: The largest, named patrilineal descent group that is recognised by the Enga. It is not exogamous, it is sometimes localised and sometimes scattered, and it comprises a number of clans.

PIDGIN ENGLISH: A lingua franca in Melanesia whose vocabulary is mostly derived from English, with words from European, Melanesian and other languages. Sometimes called Neo-Melanesian. Used between natives from different language areas and between natives and foreigners. Varies slightly in grammar and vocabulary between different parts of Papua New Guinea and varies tremendously between Papua New Guinea and other Melanesian countries.

PRESTATION: A customary ceremonial gift which establishes or maintains relationships between persons or groups.

SUB-CLAN: In the Enga case, a named patrilineal descent group which is a segment of a clan and contains a number of patrilineages.

B) Raiapu Enga Glossary. The following are Raiapu words which are used frequently in this thesis and which are not always accompanied by a translation.

Kamóngo: A Raiapu leader or Big Man, influential in politics and prominent in the tée and other exchanges.

Kumánda: The period of mourning which follows a Raiapu death and particularly a ceremonial wealth distribution which terminates this mourning.

Nemóngo: A spell or magic, usually performed by a tópolí.

Tée: A massive ceremonial exchange cycle involving perhaps 100,000 Enga and featuring the rearing and distribution of large numbers of pigs.

Timóngó: The ghost of a recently deceased person. Believed to wander restlessly about its clan territory and cause illness, death and misfortune. It is invisible, moves mainly at night, and is a source of continual apprehension and fear for the living. For details see Feachem (1973c).

Topólí: A specialist in magic who is hired by individuals or groups to perform cures or to undertake many kinds of dealings with the spirit world. For details see Feachem (1973c).

Yályakali: Sky people who live in a world above the Enga and have little contact with the daily lives of men. Believed to be the creative beings and to be generally benevolent. For details see Feachem (1973c).

NOTES

A) RAIAPU ORTHOGRAPHY. I have endeavoured to follow the orthography adopted by the New Guinea Lutheran Mission who have been responsible for most of the research on the Enga languages. However, I have no training in linguistics and the spellings used in this thesis must be regarded as tentative. While in the field, I did not record tones or stresses and the marks indicating tones have been added later after correspondence with Dr. R. Lang and after reference to various linguistic publications by the New Guinea Lutheran Mission. Where a word has no tone marks it probably indicates that I have no information on its correct pronunciation. I gather that the letter 'r' is now excluded from the Enga alphabet and therefore Raiapu should be Laiapu throughout. I am grateful to Dr. R. Lang for his comments on some of the linguistic material in this thesis.

B) ABBREVIATIONS. In addition to the normal abbreviations for units of length, mass and time, the following are used:

A.P.O.	Aid Post Orderly
C.S.I.R.O.	Commonwealth Scientific and Industrial Research Organisation
CV	coefficient of variation
df	degrees of freedom
F	Snedecor's variance ratio
FC	faecal coliform
FS	faecal streptococci
ha	hectare
MPN	most probable number

p	probability
p.p.	period prevalence
r	coefficient of correlation
R	coefficient of mutliple correlation
sp.	species
w.p.p.	weekly period prevalence
X^2	chi-square

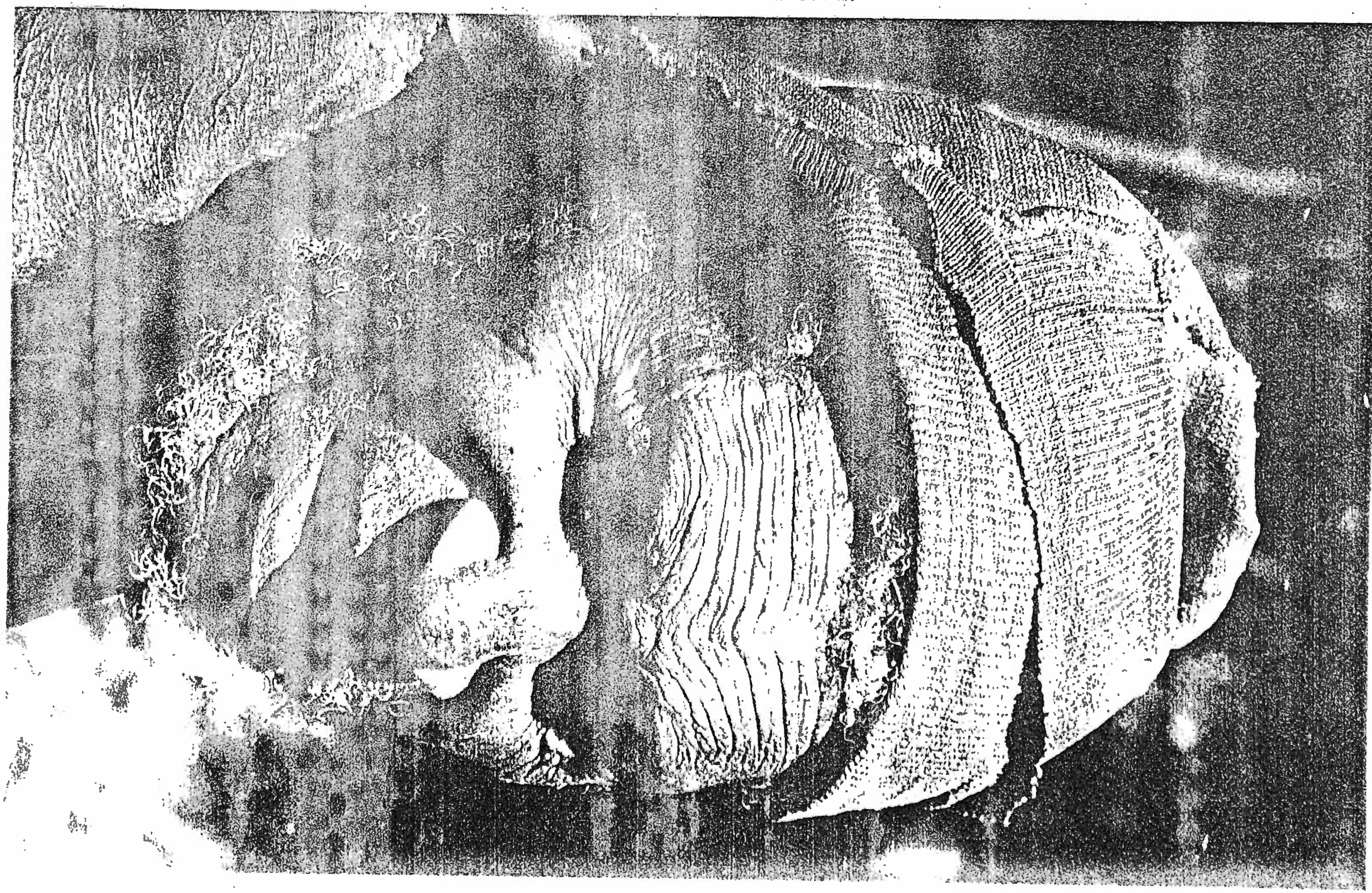
C) CONVERSIONS. To convert litres to U.S. gallons or imperial gallons, divide by 3.79 or 4.55, respectively.

To convert people per sq. kilometre to people per sq. mile, divide by 0.386.

D) MAPS. Six maps are included in this thesis. They were all drawn originally from aerial photographs taken from 25,000 feet in July 1959 and supplied by the Division of National Mapping, Canberra. Detail not visible on the photographs (e.g., houses), and items not present in 1959 (e.g., the Saka roads), have been added following a compass and Abney clinometer survey by the author.

E) PHOTOGRAPHS. Most of the photographs in this thesis were taken by Zuzana Feachem and the remainder by the author. The enlargements were made by the author.

Wakeo, aged about 67 years, the oldest member of Tombeakini Clan.



PART I

THE SETTING

CHAPTER 1

THEORY AND INTENTION

The study of the operations of natural systems in the real world, as opposed to idealised systems in laboratory situations, has been the focus of effort in the biological sciences for many years. Recently, certain disciplines have begun to investigate natural systems which include man as the dominant, or at least a highly important, organism. These studies of systems including man [1], often referred to as studies in human ecology, have been pursued particularly by anthropologists, geographers and human biologists.

It is perhaps unfortunate that the term human ecology has been widely used to describe these studies since it may have encouraged an excessive emphasis on man as a distinct and exotic component of the total ecosystem and have lead to a polarization of the concept or man-included systems in which man, on the one hand, is seen to react with his environment, on the other. It is this polarization which contributed to the controversy between those who saw man as controlling and modifying his surroundings and those who held that man and culture were moulded and determined by the environment.

Since then, a more integrated view of man-included systems has been espoused in which man is seen as just one component in a complex and dynamic system of interacting elements. The concept of the "ecosystem" (Tansley, 1935) has been taken from the biological sciences and man has been studied as an element in a local ecosystem.

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1. It should be noted that "systems including man" are very different from "human systems".

Clarke (1971:200) writes that thus "both man and environment are seen as parts of a single unit, the whole of which is worthy of study". Stoddart (1965) argues that the ecosystem concept is monistic and that "it brings together environment, man and the plant and animal worlds within a single framework, within which the interaction between the components can be analysed".

Various theoretical papers on the applications of ecosystem concepts to anthropology and geography have appeared (for instance, Stoddart, 1965; Vayda and Rappaport, 1968; Walmsley, 1972) and the approach has been applied in a number of studies of rural societies in Australasia and the Pacific (for instance, Conklin, 1957; Clarke, 1971; Fosberg, 1963; Geertz, 1963; Rappaport, 1968; Waddell, 1972b). The research reported in this thesis was conceived and carried out within this conceptual framework of man as an integral part of a local ecosystem.

Since all natural ecosystems are open systems and seldom have clearly defined boundaries, and since ecosystems including man are typically too complex to be studied in totality, 2 questions must be answered by the researcher. What are the spatial limits of the system to be studied and which sub-systems and elements, within the total ecosystem, are to be investigated in detail? The answers to both these questions are largely subjective and reflect the perceptions, interests and intentions of the researcher.

With regard to the spatial extent of the ecosystem studied, it has been usual in recent studies in the rural tropics to select small communities and their territories for study because it is only by so limiting the scale of the investigation that acceptable detail and precision can be obtained. These studies of "microregions" have been criticised on the grounds that regional generalisations cannot emerge from such local studies and that an aggregation of information about small systems does not necessarily lead to an understanding of the operation of some larger system[1]. However, the study of small and local ecosystems has great value when knowledge of the overall regional picture is too limited to permit any wider-ranging analysis. Brookfield (1962) writes:

> Most activities (in underdeveloped countries) are organised within small communities, largely independent for production and consumption. Over a wide range of geographical problems it would aid comprehension in depth to start by studying interrelated distributions in small areas, at the level meaningful to the local people. Then comparison of data from a number of localities may be used both to illuminate the local detail and to approach synthesis.

Clarke (1971:205) writes that studies of microregions in New Guinea provide:

> a vivid and accurate image of what is present and what is happening in parts of a wider region and thus lead to a deeper understanding of the diversity of life and environment in any region.......

The choice of components within the ecosystem, which will be subjected to detailed study, depends upon the intentions of the researcher. Rappaport (1968:5) writes:

> The selection of variables is a product of hypotheses concerning possible interrelations among the phenomena under investigation and these, in turn, flow from the interests and the theoretical conceptions of the analyst.

Most studies of man-environment systems in the rural tropics have

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1. In other words, an ecosystem is not merely the sum of its component parts - a concept which is fundamental to the theory of the ecosystems.

been carried out by anthropologists and geographers and so have focused upon the relationships between man, culture, land and domestic animals.

This thesis reports an investigation into the ecosystem which includes a small community of Enga-speaking people in the Western Highlands District of New Guinea. By extension, the findings reported have application, with varying degrees of confidence, to the Enga region as a whole and to other densely populated areas of the New Guinea Highlands. The methodological techniques, and theoretical frameworks, employed to elucidate the Enga ecosystem, have validity in many rural regions of the developing world and this thesis may focus attention on aspects of the man-environment system which have been neglected in most previous researches.

The original intention was to investigate those elements of the system which were associated with man and water; in other words, the interactions between man and his "hydro-environment". This has been done and major sections of this thesis are devoted to the analysis of water use, water pollution by man and his domestic animals, and the health hazards associated with polluted water supplies. However, as field-work progressed it became increasingly obvious that the impact of polluted water on health could not be neatly isolated from other environmental influences on health. Therefore the elements of the ecosystem under scrutiny were expanded to include, not only man and water, but also man and various physical and cultural components of his environment which could have a bearing upon human health.

The thesis is therefore a study of environment and health with special attention to those environmental aspects associated with water. The term environment is used here, and throughout the thesis, in a very broad sense. With respect to the health of an individual, environment includes the physical, biological and cultural environments, because elements of all these will affect levels of morbidity and mortality. The environment also includes the environment as seen by the individual - the perceived environment (Brookfield, 1970) - which is distinct from the real, or scientifically defined, environment. The decisions of the humans within the ecosystem are made with regard only to the perceived environment, and choices are made only between perceived alternatives. Therefore, if human behaviour is to be understood and integrated into a model of the ecosystem, then it is the relationships between behaviour and the perceived environment, which, in turn, is related to the real environment, which must be analysed. In this study, an understanding of the perceived environment is necessary before human activity can be fully comprehended. For instance, the choice of water source is made only between perceived alternatives and the Enga response to sickness is comprehensible only if we recognise that the perceived environment includes many malevolent, and sickness-causing, ghosts. Chapters 6 and 16 of this thesis are particularly concerned with the environment as perceived by the Enga.

While agreeing with Clarke (1971:202) that the study of people in relation only to their perceived world (sometimes called ethnoecology - see Frake, 1962) is of little value in understanding the operations of real systems, I believe that the perceived environment must be included as an element in any ecosystem analysis which includes human behaviour since, in all cultures, the commonly perceived environment is substantially different from the scientifically defined environment[1]. In studies relating to environmental health, the concept of perceived environment is especially pertinent, since behaviours concerning hygiene, and care and treatment of the sick, will all be conditioned by aspects of the perceived environment. Similarly, any attempt to change hygiene through health education is essentially an attempt to alter the perceived environment.

For the purposes of presentation, the thesis is divided into 5 distinct parts. Part I introduces the setting, theoretical, physical and cultural, of the study. Part II describes water use, Part III water pollution and Part IV analyses a wide range of aspects of the environmental health situation amongst the Enga. Part V considers the synthesis of this material and also discusses the practical implications of this research with respect to government policy.

For those readers not familiar with Papua New Guinea, or with the Highlands which are the location of this study, the following references will provide much background information. On the geography of the Highlands, see Anas (1960), Brookfield (1961, 1962, 1964) and Howlett (1962). For a collection of papers on the anthropology, geography, pre-history and linguistics of the Highlands, see Watson (1964) and on pre-history also see Brookfield and White (1968). Of particular relevance to this study are those works which describe detailed investigations of man and environment among small communities of rural New Guineans. Five outstanding examples of this type of study are Brookfield and Brown (1963), Clarke (1971), Lea (1964), Rappaport (1968), Sinnett (1972b) and Waddell (1972b).

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1. For instance, the perceived environment of most of the world's people does not include microscopic organisms, whereas the scientifically determined environment invariably does.

CHAPTER 2

THE ENVIRONMENTAL SETTING

On June 11th, 1934, a party of explorers, lead by Michael Leahy, left their base-camp near what is now the town of Mount Hagen and travelled to the south-west. Having crossed into the valley of the River Kaugel, they ascended Mount Giluwe (4, 200m) on June 15th. From here they went north, crossed the hills at the head of the Kaugel Valley, and camped at Walya on the Minyampu River on June 20th. They were now, unknown to them, in Enga-speaking country, and they continued through the heart of the Enga region, up the valleys of the rivers Lai and Ambum. In the Ambum, after a series of skirmishes in which many Enga were shot by Leahy's party, they turned back and reached Mount Hagen again on July 10th [1]. It was thus, only 40 years ago, that the Enga were violently introduced to the white man and, through him, to the rest of the world.

The Enga and their world are the subjects of this thesis and it is an underlying theme of the thesis that information on specific technical facets of Enga life (in this case information on environment and health) should be viewed in the light of a thorough appreciation of Enga society and its physical setting. Chapters 2 and 3 are presented to provide such an appreciation in order that what follows may be seen in its true context. Chapter 2 will deal with the Enga environment [2].

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1. This expedition is described by Leahy (1936). Leahy calls the Lai, the Gai; the Minyampu, the Miump; and Mount Giluwe, Mt. Keluwere.

2. See also the C.S.I.R.O. (1965) report entitled "Lands of the Wabag - Tari Area, Papua New Guinea".

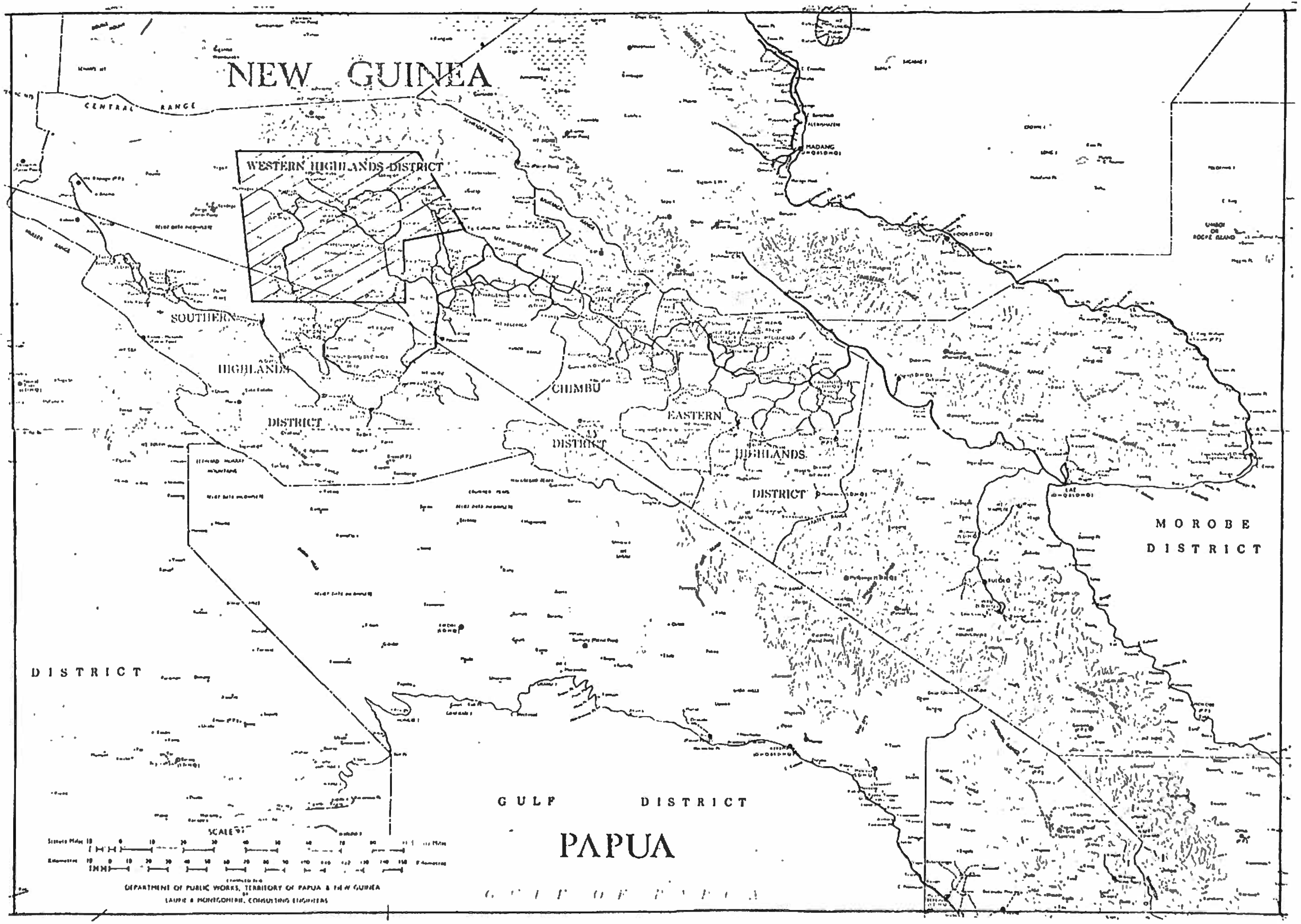
2.1 THE NEW GUINEA HIGHLANDS

The mountainous spine of the island of New Guinea stretches for 2,400 kilometres and is one of the great mountain ranges in the world. The terrain is generally rugged, with only the occasional stretch of flat country, and is mostly over 1,500m with a few peaks rising to over 4,000m. Just over half of the range lies in Papua New Guinea with the remainder falling within the Indonesian territory of West Irian.

The phrase "New Guinea Highlands", or simply "Highlands", will be used here exclusively to refer to the 4 administrative districts of Papua New Guinea which lie entirely within the mountains. These are, from East to West, the Eastern Highlands District - population 242,000, area 13,000 sq. kilometres and administered from Goroka and Kainantu; the Chimbu District - population 187,000, area 5,900 sq. kilometres and administered from Kundiawa; the Western Highlands District - population 336,000, area 25,000 sq. kilometres and administered from Mount Hagen; and the Southern Highlands District - population 215,000, area 18,000 sq. kilometres and administered from Mendi. Sections of the main range also lie within the Western, West Sepik, Gulf, Morobe, Central, and Northern Districts, but these mountains are not embraced by the term "Highlands" as used here. Nearly one million people, out of a total Papua New Guinea population of approximately $2\frac{1}{2}$ million people, live in the Highlands and these Highlanders were not known to the outside world prior to the 1920s.

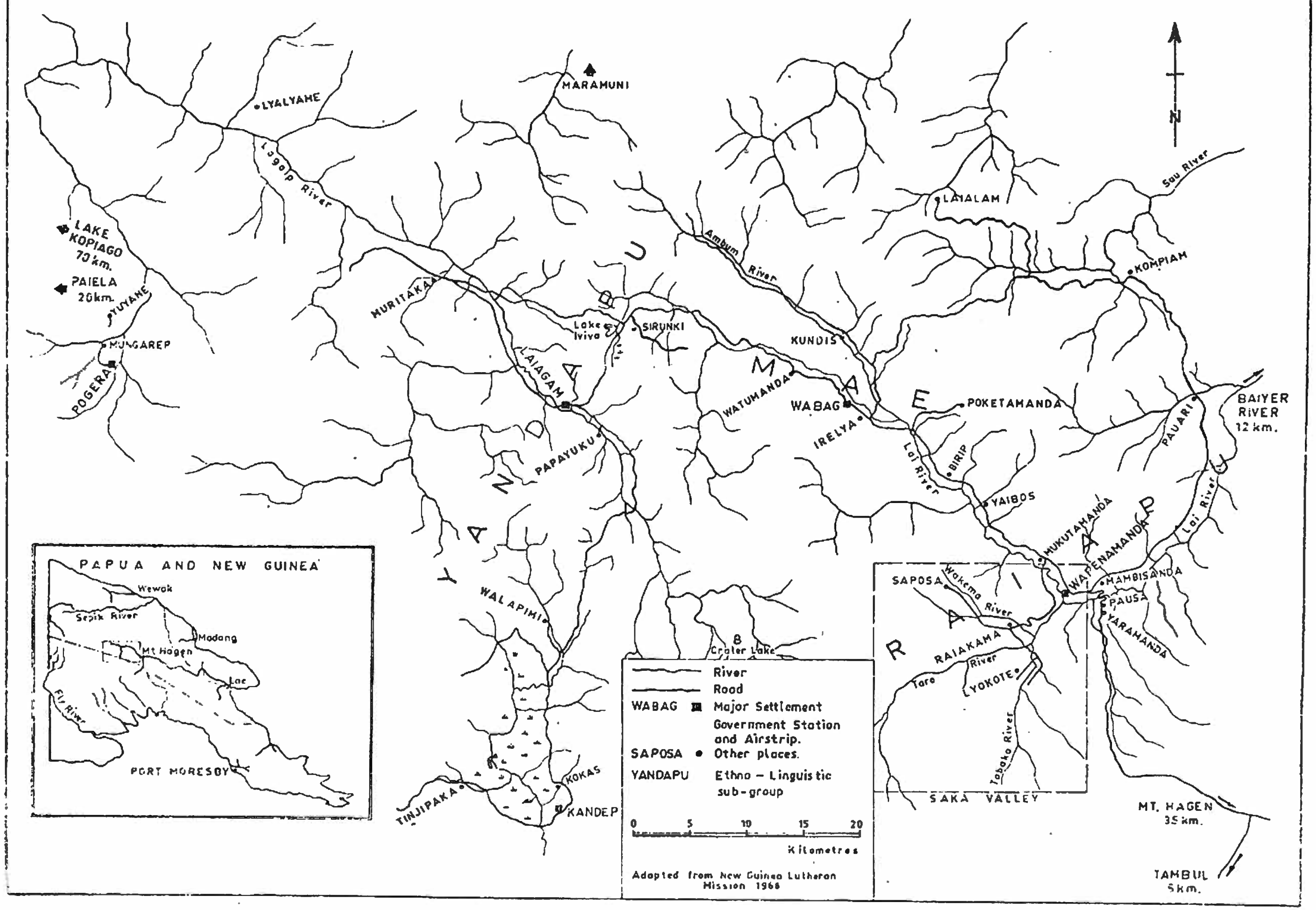
The position of the 4 Highlands districts is shown in Map 1. Of special note is the Highlands Highway which, with its feeder road system, links most of the Highlands to the coast at Lae. Map 1 also shows the position of the Enga region within the Western Highlands

MAP 1. THE PAPUA NEW GUINEA HIGHLANDS. THE ENGA REGION HATCHED.



MAP 2.

THE ENGA SPEAKING REGION OF THE NEW GUINEA HIGHLANDS



District[1].

2.2 LAND SYSTEMS

The Enga region is shown in Map 2. It stretches from the Lai headwaters in the west to the Mount Hagen Range in the east and from Maramuni and Kompiam in the north to Kandepe and Tambul in the south. The highest peak in the area, the Sugarloaf (3,900m), is part of a range which divides the Lai river system, draining northwards into the Sepik, from the Lagaip, Waga and Marient river systems which eventually drain southwards into the Fly, the Kikori and the Purari. Most Enga live in the valleys of the Lai and its tributaries, and also in the Lagaip Valley.

The region is a mixture of rugged, dissected terrain and broader open valleys, and C.S.I.R.O. (1965) define a number of land systems which are found in the area. The densely populated valleys of the middle Lai (between Wabag and Wapenamanda), the lower Ambum and the Tare[2] are all within the Wabag land system. This land system is so characteristic of the Enga environment that the relevant details from the C.S.I.R.O. (1965:51) are reproduced in full.

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1. A separate Enga District may soon be established by the Government, with its headquarters at Wabag.

2. The valley of the River Tare is called the Saka. In other publications it appears as Tsaka, Tsark, Tchark, Tschak, etc.

Wabag Land System (60 sq miles)

Dissected valley fill, mainly in La iand Tschak valleys.

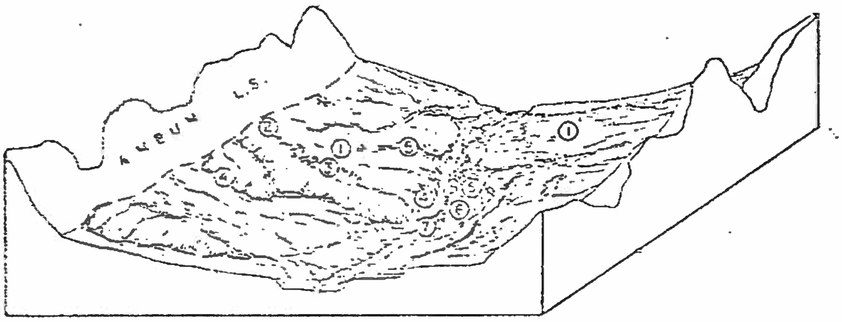
Geology.—Colluvial and alluvial deposits derived from greywacke, volcanic ash, and lavas.

Landscape Description.—Terraced valley fills and associated colluvial fans. Deeply dissected by narrow streams.

Landscape Dynamics.—Terrace and fan surfaces fairly stable. Moderate slumping on steep valley slopes.

Altitude.—5000–7500 ft.

Population and Land Use.—16,000 people. All land used for cultivation.



Unit	Area	Land Form	Soil	Vegetation
1	Large	Undulating to flat high and middle terraces, slopes <5° on middle and lower sectors of valleys, but up to 15° in head-water sectors	Mainly humic brown clay soils of Wapenamanda and Tabunaka families, uppermost slopes may be stony and bouldery	Gardens and garden regrowth. Sword grass and shrub regrowth
2	Small	Undulating convex fans, slopes 5°–10°, adjacent to bounding mountains	Humic brown clay soils of Nenja family	
3	Small	Depressions in high terraces	Gleyed plastic heavy clay soils of Pumakos family with concretions	*Leersia* and *Phragmites* swamp
4	Medium	Steep valley slopes	Humic brown clay soils of Wapenamanda family, minor skeletal stony soils	Sword grass and shrub regrowth. Gardens and garden regrowth
5	Very small	Swampy flats and drainage depressions on high terraces and on flood-plains	Peaty soils of Kiakau, Tirriraga, and Mango families	*Phragmites* swamp. Sedge bog
6	Small	Flood-plains 200–1000 yd wide, 5–20 ft above river bed	Mainly fine-textured recent alluvial soils, locally stony and bouldery	Sword grass and shrub regrowth. *Casuarina* plantations
7	Very small	Channels		

Other important valley land systems, on which the Enga have dense settlement, are the Laiagam and Wongum systems. These are found commonly in the western part of the Enga region in the Laiagam-Sirunki area (Map 2).

Above the dense settlement of the Wabag, Laiagam and Wongum systems, and separating one valley population from the next, is the Ambum land system. This system is characteristic of the higher areas of Enga settlement and of the forests, through which the people travel and in which they hunt for possums. Again the relevant section from the C.S.I.R.O. (1965:24) is reproduced in full.

AMBUM LAND SYSTEM* (1550 SQ MILES)

Mountains on soft, non-calcareous, sedimentary rocks.

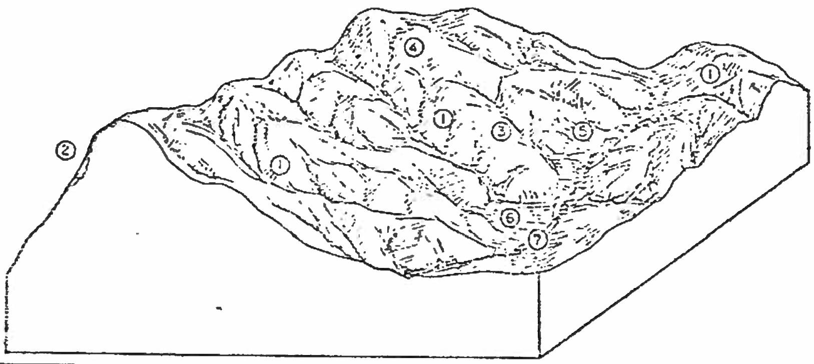
Geology.—Gently to moderately dipping greywacke sandstone, siltstone, and minor conglomerate, shale, marl, and limestone, partly of Mesozoic, mainly of Tertiary age; partly covered by Pleistocene ash.

Landscape Description.—Branching or parallel, steep-sided hill and mountain ridges, generally with narrow crests; locally with strong structural control, forming chevron ridges and minor cuestas. Strongly dissected by a rectangular or subdendritic pattern of narrow valleys with minor colluvial foot slopes.

Landscape Dynamics.—Steep slopes undergoing alternate weathering and slumping at moderate rates, with more rapid slipping in areas with ash cover. Active stream erosion. Slow build-up of colluvial aprons and embayment fills.

Altitude.—Mostly 4000–9000 ft. Some areas as low as 3000 and as high as 11,000 ft. Internal relief up to 2000 ft.

Population and Land Use.—Mostly unpopulated but 53,100 people are concentrated on 526 sq miles of land used for cultivation (lower, broader, and more gently sloping valleys).



Unit	Area	Land Form	Soil	Vegetation
1	Large	Normal steep slopes 20–40° and up to 500 yd long with rounded salients and re-entrants, undulating or hummocky surfaces	Mainly humic brown clay soils of Vakari family. Humic brown clay soils of Wapenamanda family on ash, gleyed plastic heavy clay soils of Kumundan family on shales	Sword grass and shrub regrowth. Gardens and garden regrowth. Lower montane rain forest (oak, beech, and mixed) especially above about 8500 ft. *Casuarina* plantations. *Imperata* and *Ischaemum* grasslands and *Leersia* swamp. Minor lowland hill forest below about 4000 ft
2	Medium	Unusually steep slopes 40–60° and up to 250 yd long with sharper salients and re-entrants	Mainly humic brown clay soils of Nenja family	Lower montane oak or beech rain forest. Sword grass and shrub regrowth
3	Medium	Dip slopes, mainly smooth, structural surfaces, 5–35° and up to 3000 yd long	Shallow humic brown clay soils of Nenja family with sandstone outcrop, humic brown clay soils of Wapenamanda family on ash	As unit 1
4	Very small	Minor rounded crests, up to 50 yd wide, with convex slopes attaining 35°	Mainly humic brown clay soils of Vakari family, some reddish clay soils of Herep family. Humic brown clay soils of Wapenamanda family on ash remnants	
5	Very small	Lower slope-embayments, concave slopes 3–15° and up to 250 yd long in colluvial embayments and alcove floors	Mainly humic brown clay soils of Vakari family, humic brown clay soils of Wapenamanda family on ash colluvium, some peaty soils of Mango family	
6	Very small	Gently concave colluvial aprons and toes attaining 10° and up to 400 yd long, locally hummocky or rolling surfaces	Humic brown clay soils of Vakari and Nenja families, gleyed plastic heavy clay soils of Laiagam family. Humic brown clay soils of Wapenamanda family on ash colluvium	Gardens and garden regrowth. Sword grass and shrub regrowth. Lower montane rain forest. Minor lowland hill forest below about 4000 ft
7	Very small	Channels up to 10 yd wide and up to 15 ft deep, ungraded and graded beds with boulder gravel		

*Comparable with Kuta and Koge land systems of the Goroka–Mt. Hagen area. Unmappable inclusions: Kaijende, Suma, Nop, Wongum, Andabare, Tsang, Laiagam, Tibinini, Kandep, and Kaugel land systems.

The altitude of settlement ranges from around 1,000m on the Lower Lai near Pauari (Map 2) to 2,700m at the Lai headwaters. However, population is not dense above approximately 2,300m due to the frequency of severe frosts which kill the staple crop of sweet potato.

2.3 CLIMATE

Various climatic data, mainly from Wabag, reported in C.S.I.R.O. (1965) are reproduced in Table 2.1 Mean annual rainfall is in the range of 2,134mm at Laiagam to 2,896mm at Wabag. Wabag temperatures are given in Table 2.1 and Waddell (1972b:16) estimates that mean maximum and minimum temperatures at Wapenamanda are 23.7°C and 12.5°C, respectively.

C.S.I.R.O. (1965:56) comments, with reference to the climate of the whole "Wabag-Tari" area:

> The most conspicuous feature is the lack of seasonal contrast in virtually all elements. The annual range of mean temperature is about 4°F, or only about one fifth of the average daily temperature range. Rainfall is high over the whole of the area, the lowest observed mean annual amount being 85in. In the northern part of the area a period of lesser rainfall over several months is characteristic, but nowhere are the falls so light as to justify reference to this interval as a "dry" season.

2.4 VEGETATION

Only the vegetation of the Wabag and Ambum land systems will be described since it is these systems which are the home of the Enga population studied in this thesis.

The Wabag system of densely populated valleys is characterised by secondary regrowth. This regrowth is mainly gardens and

TABLE 2.1

CLIMATIC DATA FOR THE ENGA REGION

(a) Rainfall

MEAN RAINFALL IN INCHES (a), MEAN NUMBER OF DAYS WITH RAIN (b), AND HIGHEST AND LOWEST ANNUAL TOTALS ON RECORD

Station		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Highest Annual	Lowest Annual
Laiagam	(a)	8·5	11·0	9·1	11·2	5·7	3·5	2·3	4·4	6·2	7·0	8·5	7·1	84·5	101·9	64·0
	(b)	26	22	26	26	16	13	14	17	18	19	21	21	239		
Wabag	(a)	12·9	11·7	13·6	13·3	8·0	4·7	4·7	6·4	9·5	8·0	9·7	12·4	114·8	131·9	99·9
	(b)	25	24	27	26	19	16	16	20	22	22	23	24	264		
Wapenamanda	(a)	18·8	9·6	11·0	11·4	5·1	3·9	5·0	5·2	8·0	6·1	7·5	9·3	90·9	100·9	82·2
	(b)	24	25	26	24	18	18	23	24	28	22	27	31	290		
Baiyer River	(a)	11·2	13·5	14·7	13·3	5·7	3·7	3·0	4·1	6·4	6·1	9·3	12·7	103·8	123·4	90·2
	(b)	24	24	25	24	14	13	12	12	16	17	18	23	222		

PERCENTAGE OF RAIN DAYS WITH RAINFALLS WITHIN SPECIFIED LIMITS

Amount (in.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Laiagam						
0·01–0·24	56	46	53	37	54	65	76	67	53	50	44	50
0·25–0·99	40	43	41	52	42	29	24	29	39	47	44	43
1·00–1·99	4	11	5	10	3	3	—	4	7	3	12	7
2·00–3·99	—	1	1	—	—	—	—	—	1	—	—	—
Mean no. of rain days	26	22	26	26	16	13	14	17	18	19	21	21
						Wabag						
0·01–0·24	41	46	44	36	40	63	61	59	48	43	42	42
0·25–0·99	49	41	39	53	54	31	9	36	39	47	50	46
1·00–1·99	9	12	15	10	5	5	5	4	11	8	8	11
2·00–3·99	1	1	2	1	1	1	—	1	1	1	1	1
Mean no. of rain days	25	24	27	26	19	16	16	20	22	22	23	24

MEAN DURATION OF RAINLESS PERIODS AND LONGEST RAINLESS PERIODS OBSERVED (IN DAYS)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Wabag (8 yr, 1953–60)						
Mean	1·9	1·8	1·3	1·6	2·6	2·6	3·1	2·4	1·6	1·9	1·9	1·7
Longest observed	5	7	4	3	11	7	12	11	4	5	6	5

(b) Temperature

MEAN MONTHLY AND ANNUAL TEMPERATURES AND HIGHEST AND LOWEST TEMPERATURES (°F) ON RECORD

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Wabag (6800 ft)													
Mean maximum	73·3	72·7	73·2	72·3	73·1	72·9	71·2	71·4	72·2	72·6	73·6	73·0	72·6
Mean	62·9	62·9	63·2	62·6	62·6	61·7	60·6	61·1	61·5	61·6	62·1	62·7	62·1
Mean minimum	52·5	53·1	53·2	52·9	[illegible]	50·6	50·1	50·8	50·8	50·6	50·6	52·5	51·6
Highest maximum	79·0	79·0	78·0	77·2	81·0	79·0	76·0	76·2	84·4	79·0	81·2	77·0	—
Lowest minimum	42·9	46·3	44·6	45·3	44·0	40·4	41·0	41·9	36·9	39·7	41·8	44·0	—

(c) Humidity

MEAN MONTHLY AND ANNUAL RELATIVE HUMIDITY (%)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
						Wabag							
9 a.m.	79	78	82	82	82	82	82	80	77	74	73	77	79
3 p.m.	71	70	71	63	59	62	64	61	72	62	67	69	66

(d) Cloudiness

MEAN MONTHLY AND ANNUAL CLOUDINESS (%)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
						Wabag							
9 a.m.	82	84	82	81	63	55	65	69	66	65	75	82	73
3 p.m.	92	96	94	90	84	76	85	82	86	85	91	93	88

Copied from C.S.I.R.O. (1965)

garden regrowth and thus features all the Enga garden cultigens and associated weeds. After 2 or 3 years of fallow, the garden regrowth is dominated by sword grass, Miscanthus floridus. Where Miscanthus regrowth has been repeatedly burnt it is replaced by short grass communities (particularly Imperata) which may become stabilised and maintained. Non-garden cultigens which are much in evidence are bamboo, Cordyline, Pandanus and large stands of Casuarina trees. Also found on the Wabag system are patches of Phragmites swamps, Leersia swamps and sedge bogs dominated by Cyperaceae.

The Ambum system is dominated by beech and mixed forest. The beech (Nothofagus spp.) are gregarious and form a dense canopy at about 32m. The mixed forest is mostly evergreen dicotyledonous trees, especially Cunoniaceae, Elaeocarpaceae and Lauraceae, but with many gymnosperms, especially Podocarpaceae. The lower parts of the Ambum system, where it borders the Wabag system, have been cultivated and thus feature regrowth communities similar to those described above for the Wabag system.

2.5 GEOLOGY, GEOMORPHOLOGY AND SOILS

During the late Mesozoic period, and again in the early and mid-Tertiary period, the area was part of the Papuan Geosyncline and great thicknesses of marine sediments were deposited. Much of the present day land surface is formed on Miocene sediments which vary from limestone to mixed limestone-mudstone. During the Pleistocene period, following Pliocene folding, uplift and erosion, great thicknesses of volcanic material were deposited, due to eruptions of Mt. Giluwe and Mt. Hagen. C.S.I.R.O. (1965:83) reports that the "Wabag land system consists of terraced Pleistocene valley fills and associated fans, deeply dissected by a moderately dense pattern of narrow streams".

The dominant soils of the Wabag land system are humic brown clays of the "Wapenamanda family" (C.S.I.R.O., 1965:88). These soils have a black to dark grey-brown A horizon, which is generally more than 0.38m deep, and which overlies a yellow-brown to strong brown B horizon of gritty texture. The Wapenamanda family of soils are generally well drained and permeable and have developed on volcanic ash. Alluvial soils, peaty soils and gleyed plastic heavy clay soils are also encountered on the Wabag land system. Further information on soils of the Enga region will be found in Rutherford (1964) and Pain (1973), and further details of soils in the Saka Valley will be given in section 13.1.1.

CHAPTER 3

THE CULTURAL SETTING : THE RAIAPU ENGA

3.1 THE ENGA

The term Enga is used here (and commonly by other authors) to designate a group of people who occupy the region shown in Map 2, excluding the Pogera Valley (where the Ipili live) and including the Kyaka Enga at Baiyer River and some Enga-speakers living at the head of the Kaugel Valley above Tambul. The Enga number approximately 160,000 people and thus form the largest ethno-linguistic group in Papua New Guinea, with each Enga subgroup displaying variants of a recognisable common culture and language. Wurm (1971:550) considers that the Enga language is a subfamily of the West Central Family (having approximately 270,000 speakers and including such important neighbouring groups as the Huli, the Mendi and the Wiru) which in turn is within the East New Guinea Highlands Stock, which includes most of the languages of the New Guinea Highlands.

A distinction is drawn between Central Enga and Fringe Enga. Fringe Enga are those at Baiyer River (known as Kyaka Enga), at Tambul, at Kandepe, at Kompiam, at Maramuni, and those in the extreme west near Muritaka. Central Enga occupy the Lai Valley, the Saka and the Laiagam region of the Lagaip Valley. They form a core population of the Enga region and exhibit consistently high population densities and a great uniformity of culture.

Central Enga may be roughly divided into ethno-linguistic subgroups as shown on Map 2. In the Laiagam-Sirunki area are the Yandapu, in the Wabag area live the Mae and in the Wapenamanda area live the Raiapu[1]. The Mae and Yandapu number approximately 41,000 while the Raiapu number 31,000, giving a Central Enga population of 72,000.

The Enga, and their neighbours, are among the best described peoples of Papua New Guinea. For ethnographic information on Fringe Enga, and neighbouring groups, one may consult Bulmer (1960a, 1960b, 1972) on the Kyaka Enga, Bowers (1965, 1968) on the Kakoli, Strathern (1971, 1972) on the Melpa and Ryan (1955, 1959, 1961) on the Mendi. For the Central Enga, Meggitt (see bibliography) on the Mae and Waddell (1969, 1972a, 1972b), Westermann (1968) and the author (Feachem, 1972, 1973a, b, c, d, e) on the Raiapu, may be consulted[2]. In particular it is due to the extensive work of M.J. Meggitt that so much is known about Mae society and, by extension, about Central Enga culture in general.

The site of this study is the Saka (the valley of the River Tare, see Map 2), which is populated by Raiapu Enga. A brief description of some important facets of Raiapu culture follows. Data that are reported derive mainly from the author's own ethnographic observations of the Saka Raiapu. However, use has also been made of publications by Waddell and Westermann on the Raiapu, and by

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1. The Yandapu and Mae are often considered jointly and called Mae. The Raiapu are sometimes (Meggitt, 1965) separated into the Raiapu of the Lai Valley and the Syaka of the Saka. The Raiapu are often called Laiapu in the literature.

2. This is merely a brief summary of some relevant publications. For a more complete list, see the special bibliography of non-medical Enga material at the end of this thesis.

Meggitt on the Mae, who closely resemble the Raiapu in most aspects of their culture.

3.2 RAIAPU SOCIAL ORGANISATION

The Raiapu, like the Mae, form a series of hierarchies of patrilineal descent groups, each of which bears the name of its putative founder. The largest of these patrilineal groups is the phratry [1] and Meggitt (1965:6) reports a mean Mae phratry size of 2,290, with a range of 920 to 5,400 persons. Westermann (1968:80) reports a mean phratry size for the Raiapu of 1,130.

Male members of a phratry consider themselves to be brothers and all claim agnatic descent from the eponymous phratry founder. This founder is said to have been the first settler on the land which the phratry now occupies, and some say that he was created by the sky people (yálvakali) [2], who also allocated the phratry's territory. The phratry may occupy a continuous stretch of territory but, due to the fortunes of war, most phratries are now scattered. The phratry is neither exogamous nor endogamous.

The phratry is not an important group in Raiapu daily life. Phratries never act collectively, whether for ceremonial or military purposes, and warfare is as likely to be intra-phratry as inter-phratry.

Phratries are made up of a number (on average 4.9, Westermann, 1968:80) of clans and it is these clans which are the single most important Raiapu descent group. Clansmen trace agnatic descent from

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1. For the definition of a phratry, and of other technical terms used in this chapter, refer to the glossary at the front of this thesis.

2. For discussions of sky people see Feachem (1973c), Meggitt (1972a) and Westermann (1968:205-207).

their putative clan founder, after whom the clan is named, and who is usually the son of the putative phratry founder. Westermann (1968:69) gives a mean Raiapu clan size of 225 with a range of 106 to 392, but my data on the Saka Raiapu will show a situation closer to that reported for the Mae (Meggitt, 1965:9), who have a mean clan size of 350 and a range of 100 to 1,000 persons.

The members of a clan occupy a continuous stretch of territory which is deemed to be a clan possession. This territory comprises a number of named localities, the name of one of which may be used to refer to the whole territory. A clan's territory typically stretches from a stream at the valley bottom up to the crest of a ridge and thus includes a range of ecological zones, including the forested ridge-tops which are important sources of possums, pandanus nuts and pig foraging areas. Borders between clans on opposite sides of a valley are normally formed by a stream or river and are not often subject to dispute. However, borders between neighbouring clans on the same hillside are frequently indefinite and subject to fierce dispute and ultimately warfare. My observations indicate that it is these undefined borders which are the single most important cause of the fighting which is such a prominent feature of the Raiapu region today. Even if a disputed border is not the stated cause for a fight, it is often a border which gives rise to the tension which leads to war on some other pretext. Inter-clan tension, and extreme uneasiness and suspicion, are some of the most striking characteristics of Raiapu society today[1].

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1. Meggitt (1972b) writes that "there has been a striking resurgence among Central Enga of interclan violence (fights, killings and arson) which can be directly attributed to the growing pressure on land resources stemming from population increase and the spread of commercial agriculture and animal husbandry".

Clans are ideally, and nearly always in practice, exogamous and so they comprise male agnates (or putative agnates), unmarried female agnates and wives from other clans. If the Raiapu clan ideals of agnatic recruitment, exogamy and patrilocal residence were strictly adhered to, then a clan would comprise only true agnates (all descendents of the clan founder), their wives and unmarried female children. In practice, however, each clan contains certain attached members who fall into none of these categories. Meggitt (1965:10) surveys 2 Raiapu clans and shows that, in one, only 96% of males are true agnates while, in the other, only 89% are so related. Most attached males are cognates rather than affines, and the reasons for the recruitment of non-agnates amongst the Mae is discussed at length by Meggitt (1965:25-48).

In view of the discrepancy between the patrilineal ideal and the flexible practice, anthropologists have argued over the extent to which societies like the Raiapu may be regarded as truly patrilineal, in the manner in which certain African societies are (Barnes, 1962, 1967, 1971; Langness, 1964; de Lepervanche, 1967/68). Barnes (1962) considers that they display cumulative patrifiliation rather than agnatic descent and Langness (1964) wonders whether descent groups are really cognatic with patrilineal bias or agnatic with accretions. The relative roles of kinship and residence in determining group membership are crucial and lead to the question; does a man belong where he lives, or live where he belongs?

The Raiapu, in my view, should be considered as a patrilineal society because the Raiapu themselves place great and explicit stress on agnation. It is true that all clans take in, or even actively recruit, non-agnates but, having done so, efforts are made to disguise the fact that these recruits are non-agnates. The

European mind may conclude that, in reality, it is residence which dictates group membership and that a recruit joins a clan simply through living on its territory (in other words, he belongs where he lives). This is one view of the situation but it is not a Raiapu view. The Raiapu, having admitted a non-agnate into a clan will then proceed to provide him with a distorted genealogy so that, at least his grandchildren may appear to be true descendents of the clan founder. A man who is known to be a non-agnate will not say, "I live here because my grandfather settled here many years ago and so my family now has rights to clan membership". Rather he will quote a false genealogy which will show him to be a true agnate, and other clansmen listening will usually not contradict [1].

It is primarily the association between a clan and its territory and the resultant need for clansmen to defend, or perhaps enlarge, that territory which makes the clan such an important social group. For the individual, clan membership provides both a genealogical and a residential identity. The function of the clan, aside from this territorial aspect, and the degree to which clansmen act collectively, vary very much from clan to clan and depend largely on the clan population. A large clan, of over 500 people, may never act collectively except in times of major war, to make a funerary wealth distribution following the death of an important leader, or to take part in the *tée* exchanges which will be discussed later. A large clan may even experience internal warfare which can lead to fission and the

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1. A young man in the Saka, who was well-known to me, was a first generation non-agnate in his adopted clan. The fact that his father was from Tambul was never publically referred to, or even admitted by the man concerned. He lived in the clan of his mother's second husband and only the most persistent questioning would reveal that his step-father was not his true father.

formation of 2 new clans (Meggitt, 1962b). A small clan, on the other hand, of under 250 people, may act collectively in war, for the *tée*, in mourning, in funerary wealth distributions, in various exchanges and compensations and even in buying a clansman's bride. A small clan may, especially if it feels threatened, be a fairly close-knit community and it may even exhibit a high degree of co-operation between clansmen; this is an unusual attribute amongst the Raiapu [1]. A small clan is most unlikely to fight seriously within itself, although petty feuds and squabbles occur continually.

Clans are composed of sub-clans which are themselves composed of patrilineages. The putative sons of the clan founder are usually the eponymous sub-clan founders, and similarly, the putative sons of the sub-clan founders are typically eponymous patrilineage founders. The sub-clans and patrilineages form patrilineal descent groups within the clan and provide social units for the activities which are too trivial to exercise the entire clan. The role which particular sub-clans and patrilineages play depends on their size, and a sub-clan in a larger clan may well behave like a small clan. Further discussion of Raiapu sub-clans and patrilineages appears in Westermann (1968: 65-72) and, for the Mae, in Meggitt (1965:14-19).

In summary, therefore, phratries are made up of clans, which are made up of sub-clans, which are made up of patrilineages, which

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1. These periods of threat correspond to the systole phase of the diastole-systole cycle discussed by Meggitt (1967). Meggitt describes a diastole phase of "relative peace and relaxation within the group and *vis-a-vis* other groups", followed by a systole state "of opposition, or actual conflict, between segments, especially between clans. Situations of segmentary opposition demand corporate activity and support". Meggitt argues that, during this later period of threat, the clan leaders forsake the well-known Melanesian Big Man model of leadership (Sahlins, 1963) in favour of a more rigid and authoritarian leadership.

are naturally made up of families. Table 3.1 sets out this descent group hierarchy and gives data on the size of each group. All these descent groups are ideally patrilineal and all except the phratry are ideally exogamous. It is the clan which is most relevant to the study reported here and it will be clans and their activities which are commonly referred to in the following pages [1].

3.3 LEADERSHIP AND BIG MEN

Although the Raiapu have no formalised, elected or inherited positions of authority, they are by no means a leaderless society. As in many Melanesian societies (Sahlins, 1963) the Raiapu have "managers who through skilful manipulation of wealth and social relationships have created personal followings that help to maintain them in positions of influence" (Meggitt, 1967). These managers have come to be called Big Men, in the literature on Melanesia, and the Raiapu refer to their Big Men as kamóngo.

The position of kamóngo is neither inherited nor ascribed but rather must be achieved by the ambitious individual through the display of certain desirable qualities. These qualities include wealth (which is not hoarded but which is used as a means to manipulate exchanges), generosity (a kamóngo seeks to make others obligated to him by the shrewd and generous distribution of his wealth), wisdom (a kamóngo must gain a reputation as an orator, an arbiter and a sage) and courage in war or other emergency. However, it is not correct to suggest (cf. Westermann, 1968:106) that the Raiapu are an egalitarian society and that all men who display the necessary qualities have an equal chance

1. This picture of Raiapu descent groups is highly simplified and there are many complexities, inconsistencies and irregularities of the rather neat hierarchial system of nesting segments which is described here.

TABLE 3.1

THE HIERARCHY OF CENTRAL ENGA DESCENT GROUPS WITH POPULATION SIZES

Descent Group	Raiapu Populations*		Mae Populations*	
	Mean	Range	Mean	Range
Phratry	1130	?	2290	920 - 5400
Clan	225	106 - 392[1]	350	100 - 1000
Sub-clan	60	10 - 248	90	45 - 145
Patrilineage	25	4 - 74	48	?
Family	4.5	2 - 12	5	2 - 14

* Raiapu data from Westermann (1968)
Mae data from Meggitt (1965)

1 Westermann's upper limit on clan size is certainly not correct for the Raiapu of the Saka (Table 4.1) where clan sizes rise to 947.

of becoming kamóngo.

The constraints which surround the possible rise of a young man to become a kamóngo are of 3 kinds. Firstly, there are "qualifications imposed by the nature of the social structure" (Meggitt, 1967). Meggitt continues, referring to the Mae but with equal validity for the Raiapu:

> What is significant among the Mae is the way in which the segmentary lineage system can function to predefine the personnel of the groups of followers even before they possess leaders. That is to say, 'followers' (who are largely allocated in agnatic terms) are the constant; it is they who demand and create leaders, rather than the more usual Melanesian pattern whereby leaders emerge by recruiting followers.

The second constraint is the need for wealth - wealth of all kinds but especially pigs, shells and money. An aspiring kamóngo is in competition with other aspiring kamóngo and so, to be successful, he must build up his economic position rapidly. To do this he must marry, preferably several times, and with his wives he must form a prosperous area of gardens on which to raise his pig herd (cf. Feachem, 1973b). To raise the wealth needed for wife purchase, to obtain sufficient arable land without antagonising one's fellow clansmen and to launch oneself into the complexities of exchange and inter-clan politics are all far easier if one is the son of a kamóngo, or at least of a prosperous and well-respected man. A poor man's son can become a kamóngo, but he would need to be exceptionally gifted and exceptionally fortunate to do so. The third constraint, and one which has not been referred to by previous writers on the Central Enga, is that of access to magic. Although magical abilities are not a prime kamóngo quality, and although ritual specialists and magicians (topóli) are seldom kamóngo (similarly for the Mae; Meggitt, 1967), nevertheless a Raiapu kamóngo is believed to possess certain magical spells (nemóngo) and ancient and sacred objects. It is by the performance of secret rituals, utilizing these spells and sacred objects, that the kamóngo strives to maintain or gain prominence in exchanges and particularly in the tée. Typically, people say that a kamóngo's spells will draw and compel his exchange partners to give generously to him at the next prestation. It appears that all kamóngo know and practise these rituals and that they generally possess ancient bundles of magical items which are believed to have great power and which are manipulated by the kamóngo in his rituals [1]. These bundles are said to be inherited by a kamóngo from his father and so, here again, we see that an aspiring kamóngo is greatly aided if his father is also a kamóngo.

Due to these constraints, and other factors, it is noticeable that Raiapu clans contain prominent families. Within these families will be found, not only most kamóngo and aspiring kamóngo, but also most of the prosperous and influential members of the clan and it is these families which exert a considerable influence in all aspects of clan politics. It is also from these families that children are more likely to attend school and perhaps eventually gain secondary and tertiary education.

It is noteworthy that a kamóngo has no badge of office and a stranger could not know from looking at a kamóngo, or at his house, that he was not a perfectly ordinary man. Kamóngo are usually middle-aged, since young men have not had time to build up their reputations and status, and old men lack the physical stamina which a kamóngo needs to constantly travel around the region and talk with exchange partners and other kamóngo. Kamóngo are gradually eclipsed by their younger rivals as they become senile.

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1. For more on these kamóngo rituals and magics see Feachem (1973c).

3.4 EXCHANGE AND THE TÉE

Having discussed kamóngo it is appropriate to discuss the primary preoccupation of most kamóngo, namely exchange and the manipulation of wealth. Wealth to the Central Enga is expressed mainly in terms of cassowaries, pigs, pearl-shells and money (Australian currency) and it is pigs, pearl-shells and money which are the basic commodities in Enga exchanges. These exchanges form "networks of ceremonial prestations" (Meggitt, 1971) and Meggitt adds that "not only do they link exchange partners in enduring dyadic relationships, as to some extent do trade ties, but they also connect corporate descent groups (such as clans, sub-clans and lineages) in highly formalised, public transactions". Meggitt also notes that these prestations are often associated with magic to bring good fortune, whereas trade is generally without magical associations.

Prosperous men, especially kamóngo, place great importance on success and prominence in exchanges. This is not because these activities are an end in themselves but mainly because, through exchange, a man may attain prestige and influence and, as his standing improves, so may the fortunes of his descent group. A clan which is successful in its exchange activities, and which has kamóngo of great status and renown, will be a strong clan and will be able to secure, or enlarge by warfare, its territory [1].

Exchanges take many different forms and occur in many different circumstances. Wealth is exchanged at funerals, at weddings, at the culmination of bachelor purification rituals (sandárú), at homi-

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1. Thus exchange leads to status which leads to security for the group, and particularly to territorial security. Meggitt (1971) comments that "the basic preoccupation of the Mae is with the possession of scarce arable land", and the same is true of the Raiapu.

cide compensations, following divorce, following illness, and most importantly, at the _tée_. The _tée_ is the great Central Enga exchange cycle and it provides "the ultimate rationale for the interlocking structure of prestations" (Meggitt, 1971). All minor exchange activity is geared to the demands of the forthcoming _tée_ and the explicit goal of all a _kamóngo_'s wealth manipulations is to achieve prominence in the _tée_.

Aspects of the _tée_ have been discussed by Bulmer (1960a) for the Kyaka, by Bus (1951), Elkin (1953) and Meggitt (1972b) for the Mae, and by Feachem (1973b) and Waddell (1972b:108) for the Raiapu. The _tée_ today extends to the Raiapu, the Mae, the Yandapu and sections of the populations at Kandepe, the Upper Kaugel, Baiyer River and Kompiam, and thus involves between 75,000 and 100,000 people. Ideally a _tée_ cycle takes about 5 years but this interval is becoming much longer due to the increasing complexity and size of the _tée_ [1] (Feachem, 1973b).

The _tée_ cycle features 3 principal phases. During the first phase, initiatory gifts are passed, say from east to west, with the direction alternating with successive _tée_ cycles. These gifts are inter-personal and establish the pattern of exchange partners and of alliances between _kamóngo_. They may be given privately, or more typically, use is made of some ceremonial gathering (a wedding, or a funerary distribution perhaps) to make gifts and establish partners. During this phase, _kamóngo_ will also seek to expand their personal influence, and the realm of the _tée_, by making gifts to individuals in peripheral groups, such as those at Kandepe or Tambul.

The second phase, and the climax of the _tée_, comes when _kamóngo_ believe that sufficient initial gifts have been made and call

1. The last complete _tée_ culminated in 1966-7 and the next one was far from complete in late 1973.

for the return of these gifts. Since, in our example, initiatory gifts have been passed from east to west, clans will start to demand repayment from their neighbours in the west. A series of large ceremonial prestations will then take place on a clan basis, starting in the west (i.e. the Sirunki-Laiagam region) and travelling via predetermined "roads" as each clan passes on its valuables (mainly pigs but also shells, cassowaries and, recently, cows). It may take over 6 months before this series of ceremonial prestations finally reaches the extreme eastern end (Baiyer River, Minyampu Valley and Tambul) at which time the process will be reversed with gifts of cooked pork travelling back along the exchange routes to the east. This final payment of pork is the third phase, after which a new <u>tée</u> will start with initiatory gifts this time flowing from west to east.

Today most Raiapu men take some interest in the <u>tée</u> and will make exchanges of pigs or other valuables. However, it is the <u>kamóngo</u>, and aspiring <u>kamóngo</u>, who dominate the cycle and who spend a large proportion of their time in <u>tée</u> politics in order that they, and their clan, may make an impressive showing and thus acquire prestige. Success in the <u>tée</u> is measured in terms of how much wealth passes through an individual's control and, particularly, on how many pigs he is seen to receive and to give at the climactic, second phase, prestations. These ceremonies take place on the clan's, or subclan's, ceremonial grounds which are generally referred to in this thesis as <u>tée</u>-grounds.

3.5 RELIGION

I have written elsewhere on Raiapu religious belief and ritual (Feachem, 1973c) and on the Raiapu response to Christian evangelism (Feachem, 1973a). Copies of these publications are appended to this thesis and the material will not be repeated here.

3.6 SETTLEMENT AND HOUSING

Neither the Raiapu, nor the Central Enga, reside in villages but rather they scatter their houses over the clan territories. Houses are typically located on terraces or slightly elevated locations and are often in dense groves of casuarina trees. They occur singly, in pairs, or recently in small groups which form hamlets around a focal point such as a church, a store or a _tée_-ground. These modern hamlets are often found on, or near, a vehicular road.

Because the housing is scattered, and in trees, it is partially camouflaged so that a stranger, viewing the Raiapu landscape from ground-level, is quite unaware that there are so many dwellings in his vicinity. In fact, the Raiapu world is a crowded one by New Guinean standards and clan population densities in the region vary from about 70 people per sq. km to over 300 per sq. km, with a mean clan density of perhaps 110 per sq. km.

I have distinguished 4 basic types of Raiapu house. Firstly, the "men's house" (_akárvánda_) is the male club-house in which an adult male will live with his brothers, his male children who are weaned, and possibly several male friends from the same sub-clan or patrilineage. His wife lives in a "women's house" (_éndánda_) with her female, and young male, children and the family's pigs. The men's house is circular and approximately 3m high in the centre and 1.5m high at the circumference. It is one roomed, although a portion furthest from the door is often partitioned off as a sleeping area. The women's house is rectangular, with one bay end, and measures approximately 10m in length and 3.7m in width. It contains 3 rooms; an outer sitting, cooking and eating room; a room with stalls for the family pigs; and an inner sleeping room. Both types of houses have a small doorway through which the visitor has to crawl, and the women's house also has an emergency (fire and attack) escape exit at the back. Neither house type has any ventilation except for the door and the natural ability of the grass roof to allow smoke to pass out. Meggitt (1957a) has described the houses of the Mae Enga. The Mae women's house is identical to that of the Raiapu except that the Mae favour an inclined roof apex whilst that of the Raiapu is horizontal. The Mae men's house is different from the Raiapu circular house but some Raiapu men live in small rectangular houses, similar to those of the Mae.

A man will probably locate his wife's house within easy walking distance of his own and they may be almost adjacent. A polygynist will build separate, widely-spaced houses for his wives to minimise the fighting that is common between co-wives, and to exploit efficiently his scattered sweet potato fields. A polygynist's pig herd will be divided between his wives. For a description of the male-female antagonisms which underly the sexual segregation of living quarters, Meggitt (1964) should be consulted.

In recent years, a new type of house has appeared and this I have called a "mixed house". It is occupied by a complete elementary family and its pigs and structurally it is identical to the traditional women's house. A fourth type of house, called a <u>nai ánda</u> by the Raiapu, is also found today and is a mixed house which is constructed in a European style (copied from the bush material houses used on mission stations as classrooms etc.) and not in the style of the traditional <u>éndánda</u>. They are usually square, with one room, and have a large door and adequate ventilation from small windows. The family pigs are stalled in a separate outhouse.

All Raiapu houses are constructed from the same materials. The basic frame is made of casuarina (<u>Casuarina</u> spp.) poles. The

TABLE 3.2

A TYPOLOGY OF RAIAPU HOUSES

Type	Enga Name	Dimensions	Usual Occupants	Comments
Men's	Akáryánda	Circular:- 5m diameter, 3.5m high or rectangular:- 6.5m long, 3.4m wide, 2.5m high.	Adult males with their male children over 8 years old.	Mostly circular. Traditional.
Women's	Éndánda	Rectangular with one bay-end. 11m long, 3.8m wide, 2.7m high.	An adult woman with female and young male children + pigs.	Traditional.
Mixed	Kitisenánda*	Identical to women's house.	An elementary family + pigs.	Encouraged by mission. Recent.
Nai Anda	Nai Ánda or Kitisenánda	Square, high roof and woven Miscanthus walls. Copy of Administration rest-house or school class-room.	An elementary family.	Pigs usually kept in separate outhouse. Recent.

* Literally "christian house" (ánda = house).

walls are split logs (Casuarina spp.), bark and grass (Miscanthus spp.), and the roof is a thick thatching of grass (Imperata spp.). The floors are of beaten earth covered with a layer of masticated sugar-cane pith, which provides an ideal habitat for many members of the phylum Arthropoda. Of special public health significance are members of the class Insecta such as cockroaches, fleas, beetles, bed-bugs and lice. Houses are also infested with mites and ticks (order Acarina) and particularly with Sarcoptes scabiei which give rise to the high prevalence of scabies in the area[1]. All houses are dry and dark and, when a fire is burning in the fireplace, extremely smoky.

Table 3.2 presents a summary of the features which distinguish the 4 Raiapu house types discussed here.

3.7 AGRICULTURE AND DIET

The Raiapu are primarily subsistence farmers and their staple crop is sweet potato (Ipomoea batatas). Sweet potato is cultivated in large mulched mounds which are set in extensive open fields. In highly populous areas the land may be cultivated almost continuously whereas, in others, the potato mounds are allowed to lie fallow after harvesting, and grass communities develop.

In addition to these sweet potato fields the Raiapu work mixed gardens which are on steeper land and which are typically drained and securely fenced to exclude pigs. In these mixed gardens, a great range of traditional and introduced vegetables are grown. Of particular importance for subsistence are taro (Colocasia esculenta), pumpkin (Cucurbita pepo), yam (Dioscorea spp.), banana (Musa spp.), winged bean (Psophocarpus tetragonobulus), sugar-cane (Saccharum officinarum), corn (Zea mays) and various leafy greens (such as

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1. Details of some of this animal life will be given in Chapter 19.

Oenanthe javanica). The Raiapu also cultivate many introduced vegetables, partly for their own consumption but mainly for sale to Waso Ltd., of Wapenamanda (see Fairbairn, 1967, for a discussion on Waso). These include beans, broccoli, cabbage, carrot, cauliflower, irish potato, lettuce, peas and tomatoes.

The Raiapu also cultivate Pandanus for their nuts, sweet flag (Acorus calamus) for magic and ceremonial purposes (Feachem, 1973c), bamboo for knives and house-building, casuarina for timber and fire wood, Cordyline for men's clothing (Feachem, 1972), Eleocharis sphacelata and E. dulcis for women's clothing, bread fruit (Ficus dammaropsis), and tobacco (Nicotiana tabacum) for smoking.

Since the early 1960s the Raiapu have cultivated coffee (Coffea arabica) and, more recently, pyrethrum (Pyrethrum cinerarifolium), for sale to local buyers. It is the sale of coffee, pyrethrum and vegetables which has provided the Raiapu with their main, indeed almost their only, source of cash income[1]. Coffee in particular has been adopted with some enthusiasm by the Raiapu and successful coffee growers have been able to make many hundreds of dollars.

Our knowledge of Raiapu agricultural practices is extensive due to the writing of Waddell (1972b) and the reader wishing more information on this topic is referred to Waddell's excellent book. Waddell (1972b:119) reports that, of the total agricultural production of the group surveyed, 49.2% was consumed by pigs, 42.6% by humans, 6.8% was sold and 1.4% was used as planting material. Further, 63.9%

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1. Alternative sources of income for the Raiapu are either local work (with government or mission) or, for the adventurous and young, work in an urban centre. The number of local work places are extremely limited, and men travelling to find work in towns often return with little or no money saved. The sale of coffee, vegetables and pyrethrum therefore becomes the only substantial source of monetary input for the Raiapu community.

of the sweet potato crop was fed to pigs. These figures reveal the enormous effort, over and above that necessary to support the human population, that the Raiapu must put into their agriculture if they are to support their pig herds and increase them to the desired size of more than 2 pigs per human (Feachem, 1973b). A huge input of energy into agriculture is required to support the pig herds, which are then used, not as a source of protein-rich food, but as prestige-markers and as the basic currency of the <u>tée</u> exchange.

Waddell (1972b:121-128) also gives useful data on Raiapu diet, and this will be briefly summarised here. Of the total daily food intake by weight, 63% is sweet potato. Approximately 2,400 calories per day are consumed and about 73% of these are from sweet potato. The daily protein intake is between 29g and 35g with about 32% of protein deriving from sweet potatoes. Other important sources of protein are yams, banana, tinned fish and pulses and approximately 44% of the protein intake comes from the vegetable produce of the mixed gardens. Raiapu diet compares favourably with Chimbu dietary data (Hipsley and Kirk, 1965) and the Raiapu adequacy, especially of protein, appears to be related to their ability to allocate scarce land for vegetable growing in mixed gardens. Should rising populations, and greater demands for land on which to cultivate coffee, reduce the size of Raiapu mixed gardens, then one can anticipate a fall in protein availability. However, this could be offset by the expenditure of coffee profits on trade-store food (such as tinned fish and rice) which, at present, account for only $3\frac{1}{2}$% of the calorie intake and 10% of the protein intake.

From Waddell's data it is apparent that pork, to the production of which such a substantial agricultural effort is devoted, provides, at the most, 5% of the daily protein intake and, more typically, provides no protein since pork is rarely eaten except on ceremonial occasions. This is a facet of what appears to me to be an interesting paradox of

Raiapu society. Energy and land are devoted to additional agriculture in order to raise pig herds; these are then used as prestige-markers and enable kamóngo (and their clans) to take part successfully in the tée exchanges; this leads to generally improved fortunes for the successful clan which will attract wealth and brides and will grow in size and prestige; the prospering clan will then find that, if it is to maintain its growth and particularly if it is to maintain, or increase, its pig to human ratio, it must expand and take over new land; the need for new land will lead to warfare with neighbours and the whole cycle will begin again. In other words, we see a cycle of growth, expansion, more growth etc. which will continue until the expanding clan meets a stronger neighbour or until internal frictions cause the clan to fragment (cf. Meggitt, 1962, 1967). The pig is the central item of this cycle since it is the acquisition and manipulation of pig herds which enables the clan to become great and grow, and it is the large agricultural effort and land allocation needed to support the pig herds which give rise to acute pressure on land and thus to the need to expand.

The paradox lies in the fact that, despite the crucial importance of pig husbandry in the control of these cycles of clan growth, and despite the fact that the Raiapu habitually support large pig herds (Feachem, 1973b), yet the great potential of these pigs as a source of protein to a protein-deficient people goes almost completely unused. Pork is seldom consumed except on ceremonial occasions and those in greatest need of extra protein (children, pregnant and lactating women and the sick) may consume no pork for months on end. One solution to the growing problem of land shortage and population growth which faces the Raiapu today, is the rationalisation of pig husbandry so that this large and established source of protein-rich food may be put to better use.

3.8 DEATH AND MOURNING

Clearly one could continue at some length to give brief sketches of aspects of Raiapu culture. Space does not permit this here, but it is appropriate to mention one final facet of Raiapu life; namely the community's response to death.

The Raiapu use the word kumánda to refer to a period of mourning which follows a death, and particularly to refer to a ceremonial wealth distribution which terminates this mourning period. The kumánda is of importance because it is the only large public ceremony which the Raiapu hold regularly and often, and also because it is "one of the most formalised and significant features of the relatationship between a man and his maternal kin" (Meggitt, 1965:214). In terms of this thesis the kumánda is important because a death occurred during the morbidity survey reported in Part IV and this provided an opportunity to evaluate the influence of housing on health (see Chapter 19).

Although the kumánda will vary in scale depending on the age, sex and status of the deceased, the basic form of Raiapu funerary behaviour remains the same. Immediately the death is confirmed, the news will be yodelled up and down the valley and all concerned persons will rapidly gather on the tée-ground of the deceased's clan or sub-clan. A period of several hours of intense wailing and public grief will then take place during which men may remove their wigs, cut their hair and pluck their beards, while close female relatives of the deceased may amputate one or more finger ends.

