A socio-economic evaluation of the Regional Fruit Fly Projects

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Executive summary

Fruit flies are one of the world's major insect pests of fresh fruit and fleshy vegetables. In every Pacific island country and territory, there is at least one, and usually more, damaging endemic fruit flies present. These serious pests infest a wide range of edible fruits and vegetables. It has been recognised for some time that unless fruit flies are understood and managed effectively, prospects for improving the production and quality of fresh fruits and vegetables are limited, and the possibility of developing horticultural exports is virtually non-existent. Furthermore, most rural households grow fruit for their own consumption and the adverse consequences of exotic fruit flies are potentially even greater on domestic consumption and markets than on the export sector.

The Regional Fruit Fly Projects

The first Regional Project on Fruit Fly Control Strategies in the South Pacific was launched in September 1990 in Fiji, Tonga, Western Samoa, and Cook Islands. It aimed to ameliorate the problem of fruit flies, initially to develop export markets for locally grown produce, by:

- Upgrading technical knowledge about fruit flies and ensuring that plant protection, quarantine, and private sector personnel understood the impact of fruit flies on the production and export of fresh fruit and fleshy vegetables;
- Reducing the extent of ruit fly damage in fresh fruit and fleshy vegetables caused by fruit flies; and
- Strengthening the capacity of quarantine services and the private sector to overcome quarantine restrictions imposed by importing countries on Pacific island exports of fresh fruit and fleshy vegetables.

The first priority was to set up national fruit fly databases and quarantine surveillance systems. This involved:

- Generating the necessary data to negotiate non-host status protocols that would allow certain fruit and vegetables to be imported into New Zealand;
- Providing the necessary research data to certify commercial quarantine treatments that are based on heat.

Field control development work concentrated almost entirely on protein bait spray trials in Fiji, Tonga, and Cook Islands.

Despite the good progress that was made, particularly in developing fruit fly databases, it became clear that all project objectives could not be achieved within the initial three-year period. The RFFP was then extended for a further three years to 1997, and expanded to include Vanuatu, Solomon Islands, and Federated States of Micronesia. As well as continuing the database, quarantine surveillance and quarantine treatment work, more effort was given to developing protein bait sprays as a means of field control of fruit flies. The introduction of field control components

broadened the potential benefits of the project beyond promoting exports to also increasing domestic fruit consumption.

In May 1997, the project was again extended, this time to cover all 22 Pacific island countries and territories, and with its name changed to the 'Project on Regional Management of Fruit Flies in Pacific (RMFFP).' Activities of the project were expanded to include:

- Establishment and monitoring of quarantine surveillance;
- Improving emergency response preparedness;
- Developing and demonstrating technology for the field control of fruit flies;
- Expanding the use of existing quarantine treatments for fresh fruit and vegetables exports based on non-host status and high temperature forced air (HTFA);
- Increasing public awareness about the risk of exotic fruit fly incursions; and
- Transferring technology between countries.

This sustained regional effort over nearly a decade has brought a solid achievement in expanding fresh produce exports. The magnitude of export expansion and the range of parties that have benefited from this expansion have, however, been less than what was first envisaged. New Zealand remains the predominant market for fruit and Fiji remains by far the main supplier to this market. From the outset, it was recognised that in order for the RMFFP to have a widespread and sustainable impact it needed to also contribute significantly to domestic fruit production and consumption. In contrast to export production, however, very little was known about domestic fruit consumption or the effects that damage caused by fruit flies had on food security, nutrition, rural employment, or poverty. These issues are the subject of the second part of this report. This study complements a 1996 report by the same author that evaluated the benefits and costs of the RFFP in terms of generating exports. For completeness, the 1996 study is briefly reviewed here and updated.

An evaluation of the export benefits of the Regional Fruit Fly Projects

The 1996 Report, which covered the period 1993 to 2002, evaluated the benefits of the RMFFP solely in terms of increased export earnings, recognising, of course, that there can be a substantial lag between a project activity and the realisation of any export growth. The 1996 Report calculated the total consolidated benefits over the 10 years of the project were worth US$24.5 million. Of this, US$8.9 million accrued to Fiji, US$6.9 million to Tonga, US$4.3 million to Vanuatu, US$2.4 million to Samoa, and US$1.5 million to Cook Islands. (With the exception of small quantities of bananas sent from Federated States of Micronesia to Guam, neither Federated States of Micronesia nor Solomon Islands exported fresh fruits or vegetables.) When compared with project costs, this benefit flow generated an internal rate of return of 37 per cent. These projections assumed that the minimum funding of core project activities continued to be maintained.

In 1999, the 1996 estimates were re-evaluated. The 1999 Study valued the total benefits of the project from 1993 to 2002 some 40 per cent lower, at US$12.6 million. Approximately half of these benefits accrued to Fiji which now has a viable HTFA business.

Even Fiji, however, did not do as well as expected, due largely to a significant shortfall in papaya exports. Part of this shortfall was due to the agonisingly slow progress of Australian Quarantine and Inspection Service (AQIS) and United States Department of Agriculture (USDA) approval processes for Fiji's HTFA-treated papaya. This delay can in part be explained by the fact that this was a minor product from a small country and was given low priority in allocating resources to the necessary assessment of pest risk. Fiji's Ministry of Agriculture, Fisheries and Forests (MAFF) Quarantine Department, furthermore, was not sufficiently proactive in pushing the process along. Fortunately, much of the shortfall in papaya has been taken up by eggplant. Once seen as a relatively minor product, eggplant has become the cornerstone of the viability of the Fiji's commercial HTFA facility. Breadfruit is also a more important product than was envisaged in 1996.

The 1996 Study valued the benefits of RMFFP activities that accrued to Tonga at US$6.9 million. In 1999, this figure was reassessed downward to US$3.8 million, a decrease largely due to Tonga's decreased earnings from squash exports, but also because watermelon and papaya exports were significantly less than what was envisaged in 1996. Of all HTFA-treated products, breadfruit now probably offers the best prospects for Tonga.

Samoa was the only country where the 1999 assessment of project benefits exceeded the 1996 assessment, mainly because of better than expected exports of bananas to New Zealand. A quarantine protocol is now in place for the export of all bananas of the genus *Musa* to New Zealand, and this was assisted by the host status surveys conducted by the RMFFP.

In Cook Islands, the 1996 Report estimated the benefits of RMFFP activities would be worth US$1.5 million, but in 1999 this figure was moved down to US$890,000. This decrease was due to declining exports of Cook Island papaya to New Zealand. Similar to Fiji, Cook Islands has found that the barriers to exporting papaya beyond New Zealand are more intractable than envisaged in the 1996 Report; both countries still await AQIS certification of their HTFA treatment facilities.

Vanuatu, disappointingly, had the largest gap between the 1996 and 1999 assessments of project benefits. In 1996, the fledgling Vanuatu fruit fly programme was thought to be a major success story, with its benefits valued at US$4.3 million. In 1999, this figure was reassessed down to only US$840,000, a huge shortfall caused almost entirely by the sudden closure of Vanuatu's squash industry.

Project benefits that accrued to Federated States of Micronesia were estimated in 1996 to be worth US$465,000. This was based on the possibilities that had been opened up of exporting fruit and vegetables to the adjacent territories of Guam, with its large military population, and the Commonwealth of the Northern Marianas, with its large tourism

industry. None of these projected exports have however materialised, or look likely to soon do so.

Overall, the 1996 Study calculated the internal rate of return of the project to be a very substantial 37 per cent. The 1999 Study almost halved this estimate, down to 19 per cent, but this is still a healthy figure. Also, donor contributions for the years 1997 to 1999 were substantially more than what was expected in 1996.

The experience of the last few years has shown that, without Fiji and based on export growth alone, it is unlikely that the RMFFP would be viable. This is particularly so with the recent inclusion of countries such as Papua New Guinea and those in the Northern Pacific and Micronesia which have few export prospects but have increased the project's costs. If the project is to achieve wide-based viability, it needs to significantly contribute to domestic fruit production and consumption. Meanwhile, export-based returns from RMFFP activities could be increased and more widely distributed if more attention was given to:

- A more realistic approach to establishing HTFA facilities;
- Greater emphasis on developing non-host protocols;
- Promoting the use of the New Zealand non-host methodology by other importing countries; and
- Encouraging a more proactive, regional approach towards dealing with the regulatory authorities of importing countries.

Evaluating the domestic benefits of the Regional Fruit Fly Projects.

The measurement of domestic losses due to fruit flies must take into account several aspects, namely:

- The extent of damage caused by fruit flies in the various Pacific island countries;
- The nature and level of fruit production and consumption in the various countries;
- The impact of fruit fly damage on fruit consumption at the subsistence or self-sufficiency level; and
- The impact of fruit fly damage on fruit consumption at the commercial level.

To assess the nutritional and economic significant of fruit fly damage, it is necessary to determine the nature and level of fruit production and consumption in the Pacific islands. Fruit consumed by Pacific Islanders can be broadly classified into staple and non-staple food. The main staple fruits are breadfruit and cooking bananas. These staples are considered 'real' food that make a major contribution to the diet and food security. Staple fruits are, by definition, high in energy, but they contribute more to household nutrition than just energy. Breadfruit is the leading staple in terms of

dietary fibre, while cooking bananas beat all starchy staples and imported cereals in terms of potassium. Cooking banana is the best possible source of vitamin A and β-carotene. Breadfruit also provides a good source of vitamin A and more riboflavin than any other staple food.

Breadfruit is an important seasonal staple throughout the region and is cultivated on both high islands and atolls. The profuse seasonal supply of food that breadfruit trees provide makes a major contribution to people's diets, especially on the atolls and smaller islands. Any pest or disease that had a significant impact on breadfruit production would have serious nutritional and financial implications for households. In some places, fruit flies are a serious pest in breadfruit.

Worldwide, banana (*Musa* spp.) is the most exported fruit. Roughly half of the bananas of the world are eaten cooked as a starch, as is often the case in the Pacific Islands. In much of Vanuatu, Solomon Islands, island and coastal Papua New Guinea, and Samoa, banana is a major food crop. While bananas can be a fruit fly host, this is not usually so in the Pacific island region. Banana fruit fly is major pest in Queensland, Australia, and Papua New Guinea, where it lays its eggs in immature green fruit, but the main concern is Asian papaya fruit fly. This particularly damaging fruit fly has recently become established in Irian Jaya and Papua New Guinea, and has been introduced to north Queensland. Any further incursion of this pest into the Pacific islands could have major food security implications–particularly through its impact on bananas. As breadfruit is also a host, the consequences could be devastating.

On the high islands, many other fruits and fleshy vegetables are grown that can be classified as non-staple fruits. Non-staple fruits are of distinctly secondary importance compared with breadfruit and bananas. Even so, they make an important contribution to the nutrition of Pacific Island households, a contribution that is often under-estimated because most fruit is consumed as 'snacks' and not as meals. At times of natural disaster, some non-staple fruit assumes critical nutritional importance. A pest or disease affecting a particular non-staple would probably not have a major impact on household food consumption and nutrition, for any one fruit is unlikely to be a major part of the household's diet and alternative fruits are usually available. In contrast to staple fruit, most non-staple fruits, while sweet, are low in calories. They are, however, a further source of dietary fibre and are packed with nutrients, especially vitamins.

The volume and value of fruit and vegetable exports are readily quantifiable. These data are obtainable from several sources, including quarantine records and the trade statistics of exporting and importing countries. For domestic food consumption, no such data are available. The predominant self-sufficiency nature of Pacific food production systems accentuates measurement problems. Most food grown or harvested by Pacific island households is not traded for cash, but consumed or exchanged.

Estimating household food consumption, also difficult, can be approached from either the production or consumption side. A timely and comprehensive Agriculture Census

is the best tool for estimating levels and trends in national fruit production and consumption. In most Pacific island countries, however, agricultural censuses have shortcomings that undermine their usefulness in measuring self-sufficiency food consumption. According to the most recent Agricultural Census in Fiji, the total estimated value of fruit production was F$134 million, but this is probably a considerable over-estimation. Yet even if the true value was only half this figure, it still is considerable. Data from Samoa, Tonga, and Vanuatu also indicate high levels of fruit production and consumption.

This study conducted household surveys of fruit consumption in Fiji and Vanuatu. The Fiji survey covered Fijian rural households in the Province of Cakaudrove, Vanua Levu, and Indian households at Votualevu on the outskirts of Nadi on Viti Levu. In Cakaudrove, fruit consumption was quite high, despite a severe drought at the time of the survey. The most important fruit, by far, was breadfruit and, as expected, most non-staple fruits were consumed as snacks and not at meals. The Votualevu survey indicated a much lower level of fresh fruit consumption in this rural Indo-Fijian community. In Vanuatu, the household surveys confirmed that bananas were the most important everyday staple. Breadfruit did not feature because it was out of season at the time of the survey.

The overall impact of fruit flies on domestic fruit consumption and nutrition.

Evidently, fruit flies **at present** do not have a significant impact on fruit consumption and nutrition at the household self-sufficiency level. There are different reasons for this, between staple and non-staple fruit. For households throughout the region, bananas and breadfruit are the most important food staples. In most places, fruit flies do no, or little, damage to bananas—although Papua New Guinea and Palau are important exceptions that demonstrate the risk fruit flies can pose. Fruit flies do considerable damage to breadfruit, as is evident from data from Kiribati, Federated States of Micronesia, and North Ambrym (Vanuatu). On atolls, there are no real alternatives to breadfruit, other than imported rice. High breadfruit losses can therefore have a significant impact on food, nutrition and household incomes—although this is mitigated by the large surplus of breadfruit that is usually available and the fact that fruit fly damaged breadfruit can usually still be eaten.

For non-staple fruit also, damage caused by fruit flies does not have a major impact on subsistence consumption and nutrition. This is because non-staple fruit is of relatively minor importance, a variety of other fruits is usually available, and sufficient non-infested fruit can normally be found.

It appears that fruit flies are likely to have significantly greater impact on domestic commercial production than on self-sufficiency consumption and, therefore, greater impact on urban than rural consumers. Reduced urban fruit consumption nevertheless has implications for the income generating capability of rural people.

The incursion of an exotic species such as Asian papaya fruit fly or Oriental fruit fly could have a devastating impact on domestic fruit sales. The recent establishment of Oriental fruit fly in Palau indicates the potential extent of these losses for a small

island economy. In places like Samoa, where a particular fruit is the main traded staple, an incursion of a serious exotic fruit fly could cause even greater commercial losses.

Mitigation and control measures for domestic fruit production

The 1999 study found a lack of traditional control and mitigation measures, probably because fruit flies were not seen to be a major problem by village communities. Bait spray technology has been identified as having good potential to expand domestic consumption of fruit and vegetables. Both village-based and commercial production bait spray trials were conducted in Vanuatu as a part of this study. The objectives of North Ambrym village bait-spray trial were to:

- Test the practicability of lure bait spraying in an isolated village situation;
- Find whether lure bait spraying significantly reduced the damage caused by fruit flies, according to the community; and
- Determine the willingness of the community to adopt lure bait spraying and how this could be done in a successful and sustainable way.

As a formal experiment, the village bait-spray trial proved not to be successful. The North Ambrym trial encountered the same difficulties found in very wet conditions elsewhere. These difficulties are compounded in a village situation where the discipline of re-spraying cannot be assured. But even if better results had been achieved, the survey raised serious doubts about the applicability and sustainability of bait spraying in isolated villages. The most positive lesson that could be drawn from the North Ambrym trial was the evident capability of a local NGO to carry out fruit fly field research if the right training was provided. This experience augurs well for the sustainability of fruit fly research in the region. In contrast to the village trial, the bait spray trial on a commercial orchard was successful.

Fruit bagging was another technique examined at the village level. There, bagging has a number of decided advantages over bait spraying, such as:

- The mechanics of the technique are intuitively easy to understand;
- The handling of hazardous chemicals is avoided;
- The problem of ensuring a continued supply of purchased materials is avoided;
- The technique is likely to be equally effective as a barrier against the fruit-sucking moth, which at times can be an even more serious pest.

The principal difference is that the bagging of fruit depends on the responsibility of individual households, while protein bait spraying depends on communal responsibility.

The standard bag used in Malaysia is constructed from a double layer of newspaper sown together. This is both cheap and effective. However, in many Pacific Island

villages, newspaper is not available and a suitable local available material must be found. The most obvious materials are leaves, and this study included a preliminary assessment of a variety of these.

Fruit fly eradication: the Nauru Programme

One fruit fly eradication technique involves the annihilation of the male of a particular species. This technique can be used in the special case where male flies cannot migrate from an untreated area into the area being treated, such as on a small isolated island. Nauru presented itself as an ideal candidate for male annihilation, particularly as the necessary conditions of need and technical feasibility were in place. The Nauru Fruit Fly Eradication Programme aimed to:

- Reduce the risk of the incursion of melon fly and Oriental fruit fly into other Pacific island countries by eradicating these species from Nauru;
- Train agriculture staff from other Pacific island countries in fruit fly eradication and so enable them to mount rapid response programmes against the incursion of an exotic fruit fly; and
- Improve Nauru's food security by eliminating fruit fly damage to locally grown fruit.

A little over a year after the eradication programme began, Nauru was declared free of Oriental fruit fly and melon fly, thus demonstrating the efficacy of the male annihilation technique on an isolated island. It also showed that this technique could effectively stop the spread of an exotic fruit fly if an emergency response programme was mounted quickly enough. For the first time in a decade, Nauruans can now enjoy some undamaged, locally grown fruit, so improving food-security and nutrition on the island. The Nauru eradication programme also reduced the risk of exotic fruit flies spreading from Nauru throughout the Pacific region and improved the emergency response capability of other Pacific island countries. Nauru now has, for the first time, an Agricultural Quarantine Act. Overall, the Nauru fruit fly eradication project was shown to have a very high economic rate of return.

The importance of surveillance and emergency response programmes for domestic fruit production.

While fruit flies at present do not have a significant impact on fruit consumption and nutrition at the household level, the important exception is where there has been an incursion of a particularly damaging exotic fruit fly. These include Oriental fruit fly in French Polynesia, Palau and Nauru; Asian papaya fruit fly in parts of Papua New Guinea; and melon fly in parts of Solomon Islands. The incursion of these fruit flies has had considerable repercussions on food and nutrition, particularly where they have affected major food staples. These fruit flies could cause even more damage if they spread more widely in these countries. For example, Asian papaya fruit fly is known to infest coffee cherry. If this fruit fly becomes established in the coffee growing areas of the Highlands of Papua New Guinea, the economic consequences

could be catastrophic, for coffee is not only Papua New Guinea's largest agricultural export commodity, but arguably the country's most important industry.

Fruit production has a high economic value in Fiji, but the incursion of Asian papaya fruit fly could jeopardise a large part of this. To domestic fruit consumption losses would have to be added losses in export earnings, both current and future foregone. The magnitude of the potential losses justifies a high priority being given to surveillance and emergency response programmes. The recent experience of New Zealand, with the incursion and subsequent eradication of Mediterranean fruit fly shows how effective such programmes can be. Thanks to the Nauru fruit fly eradication project, staff from departments of agriculture throughout the region have the necessary skills to mount rapid reaction programmes in response to a fruit fly incursion.

By August 1998, a basic quarantine surveillance system, based on permanent strategically located traps baited with male lures, had been established in each of the 22 Pacific island countries and territories. These systems provide early warning of an exotic fruit fly incursion and need to be maintained by the respective governments. Further emergency response planning must continue at national and regional level in order to ensure a quick response to fruit fly incursions.

Consolidating and sustaining Project activities

A high economic rate of return can be attributed to the RMFFP in terms of expanding export earnings and protecting domestic food production. To fully capture and sustain these benefits, there is a strong justification to continue the regional component of the RMFFP to work in collaboration with national fruit fly programmes. Continuation of the RMFFP beyond its current phase needs to be based on consolidation, back-stopping national programmes and focusing on activities that are likely to provide the highest rates of return. Several highly beneficial activities were identified that meet these criteria. These activities can broadly be divided into those that expand the level and distribution of export earnings and those that expand and protect domestic food production. They include:

- Assistance in developing non-host protocols for export produce;
- Facilitating acceptance of the New Zealand non-host technology among other importing countries;
- Assisting Pacific island countries to become more proactive in dealing with the quarantine authorities of importing countries;
- Promoting bait spray technology amongst commercial farmers;
- Promoting fruit bagging techniques by rural and urban households;
- Establishing a regional service to audit national fruit fly surveillance programmes and provide technical assistance to maintain and improve these programmes;
- Providing on-going assistance to establish, maintain, and implement emergency response programmes; and

- Under the auspices of the Secretariat of the Pacific Community, establishing a regional rapid response capability to assist individual countries to deal with fruit fly incursions. This expertise would cover both expertise and equipment.

Of these activities, highest priority needs to be given to providing support for quarantine surveillance and emergency response programmes.

Mechanisms to ensure sustainability

The on-going sustainability of the activities that have been supported by the RMFFP depends on the self-reliance of national fruit fly programmes. To achieve this, it is incumbent on national governments to provide adequate numbers of trained personnel and sufficient financial support. In allocating resources, national governments should give priority to quarantine surveillance and emergency response programmes. There is also a continuing regional responsibility in these areas because the consequences of fruit fly incursions extend beyond national boundaries.

The tapping of funding from industry

To date, governments have provided most funding and resources for national fruit fly programmes, and in most countries government funding needs to increase in order to properly sustain these programmes. This sustainability also requires greater industry and community participation. There is no guarantee that sufficient public funding will be available to sustain these activities in the future. The 1996 Report recommended ways to encourage industry funding in the various countries. Initial responses from the private sector have yielded mixed results. Ways to effectively impose levies on industry need to be again addressed by the RMFFP.

Furthermore, staff of departments of agriculture, under the supervision and guidance of the RMFFP has implemented almost all fruit fly project activities. Much effort and resources have been devoted to training these staff and a strong cadre of competent personnel is now in place. In the interest of sustainability, some activities, particularly for quarantine surveillance, need now to be devolved to civil society.

Chapter 1: Fruit flies and agriculture in the Pacific Islands

Background

Fruit flies are one of the world's major insect pests of fresh fruit and fleshy vegetables. In every Pacific island country and territory, there is at least one, and usually more, species of endemic, damaging fruit flies. These serious pests infest a wide range of edible fruits and vegetables. It has been recognised for some time that unless fruit flies are understood and managed effectively, prospects for improving the production and quality of fresh fruits and vegetables are limited, and the possibility of developing horticultural exports, for which there are market opportunities, is virtually non-existent. With respect to fruit flies there are potentially three categories of fresh produce exports:

1. Products that are not considered to be fruit fly hosts and therefore do not require quarantine treatment for fruit flies; e.g. root crops, beans, and okra;
2. Products that are exported under a non-host 'quarantine treatment' protocol, which, depending on the country, could include squash, green bananas, pineapples, chillies, and zucchini; and
3. Products that are exported under a high temperature forced air (HTFA) quarantine treatment protocol, e.g. papaya, mango, eggplant, and breadfruit.

Most rural households in the Pacific islands grow fruit for their own consumption. The adverse consequences of exotic fruit flies are potentially even greater on domestic consumption and markets than they are on the export sector.

The Regional Fruit Fly Projects

The Regional Project on Fruit Fly Control Strategies in the South Pacific (RFFP) was launched initially as a one-year project by FAO's Technical Co-operation Programme in September 1990. This first phase involved four countries: Fiji, Tonga, Western Samoa, and Cook Islands. The project was later extended to 1993 and then to 1997, with funding from UNDP, AusAID, the South Pacific Commission, and FAO. The Australian Centre for International Agricultural Research (ACIAR) initiated a project on the Identification and Control of Pest Fruit Flies in the South Pacific that operated in a complementary way. The primary purpose of these projects was to ameliorate the problem of fruit flies in order, initially, to develop export markets for Pacific island produce. The RFFP aimed to do this by:

- Upgrading technical knowledge about fruit flies and ensuring that plant protection, quarantine, and private sector personnel understood the impact of fruit flies on the production and export of fresh fruit and fleshy vegetables;
- Reducing damage to fresh fruit and fleshy vegetables caused by fruit flies; and

- Strengthening the capacity of quarantine services and the private sector to overcome quarantine restrictions imposed by importing countries on Pacific island exports of fresh fruit and fleshy vegetables.

The RFFP focused its efforts on three broad activities: establishing a quarantine surveillance datanbase on fruit flies; facilitating the development of quarantine treatments; and developing field control systems using inexpensive and environmentally sound methods.

The first priority as to develop the fruit fly database and quarantine surveillance systems. Through the introduction of methodical trapping and fruit collection programmes, each country now has good quality data on the types of fruit flies present, their geographic and seasonal distribution, the damage they cause, their host ranges and parasitoid fauna, and the stages of maturity at which fruits of commercial value become susceptible. The systematic generation and presentation of these data has created the necessary conditions for the development of horticultural exports. The challenge now facing Pacific island countries is to ensure that a quarantine surveillance system is put into place to ensure that these databases are maintained.

The quarantine treatment development work of the RFFP has involved two activities:

- Generating the necessary data to negotiate non-host status protocols that allow the importation of certain fruit and vegetables into New Zealand; and
- Providing the necessary research data to certify commercial quarantine treatments based on heat. This involved determining the heat tolerance of eggs and larvae to ascertain the most heat-tolerant stage of economically significant species in each country. These data are then used in confirmatory tests on fruits that are artificially infested at the recommended stage using high temperature forced air treatment (HTFA). Fiji and Tonga pioneered this work. It involved a major injection of technical assistance and specialised equipment from the Agriculture Research Service (ARS) of the United States Department of Agriculture (USDA) and the University of Hawaii, assistance that was co-ordinated by the RMFFP.

The field control development work has concentrated on protein bait spray trials in Fiji, Tonga, and Cook Islands.

Despite the good progress that was made, particularly in developing the fruit fly databases, it was clear that all project objectives could not be achieved within the initial three-year period. The RFFP was therefore extended for a further three years and expanded to include Vanuatu, Solomon Islands, and Federated States of Micronesia. As well as continuing the database, quarantine surveillance and quarantine treatment work, greater emphasis was given to developing protein bait sprays as a means of field control of fruit flies. The introduction of field control

components broadened the potential benefits of project activities beyond promoting exports to increasing domestic fruit consumption.

In May 1997, the project was again extended, this time to cover all 22 Pacific island countries and territories, and with its name changed to the 'Project on Regional Management of Fruit Flies in Pacific (RMFFP).' This name change reflected the broadening of the activities of the project and an increased emphasis on management and control. Activities of the expanded project included establishing and monitoring quarantine surveillance; improving emergency response preparedness; developing and demonstrating technology for the field control of fruit flies; expanding the use of existing quarantine treatments for fresh fruit and vegetables exports based on non-host status and HTFA treatment; increasing public awareness about the risk of exotic fruit fly incursions; and transferring technology between countries. For the remainder of this report, the previous RFFPs will be subsumed under the new name, RMFFP.

This sustained regional effort over nearly a decade has brought about a solid achievement in expanding produce exports. The magnitude of export expansion and the range of parties that have benefited from this expansion have, however, been less than what was envisaged. New Zealand remains the predominant market for fruit and Fiji remains by far the main supplier to this market. From the outset, it was recognised that if the RMFFP was to have a widespread and sustainable impact it must also contribute significantly to domestic fruit production and consumption. In contrast to export production, however, very little was known about domestic fruit consumption or the effects that fruit fly damage had on food security, nutrition, rural employment or poverty. These areas are the subjects of the second part of this report.

This study complements a 1996 report by the same author that evaluated the benefits and costs of the RFFP in terms of generating exports. For completeness, the 1996 report is briefly reviewed here and updated. As in the 1996 report, a case study approach has been adopted. Almost no data were available on domestic fruit production and consumption and it was therefore necessary to collect some primary data. While far more data was needed than could be generated with the limited resources available to this study, sufficient information was obtained upon which to draw some useful conclusions.

Agriculture in the Pacific island countries: a summary

The countries and territories of the Pacific island region are spread over a vast area of the world's surface. This area stretches from the Commonwealth of Northern Mariana Islands (20^{o}N) in the north, Irian Jaya and Palau (135^{o} E) in the west, Easter Island (110^{o} W) in the east, and New Caledonia and Tonga (25^{o} S) in the south. Within this area there are some 22 discreet political entities, including some of the world's smallest countries (Map 1). The total land area of these countries is 550,000 sq. km. of which Papua New Guinea (461,690 sq. km.) makes up 84 per cent. The total population of the sub-region is around six million, of which 4.3 million people (72 per cent) live in Papua New Guinea.

There is great diversity among these countries in terms of their size, population, resource endowments, and the importance of agriculture to the national economy (Table 1). Countries like Tuvalu and Papua New Guinea have little in common other than their approximate location on the globe. Tuvalu is a small atoll country with a population of 10,000 people and a mere 26 sq. km of land. Papua New Guinea, with a population over 4 million occupying a land area of some 460,000 sq. km., is one of the world's largest producers of minerals and has vast endowments of arable land, forests, and minerals. Pacific island countries run the full range of human development status, as shown by the 1999 Human Development Index which ranged from 0.863 for the Cook Islands to 0.302 for Papua New Guinea.