This short period of public grief is followed by a far longer period of mourning. This mourning may last from a few days to 8 or 10 weeks, depending on the degree of tragedy attached to the death. The other extremely variable characteristic of mournings is the number of people who take part. An important man will be mourned by his entire clan, if his clan is small, or by at least one sub-clan, if his clan is large. On the other hand, old persons, especially old women, who die may be only mourned by their family, or at most by their patrilineage. Despite the variability in the scale of these two elements of the mourning (the duration and the number of mourners), the basic form of the mourning is fairly uniform.

During mourning, all normal daily activities cease. Male mourners spend their time sitting and talking, or perhaps visiting the natal clan of the deceased's mother to discuss the forthcoming wealth distributions. Male gardening tasks cease, as do all cash cropping activities with coffee, pyrethrum and vegetables. Male mourners even eschew the ubiquitous card games which have become the foremost pastime of many Raiapu men. Adult female mourners confine themselves indoors during the period of mourning. They do no work in the gardens and very rarely leave their houses. Food is brought to them by fellow clansfolk who are not mourning (if the entire clan is not taking part) and by friends and relatives from other clans. Both male and female mourners are likely to move to different houses during this period. If an entire clan is mourning, many of the clan's houses will be left empty while the clansfolk crowd into certain selected houses.

When the mourning period is over, the close agnates of the deceased will organise a ceremonial wealth distribution. These distributions are complex and cannot be fully described here[1]. The principal theme is the compensation of the deceased's maternal kinsmen, by the deceased's agnates, in recognition of the belief that a

1. Meggitt (1965:181-217) has described the Mae <u>kumánda</u> in some detail, and that of the Raiapu is similar in many respects.

[error in pagination: no p. 43]

man's flesh and blood come primarily from his mother, whereas his spirit is inherited agnatically from, or through, his father. The maternal origins of a man's body give his maternal kin the right to demand indemnity from his agnates in the event of injury or death, and particularly so if the death is due to attack by agnatic ghosts (timóngó), which implies that the deceased's agnates have been negligent in placating the clan's ghosts and protecting their fellow clansmen. Therefore the main flows of wealth at the distribution ceremonies are from deceased's agnates to deceased's maternal kinsmen, from deceased's agnates to deceased's matrilateral relatives, and from the mourning group to those who provided food and fuel during the mourning.

CHAPTER 4

THE STUDY SITE

Following the brief picture of Raiapu culture presented in Chapter 3, the site of the study reported in this thesis will now be described. All investigations were made in the Saka Valley (Map 2) and most were made on the Tombeakini clan, who live at Lyokote in the south-eastern Saka. It was the Tombeakini clan with whom the author resided during 1971. Chapter 4 will firstly describe the Saka and, secondly, the Tombeakini population and their local environment.

4.1 THE SAKA VALLEY

The Saka Valley (also known as Tschak, Sark, Tsak, etc.) is the valley of the River Tare and its major tributaries the rivers Tobaka and Wakema. The Saka (shown in Map 3) is a broad open valley measuring approximately 15km by 10km and falls mainly within the Wabag land system (C.S.I.R.O.,1965 and section 2.2). The valley floor is between 1,850m and 2,000m above sea level and the hills which encircle the valley rise to 2,600m, are densely forested and fall within the Ambum land system (C.S.I.R.O.,1965 and section 2.2). Also within the valley are small, but very prominent, areas of rugged limestone ridges (Kaijende land system) and an area of dissected volcanic slopes (Nemarep land system).

Although the early Leahy expedition missed the Saka (Leahy, 1936), James Taylor's "Hagen-Sepik Patrol" set up a camp in the valley during 1938-39 (Taylor, 1940) and sustained contact with the Saka Raiapu began in the early fifties. In the early and mid-fifties, the Catholic and Lutheran Missions both established stations in the valley (Map 3) and the missionaries have provided the only permanent

MAP 3 THE SAKA VALLEY

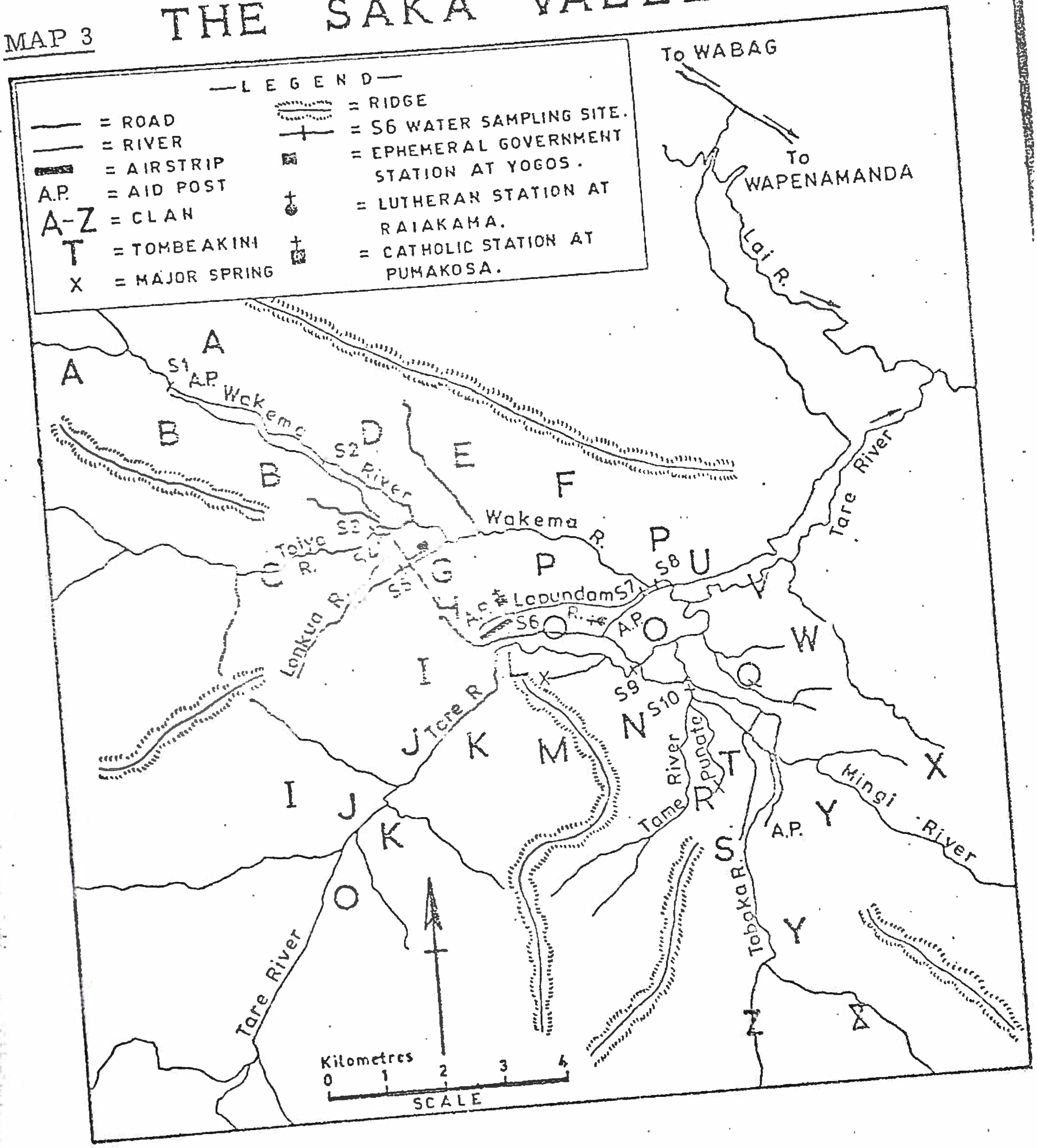

TABLE 4.1

THE PHRATRIES AND CLANS OF THE SAKA VALLEY WITH ESTIMATES OF THEIR POPULATION

Putative Origin	Phratry	Clan	Population
Descended from Pembe of the Saka	Waimini	Yanga (U)	437
		Kombanikini (V)	
		Indapatakini (W)	296
		Several clans just outside the Saka entrance	?
	Pauahaka	Walupu (Z)	444
		Penale (X)	
		Kanipianda (L)	213
		Yakaemandani (Y)	947
	Yambatani	Watenge (O)	779
		Pausa (P)	777
		Yana (N)	367
		Mama (G)	189
		Yandamau (E)	203
		Poyo (K)	401
From the Saka	Tsigini	Mamakini (I)	261
		Yopo (C)	805
		Palinau (A)	597
		Waimbau (B)	389
		5 clans now living in the Lai Valley	?

Table 4.1 Cont'd.

Putative Origin	Phratry	Clan	Population
From the Lai Valley	Itokoni (D)	Rajatakini	250
		Karakuni	
		6 clans living in the Lai Valley	?
From Wabag	Kalya	Gipini (J)	183
		Ulindani (H)	396
		Wambulini (M)	189
From the Lai Valley	Aruni	Keepe (F)	440
		Several clans from the Lai Valley. (See Waddell, 1972b:18)	?
From the Upper Kaugel Valley	Lyomoi	Tombeakini (T)	211
		Tashikini (Q)	270
		Ipalangane (X)	199
		Pindakini (S)	399
		3 clans at Tambul, 2 at Walya and 2 at Mendi	?
	?	Yanuni (R)	321
		Several clans at Tambul	

NOTE Letters in parentheses refer to the clan locations on Map 3. This view of the Saka clan map is that held by Tombeakini clan. Others would divide the valley slightly differently. In particular, some Raiapu would consider the large clans Yakaemandane and Pausa to be sub-phratries and further divide them into clans. See Waddell (1972b:18) for a similar discrepancy of opinion.

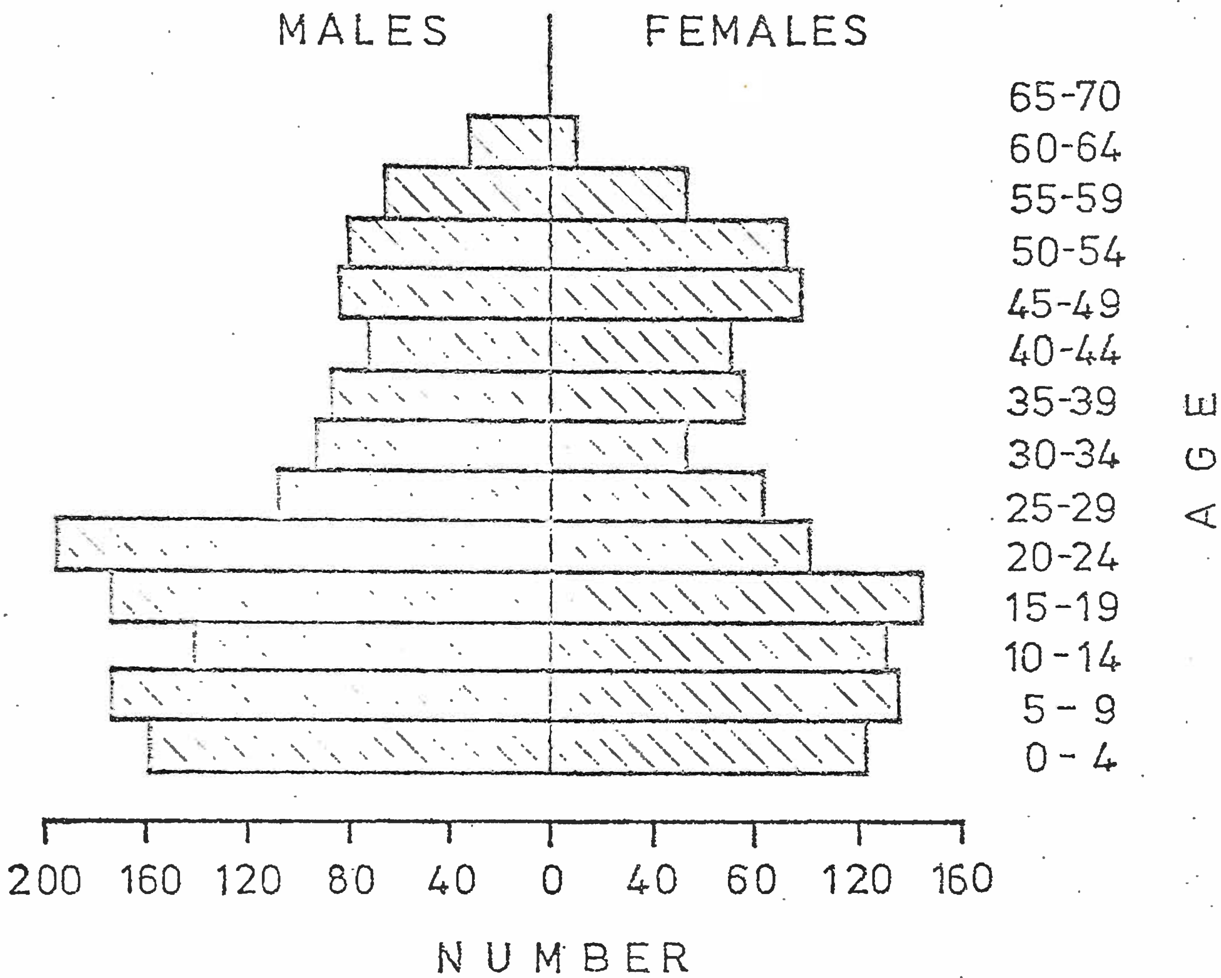

FIG. 4.1 AGE-SEX STRUCTURE OF 8 CLANS IN THE SOUTH-EASTERN SAKA

white presence in the Saka up to the present time. The valley is now linked, by a feeder road, to the Highlands Highway which runs down the Lai Valley from Wabag to Wapenamanda (Map 2) and thence over the Hagen Range to Mt. Hagen, Goroka and the coast at at Lae (Map 1).

The Saka is a densely populated valley in which approximately 10,000 Raiapu Enga dwell. It contains the elements of 9 phratries with a total of 28 clans. Table 4.1 tabulates the phratries and clans of the Saka and gives estimates of their populations taken from the 1972 government census. A total of 28 Saka clans have a population of 9,963, giving a mean clan size of 356 and a range of 183 to 947. A glance at Table 3.1 shows that the Saka Raiapu clan sizes resemble those reported by Meggitt for the Mae, rather than those reported by Westermann for the Lai Valley Raiapu. Only 2 phratries lie completely within the Saka; namely, Pauakaka (with 4 clans and a population of 1,60[illegible]) and Yambatani (with 6 clans and a population of 2,716). These phratries, and especially the large clans Yakaemandane, Watenge and Pausa, exercise considerable power in the Saka and play a dominant role in politics and exchange. The letters in parentheses following the clan names in Table 4.1 refer to the clan locations which are shown on Map 3.

Figure 4.1 shows the age-sex structure of the clans Ipalangane, Penale, Pindakini, Tashikini, Tombeakini, Walupu, Yakaemandane and Yanuni of the south-eastern Saka (Map 3) according to the 1971 government census. This population totals 2,679 and 33% are under 15 years. This is a low under-15 population, since Vines (1970:47) reports an overall figure of 38% for his Highlands region sample of 1,056 individuals, and Keesing (1941, cited by Vines) considers that "a primitive population" must have an under 15 years segment of over 40% to be considered thriving. The replacement ratio

$$\left[= \frac{\text{children } 0-4 \text{ years}}{\text{women } 15-44 \text{ years}} \right]$$

for the Saka population is 0.52, which is higher than the Highlands' figure of 0.45 (Vines, 1970:52). Life expectancies of males are greater than of females (similarly with Vines' population) and 55.1% of the Saka population is male, whereas Vines reports only 51.1% for the Highlands [1]. Figure 4.1 indicates a deficiency in the 20 - 40 years age group, which could relate partially to the 1941 dysentery epidemic, and to a general increase in mortality rates in the forties and early fifties following the opening up of contact between the Enga and the outside world [2]. It may also be partly an aberration of the data due to the inaccuracy of government census procedures [3] (cf. Sturt and Stanhope, 1968).

4.2 TOMBEAKINI CLAN

During 1971 the author lived with the Tombeakini clan which is indicated on Map 3 with a T. Most data reported in Parts II and IV of this thesis are drawn from the study of Tombeakini clansfolk and the pollution study, reported in Part III, concerns the water

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1. Hunt <u>et al</u> (1965) report neonatal sex ratios from Yap, American Samoa and New Guinea (Huon Peninsular) of 52.3%, 51.3% and 51.9% male, respectively.

2. The establishment of this contact with the Enga almost certainly introduced exotic pathogens into the region. For instance, Ward (1957/58) reports no tuberculosis among the Mae Enga in the mid-fifties and the Mae had an epidemic of this disease in 1973.

3. The 1941 dysentery epidemic is discussed in Chapter 19 and the government census procedures are discussed in Chapter 18.

sources in or near Tombeakini territory.

Tombeakini territory is shown on Map 4, and Figure 4.2 gives a profile of the territory from the peak in the south to the River Tobaka, just west of the road bridge, in the north. Map 4 shows the areas devoted to sweet potato cultivation and other land use categories (marked by capitals B - G) which are described and measured in Table 4.2. Figure 4.2 shows that most of Tombeakini territory falls within the Wabag land system (see section 2.2), while its southern border is formed by a steep-sided limestone ridge which is classed as part of the Kaijende land system (C.S.I.R.O., 1965).

A member of Tombeakini clan is defined in this thesis as a person who habitually (and particularly during 1971) lives on the Tombeakini territory and considers himself to be a Tombeakini clansman. This excludes those persons (approximately 15 in number) who, although still calling themselves Tombeakini, have settled in other clans. During 1971 there were 211 Tombeakini members according to the above definition and, since the total area of land claimed by Tombeakini is 0.56 sq. km, a population density of 377 people per sq. km is derived. This density (which equals 980 per sq. mile) is extremely high by New Guinean standards. However, excluding land which is disputed (some of which is used by Pindakini, as shown on Map 4), a density of 515 per sq. km (1,338 per sq. mile) is obtained. Excluding land which is of no agricultural use (categories D and G; Map 4 and Table 4.2), in addition to that land claimed by Pindakini, a density of 620 per sq. km (1,610 per sq. mile) is obtained. These figures reveal an extremely densely settled region and suggest the possibility of considerable pressure on agricultural resources. This dense settlement results partially from the fact that Tombeakini

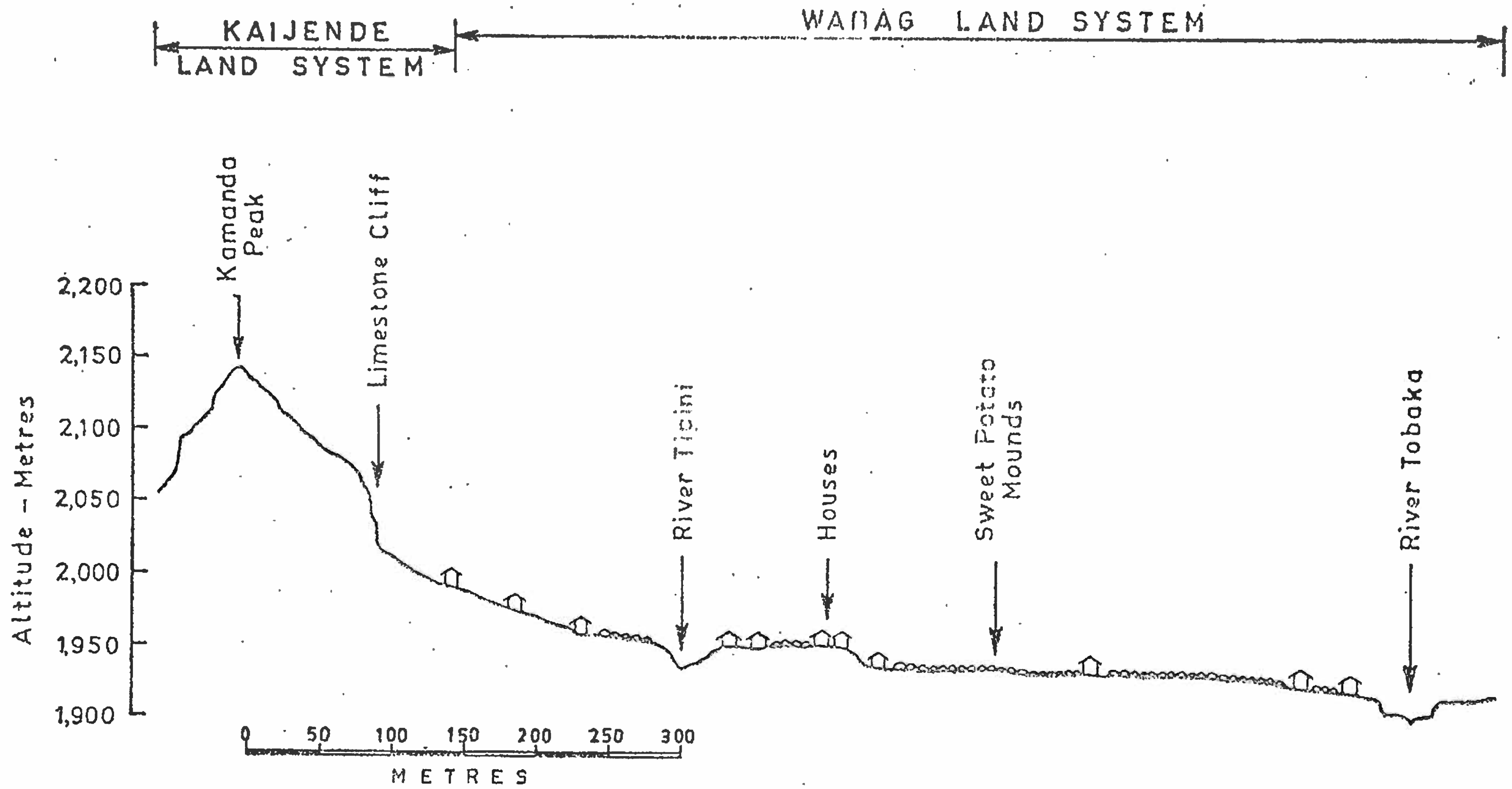
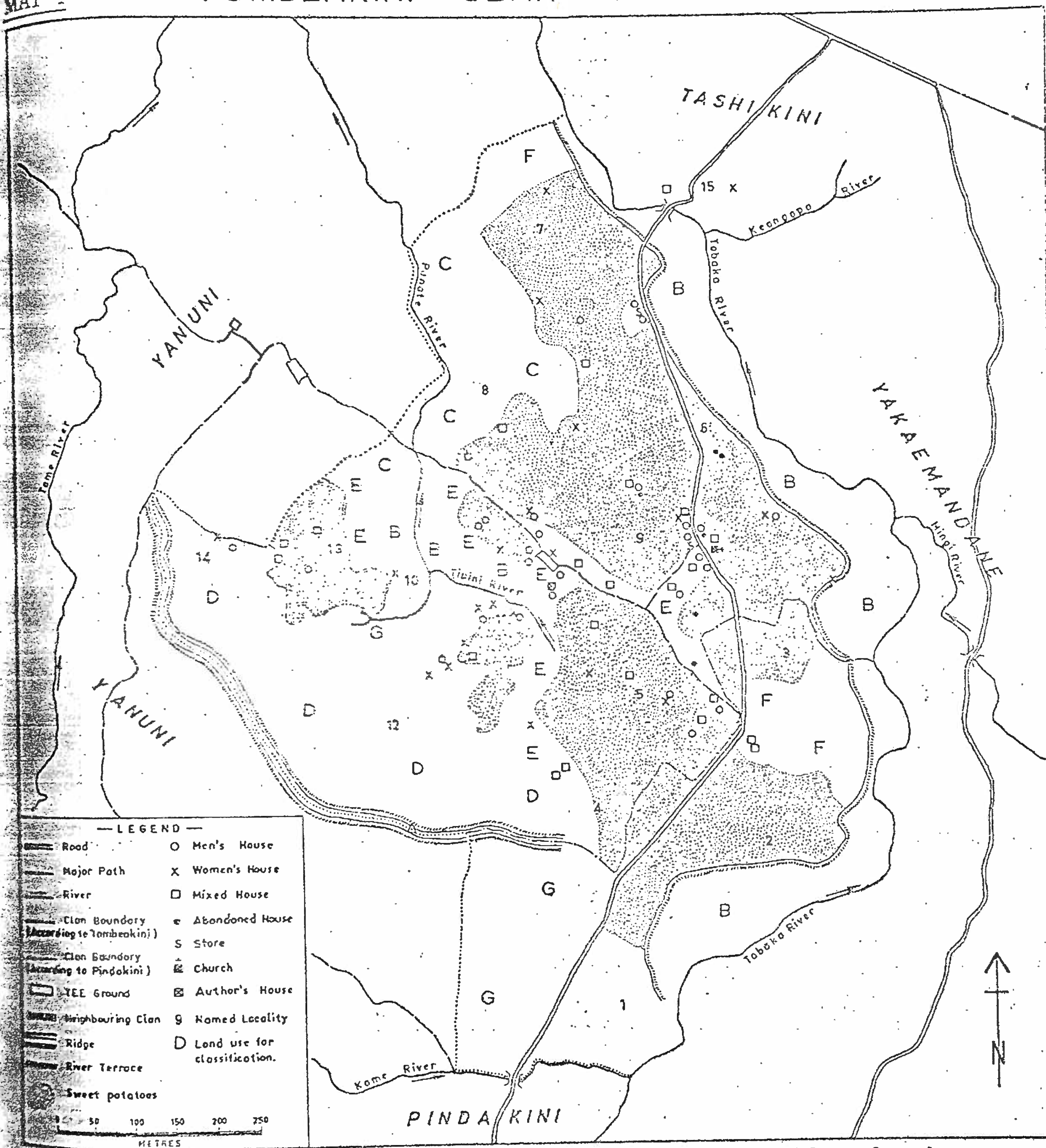


FIG. 4.2 PROFILE OF TOMBEAKINI TERRITORY FROM KAMANDA PEAK IN THE SOUTH TO THE RIVER TOBAKA, JUST WEST OF THE ROAD BRIDGE, IN THE NORTH

MAP 4 — TOMBEAKINI CLAN TERRITORY —



For explanations of the land use classification see Table 4.2 and for a list of the named localities see Table 4.4.

TABLE 4.2

LAND USE CLASSIFICATION OF

TOMBEAKINI TERRITORY (SEE MAP 4)

CATEGORY	AREA sq. km.	% OF CLAN AREA	DESCRIPTION	UTILISATION
Sweet Potato Fields	0.21	38	Extensive open fields in which Ipomoea batatas is cultivated in large mulched mounds	Produces dietary staple and supports pig herds.
B	0.09	16	Swampy river flats with casuarina stands and ponds for kuta cultivation	Casuarina oligodon for timber. Kuta (Eleocharis sphacelata and E. dulcis) for women's aprons. Pig foraging.
C	0.04	7	Grassy swamps	Some taro (Colocasia esculenta). Pig foraging.
D	0.07	13	Steep hillside with grass, shrubs and limestone out-crops.	Miscanthus floridus and Imperata cylindrica for house construction. A little honey. Caves used as retreats in times of war.
E	0.08	14	Mixed gardens and coffee gardens.	Wide range of traditional and introduced vegetables and coffee. Often sold to provide main source of cash income
F	0.03	5	Sweet potato garden lying fallow or with disputed ownership.	Pig grazing
G	0.04	7	Steep hillside with cover of trees and scrub. Also limestone outcrops.	Pig foraging and timber. A little honey.

territory lies almost completely on fertile terraces, whereas most clan territories stretch up to steep and forested ridge-tops and thus have lower overall clan densities. Waddell (1972b:17) reports that Aruni have an overall density of 71 per sq. km, whereas one community within Aruni, who occupied a fertile terrace section, had a local density of 690 per sq. km, and another neighbouring community had a local density of 420 per sq. km (1972b:21). The reasons why Tombeakini occupy only mid-valley land and are surrounded by other clans (Maps 3 and 4) are mainly connected with the arrival of Tombeakini, and 3 other clans in the Lyomoi phratry (Table 4.1), from the Kaugel Valley in approximately 1910. These clans have had to fight to gain and retain sufficient arable land and the 2 smallest clans (Tombeakini and Ipalangane) have not succeeded in controlling desirable or adequate territories. Tombeakini has become surrounded by powerful neighbours and is continually in danger of losing what little land it has, while Ipalangane has retreated to dwell high on the hills overlooking the valley (Map 3, symbol X) with little flat land on which to cultivate sweet potato.

Using the total area claimed by Tombeakini, figures of 0.10ha per capita of sweet potato field, 0.028ha per capita of mixed gardens and 0.01ha per capita of coffee and pyrethrum cultivation are obtained. Waddell's sample (1972b:116) had 0.11, 0.04 and 0.02 ha per capita of sweet potato, mixed garden and cash-cropping land, respectively. This comparison indicates that the pressure on agricultural land has forced Tombeakini to cut down on land allocated for mixed gardens and coffee, in order to keep the area under sweet potato at a desired level of about 0.1ha per capita. In section 3.7 it was shown that mixed garden produce is crucial in the maintenance of the Raiapu Enga protein intake levels, and therefore it is to be expected that Tombeakini, and other similar clans who lack adequate space for vegetable gardens, will receive a less adequate diet than their more fortunate neighbours.

Tombeakini recognise 5 sub-clans, the founders of which are said to be the sons of Tombeakini. Table 4. 3 identifies these sub-clans and also shows the position of Tombeakini within the scattered Lyomoi phratry. Map 4 indicates 14 named localities, into which Tombeakini divide their territory. Table 4.4 identifies these localities and gives the approximate numbers of houses (excluding the author's house and abandoned houses) in each locality. It will be seen from Table 4.4 and Map 4 that houses are scattered throughout the territory with the exception of Keambuanda and Tobakaposa, which are the localities under dispute with Pindakini. Two prominent clusters of houses are noticeable on Map 4; one around the <u>tée</u>-ground and the other around the church and the store and situated on the road. Both these hamlets fall within the locality called Lyokote and thus Table 4.4 shows that Lyokote containd 34% of Tombeakini houses. The name Lyokote is frequently used by members of other clans to refer to the entire Tombeakini territory.

Three types of house (men's, women's and mixed) are marked on Map 4, and abandoned houses are also shown. The house types are defined in accordance with Table 3. 2, except that Tombeakini's one <u>nai ánda</u> is classed as a mixed house and not separately marked. Table 4. 5 shows that 69% of Tombeakini houses contain between 1 and 3 people and that 45% of clansfolk live in these houses. The maximum number of residents per house is 8. Table 4. 6 shows that 48% of the clan now live in the new mixed houses, whereas traditionally a man would nearly always live in a separate house from his

TABLE 4. 3

CLANS OF THE LYOMOI PHRATRY WITH SUB-CLANS OF TOMBEAKINI

Phratry	Clans	Tombeakini Sub-Clans	Location
	Ipalangane (199)		
	Pindakini (399)		
	Tashikini (270		
Lyomoi	Tombeakini (211)	Kande Kiapakini Koimba Panyambe Waimba	THE SAKA, (See Maps 3 and 4)
	Tsigidakini	The Minyampu Valley near Walya	
	Tsangopakini		
	Iogun	The Upper Kaugel Valley, above Tambul	
	Tendepo		
	Yanan		
	Pupu	Near Mendi	
	Yagump		

NOTE Figures in parenthesis are populations.
This table gives the Tombeakini view of the Lyomoi phratry

TABLE 4.4

TOMBEAKINI NAMED LOCALITIES AND HOUSE DISTRIBUTION

(See Map 4)

No of Locality Map 4	Locality Name	No. of Houses
1	Keambuanda	0
2	Tobakaposa	0
3	Potaiakama	7
4	Kopeanda	2
5	Kamogotisa	6
6	Tobakamanda	7
7	Kokyaparisa	1
8	Kalipandisa	3
9	Lyokote	24
10	Punataposa	3
11	Tipinaposa	5
12	Kamanda	6
13	Yangimanda	4
14	Talyokosa	2

TABLE 4.5

TOMBEAKINI HOUSEHOLD SIZES

No. of Residents per House	No. of Houses	Percentage of Total No. of Houses	No. of Residents	Percentage of Clan Population
1	14	20	14	7
2	21	30	42	20
3	13	19	39	18
4	5	7	20	9
5	10	14	50	24
6	5	7	30	14
7	0	0	0	0
8	2	3	16	8
All Houses	70	100	211	100

TABLE 4.6

RESIDENCE PATTERN OF TOMBEAKINI BY HOUSE TYPE

Type of House	No. of Houses	Percentage of Total No. of Houses	No. of Residents	Percentage of Clan Population	Average No. of Residents per House
Men's	26	37	56	27	2.1
Women's	21	30	54	25	2.5
Mixed	23	33	101	48	4.3
All Houses	70	100	211	100	3.0

TABLE 4.7

RESIDENCE PATTERN OF TOMBEAKINI BY GENERATION

No. of Generations per House	No.of Houses	Percentage of Total No. of Houses	No. of Residents	Percentage of Clan Population	Average No. of Residents per House
1	22	32	32	15	1.4
2	45	64	167	79	3.7
3	3	4	12	6	4.0
All Generations	70	100	211	100	3.0

wife [1]. Mixed houses are seen to have nearly twice as many occupants per house as either men's or women's houses. Table 4.7 shows that 64% of Tombeakini houses (containing 79% of the clan population) contain 3 generations of occupants. No house contains more than 3 generations and indeed there are no Tombeakini families in which more than 3 generations are alive. The 211 members of Tombeakini live in 70 houses and thus have a mean household size of 3.

The age-sex structure of the Tombeakini clan is shown in Table 4.8 and Figure 4.3. The under 15 years proportion is 37% which indicates that Tombeakini is more youthful than the Saka (33% under 15) and similar to the Highlands (38% under 15). The replacement ratio for Tombeakini is 0.63, which is higher than that for the Saka (0.52) and than that for the Highlands (0.45). This youthfulness, and elevated replacement ratio, indicates a healthier demographic picture for Tombeakini than for the Saka, or for the Highlands as a whole. The preponderance of males in all age groups (except 20 - 24 and 35 - 44) of Tombeakini is striking, as is the greater life expectancy for males.

Of the 67 Tombeakini males of over 20 years, 17 (25%) are bachelors, 1 (1.5%) is divorced, 7 (10%) are widowers, 2 (3%) have 2 wives and the remaining 47 (70%) [2] have 1 wife each. Of the 125 male Tombeakini clansmen, 5 (4%) are first generation non-agnates whose natal clans are not Tombeakini.

Of the Tombeakini male population, 32 (6%) speak neo-

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1. It is to be expected that the proportion of Raiapu who live in mixed houses will increase steadily, as traditional male views of female pollution are modified.

2. Note that this figure 47 is equal to the total number of Tombeakini women over 20 years of age.

TABLE 4.8

AGE-SEX STRUCTURE OF TOMBEAKINI CLAN

Age	TOMBEAKINI CLAN POP. 211					
	Males		Females		Total	
	%	Number	%	Number	%	Number
0 - 4	9.0	19	5.2	11	14.2	30
5 - 9	7.1	15	3.8	8	10.9	23
10 - 14	6.6	14	5.2	11	11.8	25
15 - 19	4.7	10	4.3	9	9.0	19
20 - 24	2.8	6	4.7	10	7.6	16
25 - 29	4.3	9	1.9	4	6.2	13
30 - 34	4.3	9	1.9	4	6.2	13
35 - 39	2.8	6	5.2	11	8.0	17
40 - 44	4.7	10	4.7	10	9.5	20
45 - 49	5.7	12	2.8	6	8.5	18
50 - 54	2.8	6	0.9	2	3.8	8
55 - 59	1.9	4	0	0	1.9	4
60 - 64	1.9	4	0	0	1.9	4
65 - 69	0.5	1	0	0	0.5	1
All ages	59.2	125	40.8	86	100	211

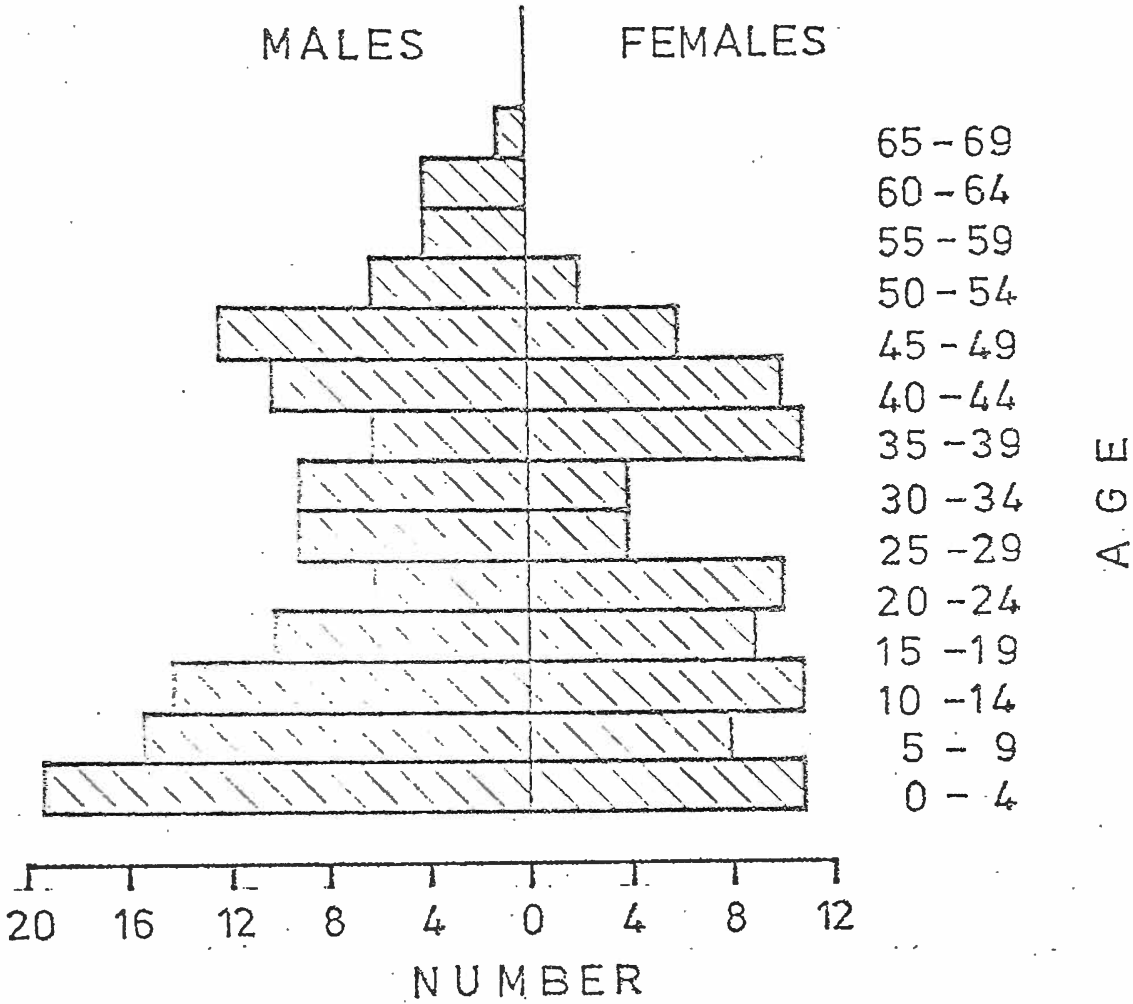
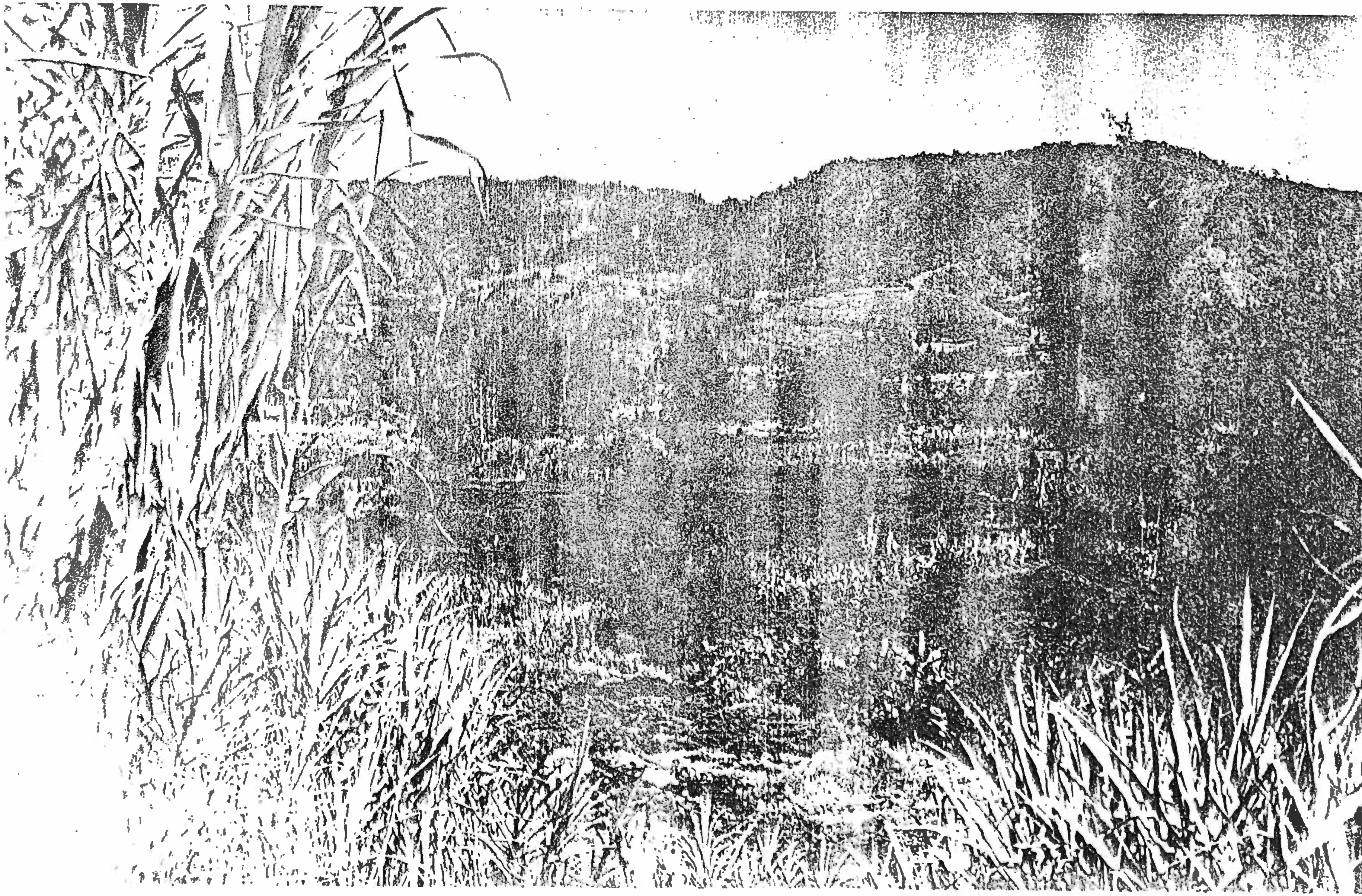


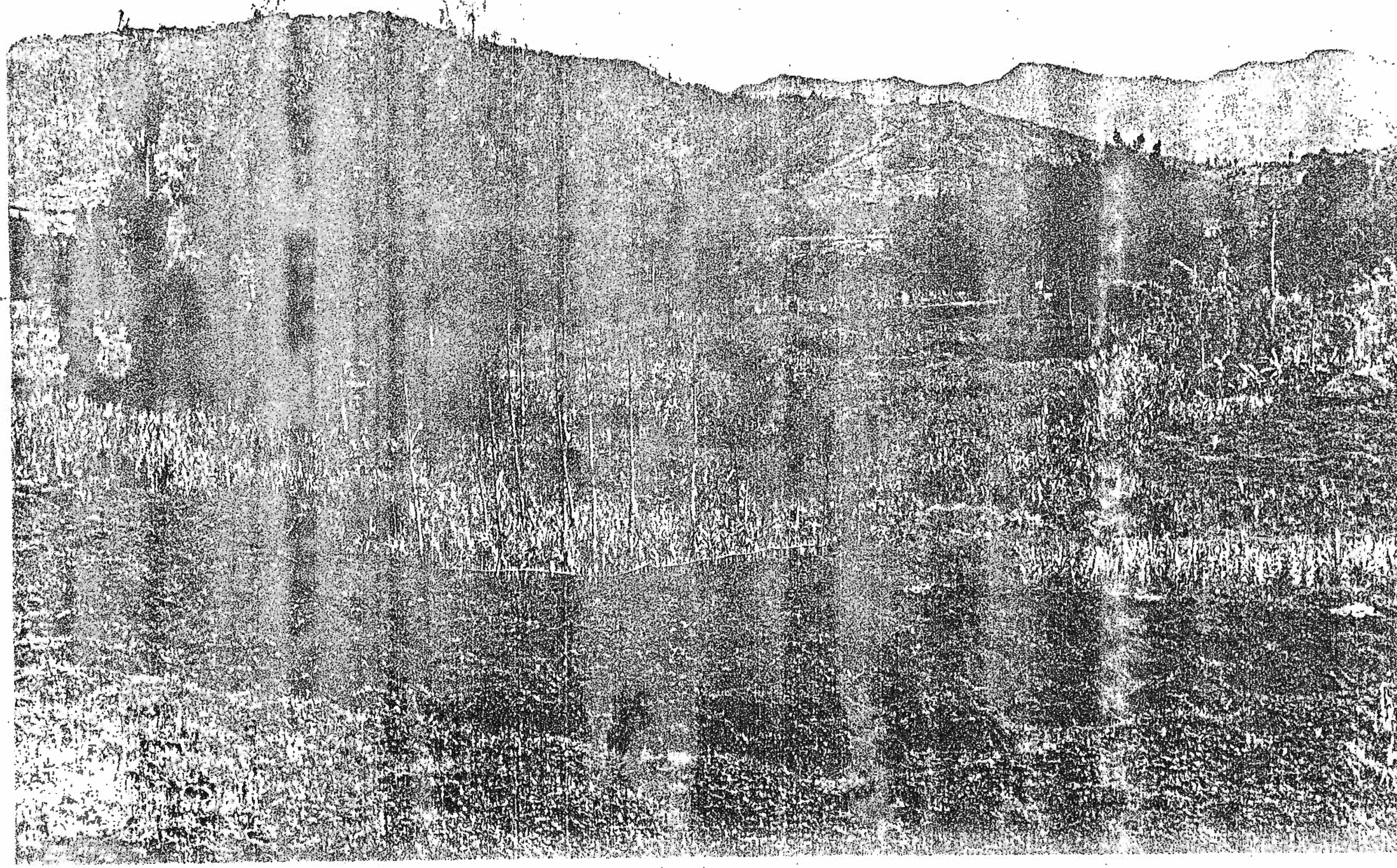
FIG. 4.3 AGE-SEX STRUCTURE OF TOMBEAKINI CLAN

Melanesian (pidgin English) as well as Raiapu, 16 (13%) are at school or have attended school and 24 (19%) have worked outside the Enga region. For Tombeakini females the figures are 3 (3%) speaking pidgin, 2 (2%) at school and 1 (1%) having worked away. No one over 39 speaks pidgin, has been to school or has worked away. 22% of Tombeakini children of school age (33% of boys and 7% of girls) currently attend school, which compares closely with the figure for the whole Saka (taken from the 1972 government census) of 20%.

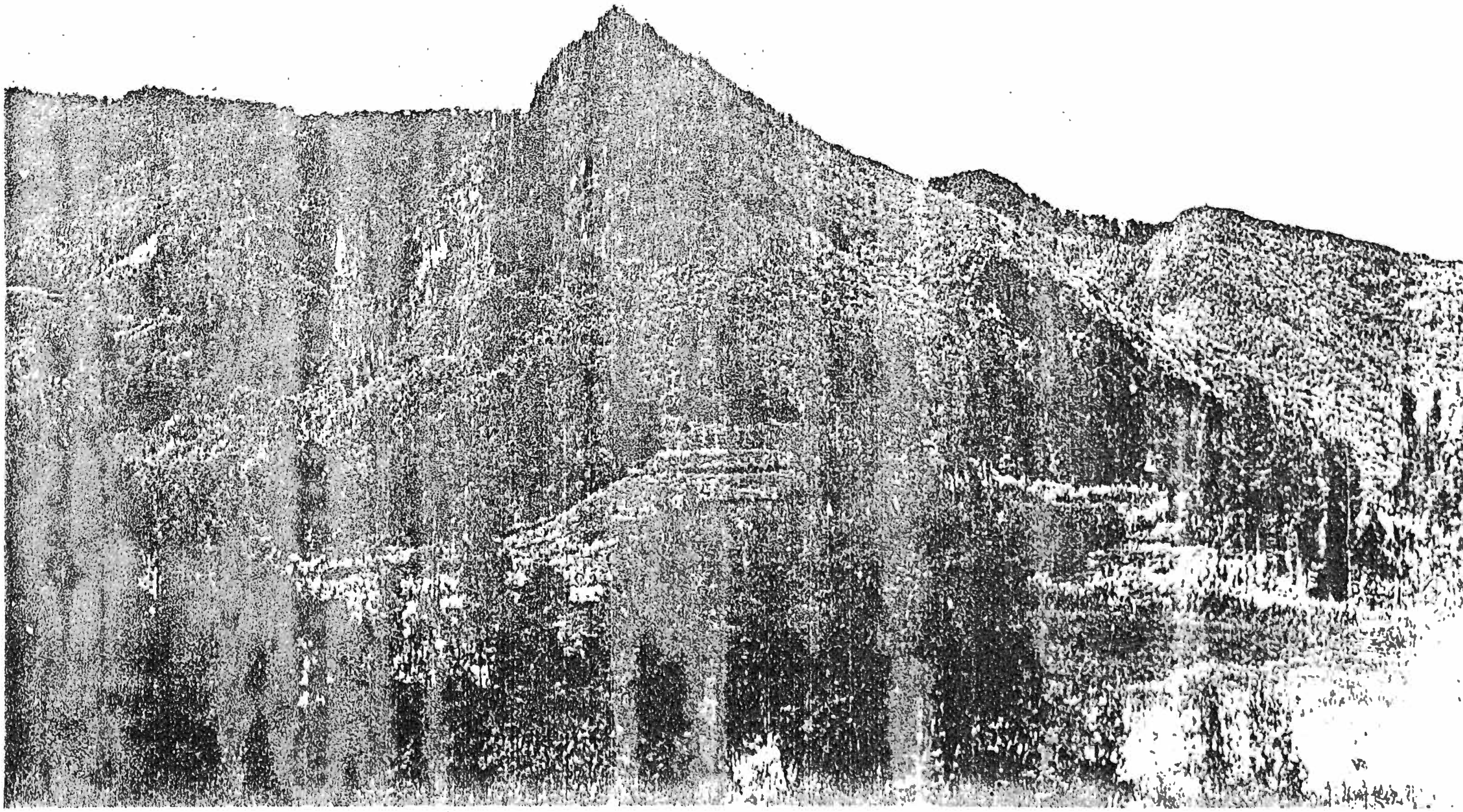
Looking north-west from Lyokote across the gardens of the Saka Valley.



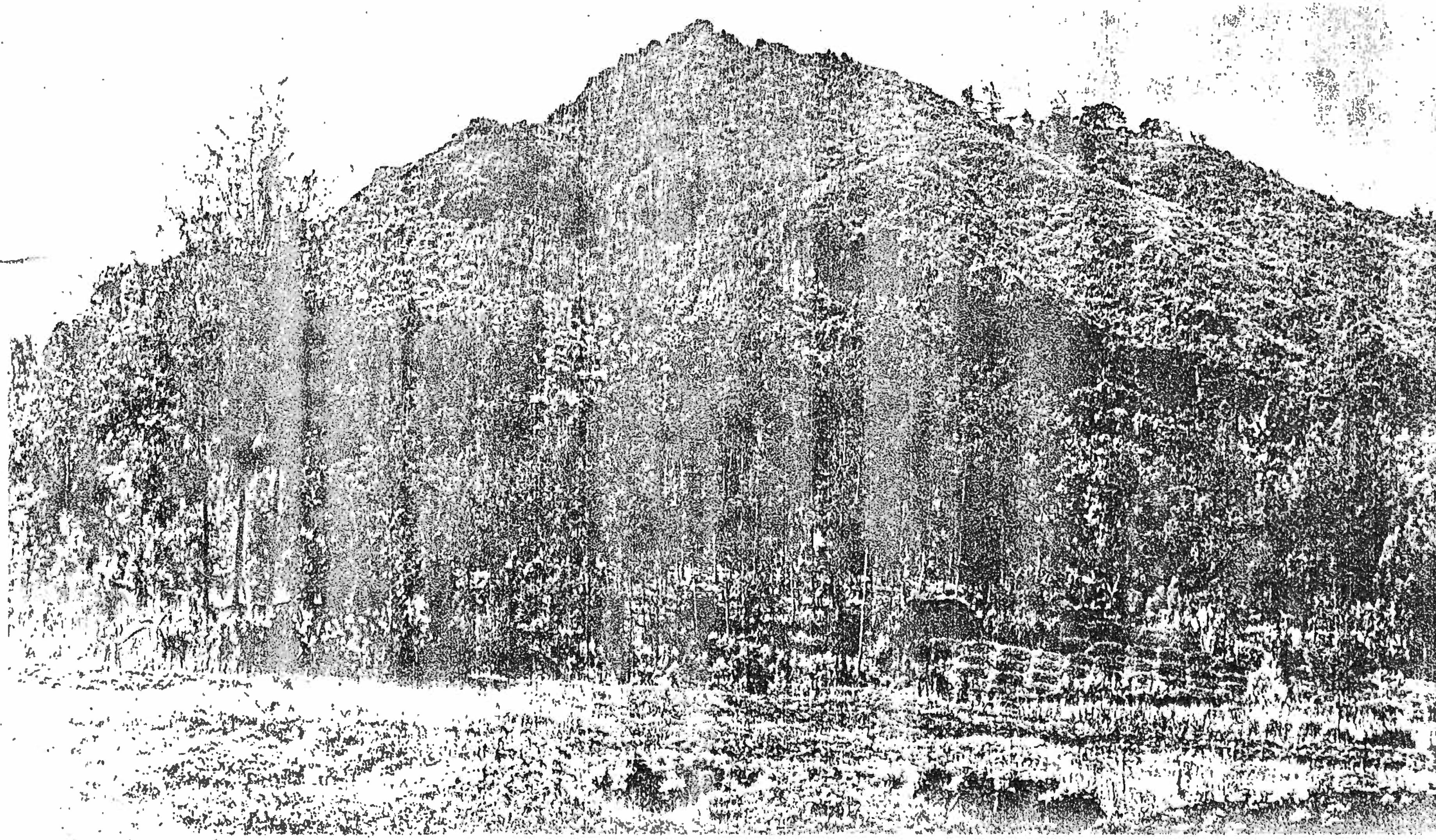
Looking northwards from Lyokote across the sweet potato mounds of Tombeakini Clan to the Lai Valley in the distance. Note the casuarina stands and the "women's house", with a smoking roof, on the extreme right.



Tombeakini territory and the hill Kamanda seen from across the River Tobaka from the territory of Yakaemandane (Map 4).



Tombeakini territory with the hill Kamanda in the background. In the foreground are sweet potato fields in various stages of maturity and, behind them on the slope, are mixed gardens of bananas and vegetables set in casuarina trees.



PART II

TOMBEAKINI'S WATER USE

CHAPTER 5

INTRODUCTION AND METHODS

5.1 INTRODUCTION

A large proportion of the world's population lives in the rural areas of what are generally described as developing countries or the countries of the "third world". Typically these rural farmers live in conditions which are far from healthy and enjoy very low standards of sanitation and environmental health protection. Of central importance is the inadequate nature of water supplies - in terms of both the quality, and the availability, of the water which is used. Wagner and Lanoix (1959:10) claim that "in most small towns and villages in rural areas, more health benefits can be gained from money spent on a water-supply programme than in any other way". While this assertion is not substantiated, and may well be untrue in many areas, it is certainly correct that water supplies are among the crucial factors which determine the health status of rural communities.

In order to plan, design and implement water-supply programmes for rural areas, the public health engineer needs a variety of data which are not readily available. He needs data on the likely benefits which may be anticipated to accrue from a particular scheme and he needs data on existing water-use patterns and the way in which these may change in response to improved water supplies. He also needs information on a wide range of cultural aspects of the community concerned in order that the water-improvement programme may blend, and not be in conflict, with local custom so that the scheme may enjoy maximum local participation and support.

This type of data is in very short supply and, in some parts of the world, it is non-existent. Even data on current water-use patterns, which are probably the easiest to collect and accurately quantify, are often unavailable. White et al (1972: 109) have discussed this problem in the East African context and conclude that "only a handful of accurate data is available about actual domestic use within municipal water systems. Even less is known about the water carried from sources outside the household". White et al (1972) also review existing data on water usage and, for unconnected dwellings in rural areas, they quote only 5 reference sources from throughout the world (see Table 5.1).

Probably the most detailed data on water usage are provided by White et al's own study in East Africa. They report water usage for rural households, without piped supplies, at 12 sites in Kenya, Uganda and Tanzania. Mean per capita daily use ranges from 4.4 to 17.6 litres, and this use is related to size of household, size of container, cost of water and material wealth (1972: 109-149). Of particular interest is White's data for Mwisi - a settlement in south-western Uganda occupied by the Chiga people. The Chiga are subsistence farmers, they draw water from springs, wells and rivers and they have a population density of approximately 250 per sq. km. Mwisi is set in hilly country at about 1,800m altitude. It resembles the New Guinea Highlands' situation more closely than other sites in White's sample and data from Mwisi will be quoted in the following pages for comparative interest[1].

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1. Much information on rural water supplies in Tanzania is contained in a series of reports by the Economic Research Bureau and the Bureau of Resource Assessment and Land Use Planning of the University of Dar es Salaam. Readers with an East African interest are referred to this source.

TABLE 5.1

WATER USAGE IN RURAL AREAS WITHOUT HOUSE CONNECTIONS: FROM WHITE ET AL (1972: APPENDIX D)

Country	Place	Estimated Daily Per Capita Use. Litres	Original Source
Bolivia	7 villages	10	Teller (1969)
Kenya	Zaina	7	Fenwick
Nigeria	Anchau district	23 - 27	Nash (1948)
Sudan	Kordofan	9 - 16	F.A.O. (1967:238)
Tanzania	26 villages in 10 districts	5 - 26	Warner (1969)

White et al (1972: 113) also survey the water use figures which are adopted by engineers as a design basis for domestic supplies. For piped connections in rural developing areas, the estimates range from 100-125 litres per capita per day for Venezuelan villages to 60 litres per capita per day for Guatemalan rural communities. For village stand pipes, design figures range from 40 litres per capita per day in Latin America to 10 litres per capita per day in Tanzania. Wagner and Lanoix (1959: 43) comment that "few reliable data are available regarding water consumption when the source of supply is a hand- or motor-pumped well or a public tap". They quote a design figure from Venezuela of 15 litres per capita per day for supply to small towns through public taps.

Data for Oceania are extremely scarce and, so far as I am aware, there is no existing information on rural water usage in Papua New Guinea. Dirks (1968: 30) quotes figures of 682 litres per capita per day for expatriate households in urban areas; 400 litres per capita per day for indigenous households in Port Moresby and an overall Port Moresby figure of 468 litres per capita per day.

Most existing information on rural supplies in Papua New Guinea is contained in a series of reports by the Bureau of Mineral Resources of the Australian Government. The fullest reports are on the Milne Bay District (MacGregor, 1966) and the East and West Sepik Districts (Read, 1967) and these are summarised in MacGregor and Read (1967). These reports contain a brief description of existing supplies at 267 sites with recommendations for appropriate improvements. Data were collected on the concentrations of dissolved salts in the existing supplies but not on their bacteriological quality. An estimate is made of the future water demand at each site and this appears to be based upon an assumed demand of 45 litres per capita per day. Ground-water investigations in the Central and Gulf districts are reported by Brouxhon (1965a, 1965b) and MacGregor (1967) describes proposals for the water supply of Daru town. Dirkis (1968: 99-103) gives brief notes on the rural water supply situation in the Gulf District, the Madang District and the Markham Valley. The literature reviewed in this paragraph provides no reliable information on existing water-usage patterns and gives no details of actual demand.

The purpose of Part II is to provide detailed information on water usage in the Saka Valley. This will be of direct benefit to anyone engaged on water-supply works in the area and will facilitate the formulation of realistic design criteria. It should also be of interest to those responsible for other Highlands regions in that it indicates interrelationships and qualitative insights which may well have general validity. In addition, there will be much of interest to anthropologists and human geographers who are concerned with man-environment interactions. Much has been written on man-land relationships and agricultural systems in the Highlands (see Brookfield and Brown, 1963; Clarke, 1971; Rappaport, 1968; and Waddell, 1972b), but none of these describe the utilization of the fundamental resource of water.

5.2 THE SURVEY METHOD

The survey took place during 2 separate periods. In August, 1971, 15 domestic groups were surveyed for an average of 14 days each. In December, 1971, another 23 domestic groups were surveyed for 17 days each. The 38 groups contained 79.6% of the Tombeakini clan population. They were selected non-randomly, partly on the basis of ensuring that groups in all parts of the clan territory were surveyed, and partly due to prohibitions enforced by my assistants.

The survey was conducted by daily house-to-house visits during which a standardised questionnaire was administered. Most of this interviewing was conducted by 2 secondary school students who were living with Tombeakini. These students felt unable to survey a few domestic groups due to internal clan politics and family feuds, which made them unwelcome in certain houses. However, nearly 80% of the clan was surveyed and no bias is evident in the resulting sample. A total of 665 water collection journeys were recorded.

The students visited the selected houses each morning between 6.00 a.m. and 8.00 a.m. They asked questions about activities over the previous 24 hours: - who collected water? what in? when? from where? and for what purpose? Volumes were calculated by measuring the capacity of each group's water containers. These early morning visits coincided with a period between rising and leaving for the day's work in the gardens. It was a time when the interviewees were prepared to sit and talk and were not particularly busy. Most questions referred to the collection of water the previous afternoon or evening (the times when most water is collected) and these events were still fresh in the minds of the interviewees.

After the morning interviews, the students reported to my house for their schedules to be checked. Queries were discussed and dubious responses were spotted and could be immediately investigated. The survey procedure proved most satisfactory and provided data of good reliability. The data on choice of source, time of collection, containers used, identity of collector and the total volumes collected can be treated with confidence. Data on the volumes used for different purposes were harder to obtain and are probably only accurate to $\pm$ 20%.

The description of housing in section 3.6 is relevant to the survey of water use. The normal approach to a water-usage survey (for instance, White et al, 1972) is to deal with households and household consumption [1]. This is only applicable, however, if the household is a domestic unit with a shared behaviour pattern with respect to water collection, washing, cooking, etc. For the Tombeakini mixed household this is the case. The family is a domestic unit whose members cook and eat together and who share the water which one of them collects. In the case of the men's and women's households, the situation is more complex and flexible. A woman living with her children in a women's house will cook and eat in that house and may be joined for evening and morning meals by her husband. However, her husband may eat in his men's house or he may join another of his wives (if he is a polygynist) for his meals. An old woman living alone may eat with her daughter-in-law or may join another similar woman. It is also common for old women to be visited by their unmarried, adult sons for meals.

This complex situation leads me to define a "domestic group" for the purposes of the water-usage survey. A domestic group is comprised of people who habitually eat their evening (and perhaps their morning) meal together and who share water which has been brought to the house where they gather. They may, or may not, cohabit and they are usually closely related. The size of a domestic group is measured in consumption units which are, somewhat arbitrarily, defined on the basis of children under 10 years equalling ½ a unit and all others equalling 1 unit. All domestic group sizes are expressed as the mean number of consumption units who belonged to

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1. A household is defined as the residents of a house and, similarly, a "men's household" is the residents of a men's house.

the group during the period of the survey.

Table 5.2 shows the characteristics of the survey sample. The mean domestic group size of 3.6 consumption units is considerably larger than the mean household size of 3.0 people (Table 4.6), which illustrates the need to consider water use in terms of domestic groups. Figures 5.1 and 5.2 show the distribution of domestic group sizes, and travel times to water source, for the sample of domestic groups surveyed. Figure 5.3 shows the rainfall for the 2 periods of the water-usage survey.

Tombeakini have access to 2 major rivers - the Punate and the Tobaka. The Punate rises inside clan territory from a pair of springs at the foot of a limestone outcrop. It is soon joined by the Tipini stream. The Tobaka forms the eastern border of Tombeakini territory and rises at approximately 3,500m many miles to the south on Sugarloaf Mountain. Reference will also be made to a stream called Tsimbunai, which rises at "12" (Map 4) and flows into the Tipini near "11". It is ephemeral and is dry for at least 4 months of the year.

TABLE 5.2

DETAILS OF THE 38 DOMESTIC GROUPS SURVEYED

Measure	Units	Mean	Max.	Min.	Comments
Length of survey period	Days	15.8	21	14	15 domestic groups surveyed in August and 23 in December
No. of collection journeys per domestic group per day		1.1	1.9	0.7	
Domestic group composition	Consumption units. (Adults = 1; children under 10 yrs = $\frac{1}{2}$)	3.6	6.6	1.8	All "per capita" or "per head" water usage data quoted here are in fact "per consumption unit"
Time for round trip to nearest major source (Punate or Tobaka)	Minutes	12.5	23	4	Timed by walking the distance at the speed of an Enga woman carrying water (a brisk pace)

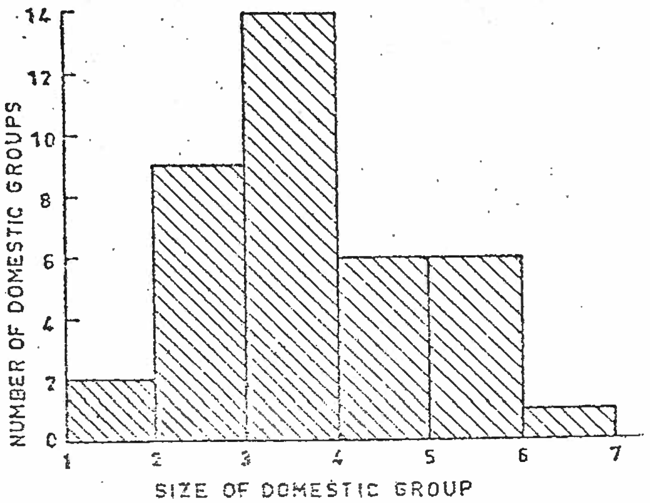


FIG. 5.1 THE DISTRIBUTION OF DOMESTIC GROUP SIZES IN THE SAMPLE OF DOMESTIC GROUPS SURVEYED

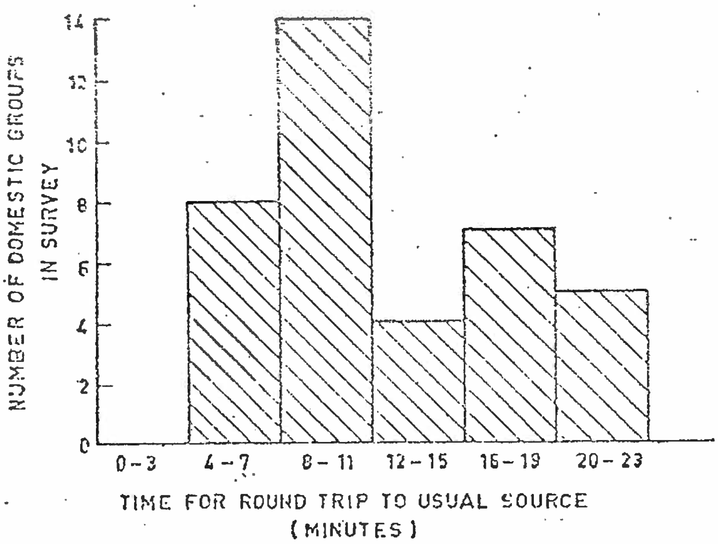


FIG. 5.2 THE DISTRIBUTION OF TRAVEL TIMES TO THE USUAL MAJOR SOURCE (TOBAKA OR PUNATE) FOR THE SAMPLE OF DOMESTIC GROUPS SURVEYED

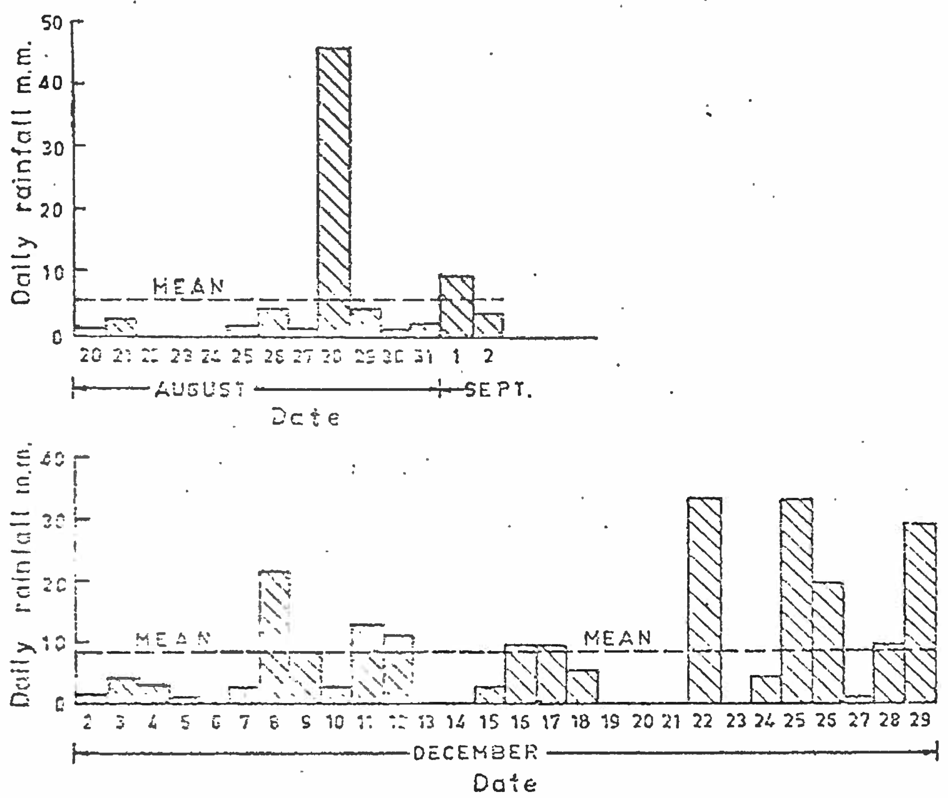


FIG. 5.3 DAILY RAINFALL DURING THE TWO PERIODS OF THE WATER USE SURVEY - 1971

CHAPTER 6

ATTITUDES TO WATER

In any attempt to upgrade the water supply of a rural community, it is of crucial importance that the attitudes and beliefs of the people should be fully understood. If this is the case it is possible to assess the local demand (or "felt need") for improved water, to design a scheme which is approved of by the users, to enlist the community's co-operation in construction and maintenance and to ensure that the new supply is used to the best advantage and that maximum benefits are derived from it. An understanding of Raiapu attitudes to water will also help the reader to appreciate the data on water use in their cultural, as well as their environmental, context.

The Raiapu view of water is generally prosaic. The rivers have never been known to dry up and they are very much taken for granted. Droughts occur (for instance in 1972), but it is the frosts which accompany the droughts that the Raiapu really fear since they kill the sweet potatoes. No religious ritual or magic is undertaken to promote rain and people are more concerned with flooding than droughts. It is appreciated that heavy rain in the hills will cause rivers (like the Tobaka) to flood, causing damage to <u>kútá</u> ponds, casuarina stands and the swampy flats which are much used for pig grazing (see Table 4.2, category B). Floods also bring down earth which makes the rivers unpleasantly turbid and occasionally people and pigs are drowned in swollen rivers.

The Raiapu perceive the fundamentals of hydrology and are generally uncurious about more complex aspects. They know that rainfall drains into rivers and that heavy rain will lead to floods. They appreciate the power of water to erode and the way in which rivers change their course and eat away their banks. It is now known that the rivers flow down to the sea, but before contact it was not known where they went. The source of rain is the yályakali or "sky people" who live in a world above the earth and are the creative beings. It is said that rain is caused by sky women (yálya énda) swimming in a lake which then spills over the edge and falls to earth. Some say that rain is caused by the sky women urinating. Other meteorological and natural phenomena (earthquakes, lightning, stars and strong winds) are also associated with the yályakali, but no attempt is made to influence nature by appeals to the sky world. If heavy rain comes, it is treated fatalistically and the yályakali are not blamed or appealed to.

Since water is generally plentiful, its ownership is not a source of dispute or litigation. Rivers frequently form the boundary between two clans and, in these cases, the river is said to belong to both. If a river flows through a clan's territory it will belong to the clan in that stretch, but others would not be prevented from using it. Ownership is more assertively claimed in the case of a spring rising inside a clan's territory - as with Tombeakini and the River Punate. A spring produces water which is clear and cold (the properties most valued) and it is not subject to fouling in floods or poisoning by up-stream enemies. A clan possessing a major spring (of which I knew of only 2 in the Saka, see Map 3) will be proud of this resource and will even boast about it.

Tombeakini, for instance, see the Punate as one of their major assets, but they would not prohibit its use by others unless they were enemies. They also claim no rights to the Punate after it has left their territory and flown into Yanuni. The Punate has become a feature of the stories which support Tombeakini's claim to their territory. It is told that two descendants of Tombeakini (the clan founder who lived in the Kaugel Valley above Tambul) came, after various hardships, to the Saka where one settled to the west of the Punate spring while the other built his house on the eastern side. Several old casuarina trees, which are used to record the dates of historical events ("we fought a great battle with Tashikini when that tree was small"), are also standing near the Punate springs.

Generally, the Raiapu do not undertake any improvement or protection works for their water sources. The only source protection I saw was an impressive dry stone wall which surrounds the other major spring in the Saka. This wall was designed to keep pigs and cattle away from the spring, but it also served to advertise the pride with which the spring was regarded by the clan who owned it.

The qualities of water most appreciated by the Raiapu are clearness and coldness and they prefer to drink water of this type. Warm and turbid water will be drunk if that is all which is available, and it is not generally felt that any sickness or other bad outcome will result. Some say that drinking very turbid water will lead to a blockage of the small intestine, but most Raiapu do not worry about this. If turbid water is collected, it is often left to settle before drinking. On a hot day water will be collected in a gourd or bamboo because it is thought (quite correctly) that it stays cooler than in a metal pot or bottle. Water is almost never stored inside a house lest it becomes unpalatably warm.

Rain-water is considered good water but it will not be caught off the roof of a house. Roofs are made of thatched Imperata cylindrica and water that has run off them contains a heavy load of dust and small grass particles. Rain-water is collected from dripping trees during heavy rain.

Water is not used directly in religious rituals (compare, for instance, Maring practice - Rappaport, 1968: 205) but there are interrelationships between water and religion. Perhaps the most important of these is the fear of sorcery. The Raiapu are continually apprehensive about the possibility that enemies will introduce menstrual blood, faeces or parts of a corpse into their food or water. To consume these items would mean serious illness or death. The ownership of a spring precludes such a danger, but many Raiapu use water which has travelled through the territories of other clans, some of which may well be hostile. This gives rise to accusations and litigations concerning the poisoning of water supplies and may well lead to warfare. Such disputes are not common, however, when compared with other sources of inter-clan strife. Feachem (1973c) should be consulted for an account of Raiapu religious belief, ritual and sorcery.

The Raiapu also believe in sacred pools (yáká peté or yálya peté) which are inhabited either by ghosts of the recent dead (timóngó) or by demons (putútuli). They avoid these places and one such pool in Yanuni territory (see Map 4) was drained when a boy drowned in it a few years ago. It was said that a timóngó held him under and a ritual specialist (topólí) was employed by Yanuni to exorcise the area.

The only other magical associations of water which I have encountered are in rituals designed to cure sick dogs and promote healthy growth of a young man's hair. In the veterinary ritual, the dog is held near a large river (like the Tobaka) and a tree fern (tambu ita) branch is held near it. Spells are recited and the branch is cast into the river, thus symbolically removing the poison from the dog's body. In the second ritual, a specialist (topólí) will pour bespelled water over a young man's head to promote a luxuriant growth of hair and beard.

Two prohibitions concerned with drinking water should be mentioned. Firstly, the Raiapu fear that the "juice" of a corpse may contaminate a river and so people are usually buried far from rivers. A few years ago the River Tame (see Map 3) changed course and cut into an old grave. This caused Yanuni to stop using the Tame as a water source for approximately 6 months, in order that all the "juice" could be washed away. Secondly, males are constantly aware of the contaminating nature of women which can cause them to become prematurely old and lose their vigour and potency. Meggitt (1964) gives an account of male-female antagonisms amongst the Mae, and the Raiapu case is very similar. Due to this, males will never drink immediately down-stream of a place where women are standing or have recently waded. A woman, who notices that a man is about to inadvertently drink down-stream of a place where she has been standing, will often call out to warn the man of his danger. If she does not do this, and is observed by other men, she will be severely chastised for not drawing attention to the hazard.

Women are not permitted to bathe in the Punate, or the Tipini because it runs into the Punate, lest this excellent water source should be contaminated. It is said that female bathing in the Tobaka is permissible because the greater flow will cause any polluting substances to be swiftly washed away. It is indicative of how dangerous female contamination is regarded to be that, while women may not bathe in the Punate, the intestines of pigs are commonly taken by women and children to be cleaned out and washed in the Punate. Tombeakini appreciate that the contents of the pigs' intestine are foul and potentially harmful but it is thought that, if the cleaning is carried out in mid-stream, the danger will be quickly washed away.

Generally speaking, larger rivers are regarded as safe from all types of pollution since contaminants will be quickly carried down-stream. Small rivers, like the Punate, need to be protected from major pollution (e.g., women) but are acceptable as washing places for pigs' intestines. The smallest rivers, like the Tipini, are not considered capable of cleansing themselves at all and so they are not used for any washing activities. Standing water, such as in the kútá peté, are also unable to receive any pollution and it is said that, if pigs' intestines were washed in a kútá peté, the kútá would soon die.

Finally, it can be noted that the Enga use rivers as a means of geographical reference. River names are surprisingly standardised, so that people from a wide area will all agree on a particular river's name. These names are then used to describe locations. Most people of the Wabag area have never heard of Tombeakini, but they know of the river Tobaka and the other major Saka rivers - the Tare and the Wakema (see Map 3) - and use these as points of reference when discussing the Saka.

CHAPTER 7

TOMBEAKINI WATER USE

7.1 THE CHOICE OF WATER SOURCE

Decisions regarding the choice of water source are not made with respect to the situation as a sanitary engineer would define it, but rather with respect to the situation as it is perceived by the water user. The choice is made, not between all available sources, but between all perceived sources and it is made according to Raiapu concepts of suitability. A useful model for the analysis of this choice "views the water user as a person who perceives the choices open to her with varying degrees of accuracy and who judges according to her own perception of the quality of the source, the technical means available to her in drawing on the source, the expected returns and costs, and the interaction with other people which such use involves" (White et al, 1972:227). These 4 criteria will be labelled "quality", "technology", "efficiency" and "human interaction".

Tombeakini perceive 6 alternative sources within their territory and these are listed in Table 7.1 with an assessment of the consensus of opinion towards them under the 4 criteria stipulated.

Table 7.1 shows that there are 3 permanently available sources, the choice between which rests solely on 2 criteria - quality and efficiency. Human interaction is not an operative criterion in the choice between the 6 sources within Tombeakini territory, but it is operative in the exclusion of nearby sources. For instance, people living at 14 (Map 4) might well consider the

Tame as a possible source, except that this would involve a journey into Yanuni territory which would be unacceptable on a regular basis. The quality judgments follow from the attitudes to water which were discussed in the previous section. The Punate is cold and clear and therefore perfect. The Tobaka is cold but sometimes turbid and the Tipini is warm and turbid. Table 7.2 presents quality data on these same rivers and it is clear that Tombeakini perception corresponds closely to scientific perception and leads them to prefer a source which has an appreciably lower load of faecal material than other available sources. The water quality of these rivers will be analysed in detail in Part III of this thesis.

Table 7.3 shows the utilization of the 6 sources already mentioned plus collection, by travellers returning home, from external sources and collection from my water tank which was only available during 1971. A total of 665 water collection journeys was surveyed and, of these, 85% were from the Punate or the Tobaka. The Tsimbunai was used by 2 domestic groups who lived adjacent to it. Rain-water is collected in times of heavy rain by placing an open container underneath a tree where there is a natural spout. Reliance on rain-water varies with the weather and, overall, 8% of collection journeys were for rain-water. During August, only 1% of journeys were for rain-water and 87% of groups used no rain-water. During December, 13.5% of journeys were for rain-water and only 22% of groups used no rain-water. A strong seasonal variation in rain-water usage exists although the difference in mean rainfall during the August and December survey periods is not particularly great (see Figure 5.3). Rain-water can only be collected during periods of heavy precipitation. During December, 25% of days had a precipitation of > 10mm, whereas August had only 7% of similar days. It is this

TABLE 7.1

CRITERIA AFFECTING CHOICE BETWEEN SIX ALTERNATIVE WATER SOURCES

<table>
<tr><th>NAME OF SOURCE</th><th>QUALITY</th><th>TECHNOLOGY</th><th>EFFICIENCY</th><th>HUMAN INTERACTION</th></tr>
<tr><td>Punate</td><td>Excellent</td><td rowspan="3">Readily available at all times</td><td rowspan="6">In all cases this depends upon the distance, and length of travel time, between source and dwelling.</td><td rowspan="6">All these sources are reached without going outside Tombeakini territory or encountering hostile groups. Also water collection points are not social meeting places. Human interaction, therefore, is not an operative criterion.</td></tr>
<tr><td>Tobaka</td><td>Good</td></tr>
<tr><td>Tipini</td><td>Bad</td></tr>
<tr><td>Tsimbunai</td><td>Satisfactory</td><td rowspan="3">Only in times of heavy rain</td></tr>
<tr><td>Rain Water</td><td>Excellent</td></tr>
<tr><td>Ponds or Puddles</td><td>Bad</td></tr>
</table>

TABLE 7.2

MEAN FAECAL BACTERIAL CONCENTRATIONS, TEMPERATURES AND TURBIDITIES IN FOUR SAKA RIVERS DURING JUNE - DECEMBER, 1971.

RIVER NAME	MEAN TEMP. AT TIME OF COLLECTION °C	MEAN TURBIDITY	FAECAL COLIFORMS. COLONIES PER 100 ml.	FAECAL STREPTOCOCCI. COLONIES PER 100 ml.
Punate (Near spring)	15.1	11	8	40
Tipini	20.5	56	1,563	1,405
Tobaka	14.4	53	220	270
Tame	21.2	29	669	559

TABLE 7.3

UTILISATION OF EIGHT ALTERNATIVE WATER

SOURCES BY SURVEY SAMPLE

NAME OF SOURCE	NUMBER OF JOURNEYS MADE TO GIVEN SOURCE	PERCENTAGE OF TOTAL NUMBER OF JOURNEYS
PUNATE RIVER	337	50
TOBAKA RIVER	232	35
TIPINI RIVER	6	1
TSIMBUNAL STREAM	25	3½
RAIN WATER	52	8
PONDS OR PUDDLES	6	1
RIVERS OUTSIDE TOMBEAKINI TERRITORY	2	½
TANK ON AUTHOR's HOUSE	5	1
ALL SOURCES	665	100

TABLE 7.4

MULTIPLE WATER SOURCE USAGE AMONGST SURVEY SAMPLE

NUMBER OF SOURCES USED	NUMBER OF DOMESTIC GROUPS USING GIVEN NUMBER OF SOURCES	PERCENTAGE OF NUMBER (38) OF DOMESTIC GROUPS SURVEYED
1	9	24
2	16	42
3	8	21
4	3	8
5	2	5

TABLE 7.5

TOMBEAKINI'S CHOICE OF WATER SOURCE

USUAL SOURCE OF WATER	NUMBER OF HOUSES	PERCENTAGE OF TOTAL NUMBER OF HOUSES	NUMBER OF RESIDENTS	PERCENTAGE OF CLAN POPULATION
PUNATE	30	43	83	39
TOBAKA	28	40	80	38
PUNATE AND TOBAKA	12	17	48	23

seasonal difference in the frequency of high rainfall days which explains the greatly increased usage of rain-water during December.

As has been mentioned, the choice between the permanently available sources (Punate, Tobaka and Tipini) rests upon assessments of quality and efficiency. The Tipini is clearly rejected (only 1% of journeys) because of its bad quality. (Tables 7.1 and 7.2). This leaves the Punate and Tobaka between which Tombeakini have to choose and from which they collect most of their water. It is instructive to inquire whether this choice is primarily influenced by quality judgments or by efficiency. Efficiency in this case means proximity to the water source and the relevant measure of this is the round-trip travel time from dwelling to source and back. A measurement of distance would not be meaningful since some journeys involve the descent and ascent of steep muddy slopes whereas other journeys, which may be of equal distance, are over relatively flat terrain.

Although 8 sources were utilized by the sample of domestic groups, 85% of journeys were made to the Punate or Tobaka and all groups made some use of one or both of these sources. Table 7.4 shows that 87% of groups used between 1 and 3 sources during the survey. All domestic groups have been classified according to their usage of the 2 major sources. Groups are either Punate-users, Tobaka-users or Punate-and-Tobaka-users. Since utilization of other sources is so low, this is a reasonable division and, in fact, Tombeakini often characterise themselves in this way. A man who lives near the Punate but who also uses some rain-water, will say he is a Punate-user and will not refer to rain-water unless closely questioned. Table 7.5 shows the whole clan divided (by household) according to their usage of the 2 major sources. Map 5 shows the geographical location of these houses and it can be seen that the choice between Punate and Tobaka is closely related to the household's relative position between the two sources.

Is the decision between Punate and Tobaka made purely on the basis of efficiency (as Map 5 might suggest) or do domestic groups display a preference for the Punate which they all agree is a source of superior quality? Figure 7.1 displays this problem. If efficiency (travel time from source) were the only criterion then quadrants B and D would be empty and all groups would be symmetrically placed in A and C. We find, however, that 4 groups are in B and 3 are in D and that those in B are more centrally placed within that quadrant. This indicates a slight preference for the Punate. Of the groups in A, 79% never use the Tobaka ($P/(P+T) = 1.0$) whereas only 42% of those in C never use the Punate. A further indication of preference is that 100%, of the 24% of domestic groups who use only one source (Table 7.4), are Punate-users.

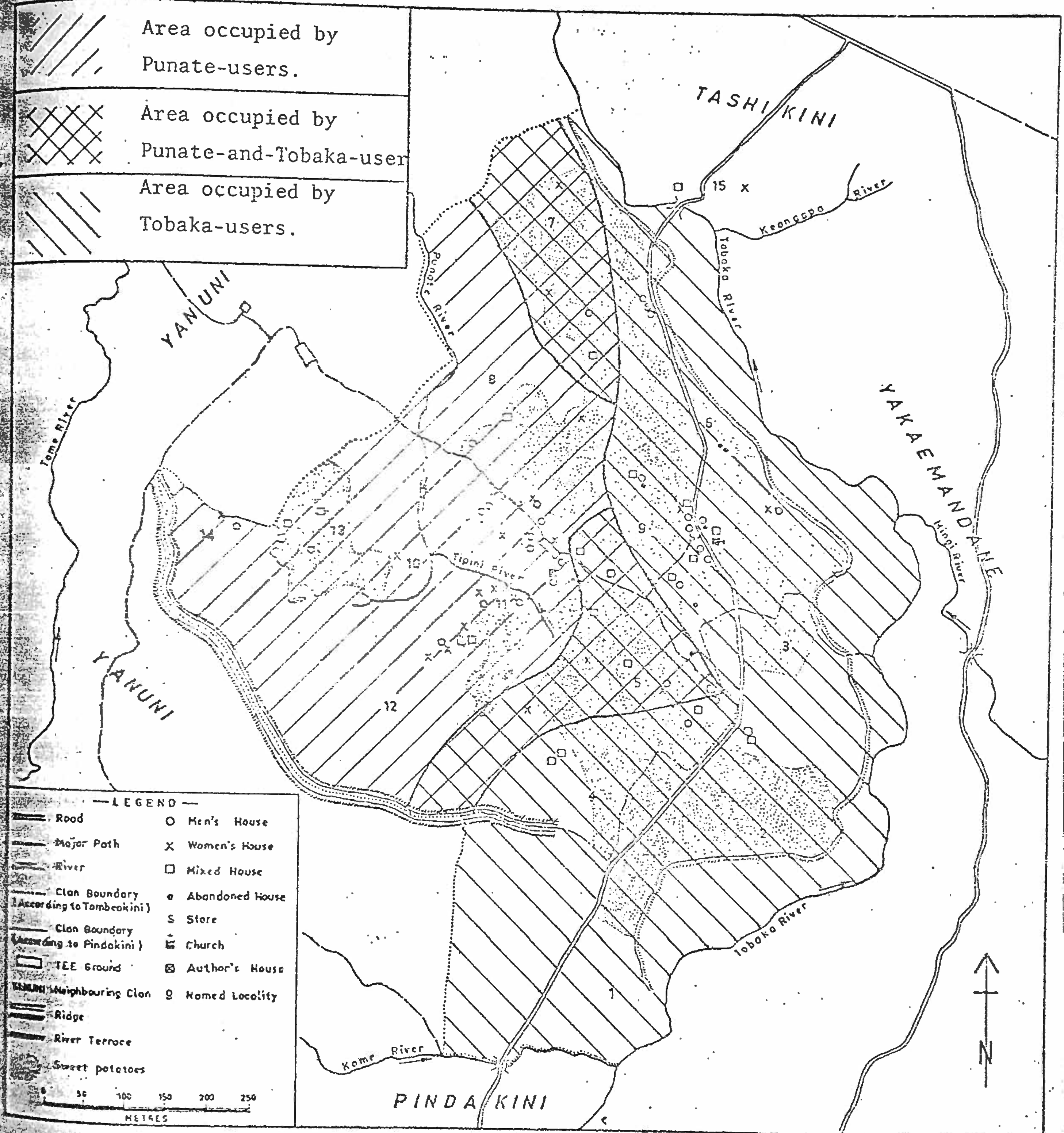
This evidence indicates a slight preference for the Punate - attributable to its clearness, coolness and its lack of exposure to poisoning or flooding. However, Map 5 and Figure 7.1 show that it is a preference affecting only a few houses which are located in a marginal position between the 2 sources. For most domestic groups the choice is simply dependent upon which source is the nearer.

7.2 THE COLLECTION OF WATER

When is water collected; by whom; and in what? Tables 7.6, 7.7 and 7.8 answer these questions. Water is collected at all times except at night and mainly in the late afternoon. Slightly more is collected by females and people of all ages participate. 47% of journeys are made by children or teenagers. It is collected most

MAP 5

TOMBEAKINI TERRITORY DIVIDED ACCORDING TO CHOICE OF WATER SOURCE



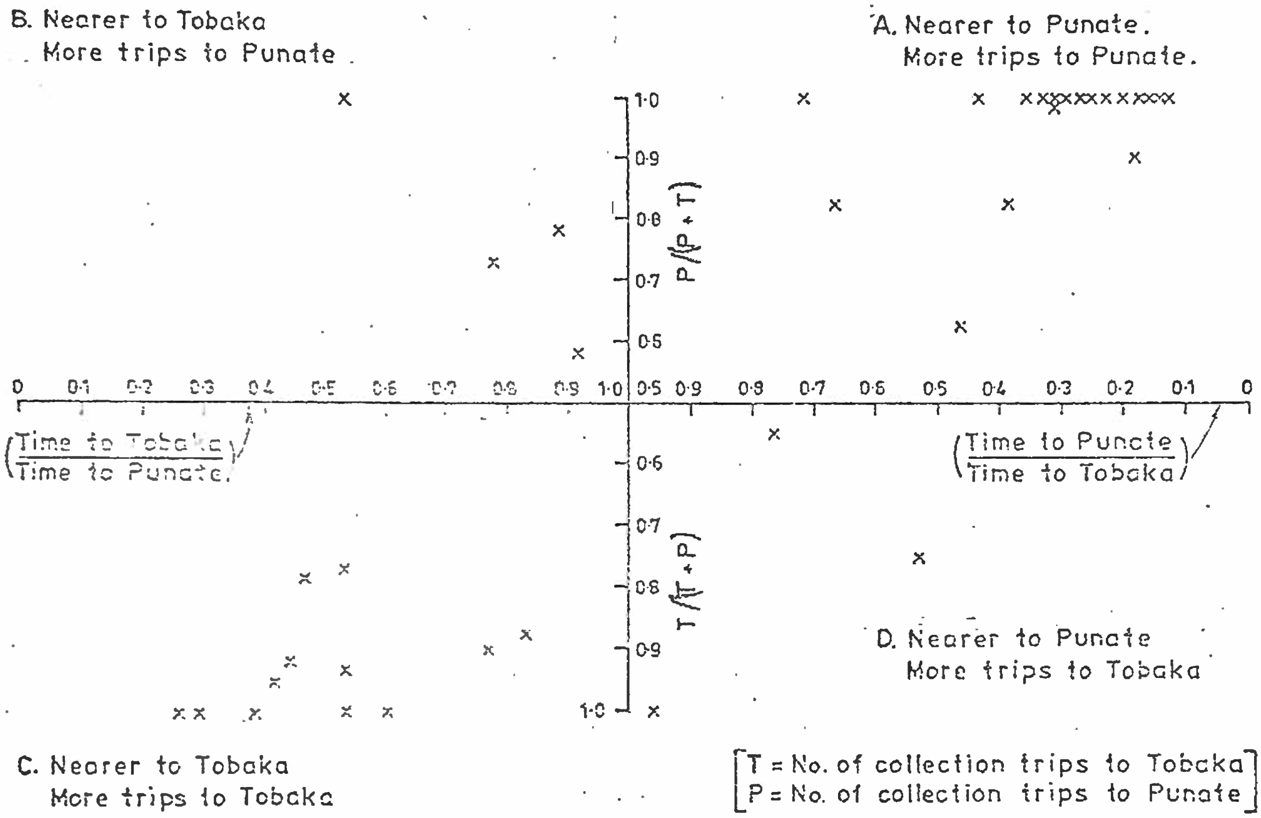


FIG. 7.1 THE DISTRIBUTION OF DOMESTIC GROUPS SURVEYED ACCORDING TO THEIR PROXIMITY TO THE MAJOR WATER SOURCES AND THEIR RELATIVE UTILISATION OF THOSE SOURCES

TABLE 7.6

TIMES AT WHICH WATER COLLECTION JOURNEYS ARE MADE

TIME	NUMBER OF JOURNEYS MADE AT GIVEN TIME	PERCENTAGE OF TOTAL NUMBER OF JOURNEYS
06.00 - 11.59 MORNING	64	10
12.00 - 15.59 EARLY AFTERNOON	197	29
16.00 - 18.59 LATE AFTERNOON	378	57
19.00 - 20.59 EVENING	26	4
21.00 - 05.59 NIGHT	0	0

TABLE 7.7

COMPARISON OF THE NUMBER OF WATER COLLECTION JOURNEYS MADE BY INDIVIDUALS IN DIFFERENT AGE-SEX COHORTS

AGE	NUMBERS AND PERCENTAGES OF JOURNEYS					
	MALES		FEMALES		TOTAL	
	No.	%	No.	%	No.	%
0 - 9	59	9	65	10	124	19
10 - 19	67	10	121	18	188	28
20 - 29	35	5	105	16	140	21
30 - 39	48	8	37	5	85	13
40 - 69	68	10	60	9	128	19
ALL AGES	277	42	388	58	665	100

TABLE 7.8

THE FREQUENCY OF USAGE OF FIVE TYPES OF WATER CONTAINER

TYPE OF CONTAINER	VOLUME OF CONTAINER LITRES			NUMBER OF CONTAINER - JOURNEYS MADE	% OF TOTAL NUMBER OF CONTAINER - JOURNEYS MADE
	MEAN	MIN	MAX		
GOURD	1.3	0.3	2.8	264	29
GLASS BOTTLE	0.4	0.3	0.8	237	26
COOKING POT	3.0	1.3	5.6	193	21
BAMBOO	1.7	0.4	3.0	107	12
TIN	2.6	0.8	3.0	104	12
ALL TYPES	1.8	0.3	5.6	905	100

commonly in gourds or glass bottles but pots, bamboos and tins are often used.

Traditionally all water would be collected in gourds or bamboos and 41% of journeys are still made with these containers. The gourd (Lagenaria sp.) is an object of beauty and it is a slow and skilful task to make one. Gourds are items of traditional value and are kept as family heirlooms or exchanged in minor prestations. Larger gourds (> 2 litres) are fragile and are not often used for water collection. On hot days, gourds and bamboos are the preferred containers since water remains cooler in them.

In assessing the benefits which may accrue from a new water supply scheme, it is necessary to know the cost of water in the existing water use system in order that this may be compared to the cost from the proposed new supply. Where an urban authority charges for water piped to the house, this charge will usually represent the whole direct cost to the consumer, even if the charge is merely a nominal percentage of the real cost of supply. For unpiped supplies, costs may include the charge made at the stand-pipe or by the water carrier and the energy expended in carrying the water home.

The Raiapu clearly have to make no direct payment for their water. The cost therefore is simply the energy cost of water collection added to the cost of the time spent in water collection which could be otherwise employed. The estimation of these costs in a subsistence, or partly subsistence, economy, presents real problems. The procedure adopted here is that proposed by White et al (1972:93-98) and appears appropriate to the Raiapu situation. The energy cost is calculated by costing the quantity of staple food required to provide the amount of energy used in water collection. It is not possible to produce a realistic estimate of the opportunity cost of the time spent in water collection. I assume, however, that the time is worth at least the cost of food consumed in that time which is calculated by distributing the total daily caloric intake uniformly over a 24hr period. The energy cost and the time cost are added to give a value for the total cost of water collection.

The average domestic group collects 2.46 litres of water per day, in 1.1 journeys, each of 12.5 minutes' duration (Tables 5.2 and 7.9). Considering the weight of the load (2.46kg + container), the hilly terrain and the age of the carriers (Table 7.7), a figure of 5.0 calories per minute is estimated (from the data of Hipsley and Kirk, 1965:43) for Tombeakini energy expenditure during water collection. Therefore, 5.0 x 12.5 x 1.1 = 68.75 calories per domestic group per day are spent on water collection. A mean of 12.5 x 1.1/60 = 0.23 hours are spent collecting water per day which, assuming a total caloric intake of 2,400 calories per day (Waddell, 1972b:126), is equivalent to 2,400 x 0.23/24 = 23 calories per domestic group per day.

Adding the energy cost to the time cost gives 91.75 calories per domestic group per day. This is converted into monetary units by assuming a cost of sweet potato of 1 cent (Australian currency) per pound (the price paid by Waso Ltd. of Wapenamanda during 1971) and a caloric content of 150 calories per 100g of sweet potato (Hipsley and Kirk, 1965:39). Applying these data, costs of 0.134 cents per domestic group daily, 0.037 cents per capita daily and 0.054 cents per litre are obtained.

These costs are negligible, but they are similar to those for Mwisi, where White et al (1972:103) report a cost of 0.028 U.S. cents per litre and 0.126 U.S. cents per capita daily. The costs for the entire Tombeakini clan are only 7.81 cents per day and $28.5 per annum.

7.3 WATER USAGE

The pattern of domestic water usage is tabulated in Table 7.9. It should be stressed that figures refer only to water which is brought to the dwelling and do not include any extra-domiciliary water usage. 79% of water collected is drunk. Of the remaining 21%; 47% is used for cooking, 36% for pigs, 4% for washing, 2% for dogs and chickens and 11% is thrown away. 29% of domestic groups surveyed used water only for drinking. Per capita usage is shown in Table 7.10.

The most striking feature of the data in Tables 7.9 and 7.10 is the extremely low level of water use. Data for Mwisi (White et al, 1972:119) show a mean per capita daily use of 4.4 litres and a minimum per capita daily use of 1.4 litres. Water use at Mwisi was appreciably lower than at any other East African site studied by White. The Raiapu use little water for purposes other than drinking and drink little water. This results in low per capita total usage.

The only comparable data from the New Guinea Highlands are provided by Hipsley and Kirk (1965:79) from their study of the Chimbu settlement of Pari (near Kundiawa - see Map 1) and by Oomen and Corden (1969:16) from their study on the Kyaka Enga at Baiyer River. Hipsley and Kirk report extremely low daily fluid intakes of 0.07 and 0.01 litres per capita for men and women, respectively. It appears (1965:143) that they obtained these figures by questionnaire and observation and, in the absence of further details, one must view the validity of this data with suspicion. Hipsley and Kirk add to these consumption figures water from food and water from food oxidation to obtain total volumes of available water. These are again low when compared with the clinical norm of 2.5 litres for "resting conditions

TABLE 7.9

WATER USAGE PER DOMESTIC GROUP

USAGE CATEGORY	VOLUME USED - LITRES PER DOMESTIC GROUP PER DAY			% OF TOTAL USED (MEAN)	COMMENTS
	MEAN	MIN.	MAX.		
Drinking	1.93	0.60	4.37	79	Mainly drunk with the morning and evening meals.
Cooking	0.25	0	2.08	10	Cooking purchased rice, pumpkin leaves and vegetable soup. 45% of d.g.s.* used no water for cooking.
Washing (plates etc)	0.02	0	0.15	1	84% of d.g.s. used no water for washing.
Pigs (for drinking or cooking pig's food)	0.19	0	1.94	7	Pigs are fed small tubers and leaves normally boiled in water. 55% of d.g.s. used no water for pigs.
Dogs and/or Chickens. (for drinking)	0.01	0	0.13	½	86% of d.g.s. used no water for dogs or chickens.
Thrown Away	0.06	0	0.58	2½	63% of d.g.s. threw none away.
Total Collected	2.46	0.60	4.99	100	

*d.g.s. = domestic groups surveyed.

TABLE 7.10

PER CAPITA WATER USAGE

USAGE CATEGORY	VOLUME USED - LITRES PER CAPITA PER DAY		
	MEAN	MIN.	MAX.
Total Collected	0.68	0.19	1.27
Drinking	0.54	0.19	1.16

TABLE 7.11

FLUID CONSUMPTIONS OF CHIMBUS AT PARI

AFTER HIPSLEY AND KIRK (1965:79)

LITRES PER CAPITA PER DAY

TYPE OF FLUID	MALES	FEMALES
Water	0.036	0
Water (as tea)	0	0.007
Cooking water	0.035	0.006
Total Fluid	0.071	0.013
Water in food	1.234	0.963
Total consumed	1.305	0.976
Water of Oxidation*	0.355	0.243
Total available	1.660	1.219

*Calculated as 150 ml./1000 calories of food oxidized.

in a moderate climate" (1965:144). The authors discuss this low intake and conclude that it is possibly related to the low-protein and low-sodium dietary characteristics which lead to a reduced demand for water as a "vehicle for waste nitrogenous products and other solutes" (1965:146). The Chimbu data of Hipsley and Kirk are reproduced in Table 7.11.

Oomen and Corden (1969) provide fluid intake data in their study of dietary intakes and nitrogen metabolism among 24 subjects at Baiyer River (see Map 2). They report that between 0.23 and 0.43 litres per capita per day were drunk although these figures may be high because the experimental subjects had water close to hand at all times. Allowing for water in food, but not for food oxidation, Oomen and Corden compute a total daily per capita intake of 1.56 litres for adult males and 1.95 for adult females. The authors suggest that these low fluid intake figures may relate to the low-sodium nature of the diet caused partially by extremely limited salt use and the apparent absence of salt hunger. They note that traditional salt is used mainly on ceremonial occasions (see Meggitt, 1958a) and that, in any case, this type of salt is primarily potassium based. Oomen and Corden do not comment on the recent development of purchasing packaged salt from native-owned stores and this practice is certainly common in the Saka. It may be that the taste for salt will grow and with it the Enga thirst.

Tombeakini data (Table 7.10) show a considerably higher level of fluid intake amongst the Raiapu than the Chimbu. Also, 0.54 litres per capita daily excludes any water that is drunk away from home and also excludes water drunk in the form of soup (the Raiapu do not typically drink tea or coffee). My impression is that, during days of light work and moderate weather, the Raiapu will drink little or nothing away from home. However, during heavy tasks (clearing new gardens, house-building, etc.) or hot weather, they will drink heavily while at work. I therefore suggest a mean figure of 0.7 litres per capita daily for water consumed throughout the day. Waddell (1972b:121) provides dietary data for a Raiapu clan at the entrance to the Saka Valley. Using this, I calculate that the Raiapu consume approximately 1.38 litres per capita daily of water in food[1] and 0.36 litres of water of oxidation (assuming 150ml of water per 1000 calories of food oxidized). This gives a total daily water availability of 0.7 + 1.38 + 0.36 = 2.44 litres, which corresponds closely to the clinical norm of 2.5 litres.

If Hipsley's explanation of the low Chimbu water consumption is correct, we should expect the Raiapu to have a diet richer in protein than the Chimbu. This appears to be the case. Waddell (1972b:126) reports 29.5g and 34.7g of protein daily during his 2 survey periods, while the mean Chimbu figure is only 21g of daily protein (Hipsley and Kirk, 1965:146). It is likely that other Enga groups have a diet which is lower in protein than the Raiapu and indeed Sinnett (1972c) reports a protein intake of 25g per day for an Enga clan near Sirunki (see Map 2). It may be anticipated therefore that these Enga will require less water than the Raiapu.

A notable feature of Table 7.9 is that, with the exception of the 1% of water used for washing utensils, water is not utilized for hygienic purposes within the home. Most Raiapu households own a

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1. Enga men relish sugar-cane (Saccharum officinarum) and will eat large quantities when it is available. It is considered to be extremely thirst-quenching and the Raiapu say that it is their substitute for water. It contains 82% water by weight (Hipsley and Kirk, 1965:40) and its consumption may dramatically increase the figure of 1.38 litres given here. However, women eat little or no sugar-cane and men who are old, or who are not prosperous, will eat little because they have none and are unlikely to receive any from other men. Sugar-cane water cannot, therefore, be included in any generalisations concerning Raiapu water intake.

few metallic eating and cooking utensils, but only 16% of domestic groups surveyed carried any water to the house for the purpose of washing these. Tombeakini clansmen never wash their bodies at their houses, and this is probably true throughout the Enga region and indeed for most of the New Guinea Highlands. The Enga pay little attention to personal hygiene of any sort but do occasionally bathe all or parts of their bodies in rivers. This river bathing only occurs on hot days and is practised very rarely by adults of either sex. Some Enga, perhaps even many Enga, live their whole lives without ever thoroughly washing themselves. This situation clearly has medical significance and its influence on morbidity patterns will be discussed in Chapter 19.

7.4 FACTORS AFFECTING WATER USAGE

In this section, I shall briefly consider the 2 major factors which are likely to influence patterns of Tombeakini water use. White et al (1972:109-149) found East African usage to be associated with size of household, cost of water, size of container and material wealth. Since there is little variation in material wealth between Tombeakini families, and since all families have a similar selection of containers, it is only household size and cost which are likely to influence Tombeakini usage.

(a) Size of Domestic Group: Figure 7.2 shows that usage per domestic group increases with the size of the domestic group. Figure 7.3 indicates a tendency for per capita usage to decrease as group size increases, for groups of at least 2 consumption units. The low per capita usage in the smallest groups is due to these small groups being almost exclusively composed of elderly people who are not very active and have a diminished need. The elevated demand displayed by the 6-7 units domestic group is probably atypical and results from there being only one group of this size in the sample. Had there been more groups of > 6 units, their mean usage would almost certainly have been < 0.6 litres per day. White et al (1972:123) also found a decreasing per capita demand with increasing household size.

Figure 7.4 shows the influence of domestic group size on the amount of water used for purposes other than drinking. The 6-7 units group should be ignored for the reason mentioned above. The remaining data show maximum general usage by the middle sized (3-4 units) groups. The old people in the smallest groups use little water except for drinking because they do not keep pigs, dogs or chickens and they do not often cook soups.

(b) Travel Time to Source: As has been discussed in section 7.1, the relevant measure of the cost, or efficiency, of water collection is the round-trip travel time from dwelling to source. Figures 7.5, 7.6, 7.7 and 7.8 show that this travel time is not correlated with per capita usage, per capita consumption, the percentage not drunk or the frequency of rain-water collection. This lack of association stems from the proximity of all Tombeakini dwellings to either the Punate or Tobaka (see Map 4 and Fig. 5.2). The range of times is only 4 minutes to 23 minutes (Table 5.2) and it appears that this range is not great enough for travel time to become a significant influence on water usage.

White et al (1972 :127-130) also found that travel time and distance did not play the role that might have been expected. They report:

> At the outset we thought it reasonable that the longer the distance carried the less water would be consumed. Observations soon showed this to be doubtful ... Up to some critical distance - in most sites it appears to be about one mile - there is a tendency to use the same

FIG. 7.2

DOMESTIC GROUP SIZE VERSUS THE VOLUME OF WATER USED PER GROUP PER DAY

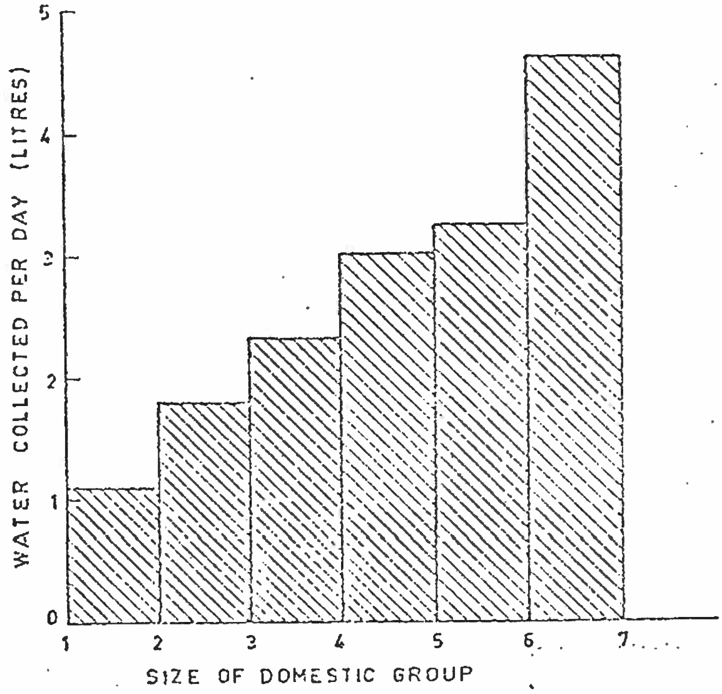
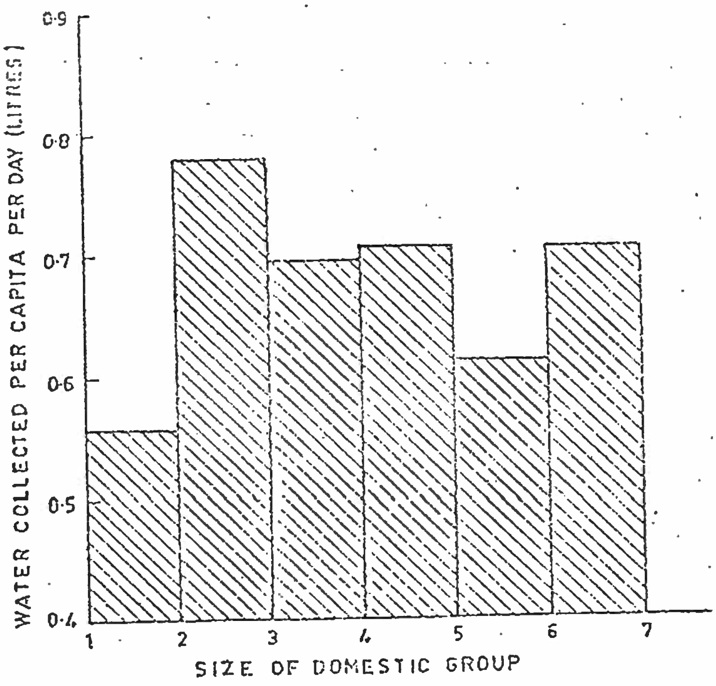


FIG. 7.3

DOMESTIC GROUP SIZE VERSUS THE VOLUME OF WATER USED PER CAPITA PER DAY



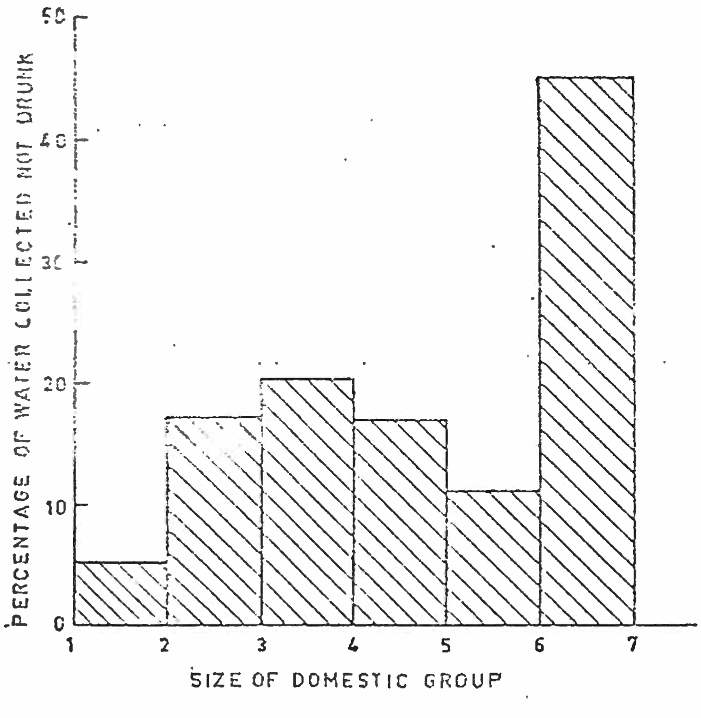


FIG. 7.4 DOMESTIC GROUP SIZE VERSUS THE PERCENTAGE OF WATER USED FOR PURPOSES OTHER THAN DRINKING

FIG. 7.5

TRAVEL TIME TO USUAL SOURCE VERSUS PER CAPITA USAGE

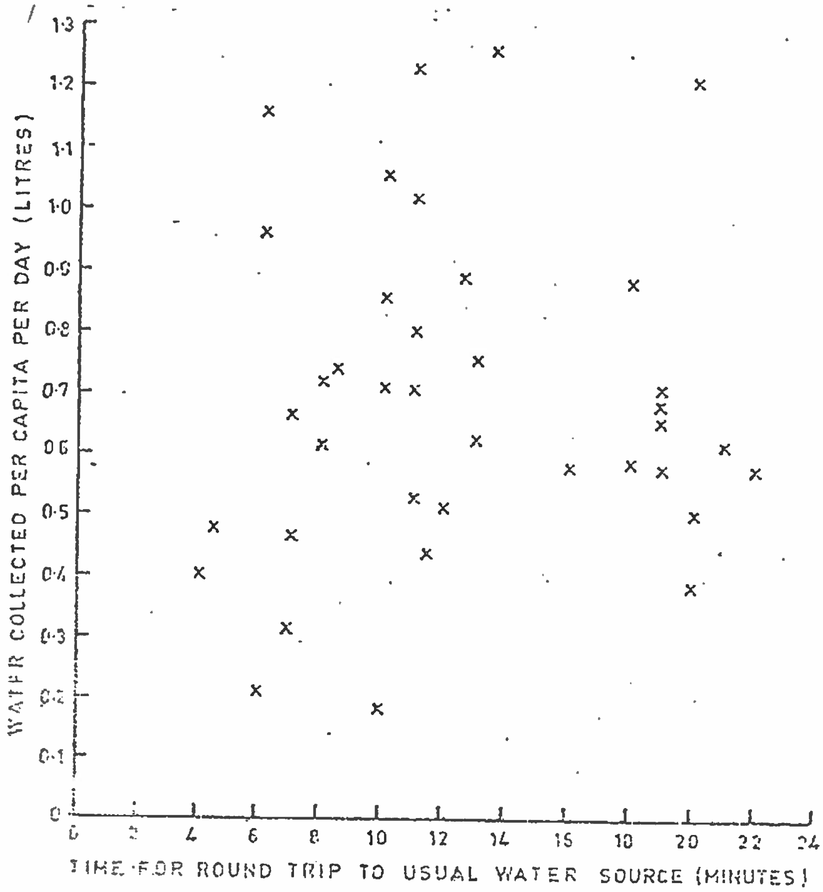


FIG. 7.6

TRAVEL TIME TO USUAL SOURCE VERSUS PER CAPITA CONSUMPTION.

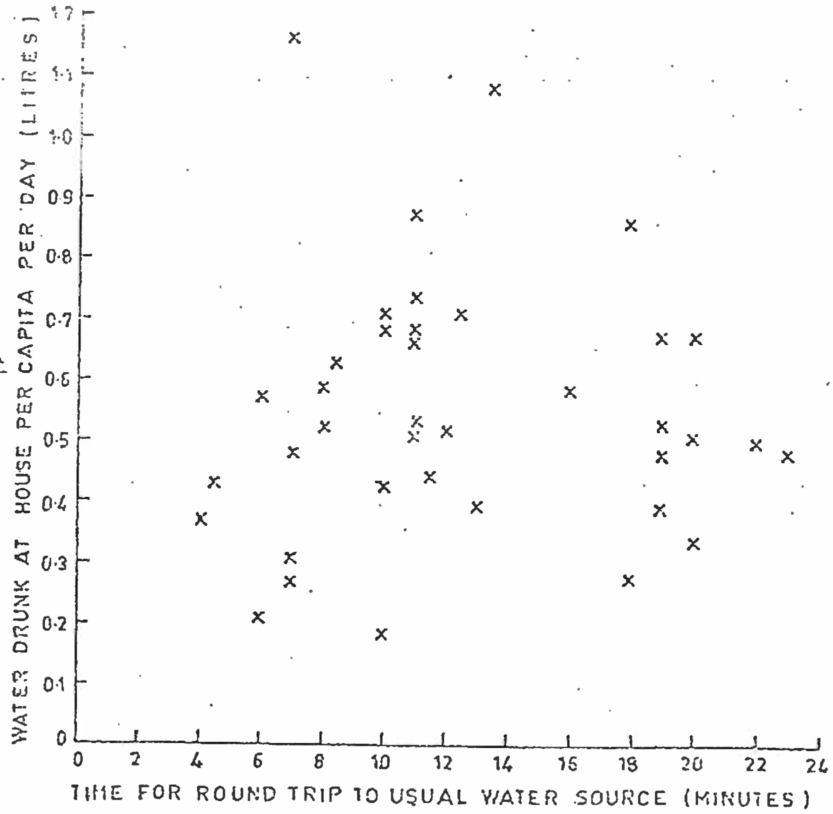


FIG. 7.7

TRAVEL TIME TO USUAL SOURCE VERSUS PERCENTAGE OF WATER USED FOR PURPOSES OTHER THAN DRINKING

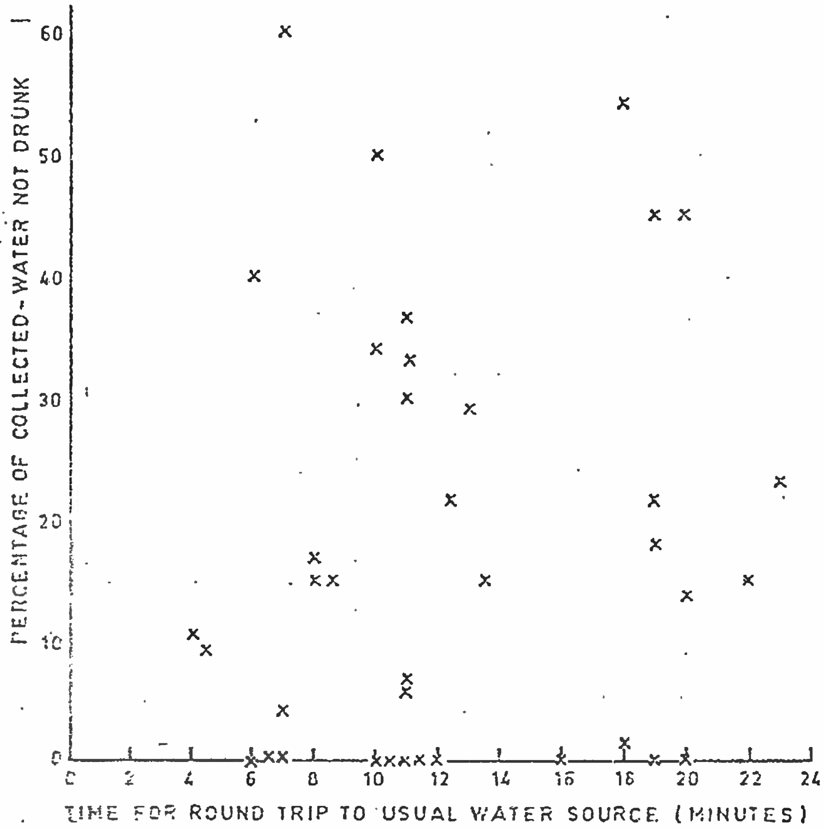
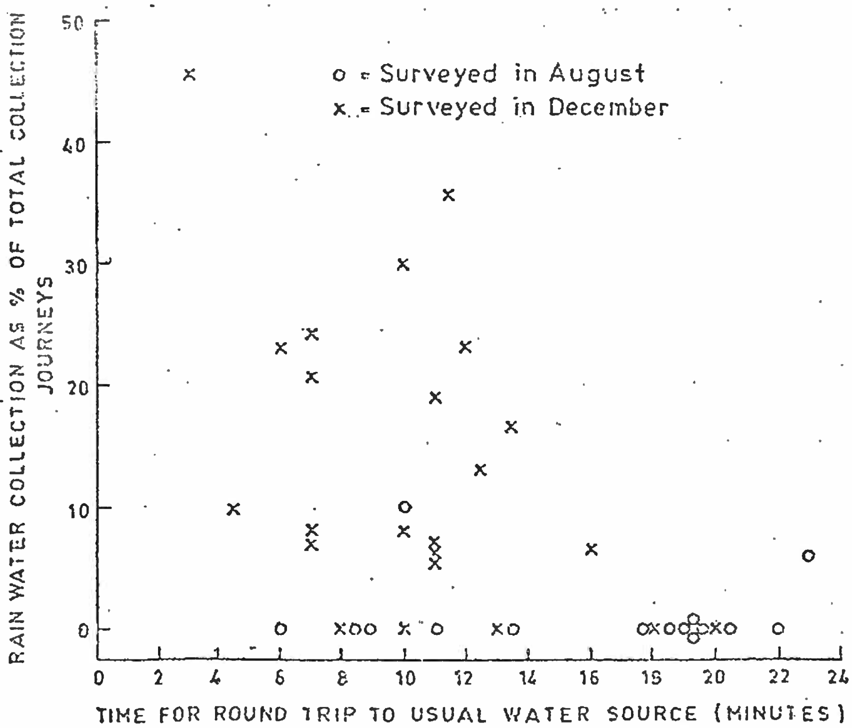


FIG. 7.8

TRAVEL TIME TO USUAL SOURCE VERSUS PERCENTAGE OF JOURNEYS MADE FOR RAIN-WATER



> range of water per capita, but beyond that point the tendency is to reduce the range toward whatever is a minimum for the area ... If distance is influential only for the near and far distances it may be asked whether time, energy and other expenditures show any different association. Distance, time energy expenditures and terrain gradient are highly intercorrelated, and no major variations are found.

Since no Tombeakini dwelling is more than 300m from either the Punate or Tobaka, it is not surprising that travel time does not affect water usage patterns. In some other parts of the New Guinea Highlands, where ridge-top villages cause much greater travel times, a contrasting situation may exist.

7.5 NON-DOMESTIC WATER USAGE

In order to complete the picture painted in the previous sections, I will briefly describe the principal non-domestic uses of water amongst the Raiapu.

(a) Coffee: Since 1959 (Waddell, 1972b:59), the Raiapu have been enthusiastically growing coffee for sale to Waso Ltd. and other coffee buying enterprises. Tombeakini are no exception and, despite their critical shortage of land, they devote 0.01ha per capita to the cultivation of coffee (Coffea arabica) and pyrethrum (Pyrethrum cinerarifolium) and, of this area, about 90% is under coffee. Most Raiapu clans probably assign more land to cash-cropping and Waddell's sample had 0.02ha per capita under coffee and pyrethrum (1972b:116). The processing of this coffee involves the use of considerable volumes of water. Waddell (1972b:60) writes that the cherries are picked,

> split between thumb and forefinger or between the teeth, and the bean placed in a cooking pot. The pot is then filled

with water, the beans soaked, "washed", and then laid out to dry.

A family often has a special container reserved for coffee washing and the process usually occurs at a public place (such as the tée-ground or near the church) where men will gossip while they prepare their coffee. Others will wash coffee outside their houses, but water collected for this purpose is excluded from the data previously presented. Any water will be used and it is not considered important that it be clean.

(b) Kútá: Raiapu women make aprons and skirts out of a reed-like plant called kútá (Eleocharis sphacelata and E. dulcis). This is cultivated in large man-made ponds and ditches (all called kútá peté) and grows with its roots well submerged. Tombeakini women grow a great deal of kútá, some of which is sold to other clans (approximately $2 for a completed apron). Kútá peté are mostly constructed by digging into the swampy flats (category B - Map 4) near the rivers Tobaka and Punate. These naturally fill with water and are surrounded by banks or fences to exclude pigs and children. A kútá peté is normally round, about 3m in diameter and will have up to 1m of water in it.

Some kútá peté are made by damming the Tipini and creating a series of small ponds, one below the other. Water flows down through the ponds and the heights of the "spillways" are adjusted to allow for differing rainfall conditions. These ponds remain comparatively clean and are also used for breeding fish.

(c) Taro: The Raiapu cultivate taro (Colocasia esculenta) either in swampy depressions or in a system of man-made ditches. These ditches are not fed by water from a stream and rely on rainfall, and seepage from nearby swamps, for their supply of water.

(d) Sweet Potato: Sweet potato (Ipomoea batatas) is harvested daily by women. On their way home, they will stop by a convenient stream to wash the tubers. The streams most commonly used are the artificial ones which run in ditches beside the vehicular road. However, these are dry for several months each year and, on these occasions, the nearest natural stream will be utilized.

(e) Drainage: Apart from kútá and taro, the Raiapu do not irrigate crops but they do provide drainage in their mixed gardens. This drainage takes the form of irregular ditch systems which lead water away from the swampy garden areas or break surface run-off down steeper slopes. Large ditches encountered round the perimeter of mixed gardens are, in fact, part of pig exclusion works and are not primarily for drainage.

(f) Fish: Encouraged by officers of the Department of Agriculture, Stock and Fisheries, some Enga breed carp in large ponds for their own consumption or for sale to fellow clansmen. A few men use kútá peté for this purpose, but mostly the carp are kept in special and larger ponds. Westermann (1968:157) reports that these fish are "highly prized", but in the Saka this is not the case. Fish are considered inferior to purchased tinned mackerel because they lack the oil which is greatly appreciated. There is little fish breeding in the Saka and people display scant enthusiasm for it.

CHAPTER 8

CONCLUSIONS

8.1 IMPLICATIONS FOR DESIGN

In order to demonstrate how studies such as this one can be utilized to formulate realistic design criteria, there follows a brief list of design guides for an improved Tombeakini water supply.

(a) Tombeakini do not have a strong "felt need" for improved water supply. The Punate is regarded as an excellent source and the Punate and Tobaka together are believed to meet all water needs.

(b) If a new supply were built (perhaps for medical reasons), it would be welcomed if it provided cold and clear water and it would be used by those who lived closer to it than to their original source. It is unlikely that people would utilize the new source if it entailed a more time consuming collection journey than that to their old source. Outlets would therefore need to be sited so that most dwellings were nearer to a tap than to either the Punate or the Tobaka.

(c) At least initially, there would be enthusiasm for a new supply because it would give cold, clear water, it would be safe from poisoning and fouling in floods and it would give great prestige to Tombeakini. A high degree of local co-operation could be anticipated in the construction of the supply, but long-term maintenance could prove to be a problem.

(d) The new supply would need to serve Tombeakini and only Tombeakini. Any attempt to supply 2 or more clans with one supply would be completely unacceptable. Accusations of poisoning would abound and, in the event of a major dispute or warfare, the clan upstream on the supply would sabotage the pipes. This latter problem has occurred frequently in the multi-village supplies of the Kainantu region of the Eastern Highlands District (see Appendix III).

(e) Present daily demand for water at the house is 0.68 litres per capita. Volumes used for drinking may increase slightly over the next few years and volumes used for cooking will probably increase considerably. At present, very little water is used for washing or other hygienic purposes and it is likely that the level of this type of water use will remain fairly low. The washing of clothes, blankets, utensils and bodies will become more common, but it will probably take place at the rivers and not affect the demand at the house. A demand of approximately 1 litre per capita daily could be assumed if washing water were not to be drawn from the new supply. If, however, facilities for washing and bathing are provided at the outlet, the demand will be greater and will rise as the popularity of hygiene increases.

The whole question of whether a water supply should be installed in a community like Tombeakini, and if so what type of supply, will be discussed in Chapter 19. The justification for a new supply rests largely on the possibility of health improvements which may be anticipated to follow. However, in Part IV it will be shown that the health benefits, resulting from the mere installation of a new water supply, may be negligible and that a new supply may be justified only if it is accompanied by comprehensive public health, and health education, programmes.

8.2 SUMMARY AND CONCLUSIONS

Clarke (1971:165) writes of water usage amongst the Bomagai-Angoiang of the Ndwimba Basin:

> No houses are located beside streams or springs, because the advantage of having water just outside the door is outweighed by the disadvantages of noise, valley fogs night and morning, and the lack of view and of freshening winds. Besides even the ridgetop houses are nowhere more than 15 minutes from water, and the need for water at the houses is small because people neither wash there nor use more than a few pints in preparing the evening meal. The energy cost of walking to fetch water is often incorporated into trips to and from gardens: the bamboo tubes used to carry water are left by the source of water on passing in the morning and filled and carried home in the afternoon.

The Raiapu also say that one reason for not locating houses near rivers is that the noise prevents communication by yodelling from one house to the next. Tombeakini also expend little energy in water collection although they usually make separate journeys for water because their afternoon return trip from garden to house does not typically take them across the Punate or Tobaka.

In order to summarise the main points of the preceding sections, there follows a story episode in which the "typical domestic group" in Tombeakini makes a typical water collection journey. A typical domestic group comprises 3 - 4 consumption units and will collect water once a day. In the late afternoon, a member of the group takes a gourd and a glass bottle and walks for about 6 minutes to either the Punate or the Tobaka. The choice between these two will probably depend on which is more quickly reached but, if they are almost equidistant from the dwelling, a preference will be shown for the superior quality of the Punate. The containers are filled with 2.2 litres of water and carried home. 79% of the water is drunk with the evening meal or stored outside the house (to keep cool) and drunk with the meal next morning. The remaining 21% may be used for cooking soups or cooking potatoes for pigs, but will not be used for washing (except 1% for cleaning plates) or other hygienic purposes.

Generally speaking, the Enga do not wash utensils, they do not wash clothes or blankets [1] and they do not wash themselves. This situation may well apply over large areas of the New Guinea Highlands and any marked hygienic tendency that does exist is almost certainly a recent innovation. Thus the Highland situation is in sharp contrast to coastal New Guinea and Papua (where river bathing is often frequent) and also to East Africa where White et al (1972: 124) show a large percentage of household water use being devoted to bathing, cleaning and dishwashing.

In order to investigate the Tombeakini attitude to washing I stocked the local stores (see Map 4) with soap which was offered for sale at the current retail price. The Raiapu appreciate the purpose and qualities of soap and all Tombeakini families have sufficient cash to purchase soap regularly if they want to. The only reason why I had to stock the stores with soap was that the particular store

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1. Traditional dress (see Feachem, 1972) is a string apron in front and leaves behind, for males, and a kútá apron for females. Shorts, shirts and cotton dresses are now fairly common, but the majority of Enga will not wash these. Some households have blankets which are also seldom, if ever, washed.

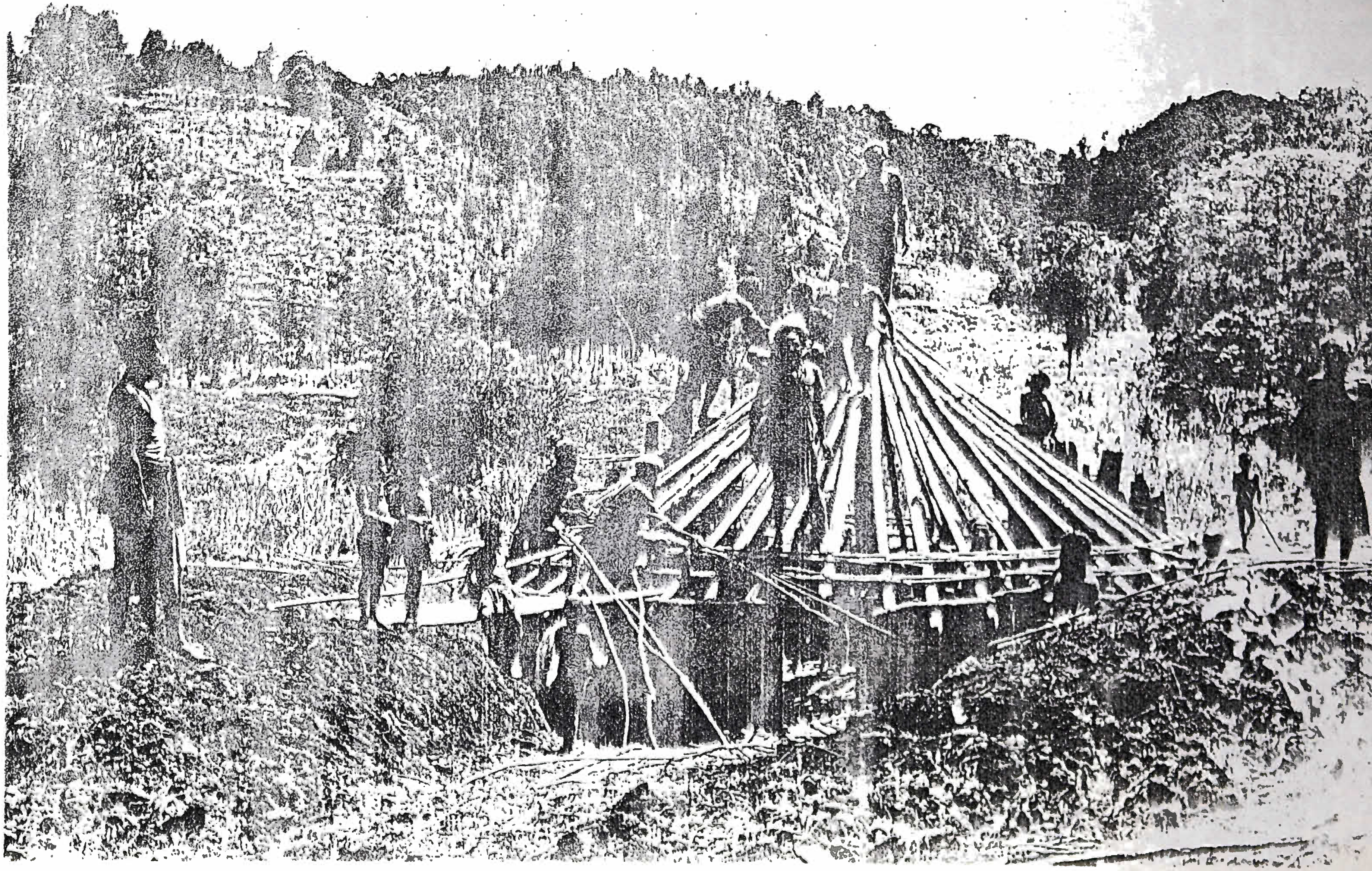
owners concerned (both Tombeakini clansmen) were not sufficiently organised to maintain stocks of anything but the 2 most demanded items - tinned fish and rice. During a period of 21 weeks, Tombeakini bought 41 small bars of soap, which gives a usage of 1.4g per capita per week. It was noticeable that the buyers were mostly from amongst the most "westernised" clansmen - those who had had some schooling, those who had travelled to seek employment outside the Saka, those who spoke pidgin English, or those who sometimes dressed in shorts, shirts or dresses. Demand for soap, and the use of water for hygienic purposes, are therefore likely to increase steadily over the next few years.

This lack of domestic and personal hygiene must clearly influence Raiapu morbidity patterns. In particular it will affect the prevalence of "water-washed diseases" (White et al, 1972: 162) which are those infections which become less common as the volume of water usage is increased, irrespective of the quality of such water. Some of the diseases, which are commonly found in the New Guinea Highlands and which are primarily "water-washed", are skin sepsis, skin ulcers, eye infections, scabies, tinea, leprosy, ascariasis and infected wounds. Other diseases which are "water-borne" as well as "water-washed" are dysentery (bacillary and amoebic), infectious hepatitis, enterovirus infections and gastroenteritis. Some of these diseases are extremely susceptible to improvement by increasing the volume of water used for domestic and personal hygiene.

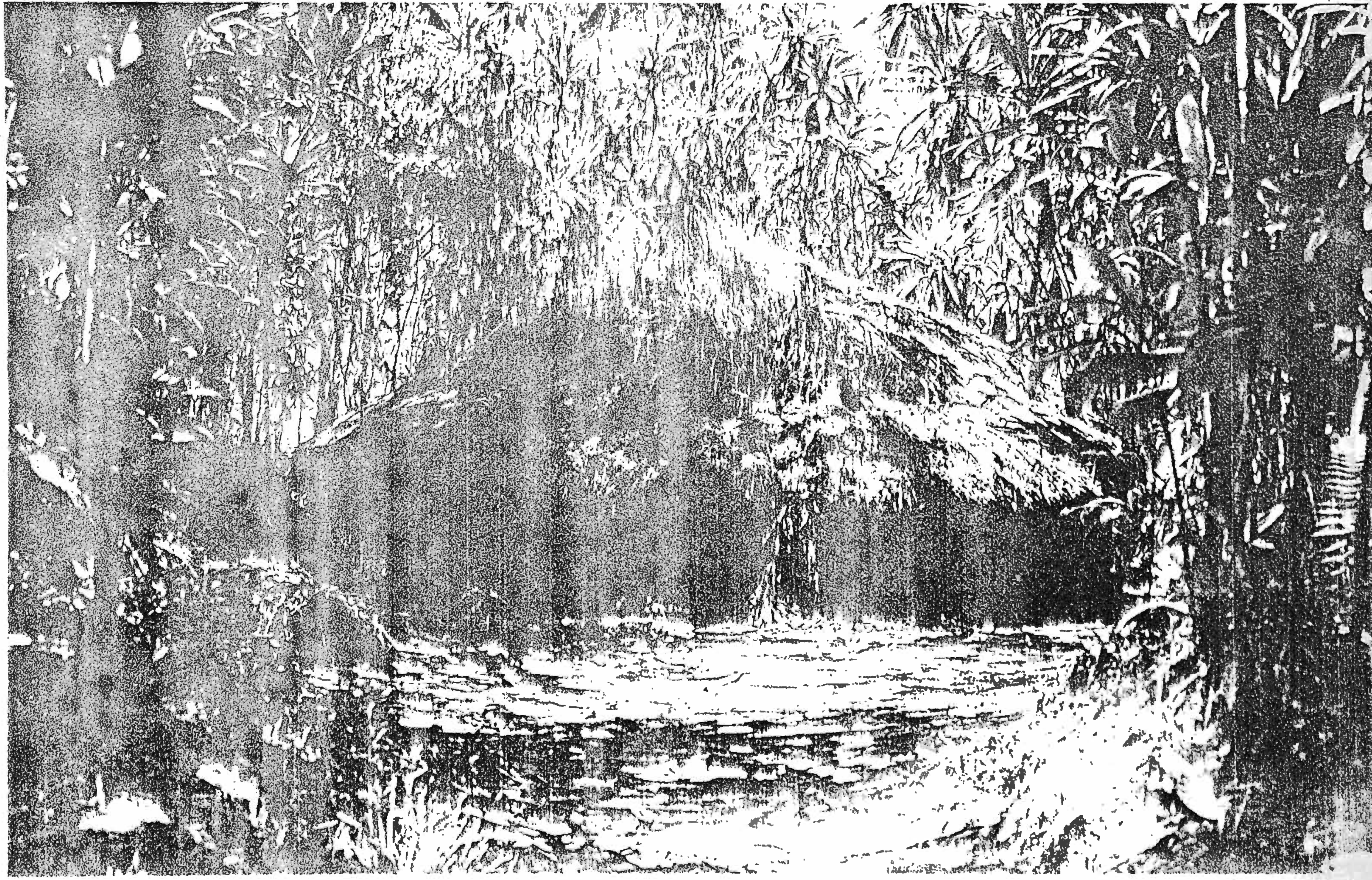
Part IV will present detailed material on Tombeakini morbidity and the effect which increased water usage and improved water quality might have upon this. Part III reports on the levels of faecal pollution in the rivers which Tombeakini use as water sources.

In conclusion, it is necessary to discuss the range of applicability of the data presented in Part II. Clearly, the precise figures given in the various tables only apply to Tombeakini. However, the water-use picture throughout the Saka (pop. = 10,000) is likely to be very similar. The Central Enga (Mae and Raiapu, pop. = 80,000) will also have a water-use pattern which closely resembles that described here. Considering the Highlands, one must make a fundamental distinction between the scattered or dispersed settlement pattern which is common in the Western Highlands, Southern Highlands and Chimbu Districts and the nucleated, village-type, settlement of the Eastern Highlands District. Villages in the Eastern Highlands will tend to utilize fewer sources and make much longer collection journeys than the Raiapu, but there may be great similarity between Raiapu water use and that of other dispersed groups.

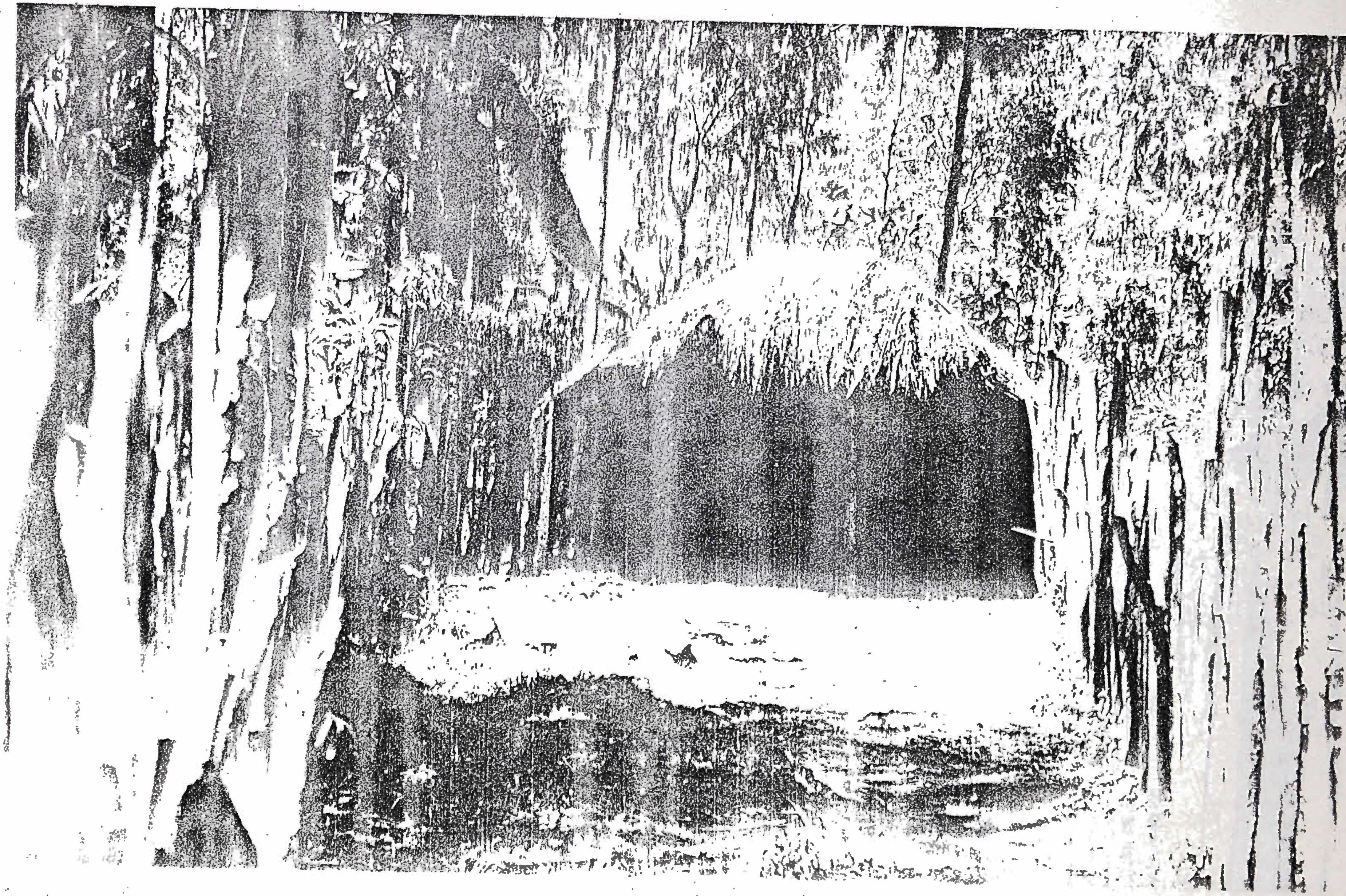
Men of Yakaemandane Clan building a new men's house.