Table 1: A summary of Pacific Island countries and territories

	Land area (sq. km)	**Population at last census***	**Geographic type**	**Importance of agricultural sector**	**Economic and social indicators**	
					GDP per capita (US$) *	Human Development Index (& global ranking) **
American Samoa	240	61,100	High islands, with a few atolls.	Minor: some subsistence and limited market gardening		
Commonwealth of the Northern Marianas	471	68,700	High islands and atolls	Limited: some market gardening and a little subsistence production		
Cook Islands	180	19,000	High islands and atolls	Considerable: main export earner - subsistence a significant component of GDP	5,301	0.863
Federated States of Micronesia	702	111,800	High islands and atolls	Some: small export earnings, some domestic cash income, and some subsistence	2,021	0.568 (120)
Fiji Islands	18,376	779,200	High islands and a few minor atolls	Fundamental: main employer and net foreign exchange earner, subsistence a significant proportion of GDP	2,661	0.668 (102)
French Polynesia	3,521	222,300	High islands and atolls	Some: small export earnings, domestic cash income, and subsistence		
Guam	549	145,400	High island	Limited: some market gardening and a little subsistence		
Kiribati	726	83,400	Predominately atolls	Considerable: important for subsistence - copra important for outer island cash income and some foreign exchange	659	0.507
Marshall Islands	720	60,000	Atolls	Limited: some subsistence and income earned from copra	1,894	0.568 (127)
Nauru	21	11,200	Raised coral island	Insignificant		0.66
New Caledonia	19,103	201,300	High island	Important, particularly in the south		

Niue	258	2,100	Raised coral island	Significant: subsistence and some root crop exports	3,117	0.677
Palau	475	18,100	High islands and atolls	Some market gardening	8,025	0.860
Papua New Guinea	461,690	4,311,500	High islands with a few small atolls	Fundamental: main source of employment, provides a substantial proportion of net export earnings, and subsistence production is a significant component of GDP.	1,198	0.302 (164)
Samoa	2,934	170,700	High islands	Fundamental: subsistence found to be strength of economy	1,025	0.598 (118)
Solomon Islands	29,785	401, 100	High islands with a few atolls	Fundamental: main source of employment, provides a substantial proportion of net export earnings, and subsistence production is a significant component of GDP.	560	0.370 (147)
Tokelau	12	1,500	Atolls	Some subsistence		
Tonga	696	97,800	High islands with a few small atolls	Fundamental : agriculture-led economic growth	1,861	0.654
Tuvalu	26	10,900	Atolls	Some: subsistence and some cash income from copra	1,255	0.590
Wallis and Futuna	255	14,200	High islands and atolls	Some subsistence		
Vanuatu	12,189	177,200	High islands with a few small atolls	Fundamental: main source of employment, provides a substantial proportion of net export earnings, and subsistence production is a significant component of GDP.	1,208	0.408 (142)

Sources: * SPC 1997**;** ** UNDP 1999

The status of fruit flies populations & RMFFP activities in Pacific island countries and teritories

Fiji[1]

There are five fruit fly species in Fiji, of which two (*B. passiflorae* and *B. xanthodes)* are of economic significance. Another economically significant species, *B. kirki,* has been found on the remote northern island of Rotuma. A good quality database has been established on the geographic distribution, seasonal abundance, the level of damage caused, host ranges, and the stages of maturity at which fruits of commercial value become susceptible. Fiji has been able to successfully establish and usually maintain laboratory colonies for both *B. passiflorae* and *B. xanthodes* which have provided the basis of the most successful quarantine treatment research programme in the region.

The Project outputs for Fiji are listed in rows of table 2. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 2: The status of RMFFP outputs in Fiji

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B
Results achieved										
Proved major international fruit flies are not present	●	●								
Non-host protocol for the export of two varieties of chillies to NZ	●	●		●				●		
Approval for HTFA-treated papaya, eggplant, mango, & breadfruit exports to NZ					●	●	●	●		
Inclusion of pineapple varieties other than smooth cayenne in the export protocol to NZ	●	●		●						
Protocol for transhipment of low risk products through Hawaii to Canada	●	●		●						
Improved quality of commercial mango, eggplant, & breadfruit production									●	
Training in fruit-fly eradication techniques										
Development of emergency response plans										
Results expected in 2 years										
Acceptance of HTFA treated fruit for transhipment through Hawaii to Canada	µ	µ		µ	µ	µ	µ	µ	µ	
Expansion of products for transhipment through Hawaii to Canada	µ	µ		µ				µ		
Approval to export HTFA treated *vudi* (plantains) to NZ	µ	µ		µ	µ	µ	µ	µ	µ	
Approval to export HTFA treated papaya, mango, egg plant, breadfruit, mango, & *vudi* (plantains) to Australia	µ	µ		µ	µ	µ	µ	µ	µ	

[1] For a detailed discussion see E. Tora Vueti et al.

Non-host protocol for the export of zucchini & rock melon to NZ	µ	µ		µ				µ		
NZ non-host methodology accepted by Australia	µ	µ		µ				µ		
Approval to export HTFA treated papaya, mango, & egg plant to United States	µ	µ		µ	µ	µ	µ	µ	µ	

Key: **HS**: Host fruit surveys; **T**: Fruit fly trapping; **FC**: Fruit fly colonies for testing; **HR:** Host-status research on immature stages; **HTR**: Heat-tolerance research; **ET**: Efficacy tests for quarantine treatments; **CT:** Confirmatory tests for quarantine treatments; **NQP:** Negotiations on quarantine treatment protocols; **BS**: Protein bait spray; **B:** Bagging; **TET**: Trainging in fruit-fly eradication technique; **ERP**: Development of emergency response plans.

Tonga[2]

Tonga has six fruit flies of which three (*B. facialis, B. xanthodes,* and *B. kirki)* are of economic significance. *B. facialis* is a particularly damaging fruit fly with a wide host range that includes 64 edible and commercial fruits, among them chillies, mango, citrus, and banana. The RMFFP has been able to successfully establish and maintain colonies for *B. facialis* and *B. xanthodes* which have been used to support active host status and quarantine treatment research programmes.

The Project outputs for Tonga are listed in rows of table 3. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 3. The status of RMFFP outputs in Tonga

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B
Results achieved										
Proved that major international fruit fly spies not present	●	●								
Proved that melon fly, cucumber fly, & other species that infest cucurbits not present in Tonga	●	●								
Effective field control system for watermelon									●	
Commercial production of bait spray by the Royal Brewery – Royal Tonga lure.									●	
Enhanced domestic fruit & vegetable consumption									●	
Training in fruit-fly eradication techniques										
Development of emergency response plans										
Results expected in 2 years										

[2] For a detailed discussion see V. Heimoana et al.

Acceptance to export HFTA treated breadfruit, plantains & eggplant to NZ	μ	μ		μ	μ	μ	μ	μ	μ	
Acceptance to export HFTA treated papaya & breadfruit to Australia	μ	μ		μ	μ	μ	μ	μ	μ	
Non-host protocol for the export of zucchini, rock-melon & squash to NZ	μ	μ		μ						

Key: See Table 2.

Samoa[3]

Seven fruit fly species have been identified in Samoa, of which two (*B. kirki* and *B. xanthodes)* are of economic importance. Substantial colonies of both species have been established but not consistently maintained. This has undermined Samoa's ability to undertake host status work, thereby achieving less in this area than Fiji or Tonga. Heat tolerance work in Samoa also lagged well behind these countries but, with technical assistance from New Zealand, it has been able to catch up. On the positive side, the RMFFP has collected over 5,400 samples of fruits and vegetables and has valid host records. This together, with RMFFP's trapping programme, undoubtedly provided the necessary confidence for the New Zealand Ministry of Agriculture and Fisheries to negotiate a protocol to allow the importation of bananas from Samoa. These data also provide a basis for future negotiations of quarantine protocols with other importing countries. New Zealand authorities have accepted data on heat tolerances of immature stages of *B. xanthodes* and *B. kirki.*

The Project outputs for Samoa are listed in rows of table 4. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 4. The status of RMFFP outputs in Samoa

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B
Results achieved										
Proved that major international fruit fly spies not present	●	●								
Heat tolerance data accepted by NZ (done by HortResearch)	●	●								
Proved that banana fruit fly & other exotic species not present in Samoa	●	●								
Training in fruit-fly eradication techniques										
Results expected in 2 years										
Non-host protocol for the export of bananas to NZ at the colour break stage	μ	μ		μ				μ		

[3] For a detailed discussion see V. Heimoana et al.

Non-host protocol for the export of zucchini & rock melon to NZ	μ	μ		μ				μ		
HTFA quarantine treatment for the export of papaya & breadfruit to NZ.	μ	μ		μ	μ	μ	μ	μ	μ	

Key: See Table 2.

Cook Islands[4]

Cook Islands has two fruit fly species of economic significance, *B melanotus* and *B. xanthodes,* both of which have wide host ranges. In Cook Islands, both species affect the Waimanalo variety of papaya at the quarter-ripe stage, although the damage is not great. Research undertaken by the RMFFP has shown 12 per cent losses during summer months and one per cent losses in the winter, if the fruit is allowed to ripen on the tree.

The Project outputs for Cook Islands are listed in rows of table 5. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 5. The status of RMFFP outputs in Cook Islands

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B
Results achieved										
Proved that major international fruit fly spies not present	●	●								
NZ HFTA certification for papaya	●	●	●							
NZ HFTA certification for mango	●	●		●	●	●	●		●	
Improved quality of papaya exports									●	
Results expected in 2 years										
NZ HTFA certification for eggplant & star fruit (carambola)	μ	μ	μ							
A non-host protocol for chilli (bird's eye), zucchini, rock melon, & pineapple to NZ	μ	μ		μ				μ		

Key: See Table 2.

Vanuatu[5]

Vanuatu has 14 known fruit fly species but only two, *B. trilineola* and *B. umbrosa,* are of economic significance. *B. trilineola*, found throughout Vanuatu, has 24 commercial hosts.

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[4] For a detailed discussion see M. Purea et al.

[5] For a detailed discussion see A. Allwood.

These include citrus, guava, mango, soursop, and *nakavika* (*syzggium* spp.). *B. umbrosa* is a major pest of breadfruit and jackfruit. Laboratory colonies of both species are being maintained in an ongoing programme of developing quarantine treatments. With only two economically significant species, Vanuatu at present has an excellent current fruit fly status, but it is in a vulnerable position. To the north lies Solomon Islands, where melon fly (*B. cucurbitae)* is already established on Guadalcanal. Close to the west of Vanuatu lies New Caledonia, where Queensland fruit fly (*B. tryoni)* is now established. Further west is Papua New Guinea, where there is Asian papaya fruit fly (*B. papayae*) and at least 16 to 18 other economically significant species.

The Project outputs for Fiji are listed in rows of table 6. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 6. The status of RMFFP outputs in Vanuatu

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B
Results achieved										
Proved that major international fruit fly spies not present	●	●								
Non-host protocol for export of squash & cucumber to NZ	●	●		●						
Training in fruit-fly eradication techniques										
Development of emergency response plans										
Results expected in 2 years										
Non-host protocol for chilli, zucchini, rock melon, & pineapple to NZ	µ	µ		µ				µ		
Approval to export HTFA treated papaya & pompulmous to NZ	µ	µ		µ	µ	µ	µ		µ	
Commercial production of guava on Efate									µ	
Commercial production of bait spray & livestock protein supplements in Vanuatu									µ	
Adoption of bagging techniques at the village level										µ

Key: See Table 2.

Solomon Islands[6]

The fruit fly situation in Solomon Islands is one of the most complex and least favourable of all the countries participating in the RMFFP. Trapping and host surveys have shown that about 48 fruit fly species are present in the country, including melon fly. Other species of economic significance include mango fly (*B. frauenfeldi*), *Dacus solomonensis,* and *B. umbrosa.* A wide range of cucurbits are hosts to melon fly and *D. solomonensis*, including squash, zucchini, and various melons and gourds. Fruit fly damage to snake

[6] For a detailed discussion see M. Vagalo et al.

gourd, for example, can approach 90 per cent, and for squash and pumpkin, between 60 and 90 per cent. Mango fly has a wide range of hosts including guava, mango, papaya, and breadfruit, and over 50 per cent damage to guava has been recorded. Laboratory colonies of mango fly*, D. solomonensis*, and melon fly are being maintained for heat tolerance studies and the parasitoid releases for melon fly.

In recent years, melon fly has spread throughout most of Solomon Islands. It was first recorded in the Shortland Islands, adjacent to Bougainville in 1984, and by 1988 had moved south to Isabel Province. The first trappings and fruit surveys conducted by the RMFFP in 1994 found that melon fly had reached Malaita Province. At the end of 1995, it was discovered in a trap near the Honiara market. In collaboration with the Ministry of Agriculture, the RMFFP mounted a containment programme on Guadalcanal using protein bait sprays. This was continued until eradication was found to be no longer feasible, primarily because the movement of produce in and out of the infested area could not be prevented. Melon fly is now well established on Guadalcanal. The Provinces of Makira, Temotu and Rennell-Bellona are still free of melon fly.

The Project outputs for Solomon Islands are listed in rows of table 7. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 7. The status of RMFFP outputs in Solomon Islands

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B	TET
Results achieved											
Timely identification of the arrival of melon fly on Guadalcanal, & proof that other exotic fruit flies do not exist	●	●									
Results expected in 2 years											
Containment of melon fly on Guadalcanal through use of bait sprays & introduction of the parasitoid *Psyttalia fletcheri* (in collaboration with USDA Hilo Hawaii Laboratory)									µ		µ
Adoption of bagging techniques at the village level										µ	
Commercial utilisation & production of bait spray, especially for cucurbit production									µ		

Key: See Table 2.

Federated States of Micronesia[7]

Federated States of Micronesia has a favourable fruit fly status, as the mango fly is the only one present. This fly, however, has a wide host range, with 61 hosts in its

[7] For a detailed discussion see L. Leblanc.

geographical range, and does considerable damage. Assessments of damage on economic crops in Federated States of Micronesia have shown infestation of up to 91 per cent of guava, 37 per cent of breadfruit, 20 per cent of tangerines, eight per cent of mangoes, and four per cent of oranges. The States of Pohnpei and Kosrae are volcanic, fertile high islands where fruit and vegetables grow well. The adjacent territories of Guam, with its military population, and the Commonwealth of the Northern Mariana Islands (CNMI), with its large tourist numbers, offer significant market opportunities for fresh produce. Both these territories, however, come under the umbrella of the United States Department of Agriculture's APHIS, so making the regulatory obstacles to exporting produce there as difficult as to the United States. Federated States of Micronesia has small and limited prospects to export produce to Marshall Islands, Palau, Kiribati, and Nauru.

The Project outputs for Fiji are listed in rows of table 8. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 8. The status of RMFFP outputs in Federated States of Micronesia

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B
Results achieved										
Proved that major international fruit fly spies not present in FSM	●	●								
Confirmed that exotic fruit flies are not present in FSM	●	●								
Results expected in 2 years										
Approval for the export of non-host status/low risk fruit to Guam, CNMI, Marshall Islands, & Kiribati	µ	µ			µ					
Adoption of bait spray technology									µ	
Development of data on heat & cold tolerances of eggs & larvae of mango fly					µ					

Key: See Table 2.

Papua New Guinea[8]

Papua New Guinea has the least favourable fruit fly status in the region. About 200 species exist there, of which 18 to 20 are economically important, including Asian papaya fruit fly and melon fly. This situation poses a major threat to the Pacific island region, including Australia and New Zealand. The Papua New Guinea Fruit Fly Project encompasses the RMFFP (since May 1997) and an ACIAR funded project. The RMFFP has established some 120 trap sites in commercial and rainforest areas to survey fruit fly fauna in Papua New Guinea. Protein bait spray plots have been established in the East New Britain, Lae and Laloki areas. Laboratory colonies of various species have been established in each area for quarantine treatment work.

[8] For a detailed discussion see D. Tenakanai.

The Project outputs for PNG are listed in rows of table 9. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 9. The status of RMFFP outputs in Papua New Guinea

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B
Results achieved										
Valid data showing Papua New Guinea has about 200 species, of which about 20 are economically important, including sw & Asian papaya fruit fly (RMFFP 65%; ACIAR 35%)	●	●								
Field control methods adopted									●	●
Laboratory colonies set up in Bubia & Kerevat			●							
Training in fruit eradication techniques										
Results expected in 2 years										
Acceptance of heat tolerance data for six economic species by NZ, Australia & USA			μ		μ					
Improved quality/quantity of edible fruits & vegetables									μ	
Protein bait spray made from modified brewery waste yeast									μ	

Key: See Table 2.

New Caledonia[9]

Thirteen species of fruit fly have been recorded in New Caledonia, of which three are of economic significance. Eight species are endemic to the island. Queensland fruit fly was introduced in 1969. The fruit fly research programme in the Territory, which operates under the auspices of CIRAD, has involved fruit survey, trapping, host status, and heat tolerance work. Protocols have been established to export watermelons, squash, and limes to New Zealand.

The Project outputs for New Caledonia are listed in rows of table 10. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 10. The status of RMFFP outputs in New Caledonia

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B
Results achieved										
Valid data on fruit flies, Queensland fruit fly as the major pest species (5% by RMFFP)	●	●								

[9] For a detailed discussion see R. Amice and F. Sales.

Non-host protocol for pineapple & limes (5% by RMFFP)			●	●						
Heat tolerance data accepted by NZ (NZ Hort & Research)			●		●	●				
Quarantine heat treat for mango & capsicum (Govt. & NZ Hort & Research)										
A BQA for export of watermelon to NZ				●						
Results expected in 2 years										
Quarantine treatment expected for Australia (NPQ mostly by Govt.)					µ	µ	µ	µ		
Improved fruit quality with use of bait sprays produced from modified waste brewery yeast (20% by RMFFP)									µ	
Training in fruit fly eradication techniques (60% by RMFFP)										
Capacity for emergency responses to exotic fruit flies (60% by RMFFP)										

Key: See Table 2.

French Polynesia[10]

French Polynesia has three fruit flies of economic importance: *B. kirki,* Queensland fruit fly, and Oriental fruit fly (*B. dorsalis).* Oriental fruit fly is the most recent incursion. It was first detected in Tahiti in July 1996 and later spread to the nearby island of Moorea. Its hosts include papaya, pomplomous, mango, and guava. *B. kirki* was first recorded there in 1928 and appears to have a wider host range than Oriental fruit fly. Queensland fruit fly, first recorded in 1970, has an even wider host range than *B. kirki.* None of these three fruit flies are found in the Marquesas Islands of French Polynesia. Oriental fruit fly was the subject of an eradication programme that used male annihilation and strategic protein bait spraying but, unfortunately, the Government ceased funding when the programme was within four months of being successful. As a result, Oriental fruit fly has reinfested many areas of Tahiti and Moorea and the US$1.6 million spent on the eradication programme has been wasted. People in French Polynesia are now suffering significant losses to their staple fruits and a range of non-stable fruits. Trapping was recently introduced and was established on Raivavae, Austral Islands in late 1998 (Allwood, pers. com).

The Project outputs for French Polynesia are listed in rows of table 11. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 11. The status of RMFFP outputs in French Polynesia

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B	FE	TET	ERP
Results achieved													

[10] For a detailed discussion see M. Purea et al.

Valid data on existing species, showing Queensland fruit fly & Oriental fruit fly are present	●	●											
Capacity to undertake emergency response to exotic fruit flies												●	●
Protocol to export pineapples				●									
Results expected in 2 years													
Eradication of Oriental fruit fly												μ	μ

Key: See Table 2.

Nauru[11]

Because of the previous absence of any quarantine controls, a number of exotic fruit flies of serious economic significance became established on Nauru, namely Melon fly, mango fly, Oriental fruit fly, and *B. xanthodes*. These species posed a significant quarantine risk to other Pacific island countries, where they do not already occur. To reduce this risk and provide training for plant protection and quarantine staff from other Pacific island countries, an eradication programme began in October 1998, assisted and organised by the Nauru Government, RMFFP, and the Crawford Fund for International Agricultural Research, Australia. The programme used a combination of male annihilation and protein bait spraying and concentrated first on eradicating Oriental fruit fly and *B. xanthodes,* both of which are attracted to methyl eugenol lures. The male annihilation method involved the distribution of fibreboard blocks soaked in methyl eugenol and the insecticide tipronil. The results were very promising with no Oriental fruit flies or melon flies being recorded for over 36 weeks. Numbers of *B. xanthodes* are now very low and mango flies have been reduced from between 1,500 and 2,000 flies per week per trap, to less than 5 flies per week per trap. For the first time in about 15 years, the people of Nauru are able to eat ripe mangoes that are not damaged by fruit flies.

The Project outputs for Nauru are listed in rows of table 12. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 12. The status of RMFFP outputs in Nauru

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B	TET	ERP
Results achieved												
Valid data on species present: Oriental fruit fly, melon fly, mango fly, & *B. xanthodes*	●	●										
Successful eradication campaign mounted									●		●	
Improved quarantine capacity & draft Agricultural Quarantine Bill											●	●

[11] See E. Tora Vueti et al.

Results expected in 2 years												
Freedom from fruit flies									μ		μ	μ

Key: See Table 2.

Palau[12]

Mango fly, Breadfruit fly (*B.umbrosa)*, Oriental fruit fly and *B. calophylli* occur in Palau. Oriental fruit fly was found in Palau in 1996, with very high levels of damage reported to guava, papaya, ripening bananas, and mango. The presence of this exotic fruit fly is a threat to all of Micronesia. Intensive trapping on 100 sites and fruit sampling is being done in preparation for an eradication programme for Oriental fruit fly. Recently completed technical and economic feasibility studies indicate that eradication is worthwhile.undertaking.

The Project outputs for Palau are listed in rows of table 13. These are divided into achieved outputs, and those expected to be achieved in the next two years. The columns shown the RMFFP's component contributing to each output.

Table 13. The status of RMFFP outputs in Palau

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B	FE	TET	ERP
Results achieved													
Valid data on species present: Oriental fruit fly, breadfruit fly, & mango fly	●	●											
Feasibility study on eradication of Oriental fruit fly & breadfruit fly													
Results expected in 2 years													
Eradication of Oriental fruit fly & breadfruit fly												μ	μ

Key: See Table 2.

Niue[13]

Niue is a small raised atoll that is relatively isolated. It has three fruit fly species, all of which are of economic significance, namely *B. xanthodes, B. kiki,* and *B. passiflorae.* These are widely distributed throughout the island and occur in large numbers during the fruiting season of host plants.

The status of RMFFP outputs in Niue is shown in Table 14.

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[12] See L. Leblanc

[13] See V. Heimoana et.al.

American Samoa[14]

Fruit fly surveys commenced in American Samoa in June 1996 as part of RMFFP's quarantine surveillance programme. To date, four fruit fly species have been detected, namely *B. xanthodes, B. kirki, B. distincta* and *B. obscura.*

The status of RMFFP outputs in American Samoa is shown in Table 14.

Kiribati[15]

The islands of Kiribati are spread over an area equivalent to continental United States, ranging from Christmas Island in the north to the heavily populated Gilbert Islands in the south. In common with Micronesia generally, there is very little published data on fruit flies in Kiribati. Melon fly was detected on Christmas Island in 1987, imported in infected cucumbers from Hawaii. However, the cessation of cucurbit cropping for two years is reported to have been sufficient to eradicate the fly. Mango fly is native to the Gilbert Islands and a fruit fly surveillance programme has been established there.

The status of RMFFP outputs in Kiribati is shown in Table 14.

Marshall Islands[16]

Marshall Islands, like Kiribati, has limited information about its fruit fly populations but a quarantine surveillance system for exotic fruit flies is now in place. Mango fly is native to the Marshall Islands and is the only species present.

The status of RMFFP outputs in Marshall Islands is shown in Table 14.

Tokelau[17]

This small atoll lies in close proximity to Samoa. The fruit fly species present in Tokelau are likely to be similar to those in Samoa, given the close links between the islands. A fruit fly trapping programme began in 1996, with a species similar to *B. passiflorae* having been identified, namely near *passiflorae*.

The status of RMFFP outputs in Tokelau is shown in Table 14.

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[14] See V. Heimoana et al.

[15] See L. Leblanc

[16] See L. Leblanc

[17] See E. Tora Vueti et al.

Tuvalu[18]

Temporary fruit fly traps set up on the main atoll of Funafuti have identified the presence of *B. sp.n* (near *passiflorae*). Host records and damage assessments are yet to be obtained for the islands of Tuvalu. Tuvalu now has a quarantine surveillance system in place, developed under the auspices of the RMFPP.

The status of RMFFP outputs in Tuvalu is shown in Table 14.

Table 14. The status of RMFFP outputs in American Samoa, Kiribati, Marshall Islands, Niue, Pitcairn Islands, Tokelau and Tuvalu

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B	FE	TET	ERP
Results achieved													
Valid data on fruit fly species	●	●											
Trained personnel on eradication procedures & draft emergency response plans												●	●
Transfer of technology on field control									●	●			
Results expected in 2 years													
Eradication of Oriental fruit fly & breadfruit fly												µ	µ
HTFA treatment approved by USDA	µ	µ	µ		µ	µ		µ	µ				

Key: See Table 2.

Wallis and Futuna[19]

Recent fruit fly trapping programmes have shown the presence of *B. passiflorae, B. obscura, B. kirki,* and *B. xanthodes* on both Wallis and Futuna. *B.distincta* occurs on Futuna, but not on Wallis.

Guam and CNMI

Melon fly is the only fruit fly species present in the Marianas (Guam and the Commonwealth of the Northern Marianas Islands). Oriental fruitfly was successfully eradicated from the Marianas in the 1960s. The eradication of melon fly could be achieved by the sterile inspect release technique (SIT). The very high cost of SIT may make eradication difficult to economically justify.

Table 15. Status of RMFFP outputs in Guam and the CNMI

	HS	T	FC	HR	HTR	ET	CT	NPQ	BS	B	TET

[18] See E. Tora Vueti et al.

[19] See E. Tora Vueti et al.

Results achieved											
Valid data on species: melon fly the only species present	●	●									
Results expected in 2 years											
A full economic feasability study undertaken on the eradication of melon fly									μ		μ

Key: See Table 2.

Chapter 2: An evaluation of the export benefits of the Regional Fruit Fly Projects.

The 1996 Study

A benefit and cost analysis of the RMFFP undertaken in 1996 for the period 1993 to 2002 measured the realised and expected impacts of the RMFFP on increasing export earnings (McGregor, 1996). This is referred to here as the 1996 Report. The analysis was necessarily limited because, due to the time lags involved, few project results had actually been realised in 1996 although several were imminent. For example, the Fiji HTFA facility was then yet to be certified to allow the export of papaya to New Zealand, but these exports were expected to soon begin. Some other outcomes were then only thought to be possible, such as certification by the United States Department of Agriculture (USDA) for the Fiji HTFA facility, to allow Fiji produce to be exported to the United States. There were also substantial lags between some project achievements and the realisation of increased exports. While Vanuatu had obtained non-host status to export squash to New Zealand, for example, no shipments had yet been made.

The 1996 Study divided the benefit stream into three categories:

- benefits based on 'achieved' results, such as exports of Fiji chillies to New Zealand on a non-host protocol (a result that was assigned a 100 per cent probability of occurring);

- benefits based on 'likely' outcomes over the next two years, such as exports of Vanuatu squash to New Zealand on a non host protocol (a result that was assigned a 70 per cent probability of occurring);

- Benefits based on 'possible' outputs over the next three years, such as a protocol to allow the export of HTFA treated papaya from Fiji to the United States (a result that was assigned a 20 per cent probability of occurring).

The 1996 Study then apportioned part of each 'actual', 'likely', and 'possible' benefit to the activities of the RMFFP, this apportionment requiring some judgement on the part of the analyst. Some examples include:

- *Tongan squash exports to Japan*. Fruit collection surveys by the RMFFP confirmed that fruit flies do not attack squash in Tonga. These surveys and trapping trials also confirmed the absence of exotic fruit flies of particular concern to Japan. These findings undoubtedly gave the Japanese authorities confidence about the safety of importing Tongan squash. The RMFFP, thereby, contributed to the establishment and maintenance of the Japanese squash market, which is the mainstay of the Tongan economy. How much of the income generated by the squash industry that can be attributed to the RMFFP is difficult to judge. The 1996 Study conservatively estimated this to be 5 per cent. In 1996, this represented an annual benefit of around $T500, 000.