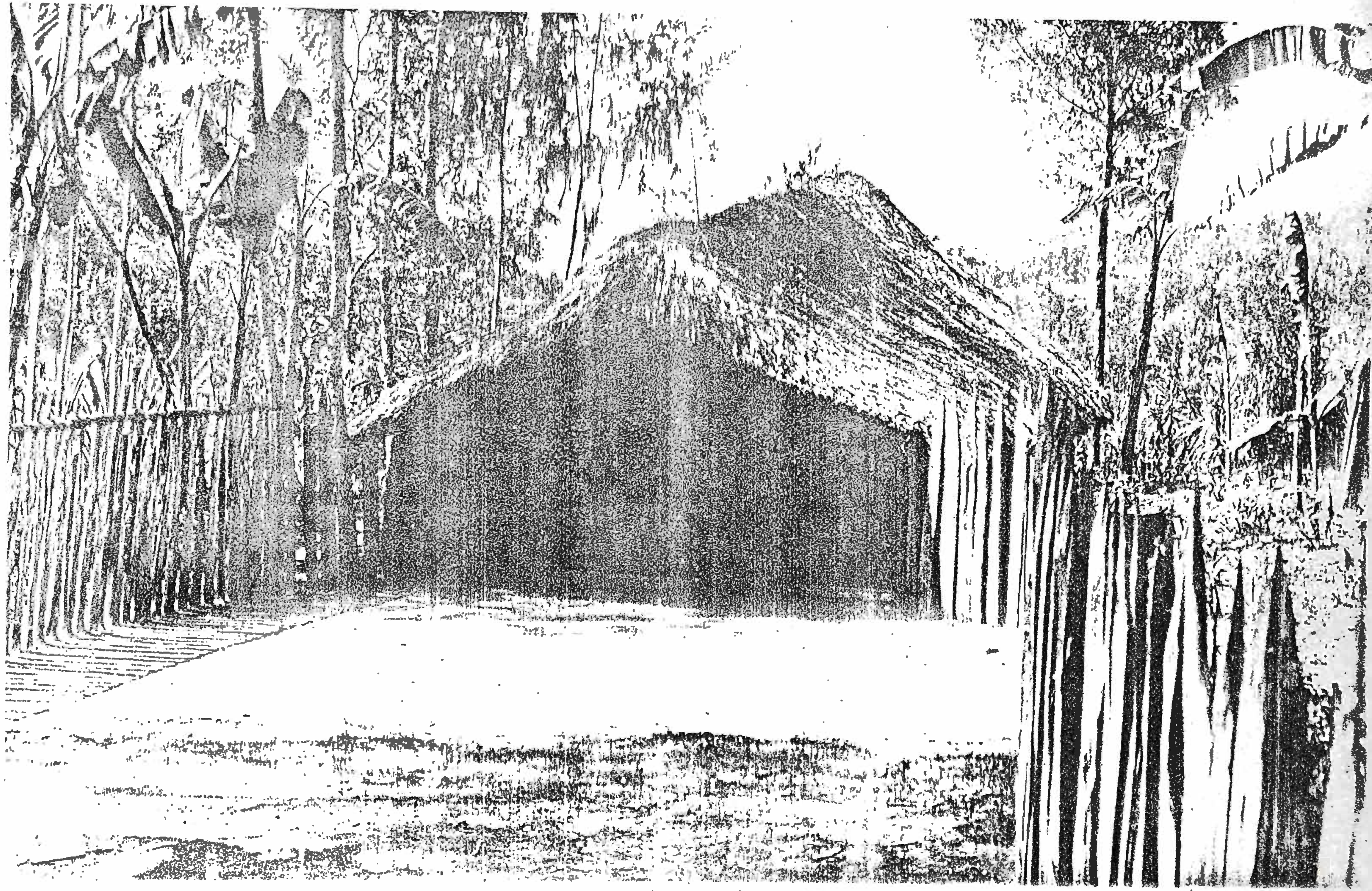
An old and dilapidated "men's house" set in a grove of Cordyline fruticosa.



The front of a women's house in the Saka Valley. The house stands in a grove of casuarina, banana and coffe
trees.



A Mae Enga women's house from near Wabag. The Raiapu women's house is the same except without the sloping roof apex.



PART III

WATER POLLUTION

CHAPTER 9

INTRODUCTION AND LITERATURE SURVEY

The study of the faecal microbiology of streams in Papua New Guinea is of importance for two main reasons. Firstly, since the great majority of Papuans and New Guineans live in rural areas and draw their water from natural streams, it is necessary to know whether or not they are utilising water which contains potentially pathogenic organisms. Secondly, it is of considerable interest to investigate the "bio-hydrology" of New Guinean catchments. By bio-hydrology I mean the study of a catchment and its hydrology in conjunction with the micro-organisms which the living populations of the catchment introduce into the various water flows. If an understanding can be gained of the mechanisms which control the input of faecal contaminants into the water flows, and the manner in which the concentrations of these contaminants fluctuate, it will be possible to take rational steps to modify the existing pollution situation. By studying the faecal content of streams one can hope to say whether or not they constitute a health hazard when used as domestic water sources, and what action can be taken to minimise this hazard.

Part II of this thesis has described the water-use patterns of the Tombeakini clan, and Part III will now describe the faecal contamination of natural waters in and around Tombeakini territory. Unless otherwise specified, all bacteriological work described in Part III was carried out by the author in his laboratory in the Saka (see Appendix II).

9.1 STREAM MICROBIOLOGY IN PAPUA NEW GUINEA

Before proceeding to describe the results of investigations in the Saka, existing information on stream microbiology in Papua New Guinea will be briefly reviewed. Few data are available and local health authorities typically display little interest in determining the extent of rural water supply pollution.

At my request, the Department of Public Health circularised all District Health Inspectors to discover what investigations had been carried out in their areas. Replies were obtained from four districts[1]. The Central District reported 2 E. coli counts from Sogeri and also some from the Western District which appear to be related to the needs of mineral exploration companies. The Chimbu District reported high concentrations of E. coli in 5 rivers and West New Britain reported 1 test. Bougainville reported a short series on 2 rivers, both of which were connected with the installation of new water supply schemes. In other words, there is no regular or systematic testing of rural water quality and little interest in waters which are not either the subject of a proposed new supply or to be used as a source by white men engaged in mineral exploration.

Most relevant work in New Guinea was done by the Commonwealth Serum Laboratories Research Unit when it was temporarily stationed at Wewak (see Morahan, 1968a). Lane (1967) enumerated E. coli by a 2 stage membrane filtration procedure, and qualitatively detected faecal streptococci, in 14 traditional supplies and 10 wells in the Wewak region. The traditional supplies were found to be heavily polluted with E. coli and most contained faecal streptococci. Of the

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1. Papua New Guinea has a total of 16 districts.

63 tests carried out on traditional water supplies; 81% were > 100 E. coli per 100 ml, 36% were > 1,000 and 19% were > 2,000. The wells were generally cleaner and Lane concludes that "properly constructed and thoughtfully situated wells were of very much higher bacteriological quality than the waters from most traditional supplies". Morahan and Hawksworth (1969a) isolated Salmonella from 61.5% of streams tested, and from 72.7% of waterholes tested, by the use of a submerged swab technique.

9.2 REVIEW OF MOUNTAIN STREAM MICROBIOLOGY

This study reports data on faecal contamination in rural mountain streams in New Guinea. Most rivers studied and reported in the literature, are in catchments containing urban or industrial development and the waters are subject to point inputs of water-borne domestic sewage or industrial effluents. The Saka streams are not subject to these inputs and so studies of developed catchments, such as those reported in Velz (1970:249) or Ohio River Valley Water Sanitation Commission (1957), are of little relevance. Investigations which are relevant are those of completely rural catchments, usually in mountainous areas, where all faecal inputs to the streams depend on the natural hydrologic behaviour of the area. A few studies of this kind have been reported from the U.S.A. and are briefly reviewed below.

Petersen and Boring (1960) studied coliform densities and E. coli serotypes in 2 mountain streams near Aspen, Colorado. E. coli were found, even in the upper reaches of these streams, and coliform densities showed surprising uniformity and lack of day-to-day fluctuation. There appeared to be an even distribution of coliforms throughout the stream cross-sections. The authors considered that contaminated soil or mud, and not fresh faecal material, might well be the source of much of the observed E. coli.

Morrison and Fair (1966) studied coliform and total bacterial counts on the Cache la Poudre River in Larimer County, Colorado. They conclude that short duration summer rainstorms are the most important cause of variation in bacterial numbers; that during stable streamflow and dry weather bacterial numbers were related to the size of the contact surface between water and the stream bed; that during increasing streamflow bacteria are deposited in water in bank storage and are later released during falling stages; that small temperature fluctuations in winter caused variation in bacterial numbers; and that cattle grazing on stream meadows contributed to the bacterial density.

Kunkle and Meiman (1967) studied a mountain watershed where both air and water temperatures were low and the influence of men and domestic animals was minimal. They conclude that there was a marked positive association between bacteria and flow, with riverbank "flushing" being an important mechanism; that faecal coliforms (FC) and faecal streptococci (FS) were found throughout the year and showed a similar seasonal variation; that coliforms, FC and FS were positively related to flow, turbidity and suspended sediment and negatively related to pH and a mutual dependency of the physical parameters and bacterial concentrations on the key factor of streamflow was suggested; that FS were less "perceptive" as a pollution detector than FC; and that turbidity and suspended sediment were positively correlated to flow and to each other.

Kunkle and Meiman (1968) again studied a mountain stream in Colorado, and monitored FC, FS and total coliform concentrations. They conclude that analytical errors were an important source of variation; that more variation occurred on a day-to-day basis than within a day; that variability was highest when concentrations were lowest; that there was a daily cycle with evening maxima and afternoon minima; that streambank "flushing" and dilution were important mechanisms with opposing influences; that water temperature was inversely related to bacterial concentrations; that sunlight caused greatly increased death rates; and that FC were more sensitive to cattle contamination than FS.

These last three Colorado studies by Morrison, Fair, Kunkle and Meiman are relevant to this work in that they investigate faecal streptococci and faecal coliforms by membrane filtration techniques, and seek to relate observed pollution to various physical parameters. They are all set in rural mountain catchments where all pollution inputs are due to natural hydrologic phenomena and where there is no urban or industrial waste. In these respects they resemble the New Guinea investigations reported here and will be referred to for comparative interest. No studies on stream pollution set in the tropics or subtropics, and concerned with catchments which support large numbers of warm-blooded animals, could be found.

CHAPTER 10

FAECAL COLIFORMS AND FAECAL STREPTOCOCCI

10.1 THE COLIFORM GROUP AND ITS IDENTIFICATION

10.1.1 INTRODUCTION

As early as 1880, von Fritsch proposed that Klebsiella pneumonias and K. rhinoscleromatis were micro-organisms whose presence in water was indicative of human contamination. Soon after this, Escherich (1885) proposed Bacillus coli as an indicator of faecal pollution and from this early work has developed the complex, and often controversial, set of techniques by which sanitary engineers seem to use the coliform group of bacteria as an indicator of water quality and pollution history.

The description of the coliform group, and its subdivisions into genera, species and sero-types has been something of a taxonomist's nightmare and there is still no clear agreement between authors on questions of taxonomy and nomenclature. Sanitary interest has focused upon the coliform group largely because it is part of a larger group of gram-negative, non-sporing aerobic rods which includes such significant human pathogens as the Salmonellae, the Shigellae and the Vibrios. The coliforms are always found in the digestive tract of warm-blooded animals; they often occur in much larger numbers than the pathogens listed above and they have the ability to ferment lactose with the production of acid and gas. These qualities made the coliforms an attractive choice as an indicator of potentially hazardous pollution.

The precise content of the coliform group is not well defined and the term is not used consistently throughout the literature. If coliforms are defined (as in Lovell and Taylor, 1949) as those bacteria which resemble Escherichia coli, with respect to their morphology and staining properties only, organisms with quite different biochemical properties such as Pseudomonas aeruginosa will be included as coliforms. Even if biochemical characteristics are considered, but examination of flagella omitted, the genus Aeromonas will be included. It is only by the consideration of morphology, staining, biochemical and cultural properties and flagellation that the coliform group takes on a more workable content and size. Bonde (1963:223) writes:

> If the designation colilike is applied to all gram-negative, non-sporing rods a considerable number of widely different groups of organisms will be included in such classification .....mostly without any sanitary importance at all.

Jawetz et al (1970:194) define the coliforms as "a large and heterogeneous group of gram-negative rods resembling, to some extent, Escherichia coli". They include in this group; E. coli derived from the intestinal tract; the Klebsiella-Aerobacter-Hafnia-Serratia subgroup; the Arizona-Edwardsiella-Citrobacter subgroup; and the Providence subgroup. Kauffmann (1954:13) considers that coliforms belong to the family Enterobacteriaceae:

> A large family of gram-negative, non-sporing rods, either motile with peritrichous flagella or non-motile. They grow on ordinary media and ferment glucose rapidly with or without gas production. They reduce nitrates to nitrites. The Enterobacteriaceae are made up of a series of interrelated bacterial types which do not lend themselves to sharp division into tribes or into genera. The transition from genus to genus is gradual, and intermediate strains are found in all cases. Nevertheless, the family is so large and unwieldy that it is

> desirable to divide it into genera for purposes of practical classification. Within the family are found dense centres composed of biochemically homogeneous strains, which are serologically related. These centres of biochemically related strains constitute the genera which are divided biochemically into species.

This quote from Kauffmann clearly sets out the difficulties involved in coliform taxonomy and species identification. The 13th edition of Standard Methods (1971) considers coliforms as "all of the aerobic and facultative anaerobic, gram-negative, non-spore-forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hr at 35C". In previous editions, this group was variously called the "E. coli group" and the "coli-aerogenes group". The testing for all members of the coliform group as indicators of undesirable pollution may have meaning in the case of urban water supply systems where the water has undergone extensive treatment. In this case one can argue that "no coliform bacteria of any kind should be tolerated" (Standard Methods, 1971:669) and so the multiple-tube fermentation procedures for the identification of the coliform group are quite adequate. However, for the testing of stream pollution, raw water sources, sewage treatment systems, bathing waters, sea waters and untreated water supplies, the coliform group is an indicator of nothing since free-living coliforms abound in the environment. In these cases a test for coliforms of faecal origin only is required since this will provide far more information about the pollution history of the water and will allow a rational, rather than an over-conservative, basis for the acceptance or rejection of a particular source. It cannot be emphasised too strongly that tests employed in the developing countries (with the possible exception of tests on treated supplies for urban areas) should be tests for faecal coliforms only and should be carefully assessed to ensure that they are, in fact, specific to faecal strains, The argument that these faecal tests are of no special value because they cannot distinguish between human and non-human origins should be discounted; firstly, because faecal contamination is still a far more rational gauge of unsuitability than mere coliform pollution, and secondly, because animal faeces (for instance, pig faeces in New Guinea) may well contain organisms that are pathogenic to man. The continued wide-spread practice of testing natural waters for the presence of the entire coliform group[1] is to be deplored, since it leads to a belief that pollution is so extensive that it is useless to try to combat it. If pollution is measured only in faecal terms it is immediately apparent that some unsophisticated and naturally occurring supplies (for instance, a protected spring) are of high quality and that it is well worthwhile promoting and protecting supplies of this kind.

A faecal coliform will be defined as one whose natural habitat is the intestine of a warm-blooded animal and it will be referred to by the abbreviation FC. Many members of the coliform group (under whatever definition) occur as free-living organisms in the environment and are in no way associated with faecal contamination. Much effort has therefore been expended to develop techniques which will accurately distinguish coliforms of faecal origin (since these are the only ones of sanitary significance) and the 4 most widely used of these techniques are discussed below.

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1. Buck et al (1968, 1970) provide examples of an unfortunate use of a total coliform count (with M-Endo Broth and membrane filtration) to assess the health hazard of water supplies in rural Peru and Chad. Extremely high counts were obtained but attempts to link these with poor health in the areas studied are weakened because the faecal origin of the pollution is not demonstrated.

10.1.2 THE IMViC CLASSIFICATION

The IMViC classification is based upon a series of 4 biochemical tests: the methyl red test (M), the indole reaction (I), the Voges-Proskauer (acetylmethylcarbinol) test (V) and the citrate test (C). These tests had been in use for many years as individual techniques to indicate whether a particular coliform was likely to be of faecal origin but none of the tests alone provided very reliable information. Parr (1938) surveyed the literature on the separation of faecal, from other, coliforms and found that it was these 4 tests which were by far the most commonly employed. He therefore proposed a composite test (dubbed IMViC) which would eliminate many of the uncertainties of conducting any of the 4 tests individually. All coliforms tested were given an IMViC classification of the form (+-+-) according to whether their reaction to the 4 tests was positive or negative. Parr proposed the following classification of coliforms.

<u>Escherichia group</u>: IMViC types (++--), (+---) and (-+--) all considered to be of faecal origin.

<u>Aerobacter group</u>: IMViC types (--++), (--+-) and (---+) which probably include the majority of soil types.

Intermediate group: the remaining 10 possible IMViC types.

Parr proposed that (++--), (+---) and (-+--), and only these, should be regarded as faecal and this classification of faecal coliforms is widely used today. The Coli-aerogenes Subcommittee (1956) described (++--) and (-+--) as <u>E. coli</u> I and <u>E. coli</u> II, respectively.

The IMViC classification is not suitable as a standard procedure for faecal coliform identification partly because it is a lengthy and complex technique and also because it is not amenable to quantitative determinations. However, it serves as a biochemical basis for the definition of faecal coliform strains and has lead to general agreement that (++--), (-+--) and (+---) are faecal coliforms or varieties of Escherichia coli. Geldreich (1966:14) has noted various drawbacks and uncertainties inherent in the IMViC procedure, but he concludes that the "faecal or non-faecal classification of the coliform group yields good results when the number of strains examined from a single source is sufficient to be statistically significant".

It is noteworthy that the latest edition (13th) of Standard Methods includes the IMViC test as a "tentative" procedure for the differentiation of coliforms. The types (++--) and (-+--) are classified as Escherichia coli I and II, with other common types being described as intermediate E. freundii and varieties of Aerobacter aerogenes.

The remaining 3 procedures are all based upon the finding of Eijkman (1904) that coliforms of faecal origin produce gas from glucose at 46°C, while other coliforms do not. This lead to a series of "elevated-temperature" tests to distinguish between faecal and non-faecal strains and the procedures below are all of this type.

10.1.3 BORIC ACID LACTOSE BROTH MULTIPLE TUBE PROCEDURE

Standard Methods (1971) recommends that this test should follow a standard coliform presumptive multiple tube test (lactose or lauryle tryptose broth). Transfers are made from all positive presumptives to tubes containing boric acid lactose broth and these are incubated at $43 \pm 0.2^{\circ}C$ for 48hr. The production of gas is considered positive indication of faecal origin. Geldreich (1966:30) investigated this technique and concludes that:

> Because of its lack of sensitivity (6.7% negative reactions) for the (++--) type and poor specificity

(13.5% positive reactions) for other IMViC types, the BALB test is not recommended as a single specific test for the accurate detection of (++--) IMViC type.

10.1.4 EC MEDIUM MULTIPLE TUBE PROCEDURE

In this test presumptive positives are transferred to tubes of EC medium which are incubated for 24hr at 45.5 $\pm$ 0.2^{o}C. The production of gas is considered positive indication of faecal origin. Geldreich (1966:32) investigated this EC technique and reported that, like the boric acid lactose broth test, it is not specific for IMViC type (++--), but it is specific for coliforms derived from warm-blooded animal faeces. The EC test can be used as a multiple tube procedure for the calculation of a "most probable number" of bacteria present, but it can also be used as a confirmatory test for presumptive faecal coliforms derived from the M-FC medium with the membrane filtration technique (see below). It was for this latter purpose that the EC test was employed in the Saka. The EC and boric acid lactose broth tests are very similar in their sensitivity and specificity and therefore the EC test is to be preferred because it requires an incubation time of only 24hr.

10.1.5 M-FC MEDIUM MEMBRANE FILTER PROCEDURE

Membrane filtration techniques involve the filtering of a volume of water through a cellulose ester membrane with pore sizes designed to retain all bacteria. The membrane is then placed onto an agar, or an absorbent pad which has been soaked in a nutrient broth, and incubated in a small petri dish. The species of organism which grow, and the colour they become, depend upon the properties of the broth or agar and the temperature of incubation. After incubation the colonies are counted with a magnifying glass and expressed as a number of colonies per 100ml. Despite the rather unenthusiastic reporting of this technique in Standard Methods (1971) it has become an extremely popular method during the last 10 years. It is now widely used for all aspects of water testing throughout the world and a large range of apparatus associated with the technique is readily available. It is a quick and simple procedure, the apparatus may be constructed of completely non-breakable materials and it is particularly applicable to testing under difficult field conditions. It permits a direct bacterial count and it is not dependent on the statistical theories which underlie the MPN calculations. It proved an ideal technique for the investigations reported here.

For the enumeration of faecal coliforms, the membranes are placed on a pad soaked in M-FC broth and incubated in a water bath for 24hr at $44.5 \pm 0.2^{\circ}C$. Faecal coliforms appear blue (as opposed to the grey-cream colour of other growths) and can be readily counted under a magnifying glass. Geldreich is largely responsible for the development of this M-FC/membrane filter technique for the enumeration of faecal coliforms. He has conducted extensive trials on this technique (Geldreich, 1966:33-41) and he reports that, of 3, 031 blue colonies selected for verification, 93.2% were confirmed as faecal coliforms and, of 460 creamy-coloured colonies selected, 83.9% were shown to be non-faecal. Bradley, writing in White et al (1972:180), reports that "over 90%"of blue colonies grown on M-FC medium from East African water sources were confirmed by "biochemical reactions" (presumably IMViC) to be of faecal origin. Bradley thereby counters the possible criticism, raised by Raghavachari and Iyer (1939), that in the tropics it is possible for certain specially adapted saprophytes to ferment lactose at $45^{\circ}C$ and thus appear as false faecal colonies in an elevated-temperature procedure.

One of the major drawbacks of the membrane filtration technique is that, if waters with high turbidity are filtered they will clog the filter paper with solid particles and may prevent the filtration of the required volume. This obstacle was occasionally encountered after heavy rain but, typically, the waters tested had a low load of suspended solids or algae which might clog the membrane. A second disadvantage of the technique is the importance of precise temperature control during incubation. The temperature of 44.5°C "represents, of necessity, a compromise between acceptable sensitivity and specificity for the faecal types" (Geldreich, 1966:15). Geldreich (1966) recommends a maximum temperature fluctuation of ± 0.5°C, while Standard Methods (1971) allows only ± 0.2°C. These limits present problems when incubation is being carried out with unsophisticated field equipment. The incubator used in these tests (see Appendix II) was only accurate to ± 1°C, and this is not ideal for faecal coliform growth on M-FC medium. The placing of the dishes, in sealed plastic bags, in a water bath within the incubator helped to further stabilise the temperature fluctuations.

10.1.6 RECENT DEVELOPMENTS IN FC ISOLATION

Buras and Kott (1969) report a modification of Geldreich's M-FC medium which they call MmFC. Filters are incubated on MmFC at 37°C for 24hr and E. coli appear blue, A. aerogenes - pink and intermediate colonies are light green. Buras and Kott (1972) now report a further development in which use is made of specific E. colibacteriophages. The filter is placed on a pad soaked with MmFC and then 1ml of bacteriophage mixture is pipetted onto the filter in order to cause lysis of the E. coli cells. A comparison of 2 replicate filters, one with MmFC and the other with MmFC plus bacteriophage mixture, enables the E. coli colonies to be enumerated. These procedures are interesting but could not be used in a field study until they have been widely tested.

10.2 THE FAECAL STREPTOCOCCI AND THEIR IDENTIFICATION

10.2.1 INTRODUCTION

> The streptococci are spherical micro-organisms, characteristically arranged in chains and widely distributed in nature. Some are members of the normal human flora; others are associated with important human diseases attributable, in part, to infection by streptococci, in part to sensitisation to them. (Jawetz et al,1970:164.)

They are comparable to other pyogenic cocci such as staphylococci, pneumococci and neisseriae (gonococci and meningococci). There is an extensive literature on the taxonomy of streptococci and particularly on the "faecal streptococci" or "Lancefield's Group D Streptococci" which are the taxa of sanitary significance. Deibel (1964) presents an extensive review of the group D streptococci. Deibel reports:

> Two characteristics, common to all group D streptococci, are the ability to grow at 45°C and in media containing 40% bile. S. bovis and S. equinus do not initiate growth at 10°C, at pH 9.6, or in media containing 6.5% NaCl, and these species usually fail to hydrolyse arginine or decarboxylate tyrosine. Generally, the enterococci give opposite reactions in these tests; thus, the primary differentiation of the 2 physiological entities is afforded.

Although the term "enterococcus" has been used somewhat vaguely by some authors, both Deibel (1964) and Standard Methods (1971:688) suggest a stricter usage. "Faecal streptococci" and "Lancefield's group D streptococci" are synonymous and denote S. faecelis, S. faecelis var. liquefaciens, S. faecalis var. zymogenes, S. faecium, S. durans, S. bovis and S. equinus, whereas "enterococci" are the above species excluding S. bovis and S. equinus. This usage will be adhered to in the following pages[1].

The normal habitat of faecal streptococci is the intestine of man and other animals and they are therefore used as indicators of faecal pollution. Deibel (1964) writes that "it may be surmised that the chief source of Group D streptococci is the alimentary canal of animals. Thus the occurrence of these bacteria in water infers either direct or indirect faecal contamination". Deibel's review reveals that enterococci are the usual streptococcal flora in humans, whereas S. bovis and S. equinus are the most numerous species in cattle, swine, sheep and horses. Workers in the U.S.A. have indicated that S. faecalis outnumbers S. faecium in humans, whereas human hosts in continental Europe appear to have a higher frequency of S. faecium. This difference may be attributable to diet.

Deibel suggests that S. bovis dominates in cattle, swine and sheep and that enterococci may constitute only 10% of the total streptococcal flora. However, there is not general agreement on this point. Geldreich and Kenner (1969) report that S. bovis plus S. equinus comprise only 19% of pig streptococcal flora. Raibaud et.al (1961) comment that "some workers have found that S. faecium or S. faecium and and S. faecalis and its varieties are the most frequent, whereas others have found S. bovis or S. equinus to be the most numerous". Raibaud et al found that 100 strains of dominant streptococci, from the alimentary tract of pigs, all showed the majority of physiological and biochemical characteristics of S. bovis. S. faecium is more common than S. faecalis in animals and, with the exception of chickens, S. faecalis appears to be rare. The probable predominance of S. bovis

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1. An example of loose usage of the term enterococci is provided by Ramadan et al (1972), who describe S. bovis as an "enterococcal species".

in swine is extremely relevant to this study since it will emerge that pig faeces are probably the source of much of the observed pollution in the Saka rivers. Since diet appears to affect the streptococcal species frequency in humans it may well do so also in pigs and therefore it is ideally necessary to await a study of the streptococcal species excreted by pigs kept in a traditional Enga manner (Feachem, 1973b) and fed largely on sweet potatoes. A further factor for consideration is that the medium used in this study (M-Enterococcus agar) is reported by the Taft Center (cited by Kunkle and Meiman, 1968:24) to be less sensitive to S. bovis than the alternative KF Streptococcus agar which some workers have employed. This leads to difficulties when comparisons between studies are attempted and it may cause underestimation of the total faecal streptococcal contamination if that contamination originates largely from pigs.

Mundt (1963), cited by Deibel (1964), has surveyed the incidence of enterococci in wild mammals, reptiles and birds. 71% of mammalian species harboured enterococci and, in wild boars, S. faecium was more common than S. faecalis. In other wild mammals, S. faecalis was predominant. 85% of reptiles contained enterococci. Eaves and Mundt (1960) have studied and reviewed the association between enterococci and insects. The association was believed to be circumstantial and enterococci are merely transient residents in the insect digestive tract. Enterococci have been commonly found on plants, especially domestic plants, and an epiphytic relationship has been suggested. Enterococci are not native to the soil and there is agreement that their presence in soil samples is indicative of contamination.

Standard Methods (1971:689) describes a multiple tube technique, a membrane filtration technique and a tentative plate count for the enumeration of faecal streptococci. Only the membrane filtration technique is relevant to this study and it will now be discussed.

10.2.2 MEMBRANE FILTER TECHNIQUE FOR FAECAL STREPTOCOCCI

This procedure is similar to the M-FC filtration technique for faecal coliforms already discussed. The petri dishes are partially filled with a layer of agar (either KF streptococcus agar or M-Enterococcus agar) and the filters are placed on top of this agar in such a way that air is not trapped between filter and agar surface. The dishes are then inverted and incubated at 37°C for 48hr. All red-pink colonies are counted and expressed as faecal streptococci per 100ml. Standard Methods (1971:690) reports that "practically 100% of the red and pink colonies that grow on filters placed on M-Enterococcus or KF agar are faecal streptococci". Confirmatory tests are therefore not strictly required and were not attempted in this study.

Many studies have assessed the relative advantages of various faecal streptococcal media and especially of M-Enterococcus (ME) and KF agars. ME agar was chosen for this study purely because it can be made by rehydrating[1] a powdered agar, whereas KF agar preparation requires the addition of sterile 2, 3, 5-triphenyltetrazolium chloride to a rehydrated medium[2]. Geldreich (1970a) has pointed out that, since many interfering organisms which may grow on these media are from a soil-water habitat, the use of a higher incubation

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1. See Appendix II for an account of the source of the water for rehydration.

2. Ramadan et al (1972) discuss the use of various media for faecal streptococci enumeration in Egypt.

temperature than 35°C should be considered. "Elevating the incubation temperature to 44.5°C would be more selective to the faecal streptococcus group, but should be approached in such a way that will not desensitise the medium to maximum recovery of all strains". Geldreich suggests the possibility of an initial 4hr incubation at 35°C followed by 44 hr at 44.5°C. This type of incubator control was not possible under the conditions of the Saka laboratory and so a compromise of 48hr incubation at 37°C was utilised. It is thought that this increased selectivity without seriously impairing sensitivity to faecal streptococcal strains.

Slanetz and Bartley (1964) reported that ME agar was essentially 100% selective. Saraswat et al (1963) found that Lactobacillus acidophilus grew on this medium, but Raibaud et al (1961) obtained low recovery and overgrowth of lactobacilli. Pavlova et al (1970) contrasted the performance of 5 alternative media for faecal streptococci. They concluded that the "highest recovery with the lowest percent of nonfecal (sic) streptococci was obtained with KF-streptococcus and PSE agars". On ME agar they write that "ME agar was low in yield and was highly selective, but still allowed growth of nonfecal streptococci in 18.4% of the isolates". KF agar is probably the preferable medium but it appears that ME is good, although conservative due to its low yields. It was adopted for the reason given above but the low yield, and the low recovery of S. bovis and S. equinus (already mentioned and also referred to by Geldreich, 1970a) should be borne in mind.

Finally, it must be noted that the FS concentration in a natural water may include a large proportion of S. faecalis var. liquifaciens, which is believed to be of little sanitary significance. Geldreich (1970a) reports between 0% and 35.3% of S. faecalis var.

liquifaciens in "prairie water-sheds". Geldreich writes that waters with high var. liquifaciens concentrations "may be devoid of recent faecal pollution, receive only small additions of contamination, or contain minute vestiges of some pollution discharge remote in time or place". This situation could lead to a basal concentration level of FS which has little faecal significance. Geldreich recommends parallel testing for faecal coliforms to evaluate the meaning of low FS concentrations and this was carried out in the Saka.

10.2.3 RECENT DEVELOPMENTS IN FS ISOLATION

Any development in bacteriology, which gets away from tedious biochemical procedures and replaces them by techniques which allow automated, continuous monitoring of polluting bacteria, must be a great advance. Pavlova et al (1972) report "that all species of group D streptococci yielded positive fluorescent antibody (FA) reactions with laboratory prepared labelled antibodies". The identification of FS with fluorescent antibodies could provide an excellent method for the monitoring of FS in streams and Pavlova et al conclude that "the FA method can be employed for the rapid enumeration and identification of faecal streptococci from water and sewerage".

10.3 THE RATIO OF FAECAL COLIFORMS TO FAECAL STREPTOCOCCI

There were 2 main reasons for electing to conduct both faecal coliform and faecal streptococcal investigations in the Saka. Firstly, since few confirmatory tests were to be conducted, it was wise to test for 2 entirely different faecal groups in order to add reliability to statements regarding the health hazards associated with a particular source. Secondly, by collecting data on both FC and FS concentrations, it is possible to suggest whether the source of the pollution is primarily human or animal in origin. This is done by consideration of FC:FS ratios which have been discussed by Geldreich (1966, 1967, 1970a), Geldreich et al (1968) and Geldreich and Kenner (1969).

In human faeces the ratio of FC to FS is 4.4, whereas in sheep, cows and pigs it is 0.4, 0.2 and 0.04, respectively (Geldreich, 1966:102 and 1967). Generally speaking, in human faeces the ratio is >4, whereas in all animal faeces it is <0.7. Extensive studies have shown that waters known to contain domestic (i.e. human) sewerage display higher FC:FS ratios than waters known to have little human contamination (i.e. farmland drainage, stormwaters, etc.).

The major drawback with the FC:FS ratio is that the ratio will change as the different bacterial species exhibit different survival abilities in an aquatic environment. For instance, since faecal coliforms survive better than S. bovis but worse than S. faecalis (Geldreich and Kenner, 1969), FC:FS ratios will increase where the FS component is mainly S. bovis but decrease where most streptococcal species are enterococci. Geldreich (1967) therefore recommends that FC:FS ratios be applied only at pollution input points or "at those sample locations within a 24hr flow time downstream of the point of pollution entry". Since pollution input points occur almost continually down the banks of the Saka rivers, this condition is automatically adhered to, but difficulty arises due to the lag between defecation and the introduction of the faeces into the flow. This lag may cause appreciable changes in the FC:FS ratios.

10.4 THE DIFFERENTIAL SURVIVAL PROPERTIES OF SOME BACTERIA

In order to correctly interpret the data collected on bacterial concentrations in the Saka, it is necessary to appreciate the behaviour of these bacteria outside their preferred enteric environment. This is particularly pertinent to the consideration of FC:FS ratios, since these will clearly change as the 2 groups respond differently to their environment. Geldreich et al (1968), Geldreich and Kenner (1969) and Geldreich (1970b) report data on the persistence of various species in storm water at 10°C and 20°C. Table 10.1 gives figures abstracted from these publications. The storm water environment used was considered by Geldreich and Kenner (1969) "to represent a typical stream environment with respect to chemical constituents".

All species exhibit die-away, although it has been reported (Lonsane et al, 1967; Platt, 1935) that coliforms will multiply in water under certain conditions. Table 10.1 shows that all species except S. bovis survive better at 10°C than at 20°C. It is noteworthy that the enterococci survive well when compared to S. bovis which exhibits an extremely rapid die-away. FS tests should therefore be extremely sensitive to variations in faecal inputs, if the primary origin of the FS pollution is non-human and therefore S. bovis outnumber enterococci. Since the survival ability of FC lies between the enterococci and S. bovis it may be that, for certain FS species compositions, the FC and FS die-away rates will be similar.

Geldreich (1970b, 1971) reports that bottom sediments may contain far higher concentrations of bacteria than their overlying waters. Geldreich (1971) writes:

> Salmonellae can be isolated from bottom sediments with far greater frequency than directly from the overlying water. Within the limits of

TABLE 10.1

NUMBER OF DAYS NEEDED FOR 90% DEPLETION OF ORGANISMS AT 10°C AND 20°C IN STORM-WATER FROM GELDREICH AND KENNER (1969)

Temperature °C	S. bovis	Salmonella Typhimurium	Faecal Colform	S. faecalis var. liquifaciens	S. faecalis
10	0.2	7.1	9.6	40 *	42 *
20	1.2	1.5	1.7	5.5	20 *

* Based on unreasonable extrapolation of data which is only in the range of 0 - 14 days.

> existing methodology, quantitation of salmonellae in mud is also possible. There is approximately a 100 to 1000-fold increase in fecal coliform bacteria in the mud as compared to the overlying water. Salmonellae were isolated from 19 per cent of the mud samples when the fecal coliform density in the overlying water was between 1 and 200 per 100ml; from 50 per cent between 201 and 2000; and from 80 per cent over 2000.

Bottom deposits provide a more protected and nutrient-rich environment and will cause greatly increased survival of bacteria which may be stirred up at any time and returned to the water flow. Most river beds in the Saka are stoney and so this is unlikely to be a major factor except in the case of the muddy bottoms of the *kútá peté* (the ponds in which *Eleocharis sphacelata* and *E. dulcis* are grown).

Lonsane *et al* (1967) and Platt (1935) also studied the die-away properties of coliforms. They found that, at both refrigerator and room temperatures, coliform densities decreased with storage time and that the decrease was the greatest at room temperature. McDaniel *et al* (1965) studied the effect of oxygen supply on *E. coli* growth and found that "the amount of growth obtained depended on the oxygen-supply rate."

Velz (1970: 242-253) has summarised the available information on the death rates of bacteria in a stream environment. It has been found that many bacteria exhibit survival properties which approximate to Chick's Law first formulated in 1908. Chick suggested that bacteria die according to the expression:

$$\frac{dB}{dt} = KB$$

or

$$\log_{10} \frac{B}{B_o} = -kt$$

where B_o is the initial population, B is the number remaining after time t, and k is the reaction or death rate. Velz reports that, although Chick's Law may describe much of the observed decline in the early stages, modifying factors will vary the value of k and may disturb the whole relationship.

Rising temperature typically increases the death rate (Bigger, 1937; Platt, 1935; Table 10. 1) as do increased acid or alkaline conditions. Competition from other micro-organisms may substantially increase the death rate and coliform bacteria placed in sterile water exhibit greatly reduced death rates (Bigger, 1937; Platt, 1935). Velz (1970: 244) concludes that:

> although it is known that these, and undoubtedly other, factors affect the survival rate of coliform and pathogenic organisms of intestinal origin, unfortunately their individual or combined effects are not sufficiently understood to permit prediction of a specific survival constant k for a given set of conditions.

Experimental work has sometimes shown appreciable deviations from the form of Chick's Law and formulae such as

$$B = B_o(10^{-kt}) + B'_o(10^{-k't})$$

have been proposed to describe the real situation. However, deviation from Chick's "constant death rate" is usually only significant in the final stages of decline when perhaps less than 1% of the original population is remaining. The initial decline, from 100% to 10% of original numbers, may closely follow Chick's Law.

Velz also reviews surveys of coliform survival in rivers in the U. S. A., and shows that large rivers tend to have $k(\text{day})^{-1} = 0.5 \pm 0.15$ while smaller rivers have $k(\text{day})^{-1} = 0.8 \pm 0.2$. Saka rivers would be classed as very small or tiny and one might expect k(day)$^{-1}$ values of $\geq$ 1.0 for coliforms. The increase of k values with decreasing stream size may relate to the effects of sedimentation and adsorption of bacteria onto the stream bed. Cool streams exhibit lower k values than warm streams. If a Saka stream had a k(day)$^{-1}$ value of 1.0 for coliforms, 90% would die within one day from their time of input.

CHAPTER 11

FC AND FS AS INDICATORS OF PATHOGENIC POLLUTION

Data will be reported here on the levels of FC and FS concentrations in Saka rivers. In order to determine the public health significance of these findings, 2 questions must be answered. Are high FC or FS concentrations, which in themselves are seldom pathogenic, likely to be associated with pathogenic micro-organisms, and, if the source of faecal contamination is non-human, to what extent may it be pathogenic to man? Literature will be reviewed below which will clarify these points.

The concept of testing waters for numerous, possibly non-pathogenic, bacteria, which are normally found in the digestive tract of warm-blooded animals, and interpreting their presence as indicative of the potential presence of small populations of pathogenic micro-organisms, is well accepted. Coliforms, faecal coliforms and faecal streptcocci are the bacteria most commonly used as pollution indicators. Clostridium perfringens (Cl. welchii) is sometimes used in situations where its long survival, and resistance to chlorination, are an advantage. In their classic review, Kehr and Butterfield(1943) suggest that the number of Eberthella typhosa per 1,000,000 coliforms in an effluent may vary from 3 to 120 as the level of typhoid fever morbidity, in the community providing the effluent, varies from .01 to 30 cases per 1000 people per year. The authors also concluded that the infectious dose of E. typhosa is 1 bacterium although only 1 or 2 percent of those who ingest this dose actually become sick[1].

1. This conclusion has since come under attack and Smith (1968) provides a useful review and discussion on the concentrations of pathogens in effluents and the dosages required to cause sickness.

Geldreich (1970b) notes that it is wise to test for indicators of all warm-blooded animal faeces (and not merely human) since the excreta of non-human animals may well contain organisms which are pathogenic to man. Geldreich cites literature on the presence of human pathogens in a wide range of wild and domestic animals. In particular he notes the incidence of *Salmonellae* in rodents, wild birds and ducks and of *Leptospira pomona* in cattle, swine and wild animals. Lins (1970) reports that 2% of the 1,380 wild mammals and reptiles caught in a remote region of the Lower Amazon forest harboured *Salmonella*.

The literature from Papua New Guinea serves to confirm strongly the importance of treating non-human faecal material as potentially pathogenic, and also provides data on the occurrence of *Salmonella* and *Shigella* in man. Morahan (1967) found that, in a prison at Wewak, 10.6% of humans had *Salmonella* in their faeces and 2.4% had *Shigella*. 50% of specimens from rats contained *Salmonella* but those from pigs and cows did not. *S. weltevreden* was the most commonly isolated serotype. Morahan (1968b) summarised *Salmonella* and *Shigella* isolations from people of the Wewak area and again reported that *S. weltevreden* was the dominant serotype. He tentatively linked these infections with animal carriers and contaminated food and water supplies. Morahan (1969a) presents another summary of *Salmonella* isolations. *S. weltevreden* constituted 66% of isolations from humans and 59% of isolations from animals. *S. thompson* was the dominant type in water (39% of isolations) and food (90% of isolations) and Morahan again links human salmonellosis to contaminated food and drinking water. Morahan (1969b) reports the incidence of *Salmonella* in all rats as 6% and in *Rattus rattus* of 8%. Morahan and Hawksworth (1969b) report that 39% of sago samples from 14 palms contained Salmonella. Egerton and Rampling (1963), Rampling and Egerton (1965) and Rampling (1967) report the isolation of Salmonella from the faeces of cats, cattle, horses, pigs, guinea-pigs, chickens, ducks and deer from coastal Papua and New Guinea. Caley (1972) reports that 9% of village pigs from Rabaul, and 54% of pigs from piggeries in Port Moresby, harboured Salmonella.

Apart from salmonellosis, the principle zoonotic disease which has received attention in Papua New Guinea is leptospirosis. W. H. O. (1967b) review the world situation and find that rodents are the most important hosts but that all other mammals are also implicated. The role of water in disease transmission is stressed:- "fresh water in all forms appearing in nature is a major factor in the circulation of leptospires in enzootic foci". Helminths and blood-sucking arthropods could play a role in leptospiral transmission but this is not clearly understood. W. H. O. stress that human leptospirosis is strongly connected to epizootics in animals and that control of the disease depends largely on rodent control and sanitation.

Morahan (1968c) isolated a leptospire from a bandicoot in the East Sepik District and Morahan (1971) reports 5 isolations from bandicoots and a dog. Kariks and Stallman (1968) report the first isolation of a leptospire from a human in New Guinea.

Willis and Wannan (1966) report the most extensive study to date on leptospirosis in Papua New Guinea. These authors investigaged leptospiral agglutinins present in the blood of humans and animals at 6 sites from throughout New Guinea. One of these sites was in the Bena Bena Valley of the Eastern Highlands District and the findings from this site may well be applicable to the Saka valley. 31% of humans at Bena Bena had leptospiral antibodies and the incidence generally increased with age. Willis and Wannan's data presentation does not permit the calculation of the total incidence of antibodies in animals. However, one can say that, at Bena Bena, at least 75% of pigs, 14% of dogs and 18% of rats (mainly Rattus exulans but also R. rattus) had leptospiral antibodies. The authors point out that if a proportion of these animals is excreting leptospires in urine, there are many opportunities for human infection - particularly in the moist conditions of the gardens.

This review strongly suggests that testing for the FS and FC bacterial groups (which do not clearly distinguish between human and non-human origins) is a relevant public health procedure. The relationships between FC concentrations and the presence of Salmonellae and Shigellae have traditionally been a focus of interest amongst sanitary engineers and recent innovations in the isolation procedures for these pathogens have provided new information. Lack of correlation between Salmonellae (or other pathogens) and FC concentrations has lead to some scepticism regarding the value of the FC as an indicator of health hazard. Geldreich (1970b) has pointed out that this lack of correlation is to be expected because Salmonellae are not the normal inhabitants of a healthy individual and their occurrence in polluted waters is highly variable. In the absence of an outbreak of morbidity it has been suggested that the percentage of individuals excreting Salmonella is 1, 2, 3 and 3.9 in the U.S.A., U.K., Australia and Ceylon, respectively. It is therefore predictable that tests for Salmonella in domestic wastes from small populations may well give negative results although the FC concentrations are high.

Geldreich (1970b) reviews data from 11 studies on the correlation between FC concentrations and Salmonella detection in stream and estuarine waters. In fresh waters it appears that there is a sharp increase in the frequency of Salmonella detection when FC concentrations exceed 200 organisms per 100ml and that, with over

2,000 FC per 100ml, Salmonella isolation is almost certain.

This discussion indicates that substantial FC or FS concentrations are almost certainly accompanied by pathogens, but that these may occur in such small numbers that their detection is very problematical. It has also been shown that animals are an important reservoir for infectious agents and therefore animal faecal pollution should be regarded as potentially pathogenic to man. The presence of Salmonella and leptospires in animals in New Guinea has been stressed and it is notable that these occur in pigs, dogs and rats, which are the 3 mammals with which the Raiapu Enga (and most New Guineans) have most contact. Table 11.1 gives a list of diseases which may be transmitted by animals to man in the Saka and the likelihood of these being transmitted by polluted water supplies is indicated. It has been pointed out in section 10.1.1 that to test for total coliforms, rather than for faecal coliforms, is of limited value except in the assessment of treated urban water supplies. The author has heard it strongly argued that the additional effort involved in distinguishing between faecal and total coliform pollution is not productive since it does not permit the separation of human, and non-human, faecal sources. This argument is countered by the above discussion. Until such time as bacteriological technology allows the ready distinction between human and non-human enteric bacteria in a field laboratory, one must test for all faecal organisms and claim that their presence is indicative of contamination which is pathogenic to humans, irrespective of its source. FC:FS ratios, and other data, will be presented to permit speculation on the probable source of the observed pollution. However, purely from the point of view of assessing the health hazard involved in utilising Saka rivers as sources of domestic water supply, these speculations are not crucial. If it is accepted that the bacteria which were cultured originated in the intestines of warm-blooded animals, then the identity of these animals should not greatly influence quality assessments of the polluted waters.

NOTE:

Since completing this chapter I have read Evison and James (1973) who raise the possibility of using anaerobic lactobacilli as indicators of faecal contamination in both temperate and tropical waters.

TABLE 11.1

SOME DISEASES WHICH MAY BE FOUND IN THE NEW GUINEA HIGHLANDS AND WHICH MAY BE PARTIALLY ZOONOTIC*

Disease	Causative Organism	Animals Involved	Possibility of Infection Via Polluted Waters	Reported Incidence in New Guinea Highlands
Arbovirus infections	Arboviruses	Rodents, birds, pigs marsupials		
Influenza	Influenza virus type A	Pigs		
Enterobacterial infection	*Arizona* spp. *E. coli*, *Salmonella* spp.	Poultry, pigs, dogs, rodents, cattle, etc.	Bacteria transmitted in faecally polluted water	
Leptospirosis	*Leptospira*	Rodents, dogs, pigs, cattle.	Possible infection via polluted waters. (W.H.O., 1967b)	Willis & Wannan (1966) report 31% of people in Bena Bena Valley having leptospiral antibodies.
Amoebiasis	*Entamoeba histolytica*	Dogs	Cysts passed in faeces and can survive for 2 weeks in water	Vines (1970) reports 16% incidence in Highlands
	Entamoeba polecki	Pigs	Cysts possibly transmitted in polluted water	McMillan & Kelly (1970) estimate 20% of Highlands infected. Not known to be pathogenic to man or pigs

Table 11.1 Cont'd.

Disease	Causative Organism	Animals Involved	Possibility of Infection Via Polluted Waters	Reported Incidence in New Guinea Highlands
Balantidiasis	Balantidium Coli	Pigs	Cysts may be transmitted through polluted waters	Heydon (1940) found 11% incidence at Mt. Hagen and Vines (1970) found 2% in Highlanders
Cestode diseases	Hymenolepsis diminuta and H. nana	Rodents	Eggs possibly transmitted in polluted waters	Vines (1970) reports 0.4% H. diminuta and no H. nana in Highlanders. McMillan et al (1971) report an incidence of 0.7% of H. diminuta and no H.nana amongst Highlanders
Trematode diseases	Schistosoma mansoni	Rodents, birds	Life cycle depends on faecally polluted waters	Schistosomiasis does not occur in Highlands. However, Blackburn & Ma (1971a) found 11.6% of Kyaka Enga had positive reaction to antigen. (Probably due to infection by avian schistosome or unidentified trematode)
Nematode diseases	Ancylostoma ceylanicum	Dogs	Eggs possibly transmitted in polluted water	Vines (1970) reports 74% hookworm incidence in Highlands
	Ancylostoma braziliense	Cats, dogs		
	Angiostrongylus cantonensis	Rats		
	Ascaris suis (A. lumbricoides)	Pigs	Eggs transmitted in polluted water	Vines (1970) reports 59% Ascariasis incidence in Highlanders

Table 11.1 Cont'd.

Disease	Causative Organism	Animals Involved	Possibility of Infection Via Polluted Waters	Reported Incidence in New Guinea Highlands
Nematode diseases	*Dirofilaria immitis*	Dogs, cats	Eggs possibly transmitted in polluted waters	Blackburn & Ma (1971b) found 9.6% of Kyaka Enga at Baiyer River had positive reaction to antigen. No clinical filariasis seen - could be cross reaction with other helminths
	Gnathostoma hispidum *Gnathostoma doloresi*	Pigs Pigs	Eggs possibly transmitted in polluted waters	Egerton & Murrell (1965) found that 75% of Highlands pigs had *Gnathostoma hispidum*
	Strongyloides stercoralis	Dogs	Eggs possibly transmitted in polluted waters	Vines & Kelly (1966) report none amongst Highlanders
Scabies	*Sarcoptes scabiei*	Dogs, pigs		Vines (1970) reports 8% amongst Highlanders. It is probably around 20% in the Saka

* Compiled from data in Egerton and Rothwell (1964), Ewers (1973), Ewers and Jeffrey (1971), Talbot (1968/69) and W.H.O. (1967a)

CHAPTER 12

DATA, ERRORS AND SPECIES CONFIRMATIONS

12.1 TYPES OF DATA COLLECTED

Several distinct experiments were conducted in the Saka during 1971 in order to obtain data on different aspects of the faecal pollution situation. Most involved the determination of concentrations (in colonies per 100ml) of FC and FS by membrane filtration using M-FC broth and M-Enterococcus agar, respectively. These principle experiments are now described.

12.1.1 REPLICATION TESTS

In order to investigate the nature of the variance caused by various analytical and sampling errors (see section 12.2), 3 samples were taken (1 each from the Punate, Tobaka and Tame) and 20 replicate pipettes were filtered from each sample. Incubabion on M-FC broth followed and a total of 3 x 20 replicate readings of FC per 100ml were obtained. This was repeated, on a different day, with M-Enterococcus agar and 3 x 20 replicate readings of FS per 100ml were recorded.

A second series of replication tests was conducted in which 10 different volumes (from 1ml to 250ml) were taken from a sample and filtered. This was repeated 3 times for FC and 3 times for FS, giving 3 x 10 concentration readings for each of the bacterial groups. These data are used to explore the problems associated with choosing the filtration volume in membrane filtration work and to assess the errors involved in filtering too small, or too large, a volume.

12.1.2 HOURLY TESTS

To investigate the cycle of bacterial concentrations within a single day, 2 series of hourly samplings were conducted. Between noon on the 13th November and 11.00 a.m. on the 14th, a sample was taken from site 2 on the Tobaka (see Map 6) every hour. These hourly samples were returned immediately to the laboratory where 5 replicate pipettes were tested for FS. Thus, 5 x 24 values of FS concentrations were recorded. A similar procedure was conducted between 6.00 a.m. and 6.00 p.m. on the 27th November and 5 replicates of each hourly sample were tested for FC, giving 5 x 13 values of FC concentrations.

Site 2 was chosen since it could be reached by motor-cycle from the laboratory in about 3 minutes and was the most accessible site. On each sampling occasion, river temperature and the preceding hour's rainfall were also recorded. In all cases, the 5 replicate pipettes were filtered, and placed in the incubator, immediately the sample had been brought up from the Tobaka. It will emerge that it would have been extremely valuable to conduct more of these hourly test series. However, this was not practicable since the 24hr FS series entailed a continuous effort for 24hr followed by a further 24hr as the dishes became ready for counting. This was a considerable effort and seriously interrupted the other aspects of my work. Additionally, it kept a large number of Tombeakini clansmen awake as I roared up and down on my motor-cycle throughout the night.

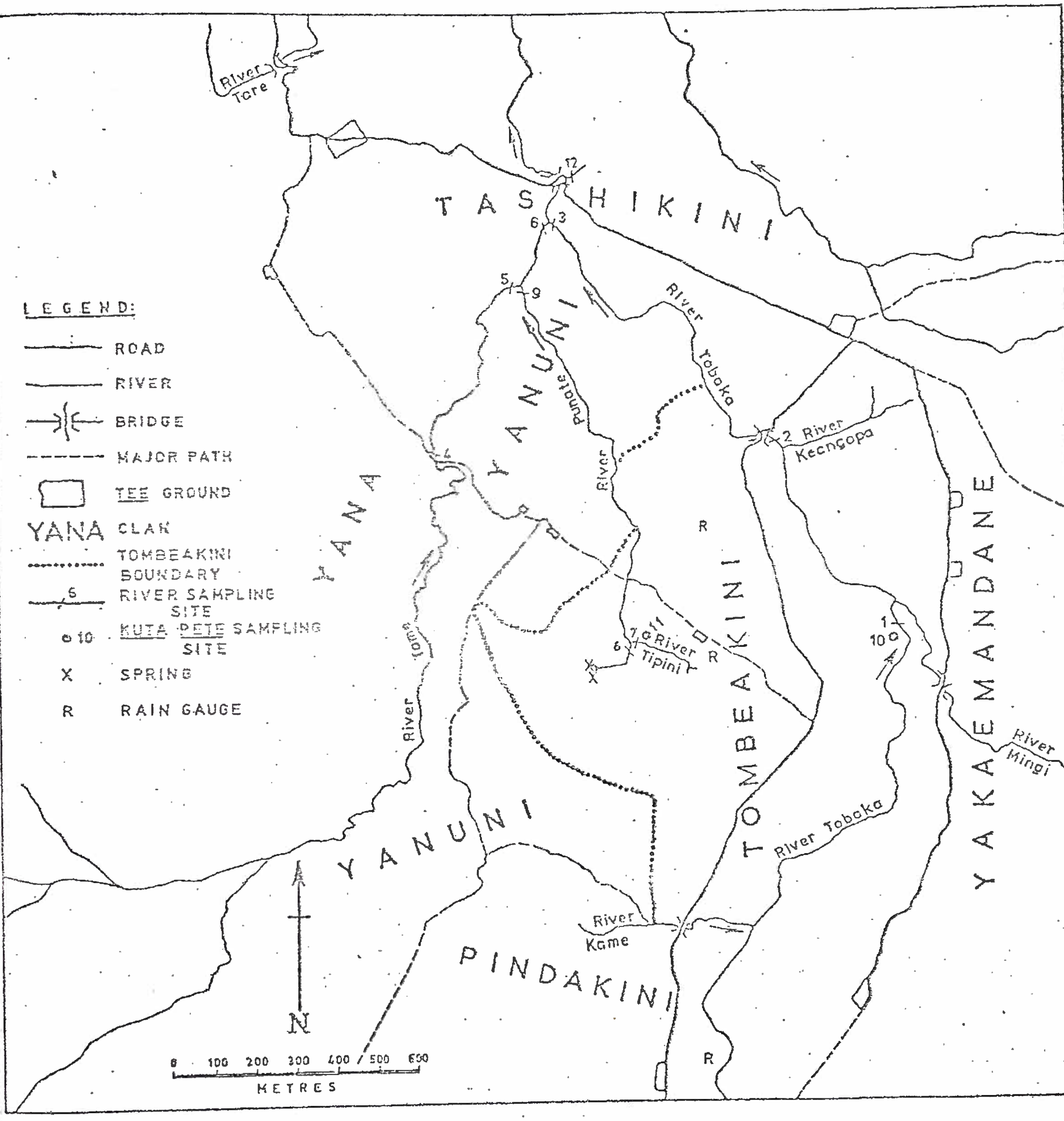
These hourly tests resulted in 24 x 5 FS replicates and 13 x 5 FC replicates. The means of these groups of 5 will be used in examining the hourly fluctuations in pollution and the replicates themselves will be used to supplement the data (described in section 12.1.1) on analytical and sampling errors.

12.1.3 SAMPLING AT 12 SITES IN THE SOUTH-EASTERN SAKA

Between the 27th May and the 4th November, each of 12 sites (designated 1-12) in or near Tombeakini territory (see Map 6) were

MAP 6

THE TWELVE SAMPLING SITES IN THE SOUTH-EASTERN SAKA



tested each week for both FC and FS concentrations. The weekly schedule was broken between the 16th September and the 10th October so that a total of 20 weekly tests were completed. Thus 12 x 20 weekly FC values and 12 x 20 weekly FS values were recorded. The laboratory facilities did not permit the testing of both FC and FS on the same day, because they require different incubation temperatures. Therefore, in each week, one day was for FS testing while another was for FC, and simultaneous FC and FS values were not obtained. One sample only was collected per site per day and only one pipette was filtered from that sample. It is this lack of replicates, within the main body of the experiment, that necessitates the analysis of replication data to determine the likely variance associated with an individual FC or FS value.

On each sampling occasion, river temperature and turbidity were also recorded. The resulting data arrays are therefore 12 x 20 FC concentrations, 12 x 20 FS concentrations, 12 x 40 river temperatures and 12 x 40 turbidities. Daily rainfall at Lyokote was also measured throughout the period of this experiment.

12.1.4 SAMPLING AT 10 SITES THROUGHOUT THE SAKA

During November and December, 10 sites (designated S1-S10) on the major Saka rivers (see Map 3) were tested 3 times for FC and 3 times for FS. River temperatures and turbidities were also recorded on each of these 60 sampling occasions. Only 1 pipette from 1 bottle was tested per site per day.

12.1.5 CONFIRMATORY TESTS

A limited number of confirmatory tests were conducted at the Saka laboratory, and also at the Mambisanda Hospital, to support the assumption that blue colonies on the M-FC medium were, in fact, faecal coliforms. These tests are reported in section 12.3. In line with the report in Standard Methods (1971:690), that "practically 100% of the red and pink colonies that grow on filters placed on M-Enterococcus or KF agar are faecal streptococci", no confirmatory tests for FS were conducted.

12.1.6 TESTS FOR PATHOGENS

Although the relationships between Salmonella, Shigella and the faecal indicators are extremely variable, it was considered worthwhile to make tentative tests for the presence of these pathogenic bacteria. Two procedures were adopted. Firstly, a series of samples was filtered and incubated for 48hr at 37°C on Bismuth Sulphite agar, as recommended by Clark et al (1951). A pad soaked with Bismuth Sulphite broth would have been preferable to the agar, but only agar was available at the time the materials were ordered. Bismuth Sulphite agar is used for the detection of Salmonella and especially for S. typhosa and positive colonies appear dark, possibly with a sheen and a black-brown halo. Samples from all the major rivers were tested and volumes of up to 1 litre were filtered. Volumes in excess of 1 litre could not be filtered due to filter clogging. Brown colonies of 3 - 10mm diameter, sometimes with a metallic sheen and halo, were commonly observed, but there was usually a heavy overgrowth of other organisms. To clarify the situation, filters which had been incubated on Bismuth Sulphite agar were sent to Mambisanda Hospital (near Wapenamanda) for further tests. The high degree of confluence and overgrowth made testing difficult but it appeared that most colonies were gram-negative rods which gave negative lactose and positive urease reactions. Many were tentatively identified as

Proteus spp. and especially Proteus rettgeri[1]. Enterobacter (or Aerobacter) hafniae were also found and the overgrowth was identified as yeast.

The second approach was to filter the largest possible volume and place the filter in a small screw-capped bottle of Tetrathionate broth which was then incubated at 37°C until it could be taken to Mambisanda Hospital. Tetrathionate broth is commonly used for the preliminary enrichment of Salmonella spp. other than S. typhosa. Tests at Mambisanda gave similar results to those for the Bismuth Sulphite investigations. Most identifications were of Proteus, with a few Enterobacter being recorded.

These negative results are not surprising in view of the very low concentrations of pathogens which may exist in the Saka rivers. I have little doubt that, if more thorough and persistent tests for Salmonellae and Shigellae had been carried out, positive identifications would have been obtained[2]. It is possible that the method of submerging swabs for many days in the flow, described by Morahan et al (1968a), would have proved to be fruitful. In view of the high concentrations of FC and FS found in some rivers (Chapter 13), it is almost certain that pathogenic bacteria are also present.

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1. Dickinson and Mocquot (1961) report that, although Escherichia were dominant among Enterobacteriaceae in pig's intestines, in 1 case they were outnumbered by Providence strains accompanied by Proteus rettgeri.

2. Geldreich (personal communication, 1973) writes that a "limiting factor to Salmonella recovery relates to choice of methodology employed, since no one approach has a high and uniform recovery for all 1200 Salmonella serotypes known to exist. Thus multiple enrichments, 2 incubation temperatures (37 and 41.5°C), 3 selective media (XLD, Brilliant Green agar, and Bismuth Sulphite agar) are frequently employed when time, staff, and laboratory facilities permit".

12.2 SOURCES OF ERROR AND VARIANCE

Throughout the main experiments (described in 12.1.3 and 12.1.4 above) only 1 reading of the bacterial concentration was made for a particular site at a given time. One bottle was filled at each sampling site (in mid-stream in the case of the Punate, Tame and Tipini, but at the bank for the Tobaka because the flow was too strong to permit wading) and 1 pipette was taken from that 1 bottle. The single value of colonies per 100ml thus obtained is therefore only a point on a distribution of values whose shape is determined by the various analytical and sampling errors inherent in the experiment. The most important sources of error are discussed below.

12.2.1 BOTTLE ERROR

Bottles taken from the same site at the same time could contain different bacterial concentrations. Kunkle and Meiman (1968:9) report that variance between bottles in their experiments was small compared to other sources of variance and they recommend that additional sampling effort should be directed towards more replicates from a single bottle rather than a greater number of bottles. Single bottles only were collected in the Saka and no attempt was made to investigate the variation between bottles.

12.2.2 PIPETTE ERROR

Different pipettes taken from the same well-shaken bottle may contain different bacterial concentrations. Since these differences only emerge after the pipette volumes have been filtered, incubated and the colonies counted, it is not possible to distinguish between "pipette errors" and "analytical errors" without conducting parallel tests which employ different laboratory techniques. This was not feasible and therefore "pipette errors" and "analytical errors" must be considered jointly.

12.2.3 ANALYTICAL ERROR

If 2 pipettes were taken, each of which was known to contain identical bacterial concentrations, and were filtered and incubated, the resulting colony counts would almost certainly be different. This discrepancy is due to the numerous sources of error inherent in the membrane filtration technique: the medium compositon may vary slightly; colonies may coalesce; colonies may die; all organisms in the water may not end up on the filter; the final number of colonies may not be accurately counted; etc. Some of these errors are associated with the skill of the experimenter and will be minimised by careful and patient laboratory work. All analytical errors are likely to be greater in tests done in field laboratories (as in this study) than in tests conducted under sophisticated and sterile conditions.

Kunkle and Meiman (1968:7) compared the variance due to the types of error mentioned above with the other sources of variance in their data and concluded that "analytical error is usually one of the most important sources of variance". These authors reported that the mean coefficients of variation (CV)[1] of data from 2 series of replication tests (on total coliform counts) were 59% and 51%, and that the CV of replicate values tended to decrease as the mean of those values increased.

Data from the replicates described in 12.1.1 and 12.1.2 were analysed and showed a mean CV of 15% (range from 5% to 32%) for FC and a mean CV of 18% (range from 5% to 37%) for FS. The data also show that the CV of a group of replicates tends to decrease

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1. The coefficient of variation equals the $\frac{\text{standard deviation}}{\text{mean}} \times 100$

as the mean of the group increases and thus reliability increases as the colony count per filter increases.

It is clear, therefore, that the reliability of a single value of FC or FS per 100ml is considerably higher than it was in the experiments of Kunkle and Meiman and this is an important confirmation of the accuracy of the Saka laboratory technique. The CV values indicate that a single FC value has a 95% chance of estimating the mean (or "true") value by $\pm$ 30% and that a single FS value has a similar chance of estimating the mean by $\pm$ 36%.

A log-log plot of the standard deviations against means of 37 sets of replicates, revealed that the standard deviations varied approximately as $(\text{mean})^{0.63}$ for both FS and FC. The variance-causing errors which are included in this value are those described above as "pipette" and "analytical" errors. What I have called pipette errors are largely sampling errors due to the uneven distribution of organisms within a single bottle and this distribution has been shown to follow closely that of Poisson in which the standard deviation equals $\sqrt{\text{mean}}$[1]. Therefore an error distribution with a standard deviation equal to $\sqrt{\text{mean}}$ is due to unavoidable sampling error and, in the case of the Saka data, it is supplemented by analytical errors to give an overall standard deviation which varies as $(\text{mean})^{0.63}$. Therefore the actual standard deviation is only 0.63/0.5 = 1.26 times greater than the unavoidable standard deviation. This figure is low and compares favourably with the value of 2.85 reported by Velz (1970: 591) for total coliform duplicate filtrations on the Detroit River in 1956-57.

It appears, therefore, that analytical errors associated with

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1. Many texts make this assumption of a Poisson distribution. England and Wales (1969: 21) make it implicitly in the statement that the 95% confidence interval of a count C is approximately $\pm$ 2 x $\sqrt{C}$.

the Saka data are well within tolerable bounds and are considerably lower than those of Kunkle and Meiman (1968) and Velz (1970). This may reflect superior laboratory technique or it may be due to the analytical errors inherent in FC and FS tests (the types used in the Saka) being less than those in the total coliform test which was used by the other authors. In either case, the following analysis of Saka data can proceed with the assurance that analytical errors are not excessive.

One type of analytical error is not included in the above calculations and deserves separate mention. In all the replication tests analysed above, an equal volume of water was filtered in each replicate. If, however, different volumes from the same bottle are are filtered, a new source of error appears in the final concentration values due to the differing number of colonies growing on the filter. If too few colonies grow, unduly large sampling errors result, and if too many grow, crowding, confluency and nutrient-competition are found and the large numbers of colonies are extremely difficult to count.

A series of replicates of different volumes were filtered and incubated and the results for 4 of these are shown in Figure 12.1. If the relationship between the volume filtered and the colonies counted is linear, the computed colonies per 100ml will remain constant irrespective of the number of colonies per filter. In other words, the lines of Figure 12.1 will be horizontal in trend, but will fluctuate in accordance with the analytical errors discussed previously. This horizontal trend is seen to exist primarily in the range of 15 to 100 colonies per filter. Colonies per 100ml tend to be underestimated when colonies per filter exceed 100 and conversely, concentrations are usually overestimated if colonies per filter are less than 15. This

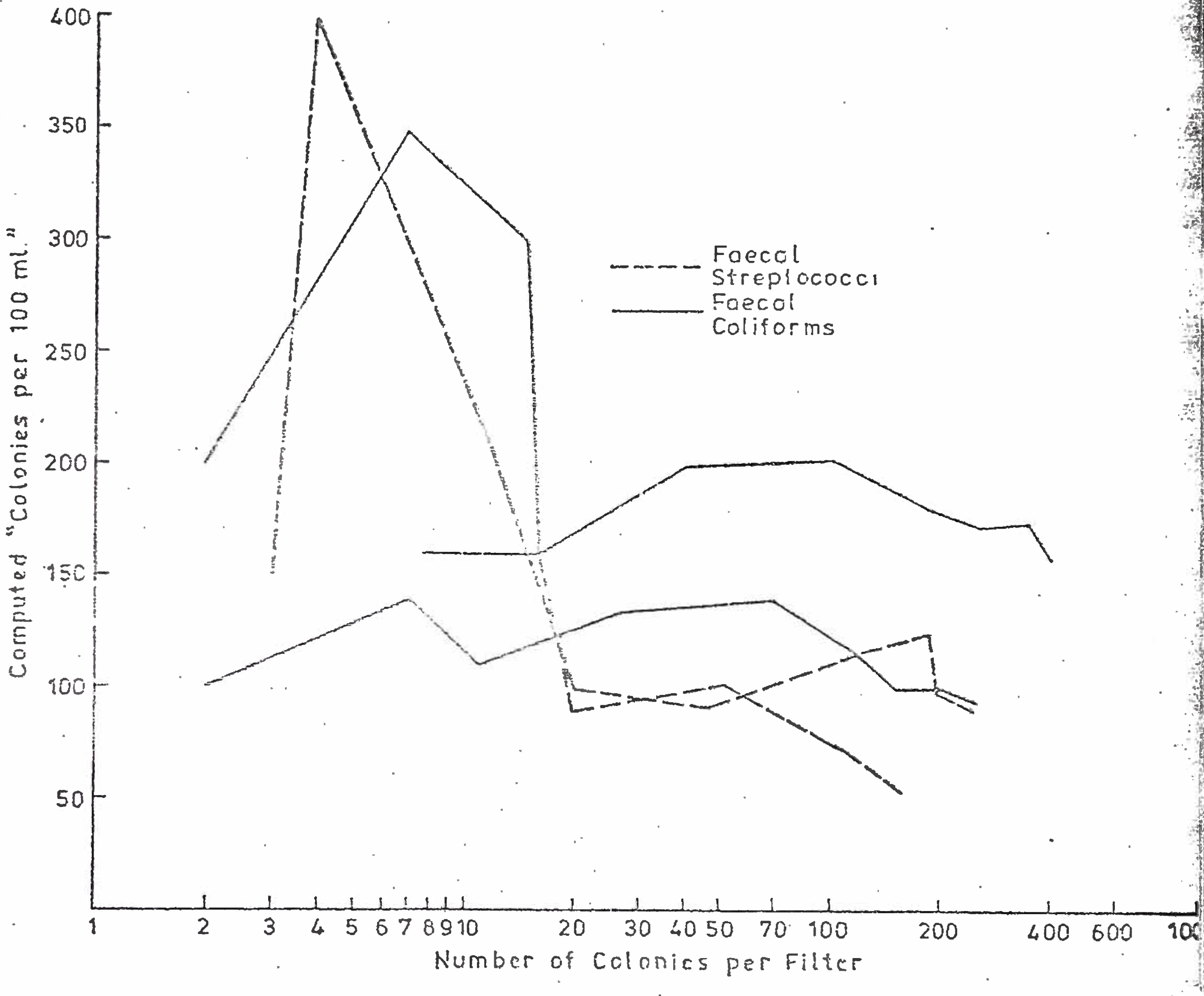

FIG. 12.1 NUMBERS OF FC AND FS COLONIES PER FILTER AGAINST COMPUTED NUMBER OF COLONIES PER 100ml

suggests that filtration volumes should be chosen so that the anticipated number of colonies per filter is in the range of 15 to 100.

Geldreich (1966:40) conducted similar tests and reported that the relationship between volume filtered and colonies counted becomes non-linear when the number of colonies per filter exceeds 80. Standard Methods (1971:685,690) recommends choosing volumes so that the numbers of colonies per filter are in the ranges of 20 - 80 for total coliforms, 20 - 60 for FC and 20 - 100 for FS. This practice was adhered to during the Saka experiments, although it should be noted that the previously mentioned property of decreasing CV with increasing mean leads to a separate criterion that higher counts per filter lead to closer approximations to the mean by a single value.

12.3 THE CONFIRMATION OF FAECAL COLIFORMS

As mentioned in section 12.1.5, tests were conducted to investigate the assumption that blue colonies on M-FC medium are FC, but no equivalent tests were considered necessary for FS. On 6 occasions, colonies were taken from filters incubated on M-FC and transferred to a tube of EC broth containing an inverted vial (see section 10.1.4). The production of gas, after incubation at 45.5°C for 24hr, was considered a positive confirmation that the blue colony was a FC. Table 12.1 presents the results of these tests and shows that 92% of the 211 blue colonies tested were gas producing in EC medium. Only 2% of the grey-cream colonies were gas producing. The percentages of confirmed faecal coliforms from amongst the blue colonies, were between 89 and 100 in all tests and the overall figure of 92% compares closely to Geldreich's (1966:39) figure of 93.2% and Bradley's figure (White et al, 1972:180) of "over 90%".

TABLE 12.1

CONFIRMATORY TESTS ON M-FC POSITIVES (blue colonies) BY TRANSFER TO EC TUBES WITH INVERTED VIALS

Date	Blue Colonies		Grey-Cream Colonies	
	No.transferred to EC Tubes	% Producing Gas	No.transferred to EC Tests	% Producing Gas
4/9	27	89	0	-
8/9	44	91	0	-
16/9	48	92	0	-
21/10	36	89	9	0
28/10	24	100	21	0
4/11	32	94	14	7
All tests	211	92	44	2

As a further confirmatory measure, a few filters which had been incubated on M-FC were sent to Mambisanda Hospital for further testing. A total of 35 colonies were transferred to Levine EMB agar and 27 (77%) of these grew as characteristic coliforms. IMViC tests were done on 3 of these EMB positives and these showed 2 x (++--) and 1 x (-+--). Of the 8 colonies which did not appear to be coliforms on EMB, 3 were tested by IMViC and 2 x (--++) and 1 x (-+++) were obtained. These tests suggest a lower reliability for M-FC than the EC tests indicated, but are difficult to interpret since, by the time the filters had reached the hospital, many of the blue colonies had turned pink-cream, indicating fundamental biochemical changes.

12.4 A TENTATIVE INDENTIFICATION OF FAECAL STREPTOCOCCAL SPECIES

M-Enterococcus agar produces pink-red colonies which are reliably considered to be faecal streptococci. It is of interest to know which FS species were present, and in what relative proportions, in order to permit additional speculation on the source of the FS pollution. The positive differentiation of FS species requires a series of biochemical procedures (see Standard Methods, 1971:691) which were not possible in the Saka laboratory. However, data provided by Pavlova et al (1970) enable a very tentative differentiation to be made on the basis of the size and colour of the colonies that grew on M-Enterococcus agar. Pavlova et al divide colonies grown on M-Enterococcus agar into 6 colour-size types (dark maroon 1 - 2mm, red with pink periphery 1 - 2mm, pink with red centre 1 - 2mm, dark maroon 0.5mm, red centre 0.5mm and pink 0.5mm) and give data on the proportions of each type which were found to be of a particular species. This data, in a revised form, is presented in Table 12.2.

TABLE 12.2

PERCENTAGES OF DIFFERENT FS SPECIES IN 6 COLOUR-SIZE COLONY TYPES DERIVED FROM DATA IN PAVLOVA ET AL (1970)

Colony Type		Percentages of Different Species					
Colour	Size mm	S. faecalis	S. liquifaciens	S. faecium	S. durans	S. bovis	S. equinus
Dark Maroon	1-2	47	24	26	3	0	0
Red,pink periphery	1-2	7	0	3	24	66	0
Pink, red centre	1-2	0	0	15	8	77	0
Dark Maroon	0.5	100	0	0	0	0	0
Red Centre	0.5	66	0	0	0	34	0
Pink	0.5	0	0	17	0	66	17

If it is assumed that these proportions (of species frequencies in different colour-size types) are of general applicability and are fairly constant, then it is possible to compute the proportions of the different FS species which were isolated in the Saka experiments. Most of the FS filters, from tests on sites 1 - 12 and S1 - S10, were counted, not only for total pink-red colonies, but also for the numbers of the various colour-size types proposed by Pavlova. Table 12.3 presents these tentative species proportions.

The data in Table 12.3 show a pattern and a consistency which give credence to the concept of applying the findings of Pavlova et al to the Saka data. S. faecalis and S. bovis account for more than 78% of the colonies at all sites with S. faecium, S. durans and S. equinus typically comprising nearly all the remainder. S. liquifaciens never accounts for more than 3% and at 9 sites the figure was 0%. Although S. bovis derives from 4 colour-size types (see Table 12.2) whereas S. equinus comes only from 1 type (and therefore there is no automatic correlation between their frequencies), a correlation coefficient of 0.73 ($p < 0.001$ with 20 degrees of freedom) is found for the association between S. bovis and S. equinus proportions at the 22 sites. This high correlation is to be expected since S. bovis and S. equinus probably both derive exclusively from non-human sources (mainly pigs) and so their proportions of the total FS count should fluctuate together. The fact that they do ($r = 0.73$) is further evidence that the application of data from Pavlova et al to the Saka situation may be valid.

The low occurrence of S. liquifaciens (elsewhere called S. faecalis var. liquifaciens) is pleasing, since it has been noted that this species is of little sanitary significance and that its presence in large numbers causes difficulties in the interpretation of the faecal

TABLE 12.3

PERCENTAGES OF DIFFERENT FS SPECIES FROM 22 SAKA SITES

Site No.	Percentages of Different Species at 22 Sites					
	S. faecalis	*S. liquifaciens*	*S. faecium*	*S. durans*	*S. bovis*	*S. equinus*
1	70	1	4	3	21	1
2	59	2	6	3	28	2
3	60	1	7	1	28	3
4	52	1	7	1	34	5
5	38	1	8	1	44	8
6	35	1	10	1	45	8
7	36	1	8	2	46	7
8	60	2	5	1	29	3
9	52	1	4	4	36	3
10	28	0	9	3	52	8
11	57	3	5	3	30	2
12	52	0	5	3	39	1
S1	41	1	8	3	42	5
S2	52	0	4	0	40	4
S3	41	0	6	6	43	4
S4	52	1	3	4	39	1
S5	41	0	4	5	47	3
S6	28	0	11	1	50	10
S7	56	0	2	2	38	2
S8	27	0	9	5	52	7
S9	51	1	4	3	39	2
S10	68	0	1	0	30	1
All sites	48	0.7	6	2.3	39	4

pollution hazard indicated by total FS data. Since S. liquifaciens is almost absent, all FS figures can be taken as indicative of pollution of sanitary significance.

A comparison between the proportion of S. bovis and S. equinus and the proportion due to the remaining FS types (enterococci) helps to clarify the possible sources of the observed FS pollution. Geldreich (1970a) comments that "S. bovis and S. equinus are specific indicators of non -human warm-blooded animal pollution" and that their rapid die-off outside the animal intestinal tract (Table 10. 1) makes them indicative of very recent animal contamination. Geldreich (1970b) shows that the percentage of S. bovis and S. equinus in animal faecal streptococcal flora varies from 0% in humans to 66% in cows. The only sanitarily significant non-human animal present in the Saka is the pig (20, 000 pigs in the Saka valley in 1971) and Geldreich gives a figure of 19% of S. bovis and S. equinus for the pig. Other authors, such as Deibel (1964) and Raibaud et al (1961), suggest a figure of nearer 90% and Saka pigs could well have a streptococcal flora substantially different from any previously studied.

Table 12. 3 shows the proportions of S. bovis plus S. equinus to range from 22% to 60% (mean = 43%) which, if valid, indicate a high proportion of these species in Saka pigs' faeces. This proportion is reduced between the time the bacteria leave the pig and the time they are monitored in the water, due to the extremely rapid die-away of S. bovis (Table 10. 1) outside the gut.

These high S. bovis plus S. equinus proportions are not without precedent since Geldreich and Kenner (1969) report figures of 90% for a food processing waste and 63% for the Missouri River and Geldreich (1966: 100) reports 41% of S. bovis in prison sewerage on laundry days (the prisoners worked on a dairy farm). However, the mean of 43%

for the Saka rivers is still higher than most previously reported data and casts some doubt upon the validity of applying Pavlova's data to the Saka experiment. Much clarification will follow from an investigation of the composition of the FS content of faeces from pigs kept under traditional New Guinean conditions (Feachem, 1973b).

CHAPTER 13

FAECAL WATER POLLUTION IN THE SAKA

13.1 THE SOURCES OF POLLUTION

Before going on to present data on faecal pollution levels at the 22 sites in the Saka which were monitored, it is helpful to discuss briefly the sources of the observed faecal bacteria. Most pollution in the Saka must clearly derive from humans and pigs, since these are the only animals which are present in any substantial numbers. The 1972 government census data for the Saka shows a human population of approximately 10,000 and my data (Feachem, 1973b) indicate an overall pig:human ratio of 2.0:1, giving a total pig population for the valley of 20,000.

Compared to these pig and human populations, the numbers of other animals and their faecal contribution are relatively insignificant. Table 13.1 gives the details of various animals, their approximate numbers, their habitat and their load of faecal flora if this is known. Table 13.1 clearly shows that humans and pigs are the foremost polluters and that other species may be ignored when discussing river pollution in the Saka.

13.1.1 HUMAN POLLUTION

The defecation habits of Saka Raiapu are relevant. Defecation takes place at any convenient, private location: usually in some thicket or in long grass. The site chosen depends mainly on where the individual happens to be at the time and individuals do not seek out a particular spot. The Raiapu are extremely modest and will not defecate unless completely unobserved by others of either sex. At night, defecation will take place near the house (Raiapu are afraid to

TABLE 13.1

POSSIBLE SOURCES OF FAECAL CONTAMINATION IN THE SAKA VALLEY

Faecal Source	Approx. Population in Saka	Usual Habitat	Faecal Coliforms Per g of Faeces*	Faecal Streptococci Per g of Faeces*
Man	10,000	Throughout the valley but not permanently above the tree-line	13×10^6	3.0×10^6
Pig	20,000	Throughout the valley. Mostly domesticated but a few feral above the tree-line	3.3×10^6	84×10^6
Cow	A few	Fenced in pastures in flat central valley areas	0.23×10^6	1.3×10^6
Sheep	A few	All at Yogos. Fenced in pastures	16×10^6	38×10^6
Hen	2,000 ?	Kept in enclosures near houses	1.3×10^6	3.4×10^6
Dog	600 ?	Mostly domesticated and kept near houses. A few feral above tree-line	23×10^6	980×10^6
Rodent	Numerous	Throughout the valley	0.16×10^6	4.6×10^6
Bird (general)	Numerous (Many species)	Throughout the valley	?	?
Cassowary (*Casuarius benn-etti*	Very scarce	Perhaps 10 in captivity in Saka with possibly a few wild ones deep in the upper forests	?	?
Cuscus (*Phalanger vestitus*	A few	Still fairly common in the upper forests	?	?
Reptiles and insects	Common Numerous	Throughout the valley	Unlikely to make any contribution to FS or FC concentrations in the rivers - see Geldreich (1966: 73-84)	

Table 13.1 Cont'd.

Faecal Source.	Approx.Population in Saka	Usual Habitat	Faecal Coliforms Per g of Faeces*	Faecal Streptococci Per g of Faeces*
Fish	A few species - not numerous	In most larger streams and introduced carp in fish ponds	Geldreich (1966:70) concludes that "there is no permanent coliform or streptococcal flora in the intestinal tract of fish".	

* From Geldreich and Kenner (1969)

venture far from their houses in the darkness - see Feachem, 1973c) but not so close that a bad odour could develop in the dwelling. The faeces are deposited on the ground and may be covered but are not buried. The fairly steady rainfall (73% of days had rain during May - December, 1971) means that no appreciable accumulation of human faeces occurs.

Under encouragement from Patrol Officers,[1] some Raiapu have built small pit latrines with shelters. These are seldom used now and it is unlikely that the government will press for their reintroduction since a badly kept pit latrine presents a far greater health hazard than the traditional system of dispersed defecation. The only water-borne sewerage disposal systems in the Saka are at the Lutheran Mission at Raiakama and the Catholic Mission at Pumakosa (Map 3). However, these are connected to septic tanks and do not discharge sewerage directly into a stream. All human sewerage in streams is therefore washed there in surface run-off after rainfall. Since the Raiapu do not live close to rivers (Map 4), most of the faeces are deposited some distance from a stream and so must travel this distance before entering the Saka drainage system.

During this journey, from point of defecation to stream, a major proportion of the bacteria will probably die. The natural tendency for die-away to occur outside the favoured environment of the gut (Table 10.1) will take its toll, and bacteria will also die rapidly if exposed to ultra-violet radiation from sunlight. Kunkle and Meiman (1968: 20) have demonstrated the extremely rapid die-away of coliforms which follows from exposure to sunlight, and Taylor (1942) has mentioned the increased death rate of coliforms in faeces exposed to direct sun-

1. Patrol Officers are the junior members of the District Administration system whose top official in each district is the District Commissioner.

light. Many bacteria will also be lost if they are washed underground in the ground-water component of run-off. Even if this water eventually joins a stream (interflow), it is likely that most or all of the bacteria will have been filtered out due to the natural filtering qualities of flow through soil.

This natural filtration process is important since it is possible that, under certain conditions, almost 100% of rainfall could infiltrate (loss rate = precipitation) and therefore all faecal material would be washed underground where bacteria, and other organisms, would be retained on the soil particles. Salvato (1958: 51) reports that "pollution travels a short distance through fine sand or clay; but will travel indefinite distances through coarse gravel, fissured rock, dried-out cracked clay, or solution channels in limestone". The Saka has a surface layer (A horizon) of 0.6m of sandy clay soil, dark reddish-brown with approximately 10% (by dry weight) of oxidizable organic matter. This is part of a 1.75m layer of "Tomba Tephra" (Pain, 1973) - an air-blown volcanic deposit which probably derives from an eruption of Mount Hagen at 35,000 B.P. A 15m volcanic ash deposit underlies this tephra in some places and beneath this is a 20m layer of lahar - a volcanic unconsolidated mud-flow of sandy clay (50% clay) and boulders [1]. The Tomba Tephra is subject to vertical cracking in places, which would lead to a high loss rate and much infiltration, but it is also characterised by slow drying and remains apparently saturated for some time after rainfall. This latter property, coupled with the fact that 73% of days have some precipitation, will cause low loss rates and a high proportion of surface run-off.

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1. For further information on soils of the area, see C.S.I.R.O. (1965) and Rutherford (1964).

Only detailed experimental work will reveal the survival and movements of bacteria deposited in faeces in the Saka catchment. From the foregoing discussion I surmise that bacteria in faeces deposited more than 100m (measured in the direction of surface flow) from the nearest stream are unlikely to reach that stream. Bacteria deposited less than 50m from a stream may well reach the stream, especially if the ground is saturated from previous rainfall and if the organisms are not exposed to direct sunlight.

Once the bacteria reach the streams they may exhibit the die-away properties similar to those proposed by Chick, and must compete with other organisms, and with each other, for available nutrients. Oxygen availability is unlikely to ever be a limiting factor since most Saka streams flow briskly over rocks and are well aerated.

13.1.2 PIG POLLUTION

Pig faeces are deposited wherever pigs graze or travel. It is noticeable that many pig faeces are deposited on paths while the pigs are moving from their houses to their grazing and foraging areas. These paths are old and have been worn down into ditches which are up to 1m in depth. Due to this, the paths become streams almost as soon as rainfall starts and the water flows down them until it reaches a stream or river. The bases of these paths are hard, highly compacted, clay and have extremely low permeability, so that almost all rain falling on them becomes surface run-off. A large proportion of the faeces which are lying on paths will therefore be washed into streams in the event of rain.

Additionally, the favoured grazing grounds for pigs (see Feachem, 1973b) are the swampy flats (category B - Map 4) which border most rivers and streams. Here the pigs can graze in wet and shady conditions; they are far from the sweet potato gardens which they are prone to damage; and they are often contained by the steep banks which separate the river-flats from the first terrace, and so need no guarding. Much of the Tombeakini pig herd will be found, during the daytime, grazing along the banks of the Tobaka and Punate and their faeces will be deposited close to these rivers.

The faeces deposited on the swampy flats are in a moist and shaded habitat which is likely to favour a high survival rate for the bacteria within the faeces [1]. They are so close to the rivers that, in the event of rain, they will be washed almost immediately into the flow and carried downstream.

The majority of pig faeces are probably deposited either on paths or river-flats. This leads to much faecal material being washed fairly rapidly into a stream by any rainfall. This contrasts sharply with the situation for human faeces which are deposited in dense undergrowth, usually near houses or gardens, and far from streams. It is therefore to be anticipated that much of the observed pollution in the Saka rivers is of porcine, and not human, origin.

13.1.3 POLLUTERS ON THE CATCHMENTS AND RIVER FLOWS

Table 13.2 shows the approximate numbers of pigs and humans which were resident on the catchments associated with the 22 sampling sites. Human populations are taken from the 1971 government census and pig populations are taken from the author's pig census reported in Feachem (1973b). Approximate relative flow data

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1. Taylor (1942) shows that coliforms will multiply in stored faeces and that the rate of multiplication increases, and the duration of multiplication decreases, as the temperature rises to a maximum of 37°C. Taylor also mentions the greatly increased coliform death rates in faeces exposed to direct sunlight and this indicates the importance of shady conditions, found along the Saka river-flats, in the promotion of bacterial survival.

TABLE 13.2

PIG AND HUMAN POPULATIONS ON THE CATCHMENTS OF THE 22 SAMPLING SITES IN THE SAKA WITH ESTIMATES OF RELATIVE STREAMFLOW

Site No.	River	Human Population	Pig Population	Relative Flow Ranking*
1	Tobaka	1,400	2,800	3
2	Tobaka	1,800	3,600	3
3	Tobaka	2,000	4,000	2
4	Tame	450	900	8
5	Tame	550	1,100	7
6	Tame	800	1,600	5
7	Tipini	30	60	9
8	Punate	10	20	7
9	Punate	200	400	6
10	Kútá peté	-	-	No Flow
11	Kútá peté	-	-	No Flow
12	Roadside Trickle	10	20	10
S1	Wakema	300	600	4
S2	Wakema	1,000	2,000	3
S3	Taiya	500	1,000	4
S4	Lankua	200	400	6
S5	Waipa	100	200	9
S6	Lapundam	50	100	6
S7	Lapundam	300	600	5
S8	Wakema	4,000	8,000	2
S9	Tare	2,000	4,000	1
S10	Tobaka	2,800	5,600	2

*1 = maximum flow, 10 = minimum flow.

Flow at sites 1, 4, and 8 were measured and found to be at

site 1 $6.27 m^3/sec$
site 4 $0.25 m^3/sec$
site 8 $0.55 m^3/sec$

are also given in order that the reader may imagine the size of the streams and rivers under discussion.

To obtain a more accurate estimate of the flow in the Tobaka, Tame and Punate, the velocities of these rivers, and their cross-sectional areas, were measured. This was done at site 1 on the Tobaka, at site 4 on the Tame and below site 8 on the Punate (see Map 6). Surface velocities were computed by timing the passage of a surface float over reasonably straight sections of the rivers. River lengths of 82.6m for the Tobaka, 39.6m for the Punate and 5.2m for the Tame were used. For each river, 10 float journeys were timed and the mean of these times was taken to be the mean surface flow velocity. Since midstream surface velocity is generally greater than bank surface velocity, the floats were not thrown into midstream but into a part of the river which appeared to have intermediate velocity. Assuming a parabolic vertical velocity distribution, and following the recommendation of Linsley et al (1949: 196), the mean surface velocity was multiplied by 0.85 to give the mean stream velocity. Knowing the cross-sectional areas, the flows could then be estimated, and are shown below.

Tobaka	-	site 1	$6.27m^3/sec$
Punate	-	site 8	$0.55m^3/sec$
Tame	-	site 4	$0.25m^3/sec$

From inspection, I believe that these flows are fairly typical and represent neither flood nor drought conditions. The Tame and the Punate had similar velocities of 0.52m/sec and 0.59m/sec, respectively, whereas the Tobaka had a mean velocity of 1.15m/sec.

13.2 THE DAILY CYCLE OF POLLUTION

As mentioned in section 12.1.2, a series of 13 hourly tests for FC and 24 hourly tests for FS was conducted at site 2 on the Tobaka (Map 6). These results are displayed in Figures 13.1 and 13.2, with the associated river temperatures and the rainfall during the preceding hour. A daily temperature cycle is apparent with a maximum of 16°C at 3.00 p.m. and a minimum of 13½°C at 8.00 a.m.

Figures 13.1 and 13.2 show that FS concentrations respond rapidly to rainfall, whereas the rise and fall of FC levels have no obvious or simple association with rainfall. Rainfall can cause the rapid introduction of faeces into a stream partly by the surface run-off "washing" suitably located faeces into the stream, and partly by the rising river stages, associated with the onset of rain, causing "flushing" of any faecal material on the banks. These 2 processes of washing and flushing will gather initially only faeces which are either located so that run-off will quickly wash them into a stream, or faeces which are situated on a stream bank. Therefore, it is pig faeces which are likely to be introduced into a stream immediately following the onset of rain.

Since pig faeces contain 25 times more FS than FC (Geldreich and Kenner, 1969)[1], it is likely that Figure 13.2 will register a greater response, of bacterial concentrations to rainfall,

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1. Throughout Part III of this thesis, data on the intestinal flora of men and pigs are taken from available published sources - mostly from the U.S. However, it may well be that the flora of New Guinean men and pigs are substantially different and therefore my interpretations of the Saka water pollution data are merely speculative and must be viewed in the light of any future studies on intestinal flora in New Guinea.

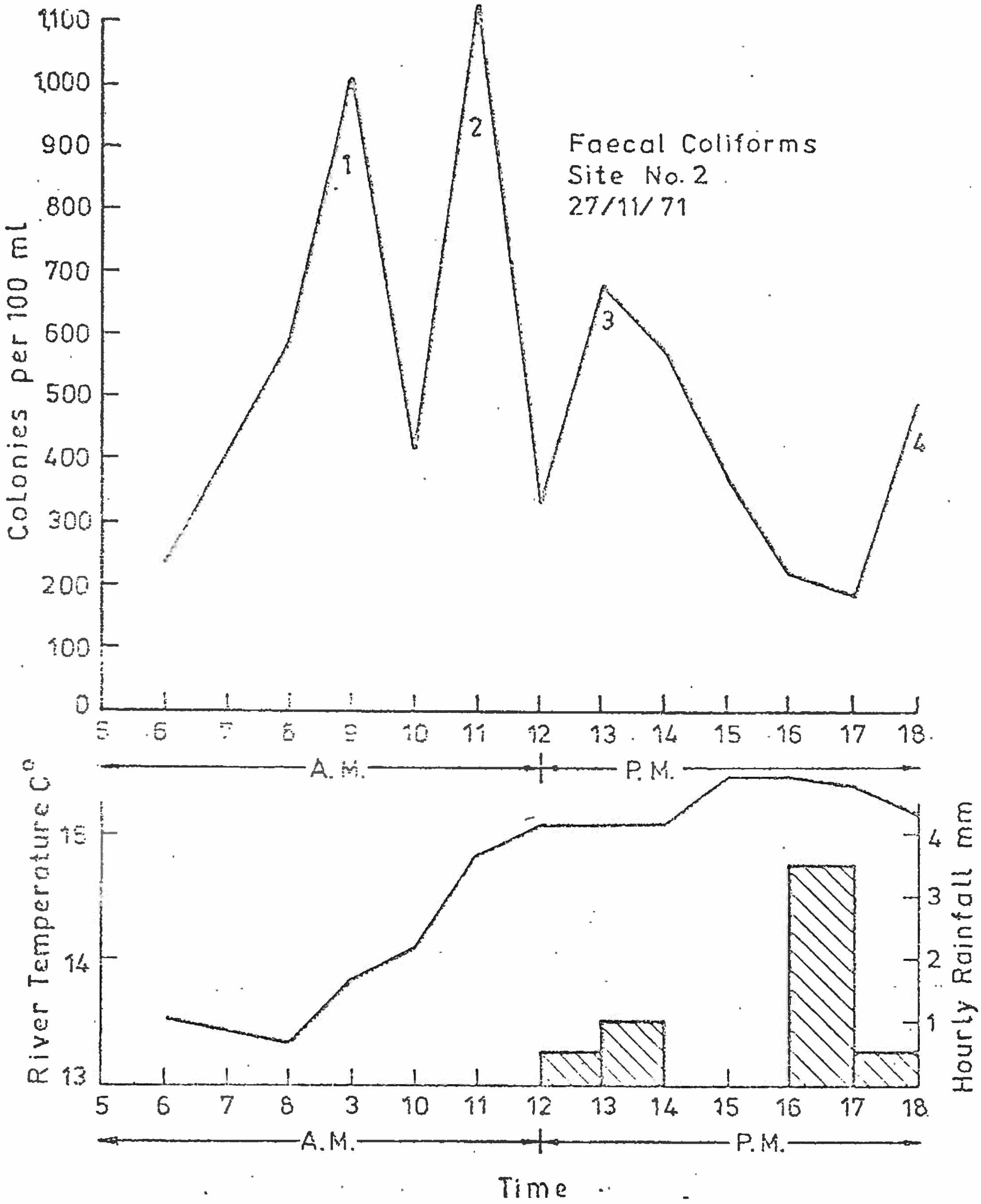

FIG. 13.1 HOURLY READINGS OF FAECAL COLIFORM CONCENTRATIONS WITH ASSOCIATED RAINFALL AND RIVER TEMPERATURE DATA

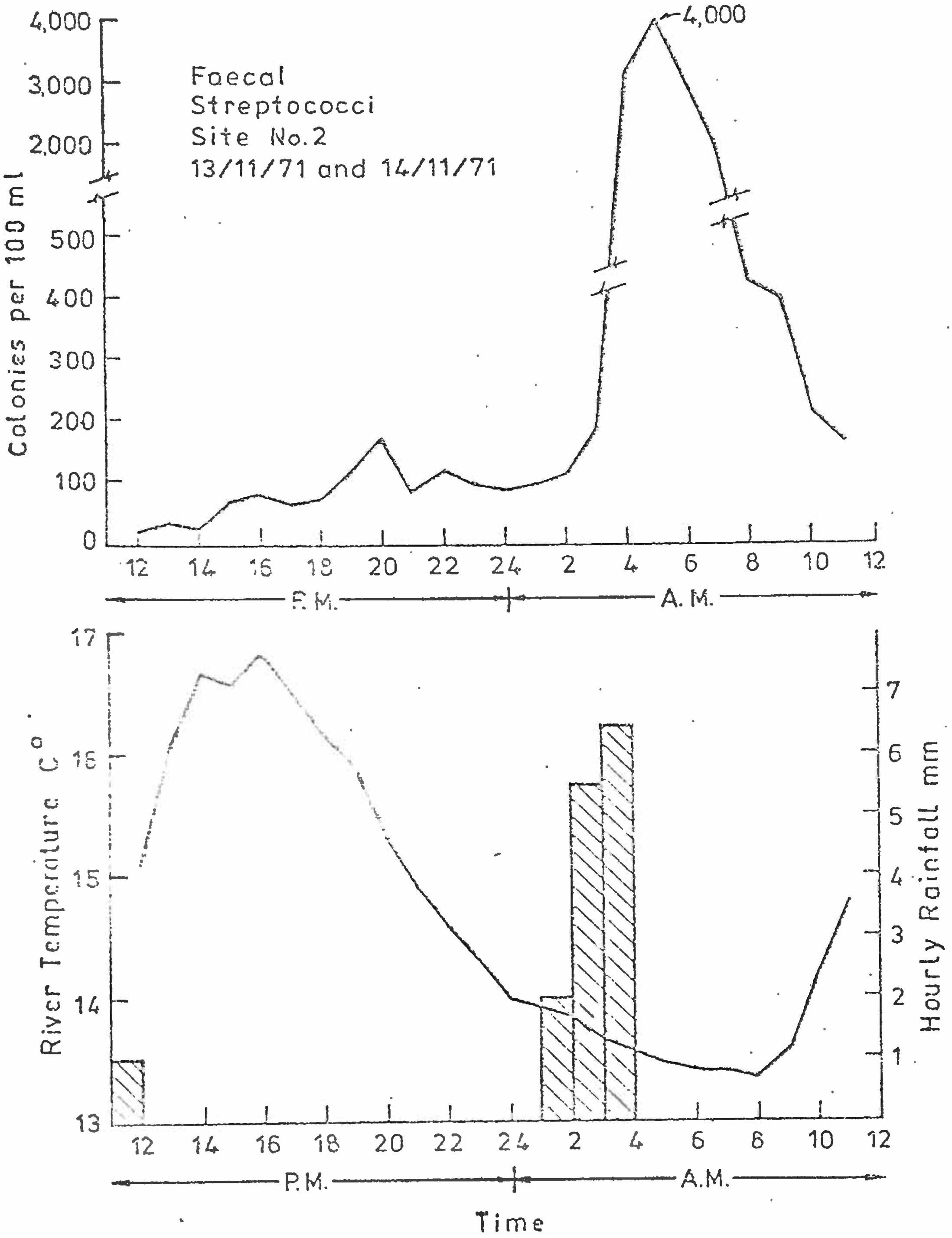

FIG. 13.2 HOURLY READINGS OF FAECAL STREPTOCOCCI CONCENTRATIONS WITH ASSOCIATED RAINFALL AND RIVER TEMPERATURE DATA

than Figure 13.1 In addition, it is possible that the dominant FS type in pig faeces is S. bovis (Deibel, 1964, indicates up to 90% S. bovis, whereas Geldreich and Kenner, 1969, report only 19%), which has been shown (Table 10.1) to die-away 200 times faster than the other FS species at 10°C and 17 times faster than S. faecalis at 20°C. This would cause FS concentrations to be "flashy": to peak quickly after the onset of rain and to fall back to a basal concentration level as the numbers of S. bovis rapidly decline. This is precisely the situation shown in Figure 13.2. A 3hr precipitation of 14mm causes a rise in the FS level from around 100 colonies per 100ml to 4,000 per 100ml in 4hr from the start of rain. The FS level has returned to 162 colonies per 100ml within 10hr from the start of rain. The last rain prior to this 3hr storm was 13hr before and so a complete afternoon and evening had passed without rain. The 3hr storm at 1.00 a.m. therefore gathered the pig faeces deposited the previous afternoon on paths and on the flats along the Tobaka.

The 1mm of rainfall at 11.00 a.m. caused little or no rise in the FS concentration. This could be due to 1mm being insufficient for the processes of washing and flushing to occur, or it could be because rainfall prior to 11.00 a.m. had already removed the bulk of the pig faeces. Only ½mm was recorded between 6.00 a.m. and 11.00 a.m. on the 13th and so the former explanation is likely.

It is notable that the start of the FS rise at 1.00 a.m. is concurrent with the start of the rainfall and it may be that this is caused by rainfall further upstream which commenced earlier than 1.00 a.m. Rainfall was recorded only near site 2 and it was noticeable that most storms started at the head of the Tobaka and moved northwards. FS levels could, therefore, be rising at site 2, due to washing and flushing activity in the upper Tobaka catchment where 1,800 people and 3,600 pigs reside, prior to the onset of rain at site 2 itself.

In this consideration of Figure 13.2 it is not suggested that washing and flushing are the only operative processes, but merely that it is they which reasonably explain the marked rise in FS levels following substantial rainfall. There will be continual FS inputs into the Tobaka by other, and more devious, mechanisms, and it is probably that falling stages will lead to a flow of water rich in FS from the saturated banks back into the stream. Temperature will affect FS levels, but no association emerges from Figure 13.2 because the effect of the 3°C variation recorded will be negligible compared to other gross influences.

The FC peaks in Figure 13.1 have been labelled 1 - 4. Peak 3 may be attributable to quick response to rain through washing and flushing if the rainfall started upstream prior to its recorded noon start at site 2. The beginnings of Peak 4 may similarly be related to the 4.00 p.m. storm. Peaks 1 and 2 are not linked to any rain during that morning at site 2, but they may derive from a 10½mm storm between midnight and 5.00 a.m. the previous night, or possibly to an unrecorded storm higher up the catchment.

Since the FC:FS ratio in humans is 4.4 (compared to 0.04 in pigs), it is possible that human faeces are the origin of most observed FC in streams. It has been shown (section 13.1) that human faeces are likely to have a far more lengthy and indirect journey to the stream than pig faeces and therefore FC levels will not respond to rain in the same way as FS. Figure 13.1 shows that, while FC levels do appear to peak during, or immediately after a storm, they also peak at other times due to factors which are not revealed by the data presented here.

A greatly expanded series of hourly tests on various catchments would have been most instructive and is surely a high priority for future research. Even the limited data given here reveal a pattern of rapid FS response to rain with FC also responding but showing other fluctuations which are not so readily explained.

13.3 FAECAL POLLUTION AT 12 SITES IN THE SOUTH-EASTERN SAKA

FC and FS levels were monitored at 12 sites, once a week for 20 weeks. These sites are shown on Map 6, and the populations on their catchments, together with a relative flow estimate, are given in Table 13.2 The sites are on the rivers Punate, Tipini and Tobaka, which Tombeakini utilize as sources of domestic water supply, and the Tame, from which Yana and Yanuni clans draw water. Sites 10 and 11 are *kútá peté* (ponds in which the reed *kútá* - *Eleocharis sphacelata* and *E. dulcis* - is grown for the manufacture of women's aprons) situated by the Tobaka and Tipini, respectively. Site 12 is on a small trickle which runs down the road embankment and is commonly used for drinking water by people walking along the road.

Table 13.3 shows the mean turbidities and water temperatures at the 12 sites. The temperatures are those at the time of sample collection. This was typically between 10.00 a.m. and 11.30 a.m., and Figures 13.1 and 13.2 show that the temperatures will therefore fall somewhere between the 8.00 a.m. minimum and the 3.00 p.m. maximum of the daily river temperature cycle. Figure 13.3 shows some negative association between temperature and estimated flow, and this association is more pronounced if the atypical point of site 8, which is just downstream from a cool spring, is ignored.

TABLE 13. 3

MEAN RIVER TEMPERATURES AND TURBIDITIES AT 12 SITES AT TIME OF SAMPLE COLLECTION

Site No.	Mean Water Temperature At Time of Collections °C	Mean Turbidity
1	14.1	53
2	14.6	53
3	15.2	54
4	21.2	29
5	20.9	30
6	16.6	27
7	20.5	56
8	15.1	11
9	15.8	24
10	21.1	40
11	25.1	39
12	17.0	15

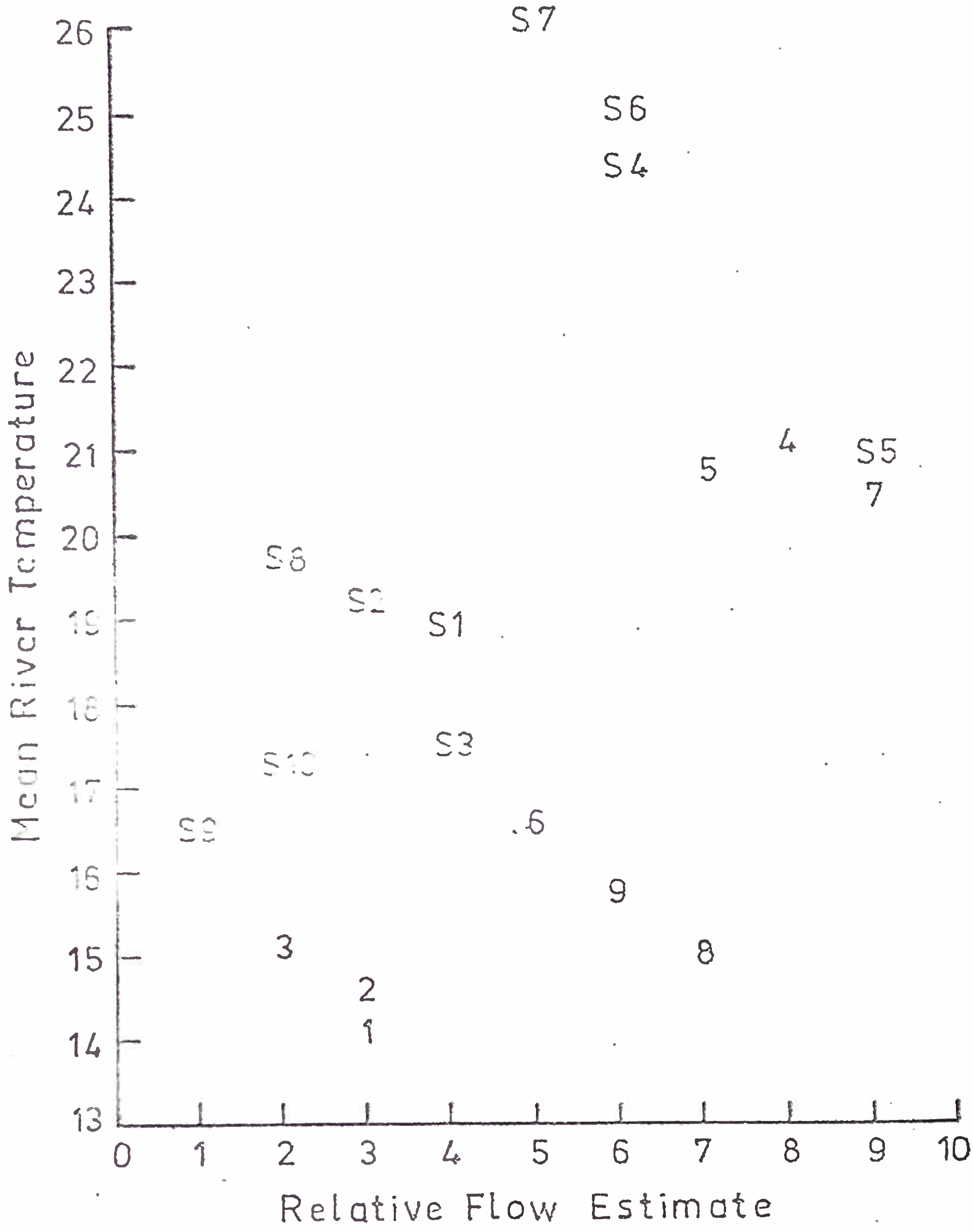

FIG. 13.3 RELATIVE FLOW ESTIMATES AGAINST MEAN RIVER TEMPERATURES AT THE 22 WATER SAMPLING SITES IN THE SAKA

NOTE: Flow estimate 1 = greatest flow
Flow estimate 10 = least flow

Table 13.4 shows the means, minima, maxima and standard deviations for FC and FS at the 12 sites. FC:FS ratios, calculated from the means, are also given. The means quoted are arithmetic means. Geometric means are used by some authors on the grounds that the disturbing effect of a few extremely high values is thereby minimised. Slanetz and Bartley (1957), for instance, give both arithmetic and geometric means, but use the arithmetic means to compute FC:FS ratios.

A high correlation exists between the FC means and the FS means at the 12 sites with $r = 0.96$ ($p < 0.001$ with 10 degrees of freedom). Thus high FC values accompany high FS values and therefore the sources of these heavy pollution loads are contributing both faecal groups. FC:FS ratios vary from 0.20 to 1.31 and this range may reveal different proportions of pig and human contamination. Assuming that all sources of faecal pollution, other than pigs and humans may be neglected; and further assuming that the FC:FS ratios for pigs and human are 0.04 and 4.4, respectively (Geldreich and Kenner, 1969): then Figure 13.4 shows the percentages of FC and FS due to pigs for different ratio values. For instance, a FC:FS ratio of 1.0 indicates 3% of FC, and 78% of FS, due to pigs, assuming that differences in death rates between FC and FS have not seriously disturbed the original defecation ratios. If the bacteria being sampled have been only recently introduced into the stream, this assumption is reasonable. However, if they have been travelling downstream from some distant input point, and if the FS group is largely composed of <u>S. bovis</u> with its extremely rapid die-away, then recorded FC:FS values will be higher than the original ones. Thus, when Figure 13.4 is consulted, the contribution of pigs will be underestimated. The estimations given below of pig contributions will therefore tend to underestimate the true contributions.

TABLE 13.4

FAECAL COLIFORM AND FAECAL STREPTOCOCCI MEANS, MINIMA, MAXIMA, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION AT 12 SITES IN THE SOUTH-EASTERN SAKA

Site Number	Faecal Coliforms					Faecal Streptococci					FC/FS Ratio [means]
	Colonies per 100 ml.				%	Colonies per 100 ml.				%	
	Mean	Min.	Max.	S.D.	C.V.	Mean	Min.	Max.	S.D.	C.V.	
1	203	40	835	195	96	294	0	1,570	386	131	0.69
2	244	50	820	173	71	239	10	1,740	406	170	1.02
3	204	[illegible]	390	95	47	294	20	1,590	426	145	0.69
4	662	[illegible]	[illegible]	323	57	559	30	2,500	557	105	1.20
5	803	[illegible]	[illegible]	482	60	609	70	3,000	762	125	1.31
6	292	[illegible]	500	[illegible]	52	286	25	1,500	351	123	1.02
7	[illegible]	[illegible]	[illegible]	[illegible]	157	1,405	40	4,000	2235	157	1.11
8	[illegible]	[illegible]	[illegible]	[illegible]	138	40	0	260	56	140	0.20
9	92	[illegible]	[illegible]	[illegible]	86	116	8	530	112	97	0.85
10	672	0	5,500	1,472	219	946	0	6,000	2125	225	0.71
11	129	0	1,000	245	190	195	0	1,790	409	210	0.66
12	46	0	500	112	243	52	6	300	71	137	0.88

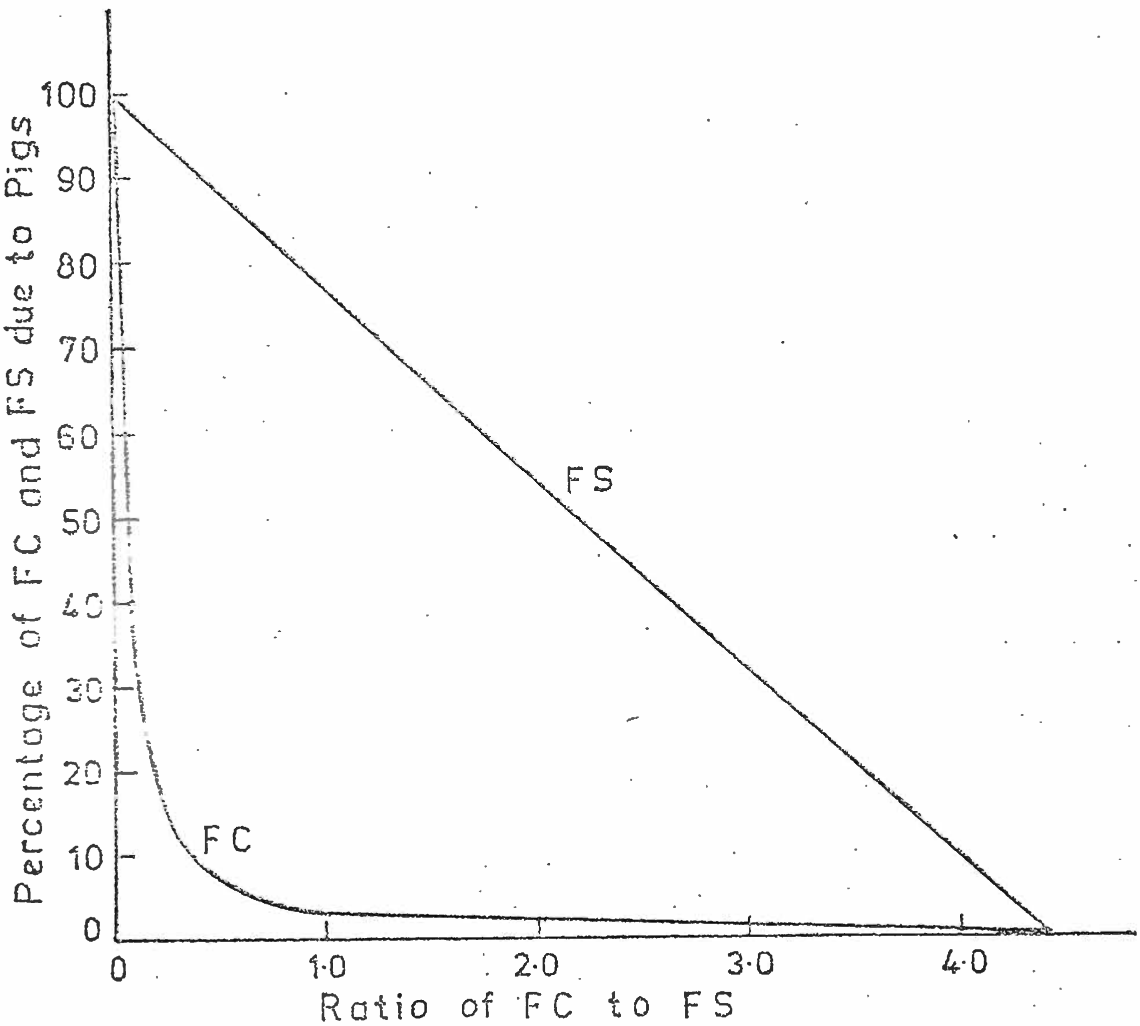

FIG. 13.4 FC:FS RATIOS AGAINST PROPORTION OF FC AND FS DUE TO PIGS

NOTE: Assumes that the FC:FS ratios in pig and human faeces are 0.04 and 4.4, respectively.

FC:FS values at sites 1 - 12 range from 0.20 to 1.31 with a mean of 0.86. Pig contributions therefore range from 19% FC + 96% FS to 3% FC + 71% FS with a mean contribution of 4% FC and 81% FS. Applying these mean figures, a total mean pig contribution to both FC and FS of 45% is derived so that slightly less than half of the faecal bacteria in the Saka rivers may be due to pigs. This figure is considerably lower than that which might be surmised from the previous discussion. However, it has been pointed out that the effect of differential survival properties may be to seriously underestimate the pig contribution.

An independent estimate of the likely pig contribution to Saka river pollution can be derived from data on the average bacterial load per day contained in pig and human faeces. Data on the flora of pig faeces are taken from Geldreich (1966:102) [1], and for humans from Geldreich and from Oomen and Corden (1969:32), who report a mean faecal wet weight for adult Kyaka Enga at Baiyer River, of 305g per capita daily [2]. Using these sources, in conjunction with the 1971 pig census figures given in Feachem (1973b), a pig contribution of 82% of FC, 100% of FS and 99% of total flora for freshly deposited faeces is derived. The overall FC:FS ratio is 0.047. The mean FC:FS ratio recorded in Saka rivers was 0.86, and it seems that this is much greater than the FC:FS ratio in the freshly deposited

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1. Geldreich reports 8.4×10^7 faecal streptococci per gram of wet pig faeces, while Raibaud et al (1961) report 6.9×10^7 faecal streptococci per gram. Geldreich reports 0.33×10^7 faecal coliforms per gram of wet pig faeces while Dickinson and Mocquot (1961) report 1.7×10^7 gram-negative bacteria per gram.

2. This figure contrasts with a normal U.S.A. figure of around 150g per capita daily (Best and Taylor, 1955).

faeces and therefore causes gross underestimation of the proportion of river pollution which is due to pigs. This sharp increase in FC:FS ratios, between the time of deposition and the time of monitoring, can be explained by 2 factors. Firstly, since FS largely originates from pigs and may be chiefly composed of S. bovis, it will experience a death rate which may be 100 times greater than the FC death rate. Secondly, the M-Enterococcus agar, used to culture FS, has been reported to have a low recovery of S. bovis and S. equinus and will therefore cause serious underestimation of the total FS concentration if the FS is due largely to pigs. Therefore, the recorded FC:FS ratio of 0.86 may reflect an original deposition ratio of nearer 0.05 and the total pig contribution could actually be nearer 99% (suggested by 0.05) than the 45% (suggested by 0.86). Figure 13.4 shows that the percentage pig contribution is highly sensitive to the value of the FC:FS ratio as that ratio approaches 0.04. A small increase in the ratio, within the range 0.04 to 0.6 , leads to a large decrease in the estimated pig contribution.

Table 13.4 shows that, of the 4 rivers and streams monitored, the Punate is the cleanest (because it rises at a spring) followed by the Tobaka, Tame and Tipini. Inspection of temperature and turbidity data (Table 13.3) and flow estimates (Table 13.2), shows that the apparent positive association between mean pollution levels and temperature [1] is probably due to the negative correlation between flow and temperature (Figure 13.3) and that the true assoc-

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1. A negative association is anticipated by theory since rising temperatures lead to rising death rates. Bigger (1937) found that coliforms survived better in water at 22°C than in water at 37°C and Collins (1960) reports that a lake contained the highest concentration of gram-negative bacteria during winter.

iation is a negative one between flow and pollution. The smaller streams (Tame and Tipini) have a shorter distance between centre of population and sampling point and thus less time for die-off to deplete the bacterial population; they have a higher overall population density because the larger catchments contain areas of uninhabited upper forests; they are slow flowing and thus possibly poorly aerated, which restricts their self-cleansing properties; and pigs actually wade in the smaller streams which they cannot do in larger ones[1]. For these reasons it is to be expected that small rivers will exhibit the highest pollution and the fact that these are also the warmest rivers may be coincidental[2].

Some correlation between faecal pollution and turbidity at different sites might be anticipated since bacteria tend to become adsorbed onto suspended particles in the flow. For FC $r = 0.41$ and for FS $r = 0.48$, neither of which are significant at the 10% level.

The coefficients of variation at the 12 sites provide a measure of the variations in pollution, relative to the means, over the 20 weeks of the survey. In all cases, except sites 7 and 12, the CV's are greater for FS than for FC and this reflects the extreme

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1. Petersen and Boring (1960) report that cattle walking in a stream, as opposed to merely grazing on its banks, caused noticeable rises in the coliform counts.

2. These 4 factors all tend to cause highest bacterial concentrations in the smallest streams. There is, however, an opposing factor which will tend to have the contrary effect. The smaller streams have greater contact between water and stream bed, and lower velocities (section 13.1.3) than the larger streams. This causes increased deposition of turbidity—causing particles from the flow onto the bed and thus increased deposition of bacteria which tend to become adsorbed onto the solid particles. (Kittrell et al, 1963; Streeter, 1934; Velz, 1970).

sensitivity of FS levels to rainfall which was shown in the analysis of the daily cycle. The greatest CV values are found for the Punate - because the means are so low that large percentage variations about them are inevitable[1] - and for sites 7, 10, 11 and 12. Sites 10 and 11 are ponds (kúta pete), and sites 7 and 12 have minute flows, and so their pollution is bound to fluctuate dramatically as they receive sudden inputs into small water volumes. It is noteworthy that the smallest CV for FC is 47%, and for FS is 97%, so that at the very best, a single value will have a 95% chance of lying between 0.06 and 1.94 times the FC mean, and between 0 and 2.94 times the FS mean.

Table 13.5 shows the mean gradients in bacterial concentrations which were recorded over stretches of rivers which have no major incoming tributary. These gradients are expressed as changes per kilometre of stream length. Increases in pollution are noted, for all except 2 cases, for both FC and FS. These increases are probably due, not to multiplication, but to inputs of faecal material from banks and river beds which exceed the depletions caused by natural die-away. Precise knowledge of death rates is needed before calculations of these faecal inputs can be made. The 2 decreases recorded, and the fact that the longest stretch (1-3) observed showed no change, are significant because they indicate that pollution will not increase steadily as one moves downstream. Data on pollution at sites S1 - S10 will further clarify this point.

Data on turbidity and preceding day's rainfall were collected with each FC and FS test, and data on river temperature were

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1. Similarly, Kunkle and Meiman (1968) report that variability is highest when concentrations are lowest.

TABLE 13.5

THE MEAN CHANGES IN FC AND FS CONCENTRATIONS PER KILOMETRE OF STREAM LENGTH FOR SECTIONS OF THE PUNATE, TAME AND TOBAKA

River Section By Sites	Change in Mean Pollution Per Kilometre in Colonies Per 100ml		Length of River Section Km
	FC	FS	
1 - 2	+68	-92	0.60
2 - 3	-44	+61	0.90
1 - 3	+0.7	0	1.50
4 - 5	-243	-91	0.55
8 - 9	+87	+72	1.05

recorded for 9 FC, and 7 FS, tests. This permits a multiple correlation between bacterial concentration, turbidity and rainfall on 20 occasions for FC and FS and between bacterial concentrations, turbidity, rainfall and temperature on 9 occasions for FC and 7 occasions for FS. Tables 13.7, 13.8, 13.9 and 13.10 tabulate the results of these correlations.

Table 13.6 shows the correlations between the independent variables rainfall, temperature and turbidity, and these correlations are summarised below.

Turbidity	v.	Rainfall	+++
Turbidity	v.	Temperature	-
Temperature	v.	Rainfall	--

It is probably coincidental that these associations are shown more strongly in the FC series than in the FS series, but this difference will affect the multiple correlation of these 3 variables with bacterial concentration.

The interpretation of Tables 13.7 to 13.10 is not entirely straightforward, but I have set out below what I believe to be reasonable generalisations based on the evidence available.

(i) The small fluctiations in river temperature are not an important influence on bacterial concentrations and, in future studies, the effort put into temperature recording could well be redeployed in other measurements.

(ii) A positive correlation between bacterial concentrations and the preceding day's rainfall is found at most sites and, at approximately 50% of sites, this correlation is strong and statistically signifncant. This correlation may be appreciably greater for FS than for FC, but in both cases, preceding day's rainfall was by far the

TABLE 13.6

CORRELATION COEFFICIENTS BETWEEN TURBIDITY, TEMPERATURE AND PRECEDING DAY'S RAINFALL DURING THE FC AND FS MULTIPLE CORRELATION TEST SERIES

Site No.	Turbidity v. Preceding Day's Rainfall				Turbidity v. Temperature				Preceding Day's Rainfall v. Temperature			
	FC Series		FS Series		FC Series		FS Series		FC Series		FS Series	
	r	p	r	p	r	p	r	p	r	p	r	p
1	0.74	****	0.13		-0.38		0.21		-0.69	**	0.55	
2	0.68	****	0.15		-0.22		-0.06		-0.77	**	0.70	*
3	0.76	****	0.20		-0.10		-0.07		-0.72	**	0.22	
4	0.36		0.46	**	-0.59	*	-0.31		-0.82	***	0.14	
5	0.60	***	0.26		-0.73	**	-0.37		-0.81	***	0.10	
6	0.47	**	0.29		-0.58	*	0.55		-0.30		-0.01	
7	0.12		-0.26		-0.33		-0.57		-0.63	*	0.30	
8	0.63	***	-0.70		-0.49		-0.66		0.86	***	-0.15	
9	-0.02		-0.03		0.23		0.55		0.20		0.26	
10	0.13		0.29		0.78	**	-0.22		-0.67	**	-0.36	
11	0.57	***	0.10		-0.39		-0.47		-0.84	***	0.24	
12	-0.31		-0.30		-0.04		-0.18		0.11		0.28	

*	$p < 0.1$
**	$p < 0.05$
***	$p < 0.01$
****	$p < 0.001$

Degrees of Freedom

Turbidity v. Rainfall

FC Series 18
FS Series 18

Turbidity v. Temperature
Rainfall v. Temperature

FC Series 7
FS Series 5

TABLE 13.7

PARTIAL AND MULTIPLE CORRELATION COEFFICIENTS AND F VALUES FOR THE CORRELATION OF FC CONCENTRATIONS AGAINST TURBIDITY AND THE PRECEDING DAY'S RAINFALL WITH 20 SETS OF OBSERVATIONS

Site No.	Partial Correlation Coefficients				Multiple Correlation Coefficients		F Value of Regression	
	Turbidity v. FC		Rainfall v. FC					
	r	p	r	p	R	p	F	p
1	-0.21		0.44	**	0.47		2.41	
2	0.12		0.25		0.44		2.02	
3	-0.05		0.39	*	0.51		3.03	*
4	-0.01		0.46	**	0.48		2.57	
5	0.23		-0.26		0.28		0.69	
6	-0.47	**	0.47	**	0.52		3.21	*
7	0.69	****	0.04		0.70	***	7.98	***
8	-0.18		0.15		0.23		0.48	
9	0.20		0.75	****	0.75	***	11.02	***
10	0.84	****	0.77	****	0.90	***	37.08	****
11	0.40	*	0.17		0.56	**	3.98	**
12	-0.35		-0.16		0.36		1.24	

*	$p < 0.10$
**	$p < 0.05$
***	$p < 0.01$
****	$p < 0.001$

$$F = \frac{\text{variation due to regression}}{\text{variation about regression}}$$ with 2/17 degrees of freedom

TABLE 13.8

PARTIAL AND MULTIPLE CORRELATION COEFFICIENTS AND F VALUES FOR THE CORRELATION OF FS CONCENTRATIONS AGAINST TURBIDITY AND THE PRECEDING DAY'S RAINFALL WITH 20 SETS OF OBSERVATIONS

Site No.	Partial Correlation Coefficients				Multiple Correlation Coefficients		F Value of Regression	
	Turbidity v FS		Rainfall v. FS					
	r	p	r	p	R	p	F	p
1	0.26		0.28		0.40		1.58	
2	0.95	****	0.68	****	0.96	***	92.48	****
3	0.07		0.46	**	0.48		2.60	
4	-0.07		0.06		0.08		0.05	
5	-0.27		0.42	*	0.44		2.06	
6	-0.16		0.49	**	0.49		2.64	*
7	-0.07		0.18		0.21		0.40	
8	0.21		0.30		0.33		1.04	
9	0.17		0.43	*	0.44		2.08	
10	-0.14		0.18		0.20		0.37	
11	0.53	**	0.76	****	0.83	***	18.16	****
12	-0.17		-0.04		0.17		0.27	

*	$p < 0.10$
**	$p < 0.05$
***	$p < 0.01$
****	$p < 0.001$

$$F = \frac{\text{variation due to regression}}{\text{variation about regression}}$$ with 2/17 degrees of freedom

TABLE 13.9

PARTIAL AND MULTIPLE CORRELATION COEFFICIENTS AND F VALUES FOR THE CORRELATION OF FC CONCENTRATIONS AGAINST TURBIDITY, PRECEDING DAY'S RAINFALL AND RIVER TEMPERATURE WITH 9 SETS OF OBSERVATIONS

Site No.	Partial Correlation Coefficients						Multiple Correlation Coefficients		F Value of Regression	
	Turbidity v. FC		Rainfall v. FC		Temperature v. FC					
	r	p	r	p	r	p	R	p	F	p
1	-0.22		0.21		0.00		0.37		0.28	
2	-0.47		0.52		0.10		0.65		1.24	
3	-0.52		0.29		-0.09		0.59		0.90	
4	-0.23		0.57		0.30		0.62		1.04	
5	0.31		0.76	**	-0.21		0.94	***	12.25	***
6	-0.46		0.44		0.10		0.58		0.85	
7	0.29		-0.13		-0.06		0.32		0.19	
8	-0.53		0.54		-0.60	*	0.62		1.05	
9	0.04		0.57		0.20		0.66		1.26	
10	0.58	*	0.55		0.61	*	0.90	**	6.85	**
11	-0.53		0.15		-0.26		0.65		1.22	
12	-0.15		-0.72	**	-0.55		0.77		2.39	

*	$p < 0.10$
**	$p < 0.05$
***	$p < 0.01$
****	$p < 0.001$

$$F = \frac{\text{variation due to regression}}{\text{variation about regression}}$$ with 3/5 degrees of freedom

TABLE 13.10

PARTIAL AND MULTIPLE CORRELATION COEFFICIENTS AND F VALUES FOR THE CORRELATION OF FS CONCENTRATIONS AGAINST TURBIDITY, PRECEDING DAY'S RAINFALL AND RIVER TEMPERATURE WITH 7 SETS OF OBSERVATIONS

Site No.	Partial Correlation Coefficients						Multiple Correlation Coefficient		F Value of Regression	
	Turbidity v. FS		Rainfall v. FS		Temperature v. FS					
	r	p	r	p	r	p	R	p	F	p
1	-0.16		0.64		0.26		0.84		2.43	
2	-0.22		0.70	*	-0.12		0.85		2.50	
3	0.15		0.74	*	-0.13		0.77		1.46	
4	-0.31		0.63		0.02		0.69		0.85	
5	0.2[illegible]		0.77	**	0.08		0.77		1.48	
6	0.32		0.86	**	-0.63		0.91		5.12	
7	[illegible]		-0.41		0.74	*	0.79		1.61	
8	0.11		0.80	**	-0.32		0.84		2.47	
9	[illegible]	*	0.80	**	-0.47		0.89		3.87	
10	[illegible]		0.85	**	0.34		0.86		2.90	
11	-0.0[illegible]		0.75	**	0.07		0.81		1.95	
12	-0.32		0.00		-0.34		0.43		0.23	

* $p < 0.10$
** $p < 0.05$
*** $p < 0.01$
**** $p < 0.001$

$$F = \frac{\text{variation due to regression}}{\text{variation about regression}}$$ with 3/3 degrees of freedom

most influential of the 3 variables recorded.

(iii) There is no generally applicable association between turbidity and bacterial concentration. Bacterial concentrations do tend to rise as turbidity rises[1] but, in the typical case where turbidity is highly correlated with preceding rainfall, a low partial correlation coefficient between turbidity and bacterial concentration is found. In cases where turbidity and preceding rainfall are not correlated (e.g., sites 7 and 10), a high partial correlation between turbidity and bacterial concentration may be found. However, I suspect that this lack of association between turbidity and rainfall reflects the inadequacy of the rainfall data and that, had rainfall data been collected for the upper regions of the catchments, an association would have been found in all cases. Turbidity is undoubtedly an influential variable, but it may well be possible to replace it by some function of rainfall since turbidity will generally be highly dependent upon rainfall over the catchment.

(iv) Accepting that temperature is not an operative variable, the multiple correlations of most interest are those in Tables 13.7 and 13.8. At 6 sites for FC, and at 3 sites for FS, the variation of bacterial concentrations explained by the correlation was significantly greater than the residual variation. It is surprising that 2 variables (rainfall and turbidity), chosen from the many variables which may

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1. Streeter (1934) found that rates of coliform decrease in the Ohio River were unusually high when turbidity was low because the sedimentation of turbidity, due to low stream velocities, carried adsorbed bacteria to the river bottom.

be relevant, should be able to account for so much variation in pollution by a simple linear correlation. This is especially so when one considers that the rainfall unit employed was the gross one of preceding day's precipitation when there is good reason to suppose that the sensitivity of the process requires that some function of the preceding hourly precipitations should be utilized.

It appears likely that, given data on turbidity, hourly rainfall over the whole catchment and river stage, a great deal of the observed variation in pollution could be accounted for by a fairly simple model.

13.4 FAECAL POLLUTION AT 10 SITES FROM THROUGHOUT THE SAKA

FC and FS levels were monitored at 10 sites in the Saka, designated S1 - S10 and shown on Map 3. Each site was sampled only 6 times, due to the transportation problems involved in bringing samples to Lyokote, and 3 FC and 3 FS tests were done for each site. Table 13.11 presents the means of these results and the associated temperature and turbidity data.

No great reliance can be placed in the FC:FS ratios calculated from the means of only 3 values. They mostly fall in a similar range (0.5 to 1.6) to those in Table 13.4, but 4 sites show higher ratios. These probably reflect the inadequacy of the data rather than a genuine high proportion of human contamination.

Figure 13.3 shows that sites S1 - S10, like sites 1 - 12, exhibit a negative correlation between mean temperature and estimated streamflow. Temperatures for sites S1 - S10 are generally higher because they were sampled in mid-afternoon, whereas sites 1 - 12 were sampled in the morning. Again, it is found that the 4 warmest sites, with the lowest flows, are the 4 sites with the highest levels of faecal

TABLE 13.11

FAECAL COLIFORM AND FAECAL STREPTOCOCCI MEANS, RIVER TEMPERATURES AND TURBIDITIES AT 10 SITES THROUGHOUT THE SAKA

Site No.	Mean Concentrations Colonies per 100ml		FC:FS Ratio	Mean River Temperature	Mean Turbidity
	FC	FS			
S1	640	487	1.31	19.0	52
S2	857	903	0.95	19.3	118
S3	90	147	0.61	17.5	28
S4	7063	743	9.51	24.5	36
S5	3620	4770	0.76	21.0	51
S6	7500	4667	1.61	25.2	35
S7	3150	383	8.22	26.2	48
S8	510	243	2.10	19.8	48
S9	2160	443	4.88	16.5	44
S10	400	737	0.54	17.4	88

pollution. These are sites S4, S5, S6 and S7, which each have either a mean FC, or a mean FS, level of over 3,000 colonies per 100ml. This confirms the point concerning smaller streams having higher pollution which was made in the previous section. Table 13.2 shows that these 4 sites have the lowest catchment populations (less than 300 humans) but, as has been pointed out, the population densities over the catchments will be higher, and the distance from centre of population to sampling site will be shorter, than for the bigger catchments. Pigs commonly waded at, or near, these 4 sites and cattle were seen wading at site S4.

An associated conclusion from Table 13.11 is that, because of the rapid die-away of bacteria in the larger, briskly flowing and well aerated rivers, sites with large numbers of polluters on their catchments (S2, S8, S9, S10) were relatively unpolluted. The lowest sampling site on the Wakema (site S8), which had the largest catchment populations, exhibited the second lowest pollution levels.

Table 13.11 also confirms that pollution is not necessarily cumulative as one moves downstream. On the Wakema, pollution rises from S1 to S2 but falls to S8. On the Lapundam, pollution falls from S6 to S7.

13.5 CHEMICAL AND PHYSICAL CHARACTERISTICS

Table 13.12 gives information on some chemical and physical characteristics of the waters at sites 2, 6 and 8[1]. These are compared with the current international standards of water quality reported in W.H.O. (1971). With the exception of turbidity, the Saka waters meet all the W.H.O. requirements for the parameters listed,

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1. I am grateful to Mr. A.A. Gerard of the Papua New Guinea Institute of Technology at Lae for conducting these tests.

and it is therefore with respect to bacteriological quality alone that the Saka waters are to be considered polluted.

A few aspects of Table 13.12 are of special interest. The Tobaka (site 2) is soft when compared to the Punate-Tame river system (sites 6 and 8) which has high total hardness, bicarbonate, alkalinity and calcium. This relates to the fact that the Punate and Tame rise on limestone country, while the Tobaka does not. Of dental interest is the low fluoride values because W.H.O. (1971: 35) report that "if the fluoride concentration in the drinking-water of a community is less than 0.5mg/l, the incidence of dental caries is likely to be high". The nitrate concentrations are strikingly low and it is probable that nitrogen is present as organic nitrogen or in free and saline ammonia. This situation may not reflect the state of the Saka waters but may be due to bio-chemical activity during the 4 week period between sample collection and testing at Lae.

TABLE 13.12

CHEMICAL AND PHYSICAL CHARACTERISTICS OF WATER AT 3 SITES IN THE SAKA

Test	Units	Saka Sampling Sites (See Map 6)			W.H.O. (1971) Standards	
		2	6	8	Highest Desirable	Maximum Permissible
Turbidity	Turbidity Units	53	27	11	5	25
Colour	Platinum-cobalt scale	<5	<5	<5	5	50
Conductivity at 25°C	Micromhos cm	80	240	250		
pH		7.2	7.8	8.0	7.0-8.5	6.5-9.2
Total Hardness	mg/l $CaCO_3$	30	107	94	100	500
Chloride	mg/l	<1	<1	<1	200	600
Sulphate	mg/l	3	3	1	200	400
Nitrate	mg/l	0	<1	<1	45	45
Carbonate	mg/l	0	0	0		
Bicarbonate	mg/l	42	139	149		
Fluoride	mg/l	<0.1	0.1	<0.1		1.3
Silica	mg/l	18	25	27		
Alkalinity	mg/l $CaCO_3$	34	114	122		
Phosphate	mg/l	0.2	0.15	0.3		
Sodium	mg/l	2	5	5		
Potassium	mg/l	1	2	2		
Calcium	mg/l	10	34	46	75	200
Magnesium	mg/l	3	5	5		
Iron	mg/l	<0.1	<0.1	<0.1	0.1	1.0

CHAPTER 14

SUMMARY AND CONCLUSIONS

Much disparate data has been presented in the preceding sections of Part III and it will be helpful to give a summary of the main results and the important opinions expressed.

(a) There is very little pre-existing data on the bacteriological quality of wells, streams or rivers in Papua New Guinea and there is no policy for the regular testing of rural water supplies. Data from throughout the world, on faecal pollution in catchments with no industrial or urban development and with pollution inputs depending entirely on the natural hydrology of the catchment, are also extremely limited. Data on stream microbiology in Papua New Guinea are greatly needed, partly because many streams are used as water sources and partly because such data will allow sound steps to be taken to minimise the levels of pathogenic faecal pollution.

(b) At the present level of field bacteriological technology, the appropriate tests for the quality of rural water supplies are those for bacteria which are definitely of faecal origin, without regard to their source. Tests for faecal coliforms (FC) and faecal streptococci (FS), by the membrane filtration technique, are especially suitable and were employed in this study.

(c) Replication tests were carried out to assess the experimental errors inherent in the bacteriological methods used. The standard deviation of replicate values from a single water sample was only 1.26 times greater than the standard deviation due to unavoidable sampling error (Poisson distribution assumed). This error is considered low and compares favourably with other reported studies.

(d) All blue colonies grown on M-FC medium were regarded as faecal coliforms. The transfer of 211 of these blue colonies to tubes of EC broth, revealed gas production in 92% of cases.

(e) Based on the work of Pavlova et al (1970), a tentative identification of faecal streptococcal species was made. The proportions of FS due to enterococci at various sites ranged from 40% to 78% with a mean proportion of 57%.

(f) Daily cycles of FC and FS were investigated by hourly testing. FS levels showed extremely "flashy" behaviour with peaking occurring soon after the onset of rainfall followed by a fairly rapid decline to basal levels. FC also peak after rain but show other fluctuations which are not so readily explained. Rainfall causes a rapid rise in pollution levels partly by the surface run-off "washing" suitably located faeces into the stream and partly by rising river stages causing "flushing" of any faecal material on the banks. FS are far more responsive than FC to both these mechanisms because they derive mainly from pig faeces which are mostly deposited on worn, deeply incised, tracks and on the river flats which are the preferred foraging grounds for pigs. Additionally, FS may be largely composed of S. bovis, whose rapid death rate will cause concentrations to fall quickly after they have peaked.

(g) Pollution at 22 sites in the Saka was monitored. One site, just down stream from a spring, showed relatively clean water with a FC mean of 8 colonies per 100ml, and a FS mean of 40 colonies per 100ml. All other sites were grossly polluted with mean FC and FS levels being typically greater than 200 colonies per 100ml. FC:FS ratios in the streams indicate a pig contribution of 45% of the total pollution, but it is suggested that FC:FS ratios at the time of defecation are much lower and that the probably true pig contribution is over 90%. Small streams are usually the most polluted.

(h) Multiple correlations between bacterial concentrations, turbidity, river temperature and preceding day's rainfall were computed. The small fluctuations in temperature are not an important influence on bacterial concentrations. Turbidity is sometimes positively correlated with pollution and is generally highly correlated with the preceding day's rainfall. Preceding day's rainfall is positively correlated with bacterial concentrations and it is likely that a function of hourly precipitations over the catchment would explain much of the variation in pollution levels.

Water was sampled from 22 sites. All these sites, except for sites 7, 10, 11, S5 and S6, were at or near places where water is collected by the Saka Raiapu for domestic purposes. Part II of this thesis shows that Tompeakini clan make 85% of their water collection journeys to the Punate and the Tobaka. Yanuni clan collect water from the Tame, and the Wakema is a source of water for approximately 8,000 people in the north-western Saka. By any health standard all these sites (except perhaps site 8) are grossly polluted with faecal material. Even the Punate, however, is totally unacceptable to W.H.O. (1971), who allow less than 10 coliforms per 100ml as a maximum even for "small community supplies". W.H.O. report that "persistent failure to achieve this, particularly if E. coli is repeatedly found, should, as a general rule, lead to condemnation of the supply". On this basis, all Saka water sources, and most rural sources throughout Papua New Guinea, deserve to be condemned.

To hold up these W.H.O. standards as short-term goals for water supply improvements in Papua New Guinea is clearly unrealistic. In the Saka, the waters are heavily polluted with faecal material and nearly all of this material may be of non-human origin. I have argued that this pollution constitutes a definite health hazard despite its origin. Two questions must now be asked - to what extent should limited human and financial resources be expended to improve the quality of water sources and how is this improvement to be made?

This Part of the thesis does not answer the first question. It has been demonstrated that the Raiapu utilize heavily polluted water, but it has not been demonstrated that any sickness actually results from this. This issue will be examined in Chapter 19.

The second question, of how one can seek to improve the Saka water quality situation, is one which is partially answered by the data reported here. Firstly, since human faeces contribute little to the observed river pollution, it is of no value to promote pit latrine usage amongst the Raiapu as a means of controlling water pollution. I strongly believe that the traditional habit of promiscuous defecation is far more hygienic than the use of poorly maintained latrines. All pit latrines in the Enga area which I have inspected have been in a revolting state and definitely constitute a major health hazard, especially to children. Since pigs will be reluctant to use pit latrines, it is pointless to promote latrines as a means of minimising faecal water pollution [1]. Secondly, water from springs is of excellent quality when compared to other available sources and steps should be taken

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1. It might be argued that, since most pollution originates from pigs, the response should be to change the patterns of pig husbandry so that pigs do not graze on the stream banks. At present, any attempt to do this would be completely unacceptable to the Raiapu, and it is hard to see how the pig herds could be supported if they were not permitted to forage freely.

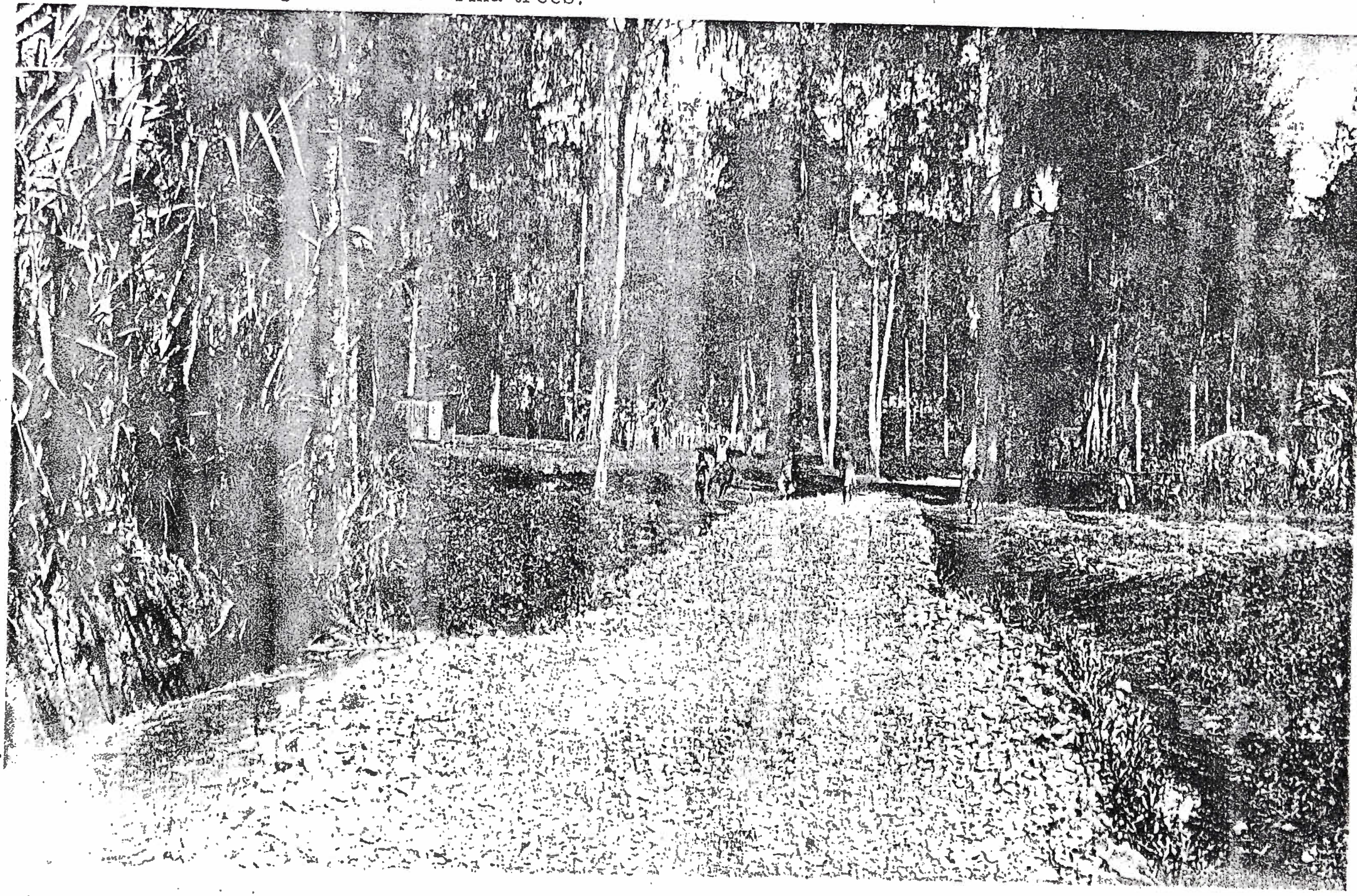
to encourage the protection and greatest utilization of springs. For instance, springs should be well fenced to exclude pigs and children. Thirdly, generally speaking, the big rivers are the cleaner ones. This fact should be publicised and the Raiapu should be encouraged to make maximum use of larger streams and rivers. The drawing of water from small streams should be vigorously discouraged.