- *Fiji's HTFA treated produce to New Zealand*: The RMFFP made a major contribution to Fiji's HTFA facility being certified to export to New Zealand by providing the necessary heat tolerance research and efficacy and confirmatory tests. A collaborative project funded by USAID provided the HTFA technology. The 1996 Study attributed 80 per cent of the export earnings from Fiji's HTFA treated produce to the RMFFP intervention.
- *Chilli exports from Fiji to New Zealand on a non-host protocol*. These exports can be attributed entirely to the host status research conducted by the RMFFP. The 1996 Study therefore attributed 100 per cent of the export earnings of Fiji's chillies to the RMFFP.

Table 16 presents the consolidated contribution of the RMFFP towards assisting exports from Fiji, Tonga, Samoa, Cook Islands, Vanuatu, and Federated States of Micronesia from 1993 to 2003, as estimated in the 1996 Report. Benefits realised between 1993 and 1995 were based actual exports, while those from 1996 to 2003 were based on export projections. Over the ten-year period, the 1996 Report estimated that the consolidated benefits would total US$24.5 million, of which US$8.9 million would accrue to Fiji, US$6.9 million to Tonga, US$4.3 million to Vanuatu, US$2.4 million to Samoa, and US$1.5 million to Cook Islands. (Apart from a small quantity of bananas sent from Federated States of Micronesia to Guam, neither Federated States of Micronesia nor Solomon Islands exported fresh fruits or vegetables.) When compared with project costs, this benefit flow generated an internal rate of return of 37 per cent. These projections assumed that funding of core project activities would be maintained over the period.

Table 16 goes here

The 1999 Update

The 1996 estimates were re-evaluated three years later, in 1999. Through the passage of time, some 'likely' project results had become 'achieved', some possible' results had been upgraded to 'likely', and some other expected outputs had failed to materialise. In 1999, the assessment of benefits based on actual exports could be extended from 1993 to 1998, and projected exports could be better assessed.

Table 17 compares the 1996 and 1999 assessments of export benefits from RMFFP activities. Overall, the total estimated benefits over the period 1993 to 2002 decreased by some 40 per cent, to US$ 12.6 million. Project outcomes in each country are discussed briefly below.

Table 17. Comparison of the 1996 and 1999 assessments of project benefits, by country (Values in $US 000)

	1996 assessment of benefits	1999 assessment of benefits	Difference between 1996 and 1999 assessments	1999 assessment as % of the 1996 assessment
Fiji	8,857	6,229	2,628	70
Tonga	6,930	3,799	3,131	55
Samoa	615	680	1,931	111
Cook. Is	1,530	887	643	54
Vanuatu	4,315	840	3,475	19
FSM	465	155	310	33
Total	US$21,182	US$12,590	US$8,592	59

Fiji

The 1999 assessment attributed US$6.2 million—approximately half of all project benefits—to Fiji. Much of this is due to Fiji's now viable HTFA business, which handled over 390 tonnes of produce in 1998 (Table 18).

Table 18: Produce treated by the HTFA facility at Nadi, Fiji, 1996-98

Commodities	1996 (kg)	1997 (kg)	1998 (kg)	Total (kg)	Estimated value (F$ Fob)
Pawpaw	33,037	90,010	85,965	209,012	836,048
Mango	-	23,072	120,209	143,283	429,843
Eggplant	-	69,615	185,155	254,770	891,695
Total	33,037	182,679	391,329	607,063	2,157,586

Source: Manager, Natures Way Cooperative (Fiji) Ltd

Despite Fiji's relatively strong export performance, the assessment of benefits in 1999 was US$2.6 million less than in 1996, a 30 per cent reduction. The main reason for

this was a far poorer than expected performance in papaya exports. Based on a number of feasibility studies, the 1996 Report had estimated the market for Fiji papaya in New Zealand would be 600 tonnes a year, yet exports in 1998 totalled only 86 tonnes. Some of this shortfall can be explained by supply factors. A severe drought affected Fiji in 1998. Packaging and quality standards are still below optimal standards. Overall, however, the recent experience of marketing Fiji papaya in New Zealand has shown that, unless prices are well below economic levels, the market is unlikely be anywhere near as large as 600 tonnes. It has to be shared with produce from Cook Islands and Tonga, where there is also a recently certified HTFA facility. Other Pacific island countries, namely Vanuatu, New Caledonia, and Samoa, are planning to establish HTFA facilities in order to target the New Zealand market. Hawaii also recently received approval to export HTFA treated papaya to New Zealand. In July 1999, Hawaiian Kapaho papaya was wholesaleing at NZ$14 per carton, compared with NZ$18 per carton for Fiji Sunrise papaya.

It is in papaya exports to Australia, however, that the main shortfall in expected exports has occurred. Prior to 1992, when an international ban was placed on ethylene dibromide (EDB) quarantine treatment, Fiji exported 50 to 150 tonnes to Australia a year. The 1996 Report assumed that this market would be re-established soon after New Zealand accepted HTFA treated produce, that Fiji's HTFA facility would be certified for Australia in 1997, and that the market for Fiji papaya in Australia would be around 500 tonnes. Yet it was not until June 1999 that confirmatory tests were undertaken at the Nadi facility for the Australia Quarantine Inspection Service (AQIS). The results achieved did not reach the inappropriate and unrealistic standards set by AQIS. It is hoped that after a further series of test Fiji will commence papaya exports to Australia some time in 2000, more than three years later than planned.

The market for Fiji papaya in Canada was estimated to be 100 tonnes a year, an estimate based on market studies and sales prior to 1992, when USDA banned the transhipment of Fiji produce through Hawaii. With HTFA treatment, it is expected that this transhipment will again be permitted, for HTFA is US technology that was developed originally for papaya and was transferred to Fiji under a USAID programme. In June 1999, USDA-APHIS sent a team to inspect Fiji's HTFA facility, a visit that was instigated by the Pacific Islands United States Joint Commercial Commission, following representations by the RMFFP to the US Embassy in Fiji in 1998. As result of this meeting, USDA approval can be expected once Fiji's Ministry of Agriculture has submitted the necessary data. In 1999, it seemed likely that shipments of HTFA treated papaya would soon commence to Canada, and possibly also to West Coast United States, although this will require specialised packaging. This has not yet occurred.

The agonisingly slow progress of acquiring Australian and United States quarantine approval for exports of Fiji HTFA treated papaya has in part been because this is a minor product from a small country and has been given low priority in allocating resources to the necessary assessment of pest risk. The Ministry of Agriculture's Quarantine Department, furthermore, has not been sufficiently proactive in pushing the process along or raising Fiji's case amongst quarantine officials in importing countries. People in the industry complain that the Ministry has been slow in supplying data required by importing countries, and, when it finally does, has not

presented these data in the format required. In hindsight, Fiji's Quarantine Department could have benefited from technical assistance in preparing submissions to the Australian and United States authorities, including the collection and presentation of the required risk assessment data. Such a technical assistance component should be incorporated into the next stage of the RMFFP, to increase the project's contribution to export earnings.

Fiji's HTFA facility is a commercial business that is owned and operated by Natures Way Cooperative (Fiji) Ltd. The business is financed by a levy of 40c per kg of fruit treated. The original feasibility study for the business was based largely on expected exports of papaya. It assumed 150 tonnes of papaya would be treated in the first year of operation and 500 tonnes by the third year. The volume of papaya treated has been far short of the level required for financial viability, unless treatment fees were raised to an uneconomically high level for growers. Fortunately, much of the shortfall in papaya has been taken up by eggplant.

Once considered to be a relatively minor product, eggplant has become the cornerstone of the viability of the Fiji's HTFA facility. It was initially expected that 25 tonnes of eggplant would be treated for the New Zealand market in the first year, increasing to 60 tonnes over five years, but the market for HTFA treated eggplant has exceeded these expectations. In 1998, some 185 tonnes were exported, much more than the 50 tonnes of ethylene dibromide (EDB) treated fruit exported in 1996. Previously, the market for Fiji eggplant was narrow, being principally Auckland in winter when no locally grown eggplant was available. With the improved quality and shelf life of HTFA fruit, eggplant shipments now continue year-round and are distributed throughout New Zealand. While the Fiji community remains the foundation of the New Zealand eggplant market, Fiji eggplant is now competing with locally grown produce on the broader market. The black beauty variety is now being planted in Fiji to supply this market, and eggplant exports to New Zealand of over 200 tonnes a year are envisaged.

West Coast Canada and Australia also have large Indo-Fijian communities, which could provide big markets for HTFA treated eggplant. Yet disappointingly, as with papaya, USDA approval for transhipment of HTFA treated eggplant through Hawaii is still pending.[20] (Negotiations with USDA-APHIS in June 1999 included the round variety of eggplant.) Besides its large Fiji community, Australia's much larger ethnic groups such as Melbourne's Greek population are potentially even bigger markets. It is surprising, therefore, that Fiji's Ministry of Agriculture has not submitted any data on eggplant for AQIS consideration.

Breadfruit is also a more important product than was envisaged in 1996. As a popular staple for most Pacific island communities, it could have as large a market as other root

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[20] Currently all varieties of eggplant, except the round variety, can be transhipped through Hawaii to Canada under a special packaging protocol negotiated by Canadian International Airlines several years ago. However, complying with this protocol is expensive, requiring the shrink wrapping of the cartons and the lining of the container with an especially designed cool guard material. These cost have significantly constrained market development in Canada.

crops in New Zealand, Australia, and the United States. In 1998, New Zealand imported almost NZ$ 8 million worth of root crops. A five per cent share of this market for breadfruit does not seem unreasonable. The markets in Australia and the United States West Coast are probably smaller and would require acceptance of HTFA treatment for breadfruit by USDA and AQIS. Quarantine restrictions currently allow breadfruit tp be exported only in frozen or cooked form, and this has precluded any real market development. A major breakthrough occurred in February 1999, when Fiji's HTFA facility was certified to export breadfruit to New Zealand. Unfortunately it took Fiji MAFF nearly a year to submit the quarantine pathway data required by the New Zealand authorities to issue an international health standard certificate for breadfruit. Breadfruit exports are required to commence in mid-2000.

Tonga

The 1996 Report estimated that RMFFP's benefits to Tonga totalled US$6.9 million. In 1999, however, this figure was adjusted down to US$3.8 million, a decrease largely due to a decline in Tonga's export earnings from squash—five per cent of squash export earnings being attributed to the project.

Watermelon and papaya exports were also significantly less than forecast in 1996. In the 1980s and early 1990s, watermelon exports to New Zealand averaged around 200 tonnes a year. It was expected that exports could be restored to this level by negotiating a non-host protocol, especially as tests had shown that the two main export varieties of watermelon were non-host for *B. facialis* or *B.xanthodes*. New Zealand, however, has not been willing to grant non-host status for watermelons because consignments could contain fruit that was damaged or had blossom end rot in which fruit fly could lay eggs. In 1985, damaged watermelon had arrived in New Zealand from Tonga infested with *B xanthodes*. In 1994, when fruit fly was again found inside a container of Tongan watermelon, shipments to New Zealand were banned. (Those fruit flies were evidently 'hitch hikers' from the wharf in Tonga, where there was inadequate quarantine security and broken, overripe fruit was not cleared away.) In 1995, exports from Tonga recommenced under a protocol that required stricter controls at the packing sheds and wharf as well as methyl bromide treatment. In 1997 and 1998, 60 tonnes and 47 tonnes respectively were exported—nowhere near the volumes exported in the 1980s.

Papaya has been identified as a major diversification crop for Tonga. Its development has been facilitated by the United States and New Zealand Governments, which funded an HTFA facility and packing shed. This facility, which is owned and operated by the Ministry of Agriculture, was certified in 1998 to export papaya to New Zealand. Some 7.5 tonnes were exported until a cyclone in early 1999 destroyed the papaya crop, halting papaya exports until late 1999 or early 2000, if they resume at all. The 1996 Report forecast that export markets for papaya would be large enough to accommodate Fiji, Tongan, and Cook Island papaya. The experience of Fiji papaya in New Zealand over the last few years and the unexpected difficulty encountered in gaining access to the Australian market, suggest this was an unduly optimistic view. Also, the expectation that the Tongan HTFA facility would be privatised after an initial start-up has not been realised. Government operated quarantine treatment facilities have not been successful elsewhere and there seems to be no reason why Tonga should be an exception.

Of all HTFA treated products, breadfruit now probably offers the best prospects for Tonga. New Zealand and, possibly, West Coast United States offer significant market opportunities. Estimated benefits from breadfruit exports have therefore been increased, while squash, watermelon, and papaya have all been much reduced.

Samoa

Samoa once rivalled Fiji's produce exports to New Zealand. In recent years, these exports have slipped to very low levels, the result of two major cyclones, plant diseases, quarantine restrictions, and greater competition for the banana market. The RMFFP offered Samoa a timely opportunity to reverse this situation and generate again the much-needed exports. The 1996 Report found that poor counterpart support had prevented Samoa from taking advantage of this opportunity, Samoa lagging well behind Fiji and Tonga in non-host status research, for example. The 1996 Report therefore estimated that the benefits from the RMFFP to Samoa totalled only US$615,000. The 1999 assessment increased this estimate slightly to US$680,000—Samoa being the only country where the 1999 estimate was higher than in 1996. This rise came about through greater exports of bananas to New Zealand than forecast.

Samoa offers ideal conditions for banana production, and bananas have now replaced taro as the country's main staple food crop. Several decades ago, during the 1950s and early 1960s, bananas was Samoa's major export. Exports to New Zealand peaked in the late 1950s when 1.15 million cartons were shipped. Soon after, the plant disease Black Leaf Streak destroyed the industry. Ecuador and the Philippines have now become the main suppliers of bananas to New Zealand. New Zealand currently imports around 73,000 tonnes of bananas, at a CF value of around NZ$ 70 million, making it the highest per capita consumer of bananas in the world. There still is a sizeable niche for bananas from Pacific island countries because of their superior flavour.

As a result of the host status surveys conducted by the RMFFP, Samoa now has a quarantine protocol for the export of all bananas of the genus *Musa* to New Zealand. In 1998, 152 tonnes were exported, at a value of around NZ$ 200,000.[21] In 1999, a speciality niche market was established for organically certified Samoan 'Lady Finger' bananas. In June 1999, two airfreight containers were being shipped each week and the exporter was looking to increase this to three containers once supplies were available.

Samoa's banana non-host protocol is still restrictive in that it requires the fruit to leave Samoa in a fully green state, which reduces Samoa's competitive advantage in terms of flavour. It also makes the exporting of bananas a risky business as some of the fruit could change colour during shipment and the whole consignment then be rejected on quarantine grounds.[22] The viability of exports would be improved if the fruit could arrive in New Zealand at colour break. Survey data collected by the RMFFP indicates that bananas are

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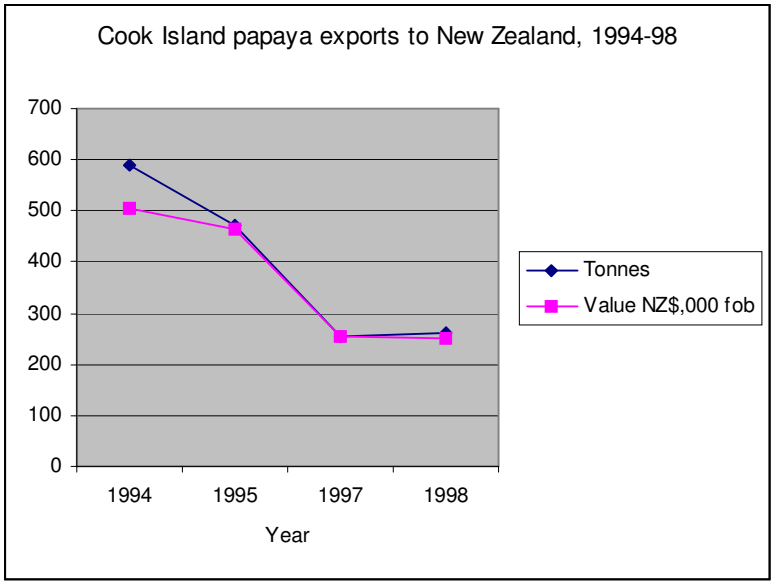
[21] South Pacific Trade Office, Auckland.

[22] If there is any ripening apparent with airfreight shipments, the whole consignment maybe rejected. With sea freight shipment there is discretionary judgement on the part of the NZ MAF inspector to decide if the bananas were harvested at the green mature stage. .

not a fruit fly host in Samoa at colour break—yet Samoa has yet to undertake the non-host status research on this that would satisfy New Zealand quarantine authorities. Once this research is successfully completed, there would seem to be no reason why exports of Samoan bananas to New Zealand could not again rise to several thousand tonnes a year.

Cook Islands

The 1996 Report estimated that the benefits of RMFFP activities to Cook Islands totalled US$1.5 million. In 1999, this figure was adjusted down to US$890,000, a decrease that is due to declining Cook Island papaya exports to New Zealand.



Source: The South Pacific Trade Office, Auckland

The initial success of Cook Island papaya exports can only be partly attributed to the RMFFP. The HTFA project was funded by the New Zealand Government and implemented by Hort+Research (NZ) Ltd. Nevertheless, certification would not have been possible without the fruit fly colonies tha were established by RMFFP for efficacy and confirmatory tests. Moreover, RMFFP data from trapping and fruit collection gave the New Zealand authorities confidence that Cook Islands was free from exotic fruit flies.

The decline in Cook Island papaya exports was principally caused by supply problems. Drought conditions have been experienced since 1996—1998 being particularly severe—and most growers do not have access to irrigation. As part of the Cook Islands Government's structural adjustment programme, furthermore, the HTFA facility was privatised and commercial rates charged for treatment. Long used to a highly subsidised service, growers have taken time to adjust to this commercial reality. Some recovery of papaya exports to New Zealand can be expected over the next few years. Cook Islands' papaya has proven to be more than competitive with Fiji papaya and still maintains about a 40 per cent market share. The larger sized 'Waimanalo' variety is generally preferred by

New Zealand consumers and the Cook Islands reputation for high quality gives its papaya a significant market premium over fruit from Fiji.[23]

As with Fiji, however, Cook Islands has found the barriers to exporting papaya beyond New Zealand are more intractable than was envisaged in the 1996 Report. Cook Islands is still waiting Australian quarantine certification of their HTFA facilities and treatment. Transhipment through New Zealand to Japan would probably be justified considering the high CIF prices (currently around US$3 per kg) and high freight rates from Fiji to Japan. Cook Islands also has air links to the United States West Coast and if USDA approval can be obtained, a niche market may be established there.

Some of the shortfall in papaya exports is likely to be replaced by mango exports to New Zealand. The islands of Rarotonga, Mauki, and Aitutaki produce good quality mangoes that are very acceptable to the New Zealand market. Prior to 1992 when EDB treatment was banned, Cook Islands exported to New Zealand around NZ$100,000 worth of mangoes a year. In 1998, certification for HTFA treatment of mangoes was obtained and 40 tonnes were shipped that year. Cook Island mangoes enter the New Zealand market during December and January, a time when the only competition comes from Fiji. If quality fruit was available, Cook Islands could probably sell 100 tonnes of mangoes in New Zealand—that is, until the cheaper Australian mangoes are again allowed to enter the market.

The 1996 Report envisaged that cucurbits, such as zucchinis and rockmelons, would also be exported to New Zealand under a non-host protocol, but these protocols have not yet been developed. Part of the reason for this has been a sharp cut back in the resources available for agricultural research, as a result of the national structural reform programme.

Vanuatu

Disappointingly, Vanuatu had the largest gap between the 1996 and 1999 assessments of benefits. In 1996, the fledgling Vanuatu fruit fly programme was expected to be a major success story, with its benefits valued at US$4.3 million. In 1999, this estimate was reassessed downwards to US$840,000, a huge reduction due almost entirely to the sudden closure of Vanuatu's squash industry.

In 1992, when Vanuatu began exporting squash to Japan, one New Zealand-owned company, Paradise Growers Ltd (PGL), accounted for 95 per cent of Vanuatu's squash production. The industry grew rapidly and by 1996, squash had become Vanuatu's most important diversification crop. In 1995, Vanuatu exported 2,600 tonnes of squash to Japan valued at US$5.4 million, which amounted to six per cent of Vanuatu's total export earnings. The host surveys and trapping programme conducted by the RMFFP indirectly contributed to the development of this market by giving the Japanese authorities confidence that there was no risk from fruit fly infestation. More importantly, the surveillance programmes established by the RMFFP were seen as critical to safeguarding

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[23] During May 1999, according to the South Pacific Trade Office, the following wholesale papaya prices prevailed: Cook Islands Waimanalo variety: 8-9 count at NZ$40 per carton; Fiji Sunrise variety 9-10 count at NZ$24 per carton. This level of price differential has been typical of the last 12 months.

this new industry. The 1996 Report attributed five per cent of the current export value of the squash industry to the RMFFP, an annual benefit of US$275,000.

As a result of the surveillance work of the RMFFP, at the end of 1996 Vanuatu secured a non-host protocol to export squash to New Zealand. New Zealand is the largest supplier of squash to the Japanese market, currently exporting around 94,000 tonnes a year, but the New Zealand harvest starts in late December, six weeks later than for Vanuatu or Tonga. During this period there is no squash available in New Zealand, and this was a potential market for Vanuatu producers. In 1996, PGL estimated that they would sell to New Zealand 400 tonnes of reject squash (that is, smaller than the minimum size required by the Japanese market). This would provide an annual export earning of US$400,000, assuming an average fob price of US$1,000 per tonne (approximately half of the 1995 export price to Japan). The value of these exports was all attributed in the 1996 Report to the RMFFP.

Unexpectedly, PGL ceased operations at the end of the 1996 season, reportedly because of the restructuring of its parent company. Since then, there have been no squash exports to Japan or New Zealand. The financial viability of exporting to New Zealand is based on the fruit that is rejected for the Japanese market, by being too small—squash that has been harvested and taken to the packing shed but would otherwise be dumped. If handling and shipping costs can be covered, it is worthwhile exporting, but it is not viable to grow squash just for the New Zealand market.

The Vanuatu squash industry may in the future recover from this setback. It has proved it can grow squash that meets the demanding quality standards of the Japanese market and Vanuatu squash has a reputation for superior keeping quality than squash from Tonga, the main competitor. The Tonga industry also is under increasing environmental pressure because of the impact that agricultural chemicals are having on ground water. Experience in the first half of the decade has shown that it is viable for Vanuatu to ship squash to Japan if there is a sufficient volume. The opportunities provided by the RMFFP, however, now represent future possibilities, not the immediate benefits expected in 1996.

Federated States of Micronesia

The 1996 Report estimated that the benefits of the RMFFP to Federated States of Micronesia were worth US$465,000. This figure was based on the possibility that fruit and vegetables would be exported to Guam or the Northern Marianas. Small export prospects were also identified in Marshall Islands, Palau, Kiribati, and Nauru. None of these prospects have materialised, however, or appear likely to soon do so, so reducing the assessed benefits of the RMFFP to an insignificant level. This disappointing situation could change, for the USDA's Agricultural Research Service and the RMFFP are planning to conduct research into quarantine treatments to combat mango fly in Palau. The results of this research will be directly applicable to Federated States of Micronesia, and this may reopen their prospects of exporting mango and citrus fruits (Allwood, pers. comm.).

Comparison of the 1996 and 1999 economic rates of return based on exports

Confirmation of an overall high level of economic viability

The 1996 Report estimated that the internal rate of return of the RMFFP was a very substantial 38 per cent. The 1999 assessment of the project's internal rate of return (which is based on nine years of actual data) reduced this by about half to 19 per cent, which still is a high level of economic viability. Table 21 sets out the 1996 and 1999 assessments of benefits for exports, in relation to project costs.

Table 21. Comparison of the 1996 and 1999 assessments of project benefits and costs

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Benefits (US$, 000)													
- 1996 assessment	0	0	0	580	689	683	1028	1516	2304	2882	3880	4485	4665
- 1999 assessment	0	0	0	580	689	683	555	770	1260	1293	1740	2128	2894
Costs (US$,000)													
- 1996 assessment													
Donor*	216	310	440	570	574	640	550	110	110	110	110	110	110
Pacific island countries*	61	61	61	89	89	89	89	275	275	275	275	275	275
Total	277	371	501	659	663	729	639	385	385	385	385	385	385
- 1999 assessment													
Donor	216	310	440	570	574	640	550	547	650	464	108	110	110
Pacific island countries	61	61	61	89	89	89	89	275	275	275	275	275	275
Total	277	371	501	659	663	729	639	822	925	739	383	385	385
Benefits – Costs													
- 1996 assessment	-277	-371	-501	-79	26	-46	389	1131	1919	2497	3495	4100	4280
- 1999 assessment	-277	-371	-501	-79	26	-46	-84	-52	331	554	1357	1743	2509
Internal rate of return													
1996	**38%**												
1999	**19%**												

*Source: 1996 Report

The increasing predominance of benefits to Fiji

The 1996 Report estimated that 42 per cent of the project's benefits had accrued to Fiji, and by 1999, this had increased to 50 per cent. The project has had most impact on increasing produce exports, and Fiji has benefited most from this. Fiji's predominance in the region as a produce exporter is evident in its share of exports to New Zealand, which is the main market for Pacific island produce exports (Table 22). In 1998, 87 per cent of the exports from Pacific island countries to New Zealand were from Fiji. Of all exported

produce, potential fruit fly host material alone is valued at NZ$2.6 million, of which around 60 per cent is from Fiji.

If the value of RMFFP activities were measured by exports alone then without the success achieved in Fiji, its impact would not have been so significant. The overall economic return on project activities has been further diminished by the recent inclusion in the project of Papua New Guinea and countries in the Northern Pacific and Micronesia. These countries have few foreseeable prospects of exporting produce, yet have increased the overall cost of the project. The best way to overcome this situation and to achieve widely dispersed viability, is for the Project to concentrate more on improving domestic fruit production and consumption.

Table 22. Produce exports from Pacific island countries to New Zealand, 1998 (NZ$, 000, CF) (Share of Pacific regional exports in parenthesis)

Product	Cook Is	New Caledonia	Niue	**Fiji**	Samoa	Solomon Islands	Tonga	Vanuatu	Total
Bananas					220 (100)				220
Coconuts			7 (3)		2 (1)	53 (24)	160 (72)		222
Pawpaw	303 (57)			**178 (34)**			47 (9)		528
Cassava							106 (100)		106
Taro	21 (.2)		54 (1)	**7,608 (98)**	12 (.01)		43 (1)		7,738
Sweet Potatoes							9 (100)		9
Mangoes	85(30)			**200 (70)**					285
Squash		54 (100)							54
Limes		89 (100)							89
Honey			11 (65)			6 (35)			17
Preserved fruit and vegetables				**773 (100)**					773
Ginger				**435 (100)**					435
Chillies				**461 (100)**					461
Eggplant				**650 (100)**					650
Cocoa beans				**79 (52)**		48 (32)		8 (5)	135
Flowers				**84 (100)**					84
Watermelon		233 (85)					42 (15)		275
Total	**409 (3)**	**376 (3)**	**72(.05)**	**10,468 (87)**	**234 (2)**	**107 (1)**	**407 (3)**	**8(.01)**	**12,081**

Source: Statistics New Zealand and the South Pacific Trade Office, Auckland.

Increasing the level and distribution of export based returns from the RMFFP

The experience of the last few years in implementing the RMFFP indicates that the economic returns of the project could be increased and distributed more widely if more attention was given to:

- A more realistic approach to establishing HTFA facilities;
- Greater emphasis of developing non-host protocols;
- The promotion of the broad acceptance of the New Zealand non-host methodology by importing countries; and
- A more proactive and regional approach in dealing with AQIS and USDA-APHIS.

A more realistic approach to HTFA facilities

Fiji's potential for developing significant fresh fruit export industries is now starting to be realised. Its HTFA quarantine facility has considerably contributed to the diversification of agricultural exports. The facility is now approaching a level of product throughput that will provide its sustained viability. In Cook Islands also, papaya is the most important export industry. This too would not have been possible without its HTFA facility. If papaya exports can be restored to the level of the early 1990s, the financial viability of the Cook Island industry can also be assured.

Tonga has a certified HTFA facility and some other countries are establishing these facilities. In most of these countries, however, the throughput will probably not be sufficient to support a viable business. Most of these countries are looking to export papaya to the limited New Zealand market as the basis of their HFTA operations. In some countries, operation by the government is seen as the only way to ensure financial viability during the start-up phase. This government operation, however, is unlikely to be successful and will create a conflict of interest between the operators and the certifiers of the treatment facility.

Because of their very limited capacity for air freight, an HTFA facility of a similar size to the one in Fiji would not be economically viable in most other Pacific island countries. The capital costs alone of such a facility in Vanuatu would be around US$354, 000. There are smaller scale units now available that can handle as little as 300 kg of produce that would be more appropriate for Vanuatu (McGregor, 1997).[24] This viability would require that:

- the facility was operated by an existing commercial Efate-based market garden enterprise;
- the chamber was located in an existing building, with minimal cost of modification;
- overhead and management costs were shared with other activities;

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[24] Quarantine Technologies International Inc, have indicated that they can have manufactured in New Zealand a HTFA unit that can treat 36 lugs (320 kgs) to 108 lugs (950 kgs). It is estimated that such a facility could be commissioned in Vanuatu for approximately $US45,000 (Personnel communication Quarantine Technologies International Inc.)