Further studies on stream pollution in Papua New Guinea may add to these recommendations and will indicate whether they are applicable to other regions of the country.

PART IV

ENVIRONMENT AND MORBIDITY

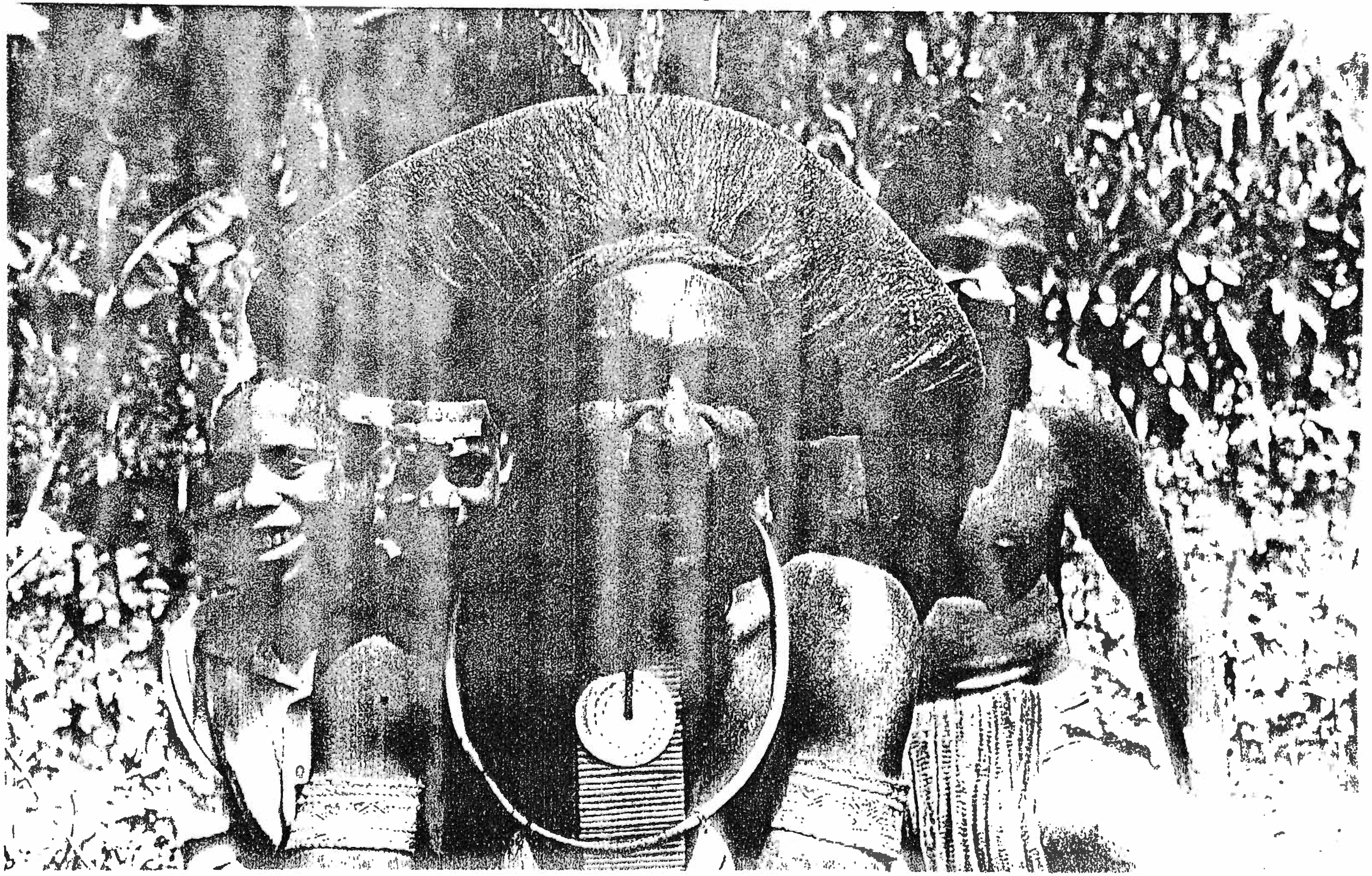
The road through Tombeakini territory at Lyokote. The metal trade-store, owned by a Tombeakini clansman, is on the left set in a grove of casuarina trees.



Men from the Saka Valley relax on their clan's tée-ground.

Mother and child sit in a new mixed garden which they are preparing.

A young married man from the Saka Valley wearing a wig of human hair.



A wig-maker from Tombeakini Clan prepares a new wig for a bachelor.

CHAPTER 15

INTRODUCTION

15.1 THE NEED FOR MORBIDITY DATA

Much has been written in the last decade (for instance Hetzel, 1971) about the need for health services in developing countries to be oriented towards the rural areas where the majority of people live, become sick and die. While there is general consensus on this point, there is considerable divergence of opinion on the structure and goals which rural health services should have. Essentially the problem is an economic one and concerns the optimum utilisation of available financial and human resources. As Radford (1971) puts it, "the maximum return in human welfare must be obtained from the limited money and skill available".

This problem of resource allocation, like all others, needs to be viewed in the light of a thorough knowledge of the benefits that can be anticipated from various alternative courses of action. Data are required which define the precise health problems of the area concerned, suggest how these problems may be most effectively attacked and enable the progress and impact of a health improvement programme to be monitored, in order that plans may be modified and guide lines postulated for future programmes. With the accumulation of such data it will become possible to nominate local and regional priorities, and to allocate scarce funds, on a rational and efficient basis.

Three principal types of data are needed. Firstly, accurate records of births, deaths and life expectancies, which have been shown (Molina et al, 1964) to provide a good general indication of community health. Secondly, basic data on the causes of morbidity and mortality and thirdly, ecological data on the cultural and environmental factors which influence disease patterns. A quarter of a century ago, Gordon and Augustine (1948) wrote of the need for data of these last two types. They lamented that there was little quantified knowledge of the tropical environment as it affects tropical disease and too much clinical study on the patient, and particularly on the white patient. Researchers, they noted, had addressed themselves "too little to the causes of tropical diseases as they are determined by age, sex, sanitary environment, local customs and other factors of host and environment. An understanding of the epidemiology of a disease as a community or group problem cannot be expected to arise from the selected and biased data of clinics and hospitals. The need is for a study of tropical disease as a whole, of populations and their reactions".

Although much research has been completed since those words were written they still have much relevance. In New Guinea there is a tremendous need for the type of research that Gordon and Augustine advocated and the work described in this thesis is an attempt to meet this need in part.

15.2 MEDICAL RESEARCH IN THE ENGA REGION

The earliest comments on health in the Highlands appear in the reports of the explorers who first penetrated into the high valleys in the 1920s and 1930s. Later the administration mounted medical patrols specifically to investigate the health status of remote groups of Highlanders, examples of which are reported by Yelland (1955) and Morahan (1957). Even in recent years medical patrols have operated in particularly isolated areas and Stocklin (1968) reports one such patrol amongst the Kukukuku.

In the last ten years much detailed medical research has been undertaken in the Highlands and space does not permit a full review here. The interested reader is referred to the forthcoming bibliography of medical work in Papua New Guinea which is being prepared by the Institute of Human Biology at Goroka.

Since the Chimbu and the Enga are New Guinea's largest ethnolinguistic groups, and exhibit the highest population densities, they have naturally been the subject of many investigations. The Enga were first contacted by white men in 1933 and, in 1938, James Taylor's (1940) Hagen-Sepik Patrol constructed an airstrip at Wabag. Tommerup (1955/56) describes an early medical patrol into the area and this was soon followed by the Nuffield-New Guinea Expedition which sponsored medical research in the Wabag area (see Fisher, 1956; Freedman and Macintosh, 1965; Macintosh et al, 1958; Ponsford et al, 1955; Rountree, 1956; Walsh et al, 1959; Ward, 1957/58).

Since that time a large proportion of Enga medical research has been directed at the Kyaka Enga of Baiyer River. The Kyaka live north-east of the Raiapu and have been described by Bulmer (1960a, 1960b). The area is easily accessible by road from Mount Hagen and has a hospital run by the Baptist Mission. Mackay (1960) and Becroft and Bailey (1965) have described protein-calorie malnutrition amongst Kyaka children and unsuccessful attempts to alleviate this by supplementary feeding with peanut butter, skimmed milk and soya beans. Becroft (1967a, 1967b) describes child rearing practices at Baiyer River and reports that weaning is usually not completed until the child is 4½ years.

Arter and Blackburn (1965), Arter et al (1968), Blackburn et al (1966) and Ma et al (1968) report the findings of a liver disease survey amongst the Kyaka and other Highland groups. Over 70% of livers examined by biopsy were abnormal with portal tract fibrosis and inflammatory cell infiltration being especially common.

Acute infectious hepatitis was reported as the commonest cause of jaundice and Simmons et al (1972) report that 9.1% of Raiapu Enga have Australia antigen[1].

Woolcock and Blackburn (1967) survey Kyaka chronic lung disease and Cleary and Blackburn (1968) link this to the breathing of smoke-filled, polluted air inside Enga houses. Further work on lung disease at Baiyer River is reported in Blackburn et al (1970) and Woolcock et al (1970, 1972). Becroft et al (1969) report mortality and life expectancy statistics and Burchett (1966) describes 46 cases of amoebiasis. Most recently Blackburn and Ma (1971a, 1971b) describe skin reactions to antigens from *Dirofilaria immitis* and *Schistosoma mansoni* and Beral and Read (1971) report Kyaka insensitivity to carbon dioxide tension.

The Central Enga (Mae and Raiapu) have been the subject of less medical research than the Kyaka. Of particular interest is the longitudinal study of a Yandapu Enga phratry near Sirunki (Map 2) reported by Blake et al (1969), Grace et al (1970), Goldrick et al (1970), Sinnett (1972a, 1972b, 1972c), Sinnett and Solomon (1968) and Sinnett et al (1970, 1973). This work will be referred to later.

Murrell (1966a) has suggested that the Wabag-Kompiam-Wapenamanda region may be an endemic focus of rhinoscleroma. He has also reported (Murrell, 1966b) a case of traumatic dermatitis in a neonate caused by transportation in a string bag in the usual Enga fashion. Wilson et al (1959) report the occurrence of tremor syndromes

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1. Cp. 7.5% reported by Woodfield et al (1972) for the Papua New Guinea population as a whole. Australia antigen is associated with serum hepatitis or hepatitis B.

in the Wabag-Laiagam-Kandepe region.

"Pig-Bel" or enteritis necroticans is an important medical problem in the Enga region and has been the subject of research which is continuing. Pig-Bel is a spontaneous enteric gangrene associated with pig feasting cycles and possibly aetiologically related to Clostridium welchii type C. Pig-Bel research is reported by Egerton and Walker (1964), Murrell (1966c, 1966d, 1967), Murrell and Roth (1963) and Murrell et al (1966a, 1966b). Volume 9, No. 2, 1966 of the Papua New Guinea Medical Journal is devoted to the problem of Pig-Bel.

Physical anthropological studies have also been made amongst the Central Enga. Macintosh et al (1958) report blood groups and Walsh et al (1959) report haemoglobin values. Freedman and Macintosh (1965) report a mean height of 156.57cm for the adult population of the Saka and Wolstenholme and Walsh (1967) report heights and weights at Mount Hagen and Wabag. Macintosh (1960) comments on the range of skin colours found in the Wabag region.

It can be seen therefore that, in the past 18 years, a considerable pool of medical information has been accumulated about the Enga. However, there is still a great need for basic epidemiological data for the region, and indeed for all the New Guinea Highlands. Hospital and aid post records are notoriously inadequate for assessing the health status of a "primitive" community since the great majority of illness is never reported. Vines (1970) has established certain morbidity prevalences for the Highlands and his research has been a great advance. The need remains, however, to study small communities in depth and thereby, not only establish basic health patterns and priorities, but also to link them to complex cultural and environmental variables.

CHAPTER 16

RAIAPU VIEWS OF SICKNESS AND CURING [1]

16.1 A FRAMEWORK FOR THE DESCRIPTION OF RAIAPU MEDICINE

Glick (1967) discusses the problems involved in the study and description of medical phenomena in preliterate societies. In particular there is the problem of disentangling the medical system from the religious and socio-cultural systems in order that it may be described as a discrete aspect of ethnography. Glick writes:

> The ethnographer who asks what causes illness is not likely to hear about bacteria or disordered physiology: instead he hears about competition, jealousy, greed, and lust; witches, sorcerers and demons; mothers, brothers and grandfathers recently deceased.

Glick (1967) proposes the use of the concept of power; power which is focused and purposeful and may give rise to disease. Identifications of the sources of power thus become diagnoses and attempts to overcome power are treatments.

This approach seems useful to the analysis of the Raiapu medical system and it will be used here. Some other concepts and definitions are also taken from Glick (1967) but the overall framework proposed below differs from his in that non-religious medical

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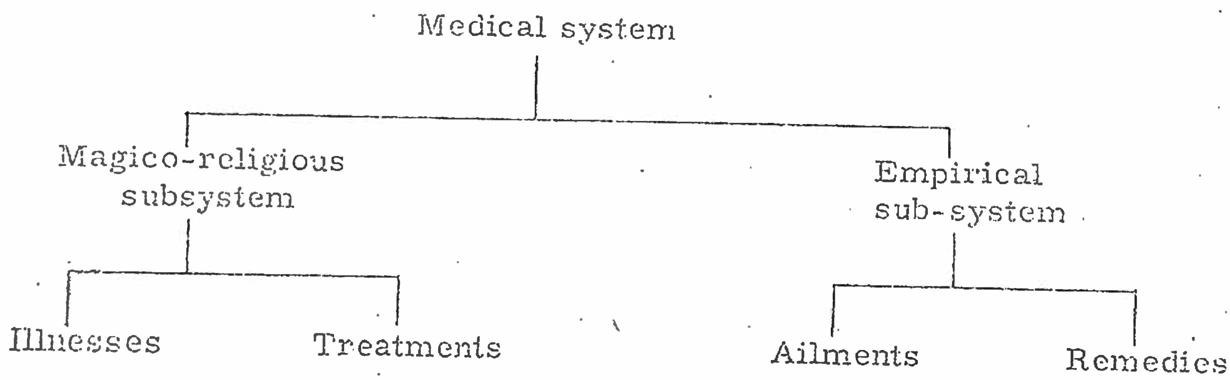
1. Materials on the ethnomedical systems of other New Guinea groups have been published. Most ethnographic monographs on New Guinea contain some reference to medical practices. In addition, see Gillam (1973) on the Wapei, Glick (1967) on the Gimi, Luzbetak (1958) on the middle Wahgi, Posala (1969) on the Kainantu region, Schiefenhoevel (1971) on the Kaluli and Waragu, Schwartz(1969) on the Admiralty Islands, Strathern (1968) on the Melpa and the Wiru, Whiteman (1965, 1966) on the Chimbu and Zigas <u>et al</u> (1972) on the Fore.

behaviour is included within the medical system. The framework suggested for the description of Raiapu ethnomedicine is as follows. The "medical system" is that set of beliefs and practices which relates to disease (disease being defined in a purely Western way). This is subdivided into a "magico-religious subsystem" and an "empirical subsystem". The magico-religious subsystem includes medical practices which are connected with defining and overcoming sources of power. A medical manifestation of power is an "illness", an identification of the source of the power, and the reason for its application, is a "diagnosis", and an attempt to overcome the power is a "treatment". The empirical subsystem, on the other hand, includes "ailments" and their "remedies". Glick defines ailments as "conditions having no significant cause and requiring no treatment other than what might be called remedies". Later he writes that ailments are "relatively minor and temporary afflictions lacking significant socio-cultural antecedents or consequences". This descriptive framework is displayed diagrammatically below.



It is not suggested that this framework is comprehensive or rigorous or that it in any way corresponds to the Raiapu perception of their medical affairs. It is merely a useful tool for the organisation of data on Raiapu ethnomedicine which would be difficult to record without a framework such as this.

16.2 SOURCES OF POWER

In order to understand the magico-religious subsystem it is clearly necessary to know the sources of power which the Raiapu believe may cause disease. This, in turn, requires an appreciation of Raiapu religion which has been described by the author (Feachem, 1973c) and will not be repeated in full.

The Raiapu believe in three sources of disease-causing power. Firstly, and most importantly, are the ghosts of the recently deceased (timóngó). I have written elsewhere (Feachem, 1973c) on timóngó as follows:

> All men, and some animals, possess an individual spirit (sometimes described as a shadow) which is essentially male and is given to the foetus by the clan ancestral ghosts. Upon death, this spirit leaves the body and becomes a ghost (timóngó) which wanders freely in the clan territory and is a source of continual fear and alarm for the living. All ghosts are malevolent and most misfortune is attributed to ghostly attack. The ghosts act out the individual animosities they possessed while alive and are likely to attack anyone who has offended, or angered, them. In practice, this probably means their immediate family, since the family situation is fraught with tensions and is a breeding ground for bitter grievances. The living are fearful of all ghosts, but especially of domestic ghosts. These ghosts are likely to attack at any time by causing sickness or death, by damaging gardens, by injuring pigs or in other ways causing trouble. Men often say, "my father attacks (and may kill) me and I will attack (and kill) my children when I am dead"...... Ghosts wander restlessly about their clan territories and are especially active at night. For this reason, Raiapu will seldom move about at night, and certainly never alone. If a man has a particular

> reason for anticipating a ghostly attack (he may have seen a kongálu or sign) he will huddle in a corner of his house, keep his fire burning brightly, and wait till dawn in a state of extreme nervousness. Any whistling sound, or rustling, especially at night is believed to indicate the presence of a ghost, and a man expecting an attack will almost die of fright if he hears such a sound ....
> These ghosts are the spirits of recently dead clansmen. It is generally thought that, when a ghost has killed one human being (it may have caused much sickness or injury prior to this) it retires to join the ancestral ghosts who act as a corporate group without individual identity.

The second source of disease-causing power is demons. I have described demons in the following terms (Feachem, 1973c):

> The Raiapu also believe in a class of demon, or sprite, usually referred to as putútuli. They are autonomous beings and not associated with a particular clan or group. They can appear in many strange guises but are often described as being extremely tall and having two-fingered claws. They are evil beings who live in the forests and will attack and eat a lone, or sick, traveller. The Raiapu are gardeners and feel ill at ease in the upper forests, which they consider to be hostile places. Their belief in putútuli expresses their fear of the forests and any death or injury occurring while a man is in the forest, or even after his return, is usually assumed to be the work of a putútuli. Men travelling through the forest will stop at intervals and erect barriers of branches across the path, and recite appropriate spells, to discourage the putútuli from stalking them.

The third source of pathogenic power is sorcerers. I have discussed sorcerers as follows (Feachem, 1973c):

> The striking thing about sorcery amongst the Enga is that everyone practises it except the people you are

> talking to. Thus Meggitt (1972:123, 128) notes that the Mae "assert that they have much less magic than do the Saui Enga and the Ipili near by" and refers to "sorcery-using non-Mae". Westermann (1968:211) reports that the Raiapu from the Lai valley "told me that Saui Enga had many powerful magic spells, and that some men in the Saka Valley were powerful sorcerers". The people of the Saka maintain that Kandepe, Tambul, the lower Lai and Baiyer River are the home of sorcerers, while in the Saka there are relatively few. Some of my informants claimed to know a few procedures but denied that they had ever practised them. Raiapu are afraid of sorcery and especially of the introduction of poison into their food or water. A Saka man travelling to Kandepe (for instance) will be most apprehensive about the possibility of sorcery and will take precautions, which may include not accepting cooked food and keeping awake at night ......
> The most frequently mentioned techniques are the inclusion of menstrual blood, faeces or parts of a corpse into the food or water of the victim......
> The effect of sorcery is believed to be sickness, or death, and it provides an explanation for diseases which cannot otherwise be accounted for.

This is the least important power source and diagnoses only implicate sorcerers if other diagnoses are inappropriate or have been proved to be false by failures in the resultant treatments.

Those sicknesses classed as illness in section 16.1, will therefore evoke diagnoses which, in the vast majority of cases, will nominate timóngó and less commonly demons and sorcerers as the sources of the power which is attacking the patient. These diagnoses, and any subsequent treatments, will be undertaken by adult Raiapu of either sex who have special knowledge of timóngó, demons and sorcerers and special abilities to counteract their attacks. Such healers are called topólí - a term which also covers people with any special spiritual knowledge or powers. I have written at length on topólí (Feachem, 1973c) and have said, in part:

> Anyone who possesses knowledge of spells, or magical procedures, and who has been proved to be effective and powerful, is a topólí. Topólí engage in all types of ritual but tend to specialise in a particular ritual, or group of rituals. Thus the name of a topólí will be associated with particular activities, and he may be described as a healer of broken limbs, or a catcher of lost ghosts. Also associated with a topólí's name is a concept of his fame and greatness. There are topólí whose names are known over a wide area and whose skills are the subject of public discussion and marvel; there are others who may be only known to their own clansmen or who are ridiculed as "quacks" by people in other clans ......
> A famous topólí will almost certainly be over forty years of age and may be a great deal older. It takes time to build up a reputation and it is not likely that a young man could become prominent. Topólí need to be physically active and will usually lose their status when they can no longer move around easily. Most, but by no means all, topólí are male and I have never encountered a famous topólí who was female. Females tend to specialise in magic which is connected with women, but again, this is not always the case.......A topólí will usually inherit his skills from a parent (a son from his father and a daughter from her mother) and the practice therefore runs in families ......
> ...Topólí are paid for their services and the amount of payment will depend on the magician's reputation, how far he has travelled, the seriousness of the problem (and the complexity of the solution) and the wealth, and status, of the client. Payment is made with pork, axes, string bags, men's aprons, salt ash, money and any other item of value to the Raiapu. Many of the more complex rituals involve the killing and cooking of a pig and, in these cases, the topólí will receive a half-side of pork.

It could be said that the topólí are themselves a source of power - a healing power which counteracts the malevolent power of timóngó. Glick (1967) indicates this view when he writes:

> An important source of power is the shaman or curer himself. He may rub or massage his patient, blow breath or smoke on him, or manipulate his body - all practices designed to impart power. These same persons, as is well known, may become sorcerers when offended.

Despite it being "well known" it is not true in the Raiapu case and I have no evidence of tópólí committing, or being suspected of, sorcery. Rather than saying that tópólí are sources of power, I feel that the Raiapu view would be more closely expressed by saying that the tópólí have knowledge of spells and manipulations, and possess certain objects, and it is these spells and objects which are the sources of power.

As already mentioned, this powerful knowledge is inherited from parents to children and it is generally believed that an old tópólí will pass on his secrets to his eldest son before he dies. However, it is said of some great tópólí that they received their secrets from the timóngó of their father after his death and this version imbues the tópólí's secrets with an enhanced mystery and spirituality.

16.3 ILLNESSES AND TREATMENTS

A sufferer from an illness believes that he is being attacked by one of the sources of malevolent power which were discussed above. In perhaps 90% of cases he believes that he is attacked by a timóngó and usually by the timóngó of someone recently dead and closely related to him.[1] The response is to employ a tópólí who will

1. Lindenbaum (1972) argues that "the choice between ancestral

ghosts or sorcerers as an explanation for death from disease may be ecologically determined". She goes on to explain that societies in which dense populations are putting pressure on scarce resources (such as the Central Enga) attribute death to malevolent ancestral spirits, whereas societies "where population increase is desired" (such as the Fore and Bena Bena) see disease primarily in terms of attack by sorcerers.

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have three tasks; to discover who is attacking, to discover why and to dissuade the attacker from continuing. Some topólí will perform all these functions while others will perform only some. The patient may summon a famous topólí who will expect a substantial payment, or he may employ a little known practitioner from his own clan. If a big man (kamóngo) is sick he will usually summon a famous topólí and the resulting interchange between the two men, both of whom have "big names", will enhance the prestige of both parties.

The divinations and treatments that the topólí may perform are numerous. Certain common elements are discernible, however. The ceremony is private and will take place in the house-compound of the patient with only the patient's close family being present. Curious visitors will be discouraged and a barricade of fern leaves may be erected, across the path leading to the patient's house, as a warning to others to keep away. Sweet flag (Enga, répé; Latin, Acorus calamus) is frequently used by the topólí as the main ingredient of any medicine which he may concoct. Sweet flag has great spiritual significance in many spheres of Raiapu life and it is the possession of special types of sweet flag, and the knowledge of how to manipulate them, that is thought to be the cornerstone of some topólí's power. A third common theme is the use of spells (nemóngo). A knowledge of spells is another vital topólí attribute and he recites these at appropriate moments during his rituals. They are usually long and recited very fast, either mumbled or spoken loudly with much drama. Some Raiapu say that these are devices to prevent the patients or spectators from learning the spells and thus usurping the <u>topólí</u>'s power[1].

These three elements - privacy, sweet flag and spells - are found commonly in Raiapu <u>topólí</u> treatments. Also common is the use of <u>arámá</u> (<u>Zingiber</u> sp. = ginger), salt ash (the traditional Enga salt source - see Meggitt, 1958a), the edible greens, <u>áwā</u> (<u>Brassica</u> sp.) and <u>takai</u> (<u>Oenanthe javanica</u>), and the liver (<u>pungí</u>) and fat (<u>amengé</u>) from a pig. These are usually used, together with sweet flag, to concoct a medicine which the patient will eat[2].

16.4 AILMENTS AND REMEDIES

As outlined in section 16.1, there is a set of Raiapu medical situations which does not involve the power of <u>timóngó</u>, demons or sorcerers and which is not essentially magical or religious in nature. These minor disorders are termed ailments here and evoke remedies which are simply folk-cures rather than magico-religious responses. This distinction between illnesses and ailments is not a Raiapu one and neither does it divide sickness into

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1. This comment reinforces my belief that it is not the <u>topólí</u> himself who is powerful but rather the secrets which he has inherited.

2. Many of these <u>topólí</u> medicines are emetic and cause violent vomiting. I know of one definite case, and I have heard of others, in which the patient died due to internal haemorrhaging following prolonged violent vomiting. Although Western medicine is not unknown to kill its patients also, this danger from traditional medical practice must be remembered by those who support the recent calls, by the Minister of Health, for Western and traditional doctors to work side-by-side.

two separate classes. Although illnesses are generally more acute than ailments, the border between them is vague and variable so that a sickness, which is an illness on one occasion, may be an ailment on another.

Ailments are thought of as having physical causes whereas illnesses have spiritual causes. Sickness which the Raiapu feel is clearly physically caused is therefore always regarded as an ailment. Thus all traumas are ailments, as are certain aches and pains which have physical explanations. To comprehend Raiapu treatments it is necessary to understand religion and, similarly, to comprehend remedies it is necessary to understand Raiapu concepts of anatomy and physiology.

Raiapu often say, when questioned about human anatomy, that they are only familiar with the pig and that they therefore assume that man is like an upright pig. The Raiapu have a detailed and comprehensive knowledge of porcine anatomy, whereas most of them have never seen a human body dissected. The heart (yamáli) is believed to provide the vital force necessary for life and also to control all bodily functions. There is no concept of blood circulation but blood (tatámá) movement is considered essential for life and the dynamic force of the heart is associated with this movement. The blood moves in tubes (kongápu) which are joined to the heart and which bring strength to the limbs. Arterial blood (bright) is considered alive whereas venous blood (dark) is dead and injuries which result in venous bleeding, cause great alarm. Blood derives from the liver (pungí) and juices (especially sugar-cane juice) which are drunk are used to replace blood which has been lost in bleeding. Some say that neither the lungs (kípiokó), nor the brain, have any important functions and that the heart is responsible for breathing.

The digestive system is seen by the Raiapu in the following way. Food and water are taken into the mouth (nengekaita) from where they pass into the oesophagus (ututu) and thence to the stomache (andatómba). The juices (liquid and nutritious portion of the food) are taken off in the upper oesophagus (pendókó) and distributed round the body in the arteries and veins (kongápu). The food and water pass into the small intestine (litísá) and then the large intestine (mátisa) where they are separated. Water goes to the bladder (pólyá) and is passed out through the penis (pongó)[1] when the bladder is full. The food goes to the rectum (ilya) and then out through the anus (yakaitakaita).

Raiapu remedies are, like treatments, numerous and of many types. A common theme, however, is that of the gathering of blood which must then be dispersed. Many aches and pains are attributed to the gathering of blood at the affected spot, which then causes pressure and pain. The remedy for this is either massage, to disperse the blood, or more usually blood-letting, to relieve the pressure. This blood-letting is performed by incisions made with bamboo knives[2]. These may be complex and major incisions performed by a topólí who specialises in blood-letting or they may be relatively minor and performed by the patient himself or a relative. Blood-lettings range from a series of long cuts to the chest to relieve a chest pain to a minor incision in the gum to cure a toothache. In all cases, the

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1. This is clearly a male anatomy. I have no data on the Raiapu view of female anatomy.

2. The bamboo knife, kept sharp by shaving it down with another knife, is the traditional Enga tool for all small and precise cutting tasks. It is extremely sharp.

rationale is the same: blood has gathered, thus causing pain, and this excess blood must be drained off. Bleeding is also used when it is thought that a poisonous substance has entered the blood. This is remedied by making incisions designed merely to cause profuse bleeding which, it is hoped, will drain out the poison. Sick pigs have their tails amputated for this reason.

Skin infections are regarded as minor and are always ailments, rather than illnesses. The application of chicken or pig blood is a common cure, as is the covering of the infected area with mongálo (Cordyline terminalis) or lyambí (Olearia sp.) leaves. Talcum powder, bought at the local store, is nowadays applied to wounds in the belief that it is the same as the antibiotic powders which are dispensed at the aid posts and hospitals. Finally, ginger is commonly chewed, or rubbed on the skin, as a self-cure for many minor ailments.

The Raiapu, like other Melanesian peoples, use a wide range of plants in their traditional medical practice. Some of these plants have been referred to in this chapter, but the reader will find a more extensive, but in no way complete, listing in Appendix I.

CHAPTER 17

THE AVAILABILITY AND USE OF MEDICAL SERVICES

Today the Raiapu have resort to 2 types of medical service. Firstly, there is the traditional system which has been described in Chapter 16 and, secondly, there is the introduced system of Western medicine which has been established by the white man. These alternative medical facilities will be referred to as traditional medicine and Western medicine, respectively. The purpose of this chapter is to describe the Western facilities which are available to the Raiapu, to report data on the manner in which the Raiapu utilise these facilities and to discuss the choice which a sick man must make between visiting a <u>topólí</u> or visiting a hospital.

17.1 RURAL HEALTH SERVICES IN THE SAKA

As in other parts of Papua New Guinea, the Raiapu region has a hierarchy of curative services to which sick people can turn. At the local level, and of most importance, are the aid posts of which there are 4 in the Saka, as shown on Map 3. These aid posts are staffed by Aid Post Orderlies (A.P.O.s) who may have primary school education and have received a basic medical training. They are all Raiapu Enga and most come from the Saka itself so that the business of the aid posts is conducted entirely in the vernacular. They are generally semi-literate in English and are able to read medicine labels and fill in standardised forms. The A.P.O.s provide a fairly comprehensive primary care service and administer a wide range of drugs and treatments. Some of them become extremely skilful and acquire reputations which are known throughout the valley.

The aid posts at Saposa, Raiakama and Yumbitesa (Map 3) are all administered by the Lutheran Hospital at Mambisanda, near

Wapenamanda (Map 2), and the A.P.O.s at these aid posts were trained at Mambisanda. The fourth Saka aid post, at Pumakosa [1], is rather different since it is run by the Catholic Mission and is staffed by an Australian nursing sister as well as by A.P.O.s. It therefore provides a higher level of service than the usual aid posts and is perhaps closer to a Health Centre, which is the level of institution above the aid post in the Papua New Guinea health service.

Although most of the aid post work is done on an outpatient basis, they each have a small ward where the sick can sleep and be kept under observation. In the case of the 3 Lutheran aid posts (Saposa, Raiakama and Yumbitesa) these wards are small and typically are either empty or have only 1 or 2 patients in them. At Pumakosa the ward is larger and is often busy.

Patients who the A.P.O.'s regard as too serious are referred to the Mambisanda Hospital which is large, well equipped and has European doctors, nurses and laboratory staff. However, this hospital is a day's walk from the western end of the Saka and so few people will consider visiting it unless vehicular transport is available, or unless the patient is travelling to Wapenamanda for other reasons. Mambisanda is important as a base from which the Saka aid posts are administered but it does not otherwise play an

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1. In order that the reader may follow this chapter, it is necessary to describe which aid post on Map 3 is associated with which name. Saposa aid post is at the western end of the Saka near the River Wakema; Pumakosa aid post is at the Catholic Mission; Raiakama aid post is at the Lutheran Mission; and Yumbitesa aid post is at the eastern end of the Saka road, and across the Tobaka River from Tombeakini clan. All aid posts are on the vehicular road.

important role in the medical affairs of the Saka. The exception to this is in the event of some emergency, such as a war or an epidemic. In the case of war, vehicles rush the badly wounded to Mambisanda where surgery can be performed and many lives have been saved in this way. The Catholic aid post at Pumakosa has vehicles on hand at all times and so is able to send patients from its ward into Mambisanda if their condition becomes serious.

Generally speaking, to the people of the Saka, Western medicine means aid posts and most opinions and beliefs regarding the white man's medicine are formed through experiences at the aid posts.

The 11,000 people of the Saka are served by 4 aid posts and by 6 A.P.O.s and 1 nurse. This gives 2,750 people per aid post and 1,571 people per medical worker. This is somewhat better than the Papua New Guinea average, reported by Radford (1971), of 2,000 people per A.P.O., and Radford comments that this figure is two and a half times better than in the British Solomon Islands and 5 times better than in Uganda[1]. Vines (1970:74) reports figures of 1,486, 894 and 830 people per aid post in the Highlands, Mainland and Islands Regions, respectively.

The most crucial statistic on village-level medical services, such as aid posts, is not the population served by each but the distance between the people served and the facility[2]. In a situation where the

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1. Data from the Department of Public Health (1972) give figures of 1,524 people per A.P.O. and 856 people per health worker (including doctors, nurses, health extension officers and A.P.O.s), assuming a population of 2,500,000 for Papua New New Guinea.

2. Frederiksen (1971:12) reports that, in India, "attendance declines exponentially with distance and only a minute fraction of those sick within a 5 mile radius seek attention at the Dispensary either in person or by proxy".

patient must walk, or be carried, to receive treatment, people will attend aid posts if they are close enough and they will not if they are distant. What constitutes "close enough" will vary from one community to another and depends ultimately on the patient's perception of the efficacy of an aid post visit. Map 3 shows that no-one in the Saka lives more than 7 kilometres (2 hour's walk) from an aid post and I estimate that the mean distance between dwelling and aid post in the Saka is less than 3 kilometres (1 hour's walk). Vines (1970: 72) shows that, in the Highlands Region, 79% of people live within 2 hour's travelling time of the nearest medical facility and that in the Mainland and Islands Regions the proportions are 62% and 89%, respectively. Vines also shows that, of his Mainland Region sample, 13% lived more than 5 hour's travelling time from a medical facility and that 18% lived over 2 days away from a hospital. In the Saka, everyone is within 2 hours of an aid post, and within approximately 6 hours of a hospital, and half the people of the Saka probably have a journey of less than 1 hour to reach an aid post. Thus, by New Guinean standards, it appears that the Saka may not be well provided for in terms of population per medical facility, but, with respect to the more important factor of travel time to the facility, the people of the Saka are well supplied with both low and high grade medical services.

Radford (1971) lists the activities which an A.P.O. could reasonably be expected to undertake, as follows:-

1. Record basic demographic data relating to births, deaths and pregnancies.
2. Provide primary curative care for acute respiratory and alimentary tract infections, malaria and common skin conditions.
3. Implement ambulatory or domiciliary treatment for TB and leprosy.
4. Help in maternal and child health clinics.

5. Regularly patrol villages in his area on a roster prepared for him to detect overt disease, find non-attenders at clinics, remind villagers of the dates of M.C.H.[1] clinics and other patrols and inspect village water supply systems.
6. Collect slides in malaria and other programmes.
7. Report epidemics.
8. Distribute health education and other health materials.
9. Act as a dissemination point for improved nutrition techniques.

If the A.P.O.s in the Saka carried out all these duties they would indeed provide an effective basic medical service. However, unless specifically encouraged to do otherwise during some special programme, they typically only undertake item 2 regularly, and items 3, 4, 5 and 6 occasionally. It is noteworthy that items 5 and 8 are carried out infrequently, or not at all, because it is these activities which would bring the A.P.O. into closest contact with the total population (healthy as well as sick) and would thus have a potential for influencing Raiapu attitudes towards Western medicine and for changing patterns of domestic and personal hygiene[2].

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1. Maternal and Child Health.

2. Item 5 is perhaps the single most important item on Radford's list because, if carried out, it converts a static medical facility into a mobile one and provides the basis for a preventative medical service. Frederiksen (1971: 13) writes:

> Whereas medical relief might be offered conveniently in a static facility, it would not be realistic to expect attendances for preventive services, when even medical relief has such limited power of attraction. But the primary health services need not be restricted by the walls of a building. Medical relief might be considered as an incidental aspect of a health center, which might be viewed as the base of operations for certain essential health services to prevent epidemics and control endemics throughout the area.

Medical services at the aid posts are not given free. A patient is required to pay 10 cents (Australian) for any treatment and to pay 50 cents for admission to the ward, irrespective of the length of stay in the ward. An alternative system was introduced in the Saka by the Lutheran Mission in 1971. Under this new scheme, people are invited to buy a ticket (adults 20 cents, children 10 cents) once a year and this ticket entitles the owner to free treatment and free ward admission for 1 year. In 1971 the Catholic Mission (with its aid post at Pumakosa) was not included in this scheme but, in 1972 and 1973, all aid posts in the Saka co-operated. In 1971, over 4,000 tickets were sold, indicating an interest in the scheme by 40% of the Saka population. Almost 100% of certain clans purchased tickets, while other clans displayed little interest, and these differences in response seem to relate to the distance of the clan from an aid post (clans living close to an aid post showed most interest), to the effort that was put into selling tickets in each area of the valley, and possibly also to the attitudes adopted towards the scheme by meetings of important clansmen.[1]

17.2 THE UTILIZATION OF AID POSTS IN THE SAKA

Although one of the duties of an A.P.O. is to complete a form which reports his treatments over the past month, the data contained on these forms are of very questionable reliability. It cannot be assumed that these records provide a good picture of the number and types of treatments administered by an A.P.O. Table 17.1 is an abstract of the information reported by 3 Saka A.P.O.s between March

1. For instance, Tombeakini clan, at such a meeting, decided that the scheme was worth joining and so 201, of the 211 clan members, bought tickets.

TABLE 17.1

AID POST RECORDS FROM THE SAKA BETWEEN MARCH AND SEPTEMBER, 1971

DISEASES	RATAKAMA AID POST							
	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE MAR-SEP
MALARIA	26	20	16	16	20	45	8	22
DYSENTERY	6	16	26	9	25	18	29	18
PNEUMONIA							4	1
YAWS								
HOOKWORM	9	8	8	8	8	8	12	9
TROPICAL ULCER	43	48	26	25	45	16	15	31
SCABIES	225	54	110	220	317	238	473	227
INFECTED WOUNDS	222	126	126	110	205	187	[illegible]	178
EYE CONDITIONS	6	10	4	16	10	7	6	8
EAR CONDITIONS	15	8	6	10	15	4	8	9
TUBERCULOSIS (various types)								
FILARIASIS and HELMINTHS								
LEPROSY								
MEASLES								
PERTUSSIS	240	124	205	100	55	130	120	139
MUMPS								
INFLUENZA								
CEREBRO-SPINAL MENINGITIS								
SCARLET FEVER								
DIPTHERIA								
MISCELLANEOUS	169	196	120	215	550	520	354	303
EPIDEMICS								
INJURIES	37	54	25	98	43	6	6	38
ALL DISEASES	998	664	672	827	1303	1179	1254	985

DISEASES	SAPOGA AID POST							
	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE MAR-SEP
MALARIA	17	21	16	4	17	13	10	14
DYSENTERY	6	6	26	13	20	11	8	13
PNEUMONIA			7	4	2	1	4	3
YAWS								
HOOKWORM	9		13	7			5	5
TROPICAL ULCER	1	18	7	4	2	1		5
SCABIES	2	17	40	4	102	145	120	62
INFECTED WOUNDS	175			62	168	8	12	61
EYE CONDITIONS	11	11	2	10	4	3	3	6
EAR CONDITIONS	7	18		13	4	1	8	7
TUBERCULOSIS (various types)								
FILARIASIS and HELMINTHS								
LEPROSY				5				1
MEASLES				3				1
PERTUSSIS	23	44	76		73	23	25	38
MUMPS								
INFLUENZA				78				11
CEREBRO-SPINAL MENINGITIS								
SCARLET FEVER								
DIPTHERIA								
MISCELLANEOUS	77	229	187	404	99	275	230	214
EPIDEMICS								
INJURIES	37	63	28	37	33	23	52	39
ALL DISEASES	365	426	402	648	524	505	477	478

DISEASES	YUBBITEGA AID POST							
	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE MAR-SEP
MALARIA		8	15	2	7	10	1	6
DYSENTERY	13	32	20		50		1	18
PNEUMONIA	35		60				4	10
YAWS								
HOOKWORM							2	1
TROPICAL ULCER	18	18		12				7
SCABIES	95	100	300	40	90	133	235	142
INFECTED WOUNDS	115	215	250	35	150	17		112
EYE CONDITIONS	5		20	10	28			9
EAR CONDITIONS	7	5	12	5	17	5		7
TUBERCULOSIS (various types)								
FILARIASIS and HELMINTHS								
LEPROSY								
MEASLES								
PERTUSSIS		50	117	30	81	125		30
MUMPS						5		1
INFLUENZA								
CEREBRO-SPINAL MENINGITIS								
SCARLET FEVER								
DIPTHERIA								
MISCELLANEOUS	106	86	190	36	90	530	568	229
EPIDEMICS								
INJURIES						2	3	1
ALL DISEASES	394	514	994	170	513	829	314	604

and September, 1971. The reliability of these Aid Post records depends solely on the competence and the diligence of the A.P.O., and so the quality of the records may vary considerably. Table 17.1 indicates that the Raiakama records are more trustworthy than those of either Saposa or Yumbitesa, in which obvious omissions and inconsistencies are seen.

It is probable that the figures for the total number of treatments per month are fairly reliable, except for Yumbitesa, where they fluctuate in an unlikely fashion. Raiakama treats approximately 1,000 patients per month, while Saposa and Yumbitesa treat approximately 500 and 600, respectively. The allocation of treatments according to diagnoses is to be treated with suspicion and the A.P.O. is clearly not helped in his task by the unnecessarily complicated list of diagnostic categories. In some months, over 50% of patients seen are classed as "miscellaneous" and in 1 month at Yumbitesa, 70% of patients are so classed. At all 3 aid posts, miscellaneous is the most common diagnosis, which is a singularly unhelpful state of affairs. After miscellaneous comes "scabies" at all aid posts and this is followed by "infected wounds". The fourth most common diagnosis is "pertussis" and I assume that this includes all patients reporting with coughs and not merely pertussis [1]. This

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1. There was an epidemic of whooping cough in the area in 1971 which is reported (Dept. of Public Health, 1972: 128) to have "petered out" in early June, 1971. I doubt whether this epidemic could have approached the scale suggested in Table 17.1 and I suspect that it was because the A.P.O.s were aware of the epidemic that they diagnosed coughs as pertussis. Table 17.1 does not indicate a drop in pertussis treatments around June, which was the reported end of the epidemic. Paine (1973) reports that the pertussis epidemic occurred concurrently with a bronchitis epidemic and that this led to inaccuracies in hospital statistics. It is no wonder, therefore, that aid post statistics should also give a false picture.

assumption is reasonable since respiratory disease, with associated coughing, is the dominant cause of serious morbidity in the area and the only other respiratory diagnosis on the list is pneumonia, of which very few cases are reported in Table 17.1.

Bearing in mind reservations about their reliability, the A.P.O. records in Table 17.1 indicate the following situation; that approximately 2,100 patients per month were seen at the 3 Lutheran aid posts; that the most common reasons for aid post attendance were skin infections and coughing, with malaria, injuries and dysentery also being frequently reported; and that the level of education of the A.P.O., and the design of the form he is required to complete, are not compatible, so that up to 70% of patients are recorded as having a "miscellaneous" diagnosis.

Additional information on aid post utilization is provided by a survey of the aid post attendance of Tombeakini clan which the author conducted between June and November, 1971. Every week for 22 weeks, the Tombeakini clansmen were asked whether they had attended an aid post in the past week, on how many occasions, for what reason(s), and whether the outcome was satisfactory. The survey was conducted as part of a weekly morbidity survey of Tombeakini. All details of the organisation of this survey are reported in Chapter 18 and in Tables 18.1, 18.2, 18.3 and 18.4.

During the 22 weeks of the survey, 95 individuals from Tombeakini made a total of 544 visits to either Yumbitesa or Raiakama aid posts. This figure of 544 visits by Tombeakini in 22 weeks gives a statistic of 18 visits per week per 100 people [1], which gives 103,000

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1. Vines (1970:78) reports 2.4, 6.3 and 7.0 visits per 100 people per week for the Highlands, Mainland and Islands Regions, respectively.

aid post visits for the Saka in a year. The comparable figure calculated from the A.P.O. records (Table 17.1) is 36,000 [1] visits per year, at the very most, and thus it is concluded that the Tombeakini clan attend at least 3 times more frequently than the Saka average, or else the A.P.O. records seriously underestimate the number of patients seen. It should be noted that the figure derived from the Tombeakini survey is 18 visits per week per 100 people and not 18% of the population making an aid post visit every week.

Table 17.2 shows the reasons why Tombeakini made the 544 reported visits. The reasons are recorded according to symptoms and each category is related to the corresponding morbid symptom which was investigated in the health survey and shown in Table 18.1 . Table 17.2 shows that 65% of visits were due to skin infections and the dominance of skin infections as a reason for seeking treatment is supported by Table 17.1, which shows that between 27% and 44% of treatments were for skin infections at the 3 aid posts. The 15% of visits for diarrhoea is not supported by Table 17.1 [2], and neither is the low reporting for coughs. In view of the uncertain reliability of Table 17.1, and the unknown content of the large miscellaneous category, Table 17.2 probably presents a better picture of the reasons why the people of the Saka seek treatment at an aid post.

Vines (1970:75) provides a synthesis of aid post records from throughout the Highlands and shows that 37% of all visits were for skin infections, 22% for respiratory disease, 11% for injuries and 7% for

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1. This assumes that the Catholic aid post increases the total monthly treatments in the Saka to 3,000.

2. It is noteworthy that the list of diagnostic categories available to the A.P.O. (Table 17.1) does not include an undifferentiated diarrhoea diagnosis, so it may be that many diarrhoeas are classified as miscellaneous.

TABLE 17. 2

REASONS FOR AID POST VISITS BY TOMBEAKINI DURING JUNE-NOVEMBER, 1971

Reason for Visit	Symptom Name In Table 18.1	Number of Visits	% of Total Number of Visits
Skin infections, mostly infected scabies	Skin	352	65
Diarrhoea	Diarrhoea	83	15
Coughing	Cough	24	4
Febrile symptoms	Fever	20	4
Abdominal pain	Pain	18	3
Trauma	Trauma	17	3
Toothache	Toothache	14	3
Musculoskeletal aches and pains	Ache	11	2
Other	--	5	1
All reasons	--	544	100

diarrhoeal disease. Thus Vines, Table 17.1 and Table 17.2 are in agreement that skin infections are the dominant cause for aid post visiting. By contrast, Vines (1970:76) and the Department of Health (1972:14) show that the major reasons for hospital treatments, both in the Highlands and elsewhere in Papua New Guinea, are respiratory disease, diarrhoeal disease and malaria. Only 5% of hospital admissions in the Highlands, and 6% hospital treatments from throughout the country, are for skin infections. This indicates the role of the aid posts in relieving the hospitals of the task of treating skin infection, which is the country's most prevalent morbid condition.

Ninetyfive members, or 45%, of Tombeakini visited an aid post on at least 1 occasion during the 22 weeks of the survey. Since it will be shown in Chapter 18 that certain symptoms were experienced by many more than 45% of the clan [1], it is interesting to enquire who sought treatment, who did not, and why. Figures 17.1 and 17.2 show that an approximately equal proportion (44%) of the males and females in Tombeakini utilized the aid posts. Figure 17.1 shows that males attend most frequently in the 0 - 9 and 40 - 49 age groups, with least attendance during 10 - 19 years. Females (Fig. 17.2) attend most in the 0 - 4 and 25 - 39 age groups, with no attendance during 5 - 9 years. Generally the pattern is similar for both sexes; high attendance for the very young, followed by a low attendance period, followed by high attendance in middle-age with falling attendance in old age. The great difference between the sexes is that the onset of the middle-age attendance increase comes at 25 years for women and at 40 years for men. This could relate to the more rapid aging of women which is

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1. Table 18.10 will show that 99.5% of Tombeakini had skin infections and 89.9% had a cough at some time during the health survey.

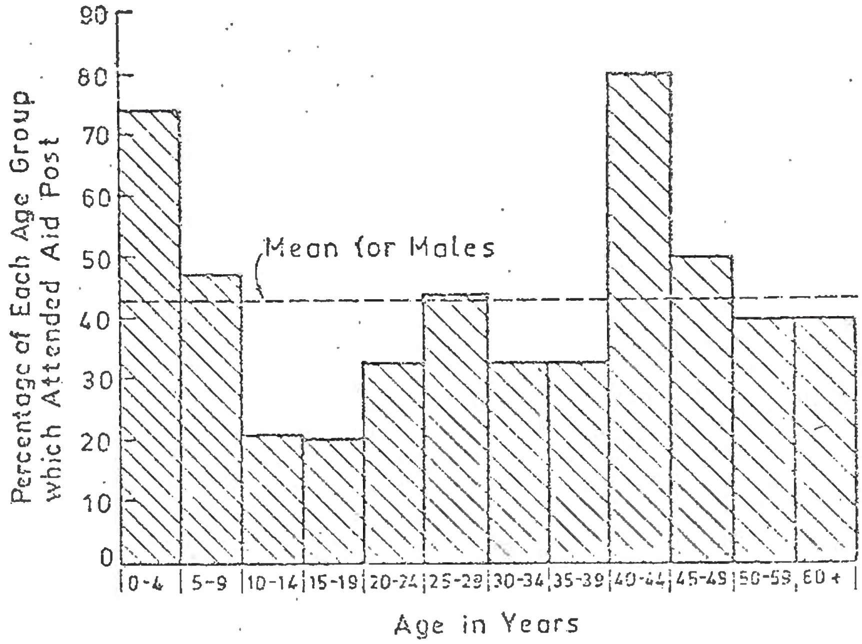

FIG. 17.1. PROPORTIONS OF MALES IN VARIOUS AGE GROUPS WHO ATTENDED AN AID POST

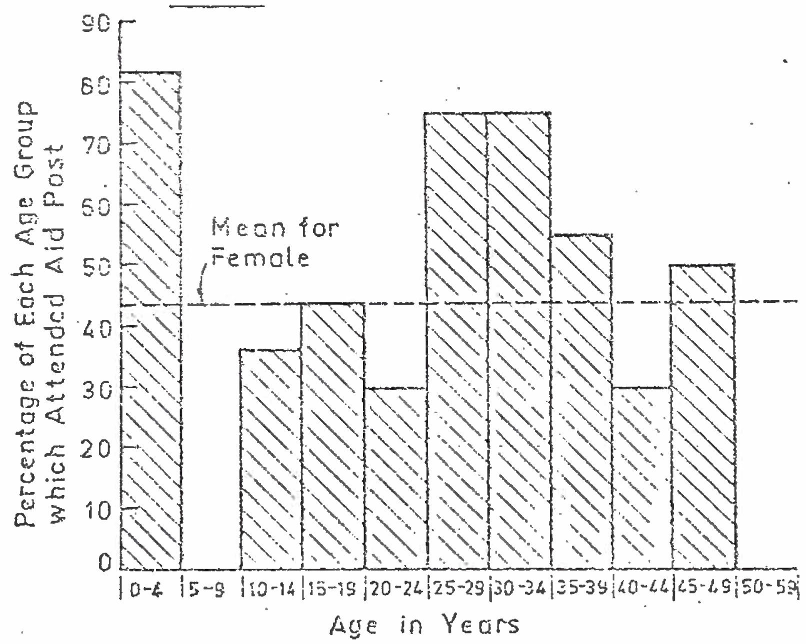

FIG. 17.2 PROPORTIONS OF FEMALES IN VARIOUS AGE GROUPS WHO ATTENDED AN AID POST

reflected in their lower life expectancy (Table 18.4) and is probably due to the strain of continual cycles of childbirth and lactation.

Of the 211 members of Tombeakini clan, 95 (45%) were aid post attenders during the period of the survey. If these individuals were distributed randomly in the 70 Tombeakini households, then one would expect all households to contain approximately 45% of aid post attenders. However, Figure 17.3 shows that, of the 56 houses which have more than a single occupant, 11 have no attenders in residence, while 12 are occupied entirely by aid post attenders. There is a marked tendency for aid post attenders to be clustered by houses and therefore the beliefs and attitudes which cause a patient to seek treatment at an aid post must sometimes be shared by members of the same household.

A final point which emerges from the survey of aid post attendance concerns the outcomes of the treatments received. A "course of treatment" is defined here as a number of aid post visits on consecutive days for the treatment of a single complaint. Courses of treatment ranged from a single visit to 9 consecutive visits, with the patient often living with friends near the aid post in order to receive daily treatment. There were 232 courses of treatment in the survey and 63% of these had negative outcomes. A negative outcome was one in which the patient was clearly not cured, or in which the patient expressed strong dissatisfaction with the lack of improvement in his condition. The principal reason for this high proportion of ineffective treatments is that skin infections, which comprised 65% of aid post visits (Table 17.2), are not amenable to improvement through medication if the lack of hygiene which caused them remains unaltered.

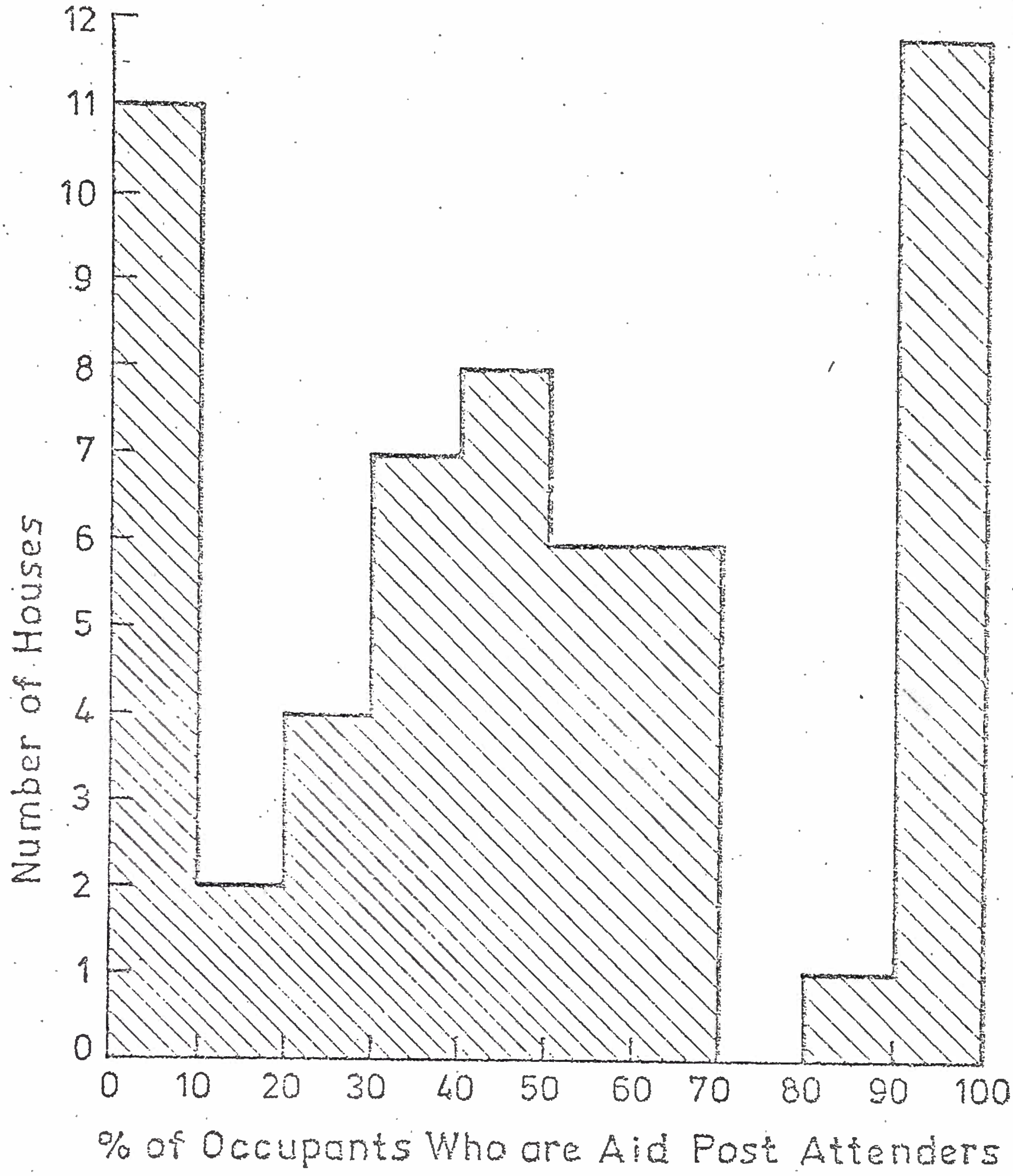

FIG. 17.3 DISTRIBUTION OF AID POST ATTENDERS BY HOUSEHOLD

17.3 THE PATIENT'S CHOICE: A.P.O. OR TOPÓLÍ

In Chapter 16, and the preceding sections of Chapter 17, the traditional and the introduced medical services which are available to the people of the Saka have been discussed. A few general comments will now be made concerning the choice which a sick individual must make between the alternative curative services available.

The choice between trying a remedy, employing a *tópólí* for a treatment[1], or visiting an aid post, depends largely on the previous medical experience of the sick individual. If the patient has previously had good results from an aid post visit then he is likely to try this again as a first choice. Similarly, if he believes, from personal experience, or from the experience of close relatives, that a particular *topólí* is skilful in the cure of his symptoms, he will call the *topólí*. The Raiapu see no conflict between traditional and Western medicine and, if either the aid post or the *topólí* fails, then the patient may quickly turn to the other. I have observed individuals with chronic conditions to visit both a *topólí* and an aid post regularly over a period of several weeks in the hope that one of these cures, or a combination of both, will prove effective. At least 1 well known *topólí* in the Saka lives next to an aid post and draws many of his patients from disappointed aid post visitors.

A major consideration for a patient, especially for one who is frequently ill, is the relative costs of these medical alternatives. A remedy will usually cost nothing (except that a chicken or pig must be killed if blood is required), an aid post will cost 10 cents, unless

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1. The words remedy and treatment are used here in the senses defined in Chapter 16.

the patient has bought an annual ticket for 20 cents, and a <u>topóli</u> will cost at least \$2 or a string bag, and usually a pig will be slaughtered and the <u>topóli</u> given half. This cost structure provides a major deterrent against the use of <u>topóli</u>, especially since a famous <u>topóli</u> will certainly expect a half-side of pork as payment.

If a patient has decided to visit an aid post, he then has to decide which aid post. Tombeakini live close to the Yumbítesa aid post, which is 1 kilometre distant if one walks directly across the Tobaka River, or 3 kilometres if one walks around by the road. However, most Tombeakini use the Raiakama aid post, which is approximately $4\frac{1}{2}$ kilometres away. This preference for the Raiakama aid post is due to the superior reputation of the Raiakama A.P.O., and also to the fact that Tombeakini have affinal, matrilineal and exchange ties with the Yambatane Watenge clan at Raiakama, whereas relations with the Yakaemandane clan at Yumbitesa are often tense. These inter-clan relationships have considerable influence on aid post utilization and this becomes most marked in times of warfare, when it may be too dangerous for members of a clan to visit an aid post, or to travel through other clans' territories to reach one.

Some A.P.O.s are believed to give injections more readily than others and this causes them to be more frequented. The Raiapu believe that the injection is the most powerful of the cures which an A.P.O. can administer and will often request an injection for any kind of sickness. It is said that the injection places medicine at a place where blood has been gathered and thus disperses the blood and cures the illness.

CHAPTER 18

A SURVEY OF TOMBEAKINI MORBIDITY

18.1 THE SURVEY DESIGN

The instigator of a morbidity survey is faced with three basic decisions: what questions to ask, what examinations to make, and who to select as subjects. Circumstances may often dictate the answers to some or all of these questions - or at least seriously restrict the range of possible choices. The survey reported here was concerned with morbidity as perceived by the subjects and was conducted without the assistance of trained medical personnel. The survey was restricted therefore to morbid symptoms (rather than diagnoses) which were selected on the basis of their expressed importance to the subjects. Table 18.1 lists the morbid symptoms surveyed and links them to possible diagnostic categories. The symptoms have been given shortened names (for instance, ACHE) and these will always appear in capitals. A brief pilot survey was conducted to discover which symptoms were most likely to be dominant and which were thought to be most serious by the subjects. By surveying only those symptoms which the Raiapu Enga felt to be important, many of the problems of cross-cultural health surveys, discussed by Chance (1962), were avoided.

The choice of survey sample is complex and requires the application of the statistical theories of sampling. Applying statistical criteria only, one may be led to a design which utilises the largest possible random sample drawn from the largest possible population and incorporating the greatest degree of proportionate stratification. Such a design gives the greatest confidence that the sample

TABLE 18.1

DESCRIPTIONS OF THE SYMPTOMS WHICH WERE SURVEYED WITH THEIR DIAGNOSTIC ASSOCIATIONS

DESCRIPTIONS OF THE SYMPTOMS WHICH WERE SURVEYED WITH THEIR DIAGNOSTIC ASSOCIATIONS

SYMPTOM NAME	DESCRIPTION	DIAGNOSTIC ASSOCIATIONS	W.H.O. LIST A CLASSIFICATION	COMMENTS
ACHE	All aches and pains excluding pain specifically associated with other symptoms. (e.g., Abdominal pain = PAIN, head-ache = FEVER and pain from recent accident = TRAUMA).	Musculoskeletal conditions. Possibly tropical myositis (especially in 10-29 years age group). Fevers (especially in younger subjects).	A121-A125 A31 A90	It was hoped to restrict this symptom to musculoskeletal complaints. However, some pain associated with FEVER, PAIN and TRAUMA has been unintentionally included. Pain associated with non-recent TRAUMA (particularly sprains and strains) has been included here.
EYE	All painful or inflamed eye conditions, impaired vision or blindness.	Conjunctivitis Pterygium Cataract Trachoma Corneal opacities	A75-A79	Tombeakini had only one individual who was completely blind and two who were blind in one eye. Some eye problems were due to non-recent TRAUMA. Working or travelling in *Miscanthus floridus* (or other tall grasses) is a frequent cause of corneal injury and phthisis bulbi.
SKIN 1, SKIN 2 and SKIN 3	All surface infections. The classifications 1, 2 and 3 refer to the size of the area infected. SKIN 1 applies to one large, or two small, ulcers, boils or infected wounds. Also mild infected scabies. SKIN 2 applies to severe ulcers, boils or infected wounds. Also large areas of infected scabies. SKIN 3 applies to acute infected scabies. This is a most unpleasant condition in which perhaps ⅓ of the body area is infected.	Scabies Sores Tropical ulcers Tinea and Impetigo.	A119-A120	The separation of skin infection into categories 1, 2 and 3 was necessarily subjective and depended on the age of the patient. For instance an area of infected scabies which would constitute SKIN 3 on a child would probably be only considered SKIN 2 on an adult. In general 1, 2 and 3 can be regarded as mild, major and severe infections respectively. Recent infected wounds are also included under TRAUMA.
FEVER	Feverish symptoms. Usually a condition of head-ache, hotness and "painful skin". A head-ache on its own was not recorded.	Malaria Viral fevers Leptospirosis	A31 A90 A44	This symptom is somewhat vague and hard to place diagnostically. It corresponds to a syndrome that the Enga now (not traditionally) tend to think of

	[illegible] SKIN 3 applies to acute infected scabies. This is a most unpleasant condition in which perhaps $\frac{1}{3}$ of the body area is infected.			In general 1, 2 and 3 can be [illegible] severe infections respectively. Recent infected wounds are also included under TRAUMA.
FEVER	Feverish symptoms. Usually a condition of head-ache, hotness and "painful skin". A head-ache on its own was not recorded.	Malaria Viral fevers Leptospirosis	A31 A90 A44	This symptom is somewhat vague and hard to place diagnostically. It corresponds to a syndrome that the Enga now (not traditionally) tend to think of as a sickness that causes the A.P.O. to dispense malarial prophylactics if reported.
PAIN	Abdominal pain.	Helminthiasis, especially *Ascaris* and Hookworm. Bacterial gut infections. "Pig-Bel".	A42-A43 A4-A5	Nearly all patients reporting DIARRHOEA also reported PAIN. Subtraction of DIARRHOEA from PAIN figures in the various tables will therefore give the numbers reporting only PAIN.
DIARRHOEA	Watery stools.	Diarrhoeal Disease	A5	
BLOOD	Blood noted in stools in addition to diarrhoea.	Dysentery	A4	All subjects reporting blood in stools also had diarrhoea.
VOMIT	Vomiting in addition to Diarrhoea.	Gastro-enteritis	A4-A5	All subjects reporting vomiting also had diarrhoea.
COUGH	Cough	Respiratory disease (*Ascaris* larvae in lungs).	A89-A96 (A43)	
TOOTH-ACHE	All pain associated with the teeth or gums.	Disease of the teeth or gums.	A97	
TRAUMA	All injury (excluding minor injury to base of the foot which is ubiquitous in a society that does not wear shoes).	Most commonly burns (from accident while sitting around fire inside house) cuts and wounds (from axes, fights or sharp sticks in garden) and wounds (usually bites) inflicted by pigs. When, and if, these wounds become infected they are classified under SKIN.	AE141 AE142 AE146-148 AE150 AN142 AN145 AN146 AN148	Some injury amongst the Enga is not easily classified. For instance injury from arrows during inter-clan warfare has to be considered as "injury due to war operations by other and unspecified forms of conventional warfare". Injury resulting from the misguided efforts of an Enga traditional healer must be considered as "complications and misadventure in other and unspecified therapeutic procedures".

[2516]

will represent the population and allows conclusions to be applied most widely.

There are two major disadvantages inherent in this type of random, stratified sample. Firstly, there is a logistical problem since the survey will involve immense difficulties in organisation and transportation. It is for this reason that random sample surveys are so seldom conducted in developing countries where the lack of communications may make the organisational obstacles immense. Vines (1970:13) comments on the logistical problems that were faced during his random sample survey of Papua New Guinea. It should also be noted that surveys such as that of Vines are extremely costly and are unlikely to be high on the list of health priorities of a developing country.

The second area of weakness in the randomly sampled survey is the accuracy of the data collected. If the survey only requires the clinical examination of subjects, and the administration of standardised tests, then problems are minimised. However, most health surveys involve some type of questionnaire in which the subject is asked to report on his health or behaviour over a specified time period. Vines (1970), for instance, required a monthly recall of thirteen symptoms or actions (like attendance at hospital) in his survey, and data of this kind should be regarded with the greatest suspicion. The monthly recall period is probably too long and, since there is little or no rapport between interviewer and subject, there is no reason to suppose that the subject will make any effort to be accurate.

In a large random sample survey, the questionnaire is administered in an impersonal manner between people who do not know each other and may even have hostile feelings towards one another. In such a case, no great validity can be attributed to the answers and there is usually no mechanism for checking the responses or assessing their validity. In direct contrast to this, there is the total survey of a small group in which the interviewer is a resident member of the group and is personally known to all his subjects. In this case there is a greater possibility of eliciting accurate information and the interviewer is in a good position to corroborate, or reject, any dubious responses that he receives.

Survey types can be thought of as a continuum from random samples of large populations to total surveys of small groups. The former type gives maximum statistical significance and the greatest chance that the results will be widely applicable, while the latter yields excellent rapport between researcher and subjects and provides the best conditions for obtaining accurate data and exploring its ramifications. The survey reported here is of the second type.

The group surveyed is the Tombeakini clan. The survey may be considered as a total survey of Tombeakini or as a survey of the Saka using Tombeakini as a non-randomly selected sample. I will discuss later to what extent Tombeakini may be thought of as representing a wider population.

The problem of an acceptable recall period for the questionnaire was resolved by choosing the shortest practicable time of one week. Mechanic and Newton (1965) have reported that a two week recall period is too long to record minor illnesses in the U. S. A. and Allen et al (1954) report that even weekly recall tends to omit minor conditions. Scrimshaw et al (1967b) comment that minor illness was forgotten within fifteen days in Guatemala.

Twenty-two weekly interviews were conducted during 1971 and the survey timetable is set out in Table 18. 2. Figure 18. 1 shows

TABLE 18.2

TIMETABLE OF SURVEY WITH ATTENDANCE FIGURES, RAINFALL AND COMMENTS

WEEK NUMBER	DATE	NUMBERS INTERVIEWED			RAIN IN PRECEDING WEEK. M.M.	COMMENTS
		MALE	FEMALE	TOTAL		
1	JUNE 11	85	60	145	60	
2	JUNE 18	62	47	109	44	
3	JUNE 25	57	58	115	62	
4	JULY 2	21	7	28	43	Survey not properly conducted.
5	JULY 9	59	17	76	38	_Kumanda_ started on July 8. Women retire to houses.
6	JULY 16	81	66	147	20	First week of house visits to interview women.
7	JULY 23	99	69	168	66	
8	JULY 30	82	58	140	1	
9	AUG. 6	99	68	167	33	
10	AUG. 13	102	62	164	5	
11	AUG. 20	93	65	158	4	
12	AUG. 27	75	51	126	9	_Kumanda_ finished on Aug. 28. All women, except immediate relatives of deceased, return to normal work. House visiting discontinued.
13	SEPT 3	82	53	135	68	
14	SEPT 10	88	65	153	61	
15	SEPT 17	70	48	118	16	Survey discontinued for three weeks.
16	OCT. 15	84	53	137	27	
17	OCT. 22	90	69	159	27	
18	OCT. 29	88	63	151	16	
19	NOV. 5	79	62	141	33	
20	NOV. 12	89	71	160	83	
21	NOV. 19	81	66	147	20	
22	NOV. 26	79	66	145	20	
ALL WEEKS		1745	1244	2989	756	Overall average weekly attendance of 64% of clan members or 68% if wks 4 & 5 are excluded.