- the Australian market became available within 2 to 3 months of commissioning the facility;
- the charge for treatment was 50vt per kg (being some 60 per cent higher than the Fiji HTFA facility); and
- Air Vanuatu's low outward freight rate policy was maintained.

Under these conditions, a small export industry could be established to eventually ship around 200 tonnes of produce. This might involve one or two of the larger growers, possibly associated with a few out-growers on Efate. The value of these exports would be around US$0.5 million. This would represent a useful, although not major, agricultural industry.

Another consideration for would be investors in HTFA facilities is that currently the only expertise available for installation and servicing these units resides in New Zealand.

Greater emphasis of developing non-host protocols

Non fruitfly host products and those that can be exported under a non host protocol avoid the high capital and operating costs of quarantine treatment, as well as the management problems associated with operating quarantine treatment facilities. Where possible, therefore, priority should be given to developing these products, especially in the smaller Pacific island countries, rather than products that require HFTA treatment.

Samoa provides a good example. Donor assistance is now being sought to establish an HTFA facility, yet such a facility offers little prospect for financial viability. As well, Samoa has yet to undertake non-host research on bananas at colour break. Yet if a non-host protocol could be established with New Zealand, the banana industry could quickly expand to export around US$100,000 worth of fruit a year (if dependant on the limited air freight capacity available) or US$500,000 a year, if based on sea freight. Unlike establishing a HTFA facility, this growth could be achieved at modest cost. Several other countries could substantially increase their exports by devoting their research resources to developing non-host protocols (Table x).

Table x Potential non-host produce exports from Pacific island countries

Country	Produce
Fiji	Zucchini, rockmelon
Tonga	Squash, rockmelon, watermelon
Samoa	Banana at colour beak
Vanuatu	Zucchini, rockmelon, possibly even papaya at colour break
New Caledonia	Rockmelon, watermelon, and zucchini

Promoting the New Zealand non-host methodology among other importing countries

New Zealand, with its population of only 3.6 million people (of which approximately 10 per cent are Pacific Islanders and Asians) provides a limited market. In 1998, seven Pacific island countries exported produce to New Zealand, of a landed value of approximately NZ$12 million. This value could undoubtedly be increased if produce prices were lowered and the quality and continuity of supply was improved. Yet even if sales were increased to, say, NZ$20 million, New Zealand does not represent a particularly large market for all the Pacific island countries.

Exports from most Pacific island countries are constrained by the limited transportation links to New Zealand. Vanuatu, for example, has better shipping and airfreight connections to Australia than it does to New Zealand, including direct shipping from Santo. Yet produce exports from Pacific island countries to Australia are negligible, merely a few million dollars worth of root crops and coconuts.

The New Zealand non-host methodology is based on an experimental procedure that does not require the costly sampling of large quantities of fruit. Even though New Zealand has no fruit flies and is particularly protective of its valuable horticultural industry, other importing countries, in particular Australia and the United States, do not accept the New Zealand method. Under the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (ASPM), Pacific island countries could have a strong case for the general acceptance of the New Zealand non-host protocol. These grounds are harmonisation (Article 3) and equivalence (Article 4), Article 5 (Assessment of Risk and Determination of Appropriate Level of Sanitary and Phytosanitary Protection), and Article 7 (Transparency). Whether Pacific island countries have the expertise and resources to see a successful outcome of such a case is another matter. Facilitating this would be a worthwhile activity of the final phase of the RMFFP.

A more proactive and regional approach in dealing with AQIS and USDA

Pacific island exports of fresh produce to Australia are less now than they were a decade ago. Fresh fruit exports ceased in 1992 after EDB quarantine treatment was banned and have not resumed since. In 1996, the Fiji HTFA facility was established and certified by New Zealand to export certain fruit fly host products, namely papaya, mango, eggplant, and breadfruit. Yet Australia has yet to accept HTFA treated fruit from the Pacific islands or Hawaii. In recent years, furthermore, AQIS has adopted pest risk assessment and industry consultation procedures that make it very difficult for Pacific island countries to obtain market access for their produce, particularly as there are no clear guidelines on what AQIS requires. Compounding this difficulty, Pacific island countries quarantine departments have proven themselves to be less than competent in dealing with AQIS.

Fiji's efforts to re-establish papaya exports to Australia are illustrative of the problems involved, but Australia's quarantine restrictions have not only affected 'fruit fly host' material. For example, southern Australia potentially offers a sizable market for

ginger growers in Fiji and Vanuatu, even though ginger is grown in southern Queensland. Imports from the Pacific, however, are not permitted on quarantine grounds—restrictions that are difficult to understand, given that Fiji exports fresh ginger to Hawaii, and Hawaii is in turn a major exporter of fresh ginger to North America. At the political level, there could be an opportunity to develop a regional strategy to address the intransigent attitude of Australian quarantine officials towards Pacific island produce.

Pacific island countries quarantine departments, starting with Fiji, could benefit from technical assistance to prepare submissions to potential importing countries. This would include the collection and presentation of risk assessment data to meet Australian requirements. In adopting this approach, however, care must be taken to ensure that a positive environment is created for these negotiations. Over time, a good working relationship has been developed between the staff of Fiji's Ministry of Agriculture and their counterparts in New Zealand. One difficulty in dealing with AQIS is that their staff change so regularly.

Chapter 3: An evaluation of the domestic benefits of the Regional Fruit Fly Projects.

This section of the report sets out to measure the benefits that RMFFP activities have had on domestic fruit production. The development of an export market can lead to the development of a domestic fruit market. In Fiji, the growth of a papaya export industry has helped create a significant domestic market for Hawaiian 'Sunrise' papaya, whereas previously the local varieties of pawpaw were a minor traded product. Local consumption of papaya will probably continue to increase as prices fall with the increasing volume of fruit rejected for export that is available on the local market. But even when there is no export crop involved, improved fruit fly control can have considerable nutritional benefits. In Solomon Islands, for example, the arrival of melon fly caused big losses to gourds, pumpkins, and melons, crops that are grown both for subsistence and the local market. In Nauru, the incursions of exotic fruit flies caused the total loss of locally grown fruit, in a country with already low nutritional standards. The activities of the RMFFP have helped to considerably reduce these losses or stop them altogether.

The cost of fruit flies to the domestic economies of Pacific island countries

The previous chapters showed that some Pacific island countries forego potential export earnings from fruit, largely because of fruit fly quarantine restrictions imposed by importing countries. Quantifying the domestic losses caused by fruit flies is a more difficult task, because much of this fruit is not traded but consumed or exchanged. Another difficulty is to account for the type and extent of damage caused to different fruits by the various fruit flies. Each fly infects a particular range of fruit, which are host for its eggs and larvae. The female fly lays her eggs under the skin of the host fruit. The holes used for egg laying and the feeding of the larvae subsequently damages the fruit through bacteria decay or by causing premature fruit drop.

Damage assessments from the RMFFP

The RMFFP helped conduct host surveys in eleven Pacific island countries between 1991 and 1996, first in Cook Islands, Federated States of Micronesia, Fiji, Samoa, Solomon Islands, Tonga, and Vanuatu, and later in Kiribati, Nauru, Papua New Guinea, and American Samoa. These tests provided data from which to estimate the percentage of fruits that are damaged by fruit flies (Allwood and Leblanc, 1996). Most samples were taken from backyards and small plantings and therefore provide a good indication of fruit losses at the domestic or village level. Table x summarises the results of these surveys.

Table 23: Losses caused by fruit flies, as a percentage of the harvest in Cook Islands, Fiji, Samoa, Solomon Islands, Tonga, Vanuatu, Kiribati, Nauru, Papua New Guinea, and American Samoa

Country	Fruit	Percentage loss	Fruit fly species
Cook Islands	Papaya – Summer	12	*B. melanotus*
			B. xanthodes
	Papaya – Winter	1	*B. melanotus*
			B. xanthodes
Federated States of Micronesia	Breadfruit	35-38	*B. frauenfeldi*
	Guava	45-91	*B. frauenfeldi*
	Orange	4	*B. frauenfeldi*
	Rose apple (*Syzygium jambos*)	62	*B. frauenfeldi*
	Tangerine	17	*B. frauenfeldi*
	Surinam cherry	80	*B. frauenfeldi*
Fiji	Cumquat	60	*B. passiflorae*
	Guava	40-90	*B. passiflorae*
	Kavika	62	*B. passiflorae*
	Mango	20-25	*B. passiflorae*
Samoa	Papaya – local var.	19-37	*B. xanthodes*
	Papaya – sunset variety	4-31	*B. xanthodes*
	Guava	45-99	*B. kirki*
Solomon Islands	Guava	30	*B. frauenfeldi*
	Snake Gourd	>90	*B. cucurbitae, D. solomonensis*
	Squash/pumpkin	60-87	*B. cucurbitae, D. solomonensis*
Tonga	Capsicum	97-100	*B. facialis*
	Chilli	89-97	*B. facialis*
	Guava	90	*B. facialis, B. kirki*
Vanuatu	Guava	95	*B.trilineola*
	Breadfruit*	30	*B.umbrosa*
	Nakavika*	64	*B.trilineola*
	Mango	11	*B.trilineola*
Kiribati**	Breadfruit	71	*B. frauenfeldi*
Nauru***	Mango	95	*B. dorsalis, B. frauenfeldi*
	Guava	90	*B. dorsalis, B. frauenfeldi*
	Breadfruit	12	*B. xanthodes*
	Soursop	<10	*B. dorsalis, B. frauenfeldi*
Papua New Guinea****	Guava - Lae	85-88	*B. frauenfeldi, B.trivialis*
	Guava – Kerevat	71-96	*B. frauenfeldi*

	Carambola – Laloki	90-95	*B. frauenfeldi, B.papayae*
	Carambola – Kerevat	13	*B. frauenfeldi*
	Banana	28	*B. musae*
	Breadfruit	75	*B. umbrosa, B. frauenfeldi*
	Bitter Gourd	95	*B. cucurbitae*
	Pumpkins	44	*B. cucurbitae, B.decipiens*
	Cashew fruit	55	*B. cucurbitae*
American Samoa*****	Breadfruit	62	*B. xanthodes*

Sources: Allwood and Lablanc p. 210; * Vanuatu Department of Agriculture and Horticulture and RMFFP 1997, Table 6; ** Records from Kiribati Government through Leblanc, Federated States of Micronesia; *** RMFFP records from Nauru Fruit Fly Eradication Programme; **** RMFFP reports on bait spray trials and fruit surveys, 1997-1999: unpublished results (provided by A. Allwood); ***** Unpublished report from Quarantine Surveillance in American Samoa (provided by A Allwood).

Confirmatory assessments of fruit fly damage in Pacific island countries

The fruit loss estimates shown in Table 23 are based on large volumes of collected fruit evaluated by professionals for the respective Department of Agriculture, with assistance from the RMFFP.[25] It could be assumed that levels of damage to fleshy fruits and vegetables in Pacific islands not covered by this survey would be of a similar scale.

Localised damage assessment surveys were conducted as part of this study by non-government organisations (NGOs). In Solomon Islands, these were conducted by the Solomon Islands Development Trust (SIDT) in Western Province and on Guadalcanal, around Honiara. In Vanuatu, the Farm Support Association (FSA) conducted surveys in North Ambrym. In Cakaudrove Province, Fiji, trials were conducted under the supervision of Ratu Semisi Rakuro, President of the Waikava Organic Producers Association. Results of these tests are summarised in the tables below.

SIDT operates in all 13 provinces of Solomon Islands and is one of the largest local NGOs in the Pacific region. Its activities concentrate on strengthening the quality of village living and include the operation of a village resource centre, women's study programme, and a conservation in development programme. Village demonstration workers (VDW) from 250 participating villages implement SIDT projects. SIDT now includes the reduction of fruit fly damage in its *supsup* garden (village food garden) programme. The VDWs have considerable experience in carrying out village surveys, an activity for which they receive a small stipend. It was for this reason SIDT was contracted to conduct the damage assessment survey in Solomon Islands, especially as this organisation appeared capable of conducting ongoing fruit fly surveillance and participatory fruit fly research.

[25] During 1990-1996 , a total 22,100 samples of fruit were collected from 7 countries (Allwood and Leblanc 1996). This amounted to 13 to 14 tonnes of fruit.

SIDT co-operated with the RMFFP and the Department of Agriculture to conduct two workshops on fruit fly management and control, one at Gizo for Western Province and the other at SIDT headquarters in Honiara for Guadalcanal Province. Workshop participants, namely SIDT staff and VDWs from the respective provinces, received basic training in assessing fruit damage, identifying larvae and fruit fly eggs, and in methods of fruit surveying. When they returned to their villages, they were instructed to inspect the fruit that was normally picked by their household and determine whether it was damaged or not. For the damaged fruit, they were to assess if the damage was from fruit flies or from another pest, such as fruit piecing moths or fruit bats, and then to classify the damage as small, half, or large, and to note whether larvae could be seen in the damaged fruit.

In Western Province, six VDW who attended the Gizo workshop returned their survey forms, which covered the period from February 12 to March 7, 1999. The fruits surveyed were breadfruit, banana, guava, orange, kavika, papaya, snake gourd, and carambola, which had been identified by the workshop participants as the eight most important fruits consumed in the Western Province. The results of this survey are presented in Table 24.

Table 24: Fruit fly damage assessment for the Western Province, by participants at the SIDT Workshop, Gizo, February 1999.

Fruit type	no. harvested	no. evaluated	No damage (%)	Damage by fruit fly (%)	Damage by other pest (%)	Fruit identified as damaged by fruit flies			
						Small damage (%)	Half damage (%)	Large damage (%)	Larvae observed (%)
Breadfruit	29	29	31	62	7	61	28	11	46
Guava	126	74	70	26	4	42	42	16	NA
Orange	35	35	69	29	3	50	30	20	54
Kavika	399	104	61	38	1	31	23	46	53
Papaya	70	54	41	48	11	46	31	23	47
Banana	61	61	44	33	23	40	25	35	30
Snake gourd	52	52	40	56	4	57	28	15	72
Carambola	5	5	40	60	0	NA	NA	NA	NA

These interesting results need to be interpreted with some caution. The amount of fruit collected is small, there are likely to be some biases in its collection, and the surveyors had limited training in assessing fruit damage or identifying fruit flies—although they did have considerable experience in conducting village-based surveys. Some of the important findings of the survey are:

- Western Province households consume a wide range of fruit.
- All of the fruits listed have some degree of fruit fly damage.
- A high percentage of damage to breadfruit was reported.

- A surprisingly high percentage of papaya was also reported to be damaged.
- Most damage to oranges was reportedly done by fruit flies, not other pests. This is surprising, given the large damage caused by fruit sucking moth (*Othreis fullonia*) that was observed in the surveys conducted in Fiji and Vanuatu.
- A significant amount of damage to bananas was attributed to fruit flies, possibly because the bananas sampled were ripe.[26] By contrast, damage reported to bananas on Guadalcanal survey was an insignificant 1 per cent.
- Fruit fly damage to snake gourd was less than expected. Melon fly has spread throughout Western Province and inflicts heavy damage on cucurbit crops. In areas of intensive cucurbit production, such as Kolobangara Island, infestation levels were high.[27] Some degree of ecological balance may have been restored after the initial devastation of the melon fly, possibly because of the introduction of the parasitoid *Psyttalia fletcheri* by the RMFFP, but also possibly because villagers adopted the recommended control practice of not having continuous plantings of cucurbits.
- A high percentage of assessed fruit fly damage was classified as low or half, and members of the household still ate the undamaged portion of the fruit.

Table x shows the 13 most important fruits consumed by households on Guadalcanal, as identified by the 36 participants in the Honiara Fruit Fly Workshop, and the consolidated damage assessments for each fruit. Surprisingly, the list excludes breadfruit, but this may be because it was not then in season, or it may not have been explained to the participants that breadfruit should be considered a fruit.

Table x

Fruit	Estimated percentage of fruit damaged
Pumpkin	0-1
Banana	1
Soursop	3
Carambola	5
Tnikori (*Spondias dulcis*)	5

[26] There are old host records for banana fruit fly (*B.musae*) in Solomon Islands (Vijaysegaran p. 23). This fruit fly species was not recorded in the trapping conducted during 1994-97, using methyl eugenol lure, which is known to attract banana fruit fly (Vagalo et al. p. 83).

[27] In 1990, the average attack levels in a survey of Kolobangara garden sites ranged from 7 to 70 per cent (Hollingsworth et al. p. 142). In Gizo, the impact of the melon fly was such that the growing of cucurbits was abandoned (Hollingsworth et al. p. 142). Thus the arrival of the melon fly had food security implications.

Green pepper	5
Mango	5-10
Cucumber	18-50
Rock melon	20-50
Papaya	50
Kavika	90
Snakegourd	100
Guava	90-100

While the same caveats apply to the data derived from the Honiara Workshop as from the Gizo Workshop, two findings were particularly interesting:

- An extremely wide range of fruit is consumed on Guadalcanal.
- There is very high damage to cucurbits (except, surprisingly, pumpkin), even higher than in Western Province. This may be because melon fly is a more recent arrival in Guadalcanal (1995) and some ecological balance is yet to be restored.

In Vanuatu, the Farm Support Association (FSA) is a small NGO that works with commercially orientated small farmers. Its activities include conducting a spices extension programme and providing organic certification for its members. The Association raises funds to support its activities by conducting participatory farmer research and surveys. FSA was contracted to do bait spraying and fruit bagging feasibility trials in a village situation. North Ambrym was selected as the location for this participatory research because from the serious threat fruit flies posed to local food security there, it seemed likely that the villagers would be responsive to adopting fruit fly mitigation technologies. North Ambrym is affected periodically by volcanic dust and 'acid rain' and villagers believed there was a correlation between these episodes and fruit fly damage. The FSA lead farmer in the area had raised concern about large losses occurring to village grown fruit, particularly citrus and breadfruit. Trappings he did in May 1998 indicated the presence of *B. trilineola* and *B. minuta* (both found in cure lure traps) and *B. umbrosa* (found in methyl eugenol traps).

Bait spray trials were conducted on breadfruit, mangoes, and nakavika (*Syzygium alaccense*) and bagging trials on citrus and guava. These trials were conducted by FSA under the supervision of RMFFP staff. The control data for breadfruit, mango, and nakavika provide a good indication of damage levels. The breadfruit bait spray trials were undertaken in the villages of Ranon and Ranbe. Breadfruit is a major staple, with large trees planted throughout both villages. Large and prolificly bearing nakavika trees abound around Ranbe. Ten breadfruit trees, five nakavika trees, and two mango trees were used for the bait spray trials and the same number selected as controls. Wekly sampling was conducted over the following periods:

- Breadfruit from December 14, 1998 to January 18, 1999.

- Nakavika from November 20 to December 18.
- Mango from November 8 to December 12.

The results from the ten breadfruit control trees are shown in Table 25.

Table 25. Fruit fly damage to breadfruit in Ranon Village, North Ambrym, Vanuatu, November 1998 to January 1999

Ripeness of fruit when harvested	Number fruit harvested	Degree of infestation when inspected 5 days later			
		No infestation (%)	Light infestation (%)*	Moderate infestation (%)**	Heavy infestation (%)***
Green	12	100	0	0	0
Half-mature	11	91	9	0	0
Mature	24	20	67	13	0
Over-mature	15	0	87	13	0

* Light infestation defined as < 50 larvae per fruit
** Moderate infestation defined as between 50 and 100 larvae per fruit.
*** Heavy infestation defined as > 100 larvae per fruit

In mature fruit, 80 per cent infestation was reported, and for over-mature fruit the infestation was 100 per cent. Relatively low infestation (9 per cent) was recorded for half-mature fruit. Half-mature breadfruit is hardly edible but some further ripening can be expected to a stage where it is edible. There was zero infestation of green fruit but, unfortunately, breadfruit that is harvested green will not mature to become edible. Overall, these results confirm the high fruit fly infestation of breadfruit found elsewhere in Vanuatu. Notably, none of the control fruit had heavy infestation (> 100 larvae/fruit) although, unexpectedly, one trial fruit did. This shows that even where there is a high infestation rate, at least some part of the fruit is likely to be usable. Villagers were observed cutting off the spoilt part of breadfruit before boiling, baking, or grating it to make *laplap*.

Heavy infestation of nakavika is also consistent with that found elsewhere in the region and in South East Asia. Even when the fruit is harvested green, the level of infestation was 84 per cent (Table 26). This delicious, highly nutritious fruit is therefore almost completely wasted by fruit fly. Zero infestation was found in mango. This finding is consistent with the low infestation for mango found in fruit collected by the Vanuatu Fruit Fly Project.[28]

Table 26: Fruit fly damage to nakavika at Ranbe Village, North Ambrym Vanuatu, November 1998 to January 1999

Ripeness of fruit when harvested	Number of fruit harvested	Fruits infested (%)	Fruits not infested (%)

[28] Department of Agriculture and Horticulture, 1997, Table 6.

Green	43	84	16
Colour break	8	100	0
Ripe	46	100	0
Over-ripe	23	100	0
Total	120	95	5

In Fiji, small-scale fruit bagging trials were conducted at Waikava, Cakaudrove Province, on Fiji's second main island of Vanua Levu, under the supervision of Ratu Semisi Rakuro. These trials involved the bagging of mango and breadfruit. Again, the control fruit for these trials provide an indication of fruit damage. Trapping conducted by Ratu Semisi in August 1998 confirmed the presence of both *B. passiflorae* and *B. xanthodes*, both of which are known to infest breadfruit. Mango is a known host for *B. passiflorae.*

Fruit sampling was undertaken at Waikava in October and November, 1998, just after a 'one hundred year' drought had broken. A significant amount of fruit fly damage was recorded, although this was relatively minor compared to the fruit piecing moth damage that was occurring at the time. Then, moth numbers were reported to be the highest ever experienced, infesting citrus, mango, and guava and, reportedly, even breadfruit. During such a period of high moth numbers, control measures that only dealt with fruit flies were considered to be of little value. Fortunately, the Waikava trials showed that fruit bagging using suitable materials provided an effective barrier against both fruit flies and moths.

An overall assessment of damage due to fruit flies

While the data presented are far from comprehensive, it is clear that fruit flies cause considerable damage to fruit throughout the region. To assess the nutritional and economic significant of this damage, however, it is necessary to determine the nature and level of fruit production and consumption in Pacific island countries. For example, in a location that has an abundant volume and diversity of fruit, a 95 per cent loss to guava may be of little significance. By contrast, on an atoll where breadfruit is the main seasonal staple, a 10 per cent fruit loss could be nutritionally important to the household and have financial repercussions if substitute rice had to be purchased. When infestation rates for breadfruit on atolls reach as high as 70 per cent, as has been shown by some damage assessment surveys, then the food security implications are considerable.

Fruit production and consumption in the Pacific island countries

Fruit in the context of traditional Pacific Island concepts of food.

Food is considered differently in different cultures, and this has implications for consumption and nutrition. Fruit consumed by Pacific Islands can be broadly classified into staple and non-staple foods. Table x summarises the overall importance of staple fruits and other staples.

Table x: Importance rating of starch foods by country, for the Central and Eastern Pacific

Country	Primary Importance	Secondary Importance	Other foods
Cook Islands			
• Rarotonga	*Colocasia* taro, **breadfruit**	taro (*tarua*), kumala, arrowroot	**plantain, bananas**, cassava
• Aitutaki	**breadfruit**	Arrowroot,	—
• Mauke, Atiu, Mangaia	*Colocasia* taro, **breadfruit**	—	—
Tuvalu	taro *('ape)*	**Breadfruit**, *Cyrtosperma*	—
Fiji			
• Eastern Viti Levu	cassava	**beadfruit**, kumala, yam	wild yams
• Rewa	*Colocasia* taro, *Cyrtosperma*	**beadfruit**, kumala, yam	—
• Western Viti Levu	kumala, cassava	**Breadfruit**	—
Futuna	*Colocasia* taro, kape	**breadfruit**, yam	**bananas**, wild yams
Kiribati	*babai*, pandanas	**Breadfruit**	—
Marquesas	**breadfruit**	**Bananas**, coconuts	*Colocasia* taro, yams
Nauru	pandanus, coconut		
Niue	*Colocasia* taro	Kumala, yams, cassava, *ufi lei*	**breadfruit**
Ocean Island	pandanus, coconut	—	—
Samoa			
• Upolo	*Colocasia* taro, **breadfruit**	*ta'amu*, **green banana**, yam	yams, kumala, cassava
• Savaii	*Colocasia* taro, **breadfruit,**	—	—
Tahiti	**breadfruit,** *Colocasia* taro	**Bananas, plantain**	kumala, wild yam, ivi, 'ape
Tokelau	coconut	**Breadfruit**	—
Tonga	yam, kape	Talo tonga, talo futuna, **breadfruit**	other yams, *ifi,* cassava
Wallis/Uvea	kape, **breadfruit**	*Colocasia* taro, yam, kumala, cassava	other yams

Source: Pollock, 1985, p.49.

The main staple fruits are breadfruit and cooking bananas. These staples are considered 'real' food and make a major contribution to the diet and food security. Except in the Highlands of Papua New Guinea, breadfruit (*Artocarpus altilis)* is an important seasonal staple throughout the region and is cultivated on both high islands and atolls. Breadfruit bears profusely in season and is important in people's diets, especially on atolls and smaller islands where it is the every-day staple. The main

breadfruit crop is usually from November to January, which in most places coincides with the middle of the new garden growing season, when food supplies are at their lowest. On small islands, particularly atolls, the preservation of surplus breadfruit was once a necessity. In a few places, breadfruit preservation is a quite strong tradition even today and provides for some self-reliance in the face of natural disasters. The main fruiting season also coincides with the main cyclone period.

There are many ways to prepare fresh breadfruit for eating: boiling, baking, and mixing it with grated coconut or green pawpaw being the most common. The seeds are also roasted and the young leaves can be used as a vegetable. The fruit is mainly carbohydrate but contains small amounts of calcium and iron. It also is a source of riboflavin, niacin, and vitamin C (Table 31).

The breadfruit tree was described in more detail than any other tree by early European explorers. The fascination with which breadfruit was held as a productive food producer was reflected in Bank's diary on visiting Tahiti in 1769, to quote:

> In the article of food these happy people may almost be said to be exempt from the curse of our forefathers; scarcely can it be said that they earn their bread by the sweat of their brow, when their sustenance, breadfruit, is procured with no more trouble than that of climbing a tree and pulling it down. Not that the trees grew here spontaneously, but, if a man in the course of his life planted ten such trees (which, if well done, might take the labour of an hour of thereabouts), he would as completely fulfil his duty to his own as well as future generations, as we, natives of less temperate climates, can do by toiling in the cold of winter to snow, and in the heat of summer to reap, the annual produce of our soil; which, one gathered into the barn, must be gathered into the barn, must again be re-sowed and re-reaped as often as often as the colds of winter or –the heats of summer return to make such labour disagreeable (in Beaglehole, 1962, p.134)

Extracts from the anthropologist, Nancy Pollock's book 'These Roots Remain,' reveal the importance of breadfruit throughout the Pacific islands. Starting from Micronesia, she notes how on Pohnpei and Kosrae 'breadfruit was a mainstay of household diet as well as being a major item of tribute to chiefs' (Pollock, 1985, p.143). Similarly, on Chuuk, the breadfruit tree was the producer of 'the main food stuff, both in the ripe form and its preserved form.' She notes that '13 types of breadfruit were found to be cultivated in Fiji in 1858,' and that it was also found in natural forests. In Samoa, 'breadfruit was an important food crop; it stayed in season for about six months and bore two crops.' It was also the food mainstay for the Tahitians. The botanist Wilder noted in 1926 that each Tahitian had several breadfruit trees in the family enclosure. 'The trees had spread away from the cultivated areas in both Tahiti and Marquesas, but everywhere were grown around house sites or in the sheltered middle area of atolls'. Referring to her own field work in Tonga, Pollock noted the tradition that: 'On Namu the people had obtained several varieties of breadfruit over the years, each distinguished by its local name and particular characteristics variety' - the people anticipated with pleasure the times when breadfruit could be harvested to provide a

change from rice as the staple (Pollock, 1985, p.55). Of the 20 islands of the Central and Eastern Pacific, eight have breadfruit of primary importance as a starchy food, and a further seven have breadfruit as secondary importance as a starchy food (Table x).

With the greater food security now provided by cash income, breadfruit is less important than it once was. Its role as an emergency food has largely been taken over by *Xanthosoma* taro and cassava. Where it is still done, preservation of breadfruit is now more a matter of food preference rather than food security. Breadfruit nevertheless remains a popular food that is regularly delivered in quantity, usually with two seasons annually, and requires no labour. Data from the Fiji Agricultural Census confirms that breadfruit continues to be the pre-eminent fruit there. In 1991, an estimated 37,000 tonnes of breadfruit was produced in Fiji, compared with 19,000 tonnes of bananas and plantains and 15,000 tonnes of eggplant (Table 34). A fruit consumption survey in Cakaudrove Province, conducted as a part of this study, found that adults consumed an average of 4.7 breadfruits per week, while youths and children consumed 2.8 and 2.7 breadfruit respectively (Table 40).