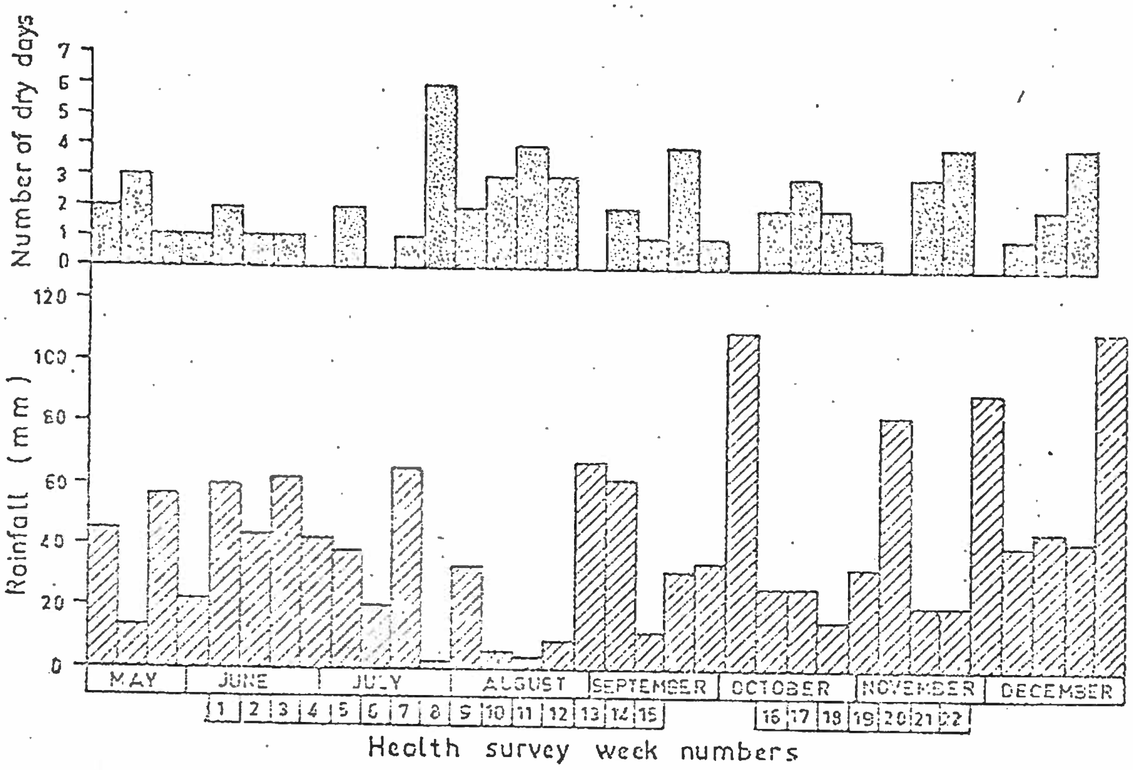

FIG: 18.1 WEEKLY RAINFALL AND DRY DAYS PER WEEK AT LYOKOTE DURING MAY-DECEMBER 1971 rainfall data for the same period[1]. The entire Tombeakini population was invited to attend each interview and those who attended were rewarded with a large biscuit or a cigarette. Attendance figures are shown in Tables 18.2 and 18.3. Although the population of Tombeakini (defined as those usually residing on Tombeakini clan territory) was 211 in 1971, at any time there were approximately 200 in residence. The remaining 11 would be visiting relatives, attending boarding school, working in other areas (especially tea-picking in the Banz-Minj area) or travelling to neighbouring valleys (especially the Kaugel) to negotiate traditional exchanges. Attendance figures were higher than anticipated with an overall attendance of 64% and with 55% of the clan attending 15, or more, interviews. Table 18.3 shows that women were better attenders than men, despite their heavy daily work load in the gardens. The men, however, although they have fewer regular commitments on their time, are extremely mobile within the valley and may well be visiting friends several miles away on the day of the interview. The interviews were conducted on the same day each week and became a regular feature of clan life. They were held on the clan's ceremonial ground (_tée_-ground) which is only 400 metres (Map 4) from the most distant dwelling. This interview pattern was interrupted on July 6th by the death of a young clansman which was followed by a period of mourning (_kumánda_) which continued until August 28th. During this _kumánda_, all Tombeakini adult females were obliged to stay inside a house

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1. A total of 2989 interviews were conducted and 16 information items were recorded at each interview. Computer analysis was required to handle the resulting 47,824 items of data. See Appendix V.

TABLE 18.3

FREQUENCY OF ATTENDANCE AT HEALTH SURVEY INTERVIEWS

Number of Interviews Attended	Numbers and Percentages of Tombeakini Attending					
	Males		Females		Total	
	No.	%	No.	%	No.	%
0 - 4	14	11	4	5	18	9
5 - 9	19	15	14	16	33	16
10 - 14	25	20	18	21	43	20
15 - 22	67	54	50	58	117	55
All Interviews	125	100	86	100	211	100

(usually not their own) and to refrain from all outdoor work. They were therefore unable to attend the health interviews and house visiting was commenced so that in weeks 6 to 12 inclusive all adult female interviews were conducted by house-to-house visiting. Males, and female children, continued to attend the weekly meetings on the <u>tée</u>-ground and were interviewed in the usual manner.

This survey may be the first documented longitudinal morbidity survey of a rural Highland community. As pointed out by Jelliffe <u>et al</u> (1962), a longitudinal survey has the ability, which a point prevalence survey does not, to highlight acute short-term conditions. The survey reports data on perceived morbid symptoms and was conducted in the context of close personal contact between interviewer and subjects. The limitations of Tombeakini as a sample of a wider population will now be discussed.

18.2 THE SURVEYED POPULATION - A SAMPLE OF WHAT?

18.2.1 AGE-SEX BIAS

As already mentioned, all Tombeakini did not attend every interview (see Tables 18.2 and 18.3). It is therefore necessary to describe the "surveyed population" which is defined as the sum of all interviewees. Thus the surveyed population is equal in size to the total number of interviews (2989) and, similarly, the size of the 0 - 4 years male cohort in the surveyed population equals the total number of interviews with 0 - 4 years old males. The resulting composition of the surveyed population is presented in Table 18.4, which also gives the corresponding age-sex data for Tombeakini clan and for the total population of the eastern Saka.

Figure 18.2 permits the examination for possible age-sex

TABLE 18.4

AGE-SEX STRUCTURE OF TOMBEAKINI CLAN, THE SURVEYED POPULATION AND THE CLANS OF THE EASTERN SAKA

AGE	TOMBEAKINI CLAN POP. 211						SURVEYED POPULATION POP. 2989						EASTERN SAKA POP. 2679					
	MALES		FEMALES		TOTAL		MALES		FEMALES		TOTAL		MALES		FEMALES		TOTAL	
	%	number	%	number	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
0 - 4	9.0	19	5.2	11	14.2	30	9.4	280	5.9	177	15.3	457	5.9	158	4.6	124	10.5	282
5 - 9	7.1	15	3.8	8	10.9	23	7.0	210	4.1	124	11.2	334	6.4	171	5.2	139	11.6	310
10 - 14	6.6	14	5.2	11	11.8	25	6.3	189	6.8	202	13.1	391	5.2	140	5.1	137	10.3	227
15 - 19	4.7	10	4.3	9	9.0	19	4.2	126	4.9	146	9.1	272	6.3	170	5.6	149	11.9	319
20 - 24	2.8	6	4.7	10	7.6	16	2.5	75	4.5	133	7.0	208	7.2	193	3.8	102	11.0	295
25 - 29	4.3	9	1.9	4	6.2	13	4.8	143	1.8	54	6.6	197	4.0	106	3.1	83	7.1	189
30 - 34	4.3	9	1.9	4	6.2	13	4.6	136	1.9	58	6.5	194	3.4	91	2.1	56	5.5	147
35 - 39	2.8	6	5.2	11	8.0	17	2.6	79	5.0	149	7.6	228	3.2	86	2.9	77	6.1	163
40 - 44	4.7	10	4.7	10	9.5	20	4.8	143	3.7	112	8.5	255	2.5	68	2.8	75	5.3	143
45 - 49	5.7	12	2.8	6	8.5	18	6.5	193	2.4	73	8.9	266	3.8	101	3.7	99	7.5	200
50 - 54	2.8	6	0.9	2	3.8	8	1.9	58	0.5	16	2.5	74	3.6	97	3.4	92	7.0	189
55 - 59	1.9	4	0	0	1.9	4	2.1	62	0	0	2.1	62	2.4	63	2.1	57	4.5	120
60 - 64	1.9	4	0	0	1.9	4	1.4	41	0	0	1.4	41	1.2	33	0.4	12	1.6	45
65 - 69	0.5	1	0	0	0.5	1	0.3	10	0	0	0.3	10	0	0	0	0	0	0
ALL AGES	59.2	125	40.8	86	100	211	58.4	1745	41.6	1244	100	2989	55.1	1477	44.9	1202	100	2679

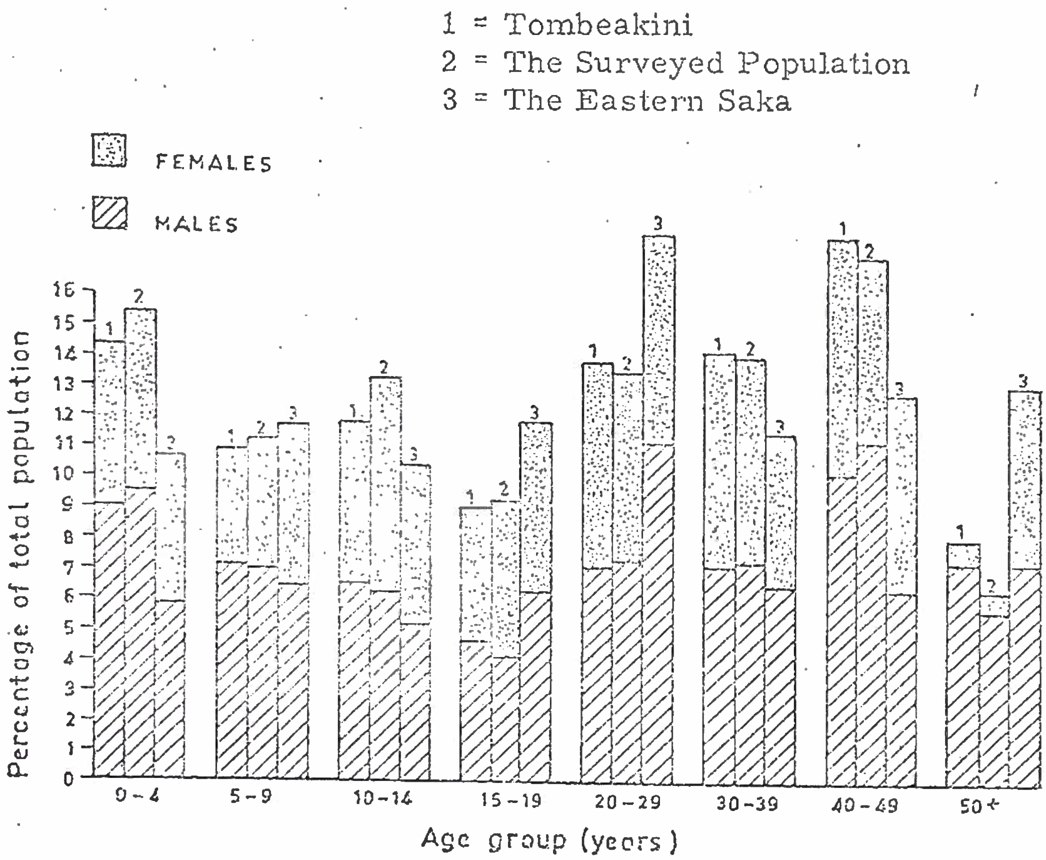

FIG. 18.2 AGE-SEX COMPARISON BETWEEN TOMBEAKINI, THE SURVEYED POPULATION AND 8 CLANS IN THE EASTERN SAKA

bias of the surveyed population as a sample of Tombeakini, or as a sample of the eastern Saka. It is apparent that the surveyed population is a good sample of Tombeakini but not so satisfactory as a sample of the eastern Saka. It tends to overestimate disease of the 0 - 4 and 40 - 49 years cohorts, while underestimating that in the 20-29 and 50+ cohorts, when total morbidity prevalences are quoted. (Age specific prevalences will not contain this bias.) This bias in total prevalence data is likely to be small and may, in fact, not exist in view of the problems of age estimation amongst the Enga. The census data for the eastern Saka is drawn from the records of the 1971 annual government census and is of low reliability. The method used by the government is the usual one (for instance, Clarke, 1971:19) of relating the subject's birth to an historical event (e.g., the coming of the white man or the construction of a particular bridge), the date of which can be independently ascertained. The technique is widely employed in preliterate societies and may give very misleading data, particularly if, as in the case of the government census, it was done hurriedly and superficially. The author's data on Tombeakini (and therefore on the surveyed population) was arrived at by considering historical information in conjunction with an analysis of the genealogies of Tombeakini families, and is of good reliability. The ages of children were readily determined and these were used to estimate the ages of parents and grandparents using information on the normal age of marriage and the spacing of children. This was done for several families and ages were then cross-checked by considering the order and spacing of siblings in the grandparents' generation. These figures were then checked with available historical data and so, by successive readjustment, ages were determined which fitted all the available evidence and were mutually compatible within the genealogies. Columns numbered 1 and 2 in Figure 18.2 are therefore of good accuracy, whereas column 3 is suspect, and adjustment for bias on this basis would be unwise.

18.2.2 CULTURAL AND ENVIRONMENTAL BIAS

In examining whether data on Tombeakini can be applied to a wider population in the New Guinea Highlands, it is necessary to compare Tombeakini culturally and environmentally with other likely areas. Environment clearly plays a vital role in the introduction and spread of disease. Culture may affect patterns of disease and the efficacy of control measures and there may well be interrelationships between social structure and disease (Hausfield, 1970; Schofield, 1970).

Table 18.5 compares Tombeakini with the Saka, the Enga and the Chimbu who live in the Kundiawa region and are the second largest ethno-linguistic group in the Highlands (see Map 1).

18.2.3 BIAS IN ATTENDANCE

Finally, it is necessary to consider whether the survey technique led to bias in the selection of individuals for interview. It is possible that sick individuals would attend more frequently or that, conversely, house-bound subjects would not attend at all. There was no indication of increased enthusiasm for attendance amongst either the sick or the healthy and house-bound individuals (of whom there were no more than 3 at any time) were visited and interviewed at home.

18.2.4 CONCLUSION

The surveyed population is a good sample of Tombeakini

TABLE 18.5

TOMBEAKINI, THE SAKA RAIAPU, THE ENGA AND THE CHIMBU COMPARED ACCORDING TO CERTAIN CULTURAL AND ENVIRONMENTAL FACTORS

Criteria	Tombeakini	Saka	Enga	Chimbu
Important reference sources	Author's data	Author's data	Meggitt (1964, 1965, 1971) Westermann (1968) Waddell (1972b) C.S.I.R.O. (1965)	Brookfield and Brown (1963) Brown and Brookfield (1968) C.S.I.R.O. (1970)
Total population	211	11,000	160,000 (incl. fringe Enga groups at Kandepe, Baiyer River, etc.)	150,00 (incl. all speakers of the Chimbu sub-family of languages, see Wurm, 1971:550)
Population density. People per sq. km. of land used.	377	Approx. 110 overall with pockets of much higher densities.	38-138	54-168
Altitude (of settlement) m	2,000	1,850 - 2,440	1,100 - 2,600 (Broad open valleys)	1,500-2,700 (Rugged terrain)
Annual Rainfall. mm	2,500	2,500	2,100-3,000	1,800-3,000
Start of sustained contact with the white man.	1938	1938	1933-1940	1933

TABLE 18.5 Cont'd.

Criteria	Tombeakini	Saka	Enga	Chimbu
Settlement pattern	Dispersed	Dispersed	Dispersed	Dispersed with some nucleation.
Social organisation	1 clan comprising 5 sub-clans	7 phatries comprising 29 clans	A hierarchical segmentary system of phratries, clans, sub-clans and patrilineages. The clan (200-1100 people) is the important agnatically recruited land-holding group.	Tribes (average size of 2,400 members) which are territorial groups. Comprising exogamous, agnatically recruited clans which are further sub-divided. Less stress on agnation than the Enga.
Subsistence agriculture	As for Enga	As for Enga	Sweet potato grown in large mulched mounds. Taro, yam, banana, sugar-cane, winged-beans, edible pit-pit and pandanus. Large pig herds kept for mainly ceremonial purposes.	Sweet potato grown in small earth mounds. Otherwise as for Enga.
Commercial agriculture	As for Enga. No cattle, some poultry	As for Enga. A sheep project has recently started at Yogos.	Coffee, pyrethrum and European vegetables. A few cattle, some poultry.	As for Enga
Protein intake	As for Raiapu Enga	As for Raiapu Enga	Raiapu Enga (Waddell, 1972b: 125) have 29g to 35g of daily protein. Yandapu Enga (Sinnett, 1972c) have 25g of daily protein.	Hipsley and Kirk (1965: 78) report 19.9g of protein daily for males and 16.9g for females.

TABLE 18.5 Cont'd.

Criteria	Tombeakini	Saka	Enga	Chimbu
Percentage speaking Neo-Melanesian or English	16%	Similar to Tombeakini	Similar to Tombeakini or slightly higher.	Probably much higher than Tombeakini
Percentage currently at school	6%	Approximately 650 out of 11,000 or 6%	Slightly higher than Tombeakini	Probably much higher than Tombeakini
Percentage who have worked or travelled away from home	12%	Similar to Tombeakini	Similar to Tombeakini	Probably much higher than Tombeakini

and an adequate sample of the people of the Saka. Its value as a sample of a wider Enga population is low but should not be discounted. The data reported here may have relevance to the Enga as a whole if it is applied with caution and consideration is given to the possible socio-economic and environmental differences involved.

Application of the quantified data reported here to the Chimbu would be unjustifiable. Apart from the differences tabulated above, the Chimbu may suffer from greater malnutrition, and associated infections, than the Enga (Table 18.5 and Venkatachalam, 1962). However, I believe that this study may be used suggestively to indicate the types of morbidity-environment interactions which are affecting the Chimbu, and indeed many other Highlanders.

18.3 THE RELIABILITY OF INTERVIEW RESPONSES

It remains to consider with what degree of confidence the responses to interviews can be accepted as accurate. Here the design of the survey is a great asset since the subjects are individually known and answers can be cross-checked and their reasonableness assessed. The recall period was the shortest practicable time (one week) and the concept of reporting the illness of the previous 7 days (i.e., since the last interview) was carefully explained at each interview. No attempt was made to recall for a period greater than 7 days, and if a subject missed one interview, he was not requested to recall for 14 days. The 1 week time unit is not a traditional Enga time-measuring device (Meggitt, 1958c) but it is universally understood today. The missions have introduced a regular weekly day of worship and the government has likewise introduced Monday as a day of compulsory road-repair work.

The interviews followed a standard pattern and were conducted on the same day each week by either the author or Zuzana Feachem. The questions were put in neo-Melanesian (pidgin English) and translated by an interpreter into standardised Enga equivalents. Subjects were encouraged to take their time in replying and did not have to answer with a simple "yes" or "no". Small children were interviewed through a parent or elder sibling but only if the subject child was present. Except for the very young, no attempt was made to interview by proxy (see Mechanic and Newton, 1965, on the dangers of this) and data were only obtained on individuals who actually attended.

This approach reduced the possibility of accepting bogus responses to a minimum, but it could not rule it out altogether. Inaccuracies which occurred randomly would tend to cancel out over the course of the survey, but it is possible that consistent false responses could occur due to hypochondria, attention seeking, shyness or other psychological traits. Sociological and psychological factors affecting "illness behaviour" and the nature of the "sick role" have been discussed by Mechanic (1962, 1963, 1964), and Mechanic and Newton (1965) have dealt with the significance of these factors as determinants of survey responses. They conclude that reporting is influenced by "illness behaviour" but are unable to link this to any particular socio-economic factors.

It appeared from this survey that there may have been consistent under-reporting by females. Males were not suspected of over-reporting, but females were often shy (although they were better attenders than males) and may well have responded negatively rather than face additional questioning on the nature of a symptom.

Table 18.15 shows that the female prevalences of all symptoms, except SKIN 1 and FEVER, were lower than for males and this may reflect inconsistencies in reporting rather than genuine morbidity differentials. This doubt should be borne in mind and will be further discussed later.

18.4 OVERALL HEALTH STATUS

18.4.1 INTRODUCTION

As a guide to the overall health status of Tombeakini, data are presented on the percentages of subjects reporting different numbers of morbid symptoms. This is unsatisfactory in that it implies that each of the symptoms is of approximately equal severity and this is not the case. However, those subjects having dysentery would report both BLOOD and DIARRHOEA and so would be counted as individuals with two symptoms. SKIN 3 is such an acute condition that it was counted as two symptoms but, otherwise, each symptom counted as only one.

18.4.2 VARIATION OF HEALTH STATUS THROUGH TIME

Table 18.6 presents this data for the 22 weeks of the health survey. Excluding weeks 1, 2 and 4 the health status remains fairly constant with between 40% and 51% of the subjects reporting complete absence of symptoms. During most weeks, a small percentage (less than 5%) reported 4 symptoms and, in only 2 weeks, a maximum of 7 symptoms were reported by 1% of subjects.

18.4.3 VARIATIONS IN HEALTH STATUS BY AGE

Table 18.7 shows the health status variation by age averaged over the total survey period. Figure 18.3 displays this data

TABLE 18.6

VARIATIONS OF HEALTH STATUS THROUGH TIME

WEEK NUMBER	PERCENTAGE OF INTERVIEWEES REPORTING GIVEN NUMBER OF SYMPTOMS								
	0	1	2	3	4	5	6	7	8
1	36	26	21	12	3	1	1	0	0
2	35	32	18	10	5	0	0	0	0
3	50	24	16	7	2	1	0	0	0
4	57	29	7	7	0	0	0	0	0
5	46	25	9	9	0	0	1	0	0
6	44	31	13	7	5	0	0	0	0
7	40	38	14	4	3	1	0	0	0
8	49	29	15	4	2	1	0	0	0
9	46	35	11	5	1	1	0	1	0
10	49	30	11	7	1	1	1	0	0
11	49	31	12	3	4	0	0	1	0
12	51	36	8	2	3	0	0	0	0
13	51	33	9	3	4	0	0	0	0
14	42	34	12	8	3	1	0	0	0
15	46	37	9	3	3	0	0	0	0
16	44	38	12	6	0	0	0	0	0
17	48	34	12	4	2	0	0	0	0
18	47	38	6	6	1	1	0	0	0
19	50	31	11	5	3	0	0	0	0
20	53	29	10	6	1	1	0	0	0
21	48	32	11	6	3	0	0	0	0
22	49	31	12	5	3	0	0	0	0
ALL WEEKS	47	32	12	6	2	1	0	0	0

TABLE 18.7

MEAN PERCENTAGES OF SUBJECTS REPORTING GIVEN NUMBER OF SYMPTOMS PER WEEK BY AGE

NUMBER OF SYMPTOMS REPORTED	AGE GROUPS (YEARS)								
	0-4	5-9	10-14	15-19	20-29	30-39	40-49	50-69	ALL AGES
0	35	60	66	77	54	39	31	9	47
1	50	36	29	16	30	35	28	24	32
2	10	3	5	5	11	13	18	33	12
3	4	1	0	1	4	4	15	21	6
4	1	0	0	1	1	3	7	9	2
5	0	0	0	0	0	1	1	2	1
6	0	0	0	0	0	1	0	1	0
7	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	0	0

TABLE 18.8

MEAN PERCENTAGES OF SUBJECTS REPORTING GIVEN NUMBER OF SYMPTOMS PER WEEK BY SEX

NUMBER OF SYMPTOMS REPORTED	MALE	FEMALE	TOTAL
0	41	54	47
1	32	33	32
2	14	9	12
3	8	3	6
4	3	1	2
5	1	0	1
6	1	0	0
7	0	0	0
8	0	0	0

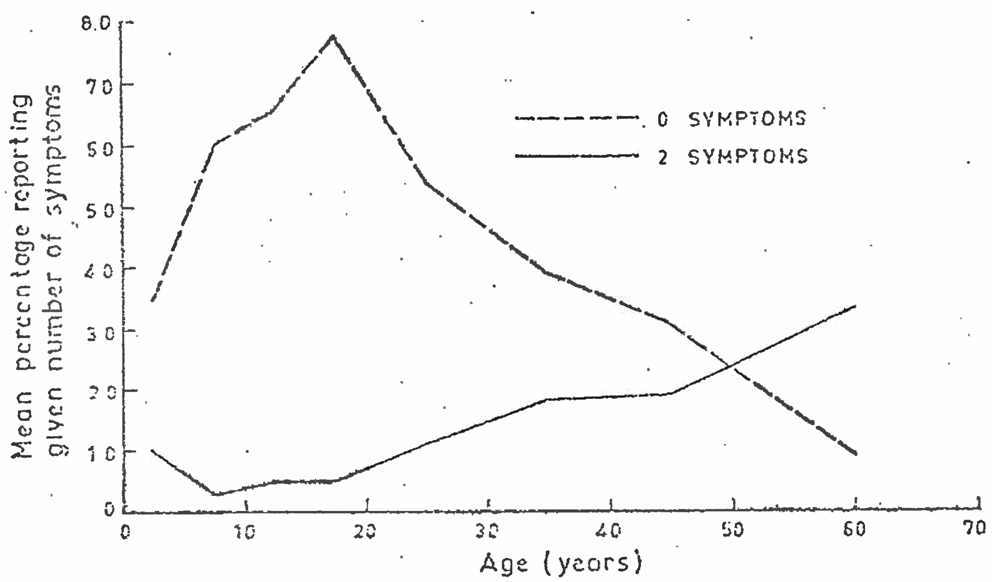

FIG. 18.3 VARIATIONS IN HEALTH STATUS WITH AGE

for the cases of no symptoms, and two symptoms reported. The poor health of the young and the old is seen in contrast to the healthy status of the 10 - 30 years age group.

18.4.4 AVERAGE HEALTH STATUS: TOTALS AND BY SEX

Table 18.8 shows males as the less healthy sex, but this data should be viewed in the light of my earlier comments about possible female under-reporting and await verification.

Data from the 1959 survey (Bagchi and Prasad, 1961) and the 1969 follow-up survey (Shivaram et al, 1970) of 4 villages in Lucknow, India, contrasts strongly with data given here. Shivaram reports that, in 1969, 22.9% of people were sick and that 5-9 years was the healthiest age group (cp. 15 - 19 in Table 18.7). Shivaram's figures are point, rather than weekly, percentages and his data are drawn from a different environment and from a population with a far greater degree of development (literacy rate of 28.3%, cp. 6% for Tombeakini). Interestingly, his data also indicate a higher sickness load amongst males and, in 1959, 11.7% of males were sick compared to only 5.2% of females. Also in India, 17.5% of people were reported sick in Kanpur (Gandhi and Siddhu, 1965) and 27.9% in Madhya Pradesh (Park and Prasad, 1963).

18.5 THE PREVALENCES OF MORBID SYMPTOMS

18.5.1 INTRODUCTION

The morbid symptoms, included in the survey, were discussed in section 18.1 and appear in Table 18.1. The relative frequency of reporting of these symptoms is shown in Table 18.9. Skin infections far outnumber other symptoms and these are followed by ACHE and COUGH which are primarily symptoms of

TABLE 18.9

RELATIVE FREQUENCY OF REPORTING OF SYMPTOMS SURVEYED

SYMPTOM	NUMBER OF TIMES REPORTED	% OF TOTAL NUMBER	RANK
ACHE	421	16	3
EYE	221	9	5
SKIN 1	619 } 811	24 } 31	1
SKIN 2	162	6	6
SKIN 3	30	1	11
FEVER	122	5	8
PAIN	137	5	7
DIARRHOEA	106	4	9
BLOOD	10	½	12
VOMIT	8	½	13
COUGH	425	16	2
TOOTH-ACHE	284	11	4
TRAUMA	39	2	10

TABLE 18.10

COMPARISON BETWEEN AVERAGE WEEKLY AND 5 MONTHLY PERIOD PREVALENCES PER 1000 AT RISK

SYMPTOM	AVERAGE WEEKLY PERIOD PREVALENCE PER 1000	FIVE MONTHLY PERIOD PREVALENCE PER 1000	WEEKLY:FIVE MONTHLY PREVALENCE RATIO
ACHE	140	523	0.27
EYE	74	265	0.28
SKIN 1	207	995	0.21
SKIN 2	54	361	0.15
SKIN 3	10	103	0.10
FEVER	40	435	0.09
PAIN	45	479	0.09
DIARRHOEA	35	405	0.09
BLOOD	3	58	0.05
VOMIT	2	51	0.04
COUGH	142	899	0.16
TOOTH-ACHE	95	494	0.19
TRAUMA	13	250	0.05

older subjects. Teeth are also seen to be a frequent source of discomfort.

Morbidity, in the following sections, will be expressed in terms of period prevalences (of persons ill rather than of sickness spells) per 1000 at risk. Generally, weekly period prevalences (hereafter sometimes referred to as w.p.p.) will be used since these correspond to the survey technique of weekly recall. To determine the w.p.p. per 1000 of diarrhoea in week 3 (for instance) it is simply necessary to divide the number of subjects reporting diarrhoea in week 3 by the number who attended the interview in that week and multiply by 1000. Average w.p.p., over the 22 weeks of the survey, are calculated by dividing the total number of diarrhoea reportings by the total number of attenders and multiplying by 1000. Such measures will be referred to as average weekly period prevalences and are, in fact, weighted means.

For definitions of the various morbidity measures employed, Swaroop (1960:197-8) should be consulted. It should be stressed that all prevalences are of persons ill and not of spells of sickness. Prevalences per 1000 can, therefore, never exceed 1000.

18.5.2 COMPARISON BETWEEN WEEKLY AND 5 MONTHLY PERIOD PREVALENCES

Table 18.10 presents the average weekly period prevalences alongside the 5 monthly (22 week) period prevalences. The meaning of this comparison is illustrated by the following example. Suppose 100 subjects were interviewed on weeks 1 and 2 only. On week 1, subjects 1 - 50 only had symptom A and, on week 2, subjects 51 - 100 only had that symptom. Then the w.p.p. for week 1 and week 2 are both 500 per 1000 and the average w.p.p. for both weeks is also 500 per 1000. By contrast, the fortnightly p.p. of symptom A is 1000 per 1000. We see, therefore, that if the weekly and 5 monthly p.p. are equal, the same individuals are reporting the symptom on each week. If, however, the 5 monthly p.p. is greater, we conclude that the symptom is "mobile" and is experienced by different individuals at different times. This comparison gives a measure of the mobility of a symptom within the community. The ratio of the w.p.p. to the 5 monthly p.p. (which must lie between .04 and 1) will be called the weekly: 5 monthly prevalence ratio and is tabulated in Table 18.10.

The high 5 monthly prevalences of SKIN 1 and COUGH are notable. During the survey period, 99.5% of Tombeakini experienced at least one spell of minor skin infections and 89.9% experienced some coughing. The weekly: 5 monthly prevalence ratios indicate least mobility for symptoms ACHE and EYE, which are often chronic conditions of older individuals. Symptoms having a prevalence ratio of < 0.1 could be said to be definitely acute and mobile rather than chronic. These symptoms include some which are clearly communicable, such as DIARRHOEA, and some which are clearly not, such as TRAUMA. In both cases, the symptom is acute and mobile; DIARRHOEA is experienced by 3.5% of people in an average week and by 40% of people over 5 months, and TRAUMA is experienced by 1.3% in a week and by 25% over 5 months.

18.5.3 VARIATIONS THROUGH TIME OF WEEKLY PERIOD PREVALENCES

Table 18.11 displays the w.p.p. of each symptom for each week of the survey. Figure 18.4 shows the variations through time for symptoms ACHE, SKIN 1, DIARRHOEA, TRAUMA and COUGH.

TABLE 18.11

VARIATIONS THROUGH TIME OF WEEKLY PERIOD PREVALENCES (OF PERSONS ILL) PER 1000 AT RISK

WEEK NUMBER	ACHE	EYE	SKIN 1	SKIN 2	SKIN 3	FEVER	PAIN	DIARR-HOEA	BLOOD	VOMIT	COUGH	TOOTH ACHE	TRA-UMA
1	262	117	97	21	7	117	117	110	7	14	179	159	48
2	229	110	174	92	18	91	55	55	9	0	165	155	82
3	156	78	130	60	17	43	69	60	8	8	121	104	17
4	35	71	178	71	35	35	0	0	0	0	35	142	0
5	131	65	210	26	26	39	65	52	0	0	131	144	52
6	156	95	156	40	13	34	74	40	0	0	244	81	34
7	125	83	166	53	11	53	71	53	11	0	220	101	0
8	114	57	207	50	0	7	57	35	7	0	185	135	0
9	137	65	185	53	23	29	47	29	5	11	155	101	11
10	146	79	158	60	30	54	24	18	0	6	140	121	6
11	145	75	177	75	12	50	56	50	6	0	101	75	6
12	111	55	198	79	0	15	31	23	0	0	119	79	0
13	103	59	207	66	14	14	44	37	0	0	103	81	0
14	143	65	274	65	0	65	65	45	6	6	137	84	6
15	118	67	228	67	0	33	33	16	0	0	110	67	8
16	153	72	211	72	14	14	21	14	0	0	116	72	7
17	125	62	289	44	0	25	12	12	0	0	100	100	12
18	105	66	278	46	6	52	26	19	0	0	112	72	0
19	148	70	219	70	7	21	35	28	7	0	113	63	7
20	137	56	225	43	6	18	31	18	0	0	125	62	12
21	122	74	265	54	0	34	27	27	0	6	149	74	0
22	117	75	275	55	0	41	13	13	0	0	151	75	0
ALL WEEKS	140	74	207	54	10	40	45	35	3	2	142	95	13

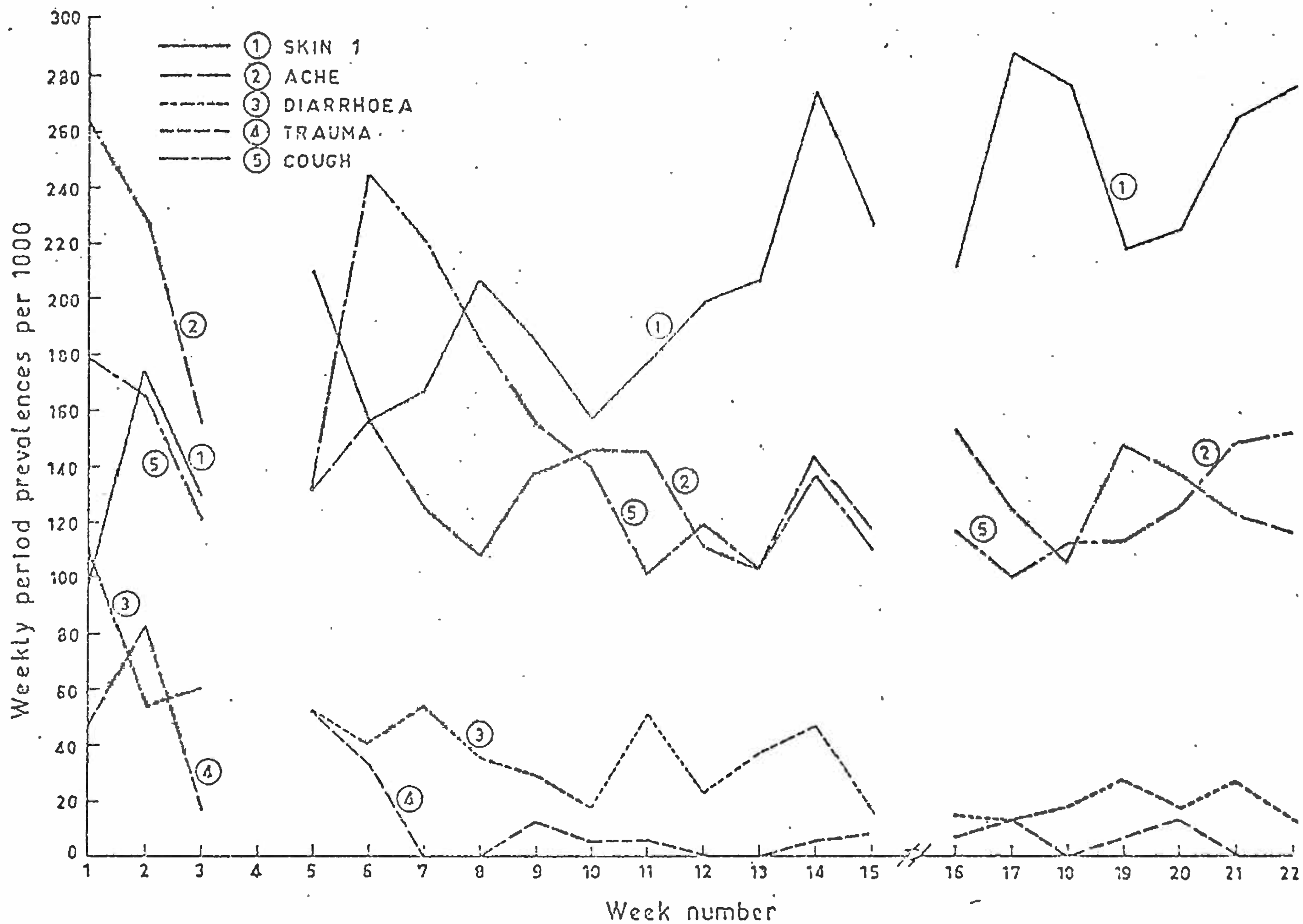

FIG. 18.4. WEEKLY PERIOD PREVALENCES OF 5 SYMPTOMS DURING THE PERIOD OF SURVEY

DIARRHOEA and TRAUMA both decline during the first weeks and then remain fairly steady. In the case of TRAUMA, this could be related to Raiapu work patterns. In the dryer months (generally May to September) more emphasis is placed on heavy "male" tasks such as clearing new gardens, fencing and house building. Waddell (1972b:89, 94) clearly shows that clearing and fencing activities increased during the dryer period of his work survey. This yearly pattern of work is maintained even when the dry period is unusually short or occurs at a different time. In 1971 the dry period at Lyokote (see Fig. 18.1) was limited to late July and August, but from June onwards there was a noticeable increase in house building, clearing and fencing. It is these tasks which are particularly likely to cause injury and this may, in part, explain the higher TRAUMA rate in the first 6 weeks of the survey. In a normal year, the trauma-causing activities would continue into September (week 13 of the survey), but in 1971 this was interrupted in early July (week 5) by a kumánda (mourning), during which all work was forbidden. The TRAUMA variations may therefore result from a combination of the increase in heavy labouring tasks in June and its interruption by the death of a clansman on July 6th. The interactions between the kumánda and morbidity will be discussed more fully in section 19.3.5

After an initial decline, the prevalence of ACHE remained steady. SKIN 1 is seen to rise steadily to week 13 and then fluctuate around a mean of about 250. The possible connections between this rise and the kumánda will also be discussed in section 19.3.5. COUGH is seen to rise sharply in weeks 5 - 10 and the relation of this rise to the kumánda will likewise be discussed in section 19.3.5.

18.5.4 AVERAGE WEEKLY PERIOD PREVALENCES IN VARIOUS AGE COHORTS

Table 18.12 shows the age-specific average weekly period prevalences. Figure 18.5 shows the variations with age of the average w.p.p. for certain symptoms. All increase rapidly with age except TOOTHACHE which finally drops off in the over fifties age group. Note the extremely high average w.p.p. of ACHE and EYE among the over fifties.

The increase of COUGH with age supports Vine's (1970:340) conclusion that "deterioration in M.E.F. (maximum expiratory flow) performance starts very early in adult life" and that this "is consistent with increasing obstructive lung disease with advancing age". Woolcock and Blackburn (1967) report coughing prevalences amongst the Kyaka Enga and Chimbu. Their data, reproduced in Table 18.13, also show increasing coughing rates with age. Woolcock et al (1972) report the sharp increase of coughing with age at Baiyer River. They comment that "few people under the age of 40 have established chronic lung disease and that over the age of 40 more females than males are affected. In fact, about 12 per cent of the population in the Western Highland District over 40 years have established CLD by our criteria".

The increase in EYE with age can be compared with data from Vines (1970) which is shown in Table 18.14. These figures reveal a similar deterioration in eye condition with age as that shown in Figure 18.5. The data from Vines appear much higher because he recorded all eye conditions, whereas I recorded only perceived eye conditions - in other words, conditions resulting in pain, discomfort or impaired vision. The figures in Table 18.14 are also high because some subjects clearly suffered from more than one condition and

TABLE 18.12

AVERAGE WEEKLY PERIOD PREVALENCES

PER 1000 AT RISK BY AGE

Symptom	Age Groups (Years)								
	0-4	5-9	10-14	15-19	20-29	30-39	40-49	50-69	All Ages
Ache	8	2	2	18	44	172	389	625	140
Eye	6	0	2	14	49	71	119	540	74
Skin 1	323	269	158	91	204	215	186	122	207
Skin 2	188	59	56	11	37	9	19	10	54
Skin 3	50	5	7	0	2	2	0	0	10
Fever	2	11	10	44	74	42	57	122	40
Pain	59	11	12	40	44	56	53	106	45
Diarrhoea	54	8	10	11	39	40	53	53	35
Blood	8	0	0	0	0	4	5	5	3
Vomit	6	0	0	0	0	7	3	0	2
Cough	70	53	86	51	103	175	282	342	142
Toothache	19	5	35	18	54	189	243	133	95
Trauma	8	2	7	18	27	11	9	16	13

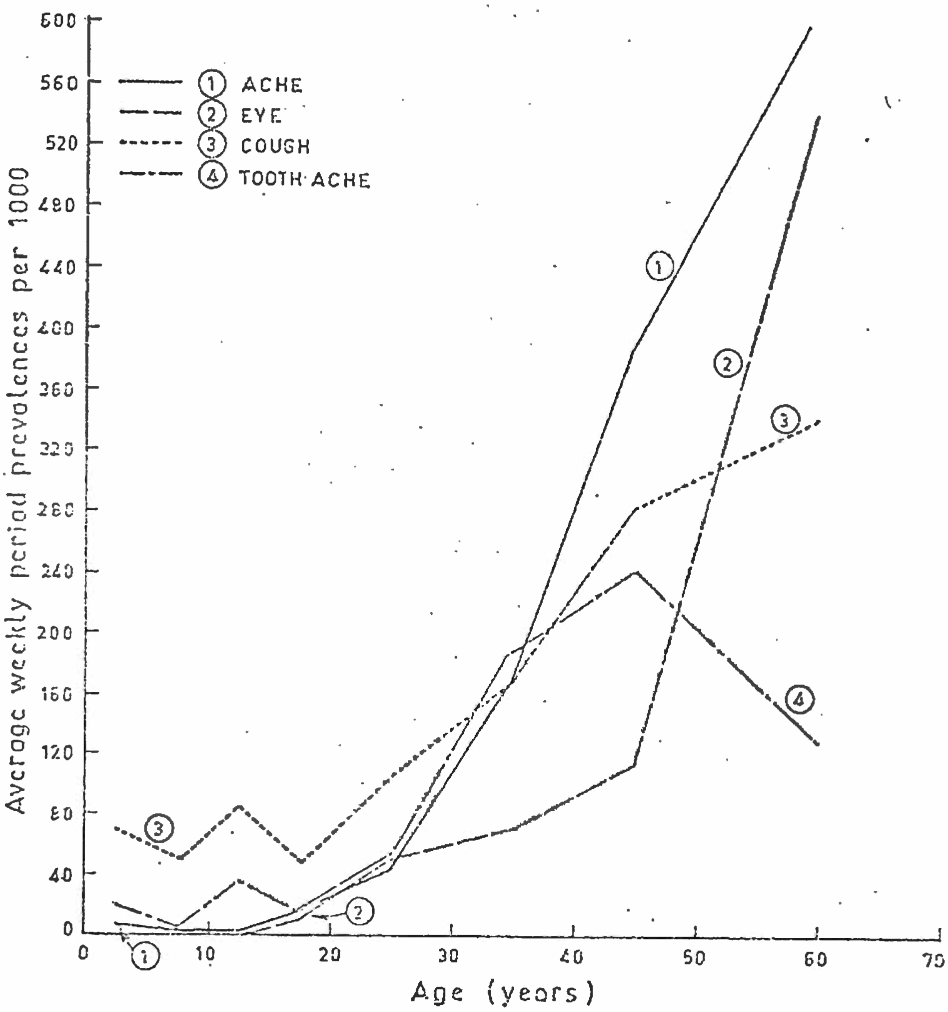

FIG. 18.5 AVERAGE WEEKLY PERIOD PREVALENCES OF 4 SYMPTOMS IN DIFFERENT AGE GROUPS

TABLE 18.13

PREVALENCE OF COUGHING BY SEX FOR 707 HIGHLANDERS FROM BAIYER RIVER AND 148 CHIMBUS (AFTER WOOLCOCK AND BLACKBURN - 1967)

Age (Years)	% With Cough	
	Male	Female
0-29	6.6	7.1
30-39	19	33
40-49	31	37
50-59	41	37
60 +	41	37
All Ages	25	27

TABLE 18.14

TOTAL NUMBER OF EYE CONDITIONS IN THE HIGHLANDS REGION TAKEN FROM VINES (1970: 434, 429)

Age (Years)	Number of Conditions Per 1000 Highlanders (Excluding Trachoma and Discrete Brown-Yellow Pigment)	Percentage Infected with Trachoma
0-4	117	2.0
5-9	343	9.2
10-14	205	7.1
15-29	333	7.7
30-44	630	12.1
45 +	1265	9.5
All Ages	776	8.9

therefore rates of more than 100% are obtained. Sinnett (1972b:145) reports a sharp fall in visual acuity with age amongst the Yandapu Enga. Sinnett further reports that cataract, pterygium and corneal opacity were the most common eye diseases with both trachoma and conjunctivitis being rare.

Figure 18.6 shows the decline with age of skin infections. The predominant cause of skin disease was infected scabies and Vines (1970:415) reports finding a peak prevalence for scabies in the 0 - 4 years age group.

Figure 18.7 shows the variations with age of FEVER, DIARRHOEA and TRAUMA. TRAUMA is seen to peak in the 20 - 29 years age group (when both sexes are most active in labouring tasks which expose them to risk of injury), whereas Vines (1970:369) shows "wounds unhealed" peaking in the 30 - 44 years age group.

Only a portion of the symptom FEVER will be attributable to malaria. However, there are similarities between Figure 18.7 and the data given by Vines (1970:145) for malarial parasite infestations, which peak in the 15 - 29 years age group, decline and then rise again in the over forty-fives. My data show that the prevalence of FEVER peaks strongly in the 20 - 29 years age group and this may be related to the tendency of this age group to travel and expose themselves to a high risk of malarial infection in lower areas. This point is expanded on in section 19.2.

DIARRHOEA is seen to be high in childhood, decrease suddenly and then rise steadily after the age of about 20. A glance at Table 18.12 reveals a similar pattern of sickness for the symptoms BLOOD and VOMIT, which indicate dysentery and gastro-enteritis. This is partly a manifestation of the well-known phenomenom of weanling diarrhoea in the tropics which is well documented (see

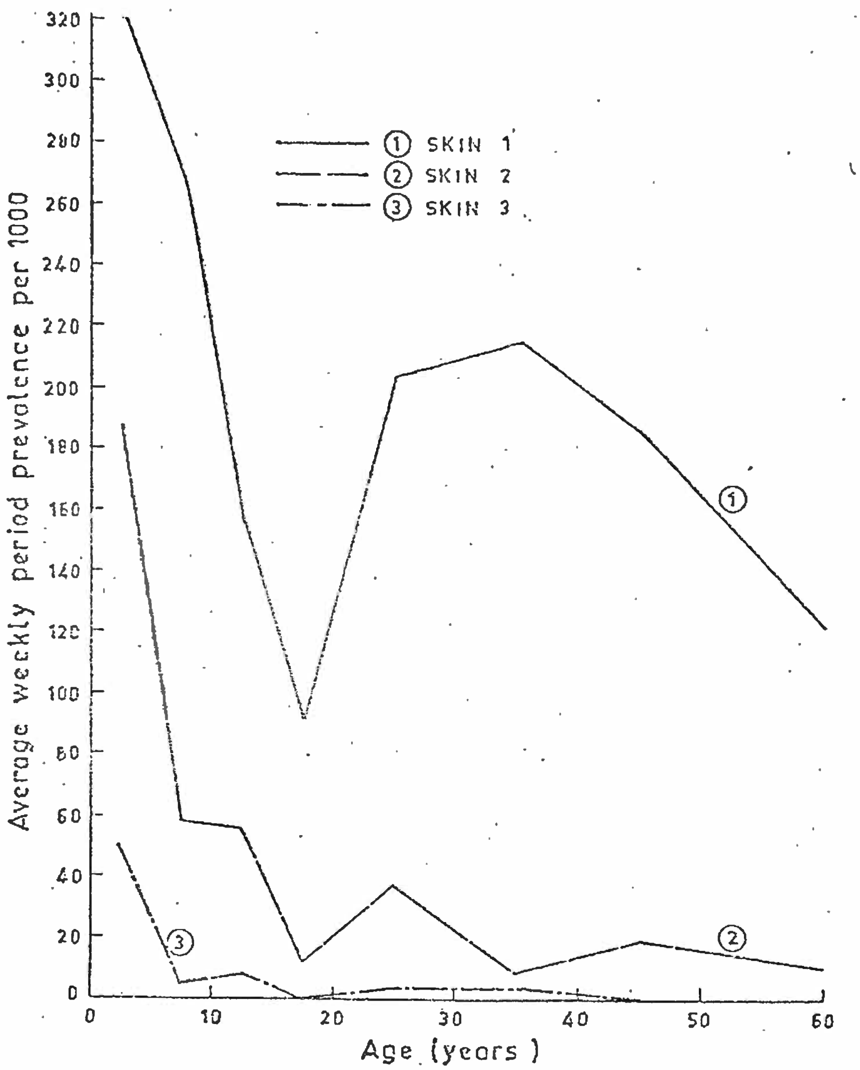

FIG. 18.6 AVERAGE WEEKLY PERIOD PREVALENCES OF SKIN INFECTIONS IN DIFFERENT AGE GROUPS

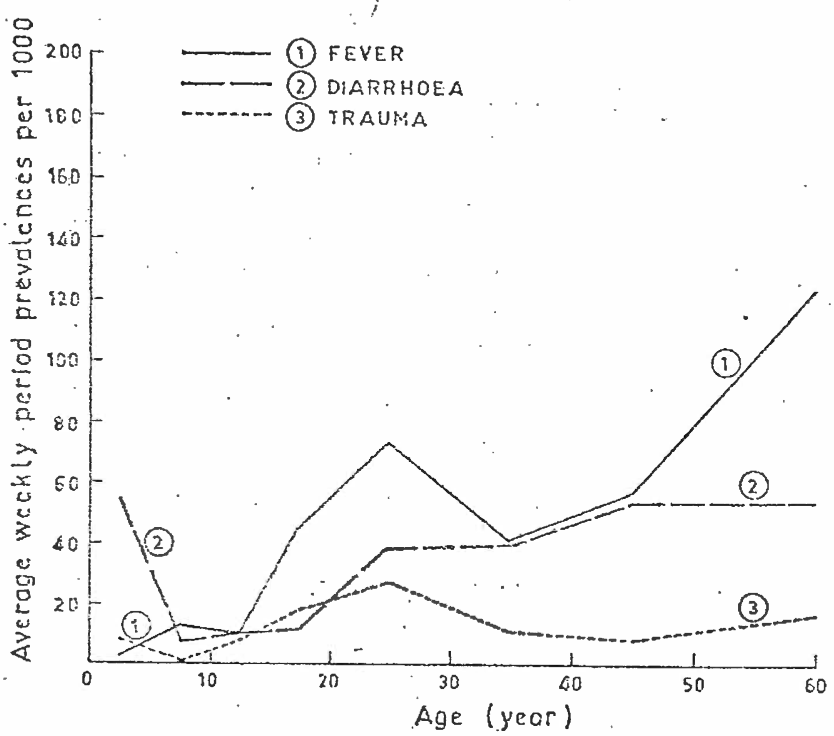

FIG. 18.7 AVERAGE WEEKLY PERIOD PREVALENCES OF 3 SYMPTOMS IN DIFFERENT AGE GROUPS

Gordon et al, 1963, 1964; Pierce et al, 1962 and Scrimshaw et al, 1962).

18.5.5 AVERAGE WEEKLY PERIOD PREVALENCES: TOTALS AND BY SEX

It is interesting to compare Table 18.15 with comparable material from Vines (1970) which is shown in Table 18.16. Considering the wide differences in methodology between the two surveys, and the fact that Vines' data are drawn from throughout the Highlands whereas the author's are from the Saka only, the close agreement of data for FEVER, dysentery (BLOOD) and TRAUMA is remarkable. Both tables indicate the far greater TRAUMA rate for males than for females and Vines found only one female out of 504 who had a "wound unhealed".

Vines' figures for skin disease are far higher than those in Table 18.15 due to his reporting conditions (as opposed to sick individuals) in a situation where some individuals have more than one condition. He was also including symptoms that were not infected, or causing discomfort, and so would not be included in Table 18.15. Both Vines' data and the Saka data show little differences in skin disease prevalences between the sexes. Vines' lower figure for diarrhoea may derive from weaknesses in the monthly recall system which were discussed earlier, in section 18.1. In particular, diarrhoea may well be considered a mild symptom in many areas and it has been shown (Mechanic and Newton, 1965) that long recall surveys are especially prone to under-report mild conditions.

As mentioned in section 18.3, Table 18.15 indicates that female prevalences of all symptoms, except SKIN 1 and FEVER, were lower than prevalences for males. Symptoms ACHE, EYE,

TABLE 18.15

AVERAGE WEEKLY PERIOD PREVALENCES
PER 1000 AT RISK BY SEX

Symptom	Average Weekly Period Prevalences		
	Male	Female	Total
Ache	189	73	140
Eye	105	29	74
Skin 1	205 } 272	209 } 267	207 } 271
Skin 2	57	49	54
Skin 3	10	9	10
Fever	36	46	40
Pain	56	30	45
Diarrhoea	41	26	35
Blood	5	0	3
Vomit	4	1	2
Cough	161	114	142
Toothache	129	46	95
Trauma	18	5	13

TABLE 18.16

COMPARABLE HIGHLANDS HEALTH DATA FROM VINES (1970)

Condition	Type of Measurement	Data	Source Page From Vines (1970)
Diarrhoea and Gastroenteritis	Monthly p.p. per 1000	10	81
Dysentery	Monthly p.p. per 1000	3	81
Fever	Monthly p.p. per 1000	52	81
Skin diseases (excluding "other toenail abnormalities" and "wounds and operation scars")	Number of conditions per 1000 subjects	Male = 719 Female = 749 Total = 735	369 370 371
Wounds unhealed	Point prevalence per 1000	Male = 17 Female = 2 Total = 10	369 370 371
Eye conditions	Number of conditions per 1000 subjects	Excluding Trachoma = 776	423
	% of subjects infected	Trachoma = 8.9 (see Table 18.14)	429

PAIN, DIARRHOEA, BLOOD, VOMIT, TOOTHACHE and TRAUMA show this sex differential particularly strongly. In the case of TRAUMA, mentioned above, this is to be anticipated (because males undertake the heavy, trauma inducing, labouring tasks) and is confirmed by Vines' data. Sinnett's (1972b:145) data on Yandapu Enga eye disease show more disease amongst males, especially more cataract and corneal opacity. Vines (1970:432) shows a significant male preponderance of cataract in the Highlands and a non-significant male preponderance of corneal opacities. Apart from EYE and TRAUMA, the higher symptom prevalences in males shown in Table 18.15 must be viewed in the light of previous remarks concerning the possibility of female under-reporting (section 18.3) and await further verification.

Table 18.17 gives figures from health surveys in India, Africa and elsewhere for comparison. The Ugandan study of Jelliffe et al (1961) is particularly interesting since the Bachiga people, of the Kayonza District, inhabit a high (1,000m - 2,200m) mountainous region, living in scattered settlements with population densities of around 57 people per square kilometre. This environment is somewhat similar to that of the Saka and the Bachiga, like the Raiapu, suffer from severe respiratory infections which are a major cause of mor-bidity and mortality. The Ugandan figure of 628, for 0 - 3 years age group skin disease prevalence per 1000, compares with the Tombeakini figure of 561 (see Table 18.12).

18.6 DURATIONS OF SYMPTOMS

Table 18.18 shows the average durations per person, and per sick person, for the thirteen symptoms recorded. Since, with this survey, it is impossible to distinguish accurately between symptoms which incapacitated (and prevented normal work) and those which

TABLE 18.17

SOME COMPARABLE MORBIDITY DATA FROM ASIA, AFRICA AND NEW GUINEA

Location and Date	Source	Type of Measurement	Disease	Data	Comments
Sarojini Nagar, Lucknow, India in 1969	Shivaram et al, (1970)	Point prevalence per 1000	Diseases of eye	27.9	Flat irrigated plain. 902mm annual rainfall. 28% literacy. 410 persons per sq. km.
			Diarrhoea and dysentery	29.0	
			Skin infections	26.5	
			Arthritis and rheumatism	6.4	
		Annual prevalence per 1000	Fevers incl. malaria	125.9	
Kayonza District, Uganda	Jelliffe et al, (1961)	Point prevalence per 1000 in 0-3 years age group	Skin diseases	628	Altitude, population density and settlement pattern similar to Raiapu
Lugbara, North-western Uganda	Jelliffe et al, (1962)	Point prevalence per 1000 in 0-4 years age group	Skin diseases	515	610m altitude
Sungai Tekam, Pahang, Malaya	Chappel and Janowitz (1965)	Point prevalence per 1000	Skin disease	Males = 280 Females = 140 Total = 220	Subjects on resettlement scheme (rubber and fruit) with good water and sanitation
Baiyer River and Chimbu, New Guinea	Woolcock and Blackburn (1967)	Point prevalence per 1000	Cough	Male = 250 Female = 270	Environmentally and culturally similar to Raiapu (except Baiyer River is 600m lower)

TABLE 18.18

AVERAGE DURATIONS OF SYMPTOMS PER PERSON SICK AND PER PERSON OVER 22 WEEK SURVEY PERIOD

Symptom	Number of Subjects Reporting Symptom	Average Durations (Weeks)	
		Per Person Sick	Per Person
Ache	71	5.9	3.1
Eye	36	6.1	1.6
Skin 1	135	4.6	4.5
Skin 2	49	3.3	1.2
Skin 3	14	2.1	0.2
Fever	59	2.1	0.9
Pain	65	2.1	1.0
Diarrhoea	55	1.9	0.8
Blood	8	1.3	0.1
Vomit	7	1.1	0.1
Cough	122	3.5	3.1
Toothache	67	4.2	2.1
Trauma	34	1.1	0.3

did not, no attempt is made to calculate the "proportion of time lost". Waddell (1972b:84) reports that only 1% of potential working time was lost through sickness at home and a further 0.6% through hospitalisation. He contrasts this with a loss-of-time rate of 4% for the Popondetta subdistrict studied by Waddell and Krinks (1968). Waddell further comments that "most of the ailments witnessed" were traumas acquired during work, whereas Table 18.18 shows that, in fact, other symptoms have durations considerably greater than that of TRAUMA. Lea (1969/70) studied the allocation of time in the Enga settlement of Kaiap. He found that 13% of journeys made away from home were to visit the sick, or to obtain treatment, but he does not specify the amount of time spent in sickness.

CHAPTER 19

MORBIDITY AND ENVIRONMENT

19.1 INTRODUCTION

The problems of relating morbidity to particular causal factors are far more difficult than those of simply quantifying the prevalences of various morbid symptoms. The problems involved are those of experimental design in a non-laboratory situation where many variables are outside the experimenter's control. Two basic approaches can be adopted. One can seek to study the influence of one variable by comparing morbidity between populations which are similar in all respects except the selected variable. This approach is unsatisfactory in most situations simply because it is often impossible to control extraneous variables or even to know whether they are being controlled.

An example of this experimental design is the study proposed by Radford (1970) in which 2 populations (shown to be similar with regard to health status and relevant cultural and environmental factors) were to be studied and then a new water supply was to be introduced into one of them. Changes in morbidity rates, resulting from the improved water supply, could then be examined. While I believe that such a study would be very worthwhile, it would be difficult to justify the assumption that only the water supply variable had changed and that the population without a new supply was really acting as a control group. Radford's (1970:7) assumption that, "any other factors which might occur in the village during the study period that are likely to affect the results will do so more or less equally in all villages", is doubtful in view of the considerable disruption caused by the experiment itself and the introduction of a new water supply.

An alternative approach is a multivariate one in which as many factors as possible, which are likely to effect morbidity, are defined. Several populations are then selected and the morbidity, and the pre-defined variables, are measured in each. A multivariate analysis can then take place designed to isolate the importance of individual variables, and of combinations of variables, and to rank these in order of importance. The advantage of this approach is that it obviates the need to make the simplistic assumptions involved in a one-variable study, and it yields data on the relative importance of a number of factors. These data are especially important in the rational allocation of limited funds for health improvement. Suppose that a study such as Radford's revealed that the new water supply caused a significant drop in the level of gastroenteric disorder. To argue for increased funds for water supply on the strength of this would be difficult because it could easily be that the same money, spent in other ways (health education or housing modifications, for instance), could have an even greater impact.

The disadvantages of the multivariate approach are mostly connected with the problems of choosing the correct variables and then devising accurate, and practicable, ways to measure them. As the number of variables increases, the experiment becomes more and more complex and the size of the population, needed to give significant morbidity data in each category, becomes prohibitive. Perhaps the solution lies in a compromise in which a few, most likely, variables are chosen (on the basis of a priori understanding or a pilot survey) and the relative influence of these on morbidity is investigated.

19.2 EDUCATION AND TRAVEL AS INFLUENCES ON MORBIDITY

It is a reasonable hypothesis that educational attainment will influence attitudes to health and personal hygiene and therefore affect health standards[1]. This is especially so since the primary school syllabus often contains courses on hygiene and health. It is also possible that the experience of working, or travelling, away from the Saka could influence beliefs in a similar way and have a beneficial influence on morbidity. A third possibility is that the ability of a person from the Saka to speak english or neo-melanesian (pidgin english), is indicative of a less traditional outlook and of a greater awareness of the concept of hygiene.

Table 19.1 shows that the individuals who can speak languages other than Enga, have been to schoool or have worked outside the Enga region, are all in the 5 - 39 years age group and are nearly all males. A simple comparison between the morbidity of school attenders and non-attenders (for instance) would thus amount to a comparison between the health of young males and the health of the rest of the Tombeakini clan. Therefore, in Tables 19.2, 19.3 and 19.4, the comparison is restricted to males in the 5 - 39 years age group. All X^2 (chi-square) values in these and later tables are computed from the absolute morbidity data and not from the calculated period prevalences per 1000 which are tabulated.

The data for the symptom FEVER are especially interesting. According to both schooling and linguistic ability, those with more education have a lower prevalence (with a 5% level of significance in the case of schooling) of FEVER. However, those who have worked

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1. Conversely, sickness may affect school attainment (Epstein, 1970).

TABLE 19.1

LINGUISTIC KNOWLEDGE, SCHOOLING AND WORK EXPERIENCE OF TOMBEAKINI CLAN

AGE (YEARS)	SEX	LANGUAGE		SCHOOLING		WORK EXPERIENCE	
		ENGLISH OR NEO-MELANESIAN	ONLY ENGA	EVER ATTENDED	NEVER ATTENDED	WORKED OUTSIDE ENGA REGION	NEVER LEFT ENGA REGION
0-4	M	0	19	0	19	0	19
	F	0	11	0	11	0	11
5-9	M	4	11	4	11	1	14
	F	0	8	0	8	0	8
10-19	M	16	8	9	15	8	16
	F	3	17	2	18	1	19
20-29	M	8	7	2	13	12	3
	F	0	14	0	14	0	14
30-39	M	4	11	1	14	3	12
	F	0	15	0	15	0	15
40 +	M	0	37	0	37	0	37
	F	0	18	0	18	0	18
ALL AGES	M	32	93	16	109	24	101
	F	3	83	2	84	1	85

TABLE 19.2

AVERAGE WEEKLY PERIOD PREVALENCES PER 1000 FOR MALES IN 5-39 AGE GROUP BY LINGUISTIC ABILITY

Symptom	Average Weekly Period Prevalences Per 1000		X^2	Level of Significance (df = 1)
	English or Neo-Melanesian Speakers	Enga Speakers		
Ache	73	45	3.40	
Eye	7	52	13.54	***
Skin 1	183	201	0.50	
Skin 2	20	43	3.50	
Skin 3	2	8	1.36	
Fever	31	45	1.15	
Pain	57	31	3.96	*
Diarrhoea	15	31	2.28	
Blood	2	1	0.08	
Vomit	7	0	4.53	*
Cough	75	100	1.73	
Toothache	52	123	41.18	***
Trauma	15	22	0.56	

* $p < .05$ ** $p < .01$ *** $p < .001$

Note: The symbol X^2 is used throughout to represent the chi-square statistic. All X^2 values are computed from the absolute morbidity figures and not from the period prevalences per 1000 which are given in the tables.

TABLE 19.3

AVERAGE WEEKLY PERIOD PREVALENCES PER 1000 FOR MALES IN 5-39 AGE GROUP BY SCHOOLING

Symptom	Average Weekly Period Prevalences Per 1000		X^2	Level of Significance (df = 1)
	Some Schooling	No Schooling		
Ache	8	64	6.79	**
Eye	8	38	3.29	
Skin 1	190	194	0.01	
Skin 2	38	33	0.06	
Skin 3	8	6	0.05	
Fever	0	46	6.28	*
Pain	15	46	2.67	
Diarrhoea	0	29	3.90	*
Blood	0	2	0.32	
Vomit	0	3	0.48	
Cough	53	96	2.58	
Toothache	30	105	7.35	**
Trauma	0	23	3.07	

* $p < .05$ ** $p < .01$ *** $p < .001$

TABLE 19.4

AVERAGE WEEKLY PERIOD PREVALENCES PER 1000 FOR MALES IN 5 - 39 AGE GROUP BY WORK EXPERIENCE

Symptom	Average Weekly Period Prevalences Per 1000		X^2	Level of Significance (df = 1)
	Worked Outside Enga Region	Never Worked Outside Region		
Ache	39	66	3.06	
Eye	62	18	12.81	***
Skin 1	197	193	0.03	
Skin 2	23	42	2.42	
Skin 3	3	8	1.08	
Fever	65	25	9.31	**
Pain	34	47	0.90	
Diarrhoea	17	30	1.54	
Blood	3	2	0.14	
Vomit	3	3	0.02	
Cough	79	98	0.99	
Toothache	39	128	20.31	***
Trauma	31	13	3.59	

* $p < .05$ ** $p < .01$ *** $p < .001$

outside the Enga region [1] (Table 19.4) have significantly more FEVER than those who have not. In other words, education decreases fever, whereas mobility increases it. The diagnostic impreciseness of FEVER renders the explanation of this phenomenon impossible, but it is clearly a possibility that it is due to travellers from the Saka being infected with malaria when they visit lower altitudes where malaria may be endemic [2].

The data for the symptom EYE is of a similar pattern to that for FEVER. Those who have travelled have significantly more eye disease, whereas those with schooling, or linguistic ability, have significantly less. This implies that those visiting the coast or the Wahgi valley have contracted eye infections (which they would not otherwise have got) which have remained with them after their return. Vines (1970:431) shows that the coast has a higher prevalence of purulent conjunctivitis (not significant), folliculosis ($p < .001$), corneal opacities ($p < .05$) and cataract (not significant) which may account for the data in Table 19.4. Table 19.5 shows the percentages of people with different eye conditions in the Highlands, in the lowlands, and among Sinnett's sample of Yandapu Enga near Sirunki. These data indicate that the Enga have appreciably less trachoma and conjunctivitis than is found elsewhere in the Highlands, or in the New Guinea lowlands, and this might explain the increased eye infections amongst those from the Saka who have travelled.

The data for skin disease are perhaps interesting. It appears

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1. Of those members of Tombeakini who have worked away from home, 75% worked on tea and coffee estates in the Wahgi valley (Mount Hagen-Banz-Minj area), while the remainder visited Madang, Rabaul, Port Moresby or Bougainville.

2. Peters et al (1958) have pointed out the high risk of infection experienced by Highlanders, with little or no immunity, when they visit malarial coastal areas.

TABLE 19.5

PERCENTAGES OF POPULATIONS HAVING EYE DISORDERS FROM VINES (1970) AND SINNETT (1972b)

Eye Disease	Highlands From Vines (1970:423)	New Guinea Coast and Foothills From Vines (1970:424)	Yandapu Enga From Sinnett (1972b:145)	
			Male	Female
Cataract	6.4	6.8	18	10
Corneal Opacities	3.8	5.9	7.7	2.4
Pterygium	7.1	4.9	4.5	5.9
Trachoma	8.9	30.1	1.3 of adults	
Conjunctivitis	13.1 (follicular)	38.8 (follicular)	0.5 of adults	

TABLE 19.6

FLOOR AREAS PER OCCUPANT IN DIFFERENT HOUSE TYPES

Type of House	Average No. of Residents Per House	Floor Area (For Humans) In Sq. Metres	Floor Area Per Resident In Sq. Metres
Men's	2.1	15	7.1
Women's (Excl. Pig Stalls)	2.5	20	8.0
Mixed (Excl. Pig Stalls)	4.3	20	4.6
All Types	3.0	18	6.0

that neither schooling, linguistic ability nor travel are associated with a significantly lower prevalence of skin infection. Since skin infections are among the most susceptible of all the symptoms surveyed to improvements in personal hygiene, it might have been anticipated that those with greater education, and contact with recently introduced health concepts, would have experienced less skin infection. The prevalence of diarrhoea, on the other hand, does appear to be reduced by schooling. Dental problems show highly significant prevalence differences in all 3 tables and this may be due to improved oral hygiene amongst the more educated. Accidents appear to happen less frequently to those who have been to school, but more frequently to those who have travelled. I suspect that this is due to the travellers being a generally more adventurous, and even reckless, group and thus sustaining a greater number of injuries.

19.3 HOUSING AND COHABITANTS AS INFLUENCES ON MORBIDITY

19.3.1 TOMBEAKINI HOUSING

Raiapu Enga house styles have already been discussed (section 3.6 and Table 3.2), as have the housing arrangements of Tombeakini (section 4.2 and Tables, 4.5, 4.6 and 4.7). Houses contain up to 8 occupants who usually comprise 2 generations. The average house contains 3 people and mixed houses tend to have more occupants (4.3) than either men's or women's (2.1 and 2.5, respectively). All houses are dry and dark and, when a fire is burning in the fireplace, extremely smoky.

The floors are of beaten earth covered with a layer of masticated sugar-cane pith, wood shavings and rubbish, which provide an excellent habitat for many members of the phylum Arthropoda. Of special public health significance are members of the class Insecta (cockroaches, fleas, beetles, bedbugs and lice) and, more importantly, mites of the order Acarina. Mites are known to be vectors of serious diseases (such as scrub typhus), they are known to cause various dermatoses, and they are reported to invade the human respiratory system causing eosinophilia and asthmatic symptoms (Hunter et al, 1960; Taylor and Murray, 1946; Womersley, 1952). The total role of mites in tropical medical ecology is not known and it is likely that future research will expose new associations between mites and human disease. Baker and Wharton (1952: 86, 87) write that "as more and more work is done on the epidemiology of human diseases it is probable that many mites will be found to play an essential role".

In the New Guinea Highlands, mites are of importance principally in the causation of dermatoses. Scabies, which is a dominant skin condition amongst Highlanders, is due to infestations of the parasitic mite Sarcoptes scabiei. Table 18.10 shows that 99.5% of Tombeakini experienced some dermatosis during the period of the morbidity survey, and a substantial proportion of these skin infections were infected scabies. Vines (1970:369) finds that scabies is a major cause of skin disease in the Highlands, in contrast to other regions of New Guinea where it is most uncommon. It is believed that the transmission of scabies is only likely in situations of close person-to-person contact and thus the crowded communal sleeping quarters of Enga houses are an excellent setting for the spread of scabies infections. Due to continual scratching, and the lack of personal hygiene, scabies infections amongst the Raiapu nearly always lead to secondary infection. Table 18.12 and Figure 18.6 show that children are particularly vulnerable to scabies.

In addition to Sarcoptes scabiei, other mites are associated with various dermatoses (Hunter, et al, 1960; Taylor and Murray, 1946) although their presence and significance have not yet been established in the Highlands. Within the sub-order Sarcoptiformes, Sarcoptes (family Sarcoptidae) and Tyroglyphus (family Acarinae) are implicated. Within the sub-order Trombidiformes, Pyemotes [1] (family Pyemotidae) and Acomatacarus, Eutrotrombicula, Schöngastia and Trombicula (all of the family Trombiculidae) are implicated. Within the sub-order Mesostigmata, Liponyssoides, Dermanyssus, Allodermanyssus and Bdellonyssus (all of the family Dermanyssidae), together with Laelaps (family Laelaptidae) are associated with human dermatoses.

Many species of Trombiculidae are known to attack man, and it is mites from this family which are also the vectors of scrub typhus. Dermatosis due to Trombiculidae is often called "scrub itch". Gunther (1942), cited by Taylor and Murray (1946:268), described a Trombiculidae attack as follows:

> It does not give rise to any symptoms for the first 6 to 12 hours; then a papule 3 to 6mm across appears. It is topped by a tiny blister and surrounded by a red areola, and itches intolerably. It is rare to find the larva once the blister has formed; it either drops off when engorged or is rubbed off immediately the itching develops. On being scratched, the blister is usually torn open and becomes infected easily. Such sores rapidly break down to small indolent sloughing ulcers, very stubborn and inclined to spread. The mites usually attack areas subjected to the pressure of clothing, such as the belt line, under garters or stockings, in the axilla and the groin, and on the genitals.

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1. Also known as Pediculoides.

I suffered from symptoms identical to these following every period spent sitting on the floor of Raiapu houses in the Saka. Although Trombiculidae, and the other mites listed above, have (with the exception of Sarcoptes) not been definitely associated with dermatoses in the Highlands, it is most likely that such an association exists. It is especially likely in the Enga region where the distinctive floor covering provides an ideal habitat for mites [1].

In order to clarify the public health importance of Raiapu house flooring, in July 1973 the author collected 8 samples of flooring material from Tombeakini houses. Flooring was collected from houses of different types (Table 3.2) and of different ages. There was much varied animal life present in all houses sampled and there was appreciably more life in the floors of the older houses. Samples were returned to the University of New South Wales, and with the assistance of the School of Zoology, large numbers of mites were recovered from all samples. Due to the methods of collection and mite recovery, the specimens were of poor quality and generally had legs, or other body parts, missing [2]. Only very tentative identifications were possible but, with the aid of acarologist Dr. Phyllis Robertson, the following picture of the mite population was obtained:

a) A large mite population is present and it includes members of the major groups, Oribatei, Sarcoptiformes and Trombidiformes.

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1. In many other regions in the Highlands, floors are of beaten earth and without a layer of rotting plant material.