Any pest or disease that has a significant impact on breadfruit production would have serious nutritional and financial implications for households. While breadfruit is a hardy tree that is relatively free of major pest and diseases, from time to time, there are disease problems. In the 1960s, breadfruit trees were seriously affected by a die back disease problem known as 'Pingelap disease' that was caused by a combination of environmental factors. There are other fungal and bacterial pathogens that may also cause disease problems in breadfruit, as well as scale and mealy bugs (SPC, 1982).

In some places, fruit flies are a serious breadfruit pest and, indeed, are rated by SPC as the most serious quarantine pest in breadfruit. Table 23 showed that there was a 35 to 38 per cent loss to breadfruit in Federated States of Micronesia from mango fly, 30 per cent losses in Vanuatu from *B.umbrosa,* 71 per cent losses in Kiribati from mango fly, 75 per cent losses in Papua New Guinea from *B. umbros* and *B. frauenfeldi*), and 12 per cent losses in Nauru from *B. xanthodes.* Table 27 shows fruit flies for which breadfruit is a recorded host. Several are not as yet found in the Pacific. Carambola fly (*B. carambolae)* is a major pest for breadfruit in Indonesia, Peninsular Malaysia, Singapore, and South Thailand, as is Oriental fruit fly in the Philippines. The incursion of these fruit flies into the region could have significant food security implications.

Table 27: Fruit flies for which breadfruit is a host.

Scientific name	Common name	Current known distribution includes	Comments
Found within the Pacific island countries region			
B. passiflorae	Fijian fruit fly	South Pacific. Fiji, Wallis and Futuna, and Niue.	Considerable damage to breadfruit observed in Cakaudrove (Fiji)
B. umbrosa	Breadfruit fly	Papua New Guinea, Palau, Solomon Is, New	Considerable damage observed North Ambrym

		Caledonia, and Vanuatu. Indonesia, Malaysia, and Southern Thailand.	(Vanuatu)
B. xanthodes		Cook Islands, Fiji, Tonga, and Samoa	Considered a serious pest. Considerable damage to breadfruit observed in Cakaudrove (Fiji)
B. facialis	Tonga fruit fly	Tonga	Known host
B. fraenfeldi	Mango fly	Federated States of Micronesia, Solomon Is., Papua New Guinea, Nth. Queensland, Marshall Is., Kiribati, Palau, and Nauru.	Major pest in Kiribati, considerable damage in other countries
B. melonotus		Cook Islands	Known host
Not found within the Pacific island countries region			
B. carambolae	Carambola fly	Indonesia, Peninsular Malaysia, Singapore, South Thailand, Surinam and French Guiana	Regarded as a major pest
B. philippinensis	Philippine fruit fly	Philippines	Regarded as a major pest

Source: Compiled from Drew and Hancock; Allwood and Drew; and Vijaysegaran.

Worldwide, the most important fruit is banana (*Musa* spp.). In terms of the gross value of production, bananas are the fourth most important food commodity, after rice, wheat and milk (Thurston, 1998, p.101). The total world production of bananas and plantains is over 84 million tonnes (FAO, 1996). Smith et al. estimates that over 90 per cent of the world's bananas come from smallholdings. Many people in temperate zones do not realise that only part of this huge production is eaten as fresh fruit. Simmonds (1966) estimates that 'roughly half of the bananas of the world are eaten raw and ripe and half are eaten cooked. Cooking bananas or plantains are produced by millions of small farmers throughout the tropics.' The Pacific Islands are no exception to the world situation. Throughout Vanuatu, Solomon Islands, Samoa, and island and coastal Papua New Guinea, banana is a major food crop, and somewhat less so in Fiji and Tonga. In Vanuatu and Samoa, bananas have become a more important food crop in recent times. To quote the Vanuatu Land-Use Profile on Root Crops and Self-sufficiency Crops:

> The food cropping systems of Vanuatu were traditionally either predominately yam (genus *Dioscorea*) or aeland taro (*Colocasia*) based. In the gardens of the wet, northern or eastern central islands, taro dominated, particularly in the upland areas. On the drier islands, yam still remains of considerable importance. However, today there tends to be far less of a yam/taro dichotomy. The most important food crops are aeland taro, banana (possibly now the most important staple), soft yam, cassava, and Fiji taro (Vanuatu Land Use Planning Office, 1999, p.13).

In Vanuatu, the 1994 Agricultural Census (1995, p.170) ranked the most dominant garden crop for the five islands surveyed as follows, with bananas featuring in four of the five islands:

Pentecost: yam, **banana**, taro

Malekula: manioc, **banana**, yam

Ambrym: **banana**, Fiji taro, manioc, fruit

Epi: **banana**, vegetables, island cabbage, kumala, yams

Tanna: manioc, yam, taro, kumala

In Samoa, bananas have replaced taro (*Colocasia esculenta*) as the main food crop since the onset of leaf blight (*Phytophthora colocasiae*) in 1993. The volume of bananas traded on the Savalalo and Fugalei municipal markets is now almost 14 times that of taro, and some 50 per cent more than ta'amu (*Alocasia* spp.) (Table 35). Since 1993, breadfruit has also become a relatively more important food crop. Paulson and Rogers describe the adjustments that occurred:

> The devastating taro leaf blight (*Phytophthora colocasiae*) appeared for the first time in Western Samoa in mid-1993. By the end of the year the disease had spread throughout the country. Yet, by January 1995, rural households were producing adequate food for their needs and the price of alternative crops (**bananas**, ta'amu, **breadfruit**, and yams) on the domestic market dropped to low levels, as village households began producing marketable surpluses (Paulson and Rogers, 1997, p.176).

Given the extent of banana cultivation world-wide, it is not surprising that a wide range of pest and diseases can affect them, particularly when they are cultivated commercially. The South Pacific region is infamous for Sigatoka leaf diseases, regarded as the most important diseases for bananas world wide because of their destructiveness, wide distribution, and high cost of control (Thurston, 1998, p.101).[29] In some places bananas are also fruit fly hosts, although not in most Pacific island countries (Table 28).

Table 28: Fruit flies for which bananas is a host

Scientific name	Common name	Current known distribution includes:	Comments
Found within the Pacific island countries region			

[29] Yellow Sigatoka disease was first identified in the Sigatoka Valley in Fiji in 1912. Over in the next 40 years, the disease spread to all banana producing countries, making it a classic, global disease epidemic (Ploetz, 1994, p.12). The more virulent Black Sigatoka disease was first identified in Fiji in 1963.

B. musae	Banana fly	Eastern Queensland, Papua New Guinea (Bismark Archipelago)**	Major pest of bananas – eggs laid in immature green fruit.
B. papayae	Asian papaya fruit fly	southern Thailand, parts of Malaysia, and Indonesian islands (including Irian Jaya) and Papua New Guinea.	Regarded as probably the most serious fruit fly pest. Eggs laid in green fruit. Has now been eradicated from North Queensland.
B. dorsalis	Oriental fruit fly	French Polynesia, Palau, and Nauru	In Palau found to cause considerable damage in ripe and colour break fruit.***
Not found within the Pacific island countries region			
B. jarvisi		Australia	Regarded as a major pest, but only for ripe fruits

Source: Compiled from Drew and Hancock; Allwood and Drew, Vijaysegaran
* *Vijaysegaran also reported Banana fruit fly in Solomon Islands. However this is considered a questionable host record. This fruit fly species was not recorded in trapping conducted during 1994-97, using methyl eugenol lure which is known to attract banana fruit fly (Vagalo et al., 1996, p. 83). Waterhouse also incorrectly reports that *B. musae* occurs in Vanuatu. During the work of the RMFFP (1990-1999) no *B. musae* has been recorded in methyl eugenol traps or reared from fruit in Vanuatu or the Solomon Islands (Allwood et al, 1996, p. 79).
*** McGregor 2000 p,28).

Banana fruit fly (*B. musae*) isa major pest in bananas in Queensland and Papua New Guinea, where it lays its eggs in immature green fruit (Vijaysegaran, 1989, p.23). There are records of banana fruit fly in Solomon Islands but these are questionable and need to be confirmed (Vagalo et al., 1996, p.83). The major concern is Asian Papaya Fruit Fly *(B. papayae)* for which banana is one of 209 recorded hosts (Drew, 1996, p.48). This particularly damaging fruit fly, endemic to southern Thailand, and parts of Malaysia and Indonesia, has recently become established in Irian Jaya and Papua New Guinea. It entered into north Queensland but was subsequently eradicated. The further incursion of this pest into the Pacific Islands would have major food security implications through its impact on bananas. With breadfruit also a likely host, the food security consequences could be devastating.

Non-staple fruits

On the high islands, a wide range of other fruits and fleshy vegetables are grown that are classified as non-staple fruits. Compared to the fruit staples, these are of distinctly secondary importance. Even so, fruit makes an important contribution to the nutrition of Pacific Island households, except on the atolls where non-staple fruits are virtually non-existent. The contribution of fruit to nutrition is often under-estimated, since most surveys of household meals—including surveys conducted for this study—show little if any non-staple fruit consumption. The reason for this omission is that most non-staple fruit is consumed as 'snacks,' including wild fruits foraged largely by children. Foraging by children is illustrated in the cover photograph of this report, from North Ambrym. Consumption of fruit goes almost unnoticed, but it contributes significantly

to the nutrition of this relatively low priority age group when it comes to allocating food at meal times.

In times of natural disaster, some non-staple fruit is of critical nutritional importance, a recent example of this being mango production in the Fiji drought of 1997-8. During this '100 year' event, possibly the worst natural disaster Fiji has experienced (Parliament of Fiji 1999, p.4) sugar production was more than halved, leaving many farmers without a crop or cash income. Although the drought had a serious impact on food production, the extreme conditions in the worst affected areas of western Viti Levu and Vanua Levu induced a recorded mango crop. The abundance of this nutritious fruit during the last months of the drought contributed significantly to averting large-scale malnutrition (Lightfoot, 1999).

A pest or disease for a particular non-staple would not likely have a major impact on the household's overall food consumption and nutrition. Any one fruit would be just one part of the household's main diet and there are usually various alternatives available. To understand Pacific Islander fruit consumption, and the scope for increasing consumption, it is important to understand the cultural context in which fruit is eaten. The case of Fiji, which might be considered fairly typical, is examined briefly below.

Pacific Island fruit consumption patterns: the Fijian concept of food

In Fijian, '*kakana'* refers to food in the broadest sense, a general term that may be qualified according to the way in which the foods are used.

- *Kakana dina* (literally 'real' food) refers to starchy staples, mainly root crops. This is the main element of any meal, for no meal is a meal without *kakana dina*. The only fruits included in this category are breadfruit (uto - *Artocarpus altilis*), and cooking banana (vudi - *Musa paradaisica).* In the Fijian context, these staple fruits can be quite important *kakana dina,* but usually less so than taro (dalo - *colocasia esculanta*), dalo-ni-tana (*Xanthosoma sagittifolium*), kumala (*Ipomea batatas*), or yam (uvi - *Diocorea alata*). Traditionally, cassava (*Manihot esculenta)* was not considered *kakana dina,* but today it probably is the most important starchy staple. Throughout the region, breadfruit is a more important *kakana dina* on most small islands, particularly atolls. Cooking bananas are more important *kakana dina* in Vanuatu and Samoa than in Fiji.
- *i coi* (accompanying foods—literally translated, relish) go with *kakana dina* to make up a meal. They include meat, fish, and leafy vegetables—these mainly being *bele* (*Hibiscus manihot)* or *rourou* (taro leaves). These foods are not eaten alone but accompany starchy *kakana dina*. Fruits are not considered to be *i coi.*
- *i vakalau* (literally refreshments or snack food). These normally require a lot of preparation. Fruit is utilised in *i vakalau,* but usually not in fresh form—for example, *lote,* which is fruit cooked with grated cassava and served with coconut cream, or *vakasoso* which is banana cooked as a

pudding with sugar and coconut. These are usually eaten alone and not considered a meal.

- *gunu-ti (*literally morning or afternoon tea). This has a drinkable component, such as tea, coffee, milo or juice, and accompanying solid food, usually a starchy type of food such as bread, biscuit, or cake. *Gunu-ti* is not a meal in a Fijian sense, but a category of food that is eaten early in the morning, mid afternoon, or as a late night snack. It would normally not include fresh fruit, but during the day it might include juice made from fruit. It is common to have *gunu-ti* as breakfast and to include rice and cassava, but again it would be unusual to include fresh fruit.
- Foods which are eaten raw, of which there are two categories:

  (a) *Vuata,* or fresh fruits which are eaten raw. These are not cooked nor usually eaten as part of a meal. In the Fijian language, most soft fruits would be described as 'drinkable' rather than 'eatable' foods.

  (b) Kokoda, which refers to any raw food, particularly leaves, fish, meat or salad.

  Traditionally*, vuata* and *kokoda* would not be served as part of a Fijian meal, but this is changing.

This last category of food—raw or non-meal—is common throughout the Pacific. 'These are products of the environment that come from the land or the sea to which, according to myth, the ancestors had granted these people access. They are considered part of the communal heritage, to be used and shared, but not abused' (Pollock, 1985, p.33). In a Fijian village, a mango, mandarin, or papaya would be considered as a *vuata* (something a child might pick and eat for himself), not a 'real food.' Similar classifications exist throughout the Pacific Islands. In Palau, for instance, this category of food is known as *kliou* and includes fruits such as papaya, mango, jackfruits, oranges, and ripe bananas (Akimichi, 1980, p.598). In Tonga, a further category of non-meal fruit is that of 'fruit soups.' Here ripe fruits are chopped and baked and boiled in coconut cream (Pulu, 1981, p.72). Soups are also made from breadfruit.

Pollock argues that the rich variety of Fijian foodstuffs is partially instrumental in the kinds of linguistic distinctions that are part of the Fijian language Pollock, 1985, p.6). She notes that they distinguish what is considered essential and non-essential food. *Kakana dina* and *i coi* are more different in nature and the way they are eaten than *vuata* and *kokoda* foods. Encouraging people to eat more local fruit is difficult, as these are non-meal-foods and cannot be incorporated easily into the Fijian concept of *kakana dina* or *i coi.* To quote:

> The question of including pawpaw with the breakfast meal was raised at a recent nutrition education. Here, the difficulty is that people are being asked to combine a *vuata* (raw snack) with *gunu-ti* which included on a prepared starch; and neither of these is considered a meal (Pollock, 1985, p.6).

Promotion of fruit as a snack rather than part of a meal may be more effective. In English, the word 'snack' has negative connotations for nutrition but in Fijian, some traditional refreshment foods have excellent nutritional value. Pollock also points to the need to recognise the irregularity of traditional Fijian eating patterns and to take into account a total assessment of the day's food intake. Terms such as 'meal planning' and 'eating a balanced meal' need to be re-assessed in terms of the day's total food intake. The surveys conducted in Fiji as a part of this study confirmed that by far most non-staple fruit were consumed as a snack.

In recent years, urbanisation has continued apace in Fiji. Almost 50 per cent of the population now live in towns. The cultural change that has accompanied this new residential pattern has including the ways in which food is viewed and consumed. For household nutrition, not all of these changes have been positive. 'Snacking' in urban areas is now more in line with the western concept of 'junk food' rather than the traditional way of eating fresh fruit and nuts.

Fruit in traditional cropping systems: the example of Vanuatu

Vanuatu is in many ways typical of rural Melanesia, in that around 75 per cent of the population live in rural areas and almost all households maintain food gardens, which supply most of their food. According to the 1993 Agricultural Census, food gardens ranged in size from an average 0.02 ha on Malekula to 0.08ha on Pentecost.

The cropping system is based on the annual clearing of forest or bush fallow for several multi-crop family food gardens. These plots are rain-fed and intensively cultivated for one, two, or three years. Some longer-term crops, such as bananas, remain in the garden for several more years. The plots are allowed to return to bush fallow before being used again for cropping. Yams (*Dioscoria spp*.) are traditionally the pivotal crop in the system, but for everyday subsistence, taro (aelan taro *Colocasia* and Fiji taro *Xanthosoma sagittifolium*) is the most important food crop. Banana, sweet potato (kumala) and cassava (manioc) have become increasingly important in most places. Island cabbage (bele in Fiji) is always part of a food garden and is by far the most important vegetable grown. Corn (kon- *Zea mays L.*) is probably the next crop most often planted with yams. Various other vegetables are scattered through food gardens, including shallots (salad: *Allium cepa*), ginger (*Zingiber officinale*), tumeric (kari: *Curcuma longa*), bottle gourd (kalfas: *Lagenaria siceraria*), snake gourd (snekbin: *Trichosanthes cucumerina*), yard long bean (yadbin: *Vigna unguiculata*), Chinese cabbage (Jaena kabis: *Brassica chinensis*), white bone cabbage (waetbon: *Brassica sp*.), tomato (*Lycopersicon esculentum*), and cucumber (kukamba: *Cucumis sativus*). Weightman describes a typical contemporary multi-crop garden in Vanuatu:

> The gardens are planted to a variety of crops, often inter-planted as single plants, though sometimes planted with patches of one crop, such as sweet potato, taro, yam or manioc. The soft yams are planted first and take pride of place where the garden offers the best conditions for their cultivation. Other crops follow: sugarcane, island cabbage, naviso, pineapple, pawpaw, water melon, tomato, Chinese cabbage, sweet potato, manioc, bananas, taro,

> and kava. A single garden will generally contain many varieties of yam or taro and several other crops (Weightman, 1989, p.54).

Usually, a variety of annual fruits are planted or allowed to grow in the second year. These might include pineapple, tomatoes, and a variety of cucurbits (gourds, pumpkin, and cucumber). Bananas, however, are by far the most important food garden fruit. Breadfruit is grown outside the food gardens and is an important seasonal food crop throughout coastal areas. It is most important and prolific on the smaller islands (Torres, Banks, Shepherds, Futuna, and Tongoa), where it is usually grown with coconuts. Breadfruit was once the main food preservation crop.

The usual traditional meal in Vanuatu is a *laplap* which can be made from any staple starch, including taro, yam, cassava, banana, or breadfruit. The starch is grated, mixed with coconut cream, wrapped in island cabbage, and cooked in an earth oven. Sometimes, the island cabbage is omitted and only coconut cream is used, or chicken, meat or seafood replaces the island cabbage. In Vanuatu, the *laplap* is the meal itself; in Fijian terms, it combines the *kakana dina* and *i coi*. As in a Fijian meal, usually no fruit is included with the meal. A *laplap* meal is nutritionally well balanced, particularly if it is supplemented with fruit and nut 'snacks' throughout the day. Studies by the South Pacific Commission that date back to the 1950s have found that 'a mixed diet of yams, taro, or sweet potato with green leaves would supply a balance of amino acids necessary for an adequate diet,'(SPC, 1994, p. iii). A rice-based meal is the common alternative to a *laplap* meal. Rice has now become a major staple throughout Melanesia. The rice is usually supplemented with island cabbage together with meat or fish, either tinned or fresh. In a stew form, the meal might include tomatoes or other fleshy vegetables, such as snake gourd.

Other than the staple fruits of breadfruit and banana, fruit consumption is mostly opportunist in nature, being eaten as snacks, while walking to or from gardens, or by children walking to school or at play. At any time, several fruits are in season. These fruits are a major contribution to household nutrition, even though they are not eaten as part of a meal. They are, however, less important than leafy vegetables. The most important of these in Melanesia is edible hibiscus leaves (island cabbage or *bele*) and in Polynesia, taro (*Colocasia esculenta*) leaves. In Fiji, both are equally important. The fruits of many forest trees and shrubs are regularly foraged and sometimes planted or cultivated (Table x).

Table x Edible cultivated and wild fruit trees in Vanuatu

Species	**Common name**	**Bislama name**	**Comments**
Cultivated			
Artocarpus altilis	Breadfruit	Breadfruit	Main fruiting season: October – January. At least 60 named varieties.
Burckella obovata	Red silkwood tree	Naduledule	Fruiting season: around February to July. Widely planted around villages. Eight named varieties on Pentecost alone. Very sweet when ripe. Some

			traded
Dracontomelon vitiense	Dragon plum	Nakatambol	Fruiting season: November to January. Fibrous – tasteless to sweet. Some traded
Morinda citrifolia	Noni	Yellow wud	Fruiting season: throughout the year. Used in Vanuatu as an emergency food. Medicinal value of the fruit now being recognised internationally, giving the fruit increasing commercial value.
Mangifera indica	Mango	Mango	Fruiting season: November through January. An introduced species found throughout Vanuatu – but particularly in the drier areas. Some traded
Pometia pinnata	Pacific Leitchi	Nandao	Fruiting season: April to July. Cultivated and wild. Very sweet fruit when ripe. Some traded when available.
Spondia dulcis	Great hog plum	Naus	Fruiting season: April to July. One of Vanuatu's principle fruit trees and is widely planted throughout Vanuatu. Quite sour until fully ripe. Some traded.
Syzygium malaccense	Golden apple/Mountain apple	Nakavika	Fruiting season: September to April. Widely planted in lowland villages, gardens and pastures. Succulent and slightly sweet fruit when ripe. Particularly large fruit varieties found in Vanuatu. However, usually severely damaged by fruit fly before ripe and thus usually not traded.
Wild fruits			
Ficus aspersa		Only vernacular names	Fruiting period: around April to July. Commonly used as vegetables with the young leaves and fruit cooked. Sometimes planted for this purpose.
Ficus wassa		Only vernacular names	Fruiting period: several times a year. Commonly used as a vegetable. Young leaves, and occasionally fruits, are picked from wild and eaten.
Maesa ambrymensis (from the island of Ambrym)		Only vernacular names	Fruiting period: August – September. The small white fruit are edible and are eaten mainly by children as forage food.
Pipturus argenteus		Only vernacular names	Fruiting period: throughout or several times a year. Commonly available in secondary forest close to villages. The small white fruit are edible and sweet, and are eaten mainly by children as forage food

Source: Wheatley, 1992.

Limes (*Citrus aurantifolia*) has reportedly existed in Vanuatu since ancient times (Weightman, 1989, p.220). A wide range of other fruit trees have been introduced

over the last century, including numerous citrus types orange (*Citrus sinensis*), mandarin (*Citrus reticulata*), grapefruit (*Citrus paradisi*), lemon (*Citrus limon*) and pomelo (*Citrus grandis*). Papaya (*Carica papaya*) are now almost always grown in second and third year food gardens, and regularly eaten. Mangoes (*Mangifera indica)* grow throughout Vanuatu, especially in drier parts, and are well adapted to the periodic cyclones that affect the country. Guava, which is becoming a weed in many areas, is an important source of Vitamin C. The wide range of fruit in plentiful supply throughout western Melanesia is evident also in Papua New Guinea (Table x).

Table 30. Months of plentiful supply for fruit and nut crops in Papua New Guinea

(Margaret a lot of the months have been omitted)

		Month											
Common name	Scientific name	J	F	M	A	M	J	J	A	S	O	N	D
Abiu	*Pouteria caimito*												
Apple	*Malus* sp.												
Avocado	*Persea americana*												
Banana	*Musa* spp.												
Brazil cherry	*Engenia uniflora*					Irregular (Lowlands)							
Breadfruit	*Artocarpus altilis*					Irregular (Lowlands)							
Bullock's heart	*Annona reticulata*												
Cape gooseberry	*Physalis peruviana*												
Cashew	*Anacardlium occidentale*												
Cherimoya	*Annona cherimola*												
Cherry guava	*Psidium cattleianum*												
Durian	*Durio zibethinus*												
Five corner fruit (carambola)	*Averrhoa carambola*												
Galip	*Canarium indicum*												
Golden Apple	*Spondias cytherea*												
Governor's plum	*Flacourtia indica*												
Granadilla	*Passiflora quadrangularis*												
Grapefruit	*Citrus paradisi*												
Guava	*Psidiun guajava*												
Jackfruit	*Artocarpus heterophyllus*												
Kumquat	*Fortunella japonica*												
Langsat	*Lansium domesticum*												
Lemon	*Citrus limon*												

Lime	*Citrus aurantifolia*												
Loquat	*Eriobotrya japonica*												
Macadamia	*Macadamia integrifolia/M. tetraphylia*												
Malay apple	*Syzygium malaccense*												
Mandarin	*Citrus reticulata*												
Mango	*Mangifera indica*												
Mangosteen	*Garcinia mangostana*												
Mulberry	*Morus nigra*												
Orange	*Citrus sinensis*												
Passionfruit, banana	*Passiflora molissima*				Irregular (Highlands)								
Passionfruit, highland, yellow	*Passiflora ligularis*				Irregular (Highlands)								
Passionfruit, lowland yellow	*Passiflora edulis f. flavicarpa*												
Passionfruit, purple	*Passiflora edulis f. edulis*												
Pawpaw	*Carica papaya*												
Pineapple	*Ananas comosus*												
Plum	*Prunus* sp.				Irregular (Highlands)								
Pomegranate	*Punica granatum*												
Pomelo	*Citrus maxima*												
Pulasan	*Nephelium mutablle*												
Rambutan	*Nephelium lappaceum*												
Raspberry, black	*Rubus iasiocarpus*												
Rockmelon (cantaloupe)	*Cucumis melo*												
Rollinia	*Rollinia deliciosa*												
Santol	*Sandoricum koetjape*												
Soursop	*Annona muricata*												
Star apple (cainito)	*Chrysophyllum cainito*												
Strawberry	*Fragaria* sp.												
Sweetsop (Custard Apple)	*Annona squamosa*												
Tamarind	*Tamarindus indica*												
Tree cucumber	*Averrhoa biimbi*												
Tree tomato	*Cyphomandra betacea*												

(tamarillo)													
Watermelon	*Citrullus lanatus*												
Watery rose apple	*Syzygium aqueum*				Irregular (Lowlands)								

	Lowlands
	Highlands
	Both

Source: Adapted from Camarotto and Bourke, 1994.

The nutritional value of Pacific island countries fruit

Staple fruits, by definition, are high in energy. Of all the staples, cooking bananas are second only to cassava in calories per unit (110kcal/100gm boiled) (Table 28). Breadfruit (71kcal/100gm) provides a little fewer calories per unit than taro. All traditional staples, however, rank well below rice and wheat flour in the calories they supply (Table 31). Yet fruit staples contribute more to household nutrition than energy. Breadfruit leads in terms of dietary fibre (2.5g/100gm) and cooking bananas has a higher content of potassium (400mg/100gm) than all starchy staples or imported cereals. Cooking banana is the best source of vitamin A (equiv. µg 19/100gm) and β-carotene (equiv. µg 116). Breadfruit also is a good source of vitamin A and provides more riboflavin (0.05mg) than any other staple.

Table 31. Nutritional composition of fruit staples and other root crops and cereals (per 100 gm boiled)

	Energy (kcal)	Protein (g)	Total fat (g)	CHO Avail (g)	Dietary fibre (g)	Sodium Na (mg)	Potassium K (mg)	Calcium Ca (mg)	Magnesium Mg (mg)	Iron Fe (mg)
Cooking banana	**110**	**0.8**	**0.2**	**26**	**1.2**	**4**	**400**	**5**	**33**	**0.5**
Breadfruit	**71**	**1.3**	**0.9**	**14**	**2.5**	**1**	**350**	**13**	**23**	**0.2**
Cassava	131	0.5	0.2	32	1.5	7	289	20	28	0.2
Kumala	97	1.4	0.2	22	1.6	52	260	29	26	0.5
Taro (black)	82	0.8	0.4	19	0.7	1	264	28	114	0.9
Taro (white)	99	0.9	0.6	22	0.8	3	264	34	114	1
Yam	82	2	0.2	18	1.5	3	271	7	20	0.6
White bread	240	8.2	2	47	2.7	450	110	32	27	1.1
White rice	123	2.3	2.3	28	0.8	5	10	4	13	0.3

Continued:

	Zinc (mg)	Vit A equiv µg	β-carotene equiv. µg	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vit. B12 (µg)	Vit. C (µg)	Vit. E (µg)
Cooking banana	0.2	19	116	0.03	0.04	1	0	9	T
Breadfruit	-	5	30	0.08	0.05	1	0	22	1
Manioc	0.5	T	2	0.04	0.02	T	0	18.6	T
Kumala	0.3	10	57	0.07	0.03	1	0	53.3	12
Taro (black)	-	6	38	0.07	0.02	1	0	4	2
Taro (white)	-	6	38	0.08	0.03	1	0	5	2
Yam	0.4	15	90	0.04	0.03	T	0	17.4	4
White bread	0.6	0	0	0.13	0.08	1	0	0	T
White rice	0.6	0	0	0.03	0.01	1	0	0	T

Source: South Pacific Commission 1994

Compared to staple fruit, most non-staple fruits are sweet but low in calories. They provide dietary fibre and other nutrients, especially vitamin C (Table 32) which is required for strong body tissue, helps the body use iron, and assists with chemical reactions in the body. Adult men (over 19 years) require 40mg vitamin C daily; children and adult women require 30mg; and infants 25mg (SPC, 1994). Fruits with orange or deep yellow flesh such as mangoes, papayas, and rock melons are high in Vitamin A, which is good for eyesight and contains beta–carotene, an antioxidant that reduces the risk of cancer. Vitamin A also helps maintain the mucous membranes of

the respiratory and digestive tracts. The high dietary fibre of fruit prevents constipation, reduces the risk of colon cancer, and helps lower blood cholesterol levels. The potassium from fruit helps regulate blood pressure.