2. Samples of live mites can be collected from rubbish using Berlese Funnels. This technique was not used, however, with the result that only poor specimens were obtained.

b) The dominant mite is the genus Chortoglyphus. Other Sarcoptiformes may be Acaridae and Glycyphagidae.

c) The Trombidiformes mites may include the families Cheyletidae and Pyemotidae.

This identification is extremely tentative, but it appears certain that the floors do contain large mite populations, that older houses have a greater infestation and that mites from many different families are present.

Table 19.6 shows the floor areas per person for the different types of houses. The overall mean of 6.0sq.m (64.6sq.ft) of floor area per resident is high for the Highlands. Vines (1970:91) shows that only 24.9% of his sample have more than 60sq.ft (5.6sq.m) per resident and 51.1% have less than 40sq.ft (3.7sq.m).

19.3.2 SIZE OF HOUSEHOLD AS AN INFLUENCE ON MORBIDITY

The question being considered in this section is whether morbidity is inversely related to the number of occupants of a house. The reasons why this might be so are obvious. In a crowded household, not only are conditions likely to be less hygienic (especially if pigs are also resident), but also an individual is exposed to close contact with a large number of other, potentially infective individuals. Conditions are most suitable for the introduction and transmission of disease.

The approach adopted here is twofold. Firstly, in Table 19.7, the health of occupants of men's and women's houses (with a mean household size of 2.3 persons and more than 7sq.m of floor space per person) is compared to that of those who live in mixed houses (with a mean size of 4.3 persons and only 4.6sq.m of floor space per person). Table 19.7 indicates that mixed house dwellers have significantly less eye disorders and significantly more skin disease. Other symptoms do not appear to be affected by house type.

TABLE 19.7

AVERAGE WEEKLY PERIOD PREVALENCES PER 1000 FOR THE OCCUPANTS OF DIFFERENT HOUSE TYPES

Symptom	Type of House		Chi-Square	Level of Significance (df = 1)
	Men's & Women's	Mixed		
Ache	151	128	3.04	
Eye	93	50	20.24	***
Skin 1	183	235	12.45	***
Skin 2	41	68	10.44	**
Skin 3	3	18	17.27	***
Fever	49	34	2.66	
Pain	40	41	0.98	
Diarrhoea	40	29	2.83	
Blood	1	5	2.38	
Vomit	1	4	0.91	
Cough	143	140	0.06	
Toothache	98	90	0.54	
Trauma	15	10	1.54	

* $p < .05$ ** $p < .01$ *** $p < .001$

Secondly, the average weekly period prevalences of individuals were correlated against the number of occupants in the houses in which they lived. This was done for different age groups (to exclude the effect of age on morbidity - see Table 18.12) and for all ages. Only 5 symtoms reveal significant correlations in any age groups and these are shown in Table 19.8. This Table, in certain respects, supports the findings of Table 19.7. The prevalence of SKIN 1 is seen to be positively correlated with the number of occupants and this is especially true for individuals in the 0 - 4 years age group (which is the age group with most SKIN 1 - see Table 18.12). Negative correlations between house occupancy and ACHE, EYE, COUGH and TRAUMA, are shown. Although significant at the 5% level, all these correlation coefficients are extremely low. They are presented here for their potential interest, but an understanding of the reasons for them must await further investigation.

19.3.3 THE HEALTH OF COHABITANTS AS AN INFLUENCE ON MORBIDITY

It is a plausible proposition that the health of an individual is positively associated with the health of those with whom he lives. To test this, individual weekly p.p. were correlated against the weekly p.p. of all cohabitants (excluding the individual himself). This was done for all symptoms and for individuals in different age groups. Only 3 symptoms showed significant correlations and these are given in Table 19.9.

SKIN 1 shows a consistent positive correlation and EYE is also positive, but less convincingly. TRAUMA shows an interesting negative correlation which is maintained in all age groups, although not significantly so. This could possibly be attributed to the cautioning influence that an individual's accident might have on other members

TABLE 19.8

COEFFICIENTS OF CORRELATION (r) AND SIGNIFICANCE LEVELS (p) FOR THE CORRELATION OF WEEKLY PERIOD PREVALENCES FOR INDIVIDUALS IN DIFFERENT AGE GROUPS AGAINST THE NUMBER OF THEIR COHABITANTS

Symptom	Age Group (Years)													
	0-4		5-9		10-19		20-29		30-39		40 +		All Ages	
	r	p	r	p	r	p	r	p	r	p	r	p	r	p
Ache	-.27		.39		-.20		-.14		.01		-.10		-.22	**
Eye	.25		0.0		-.02		-.18		.09		-.10		-.17	**
Skin 1	.42	*	.11		-.02		.04		.31		.13		.21	**
Cough	.37	*	-.17		.03		.13		-.07		-.14		-.17	*
Trauma	-.24		.39		.01		-.36		-.31		.05		-.14	*
Degrees of Freedom	28		21		39		25		28		52		203	

* $p < .05$ ** $p < .01$

TABLE 19.9

COEFFICIENTS OF CORRELATION (r) AND SIGNIFICANCE LEVELS (p) FOR THE CORRELATION OF WEEKLY PERIOD PREVALENCES FOR INDIVIDUALS AGAINST WEEKLY PERIOD PREVALENCES OF THOSE WITH WHOM THEY COHABIT

Symptom	Age Group (Years)													
	0-4		5-9		10-19		20-29		30-39		40 +		All Ages	
	r	p	r	p	r	p	r	p	r	p	r	p	r	p
Eye	.03		0.0		.29		.95	**	-.12		.28		.27	**
Skin 1	.44	*	.41	*	.10		.33		.29		.28		.32	**
Trauma	-.12		-.02		-.20		-.13		-.20		-.30		-.17	*
Degrees of Freedom	28		21		39		23		27		38		186	

* $p < .05$ ** $p < .01$

of his family. The positive correlations for SKIN 1 and EYE indicate that transmission of these symptoms is partially intrafamilial and that their occurrence is clustered by houses.

19.3.4 THE COMBINED INFLUENCE OF COHABITANT S' HEALTH AND HOUSEHOLD SIZE ON MORBIDITY

If the prevalence of a symptom among an individual's cohabitants is multiplied by the number of cohabitants, a measure is obtained of the individual's "exposure" to that symptom. For example, if 2 cohabitants had a symptom prevalence of 50%, then both might have been sick ½ the time or one of them all the time. If 4 cohabitants had a prevalence of 50%, then 4 might have been sick ½ the time, or 2 of them for all the time. In other words, an individual living in the second house is twice as exposed to the particular disease as an individual in the first house.

Individual prevalences were correlated against exposure (= the average weekly p.p. among the cohabitants multiplied by the number of cohabitants) by age groups and for all ages. This procedure was clearly not meaningful since the correlations obtained were considerably weaker than those in Tables 19.8 and 19.9. The pattern was similar, with SKIN 1, EYE and TRAUMA showing most correlations, but the values of 'r' were decreased in all cases.

19.3.5 HOUSE CONFINEMENT AS AN INFLUENCE ON MORBIDITY

One of the benefits of the type of study reported here is that the close, and sustained, contact between interviewer and subject enables unforeseen circumstances, which might shed light on problems of morbidity, to be exploited. One such circumstance, which occurred during my residence with Tombeakini, was the death of a young clansman, which resulted in a kumánda. A kumánda is a period of mourning, culminating in a distribution of wealth to the natal clan of the deceased's mother, which follows a Raiapu death. The scale of the kumánda depends upon the degree of tragedy of the death concerned and, in this case in which a 23 years old bachelor was drowned in the Wahgi River while working near Minj, the mourning was prolonged and deep. The kumánda was discussed in section 3.8.

On July 6th, the news of the drowning reached Lyokote, and the entire Tombeakini clan went into mourning. This lasted until August 28th, when the final funerary prestation took place. and life returned to normal. After the first few days of public weeping and tearing of the hair and beard (close female relatives of the deceased also amputated finger ends as a sign of extreme grief) the women retired to their houses and remained there for 8 weeks. The men, although not obliged to stay indoors, were forbidden to engage in any work and had to spend their days sitting around and discussing the death and arrangements for the compensation payments. It was the time of the year when new gardens are usually cleared and burnt and new houses are built, but these activities were prohibited. Coffee was not picked and even the ubiquitous card games had to stop.

Since the women spent this 8 week period confined to their houses - food being brought by friends and relations from other clans - it is possible to examine the effect that indoor living has on morbidity. This, in turn, can yield insights into the associations between housing and morbidity.

Clearly, the kumánda was not anticipated and so the survey design did not allow for the ready analysis of data of this nature. It is assumed that the prevalences of a symptom amongst males and females will fluctuate in a similar way through time unless some new factor is introduced which affects only one sex. It is further assumed that the 8 weeks period of female indoor confinement is such a new factor. Tables were compiled showing the prevalences, by sex, before, during and after the kumánda and an example of these is given by Table 19.10.

The above assumptions imply that the figure 37 (for females during the kumánda) is a "wild" figure which disturbs the similarity of the variations through time of the male and female samples. The procedure adopted was firstly to perform a chi-square computation on the figures $\begin{array}{c|c} 257 & 139 \\ \hline 163 & 79 \end{array}$ in order to test the suggestion that the male and female prevalences fluctuate in a similar fashion through time. If a low chi-square value (less than 3.84) was obtained, then it was accepted that the assumption was correct and the analysis proceeded to check whether the value 37 (see Table 19.10) was different fromthat anticipated if the women had not been confined indoors. This was done with a second chi-square computation in which the figures $\begin{array}{c|c} 198 & 37 \\ \hline 420 & 218 \end{array}$ were tested. If the first chi-square value was greater than 3.84 then the assumption, regarding male and female prevalence fluctuations through time, could not be accepted and so the analysis did not continue.

Table 19.11 shows the results of this analysis. All symptom prevalences, except SKIN 1, SKIN 3 and TOOTHACHE, show a low chi-square value in the first test. These were then subjected to the second chi-square test which indicated that the kumánda had no effect on all female symptom prevalences except ACHE and EYE, which both fell.

ACHE and EYE are both significantly decreased by indoor confinement. This may be primarily due to the masking of the symptoms rather than their absence. Females were interviewed in their houses during the kumánda, and they would be less aware of aches and pains than if they were active and working. The decrease

TABLE 19.10

AVERAGE WEEKLY PERIOD PREVALENCES FOR SYMPTOM "ACHE" BY SEX AND DIFFERENT TIME PERIODS

Survey Week Numbers	Comment	Average Weekly Period Prevalences by Sex	
		Males	Females
1-4	Before Kumanda	257	139
5-12	During Kumanda	198	37
13-22	After Kumanda	163	79

TABLE 19.11

CHI-SQUARE TESTS ON MALE AND FEMALE SYMPTOM PREVALENCES BEFORE, DURING AND AFTER THE KUMANDA

Symptom	X^2 for Male and Female Prevalences Before and After the *Kumanda*[1]	X^2 for Male and Female Prevalences During *Kumanda* With the Mean of Male and Female Prevalences Before and After *Kumanda*[2]		Nature of Any Significant Change in Female Prevalences During the *Kumanda*
		X^2	P(df = 1)	
Ache	0.16	32.03	***	Fall
Eye	0.88	29.04	***	Fall
Skin 1	4.00			
Skin 2	1.23	1.96		No change
Skin 3	24.02			
Fever	0.18	0.84		No change
Pain	2.47	0.35		No change
Diarrhoea	2.08	0.06		No change
Cough	0.22	0.16		No change
Toothache	22.74			
Trauma	0.48	0.35		No change

* $p < .05$ ** $p < .01$ *** $p < .001$

1. For the case of ACHE (Table 19.10) the matrix tested here is:-

257	139
163	79

2. For the case of ACHE (Table 19.10) the matrix tested here is:

198	37
420	218

N.B. 420 = 257 + 163 and 218 = 139 + 79

in eye conditions may relate to the absence of bright, and irritating, sunlight in the dark Raiapu houses. Vines (1970:444) has commented on the possible role of ultra-violet irradiation in the causation of pterygium. Indoor living also protected the women from the aggravating effect of wind and dust. One might have anticipated that the continual exposure to smoke, caused by keeping the house fires burning all day, would have had an irritating effect on the eyes. This appears not to have been the case.

It should be noted that other symptoms may have been affected by indoor confinement but that the crude analysis presented here has not exposed them. Figure 18.4 shows a distinct rise in the prevalence of coughing, for both males and females, during the mourning, but Table 19.11 indicates that this rise occurred equally amongst men and women.

19.3.6 DISCUSSION

No clear associations between health and housing have emerged from the foregoing section except for the case of skin infections. Skin disorders do appear to be significantly more prevalent in the more crowded house-type; SKIN 1 prevalences are positively correlated with the number of house occupants; and an individual is more likely to suffer from skin infections if he lives with others who do.

Eye disorders seem to be less common in the more crowded houses and amongst women who remain indoors, although they have a higher prevalence amongst those who live with others who have eye complaints.

The data presented here has failed to show any positive association between coughing and the type of house, the degree of crowding or the length of time spent indoors. The exception to this is the relationship (a positive correlation at the 5% level) between coughing in 0 - 4 year olds and the number of people with thom they live (see Table 19.8). Figure 18.4 and Table 18.11 show a sharp rise in coughing during weeks 5 - 10 of the survey or, in other words, during the major part of the kumánda. Table 19.11 indicates that this rise in coughing affected males and females almost equally despite the fact that males were not confined indoors. It is possible that female coughing increased due to indoor living while male coughing rose equally due to increased cigarette smoking during the long days of enforced idleness. Woolcock and Blackburn (1967) survey chronic lung disease in Baiyer River, and amongst the Chimbu, and comment that:

> the high prevalence of cough in all age groups suggests a high incidence of respiratory disease ... the nature of their living conditions could be a significant factor ... the smoky atmosphere produced is extremely irritating.

The authors also comment that repeated respiratory infection is the prime factor and this is abetted by protein-calorie deficiency, the high incidence of smoking and helminthiasis. Similarly, Woolcock et al (1970) comment that the highly irritant atmosphere inside houses:

> causes bronchial and bronchiolar damage with impairment of clearing mechanisms in infancy, and this is aggravated by acute respiratory infections and the early age at which tobacco smoking is started, so that by adulthood a large number of the population has chronic bronchitis.

Blackburn and Green (1966), and Cleary and Blackburn (1968) have also discussed the linkages between respiratory disease and smoky living conditions. They conclude that the high smoke densities and aldehyde concentrations are, at the very least, an aggravating factor in respiratory tract infection. However, Woolcock et al (1973) report that cigarette smoking is not an important aetiological factor in chronic bronchitis at Baiyer River.

It may be concluded from the data reported here that (with the exception of the 0 - 4 year olds) other factors are more crucial than living conditions in the aetiology of chronic lung disease. The effect of smoky houses may therefore have been masked by the influence of other variables.

19.4 WATER AND HEALTH

19.4.1 A REVIEW OF SOME RELEVANT LITERATURE

The interactions between water and human health are complex and numerous and space does not permit a full appraisal here. Many of the traditionally accepted concepts regarding health and water are intuitive in nature and are not founded on quantified experimentation or observation. Because of this, there is a great need for studies which attempt to precisely define the role of water in medical ecology and which help to predict the outcome of particular water improvement schemes (W.H.O., 1964b:25). The weaknesses in present practice and understanding are admirably summarised by White et al (1972:151):

> There are three main objections to much available discussion of this topic: first, a tendency to select from the available studies only those data supporting the writer's viewpoint; second, extrapolation of results from one area to another - especially from urban to rural areas and from temperate to tropical areas - without regard for epidemiological differences between them; and third, the fallacy of misplaced aggregation: lumping together the health problems

> resulting from poor supplies as "water-borne diseases" in such a way as to imply that only one type of improvement is relevant and necessary. The last two of these objections have great weight in developing countries because in the past many of those concerned with promoting improved supplies were chiefly oriented toward urban needs in temperate climates. . . . .
> It has become plainly evident that, for the rural tropics at least, we do not have the data to accurately compute the burden of water-borne disease, nor can estimates be made of the medical consequences of improving water supplies without running the hazard of very large error.

In a similar vein, Bradley and Emurwon (1968) write:

> The effects of changing the water source environment are therefore fairly predictable in terms of quantitative indices of pollution but prediction of the resulting epidemiological changes is not yet possible with any precision, since the simple relations which have usually been assumed to operate between pollution and disease in municipal water supplies in temperate countries by no means necessarily follow in the rural tropics.

Studies have been reported on the relationships between water and diarrhoeal disease in the southern parts of the United States (Hollister et al, 1955; Rubstein et al, 1969; Schliessman et al, 1958; Stewart et al, 1955; Watt et al, 1953). Although these authors are not reporting rigorously designed experiments, there appears to be a consensus that piping water into houses can cause great reductions in diarrhoeal disease, even amongst children, and that the availability of the water is more important than its quality. These and other studies indicate that diarrhoea associated with Shigella may be particularly prone to reduction following the installation of piped water supplies.

Studies linking water with diarrhoeal disease are complicated by the fact that the aetiology of childhood diarrhoea in the tropics has proved extremely difficult to pin down. Sen et al (1963) report that they could find no likely pathogens in 28% of the 200 cases of childhood diarrhoea studied in Nigeria. Similarly, Gordon et al (1964a) find that laboratory differentiation of diarrhoeal disease is often impossible and suggest considering a clinical syndrome of "acute undifferentiated diarrhoeal diseases". Gordon (1964) suggests that specific control measures against these undifferentiated diarrhoeas will be futile and that the correct approach is a broad ecological attack concentrating on environmental sanitation.

A study of nutrition and infection in Guatemala (Behar et al, 1968; Scrimshaw et al, 1967, 1969) found that the introduction of medical services and improved water supply (which did not include a plentiful supply to each house) improved the death rates but did little or nothing to morbidity. Gordon et al (1964b, 1964c) stress the importance of educational and cultural factors in diarrhoea control and point out that environmental measures, such as improved water supply, will have little effect on weanling diarrhoea. Bruch et al (1963) studied endemic, and periodically epidemic, diarrhoea in Guatemala. They conclude that person to person contact was the primary route of infection and that the water supplies, although polluted and inadequate, were relatively unimportant. Stanhope (1967) surveyed acute diarrhoea in the Lower Ramu Valley of New Guinea and found that hospital treatments for acute diarrhoea peaked markedly in years with exceptional floods and, within any year, in months of high rainfall and flooding. Deaths from diarrhoea also appeared to rise in the wettest months. Stanhope finds that the degree of contamination of water supplies may have some slight influence but that "the direct oral ingestion of contaminated water as a beverage is not thought to be of importance". Washing habits, on the other hand, were considered to be an important factor.

These studies of diarrhoeal disease in the developing tropics leave the reader with the following impressions: that improvements in water quality may have minimal impact on diarrhoeal disease, that improvements in water availability (and thereby the quantity that is used) may be more effective, that cultural and educational factors (such as personal hygiene, diet and child-rearing practices) are likely to be crucial and that any programme which concerns itself merely with water supply improvements is likely to achieve little. In view of this, some of the claims made on behalf of water supply improvement appear a little extravagant. Wagner and Lanoix (1959:10) comment that "more health benefits can be gained from moneyspent on a water-supply programme than in any other way". Allbrook (1972) comments that water supplies have "enormous potential for health improvement" in Australasia. W.H.O. (1964a:9) implies that cholera, typhoid, dysentery, diarrhoeal disease and viral enteric diseases are all primarily water-borne. These authors all appear to overstate the case for improved water supplies. W.H.O. (1964b:17) takes a better perspective:

> The evidence of the importance of safe municipal water supplies in controlling and preventing water-borne outbreaks of typhoid fever and cholera is highly persuasive. Similar evidence, however, of the effect of such developments on the reduction of morbidity and mortality due to diarrhoeal disease is largely presumptive.

The relevance of water to disease control throughout the world has recently been stressed by several authors. Carmichael (1972) describes the control of anopheline mosquitoes by water management; Simpson (1972) relates arbovirus diseases to water storage habits and to floods; Barua (1972) stresses the role of water pollution in explosive outbreaks of cholera in Africa and Turkey, and Jordan (1972) describes the role of water supply improvements, and the reduction of water-contact, in the control of schistosomiasis.

Writers on the Pacific region have examined the connection between water and other health parameters. Vines and Kelly (1966) report that Ascaris infection in the New Guinea Highlands is higher in areas where flatter terrain causes poor run-off. Maguire (1971) comments on the higher incidence of dengue antibodies in the wetter areas of Fiji where mosquitoes are more numerous. Peters (1965) and Peters and Christian (1963) stress the role of drainage and rainfall in determining the availability of breeding sites for A. farauti and A. punctulatus in the New Guinea Highlands. Peters and Christian (1960) report that the biting density of A. farauti is 80 times greater in the wet than in the dry season at Minj. Walzer et al (1973) report that an outbreak of Balantidiasis on Truk was due to the widespread contamination of surface and ground waters with pig faeces and that the population was forced to use these polluted waters when their normal supplies were destroyed in a typhoon. Couvee and Rijpstra (1961) and Radford (1973) have discussed the occurrence of Balantidiasis in West Irian and Papua New Guinea, and the manner in which this disease is passed from pigs to humans.

19.4.2 A CLASSIFICATION OF WATER-RELATED DISEASE

Water-related diseases will be defined as all those infectious diseases whose incidence or severity are likely to change following a change in the community's water supply. Previous classifications of water-related disease have been either confusing, inadequate or oriented towards urban and temperate situations. White et al (1972: 162) have proposed a new classification of water-related disease in

East Africa and this appears highly suited to the New Guinea situation. This classification involves 4 basic divisions; "water-borne", "water-washed", "water-based" and "water-related insect vectors". Water-borne diseases are transmitted when the pathogenic agents gain access to domestic water supplies and are subsequently ingested. Water-washed diseases are those whose prevalences will fall following an increased usage of water for personal and domestic hygiene, irrespective of the quality of the water. In other words, the pathogen is not within the water but rather the water is a cleansing fluid for removing pathogens from contaminated surfaces. Water-based infections are those dependent on aquatic organisms to complete the life cycle of the pathogenic agent. They are all forms of helminthiasis (parasitic worm infections). Finally, water-related insect vector diseases are those which are spread by insects which either breed in water or bite near it. This classification is set out in Table 19.12.

An advantage of this classification is that diseases are grouped in such a way that the preventive measures, appropriate to each group, are clear. For instance, category 1 (Table 19.12) may respond to improvements in water quality, category 2 to improvements in water availability and personal hygiene and categories 3 and 4 to better management of surface waters and drainage. It must be noted that the classification of a particular disease as water-borne (for instance) does not imply that it is not also transmitted in other ways, but merely that it may be in part transmitted by the ingestion of polluted waters. Many infections, for instance gastroenteritis, dysentery, hepatitis and cholera, must be classified in both categories 1 and 2b and it is important in the planning of preventive measures for a particular community to decide whether the spread of these infections is prim-

TABLE 19.12

A CLASSIFICATION OF INFECTIVE WATER-RELATED DISEASES ACCORDING TO WHITE ET AL., (1972:163)

Category		Example
1.	Water-borne	
	a) Classical	Typhoid
	b) Non-classical	Infectious hepatitis
2.	Water-washed	
	a) Superficial	Trachoma, Scabies
	b) Intestinal	Shigella dystentery
3.	Water-based*	
	a) Water-multiplied percutaneous	Bilharziasis
	b) Ingested	Guinea worm
4.	Water-related insect vectors	
	a) Water-biting*	Gambian sleeping sickness
	b) Water-breeding	Onchocerciasis

* Categories 3a, 3b and 4a do not occur in Papua New Guinea

arily due to polluted water or to the lack of water used for hygienic purposes. A water-related disease is one whose prevalence is likely to change following the appropriate water improvements but, since it may be also transmitted in ways having no connection with water, the most perfect water supply will not necessarily eradicate the disease.

Considering Table 19.12 in relation to the Papua New Guinean situation, it is apparent that this country is fortunate to have no diseases in categories 3a, 3b or 4a. Category 3 is comprised of diseases due to water-based helminths. These helminths have a necessary part of their life cycles taking place in an aquatic animal, as opposed to other helminths (such as Ascaris) which are not associated with aquatic animals and which fall into category 2b and possibly also category 1b. The main occupant of category 3a is bilharziasis, or schistosomiasis [1], which results from an infection of the human venous system by species of worms (most commonly Schistosoma haematobium and S. mansoni) which spend part of their life cycles in aquatic snails. Schistosome worms are not found in New Guinea. The main disease in category 3b is infection by the guinea worm, Dracunculus medinensis, which utilizes a cyclops host, and is also not found in New Guinea. Category 4a comprises a sleeping sickness due to infection by the flagellate Trypanosoma gambiense [2], which is transmitted by the tsetse fly. The trypanosomes are not found in New Guinea. Category 4b, on the other hand, is clearly an important category in New Guinea with malaria being the foremost example of this type of infection.

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1. See Smithers (1972) and Jordon (1972) for recent reviews of schistosomiasis research.

2. See Lumsden (1972) for a review of trypanosomiasis research.

Thus categories 3a, 3b and 4a can be discounted when New Guinea is under discussion. A further important absentee, from diseases which might be included in Table 19.12, is cholera which in many parts of Africa and Asia would be the most significant member of category 1a. Despite the alarming world spread of cholera since 1961 (Barua, 1972), Papua New Guinea has so far escaped this disease. However, it is reported from West Irian and the possibility of its introduction into Papua New Guinea is of the greatest concern, since the poor water supply and hygiene situation (such as that described here) would favour its rapid establishment.

Having indicated which diseases are notably absent from the water-related disease pattern in Papua New Guinea, Table 19.13 is presented to show which are present. Table 19.13 lists the more important water-related infections in the Enga region and, based on the Saka situation, estimates the likely outcome of improvements in water quality and water availability (quantity). The viral diseases (enteroviruses and infectious hepatitis) in Table 19.13 are speculative inclusions since the epidemiology of these diseases is not fully understood (Mosley, 1967). In the case of hepatitis (types A and B) there is good evidence to assume that it can be water-borne (Horst, 1972; Mosley, 1967; Villarejos et al, 1972) and for other viral infections one can say that it is probable that water-borne transmission occurs.

19.4.3 WATER POLLUTION AND MORBIDITY AMONGST TOMBEAKINI

Tombeakini water use and the faecal pollution of water sources have been described in Part II and III of this thesis. The nature of the data collected, and the small size of the sample, do not permit any thorough analysis of the interactions between water quality, water

TABLE 19.13

SOME WATER-RELATED INFECTIONS FOUND IN NEW GUINEA WITH ESTIMATES OF THEIR RESPONSE TO WATER IMPROVEMENTS IN THE SAKA SITUATION

Disease	Category (Table 19.12)	Improve Quality	Improve Availability
Typhoid	1a, 2b	***	*
Leptospirosis	1a, 2b	**	*
Bacillary dysentery	1a, 2b	**	**
Amoebic dysentery	1a, 2b	**	**
Paratyphoid	1a, 2b	*	*
Infectious hepatitis	1b, 2b	*	**
Enteroviruses	1b	*	
Gastroenteritis	1b, 2b	*	**
Skin sepsis	2a		***
Skin ulcer	2a		**
Trachoma	2a		***
Eye inflamation	2a		**
Scabies	2a		**
Yaws	2a		*
Leprosy	2a		*
Tinea	2a		*
Ascariasis	2b, 1b	*	**
Other nematodes (Table 11.1)	1b, 2b	*	*
Malaria	4b		

quantity and morbidity. However, it is possible to compare the health of those who use the Punate exclusively with that of those who use the Tobaka or the Tobaka and the Punate. As in Part II, a Punate-user will be defined as one who lives in a house which habitually collects its water from the Punate. Similarly for a Tobaka-user. The comparison is therefore between the health of those who normally drink only lightly polluted water (Punate) and those who drink heavily polluted water (Tobaka). Table 13.4 should be consulted to see the differences in faecal pollution between these water sources.

Table 19.14 sets out the comparison between those who use the Punate only and those who sometimes or always use the Tobaka. With the exception of SKIN 1 there is no significant difference between the health of these 2 groups. The higher prevalence of SKIN 1 amongst Tobaka-users is not understood since SKIN 1 lies in category 2a (Table 19.12) and it was established that Tobaka-users do not use a greater volume of water than Punate-users.

As a further attempt to clarify the influence of water pollution, and to compare it to the influence of other factors which have been discussed, an analysis of variance was conducted on the morbidity data. In the preceding sections, the influences of age, sex, education, linguistic ability, work experience and housing on morbidity have been examined. Unfortunately, if all factors are included in an analysis of variance, the factor matrix becomes so large that some individual cells are of very dubious reliability while others are completely empty. For instance, all cells containing the health of individuals over 40 years of age, who speak neo-Melanesian, are empty. Three factors only were selected in order to limit the size of the factor matrix. These are age (note that the effects of language ability, schooling and work experience are heavily confounded with that of age), health of co-

TABLE 19.14

AVERAGE WEEKLY PERIOD PREVALENCES PER 1000 ACCORDING TO WATER USAGE

Symptom	Average Weekly Period Prevalences Per 1000		X^2	Level of Significance (df = 1)
	Punate Users	Tobaka Users		
Ache	140	141	0.00	
Eye	71	75	0.20	
Skin 1	185	224	6.68	**
Skin 2	47	59	1.92	
Skin 3	6	13	3.50	
Fever	40	40	0.00	
Pain	41	49	0.98	
Diarrhoea	39	32	0.94	
Blood	2	4	0.75	
Vomit	3	2	0.14	
Cough	129	152	3.21	
Toothache	96	94	0.03	
Trauma	15	11	0.97	

* $p < .05$ ** $p < .01$

habitants (hereafter called "exposure") and water source. The particular aim here is to provide more information about the influence of water and so only those symptoms, which may be considered strongly water-related, are analysed.

The analysis of variance technique involves testing the "variance ratio" (F) of the variance due to an individual factor (or combination of factors) to the residual variance. Moroney (1970: 371-457) should be consulted for a lucid explanation of this technique. The variance ratios obtained, by conducting an analysis of variance with the factors shown in Table 19.15, are given in Table 19.16. The variance ratios are tested for significance by reference to a table of the distribution of F with the appropriate degrees of freedom.

The most striking feature of Table 19.16 is the insignificance of water source as a variance-causing factor. In all cases, except TOTAL SKIN, the variance due to water is considerably less than the residual and, in the case of TOTAL SKIN, it is only slightly greater. This confirms the impression given by Table 19.14, that those who habitually use water that is as clean as one would find anywhere in the Highlands (i.e., the Punate) are no more healthy than those who habitually use a turbid, and faecally contaminated, source.

Another feature of Table 19.16 is the failure to obtain much significance (i.e., to explain much of the variance) using only 3 factors with a total of 8 levels. This relates to the problems discussed in section 19.1. Individual morbidity is dependent on a host of factors and, for a satisfactory analysis, enough of the important factors (or combinations of them) must be employed. However, more factors lead to a larger matrix, and a larger survey sample is needed if each cell in the matrix is to contain data of reasonable reliability.

TABLE 19.15

DETAILS OF FACTORS, AND FACTOR LEVELS, USED IN ANALYSIS OF VARIANCE

Factors	Number of Levels	Range of Levels
Age	3	0-4, 5-19, 20 + } Selected by consideration of Table 18.12
Exposure (Health of Cohabitants)	3 for Skin 1, Skin 2 and Total Skin	0 1% - 20% 21% - 100%
	2 for Skin 2, Pain, Diarrhoea and Blood	0 1% - 100%
Water Source	2	Those using only Punate. Those using only Tobaka or Punate and Tobaka

TABLE 19.16

F TESTS ON VARIANCE RATIOS OBTAINED FROM THE ANALYSIS OF VARIANCE OF THE PREVALENCES OF 7 MORBID SYMPTOMS

SOURCE OF VARIANCE	STATISTIC	SKIN 1	SKIN 2	SKIN 3	TOTAL SKIN	PAIN	DIARR-HOEA	BLOOD
AGE	VARIANCE RATIO	2.7	1.6	0.5		1.4	1.2	0.4
	DEGREES OF FREEDOM	2/12	2/12	2/7		2/7	2/7	2/7
	LEVEL OF SIGNIFICANCE							
EXPOSURE	VARIANCE RATIO	4.5	0.0	0.0		0.5	0.7	0.6
	DEGREES OF FREEDOM	2/12	2/12	1/7		1/7	2/7	2/7
	LEVEL OF SIGNIFICANCE	*						
WATER	VARIANCE RATIO	0.5	0.1	0.0	1.2	0.3	0.0	0.3
	DEGREES OF FREEDOM	1/12	1/12	1/7	1/8	1/7	1/7	1/7
	LEVEL OF SIGNIFICANCE							
AGE AND EXPOSURE	VARIANCE RATIO	0.7	1.1	0.0	108.7	3.0	3.3	6.9
	DEGREES OF FREEDOM	4/4	4/4	2/2	4/4	2/2	2/2	2/2
	LEVEL OF SIGNIFICANCE				***			
AGE AND WATER	VARIANCE RATIO	1.1	1.5	0.1	7.2	0.2	0.7	1.0
	DEGREES OF FREEDOM	2/4	2/4	2/2	2/4	2/2	2/2	2/2
	LEVEL OF SIGNIFICANCE				*			
EXPOSURE AND WATER	VARIANCE RATIO	2.7	3.5	1.0	16.2	0.8	2.2	3.2
	DEGREES OF FREEDOM	2/4	2/4	1/2	2/4	1/2	1/2	1/2
	LEVEL OF SIGNIFICANCE				*			

* $p < .05$ ** $p < .01$ *** $p < .001$

NOTE Where a first order interaction (e.g., A + B) is significant, the analysis cannot continue to examine the individual effects of A and B at the same level of significance. Where first order interactions are not significant, the variance, and degrees of freedom, due to these interactions are added to the residual variance and residual degrees of freedom. The variances of individual factors are then tested against this new, enlarged residual.

19.4.4 CONCLUSION ON WATER AND MORBIDITY IN THE SAKA

In section 19.4 the literature on water and disease has been briefly reviewed, a classification of water-related disease has been presented and the Tombeakini situation has been examined.

The interrelationships between water supply and morbidity are complex and fall into 2 categories. The effect of water quantity and the effect of water quality. In section 19.4.3, those who drink faecally contaminated water were compared with those who drink less contaminated water. This, therefore, was an attempt to examine the effect of water quality. It is limited by the fact that the Punate is not a clean source (but merely a less dirty source) and also by the difficulty in defining a "Punate-user". A Punate-user was held to be someone who normally resides in a house that will always draw its water from the Punate. Such a person may, however, drink from other rivers during his daily travels or, especially if he is a bachelor or child, he may on occasions sleep with friends who use a different water source. The survey design did not allow a more rigorous test of the proposition that water quality is associated with morbidity. The comparison which was made indicated that all symptoms, except SKIN 1, were not associated.

Based on the content of section 19.4, and on other material reported in this thesis, the author has formulated a view of the role of water in morbidity causation amongst the Saka Raiapu. This view rests partially on quantitative data, such as that reported in Tables 19.14 and 19.16, and partly on speculation and estimation based on a year's residence in the Saka and on a study of the relevant literature (see section 19.4.1). This view of water and disease in the Saka will be set out below in some detail in the belief that it is a useful and original contribution to understanding in this field. However, it is not proven and parts of it are not supported, or negated, by available data. It must remain therefore for future investigations to add new information which will either support, modify, or contradict the view presented here. The author's view will be given in 3 paragraphs.

1. Although the people of the Saka utilize domestic water sources which are faecally polluted, and in some instances heavily so, the ingestion of this faecal material is not a major influence on their health. There are 3 main reasons for this. Firstly, all the pathogens which may be ingested in polluted waters are also ingested by faecal-oral contact in the domestic situation. The standards of personal and domestic hygiene are so low that direct faecal-oral contact is certainly the primary route for the spread of most infections and the small impact of polluted waters is obscured by the over-riding factor of poor hygiene. Secondly, the volumes of polluted water which are drunk are extremely small (Table 7.10) and thus the risk of receiving an infective dose of pathogens is reduced. Thirdly, the great majority of the faecal polluting material is probably of non-human origin and so, although it is potentially pathogenic, it is perhaps less so than an equal amount of human pollution.
2. Following from this is the assertion that water quantity and availability are crucial. If improved availability of water were arranged, coupled with a change of Raiapu attitudes to hygiene which resulted in increased water use, then a dramatic improvement in health is anticipated. This improvement would occur irrespective of the quality of the water being used. In other words, most water-related disease in the Saka today is primarily water-washed rather than water-borne. The important factor is the

change in attitudes and habits which would lead to increased water use and increased hygiene. The prevalences of skin infections (presently the most common water-related diseases amongst the Raiapu), eye infections and gastroenteric infections would show the greatest improvement.

3. Following from points 1 and 2 above, it is possible to predict the impact of a new water supply installation in a Saka community. Suppose a reticulated supply was installed which provided abundant water at a stand-pipe located centrally in a Raiapu clan territory. If the water was clear and cool, which it probably would be, the Raiapu would welcome it and those who lived nearer to the stand-pipe than to their original source, would use the stand-pipe. If the water supply installation was not accompanied by any supporting health programme [1], then the stand-pipe would approximate to the Punate spring in Tombeakini. It would provide good quality, but not completely pure, water and those who used it would also drink elsewhere while they were travelling or sleeping with friends. It would not in itself alter Raiapu water use patterns or change the level of hygiene. The effect on the health of those who used this new supply can be predicted to be minute or non-existant. To instal a new supply and do nothing else is to change one variable - namely water quality. Since it has been argued that this is the variable of least importance, it follows that a new supply will not cause a marked improvement in the health of its users.

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1. The reader may think that to install a new supply without any supporting medical programme is clearly ill advised and is not likely to be contemplated. However, it is precisely what occurs with most new water supply installations in the Highlands, as described in Appendix III.

This view of water and disease is based on the author's perception of the situation in the Saka in 1971. It is subject to one important proviso and that is the unknown effect of the introduction of a new water-borne pathogen into the Saka to which the people have little or no immunity. In other words, the risk of a water-borne epidemic - perhaps of cholera if it were ever introduced. Whether these comments regarding the unimportance of using faecally contaminated water would remain valid in the face of a cholera outbreak is most doubtful. It could be that water pollution would then become an important mechanism for spreading the epidemic and that those people using the imaginery new supply would enjoy a measure of protection. It is notable that the Enga residence pattern of dispersed, and sometimes quite isolated, houses is naturally resilient to epidemics. The classical situation which is conducive to epidemics is that of many people living in crowded and unhygienic conditions and sharing a common water source. The Enga are scattered and use many water sources, but there is always the danger that the faecal material in the rivers will spread the outbreak to downstream populations.

The only evidence available to judge the impact of a water-related epidemic amongst the Raiapu is information on the dysentery outbreak which occurred in the Highlands between about 1938 and 1945. Unfortunately, there are no reliable or comprehensive accounts of this outbreak and one must reconstruct the story from casual references to it by white authors (Gitlow, 1947; Simpson, 1954) and from the oral histories of the Highlanders themselves. The first prolonged contact between white men and the Saka Raiapu was in 1938-1939 when the Hagen-Sepik Patrol established a camp in the Saka

(Taylor, 1940). Soon after this, in about 1941 [1], a dysentery epidemic swept through the area and caused much mortality.

The Saka Raiapu associate the disease with the white man's arrival. They say that there was never an epidemic like this before or since and that this type of disease was unknown before 1941. They say that there was diarrhoea prior to 1941 but nothing so severe as dysentery. It seems most probable that dysentery did spread through the Highlands in early European times due to the introduction of a new pathogen to which the people had little resistance. Bowers (1971) describes the possible impact of the dysentery epidemic on the Upper Kaugel Valley, and population depletions in immediately post-contact times have been recorded for the Chimbu (Brown and Winefield, 1965), the Maring (Rappaport, 1968), the Siane (Salisbury, 1962) and the Fore and Gimi (McArthur, 1964).

The amount of mortality caused by these post-contact epidemics can be only estimated but the authors cited above indicate that the death rate could have been as high as 20%. Tombeakini claim confidently that 15 of their clan died in the 1941 dysentery epidemic. This is about 7% of the clan population and, if typical of the Saka, gives a figure of 700 deaths in the valley.

Supposing this figure is accurate, how did these 700 people (and the many more who were sick but did not die) become infected? Was the dysentery spread entirely by faecal-oral contact or did water pollution play a part? The dispersed living patterns of the Enga might lead to a belief that water pollution must have been an influence because isolated living mitigates against spread by person-to-person

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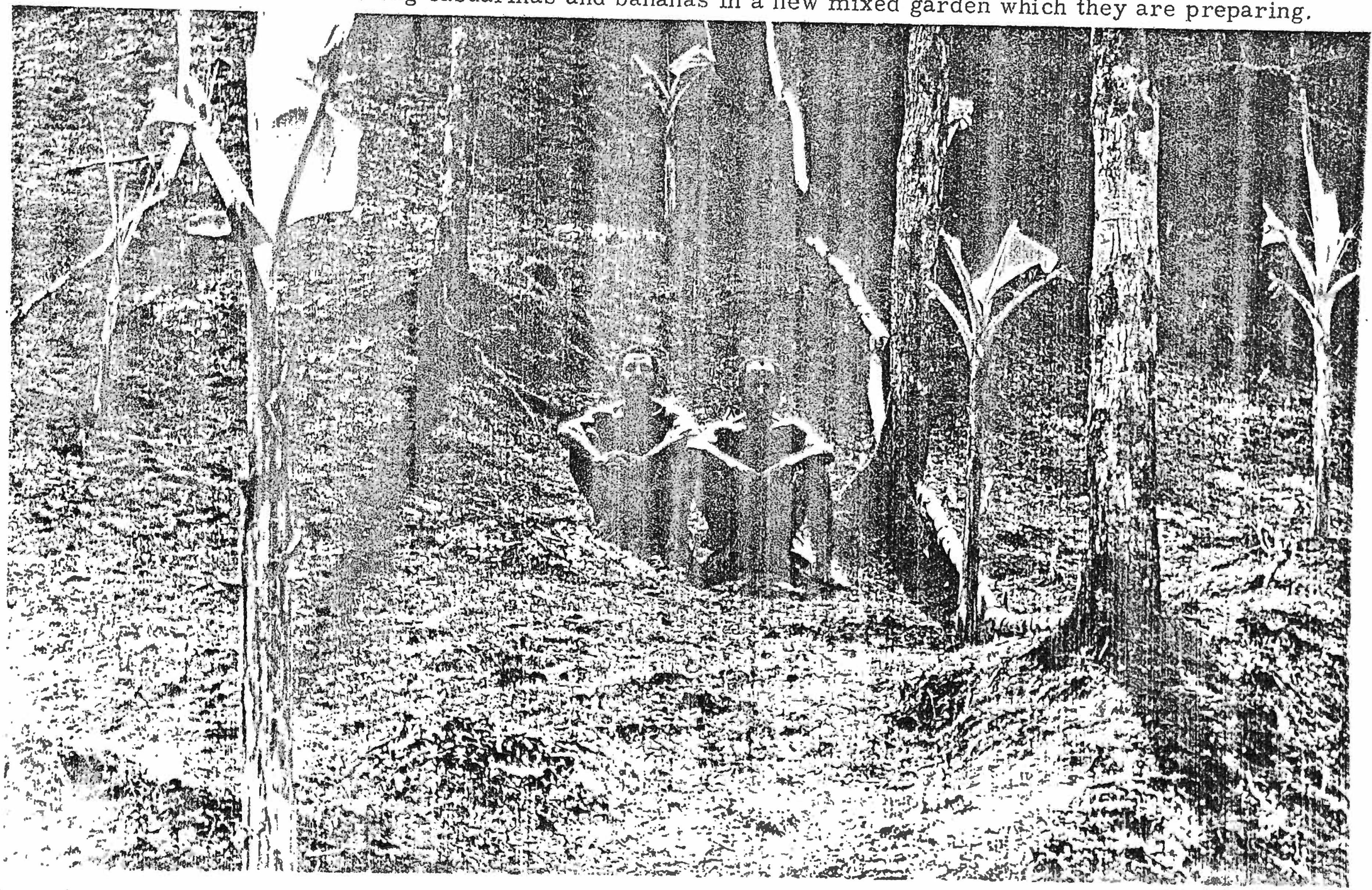
1. I believe that the epidemic occurred in 1941 or 1942 based on interviews with middle-aged Saka men who still clearly remember it.

contact. However, the Raiapu response to a death is firstly to gather in large numbers to cry and wail, then to gather in selected houses to live and sleep, thereby causing overcrowded conditions, and finally to gather again in a large ceremonial wealth distribution (see section 3.8). All these aspects of the kumánda (the Raiapu response to death) facilitate the rapid spread of an epidemic and destroy the advantages gained from dispersed dwelling patterns.

This doubt about the impact and mode of transmission of a new epidemic must remain as an important proviso to what was said earlier on the insignificance of water pollution. If 7% of the Saka population died in the 1941 dysentery epidemic, how many would die in a cholera epidemic tomorrow? More particularly, would the Saka population resist that epidemic any better if they were equipped with clean water sources or would the lack of hygiene and the kumánda behaviour be the dominant epidemiological factors?

Wakeo, Tombeakini's oldest clansman, who was a topóli before he became senile.

Tombeakini clansmen rest among casuarinas and bananas in a new mixed garden which they are preparing.



A boy fills two gourds from a small spring.

A child collects water from the Punate stream.

PART V

IMPLICATIONS AND CONCLUSIONS

CHAPTER 20

IMPLICATIONS FOR GOVERNMENT POLICY

The data on environment and health among the Raiapu, which are reported in Parts I to IV of this thesis, are clearly the types of data on which an environmental health programme can be based. The situation with respect to both morbidity and environment (especially water) is defined in some detail, and is set within a cultural context, so that rational development policies could be drawn up to achieve selected goals without instigating unforeseen and undesirable side-effects.

20.1 PROBLEMS IN DEVELOPMENT AND SOCIAL CHANGE

Raiapu Enga society is not, and was not, a static system but rather it is undergoing a constant process of adaptation and change, partly in response to changes in the circumstances and environment external to the society, and partly induced by forces generated within the society [1]. However, these involuntary changes are very different from changes deliberately encouraged or imposed by an external agency, and there is an extensive literature on the dangers and responsibilities associated with developmental planning and engineered social change. Writers have stressed that developmental strategies must be formulated in the light of the particular culture under consideration, and with full regard to the beliefs, customs, opinions and aspirations of the community affected by the proposed development. If this is not done, either the development project will fail, or unforeseen and

1. Brown (1972:121-125) describes this state of social flux, and the manner in which it was affected by the coming of the white man, amongst the Chimbu people.

deleterious consequences will result, or both.

Foster (1962), Paul (1955) and Spicer (1967) all discuss these problems at some length and present numerous case studies of development projects which have failed due to inadequate allowance for social and cultural factors. Spicer (1967:285-294), in his conclusions, isolates customs, social organisation and the role of innovators as 3 elements of particular importance. On customs he writes:

> Any given custom has meaning not only in itself as satisfying a particular need, but also as part of a larger whole which constitutes the way of life of a people....A change of apparently small magnitude in one aspect of the culture may, therefore, seem to threaten the whole system, or at least require the learning of a new viewpoint toward a whole series of customs...a knowledge of how a given people's culture is integrated, how the different customs and beliefs are related to one another, gives a basis for predicting what the effects of a proposed change will be.

On social organisation Spicer writes:

> The social organisation of any people, like the culture of which it is a part, constitutes an interrelated whole, and changes in one section will have greater or less repercussion on others...the existing channels of communication and cooperation constitute a beginning point for the introduction of anything new. They represent generations of effort in the establishment of working relations and consequently a means for the the enlistment of human energies in new directions.

On innovators he writes:

> The history of the relations of the innovator's ethnic group with the people among whom he is working may be an important basis of favorable or unfavorable attitudes towards him, regardless of his own individual characteristics...

> native innovators with prestige in the existing social system may be especially effective.

In summary Spicer (1967:291) writes:

> It should be constantly borne in mind in cross-cultural situations that the cultures in which we grow up predispose us to certain views and values. We come to another culture with preconceptions about what is good and what is rational or sensible which do not hold good universally and these preconceptions may result in great misunderstanding.

Developments associated with public health and water supply are just as dependent upon these social considerations as other kinds of developments. Case studies, of failures in water improvement projects in Peru, are reported by Holmberg (1967) and Wellin (1955), and failures and problems related to health programmes are reported in the case studies edited by Paul (1955). Foster (1962:15) takes an example from the field of water supply development to illustrate the complexity of the development process:

> The keystone of community environmental sanitation is a potable water supply. During recent years sanitary engineers in many countries have designed and built hundreds - perhaps thousands - of water supply systems in villages and small towns previously served only by wells, streams, or lakes. Unfortunately, many of these projects have functioned at less than top efficiency: breakdowns are frequent and repairs are slow in coming; mudholes sometimes develop around broken taps and flies and mosquitoes breed. Whole systems have fallen into disuse for one reason or another. These failures can be understood and some provision made to prevent them, if it is recognised that a water supply system is not simply a problem in engineering design, but rather a function of the total way of life of a group.

> A successful water installation requires a whole series of preconditions, and if these preconditions do not exist, or cannot be created, failure is probable.

These quotations provide a brief introduction to the complex question of planning for social change and illustrate the types of problems which must be borne in mind when considering health improvement policies for the Raiapu Enga.

20.2 EXISTING POLICIES ON RURAL ENVIRONMENTAL HEALTH

The Public Health Department of Papua New Guinea appears not to have very clear aims in the field of rural environmental health, nor does it appear to attach great priority to this sector of the national health endeavour. Recent annual reports of the Department of Public Health indicate that the health inspectors (trained at the Paramedical College in Madang) are to be used increasingly in urban situations. Environmental health in rural areas will become the responsibility of local government councils which, with the aid of central government subsidies, will employ health inspectors and instigate environmental sanitation, housing and water supply projects in their areas. The Kainantu Local Government Council in the Eastern Highlands District has been active in the field of water supply installation for several years and its efforts are described in Appendix III.

The 1971-72 review of the First Papua New Guinea Development Programme (Office of Programming and Co-ordination, 1972) devotes 3 out of 58 pages to reviewing progress in the health field. The review is entirely restricted to the topics of malaria, tuberculosis, leprosy, maternal and child health, clinical services and man-power. Environmental health and water supplies are not mentioned. Similarly, a recent report on development strategies (Overseas Development Group, 1973) makes no mention of environmental health policies other than those concerning nutrition.

The International Bank for Reconstruction and Development, in its report on economic development in Papua New Guinea (I.B.R.D., 1965), comments at length on policies for health, housing, water supply and sewerage. On the subjects of environmental health and preventive programmes, the I.B.R.D. writes:

> It is precisely at the village or community level that improved sanitation is most needed and the addition of an assistant health inspector to the staff of each health center, expansion of the health education campaign and more mobile infant welfare clinics can be expected gradually to bring it about . . . The Mission fully endorses the department's intention to increase preventive medicine's share of total health expenditures by technically sound steps.

On housing and water supply, I.B.R.D. directs its comments almost entirely to urban problems, but it approves the policy of central government subsidies to local government councils to assist with village water supply installations.

20.3 IMPLICATIONS FOR HEALTH POLICIES AMONGST THE RAIAPU ENGA

The main purpose of this chapter is to outline policy recommendations which follow from the preceding parts of this thesis. This will be done in 6 sections (a. to f.) which concern different aspects of health policy. All recommendations given relate strictly only to the Raiapu Enga, although they may well have some applicability amongst other groups of Highlanders. The possibility of applying data reported in this thesis to areas outside the Saka has been discussed at various points throughout the thesis and Table 18.5 presents a useful comparative survey of environmental and cultural features in different regions.

a) The most important single policy implication of this study is that the installation of improved water supplies is not justified as a health improvement measure. Data on water use in Part II, data on water quality in Part III, and the discussion of water and disease in section 19.4, have shown that, in the absence of other health improvement projects, little or no benefits to community health can be expected to follow a water supply installation. Therefore the government, or local government council, should not allocate funds to water supplies as isolated development programmes, if they are justifying the expenditure on the grounds of the anticipated improvements in health.

However, there are 3 other grounds on which they may consider expenditure on water supplies to be justified. Firstly, water supply as an amenity which will improve the quality of daily life. Secondly, water supply as a political measure designed to placate a community which feels neglected, or which has complained that it receives no benefits from the yearly taxes that each adult must pay. Thirdly, water supply as an insurance against the possible introduction of cholera into the New Guinea Highlands. However, this last justification is only operative if the people change their existing water use habits (see Part II) and make full use of the new supply. This will only occur if the houses are closer to the taps than they are to the traditional supplies (a major undertaking where houses are so scattered) and if people are educated not to drink from polluted waters while travelling or working in the gardens.

If it is decided to build a water supply, based on 1 or all of these 3 justifications, then the design guides given in section 8.1 will be of value.

b) Changes in patterns of domestic and personal hygiene may be expected to have a substantial impact upon health and improved water supplies would be a necessary adjunct to improved hygiene. Improved hygiene would lead to greatly increased volumes of water used and water supply improvements which brought the required volumes close to the houses would be essential to promote and sustain a high level of water use. Also, following improvements in hygiene, the impact of water-borne disease on the community would rise, and it would be necessary to control the faecal content of domestic water sources.

c) Points a) and b) jointly suggest the general principle that integrated, rather than piecemeal, health programmes are called for. To tackle water supply in isolation is liable to be fruitless and, similarly, to affect attitudes to hygiene, without also improving water supplies, housing and other environmental aspects, is likely to be of little value. In fact, a piecemeal development project which fails will do positive harm, because it will be harder to obtain community approval for the reintroduction of similar measures at a later date.

d) Point b) asserts that changes in hygiene are a crucial component of any environmental health programme among the Raiapu. This raises the question of whether, or how, these changes are to be stimulated. Three courses of action are possible. Firstly, one can attempt to change hygiene in a relatively short time period by mounting a massive attack on existing behaviour and by legislating to prohibit certain unhygienic practices. Secondly, one can do nothing, arguing that hygiene will gradually improve due to the increasing exposure of the community to new ideas and customs, through travel and education. Thirdly, one can launch a long-term campaign designed to bring about a rate of change of hygienic behaviour which is a compromise between the 2 extremes stated above. This can be done by increasing the component of health and hygiene instruction within the primary school syllabus, by stimulating aid post orderlies to do far more in the field of health education and by initiating a programme of adult education which would include material on health and hygiene.

It is this third alternative which should be adopted, since it is capable of improving the level of hygiene at an acceptable rate while still allowing time for the culture to adjust, with minimum stress, to new practices and ideas.

e) The aid post system is the vital front line of health care for the Raiapu. The aid posts already treat a large proportion of the less serious illnesses in the area and they should be expanded and encouraged. In particular, they should be trained to carry out the 9 functions mentioned by Radford (1971) and set out in section 17.1. The following statements regarding aid posts are made by the International Bank for Reconstruction and Development (I.B.R.D., 1965:342):

> No new aid posts should be established unless adequate supervision can be provided; present aid posts, which do not receive supervision at reasonable intervals owing to lack of access roads or other means of communications, should be closed until adequate communications are provided.

In the Raiapu Enga case these recommendations should be ignored, because the aid posts at present provide a basic medical service with practically no supervision. To remove them because they are not perfect is to deprive the Raiapu of their only access to Western medicine and thus to delay the eventual acceptance of this type of medicine by the community. Increased supervision would undoubtedly be beneficial, but the aid posts still operate effectively with very little supervision.

f) It is suggested in point d) that increased health education, through primary schools, aid posts and adult education, should be undertaken in order to cause an improvement in standards of hygiene. It was argued that this should be a long-term programme in order that the culture would not be disrupted by pressures to make sudden changes in behaviour. This raises the question of whether the education should merely encourage new practices and ideas, or whether it should actively attack existing practices which are considered to be deleterious to health.

Hypothetical examples of this latter, aggressive style of education are as follows. Dispersed settlement, although baving certain beneficial effects in the event of an epidemic, makes the installation of communal amenities, such as water supplies, a very costly undertaking. Therefore, one could seek to prohibit scattered settlement. The response to death (kumánda), and its associated rituals, expose a large number of people to the risk of infection and could therefore play a major role in sustaining an epidemic. Therefore, one could teach against these traditional funerary ceremonies. The Raiapu medical system, based on the activities of the tópólí, diverts patients away from the introduced aid post system and so delays the general acceptance of Western curative practices. Therefore, one could actively oppose tópólí and seek to compel patients to visit aid posts.

These 3 aspects of Raiapu culture today (dispersed settlement, the kumánda and tópólí activities) are examples of potential targets for an aggressive and authoritarian health education programme. However, any attack on them would be totally unjustified and could have the most damaging repercussions. They are all major strands in the fabric of Raiapu culture and, as the quotations in section 20.1 have illustrated, one cannot alter one aspect of a culture without expecting important changes in other aspects. _Topólí_ activities, for example, are largely a product of the religious beliefs of the Raiapu (see Feachem, 1973c, and Chapter 16) and cannot be tampered with in isolation.

Therefore, a health education programme designed to improve hygiene, should promote new ideas without attacking old ones. It should build from the existing culture, and work harmoniously with existing customs, rather than attacking established practices and presenting the new ideas as opposed to, and incompatible with, the old. The tendency to present rigid alternatives between the new and the old, the good and the bad, the hygienic and the unhygienic, should be avoided. There is no reason, for instance, why _topólí_ and aid posts should not operate side by side for many years to come and to present them as alternatives, between which the community must choose, is quite unnecessary and creates stress and dissension where there could be harmony and consensus.

To conclude this chapter, it is appropriate to refer to the vexed question of whether any health improvement work should be contemplated amongst the Enga, bearing in mind that they face a growing problem of population pressure on their available resources of arable land. Judging by present trends, it is true that a population-resource crisis is on the way for the Central Enga (Mae and Raiapu), and it may well be that the growing incidence of warfare in the region is a symptom of this stress. However, those who argue that therefore nothing should be done which might increase the rate of population growth are referred to papers, such as those by McDermott (1966) and Taylor and Hall (1967), which clearly expound the contrary view. Briefly, these writers argue that, although health programmes may indeed exacerbate the population growth problem in the short-term, in the long-term improved health is one of a number of essential pre-requisites without which no progress in population control, and rural prosperity, is possible. For instance, reasonable standards of community health can stimulate the demand for, and practice of, family planning and the relationships between health and the productivity of the agricultural worker are self-evident.

CHAPTER 21

TOWARDS A VIEW OF RAIAPU ECOLOGY

As stated in Chapter 1, the intention of this thesis has been to describe and quantify certain elements of that ecosystem of which the Raiapu Enga form a part. It has been recognised from the outset that natural ecosystems are typically too complex to analyse totally and therefore subsystems of the overall system must be isolated and defined for study.

The approach in this study has been to isolate from the Saka ecosystem that subsystem of variables relating to human medical ecology and the linkages between human health and elements (physical, biological and cultural) of the individual's environment. This subsystem is one of great complexity and it is inconceivable that a 4 year study by a single investigator could hope to do more than clarify the functions of some elements within the subsystem, and to examine a few of their interconnections. This has been done and it is particularly elements of the subsystem associated with human health and water which have come under close scrutiny in the foregoing chapters.

The elements selected for intensive study have been examined in some detail and many, hitherto unreported, data have been presented. In addition, aspects of the structure of the subsystem have been clarified and the linkages, between certain of the elements studied, have been analysed. However, many elements of the subsystem are not included in this study and therefore a synthesis of the medical ecology of the Raiapu Enga is not possible. Neither is it possible to present any integrated summary of the findings and conclusions of this research because the information on additional elements and mechanisms of the subsystem, which would provide a framework to synthesise the data reported here, is lacking [1]. Conclusions and findings on various aspects of this work have already been presented as follows:

on water use - Chapter 8

on water pollution - Chapter 14

on morbidity prevalences - Chapter 18

on education, travel and morbidity - section 19.2

on housing and morbidity - section 19.3.6

on water and morbidity - section 19.4

Many more months of patient field-work are necessary before it will be possible to construct a more complete model of the medical ecology of the Raiapu Enga. Already, however, an exceptionally vivid and detailed picture of many diverse aspects of the Enga life and world has been built up, so that the Enga have become one of the best documented groups of subsistence gardeners

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1. An inspection of the literature reveals that other studies of the medical ecology of rural communities have also failed to examine enough of the relevant variables, or to expose their interrelationships in sufficient detail, to permit a synthesis of results. The works of Buck et al (1968, 1970), for instance, are presented as compendia of information on different variables and, although the authors recognise that these variables are highly interconnected and interdependent, they are unable to clarify the structure or dynamics of these interconnections. Buck et al's work in Chad and Peru, and my own work in New Guinea, may appear to be merely catalogues of disparate human and environmental properties. In fact, they are far more than this, for they study a set of highly interdependent variables which, following further investigations, may be incorporated into a model of the medical ecology of a particular rural community.

in the world. The work of Meggitt on their social system, of Sinnett on their human biology, of Waddell on their agriculture and of myself on their medical ecology, constitute an impressive array of knowledge about a fascinating people.

APPENDICES

APPENDIX I

PLANTS USED BY THE RAIAPU FOR PURPOSES OTHER THAN EATING

It has been made clear in Chapter 16 and in Feachem (1973c) that the Raiapu make use of a wide range of plants in their medical and religious ritual. A list of some of these plants is given in this appendix. The common names given must be treated with great caution, because they are in no way standardised and may mean different things to different people. They may be of some help to the botanically ignorant reader.

I have not enquired into the structure of Raiapu botanical taxonomy. It appears that a plant's name may well relate to its use. For instance, lyambí is used for at least two species of Compositae which are used to clean and wrap newborn babies. Áwa describes a number of edible leafy greens, and akaipuwai refers to many plants which have strong magical associations. Acorus calamus is given many names by the Raiapu and this appears to relate to the magical purpose for which the plant is intended (Feachem, 1973c).

The legume Pueraria triloba, which appears in the following list, is of special interest. Pueraria spp. have been reported as edible tubers from various parts of the Highlands and it has been suggested that Pueraria may have been a staple food prior to the introduction of sweet potato (Bowers, 1964; Strathern, 1969; Watson, 1964). Bowers (1964) cites Meggitt as saying that the Raiapu Enga may refer to both manioc and Pueraria as korena, and the list below indicates that the Saka Raiapu use the word koténá.

I am grateful to the Division of Botany at Lae for identifying my plant specimens, and to Professor D. Anderson, Mr. J. Smith and Dr. N. Wace for their helpful comments on the following list.

Botanical Name			Common Name	Raiapu Enga Name	Uses
Family	Genus	Species			
Acanthaceae	Grapto-phyllum			sángú	For wrapping newborn babies in
	Hemi-graphis			kainumi, yakome, kondame	In magic to attract large bride-price for a girl
Amaryllidaceae	Crinum		lily	pakenana	Cultivated for decoration, used in magic to retrieve a sick man's wan-dering soul.
Araceae	Acorus	calamus	sweet flag	lepe, akaipuwai, yangupai, kuni-ani, pereme, mena kalé	Used in all types of Raiapu magic and ritual, name depends upon intended use.
Commelinaceae	Cyanotis		spider wort	kaokao, akaipuwai, yakome	To magically fatten pigs, to limit women's menstrual bleeding, eaten by pregnant women to promote easy childbirth
Compositae	Crassoc-ephalum	crepid-ioides	velvet plant	takao, kómba	To cure boils, to prevent lice infestation
	? Gnaph-alium		cudweed	tapandi	To prevent being struck by an arrow during warfare
	?Micro-glossa	pyrif-olia		mulumulu	To treat eye infections

Botanical Name			Common Name	Raiapu Enga Name	Uses
Family	Genus	Species			
Compositae	Olearia		daisy-bush	lyambí	To treat scabies, to clean newborn babies
	Senecio		bed-fordia	maimbonom, lyambi	To clean and wrap newborn babies
Cruciferae	Brassica		cabbage	áwa	A cultivated edible green, used in magic
Cyperaceae	Cyperus		umbrella sedge	kuli	Used to tie magical bundles which <u>topoli</u> manipulate
	Eleoch-aris	dulcis & sphacel-ata	spike rush	kútá	Cultivated for women's aprons
Gramineae	? Coix		Job's tears (grass)	wáku	For bandaging bone injuries, for making necklaces
	Cymbopo-gon		grass	eraiya akaipuwai	In <u>tee</u> magic, to protect travellers
	Eleusine	indica	crows-foot grass	tiwaitawai	To bandage broken bones
	Setaria	palmi-folia	palm grass, highland pitpit	líti	For stomach aches and diarrhoea
Hymenophyllaceae			filmy fern	itarumbi	In magic to promote successful possum hunt
Labiatae	Coleus	scutellar-ioides		elyamúni	For boils and ulcers

Botanical Name			Common Name	Raiapu Enga Name	Uses
Family	Genus	Species			
Leguminosae	Pueraria	triloba		koténá, wande	Cultivated and eaten, treatment of skin infections
Liliaceae	Cordy-line	fruticosa (termin-alis)	arse-grass, tanket	mongálo, ambáno	Worn as male buttock covering, to cover scabies
Loranthaceae			mistle-toe	koimbam-banari	To treat diarrhoea
Moraceae	Ficus	?adeno sperma	wild fig	potó	Contraception magic
CLASS Musci	Trema-todon		moss	kapánó	In magic to prevent ghost of dead woman from haunting her husband
	Sphagnum		sphagnum moss, bog moss	koma	Squeezed to give drinking water while travelling in forest
Myrtaceae	?Decasper-mum			konja	Magic to recall a lost soul, culti-vated for flowers
Piperaceae	Piper		wild pepper	kyangari	Eaten, magic to find lost pigs
		gibbi-limbum	wild pepper	sakali	Eaten with beetle nut, find lost pigs, wrapping babies
Polygonaceae	Polygo-num	nepal-ense		ruangatare	Treating boils and ulcers
Pteridaceae	Pteridium	aquilinum	bracken	púmá	Skin infections
Rubiaceae	Ophiorr-hyza	?nervosa		wainapeambui	To make pigs mate

Botanical Name			Common Name	Raiapu Enga Name	Uses
Family	Genus	Species			
Rhamnaceae	Alphi-tonia	incana		pokéta	For headaches, and toothaches, in magic to prevent ghost of dead woman from haunting her husband
Sapindaceae	Dodonaea	viscosa	sticky hop-bush	lokaiya	Cure knee pain, prevent infant diarrhoea and post-natal bleeding
Solanaceae	Nicotiana		tobacco	kiná	For smoking, for killing fleas in the house
Umbelliferae	Oenanthe	javanica	water drop-wort or water cress	takae	Cultivated and eaten, used in many magics
Urticaceae	Laportea		stinging tree	nakáu	To relieve pain
	?Pipturus		nettle	enámbó	Used in garden magic, source of material for string manufacture
Zingiberaceae	?Riedelia		wild ginger	kapole	Gingers are used widely by the Raiapu in magic and in folk-medicine
	?Zingiber		wild ginger	alámá	
			wild ginger	kosa	

APPENDIX II

THE BACTERIOLOGICAL FIELD LABORATORY

A grass-roofed hut, approximately 3m x 3m and $2\frac{1}{2}$m high, was constructed at Lyokote, adjacent to the author's house (Map 4). This hut was used as the laboratory for the bacteriological and turbidity testing discussed in Part III of this thesis.

All membrane filtrations were conducted using the following apparatus:-

Millipore "Sterifil" filtration unit.
Millipore pre-sterilized filters, 47mm diameter, 0.45 microns pore size, white with grid.
Millipore plastic disposable Petri dishes, internal diameter 48mm.
Millipore stainless steel forceps.
Millipore syringe and valve.

The faecal coliform tests also required the following:-

Millipore pre-sterilized absorbent pads, 47mm diameter.
Bacto-m FC Broth Base, Difco code 0883.
Rosolic acid.
Sodium hydroxide.

The faecal streptococci tests required:-

Bacto-m Enterococcus Agar, Difco code 0746.

Autoclaving was conducted in a domestic pressure cooker and sterile water (for hydrating the media and rinsing the funnel during filtration) was obtained by filtering boiled water through Millipore, 0.22 micron, filters.

Incubation was carried out in a "Labec" kerosine incubator, with a thermostat to control the temperature to $\pm$ 1^{o}C. The incubator had a water jacket heated by a kerosine-burning wick, and had internal dimensions of 14 x 12 x 12 inches.

Turbidities were measured with a "Hellige" portable turbidity tester.

APPENDIX III

WATER SUPPLY INSTALLATIONS IN THE KAINANTU SUB-DISTRICT

Vines (1970:95) shows that, in the Highlands, only 1.8% of his sample used tanked water or a reticulated supply. In the New Guinea lowlands and the Islands, the proportions were 5.7% and 31.4%, respectively. There are very few tanks or reticulated supplies in the Highlands and most Highlanders use natural streams and springs.

The few improved supplies that are to be found in rural Highlands communities are mostly located in the Kainantu Sub-district of the Eastern Highlands District (Map 1), where the Local Government Council has undertaken an extensive programme of water supply improvement. The annual reports of the Kainantu L.G.C. reveal the following situation. In the year ending June 1971, 21 supplies were completed, with an average of 2.9 outlets per supply, at an average cost of $468 per supply and serving a total population of 6,945 (averages of 331 served per supply and 114 served per outlet). Of the 21 supplies constructed, 6 were tanks and the remainder were piped supplies from a protected spring, with an average distance between the spring and the outlets of 843m. The cost of the polythene piping used amounted to up to 65% of the total cost of the supplies, with labour costs accounting for most of the remainder. In the year ending June 1971, the Kainantu L.G.C. spent $7,200 on new village water supplies and $320 on repairs to old ones. Of the $7,200, 50% was provided by a grant from the central government's Rural Development Fund, and during 1970/71 the Council committed 7% of its annual revenue to rural water supplies.

In the year ending June 1973, 8 new supplies were constructed at a cost of $4,000 ($500 per supply) and serving a population of 1,670 (209 served per supply). During this period, $1,310 were spent on repairs to rural supplies.

Today there are 32 reticulated supplies and 6 tanks in villages of the Kainantu Sub-district. These serve a population of approximately 11,500 which is 25% of the total rural population of the Sub-district. The supplies are installed without necessarily being accompanied by health improvement programmes and it is argued in this thesis that, judging by the Enga situation, their impact on morbidity may be negligible.

A major problem encountered in the installation of supplies in the Kainantu region is that of deliberate damage and it is striking that, in the year ending June 1973, 25% of the total rural water supply budget was spent on repairs. The 1972/73 Council Annual Report says:

> Many of the village water supplies are time and time again wilfully damaged. The cost of maintenance and repairs amounted to $1310. Of this amount, approximately $800 was spent on supplies which were wilfully damaged.

APPENDIX IV

DAILY RAINFALL AT LYOKOTE IN THE SAKA VALLEY BETWEEN MAY AND DECEMBER, 1971

For further information on rainfall in the Wapenamanda region, see C.S.I.R.O. (1965:56-69) and for rainfall in the South-West Pacific, see Brookfield and Hart (1966).

MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
mm	mm	mm	mm	mm	mm	mm	mm	
	1	6	12	10	2	3	14	1
	7	5	11	4	20	9	2	2
	11	10	4	2	8	5	4	3
	0	8	4	5	8	4	4	4
	0	1	3	2	23	0	1	5
	5	7	0	13	20	1	0	6
0	2	0	0	29	21	45	3	7
0	0	0	2	13	10	15	22	8
1	4	13	0	9	11	1	8	9
3	12	2	1	0	3	17	4	10
14	38	1	1	5	0	4	13	11
12	1	9	1	2	0	1	12	12
16	0	1	0	2	1	3	0	13
0	2	6	2	0	6	16	0	14
7	2	1	1	4	6	1	3	15
1	22	1	0	1	16	1	9	16
0	11	8	0	2	1	0	9	17
0	7	1	0	4	0	0	5	18
0	15	14	0	20	0	0	0	19
2	13	0	1	7	8	0	0	20
3	7	9	3	0	3	1	0	21
30	5	34	0	0	0	0	33	22
7	1	2	0	0	0	0	0	23
6	0	0	0	0	1	0	4	24
5	21	0	2	0	11	11	33	25
0	2	1	4	2	0	8	20	26
8	22	0	1	5	2	11	1	27
2	1	0	46	2	3	48	10	28
1	2	0	4	23	1	2	29	29
2	7	0	1	1	1	10		30
1	——	0	2	——	11	——		31
121	221	140	106	158	197	217	243	TOT.
25	30	31	31	30	31	30	29	Days

APPENDIX V

DATA PROCESSING

Three principal types of numerical data were collected in the Saka. Data on water use reported in Part II, data on water pollution reported in Part III and data on morbidity reported in Part IV.

a) Water Use Data. The water use survey entailed recording the details of 665 water collection journeys. The resulting data were handled on portable calculators.

b) Water Pollution Data. In addition to extensive data on rainfall, river temperature and turbidity, 425 readings of faecal coliform concentrations, and 480 readings of faecal streptococci concentrations, were obtained. These figures were put on punched tape and processed on the Wang 3300 time sharing computer of the School of Civil Engineering, University of New South Wales. For the multiple correlations (Tables 13.6 to 13.10) the data were transferred to punched cards and processed on the I.B.M. 360/50 computer of the University of New South Wales Computing Centre. The multiple correlations were computed with the programme BMD03R (version of May, 1966) of the Health Sciences Computing Facility of the University of California at Los Angeles.

c) Morbidity Data. The morbidity survey entailed 2,989 interviews comprising 47,824 items of data. These data were punched on cards and later transferred to magnetic tape. All computations were carried out on the I.B.M. 360/50 of the University of New South Wales Computing Centre. All programmes were written by the author but they are not sufficiently unusual or complex to warrant inclusion here.

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