Table 32. The nutritional composition of some common Pacific island non-staple fruits and fleshy vegetables (per 100 gm fresh)

	Energy - kcal	Protein (g)	Total fat (g)	CHO Avail (g)	Dietary fibre (g)	Sodium Na (mg)	Potassium K (mg)	Calcium Ca (mg)	Magnesium Mg (mg)	Iron Fe (mg)
Eggplant	15	0.7	0	3	4.2	3	199	10	11	0.2
Gourd	28	0.7	0.1	6	0.6	3	148	20	12	0.6
Pawpaw (unripe)	24	1.0	0.1	5	1.5	7	215	38	-	0.9
Pawpaw (ripe)	50	0.5	0.1	12	0.8	6	170	24	-	0.7
Pumpkin (boiled)	41	2.3	0.4	7	1.4	1	310	27	13	0.4
Tomato	24	1.2	0.3	4	1.4	6	200	7	-	0.6
Banana	103	1.3	0.4	24	0.8	29	241	11	-	0.6
Guava	21	0.7	0.5	4	5.4	4	150	10	12	0.6
Lemon	11	0.6	0.2	2	2.5	2	120	20	9	0.3
Malay apple (kavika)	23	0.7	0.2	5	1.9	1	38	13	5	0.8
Mandarin	37	0.9	0.2	8	2	2	141	26	11	0.3
Mango	56	1.0	0.2	13	1.5	1	250	7	7	0.5
Orange	37	1.0	0.1	8	2	2	145	29	11	0.4
Pineapple	52	0.7	0.3	12	.8	2	180	17	-	0.5
Soursop	65	1.3	0.4	14	2.7	2	294	12	-	0.5
Watermelon	24	0.6	0.2	5	0.3	4	92	8	-	0.2

Continued:

	Zinc Zn (mg)	Vit A equiv µg	β-carotene equiv. µg	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Vitamin C (µg)	Vita-min E (µg)
Eggplant	0.1	3	19	0.04	0.04	1	2	-
Gourd	-	0	0	0.04	0.03	1	15	-
Pawpaw(green)	-	3	15	0.02	0.03	T	40	1
Pawpaw (ripe)	-	118	710	0.03	0.05	T	73	1
Pumpkin (boiled)	0.1	420	2500	0.06	0.06	1	6	2
Tomato	-	58	350	0.06	0.04	T	23	1
Banana	-	8	46	0.07	0.08	1	17.3	T
Guava	0.1	73	430	0.03	0.04	1	240	1

Lemon	0.1	5	31	0.03	0.02	T	47	-
Mountain apple (Kavika)	0.1	0	0	0.02	0.04	1	8	T
Mandarin	0.1	15	87	0.06	0.03	T	47	T
Mango	0.3	400	2370	0.02	0.04	1	28	1
Orange	0.2	21	130	0.11	0.03	T	52	-
Pineapple	-	6	35	0.06	0.03	T	22	T
Soursop	-	3	15	0.09	0.09	T	26.9	T
Watermelon	-	27	160	0.03	0.03	T	6	-

T= trace
Source: South Pacific Commission, 1994.

Quantifying domestic fruit production and consumption

The volume and value of fruit and vegetable exports can readily be quantified. These data are obtainable from several sources, including quarantine records and the trade statistics of exporting and importing countries. For domestic food consumption, no such data are available. The predominant self-sufficiency nature of Pacific island food production adds to these measurement problems. Most food grown or harvested by Pacific island households is not traded for cash, but consumed or exchanged.

The production approach to measuring household fruit production consumption: using agricultural census data.

Estimating household food consumption can be approached from either the production or consumption side. A timely and comprehensive Agriculture Census is the best tool for estimating levels and trends in national fruit production and consumption. In most Pacific island countries, however, agricultural censuses have shortcomings that undermine their usefulness in measuring self-sufficiency food consumption. Because of budgetary constraints, agricultural censuses usually are neither timely nor comprehensive. A census should be conducted every 10 years but often this target is not achieved. The most recent data now available are from the late 1980s or early 1990s. The most recent Solomon Islands Agricultural Census, for example, was conducted in 1986. Furthermore, the censuses often lack a comprehensive coverage of crops by region, for they are generally biased towards cash crops and cash cropping activities. Some censuses, such as the 1993 Vanuatu Census, did not measure at production at all and are therefore of limited value. The usefulness of census data in measuring national trends is often limited by changing methodology and focus. The Fiji agricultural census of 1991 and the Samoa census of 1989, although dated, are relatively better in these respects.

The Fiji Census is the most comprehensive to be undertaken in the Pacific region in recent years. The Asian Development Bank's 1996 Agriculture Sector Review used these data to estimate Fiji's current production and value (both subsistence and traded) for various commodities, including fruits and vegetables, that are sold in the local markets. From this, the Review concluded that, 'Fiji's agricultural sector, far from stagnating at subsistence levels, has sustained a dynamic process of increased

commercialisation through the decade,' (ADB, 1996, p.4). The census covered all the provinces of Fiji and enumerated three categories of farming systems that included fruit (Table x).

Table x Farming systems in Fiji

Farming system	How enumerated	Fruit enumerated
Temporary crops in 'pure stand' harvested or to be harvested from July 1990 to June 1991	Area (hectares)	Cucumber, eggplant, pumpkin, tomatoes, watermelon,
Permanent crops in 'pure' stand harvested or to be harvested from July 1990 to June 1991	Area (hectares)	Banana, mandarin, orange, papaya, pineapple
Temporary 'mixed and interplanted stands	Area (hectares)	Other vegetables, vudi
Scattered plants and trees	No. of trees	Avocado, banana, breadfruit, chilli, custard apple, eggplant, grapefruit, guava, lemon, mandarin and tangerine, mango, orange, pineapple, custard apple and soursop, lime, and other cultivated fruits

The census data are the basis for the production estimates in Table x for the various fruit that were enumerated. Table xx shows the total estimated production for these fruit, by far the most important of which is breadfruit with an estimated production of 36,500 tonnes, followed by the other fruit staple, bananas, with 18,700 tonnes. Eggplant and mango each accounted for almost 15,000 tonnes. For seasonal tree fruits such as breadfruit, mango and mandarin, consumption is likely to be well below production. But without a comprehensive consumption survey, there is no way to estimate what this difference might be.

Table 33: Estimated fruit production in Fiji estimated from the 1991 Census

Fruit	Temporary 'pure' stand			Permanent 'pure' stand			Temporary 'mixed and inter-planted' stands			Scattered trees and plants			Total estimated production
	Ha	t/ha	tonnes	Ha. (bearing)	t/ha	tonnes	Ha	t/ha	tonnes	no. bearing	kg/tree	tonnes	
Cucumber	157	8	1,256				54	6	324				1,580
Eggplant	378	20	7,560				485	15	7,275	22,519	1	22	14,857
Pumpkin	406	10	4,060				108	8	864				4,924
Tomatoes	893	7	6,251				108	5	540				6,791
Watermelon	765	10	7,650										7,650
Banana				432	15	6,480	531	11	5,841	635,240	10	6,400	18,721
Oranges				373	10	3,730				42,528	40	1,700	5,430
Papaya				39	10	3,900				125,440	4	500	4,400
Pineapple				164	20	3,280				74,575	0.8	60	3,340
Avocado										3,272	20	75	75
Breadfruit										182,623	200	36,500	36,500
Custard apple										5,485	10	55	55
Chilli							215	4	860	14,216	3	43	903
Grapefruit										2,380	60	140	140
Guava										13,483	10	135	135
Lemon										31,123	20	600	600
Mandarin										26,219	60	1,600	1,600
Mango										146,745	100	14,700	14,700

Table 34 Ranking of estimated fruit production from the main fruit enumerated in the 1991 Fiji Agricultural Census

Fruit	Est. ann. production (tonnes)
Breadfruit	36,500
Banana/vudi	18,700
Eggplant	14,900
Mango	14,700
Watermelon	7,700
Tomatoes	6,800
Oranges	5,400
Papaya	4,400
Pumpkin	4,900
Pineapple	3,300
Cucumber	1,600
Mandarin	1,600
Chilli	900
Lemon	600

The discrepancy between consumption and production makes it difficult to value fruit production, a problem that is further compounded by seasonal variations in prices. Not withstanding these difficulties, current Suva municipal market prices were used as a guide to what the value of production might be (Table 35). From this source, the estimated total value of fruit production at the end of October 1999, was F$134 million. This is a large number indeed, and probably a considerable overestimation for the following reasons:

- For seasonal products such as breadfruit, mangoes, and mandarins, the quantity consumed is likely to be much less than the quantity produced.
- The dry season for 1999 was unseasonably wet, which lowered production of products such as tomatoes and mangoes and raised their market price.
- Prices at the Suva market include marketing margins and, therefore, lead to an overestimate of the value of subsistence production.

Even if the true value of Fiji fruit production was only half this estimated figure, or around F$ 65 million, it would still represents a considerable economic value.

Table 35. Indicative estimates of the value of Fiji's fruit production

Fruit	Est. annual production (tonnes)*	Unit value (F$ per kg)**	Total value (F$,000)

Breadfruit	36,500	0.30	10,950
Banana/vudi	18,700	1.40	26,180
Eggplant	14,900	1.50	22,350
Mango	14,700	1.00	14,700
Watermelon	7,700	1.50	11,550
Tomatoes	6,800	1.75	11,900
Oranges	5,400	3.00	16,200
Papaya	4,400	1.00	4,400
Pumpkin	4,900	1.00	4,900
Pineapple	3,300	1.00	3,300
Cucumber	1,600	1.20	1,920
Mandarin	1,600	.50	800
Chilli	900	3.00	2,700
Lemon	600	2.99	1,794
Total			**133,644**

* From Table 35

** Suva municipal market prices for the week ending October 1st 1999, except breadfruit and mandarin for which the estimated seasonal price was applied. The Fiji Ministry of Agriculture, Fisheries, and Forests supplied Price data.

In Samoa, the 1990 Agricultural Census was nowhere as comprehensive as the Fiji Census, yet it contains some information about the importance of fruit consumption and production. The Census indicated that 95 per cent of households grew bananas, most (87 per cent) mainly for home consumption. The total area under bananas was around 2,200 ha. The Census reported 95 hectares of cucumber, 94 hectares of tomato, and 65ha of pumpkin. Table x shows the total number of fruit trees in 1989. Similar to other Pacific islands, breadfruit was by far the most numerous. Eighty-nine per cent of households grew breadfruit, and there were 0.6 breadfruit trees per head of population.

Table x. Number of fruit trees in Samoa, 1989

	No. of trees
Breadfruit	95,200
Guava	24,900
Orange	18,900
Mango	13,400
Lemon	4,800
Vi	3,900
Lime	3,700

Noni	2,100
Avocado	1,600
Grapefruit	1,500

Source: Samoa Agricultural Census, 1990

In Solomon Islands, the most recent agricultural census was in 1986. This data has been used to produce the following estimates of cucurbit production prior to the incursion of melon fly. Yield estimates were gathered from interviews with 236 farmers.

	Cropping season	Est. monthly production (tonnes)	Est. annual production (tonnes)
Cucumber	All year	1.4	17
Snake gourd	All year	0.5	6
Pumpkin	All year	2.4	29
Water melon	Oct - Jan	3	12

Source: Lottie Vaisekavea, Chief Field Officer for the Western Province, 1995. (Data supplied to the Chief Technical Advisor, RMFFP.)

The consumption approach: market surveys

Market survey data can also measure fruit consumption, particularly for urban households. Unfortunately, very few data are available on the volume of produce traded on urban markets. The Central Bank of Samoa systematically collects monthly data on some fruit products. Single surveys on the volume of municipal market trade are available for Vanuatu and Tonga. All of these data indicate that non-staple fruit make up a surprisingly high proportion of produce sold on these urban markets. Casual observation at the Suva and Honiara market would suggest similar situations prevail there.

The monthly volume and price data collected by the Central Bank of Samoa on produce sold at the Fugalei and Savalolo municipal markets includes information on banana, tomato, cucumber, and pumpkin. Breadfruit is not included in the survey. These data have been used to estimate average daily volumes and prices per month (Johnson, 1999). Table x and x show these estimates translated into monthly and annual estimates of production. Bananas are second only to coconuts in terms of estimated volume of trade, but are by far the largest product in terms of value. Around 2.3 million Samoan tala (ST) worth of bananas is traded annually on Apia's municipal market. The staple second to bananas is ta'amu, for which some 1,400 tonnes is traded at a value of almost ST 2 million.

The market survey shows that large volumes of pumpkin, cucumber, and tomato are traded. The estimate of 800 tonnes of pumpkin being traded at a value of approximately ST 860,000 is surprisingly high, but nevertheless consistent with

Samoa's previous agricultural census which reported 65 hectares to be under pumpkin.

Table 36: Estimated monthly volume and value of trade for selected products sold at Fugalei and Savalolo Markets, Samoa

Month	Coconut		**Banana**		Taro		Ta'amu		**Pumpkin**		**Cucumber**		**Tomato**	
	tonnes	ST/kg	**tonnes**	**ST/kg**	tonnes	ST/kg	tonnes	ST/kg	**tonnes**	**ST/kg**	**tonnes**	**ST/kg**	**tonnes**	**ST/kg**
Jan	204	.22	**248**	**0.82**	25.6	5.95	73	1.68	**43.6**	**1.28**	**16.8**	**2.23**	**8**	**4.85**
Feb	190	.20	**198**	**0.90**	17.2	5.76	111	1.46	**43.8**	**1.26**	**23.4**	**1.79**	**2.6**	**6.42**
March	168	.20	**166**	**0.95**	30.6	5.67	110	1.43	**47.6**	**1.26**	**21.6**	**1.72**	**2.4**	**6.24**
April	159	.20	**137**	**1.10**	10.4	6.04	114	1.50	**74**	**1.19**	**26.2**	**1.31**	**2.4**	**5.38**
May	183	.20	**122**	**1.30**	7	5.91	174	1.52	**52.2**	**1.10**	**21**	**1.61**	**4.4**	**4.72**
June	212	.20	**131**	**1.30**	8.2	6.04	143	1.43	**64.6**	**1.12**	**19.4**	**1.76**	**5.6**	**4.59**
July	204	.20	**136**	**1.32**	4.8	5.78	134	1.41	**77.4**	**1.21**	**12.6**	**2.21**	**6**	**4.32**
Aug	216	.20	**157**	**1.19**	6	5.67	122	1.50	**101.2**	**0.97**	**22**	**2.01**	**8.6**	**3.46**
Sept.	212	.18	**174**	**1.15**	8.4	5.84	115	1.30	**89.6**	**0.88**	**18.6**	**1.90**	**11.8**	**2.80**
Oct	214	.18	**236**	**0.95**	11	5.64	140	1.21	**79.2**	**0.86**	**18**	**1.50**	**15.6**	**2.29**
Nov	212	.18	**214**	**0.93**	11	4.94	106	1.15	**62.6**	**0.84**	**17.7**	**1.57**	**11.4**	**2.40**
Dec	216	.20	**262**	**0.88**	16.8	4.92	95	1.12	**66**	**0.93**	**19.8**	**1.70**	**8.6**	**3.66**
Total	2,390		**2,181**		157		1,437		**802**		**237**		**87**	

Source: Derived from Johnson 1998 and 1999.

Table 37: Estimated annual estimate of volume and value of trade for selected products sold on Samoa's Fugalei and Savalolo Markets

Product	Volume (tonnes)	Average price (ST/kg)	Value (,000 ST)
Coconut	2,390	.20	478
Banana	2,181	1.06	2,312
Taro	157	5.68	892
Ta'amu	1,437	1.39	1,997
Pumpkin	802	1.07	858
Cucumber	237	1.77	419
Tomato	87	4.26	371

For Vanuatu, there are very few data about the volume of produce that is traded in urban markets. A snapshot of the volume of trade is however provided by a survey conducted at the Port Vila municipal market, 19-24 September 1998 (Greindl, 1998, p.25). Table x summarises the volume and value of produce sold in that five-day period, at a total estimated value of 5.4 million vatu. The week of the survey coincided with the peak of the mandarin season, and 36.5 tonnes of oranges and mandarins were sold for a value 2.2 million vatu, comprising around 40 per cent of all sales. Bananas were the most important

staple, with 15 tonnes sold for a value of 507,000 vatu, which comprised 9 per cent of all sales. Kumala was the most important root crop, with 6.5 tonnes sold at an estimated value of 295,000 vatu, or five per cent of all value. Extrapolation based on one week's data is difficult but it appears that over the season, some 120 tonnes of orange and mandarin could be sold, which would make a significant contribution to the nutrition of Vanuatu's small, but fast growing, urban population. At least 600 tonnes of banana sales might reasonably be expected. This figure is consistent with the more than 2,000 tonnes of bananas estimated to be sold at Samoa's markets, taking into account the larger traded produce sector in Samoa, where growers and consumers have better access to urban markets.

Table 38: Produce sold on the Port Vila market between September 19th and 24th 1998

Product	Quantity (kg)	Value (vatu)	Number of vendors
Oranges and mandarins	36,500	2,190,000	17
Bananas	15,000	507,000	271
Coconut	21,000	355,000	177
Kumala	6,500	295,000	90
Yams	2,500	294,000	90
Fiji taro	6,000	272,500	123
Round cabbage	3,000	202,000	55
Island cabbage	4,500	165,000	124
Taro	2,000	156,500	69
Lettuce	1,200	134,500	32
Cucumber	2,000	120,000	60
Laplap leaves		107,000	106
Tomatoes	1,000	97,000	30
Pamplemousse	1,600	96,500	33
White boon	2,000	91,500	66
Manioc	4,000	83,000	70
Papaya	2,000	79,000	94
Coconut crabs		78,500	30
Green beans	300	60,500	49
Other		95,900	
Total		**5,480,400**	

Source: Greindl, 1998.

For Tonga, Table 39 shows estimates of the produce sold at the Nuku'alofa and Talamahu markets in 1997. The somewhat surprising information here is that fruit makes up the largest category of produce traded, of over 1,900 tonnes and worth almost 1 million pa'aga (TOP). This is consistent with the estimate for Samoa. The category of vegetables (other than root crops) also exceeds any particular category of root crops. Unfortunately, the data available do not disaggregate fruits and vegetables

into various types, although the study mentions that bananas, papaya, and watermelons are the main fruits (Taufatofau and Taufatofau, 1999, p.5). From observation, tomatoes and capsicums are also important vegetables in Tonga.

Table 39: Major Tongan produce marketed domestically (1997)

Crop	Volume (tonnes)	Value (TOP)
Yams	544	821,621
Sweet potato	670	388,600
Talo (Xanthosoma)	582	337,560
Talo (Colocasia)	81	71,955
Kape (Alocasia)	264	145,398
Potato	31	38,440
Vegetables	**734**	**812,654**
Fruits	**1,907**	**930,544**

Source: Taufatofau and Taufatofau, 1999:5

The consumption approach: household consumption survey

Given the limited data on household fruit consumption, this study undertook some household surveys of fruit consumption. Small sample surveys were planned for Fiji, Vanuatu, Solomon Islands, and Nauru but, unfortunately, only completed in Fiji and Vanuatu.

The survey in Fiji was of rural households in the Province of Cakaudrove, on the island of Vanua Levu, and at Votualevu on the outskirts of Nadi, Viti Levu.[30] The Cakaudrove survey covered the farming community of the Nakobo-Waikava area, which were predominately indigenous Fijians. The survey covered both individuals and households.

- A stratified sample of eight individuals was selected. (The sample contained four males and four females; four were adults (people over 18 years) and four were youths (people between 12 and 17 years); four lived in the village of Nakobo and four lived outside the village. Two of the selected individuals living outside the village were Indo-Fijians.)
- A stratified sample of seven households was selected. (The previous eight individuals did not belong to these households.) Three of these households were from Nakobo and four were from outside the village. One of the households was Indo-Fijian.

[30] The Cakaudrove survey was undertaken by Janet Seruitanoa under the supervision of Ratu Semisi Rakuro, while the Votualevu survey was supervised by Mr Sant Kumar.

The Votualevu settlement is a typical Indo-Fijian urban fringe farming community with a high percentage of off-farm employment. Twenty individuals were selected for the survey; 16 males and four females aged from 13 to 67 years.

The surveys were conducted during December 1998 and January 1999. This period was somewhat atypical as it came just after the severe 1997-98 drought. One consequence of the drought, and the abnormally heavy rains that followed, was a substantial increase in the fruit piecing moth population. Large quantities of fruit were nevertheless observed in both places. The drought induced the best mango crop for many years, which undoubtedly contributed to food security during this difficult period.

Selected individuals were each given a notebook in which they listed all the fruit they ate in a designated period. Each time they ate fruit, the informants were requested to immediately record the type and quantity consumed. They were expected to carry their notebook as they went about their daily business. This method of immediately recording consumption was designed to minimise the expected under-reporting of non-staple fruit consumption, which is not usually eaten with meals.

In each selected household, one person was designated to record fruit consumption daily, after the evening meal. No doubt, some fruit 'snacking' would have been missed in this way, but it was hoped that regular daily recall sessions involving the whole household would minimise any omissions.

The notebooks were kept for seven consecutive days, and then collected by the co-ordinator. Two weeks later, new books were issued, which again were kept for seven consecutive days.

Table 40 summarises the findings for the Cakaudrove consumption survey. It showed a quite high level of fruit consumption, despite the drought. The most important fruit, by far, was breadfruit, with adults consuming on average 4.7 breadfruits per week, youths consuming 2.8 breadfruits, and children, 2.7. Altogether, sixteen non-staple fruits were eaten during this period, mainly chilli, mango, kavika, pawpaw and oranges, and, as expected, most as snacks and not at meals.

Table 40: Average weekly fruit consumption from Cakaudrove Survey (December 98 - January 1999), measured in whole units

Fruit	Adults (>18 yrs)	Youths (12-17 yrs)	Children (2-11yrs)	Infants (< 2 yrs)
Breadfruit	4.7	2.8	2.7	-
Ivi	3.7	-	2.1	-
Chilli	3.4	0.8	-	-
Banana	3.0	3.7	5.8	-
Mango	1.8	6.0	1.9	-
Pawpaw	1.8	0.6	1.4	1.8
Kavika	1.8	-	-	-

Orange	1.4	2.0	0.3	-
Pineapple	0.8	1.0	0.4	-
Eggplant	0.7	-	-	-
Guava	0.4	3	-	-
Avocado	0.4	2	0.2	0.1
Vudi	0.3	-	-	-
Watermelon	0.3	0.1	0.2	0.1
Lemon	0.2	-	-	-
Wi	0.1	0.1	0.7	-
Pumpkin	0.1	-	-	-
Lauki	0.1	-	-	-

The survey at Votualevu showed a much lower level of fresh fruit consumption in this rural Indo-Fijian community, compared to the Cakaudrove survey. People in the Votualevu settlement do not consume much fresh fruit. Mangoes are eaten in season. Papaya and bush guava, from trees grown in the settlement, are eaten fairly regularly. Some households purchase imported apples. There is, however, a high level of 'vegetable' fruit consumption, with produce such as eggplant and chilli featuring prominently in the diet. Fresh fruit consumption was lowest among the older people in the settlement, reportedly because of the high incidence of chronic gastritis problems. According to the National Food and Nutrition Committee, this is a common problem in Indo-Fijian communities. Respondents in the Votualevu survey identified high acid fruit, such as pineapples and bananas, as being particularly troublesome for people suffering gastritis.

Much of the fruit consumed in this Hindu community is associated with religious ceremonies. Fruit is offered to the gods during prayers on 'Ramayan' recitals and 'Katha' ceremonies, prayers that usually occur on Tuesdays and Saturdays. Everyone present will eat the fruit that has been offered. These fruits include banana, papaya, mango, and pineapple, as well as imported apples and grapes. During fasting, Hindus eat only fruit and might drink fruit juice, but the Votualevu survey confirmed that a great deal more sugared cordial or carbonated drinks are consumed than fruit juice. As in most Indo-Fijian communities, mangoes, limes, wi, and tamarind are pickled and preserved for year-round use as condiments with meals. Green mango is also dried to produce '*kuatai,*' which is eaten by the household and exported to expatriate Fiji communities.

Parallel to the preparation of this report, the author was involved in a comprehensive study on root crops self-sufficiency farming systems in Vanuatu, the Vanuatu Land Use Planning Project (VLUPP). As a part of this farming systems study, information was collected on household fruit consumption in North-West Malekula, South-East Malekula, North Ambrym, and South and South-East Malekula. The respondents were Farm Support Association (FSA) members in these locations, and an FSA staff member compiled the questionnaire.

The VLUPP survey was conducted in early October 1998, just before the breadfruit season. A questionnaire asked about household food consumption for the previous weeks. For each food item, the respondent was required to indicate if consumption for household was '*fulup*' (consumed at least 5 times during week and sometimes twice a day), '*samtaem*' (3 or 4 times during week), '*wanwan taem*' (one or two times during week), or '*nan*' (not consumed during the previous week). By far, the main fruit eaten was banana–with around 40 per cent of households eating banana at least five times per week, and most indicating that banana was the main every-day staple. Breadfruit did not feature because it was out of season. An interesting finding was the prominence of tomatoes, which were found in almost every garden in the survey and almost half of the households indicating '*fulup*' consumption. Tomatoes were mostly eaten as 'snacks' in the garden, although some were consumed with meals. Papaya also appeared in most gardens and was regularly eaten by most households. At the time of the survey, citrus was the main fruit in season, and around 90 per cent of households had eaten some variety of citrus during the previous week, most at least three or four times. The survey showed that very little other fruit was eaten, but it was conducted in early October when many common fruits were out of season.

The overall impact of fruit flies on domestic fruit consumption and nutrition.

At the household self-sufficiency level

The overall conclusion is that fruit flies **at present** do not have a significant impact on fruit consumption and nutrition at the household self-sufficiency level. There are different reasons for this, between staple and non-staple fruit.

The most important food staples for households throughout the region are bananas and breadfruit. In most places, fruit flies do no, or little, damage to bananas—although Papua New Guinea and Palau are important exceptions that demonstrate the risk fruit flies can pose. Fruit flies can do considerable damage to breadfruit, as is evident from data from Kiribati, Federated States of Micronesia, and North Ambrym (Vanuatu). The 71 per cent loss to breadfruit reported in Kiribati would have a significant impact on household food supply and finances for on atolls there are no real alternatives to breadfruit, other than imported rice. This loss is mitigated by the large surplus of breadfruit that is usually available and the fact that fruit fly damaged breadfruit can usually still be eaten.

- At the peak of breadfruit season, there is usually a large surplus of fruit. For this reason, breadfruit was the main food preservation crop, being either dried or

fermented. Only in a few places, however, such as the Banks and Torres Islands in Vanuatu, is the preservation of breadfruit still practised. In most villages, most of the breadfruit crop is wasted, regardless of fruit fly damage. Therefore, other than on atolls, 70 to 80 per cent infestation rates are not so disastrous.

- The North Ambrym case study showed that fruit flies seldom render the fruit completely inedible, except in over-mature fruit. Breadfruit is boiled, baked, pounded, or grated and it is of little consequence if the infested part of the fruit is cut off and discarded.

In non-staple fruit, data collected by the RMFFP over the last decade show that fruit flies do considerable damage. Some fruits, such as guava and kavika, are badly damaged in all countries. Fruit flies cause considerable damage to cucurbit crops in most of Solomon Islands and rendered mango virtually inedible in Nauru. Even so, the damage caused to non-staple fruit by fruit flies in general does not have a major impact on subsistence consumption and nutrition, because:

- Non-staple fruit is of relatively minor importance compared with leafy vegetables in the diets of most rural Pacific Islanders. Non-staple fruit nevertheless is an important part of the nutrition of rural households, even though most are consumed outside meals.
- Except on the atolls, a variety of alternative non-staple fruit is usually available, and high fruit fly infestation in any one fruit is of little consequence to the daily consumption of rural households.
- Sufficient quantities of non-infested fruit can normally be found by villagers foraging around their gardens or children walking to or from school, even if the infested part must be thrown away. Many fruits can be eaten green before any fruit fly damage occurs. In Vanuatu, almost the only time to eat nakavika is when it is green and mature, and even then most fruit are already infested. Children, particularly, do this, thereby foregoing the optimum flavour and nutrition of a fully ripe nakavika—which does represent a cost that can be attributed to fruit flies.

The case of mango in Nauru is an important exception. Nauru has limited arable soil and groves of mangoes planted communally during World War II are almost the only fruit grown on the island. The incursion of exotic fruit flies caused the almost complete loss of the mango crop and this had significant nutritional consequences for a community with an already poor nutrition status.

At the time field-work for this study was being conducted in Fiji and Vanuatu, fruit sucking moth was seen to be a more serious pest to household fruit than fruit flies. While fruit-sucking moth is a more intermittent pest than fruit flies, control measures that address only one of these pests are likely to be of little interest to village communities.

At the commercial level

It appears that the impact of fruit flies is much greater at the domestic commercial level than on self-sufficiency consumption. By implication, this has greater impact on urban than rural consumers, but reduced urban fruit consumption also has implications for the income generating opportunities of rural people.

A rural dweller may be prepared to salvage fruit fly damaged fruit he has grown or foraged, but not a consumer purchasing fruit from a road-side or urban market. Fruits such as guava and kavika are therefore seldom seen in municipal markets, certainly never at their mature best, and urban consumers miss the opportunity to consume these delicious and highly nutritious fruit. Improved varieties of both these fruits have excellent potential in more sophisticated hotel, restaurant, and supermarket markets. There are even export market opportunities if quarantine treatments can be developed and protocols negotiated with importing countries. It is for this reason that a commercial producer inVanuatu is keen to use bait spray technology on his improved variety guava plantation outside Port Vila. If guava were not a major fruit fly host, such markets would have already been developed. This forgone income represents a cost attributable to fruit flies.

From discussions with vendors at the Honiara municipal market, it appears that the presence of melon fly now restricts the volume of watermelon sold there. Consumers have become cautious in buying watermelons for fear of purchasing an infested fruit. Fruit flies are thereby having an adverse impact on watermelon sales—a situation that is ideal for introducing bait spray technology.

The incursion of an exotic species such as Asian papaya fruit fly or Oriental fruit fly could have a devastating impact on domestic fruit sales. A recent study in Palau indicated the large losses caused by Oriental fruit fly to this small island economy. Oriental fruit fly was first found in Palau in 1996, and very heavy damage has been reported to guava, papaya, ripening bananas, carambola, soursop and mango. A report by UNDP's Informal Employment and Sustainable Livelihood (IESL) Project estimated the value of the informal sector to be US$7-9 million per year, of which agriculture makes up 60 per cent. It was concluded that:

> Losses to banana, papaya, and soursop reduce a valuable source of supplementary income to the women of Palau, especially those women who work at home and grow crops as a major source of income. The prospects of establishing small enterprises based on juicing and making puree from guava, soursop, and papaya were lost because of damage done by fruit fly. There is resistance to investment into agricultural development, especially into the value-added commodities, such as juices and purees, while Oriental fruit fly is present in Palau. Anecdotal evidence from local farmers and government personnel suggests that, although mango fly and breadfruit fly were present in Palau from before the Second World War, damage from fruit flies was not obvious until after the

> establishment of Oriental fruit fly in the mid-1990s (Allwood et.al, 1999, p.7).

In Samoa, where a fruit is now the main traded staple, commercial losses would be even greater if there was an incursion of a serious exotic fruit fly. An estimated 2,000 tonnes of banana are sold annually on municipal markets for a value of ST2.3 million. Arrival of Asian papaya fruit fly could be a disaster of similar proportions to that of taro leaf blight, both on subsistence and domestic market sales. Before the arrival of the leaf blight, domestic market taro sales exceeded that of bananas, but today are only around 150 tonnes annually. Bananas have now replaced taro as Samoa's main food staple, but it is difficult to see what could readily replace bananas.

Mitigation and control measures for domestic fruit production

Traditional mitigation and control measures for fruit flies

The terms of reference for this study included an examination of traditional fruit fly control and mitigation methods, in the expectation that some of these could be used in current fruit fly management programmes. No successful traditional control measures were identified, except for the bagging or wrapping of whole bunches of bananas in Papua New Guinea. Traditional mitigation is probably confined to the early harvesting of fruit and the use of uninfested portions. The lack of traditional control and mitigation measures can be explained by the fact that fruit flies have not been perceived to be a major problem, for the reasons discussed above. In the past, they were probably even less so for village people, for some of the most troublesome fruit flies in the region are recent incursions.

This does not mean that traditional knowledge cannot be of value in designing mitigation measures. For example, the successful bagging technology developed in Malaysia uses newspaper, a material that is rarely available in rural villages in the Pacific islands. Any bagging programme in this region would need to draw on traditional knowledge about locally available substitute materials.

The use of bait sprays

Bait-sprays exploit the attractant value of hydrolysed yeast to fruit flies. Female flies need to ingest protein in order to lay viable eggs. Protein hydrolysate on the leaf surface induces rapid bacterial growth. This causes odours to be given off that attract fruit flies. The flies ingest the protein along with the added insecticide (usually malathion), and are killed. The bait is sprayed onto the underside of the leaves where fruit flies normally feed. Because the bait attracts the flies, it is not necessary to spray the entire foliage. This reduces the risk of pesticide residue in the fruit a well as the loss of pollinators and other desirable insects.

Protein bait sprays were jointly introduced as a field control measure by the RMFFP and ACIAR fruit fly projects. ACIAR's involvement follows on from a successful project in Malaysia. Bait-sprays were found to provide an efficient, cost effective and environmentally benign way to reduce fruit fly infestation and damage. They have now

become an integral part of some Bilateral Quarantine Agreements (BQAs) with New Zealand and, thereby, helped to open up export markets. They also offer the prospect of improving the quality of some export fruits, so expanding markets. The sustained efficacy of quarantine treatments, such as HTFA, depends on reducing field infestations to a very low level. Bait sprays can play an important role in this. The benefits from bait spray technology are not confined to export produce, for they can also help to expand domestic trade and improve peoples' nutrition by increasing production and improving the quality of local fruit and vegetables.

Bait sprays have been found to be particularly valuable in Tonga where *B. facialis* is a major pest species with a large range of hosts, including tomatoes, citrus, mango, chilli, capsicum and ripe banana. For crops such as capsicum and chilli, losses in untreated plots can be as high as 100 per cent. When protein bait sprays are applied weekly as a band to every third row, these losses are reduced to less than 7 per cent. Tonga's current BQAs with New Zealand all require the use of bait sprays, even in the case of some cucurbits that have proven non-host status. Bait sprays are required for watermelon in conjunction with methyl bromide treatment. Under the auspices of the RMFFP and with support from ACIAR and USAID, Tonga has been at the forefront of the commercial manufacture of protein bait spray, using waste yeast from the brewery. Benefits from this commercial development include:

- Cost savings compared with Australian bait spray. The cost of the Australian bait landed in Tonga is P$30 per litre, whereas the local bait, 'Tongalure,' produced by the Royal Brewery costs T$ 2 per litre. At that price, using even twice the amount of 'Tongalure' than the Australian protein is economical.
- Increased fruit production and improved quality for both local and export markets, because of the availability of cheaper bait spray.
- Reduced pollution run-off into the lagoon because waste yeast from the Brewery is now being used to produce bait spray.
- Excess protein is storable and stable and has approximately a 30 per cent protein content. Despite being a liquid, it can be used as a cheap protein feed additive for livestock.

In Fiji, fruit flies generally cause less damage to commercial fruits than in Tonga. Protein bait sprays are nevertheless included in Fiji's BQAs with New Zealand for mango, eggplant, and breadfruit. The use of bait sprays has significantly increased the production and quality of mangoes, and is also important in producing mangoes for the Japanese market.

Bait sprays also help improve domestic fruit production. Village-based and commercial production bait spray trials were conducted in Vanuatu as a part of this study. The village trial covered breadfruit and nakavika in North Ambrym and the commercial trial covered a commercial guava orchard near Port Vila. The results are reported on briefly here.

Technically, the major difference between a village fruit grove and a commercial orchard is that one is a mixture of fruit trees and plants, while the other is a

monoculture. RMFF staff members conducted bait spray control trials in Fiji, Vanuatu, Solomon Islands, and Federated States of Micronesia. Successful control was achieved of *B. trilineola* on guava in Vanuatu, *B. passiflorae* on kumquat in Fiji, and *B. frauenfeldi* on guava in Solomon Islands. In Pohnpei (Federated States of Micronesia), bait spray did not succeed in controlling *B. frauenfeldi* in Surinam cherry. This failure was attributed to the very high fruit fly population, the small size of the area treated, heavy and persistent rainfall that washed the bait off the leaves, and the high susceptibility of the indicator fruit to fruit fly attack (Leblanc, et al.1996, p.187).

The bait-spray trial on North Ambrym was a participatory research effort that involved members of a local NGO and a person from the community in collecting data. This first bait-spray trial to be conducted in a Melanesian village aimed to:

- Test the practicability of lure bait spraying in an isolated village situation.
- Find out how effective lure bait spraying was against damage to the fruits considered important by the community.
- Determine the willingness of the community to adopt lure bait spraying and how this could be done in a sustainable way.

North Ambrym was selected as an appropriate site for the study because of the evident need there for fruit fly control, as well as local capability to implement the programme and good prospects for its sustainability. The area faces food supply problems because of 'acid rain' and volcanic dust fallout from periodic eruptions of the nearby Mt. Benbow and Mt. Marum volcanoes. The ecological balance has been disturbed by the eruptions and this reportedly has encouraged an upsurge in fruit fly and fruit piercing moth populations. A recent UNDHA report on disasters in Vanuatu noted:

> The recent on-going eruptions from the Ambrym volcanoes take place at much longer time intervals and tend to be more violent with large quantities of material being flung out. The acid rain from these volcanic eruptions can cause serious food shortages to nearby communities. The adverse impact from ash fall out was compounded in April 1996 by cyclone Beti. Indications are that acid rain has seriously upset the ecological balance on Ambrym. The consultant was shocked to observe the extent of fruit fly damaged fruit in North Ambrym - the worst observed anywhere in Vanuatu. This was surprising since Vanuatu, along with Fiji, was believed to have the most favourable fruit fly status in the region. It might be hypothesised that this was a result of the ecological balance being disturbed by acid rain (UNDHA, 1999, p.21).

Given these pressures, it was thought that people on North Ambrym would be willing to adopt measures to reduce fruit fly damage to food crops. FSA had a strong presence in the area through its involvement in wild yam and soil conservation projects. The Association's lead farmer in the area has been particularly interested to reduce fruit fly damage and, of his own accord, had been bagging fruit trees around his house. He was identified as a potential leader in the ongoing implementation of this technology. A suitable person from the area was available to conduct the bait

spray trial over the long period that was necessary, namely Billy Homi, a graduate of the Farm Apprentice Scheme run by the FSA Vice-President, Charles Rogers. This scheme provides a strong grounding in data collection and recording. The Lolihor Development Council (LDC) is a community organisation in the area and involves all the chiefs and community leaders in villages within the Lolihor watershed. LDC has previously worked with FSP on a development project in the area. The involvement of such an NGO was seen as essential, if bait spraying was to continue and be sustainable.

The trial began in May 1998 with preliminary trapping in Fanrereo and Ranon Villages, and found *B. trilineola, B. umbrosa* and *B. minuta.* The infestation level was relatively light, at 100 to 300 flies per trap per month—which was somewhat surprising, given very high damage reported to fruit. The findings were nevertheless consistent with what is known about fruit fly populations elsewhere in Vanuatu, particularly when host fruit availability is low.[31] The light fruit fly damage suggests that a large part of damage reported may have been due to fruit piecing moth. This was confirmed in subsequent fieldwork.

Due to the isolation of North Ambrym, it was impractical to send sample fruit to the Fruit Fly Laboratory in Port Vila. Egg incubation, fruit dissection, larvae counting, etc., was undertaken on site. The research assistant was trained to carry out the trials without supervision, including fruit fly identification, trapping, preparation and use of bait sprays, incubation of fruit flies, dissection of fruit, and counting of larvae.

At the start of the trial in early November, David Tau, head of the Vanuatu Fruit Fly Project and the author of this report accompanied Billy Homi to North Ambrym. The team met with the LDC to discuss the problem of fruit flies and their management and control. Permission was obtained to conduct bait spraying on village-owned trees. The requirements of the trial were explained, these being some trees for treatment and others at a distance for control. LDC members helped select the trees. David Tau supervised the establishment of a 'laboratory' for holding fruit, incubating eggs, and rearing larvae, and oversaw the first spray application. From then on, the trial was solely the responsibility of Billy Homi.

Breadfruit and nakavika were selected for the bait-spray trial and as indicator fruit to assess damage. Breadfruit was selected because of its importance as a food staple and the damage caused to it by fruit fly. There were many heavily bearing nakavika trees in the area but almost all the fruit were wasted by fruit flies. Some initial test spraying was done on mango trees outside the villages to provide training in the use of the equipment, but otherwise mango was not bait sprayed because of its low level of infestation.

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[31] More than 2,000 *B. trilineola* flies have been trapped in a one month period in Port Vila area during the peak fruit and activity January, February, and March (personal communication David Tau, Vanuatu Fruit Fly Project)

The breadfruit trial was conducted in the village of Ranon on ten trial and control trees. Bait spraying began on 21 December 1998 and continued for eight weeks, until 18 January 1999. The nakavika trial was conducted some five km. away from Ranon Village, at Lolire Plantation and Ranbe Village where five trial and control trees were selected. Bait spraying of Nakavika started on November 23 1998 and continued for five weeks, until December 18. All trial trees were baited each week with a mixture of 50 ml of Mauri's Pinnacle Protein Insect Lure and 4 ml of 50 per cent emulsifiable concentrate malathion, made up to 1 litre with water. This was applied at a rate of 50 ml as spot per tree. Because of the large size of the trees, a bamboo pole was used as an extension(***Margaret insert the North Ambrym map here)***.

As a formal experiment, this bait-spray trial was not successful, mainly because of the continuously wet conditions, the small number trees baited, and the short period of application. In the first week of January, a small cyclone hit Ambrym, causing fruit drop and preventing David Tau's supervisory visit. Had he visited, he could have instructed Billy Homi to use his discretion to re-spray trees in wet conditions. The trial ended prematurely on February 5, several weeks earlier than planned, due to the windfall loss of fruit. The North Ambrym trial thereby confirmed the difficulties that had previously been encountered in Pohnpei, of bait spraying in very wet conditions, difficulties that were compounded in a village situation where the discipline of re-spraying could not be assured. This is particularly a problem for breadfruit, for its main fruiting season coincides with the hurricane season.

The positive lesson to be drawn from the North Ambrym trial is that a local NGO can conduct fruit fly field research if the right training is provided. Without supervision, Billy Homi was able to successfully collect and store sample fruit, incubate larvae, dissect fruit, count larvae, and maintain very good records, an experience that augers well for the sustainability of fruit fly research in the region.

Clearly, the value of bait spraying was not proven to the chiefs and community leaders in North Ambrym. Even if better results had been achieved, however, doubts would remain about the applicability and sustainability of bait spraying in isolated villages. The mechanism of bait spraying, unlike bagging, is not immediately obvious to most villagers. Even though bait spraying is environmentally sound and uses a very small amount of chemical, still a poison has to be stored and handled by people who are inexperienced in the use of chemicals. It would also involve the regular purchase and delivery of the lure and malathion. These difficulties raise the question of whether communities would feel the need to use such a strange technology even if its efficacy was proven.

Given the small extent of fruit fly damage and fruit eating patterns, this would be unlikely. The people of Ambrym have learnt to live with fruit flies in the same way they have adjusted to occasional volcanic fallout. They accommodate fruit fly infestation in breadfruit by harvesting a little earlier and discarding the damaged parts before boiling, baking, or grating. In the case of nakavika, another fruit will be foraged for instead. This situation would be quite different if an exotic fruit fly such as Asian papaya fruit fly became established, for this fly infests breadfruit at its green

stage and leave little usable fruit at the ripe stage. It is also known to infest green bananas and would likely infest various non-staple forest and garden fruits.

A commercial crop trial was also undertaken as part of this study. FSA contacted a commercial grower of citrus and improved variety guava about the potential use of bait spray. The farmer, Des Parks, has a well laid out orchard just outside Port Vila, with some 800 improved variety guava trees that are bearing. These are laid out in 16 blocks of 50 trees, with each block surrounded by a wind break of casuarina trees. As well as guava, there is a substantial area of citrus, including limes, oranges, pomlemous, and mandarin. The orchard was established some five years ago to supply Port Vila hotels and the local market with quality fruit, particularly guava. Because of severe fruit fly damage, however, the guava can not be sold. In the vicinity of Parks' orchard, the Vanuatu Fruit Fly Project in 1995 measured infestation levels of 90 per cent (Leblanc et al.1996, p.189). Not surprisingly, therefore, the farmer approached the bait spray trial with enthusiasm. With assistance from the Vanuatu Fruit Fly Project, a demonstration trial was conducted at Parks'orchard from 13 March to 16 April 1999.

Using a commercial lure supplied by the RMFFP, Parks treated one block of white guava and two nursery blocks with the standard mixture of 50ml lure, and 4ml malathion, made up to 1 litre of water. Spot spraying was undertaken each week. The simple method of collecting dead fruit flies was used to measure the success of the trial. To do this, a white sheet was placed under three guava trees in each block, and the fallen dead fruit flies counted.

This demonstration trial was an outstanding success. After five weeks of spraying, Parks reported an evident decline in the number of dead fruit flies found on the sheets, and in damage to the fruit. This encouraged him to import 20 litres of commercial lure, and in July 1999 he sprayed the entire guava plantation. He now looks forward to getting some return to his investment, initially by meeting the demand of the under-supplied Port Vila market but later, possibly, by exporting fresh guava—but this will require the development of a quarantine treatment acceptable to New Zealand or Australian authorities.

Now that there is serious commercial interest in Vanuatu to use bait spray, it is an opportune time to renew discussions with the brewery about manufacturing protein from brewery waste yeast. As evident in Tonga, there are large economies to be achieved through local manufacture of protein bait. The Port Vila brewery is managed by the same Swedish company as the Tongan brewery and the expertise can be readily transferred. The management has also expressed their enthusiasm to manufacture protein. Any excess product would have an immediate market in Vanuatu's large beef industry.

From the two trials, it is evident that demonstrable success is necessary before farmers will adopt a new technology, at either the commercial or village level. The commercial farmer had a further incentive to adopt the technology—namely, an opportunity to sell his previously unsellable product—while Ranon villagers did not. For them, their use of breadfruit did not depend on the use of bait spray technology.

But had their magnificent grove of nakavika trees been close to Port Vila where the fruit would find a ready market, chances are they would have enthusiastically taken up bait spraying once it was proven effective.

Similar differences in the choices made by village and commercial producers could be expected throughout the Pacific island region. Village cucurbit producers in Solomon Islands' Western Province would probably show little interest in bait spraying despite their high fruit losses, yet they readily adopted the simple cultural practice of creating a cucurbit free period in order to reduce the numbers of melon fly and *D. solomonensis.* On the other hand, commercial watermelon growers on Guadalcanal would probably readily adopt protein bait technology.

Bagging

Fruit bagging was another technology examined at the village level. This is a form of physical fruit fly control where a bag is used as barrier between the host fruit and the egg-laying female fruit fly. Bagging or wrapping of carambola for export is a common practice in Malaysia (Vijaysegaran, 1989). There, damage levels have been reduced from nearly 100 per cent down to 15 to 25 per cent through bagging. Bagging is also successfully used in Thailand to protect mangoes, and in Taiwan to protect melons (Allwood, 1996, p.172). As Allwood noted:

> This technique is applicable where relatively small areas of production are involved (e.g., village and subsistence); where the cost of labour is cheap; where high quality, high value, unblemished produce is necessary; and where no alternative practical method of control is available. This technique is appropriate for South Pacific island production systems and should be encouraged especially for backyard and village production (ibid, p.172).

In a village situation, bagging has several decided advantages over bait spraying:

- The mechanics of the technique are easy to understand;
- The handling of hazardous chemicals is avoided;
- The problem of the ongoing supply of purchased materials is avoided; and
- The technique is likely to be also effective against fruit-sucking moth, which can be a more serious pest.

The main difference between bagging and bait spraying at the village level is that the first depends on individual household responsibility while the second depends on communal responsibility. The successful use of bagging is therefore easier than bait spraying for fruit trees in and around a village usually belong to individual households. Each one can decide for themselves whether to bag their fruit and who will do the work. Each can also reap the reward from their effort. The decision to bait spray, by contrast, requires the collective agreement of the whole community, including funding arrangements and agreement about who will continue to do the work. Because everybody benefits, there is scope for 'freeloading' and this in turn

undermines the willingness of other people to participate. For village bait spraying to succeed, strong leadership would be required.

During the course of fieldwork for this study, some people were found to have adopted by themselves the practice of bagging fruit, usually by using plastic bags on a citrus tree close to the house. While plastic bags are unsatisfactory for several reasons, this indicates people's willingness to use bagging if the need arises.

Bagging would not be readily applicable, however, to the staple fruits, breadfruit and bananas. In Fiji, Ratu Semisi at Waikava was able to successfully bag *uto balekana*, a popular 'dwarf' Fijian breadfruit variety, but the bagging of a normal-sized breadfruit on a large tree is probably impractical. An atoll community might, however, consider this in extreme circumstances. The bagging of bananas is even more difficult, although it is practised in Papua New Guinea.

Bagging is mostly applicable to non-staple fruit such as carambola, citrus, and mangoes that grow on reasonably small-sized trees. If the need arose, it could be used on fleshy vegetables such as eggplants, tomatoes, or capsicums, and possibly even cucurbits, going by the Taiwanese experience. In Malaysia, backyard growers bag kavika in order to produce high quality and chemical-free fruits.

One issue is finding a suitable bagging material. In Malaysia, the standard bag is sewn from a double layer of newspaper, which is both cheap and effective. This type of bag has been used to bag mangoes in Fiji and would be ideal for urban backyard production. But in most villages newspaper is not available, and shipping it in to make bags would defeat the goals of self-reliance and sustainability. A suitable local material needed to be found, and this was part of the fieldwork conducted at Waikava in Fiji, North Ambrym in Vanuatu, and Gizo in Solomon Islands.

For a material to be suitable for bagging or wrapping fruit it needs to be:

- Readily available at the time of bagging;
- Strong yet pliable, so it can wrap around the fruit without breaking or splitting and without any holes for the insects to enter.
- Large enough to cover the fruit—a requirement that varies with the size of a particular crop.
- Durable enough to last some six weeks and remain sound in the face of rain wind and sun and, sometimes, attack by fruit bats.
- Allow the fruit to breathe so there is no large build up of ethylene or fungal pathogens—the major problem in using plastic bags.

The most obvious candidates for bagging are leaves. A preliminary assessment was made of a wide range of these. Another material considered was the lower fibrous skirt of the betel nut palm.

Fiji has three daily newspapers, with daily circulations of around 35,000, 8,000 and 5,000, respectively. The combined average length of these dailies is around 50 pages,

and the Saturday paper some 80 pages. There are also several vernacular weeklies. There was, therefore, no shortage of newspapers available for bagging in Waikava, which is linked by road to the town of Savusavu. Newspaper bagging was certainly possible here, and gave an opportunity to compare newspaper bagging with local material bagging.

Vava (*Alpinia hemslayana)* leaf, a member of the heliconia family, was selected as one suitable local material. *Vava* are used for wrapping food for cooking in the lovo (earth oven), wrapping *vakalolo* (sweet Fijian pudding), and serving food. The leaf is made soft and pliable by placing it above a fire and then removing the midriff. A bag is made by crossing two mature *vava* leaves, then gathering them together and tying them around the stalk of the fruit. This makes a sufficiently large bag to cover a small breadfruit or large mango.

The bagging trial commenced on 20 December 1998, using mango and breadfruit trees around the house of Ratu Semisi. These included three improved variety mango trees (Mapulehu, White Pirie, and Haden) and two *uto balekana* breadfruit trees. Over 50 per cent damage by fruit fly was found in mature breadfruit. It was also reported that fruit-sucking moths were attacking breadfruit, although this could not be confirmed. Newspaper bags were supplied by the RMFFP and five newspaper bags and five *vava* bags were placed on each tree. All the fruit was harvested at the ripe mature stage and held for a week before dissecting and inspection. The results of the trial are summarised in Table 41.

Table 41. Results of the Waikava (Fiji) bagging trial to control fruit flies in mango and breadfruit.

	No of fruit bagged	No of bags sound at the end of trial	Fruit sucking moth damage	Fruit fly damage	No damage
Mango					
- paper bag	15	12	4	1	7
- *vava* bag	15	14	0	1	13
Breadfruit					
- paper bag	10	7	0	0	7
- *vava* bag	10	9	0	0	9

Bags that lasted the length of the trial were effective in controlling fruit flies. The *vava* bags proved to be more robust with 23 (92 per cent) surviving the length of the trial intact, compared with only 19 (76 per cent) of the paper bags. The difference might be explained by a lack of experience in handling paper bags. The main superiority of the *vava* bags was in the control of fruit sucking moth which was a

more serious pest than fruit flies at the time of the trial.[32] The moth could sometimes sting through a wet paper bag if it was close to the fruit but the *vava* leaf was a more difficult barrier to penetrate.

Ratu Semisi's conclusions from the bagging trial were:

- It was not worthwhile bagging breadfruit. There was sufficient breadfruit available anyway. Further, bagging was only practical for small *uto balekana* fruit and could not be done for some 90 per cent of the breadfruit available.
- It was worthwhile to use *vava* leaves on his improved variety mango trees for they produced superior quality fruit to be consumed in the Christmas-New Year holiday period. He saw bagging of mangoes as a way to control fruit sucking moth rather than fruit flies, and planned to bag many mangoes for the forthcoming season. (Unfortunately, after the heavy drought-induced 1998-99 crop and then heavy rain, there would be no mango production at Waikava for the 1999-2000 season.)

In Vanuatu, the main newspaper is published three times a week with a usual length of about 10 pages. Its circulation is no more than a few thousand and mostly restricted to the towns of Port Vila and Luganville. Most rural villages have almost no access to newspaper, and any available is in high demand for tobacco wrappers. Newspaper bagging is an option only for urban backyard gardeners.

At Ranon, Village North Ambrym, a small bagging trial was conducted. The FSA lead farmer, George Bumseng, identified a particular *laplap* leaf as a suitable material. Both *laplap* leaves and *vava* are heliconia leaves traditionally used to wrap food in earth ovens. The r type of *laplap* leaf used for the Ranon bagging trial was especially strong and pliable, and traditionally used to make *numbas* (penis sheath) for wearing to the gardens.

Fruits on five citrus and five guava trees were bagged at Ranon. The results were disappointing compared with those achieved at Waikava using a very similar type of leaf. Most of the *laplap* leaf bags split or broke before the trial was completed, allowing access to fruit flies and moths and defeating the purpose of bagging. A small cyclone that hit North Ambrym in early January probably contributed to the poor performance. Another factor could have been that the leaves were not softened over a fire, as was done at Waikava. More experiments are required in Vanuatu on appropriate bagging techniques using local materials. This should be a priority activity of the Vanuatu Fruit Fly Project.

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[32] At the Batiri orange orchard, on the same island, moth damage records have been keep between 1988 and 1995. The damage has varied from 1.9 per cent in 1992 to 37.2 per cent in 1990. (per. comm. Wilco Liebregts). A build up in moth populations is commonly associated with natural disasters (Liebregts et.al). At the time of the trial, the area was experiencing probably the worse drought of the century.

In Solomon Islands, newspapers are in somewhat better supply than in Vanuatu. Even so, most villagers in the outer islands do not have ready access to paper. Any village bagging programme outside Guadalcanal therefore would have to rely on locally available materials.

The concept of fruit bagging was introduced to the participants at the Gizo SIDT workshop. They were asked to identify locally available materials to construct bags, based on the criteria presented earlier. They were also given time to go into the bush and gather material they thought could be suitable. There was an impressive range of suggestions. Most were leaves similar to the Fijian *vava* and the Vanuatu *laplap* leaf. The major fruit problem in Western Province is melon fly damage to cucurbits. The challenge, therefore, was to find ways to wrap large fruit like watermelon. The innovative suggestions presented by the group included using the fibrous skirt of the betel nut palm. This traditionally was used as a receptacle in which babies were bathed. It was not possible to test any of these materials in this study but given the enthusiastic interest shown by the Gizo workshop participants, testing should be a priority for the Solomon Islands Fruit Fly Project, in collaboration with SIDT.

Fruit fly eradication: the Nauru Programme

Background

One technique for fruit fly eradication involves annihilating the male fruit fly of a particular species by using a high density of trapping or baiting stations consisting of a male lure with an insecticide. The objective is to reduce the male population to a level at which mating does not occur. This was successfully done to eradicate Asian papaya fruit fly from several Torres Strait Islands, in an effort to keep the species out of Cape York in Queensland (Allwood, 1996, p.174). It was also used to eradicate Asian papaya fruit fly from over 15,000 sq. km. of the Cairns area of Queensland between 1995 and 1998.

Allwood notes that this technique is applicable to the special case where male flies cannot migrate from untreated areas into the area being treated. A small isolated island fits this requirement. Nauru presented itself as an ideal candidate for male annihilation, as the necessary conditions of need and technical feasibility were in place. Nauru is a single uplifted coral atoll with a land area of 21.2 sq. km. Situated just south of the equator at 167^0E, its closest neighbours are Federated States of Micronesia and the Marshall Islands to the north, Kiribati to the east and Solomon Islands to the south.

Due to the high income from phosphate mining, people on Nauru experienced a rapid transition in lifestyle from one of subsistence to almost total dependence on imports and outside labour. During the 1980s, phosphate mining royalties gave the ten thousand people of Nauru one of the highest per capita incomes in the world: US$20,444 in 1989 (East-West Center, 1990, p.65). Since then, however, this income has fallen sharply to US$3,450 in 1998 (UNDP, 1999, p.13), because of the depletion of phosphate reserves and poor out-comes from many of Nauru's offshore investments.

Despite the high level of cash income, health and nutrition standards on the island are poor. A notable characteristic has been the consumption of refined imported food with exceptionally high caloric and fat intake. This has resulted in especially high levels of obesity, diabetes, and circulatory disease (Galea, 1997, p.14). Life expectancy at birth on Nauru is 58.2 years; in the Pacific region, this is only lower in Papua New Guinea.

The traditional local diet consisted entirely of fish, coconut, pandanus, and some breadfruit. Nauruans never had the range of food enjoyed by most Pacific islands, because of the limestone structure of their island and the lack of good soil—the abundant phosphate being unusable by plants until it has been converted into superphosphate. Yet ethnographic reports indicate that before phosphate exports began, the population was quite healthy despite the narrow diet (Pollock, 1985, p. 209).

Apart from some breadfruit, fruit was not a part of the traditional Nauruan diet. Papaya and bananas are relatively recent introductions, and are occasionally grown by households that can find sufficient soil or make compost. A large orchard of mangoes was planted around Buada Lagoon during the Second World War by the occupying Japanese forces, on the largest area of contiguous arable land on the island. Many of these trees and their descendant seedlings remain there today, numbering some 1,000 trees. The fruit has become the common property of the whole community. Mangoes also grow in the north at Anetan and in the northwest at Baiti.

Some fruit is imported by air from Australia, New Zealand, Fiji and Federated States of Micronesia but, with the economic downturn, the volume of imported fruit has reportedly fallen sharply. Other fruit comes in the luggage of much travelled Nauruans. In 1996, some 2,000 visas were issued for Nauruans to travel to Australia alone (Galea, 1997, p.14). As no quarantine restrictions were placed on the inflow of fruit from any location, it is not surprising that several exotic fruit flies of serious economic significance became established on Nauru over the last twenty years, at considerable cost to the health and nutrition of the residents. These fruit fly species include Melon fly, mango fly, Oriental fruit fly, and Pacific fruit fly *B. xanthodes.* The host fruit for these flies included Pacific Almond (*Terminalia catappa), Calophyllum inophyllum, Guettarda speciosa,* mango, breadfruit, and bitter gourd.

The presence of melon fly and Oriental fruit fly in Nauru posed a major quarantine threat to the region. Furthermore, the losses caused by fruit flies also had serious nutritional implications for Nauru's 10,000 residents. The little fruit that had been available all but disappeared. Furthermore, in recent years, lower income and less travel meant that imported fruit had become an increasingly scarce luxury.

The eradication programme

The main aims of the Nauru Fruit Fly Eradication Programme (FFERAD) were to:

- Reduce the risk of the incursion of melon fly and Oriental fruit fly into other Pacific island countries by eradicating these species from Nauru.

- Provide staff from the Pacific island countries with practical training in fruit fly eradication, and so equip regional departments of agriculture personnel with the capability to mount rapid reaction programmes in response to the incursion of an exotic fruit fly. For most countries, eradication is only an option in the short period before a newly arrived fruit fly becomes dispersed and established.
- Improve Nauru's food security.

The eradication programme began in October 1998. Teams of four to six people from the RMFFP, national fruit fly programmes in other Pacific island countries, staff of the Departments of Works, Youth and Health of the Nauru Government and National Phosphate Corporation, and Buada Area Council members distributed fibreboard blocks (50mm x 50 mm x 12.7 mm) soaked with male fruit fly attractant—methyl eugenol—plus the insecticide Fipronil. The 'blocking' programme covered the whole of the island. The blocks were distributed every eight weeks at a density of 400-800 blocks per sq. km in the five coastal sectors and the Buada Lagoon area. Because of restricted access, the blocking density in 'Topside' —the mined area of the island—was much less, at between 90 to 100 blocks per sq. km. By mid-September 1999 six blockings had been completed. Further blockings are planned to target mango fly.

By the beginning of September 1999, Oriental fruit fly had not been recorded in traps for about 36 weeks, which is the equivalent of 9 generations. Melon fly had not been recorded in traps for 32 weeks. *B. xanthodes,* surprisingly, still occurs but in very small numbers and irregularly. Mango fly, which is a cue-lure attractant fly, is still present but is much reduced; the number found in traps has decreased from 1,500 flies per trap per week to less than ten. Protein bait sprays that use a new insecticide formulation are being used each week in all areas around the coastline and in the Buada area. Nauru could be declared free of Oriental fruit fly and melon fly by the end of 1999.

Evaluating the benefits and cost of the Nauru eradication programme

This programme has demonstrated the efficacy of the male annihilation on a small isolated island. It has shown that an exotic fruit fly can be stopped from spreading if an emergency response programme is mounted quickly enough. For the first time in a decade, Nauruans can now enjoy some fruit grown on their island. Yet the benefits of the Nauru eradication programme will be only transitory if Nauru does not initiate quarantine controls to prevent any re-incursion of fruit flies. In order to address the deficiency in quarantine regulations, the Government drafted a new Agricultural Quarantine Bill in August 1998. This was passed by Parliament in October 1999. Four quarantine workers will be sent for quarantine training in Federated States of Micronesia in early 2000.

A principal reason for the eradication programme was to remove the risk of melon fly and Oriental fruit fly entering other Pacific island countries via Nauru, a risk that was possibly heightened by the high frequency with which Nauruan people travel around the region. Given its poor quality and limited availability, however, there was little

incentive to smuggle fruit out of Nauru, and the risk of fruit flies spreading from Nauru was probably quite low. Ironically, this risk may have increased with the eradication programme for now, for the first time in years, a substantial amount of mangoes are available to be smuggled out of Nauru. An I-Kiribati worker has already been found illegally sending mangoes to relatives on Tarawa. If Oriental fruit fly was to re-enter Nauru, this could pose a high risk for nearby countries, particularly before infestation rates on Nauru again made mango inedible. Quarantine surveillance in Nauru is therefore now more important than ever and neighbouring countries need still to be continually vigilant about flights from Nauru, with respect to mango fly.

Another reason for the programme was to improve the emergency response capability of other Pacific island countries Thirty-nine quarantine and research staff from 19 Pacific island countries received practical training in the management and implementation of a fruit fly eradication programme. In most of these countries, the eradication of an established fruit fly population is not a viable option. The Nauru experience has shown that male annihilation can be a powerful tool for an immediate emergency response to the incursion of a new species. This success would depend on quick detection of the incursion and the rapid mobilisation of the eradication programme. At least one officer from each country now has experience in the latter. The potential benefits from this training are huge if this knowledge can be successfully applied in an emergency.

If a fruit fly such as Asian papaya fruit fly became established in, say, Vanuatu, this would be a biological disaster of even greater proportion than its incursion into Australia. In 1996, Drew estimated that the establishment of Asian papaya fruit fly in Australia had already cost industry some A$100 million and government A$20 million. Over five years, the total cost to government was likely to exceed A$55 million, (Drew, 1996, p.20), let alone additional and substantial environmental costs. Given the small size of most Pacific island economies, the relative cost of an incursion would likely be much more. This is because Asian papaya fruit fly would also threaten basic food security by damaging the food staples, bananas and breadfruit. Drew compared the Australian Asian papaya fruit fly experience with the incursion of Mediterranean fruit fly into New Zealand. There, early warning systems, based on male lure trapping, have been tried and tested and, if well planned and carefully executed, will provide a high level of security' (Drew, 1996, p.207). The practical experience received through the Nauru eradication programme has given Pacific island countries an opportunity to emulate the same degree of quarantine security against fruit flies as New Zealand.

Placing a monetary value on the benefits of such an improved emergency response capability presents a daunting task. Such benefits are only realised if there is a threatened incursion and the emergency response programme successfully repels it. The magnitude of the benefits will then depend on the value of the production losses that would have occurred had the exotic fruit fly become established.

Based on recent experience, any Pacific island country faces a reasonably high risk of an incursion of a damaging exotic fruit fly over the next decade or so. During the last twenty years, the region has seen the incursion of Asian papaya fruit fly into Papua

New Guinea and Queensland, melon fly into Solomon Islands and Nauru, Oriental fruit fly into French Polynesia, Nauru, and Palau, Mediterranean fruit fly into New Zealand), Queensland fruit fly into New Caledonia and Pacific fruit fly into the Austral Islands and French Polynesia.

Fiji provides a good indication of what the benefits of improved emergency response capability might be. Table 35 showed that Fiji's fruit production has an estimated annual value of F$65 million. If we assume that in any one year there is one per cent chance of the incursion of a particularly damaging fruit fly, and that if these fruit flies become established a 30 per cent loss in fruit production could reasonably be expected, then, based on these parameters, a successful emergency response would generate an annual benefit of F$195,000.

For the other smaller Pacific island countries that participated in the Nauru eradication programme, the benefits would be proportionally less. If we assume the benefits are 30 per cent less for Tonga, Samoa, Vanuatu, and Solomon Islands, and 10 per cent less for Cook Islands, American Samoa, Kiribati, Tuvalu, Niue, and Tokelau, then the total estimated benefit is around F$ 550,000, or approximately A$440,000.

The immediate direct benefits of the Nauru eradication programme can be found locally in the form of improved nutrition and food security. People on Nauru now can eat local mangoes where previously they could not. With an estimated 1,000 bearing mango trees around Buada Lagoon and 300 to 400 trees elsewhere on the island, somewhere between 13 and 20 tonnes of local fruit are now consumed annually (assuming 10 to 15 kg of usable fruit per tree per year). This is a conservative estimate, even though many of the trees are old and have grown from self-planted seedlings. In Nauru, fruiting occurs through much of the year. Unlike in most other Pacific island countries, very little edible fruit is wasted. Children particularly forage for mangoes. Women camp out over-night at Buada to collect the mangoes as soon as they fall, and take the mangoes home for their households to eat or sell them on the road side or at government offices.

The renewed availability of locally grown mangoes could not have come at a better time, given the sharp decline in the cash available to the island's population. While several kg of mangoes being consumed per capita may not appear great, it is so in the context of generally very poor nutrition on Nauru. It is difficult to give a meaningful dollar value to this consumption. Imported mangoes, when available, reportedly sold for around A$5 per kg, and local mangoes sell for around A$1 per kg. On this basis, the annual cash value of Nauru's mango crop would be between A$20,000 to A$30,000.

As well as mangoes, edible breadfruit, a traditional staple, is now available from trees scattered among houses along Nauru's coastal fringe. There are at least three hundred mature breadfruit trees on Nauru. Yields of between 200 to 300 kg per tree could be expected given the quite poor growing conditions there. Some 30 to 50 tonnes of breadfruit per year might therefore now be available for consumption. This is a relatively insignificant figure compared to Nauru's large rice imports, but greater consumption of breadfruit contributes to improved food security and greater self-

sufficiency. Now there is the prospect of harvesting most of the fruit, there is an incentive to plant more breadfruit trees and other fruit trees such as papaya. A long-running agricultural project funded by Taiwan has developed ways to successfully grow papaya under Nauru conditions.

Comparing benefits with costs

The cost of the Nauru fruit fly eradication programme to date has been A$280,000. At an on-going annual cost of A$10,000 for the next five years, a total cost of A$330,000 is estimated. The initial estimated benefit from this expenditure is A$470,000 per year. This is made up of the following components:

- Enhanced emergency response capability from the Pacific island countries: A$440,000;
- Improved nutrition and food security on Nauru: A$30,000. This can be expected to increase over time with new plantings of mangoes, breadfruit, and papaya

Based on these figures, the Nauru fruit fly eradication project gives a high economic rate of return. The estimated internal rate of return from this investment is around 200 per cent, as shown in Table x below. If the probability of the incursion of a damaging fruit fly in any particular year is reduced to 0.5 per cent, the internal rate of return still remains above 100 per cent.

Table x Estimated flow of benefits from the Nauru Eradication Project

Year	1	2	3	4	5	6	7	8	9	10
Benefits (A$,000)		460	470	480	490	490	500	500	500	500
Cost ((A$,000)	200	80	10	10	10	10	10			
B-C	- 200	380	460	460	480	480	490	500	500	500

Source: Author's calculations

The importance of surveillance and emergency response programmes for domestic fruit production.

It is evident that fruit flies at present do not have a significant impact on fruit consumption and nutrition at the household self-sufficiency level in Pacific island countries. There are, however, important exceptions where there has been an incursion of a particularly damaging exotic fruit fly. These fruit flies can have considerable food and nutrition consequences, particularly where bananas and breadfruit are major food staples.

Asian papaya fruit fly is known to infest coffee cherry. If this fruit fly becomes established in the coffee growing areas of the Highlands, the economic consequences could be catastrophic. Coffee is not only Papua New Guinea's largest agricultural

export commodity, but also the country's most important industry. The populated Highland regions of Papua New Guinea provide ideal climatic and soil conditions for growing arabica coffee. Over the last 30 years, coffee has become fully integrated into the Highlands village economy where most of Papua New Guinea's population lives. Coffee export earnings are now around 10 per cent of mineral earnings, but the economic linkages are much higher. Smallholder farmers, who produce most of the crop, use very few purchased inputs and spend most of their income in the local economy, thus the coffee income multiplier is very high. In total, around 1.3 million people are involved in coffee production, which is 35 per cent of Papua New Guinea's population (Overfield ,1994). This represents more people than the combined populations of all other Pacific island countries.

At a conservative estimate, fruit production in Fiji is valued around F$ 65 million (approx. US$33 million). If Asian papaya fruit fly became established, a high percentage of this production would be lost, as well as further losses in export earnings (both actual and potential future). The size of these potential losses justifies a high priority being given to surveillance and emergency response programmes. Experience gained from the Nauru Fruit Fly Eradication Project has equipped staff from Departments of Agriculture around the region with the skills to mount rapid response programmes against fruit fly incursions.

The minimum requirements for national quarantine surveillance and emergency response capability

The minimum requirements for national quarantine surveillance is to establish a trapping system consisting of traps baited with methyl eugenol, cue-lure and trimedlure. Trapping should focus on high-risk areas, namely. areas into which uncertified fruits and vegetables may be brought in by tourists and travellers. The high-risk sites should include a selection of tourist resorts, refuse tips associated with tourist resorts, diplomatic missions, educational institutions that have international students, urban and peri-urban areas, farming areas and locations near airports and wharves. Traps should be cleared every two weeks and lures recharged every 12 weeks. All flies should be identified. An audit sheet showing the species found in the trap must be completed and filed for inspection by the overseas regulatory authorities, when necessary. The total cost of such a quarantine surveillance system in Fiji would be in the order of F$10,000 a year.

As well as having a quarantine surveillance or early warning system in place, Pacific island countries need to develop an early response capacity to react to incursions. At least fourteen Pacific island countries have draft emergency response plans. The Secretariat of the Pacific Community, through the RMFFP, may assist with the supply of chemicals (lures, insecticide, protein bait) and equipment (traps, plastic containers) to initiate a quick response.

Chapter 4: Consolidating and sustaining RMFFP activities

This study has shown a high economic rate of return from the RMFFP in terms of expanding export earnings and protecting domestic food production. In order to fully capture and sustain these benefits, there is strong justification for the RMFFP to continue working in collaboration with national fruit fly programmes. Continuation of the RMFFP beyond its current phase, however, needs to focus on consolidation, back-stopping national programmes and focusing on activities that are likely to provide the highest rates of return. This report has identified several beneficial activities that meet these criteria. These activities can be broadly divided into those that expand the level and distribution of export earnings and those that expand and protect domestic food production. They include:

- Giving more emphasis to developing non-host protocols for export produce;
- Facilitating the acceptance of the New Zealand non-host technology more widely amongst importing countries;
- Assisting Pacific island countries to be more proactive in dealing with the quarantine authorities of importing countries;
- Promoting the use of bait spray technology amongst commercial farmers;
- Promoting fruit bagging techniques among rural and urban households;
- Establishing a regional service to audit national fruit fly surveillance programmes and to provide technical assistance to maintain and improve these programmes.
- Helping establish, maintain, and implement emergency response programmes.
- Establishing a regional rapid response capability, under the auspices of SPC, to assist individual countries to deal with fruit fly incursions. This capability would cover both expertise and equipment.

It has been shown that the incursion and establishment of exotic fruit fly populations can incur an enormous cost to Pacific island economies and societies. Developing quarantine surveillance and emergency response programmes therefore generate the greatest benefits. Of all future RMFFP activities, supporting national quarantine surveillance and emergency response programmes should be given the highest priority.

Mechanisms to ensure sustainability

The sustainability of the activities generated by the RMFFP depends on the self-reliance and commitment of national fruit fly programmes. To achieve this, national governments need to provide adequate numbers of trained personnel and sufficient financial resources. In allocating resources, first priority should be given to quarantine surveillance and emergency response programmes. There is also a continuing regional responsibility in

these areas because the consequences of fruit fly incursions extend beyond national boundaries.

The case for continuing regional funding

Nauru provides a striking example of the externalities of fruit fly activities in a particular country. The absence of border quarantine restrictions saw the establishment of Oriental fruit fly and melon fly, which put at risk the fruit production of neighbouring countries which had transportation links to Nauru. The major benefits of the Nauru fruit fly eradication programme can therefore be identified outside Nauru. Similarly, the emergent squash industry in Vanuatu has a vested interest in Solomon Islands maintaining adequate fruit fly control in its southern Temotu Province. Food security in Cook Islands is threatened by the recent establishment of Oriental fruit fly in Tahiti and Moorea in French Polynesia, islands that are closely inter-linked by cultural and family ties. There is a long-term regional responsibility to support surveillance and emergency response programmes, because the benefits and costs extend beyond national boundaries. The Secretariat of the Pacific Community is well placed to continue this role as part of its core responsibilities.

A recent report by the United Nations Department of Humanitarian Affairs on disasters and agriculture in South Pacific concluded that biological disasters, such as the incursion of exotic fruit flies, can be even more damaging than physical disasters such as cyclones (UNDHA, 1997). A major recommendation of the UNDHA study was to establish a regional quarantine disaster response capability under the auspices of the Secretariat of the Pacific Community. To quote:

> The Regional Fruit Fly Project has provided assistance in this area as part of its second and third phase, which ends in 2000. However, a more concerted effort is required in this area, particularly for biological disasters other than just fruit flies. Thus it is recommended that a specific project be established under the auspices of the Pacific Community directed at the development of quarantine emergency response plans for all member countries. These plans would cover both crops and livestock. A regional umbrella response plan to be co-ordinated by the Pacific Community would also be prepared. It is recommended that this be a two-year project that is designed and implemented in close collaboration with the Regional Fruit Fly Project, with an experienced quarantine expert appointed as Project Co-ordinator. The indicative estimated cost of this two year project is $US500, 000 to $US700, 000. This includes a provision for the stock piling of materials to allow for a rapid response to a pest or disease outbreak in the region. There would also need to be an ongoing commitment of emergency funding (UNDHA, 1999, p.95).

This study strongly endorses this recommendation of the UNDHA study on disasters and agriculture in the Pacific Islands.

Tapping funds from industry

To date, national funding and resources for country fruit fly programmes have come from governments. In most countries, government funding needs to be increased if these programmes are to be sustainable. This sustainability also requires greater industry and

community participation. While the value of the RMFFP is recognised and appreciated in the Pacific island countries, there is no guarantee that sufficient public funding will be available to maintain its core activities in the future. Most governments in the region face budgetary constraints. The 1996 Report concluded that:

> The best way to ensure the activities of the RMFFP are maintained is to establish mechanisms that facilitate industry funding. Commercial exporters and farmers have the most to gain directly from these activities. It is only reasonable that they contribute to funding and set research priorities (McGregor 1996, p.50).

The 1996 Report recommended mechanisms for industry funding on a national basis. For countries with commercial HTFA quarantine treatment facilities, namely Fiji and Cook Islands, there is an opportunity to impose a levy on treatment to fund fruit fly research and quarantine surveillance. It was estimated that in Fiji, a levy of 1c per kg would meet about 30 per cent of the cost of quarantine surveillance and quarantine treatment research within five years' (McGregor, 1996, p.51). The lower than expected volume of produce through the HTFA makes this projection somewhat over-optimistic, but the principle of using the HTFA facility to at least partly fund these activities remains valid. From the viewpoint of sustainability, it is therefore disappointing that no action has been taken on this recommendation. It was hoped that the industry-owned business that operates the facility would have sufficient foresight to impose this levy voluntarily. This recommendation needs to be formally put to the Board of Nature's Way Co-operative. Alternatively, the levy could be imposed through legislation.

A similar arrangement was proposed for the Cook Islands' HTFA facility. There a degree of industry funding was particularly urgent, for the government's structural adjustment programme had cut Ministry of Agriculture staffing to the barest minimum. As in Fiji, however, no action was taken on this recommendation.

In Tonga, it will be some years before the HTFA facility treats a sufficient volume for any levy to significantly contribute to funding quarantine surveillance and quarantine research. Such a levy should nevertheless be institutionalised from the outset. The squash industry can expect to gain the greatest quantifiable benefit from RMFFP in the foreseeable future. The 1996 Report recommended that the squash industry be the largest contributor to funding the Tonga fruit fly programme, at least for quarantine surveillance. It estimated that a levy of only $T1per tonne would be more than sufficient to meet the minimum cost of quarantine surveillance (McGregor**,** 1996, p.51). The Tonga government was already able to set export quotas and impose quality standards on squash and the same legislation could be used to impose a quarantine surveillance levy to protect the future of the industry. No action was taken on this recommendation either.

At the time of the 1996 Study, Vanuatu had a significant squash industry. The single exporter was the obvious beneficiary of the activities of the Vanuatu Fruit Fly Project. The company had expressed a willingness to pay a reasonable levy to support these activities, and legislation had been drafted to support the imposition of such a levy. Unfortunately, however, Vanuatu no longer has an export squash industry. Vanuatu may establish a small commercial HTFA facility but even if this materialises, it will never be sufficiently large to make more than a notional contribution to the fruit fly programme.

Public funding for most of the fruit fly programme will therefore be required in the foreseeable future, yet this is more that justified in the interest of national food security.

At the time of the 1996 study, Samoa had no horticultural exports and therefore, no prospect of raising industry funds for the fruit fly programme. This situation has changed somewhat with the modest reestablishment of banana exports to New Zealand. This now offers the prospect of some industry funding. This, in turn, would give focus and priority to Samoa's host status research, which offers the best prospect of expanding Samoa's fruit exports. As in Vanuatu, however, the main benefit from the fruit fly programme lies in the protection and improvement of national food security, and most funding for the programme should come from Government.

Solomon Islands has few if any prospects of exporting fresh fruit and vegetables. Domestic fruit producers and consumers nevertheless stand to benefit from a continued fruit fly programme. It is almost impossible to attribute any costs directly to these beneficiaries and the Government will therefore remain responsible for funding these activities—although this funding is somewhat precarious given the budgetary situation. Maintenance of quarantine security in Solomon Islands is of great concern for the security of the whole region for Solomon Islands is the 'bridge' from Papua New Guinea to the rest of the Pacific. It might be appropriate to allocate some regional funds, at least temporarily, to maintain quarantine surveillance there.

The involvement of civil society

The staffs of Departments of Agriculture, under the supervision of the RMFFP have implemented almost all fruit fly project activities. Much effort and resources have been devoted to training these staff, and a strong cadre of competent personnel is now in place. In the interest of sustainability, however, some of these activities, particularly in quarantine surveillance, need now to be devolved to civil society.

Most Pacific island countries are widely scattered groups of islands, and often thinly populated outside of the urban centres. Effective quarantine security requires that these isolated areas are included in fruit fly trapping programmes. Previously, agricultural extension services in most countries were well distributed throughout the country, and their officers were well placed to take on fruit fly trapping as one of their responsibilities. Budgetary constraints and in some cases structural reform programmes, have seen a sharp cut back of extension staff in the outer regions. NGOs often can provide these services in a more cost-effective way. Quarantine surveillance for fruit flies will increasingly require community participation, not just providing people to do the surveillance, but in protecting their own food security.

Two NGOs were involved in this study to assess fruit damage and evaluate fruit mitigation methods at the village level. These were the Solomon Islands Development Trust (SIDT) in Solomon Islands and the Farm Support Association (FSA) in Vanuatu. One reason for involving them in the study was to evaluate the capabilities of NGOs to implement RMFFP activities. Solomon Islands and Vanuatu are similar countries in that both are widely dispersed archipelagos and the size of their civil

services has been much reduced. In both countries, there is a relatively strong NGO movement working in rural development.

SIDT is one of the largest national NGOs in the region, with some 250 villages participating in the organisation, spread throughout the 13 provinces of the country. SIDT focuses its activities on 'strengthening the quality of village living,' and there are six separate departments involved in implementing its programme. These are the village resource centre, women's study programme, conservation in development programme, printed media department (LINK), theatre group, and network of overseas volunteers. Particular emphasis is given to sustainable forestry development for the benefit of village resource owners. Reducing the impact of fruit flies on village food production is now part of the SIDT *supsup garden* (village food garden) programme, funded by various international and NGO donor organisations. Village demonstration workers (VDW) from participating villages mainly implement these activities. The VDWs live in the village and have considerable training and experience in conducting village surveys, an activity for which they receive a small stipend. The capability and self reliance of the VDW's to undertake surveys was shown in the fruit fly damage assessments they conducted in Western Province for this study. Their network would seem to be ideally suited for the quarantine surveillance of fruit flies, and would be cost effective for VDWs are in-situ and receive only a small stipend. The ownership and value of the surveillance work is also more likely to be recognised by the community, for the VDWs are village leaders in their own right.

The Director and Deputy-Director of SIDT expressed keen interest in the Trust being involved in fruit fly surveillance work. The Permanent Secretary for Agriculture was also supportive of this concept. As part of their terms of reference for this study, SIDT was therefore asked to prepare a project proposal for fruit fly surveillance. Unfortunately this proposal has yet to be submitted, and the RMFFP and SPC should further peruse this matter.

The Vanuatu Farm Support Association (FSA) is a small NGO that works with commercially orientated small farmers in Vanuatu. Its activities include extension work on spices and providing organic certification of farms for its members. The Association raises funds to support its activities by conducting participatory farmer research and surveys, and provides services to members and clients in a cost-effective way. For example, the annual budget of FSA's spice extension service is little over US$ 5,000 (ESCAP/POC, 1998, p.22), whereas a similar service operated by the Department of Agriculture would cost many times more yet may not be as effective.

FSA has a good working relationship with the Department of Agriculture in general and Vanuatu Fruit Fly Project staff in particular, which augurs well for future collaboration. Unlike SIDT, however, FSA does not have a wide geographic coverage nor broad-based community programmes, and is less well placed to operate a comprehensive quarantine surveillance programme. It could assist, nevertheless, by supporting a national surveillance programme in locations where it has presence.

FSA's real strength is in conducting participatory research and extension, as was demonstrated in the Vanuatu bait spray trials. In isolated North Ambrym, FSA members successfully collected and stored sample fruit, incubated larvae, dissected fruit, count larvae, and maintained very good records. FSA successfully introduced bait spraying to the commercial guava plantation on Efate, and could play an important part in disseminating bait spray technology amongst commercial farmers throughout Vanuatu.

Other than SIDT and FSA, the two NGOs involved in this study, similar organisations could contribute to fruit fly management in other Pacific island countries. In Fiji, greater use could made of the Natures Way Cooperative in implementing the fruit fly programme; at very least, this HTFA business should be making a financial contribution. In Cook Islands, the NETA Papaya Growers Association could be involved. In Tonga, the Friendly Islands Marketing Cooperative (FIMCO) is a commercial farmers' organisation that could assist, as could the Farmers Association in Samoa. The RMFFP needs to evaluate these organisations to see how they could be contributing to the sustainability of project activities.

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