Pacific Horticultural and Agricultural Market Access Program (PHAMA)

Report to the Fiji Market Access Working Group

Options for the Management of the Fruit Fly, *Bactrocera kirki*, on Rotuma Island

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Prepared for

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Abbreviations

Abbreviation	Description
ACIAR	Australian Centre for International Agricultural Research
ALTA	Agricultural Landlord and Tenants Act
AUD	Australian dollar
BAF	Biosecurity Authority of Fiji
CEO	Chief Executive Officer
CI	Confidence interval
CPHST	Center for Plant Health Science and Technology
FFERAD	Nauru Fruit Fly Eradication Programme
FJD	Fiji dollar
HTFA	High temperature forced air
ISPM	International Standards For Phytosanitary Measures
IUCN	International Union for Conservation of Nature
LT99	Lethal time for 99% kill
MAFFA	Ministry of Agriculture, Fisheries and Forests and ALTA (Fiji)
MAFFM	Ministry of Agriculture, Forests, Fisheries and Meteorology (Samoa)
MAWG	Market Access Working Group
PFA	Pest Free Area
PHAMA	Pacific Horticultural and Agricultural Market Access Program
PICTs	Pacific Island countries and territories
PPQ	Plant Protection and Quarantine
PRA	Pest risk assessment
RMFFP	Project on Regional Management of Fruit Flies in the Pacific
URS	URS Australia Pty Ltd
USD	United States dollar
USDA-APHIS	United States Department of Agriculture – Animal and Plant Health Inspection Service

Executive Summary

The present fruit fly study undertaken during August–November 2011 comprised:

- An analysis of trapping and fruit sampling data to confirm the distribution of *Bactrocera kirki* within Fiji territories;
- A review of heat tolerance research undertaken in the Pacific to determine whether the current heat treatment used by Fiji for *B. passiflorae* and *B. xanthodes* will also kill *B. kirki*; and
- A scoping study to determine if *B. kirki* could be eradicated from Rotuma.

Distribution of *Bactrocera kirki* in Fiji

Discussions held with staff from the Plant Protection Section of the Research Division, Ministry of Agriculture and Primary Industries in Fiji, as well as reference to various Plant Protection Section records and six reports have confirmed the distribution of *B. kirki* in Fiji. The distribution of *B. kirki* in the Fiji Islands is restricted to Rotuma, and recent rumours that *B. kirki* had been discovered on Vatoa, one of the more remote islands located at the end of the southern Lau Group (to the east of Viti Levu), can be discounted. However, *B. obscura*, a non-economic species, has been discovered on Vatoa. This recent discovery constitutes an expansion of the distribution of *B. obscura* in the Fiji Islands compared to that recorded on the Pacific Fruit Fly Web (http://www.spc.int/pacifly) at this time.

Heat tolerance of *Bactrocera kirki*

Both published and unpublished works relevant to the assessment of heat tolerance in *B. kirki* have been accessed and reviewed. These include: Alderson *et al.* (1999), Foliaki and Armstrong (1997), Fonoti and Tunupopo (1997), Frampton and Evans (1996), Saili and Laiti (2004), Tora Vueti *et al.* (1997b), Appendices 4 and 5 from Tora Vueti and Leweniqila (2001), and Waddell *et al.* (1997). Some of these reports/publications duplicate findings. The key studies allowing the comparison of the heat tolerance of immature *B. kirki* with *B. passiflorae* and *B. xanthodes* were described in Frampton and Evans (1996) and Fonoti and Tunupopo (1997), and some specific results accessed from Alderson *et al.* (1999).

In summary, as clearly shown in Fonoti and Tunupopo (1997), Frampton and Evans (1996) and Waddell *et al.* (1997), the lethal time for 99% kill (LT99) is temperature dependent, as is the most heat tolerant life stage for the various *Bactrocera* species studied. From the published and unpublished works reviewed to compare the heat tolerance of immature *B. kirki* with *B. passiflorae* and *B. xanthodes* in Fiji, it appears that at 47°C the most heat tolerant life stage of Samoan *B. kirki* is less tolerant than the most tolerant life stage of the most tolerant species (*B. passiflorae*) in Fiji. Furthermore, Samoan *B. kirki* is significantly less tolerant than Cook Islands *B. melanotus* (Fonoti and Tunupopo 1997). Additionally, as reported in Tora Vueti *et al.* (1997b), a comparison carried out on the heat tolerances of the late egg stage of *B. melanotus*, the most heat tolerant species and stage in the Cook Islands, with the early eggs of *B. passiflorae* showed that *B. melanotus* late eggs are more tolerant than *B. passiflorae* in Fiji.

In conclusion, evidence from all the available studies leaves little doubt that the High Temperature Forced-Air (HTFA) treatment of 47.2°C fruit centre temperature for 20 minutes – the treatment used for *B. melanotus* and *B. xanthodes* for the export of papaya from the Cook Islands, and that used for *B. passiflorae* and *B. xanthodes* for the export of a range of fruit fly host products from Viti Levu, Fiji – will also kill *B. kirki.* The treatment parameters are set higher than necessary, with the treatment time being about twice the LT99 value.

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Feasibility of eradication of *Bactrocera kirki* from Rotuma

There is little doubt that fruit fly management techniques available today have enabled the suppression or eradication of populations of introduced pest fruit flies from whole countries or parts of countries. Nevertheless, wide-area suppression and eradication attempts are not simple operations – any program requires good leadership together with technical and management skills. The present scoping study to determine if *B. kirki* could be eradicated from Rotuma has drawn on experiences from two fruit fly eradication 'programs' in the Pacific: the successful Nauru Fruit Fly Eradication Programme (FFERAD) implemented between October 1999 and December 2000, and a similar one proposed for the Republic of Palau. Matters such as the high level of management capability required for planning and implementing an eradication program, and the approval of the insecticide Fipronil for use in a program using male annihilation and protein bait application have not, however, been taken into account. These matters were conditional to the finding that the proposed program for Palau was technically feasible based on their significance to the success of FFERAD. Even without taking these matters into account for Rotuma, this study concludes that, at this time, without more effective attractants for cuelure-responsive species, the technical feasibility of an eradication program for *B. kirki* on Rotuma is questionable given the island's area, terrain, vegetation and lack of infrastructure. Furthermore, the value of the benefits is unlikely to exceed the costs.

Regardless of whether an attempt to eradicate *B. kirki* from Rotuma is undertaken, the importance of Fiji's quarantine surveillance for exotic fruit flies (including the trapping/monitoring on Rotuma) must be emphasised, especially to support the Biosecurity Authority of Fiji's request of the United States Department of Agriculture Animal and Plant Health Inspection Service (USDA-APHIS) to accept the Fiji Islands **except** Rotuma as a pest-free area (PFA) for *B. kirki*. If accepted by USDA-APHIS, the PFA will require ongoing maintenance involving appropriate fruit fly trapping and monitoring. It will also require enforcement of fruit fly host movement regulations/restrictions. It is, therefore, recommended that:

- An independent audit of all aspects of Fiji's quarantine surveillance system for fruit flies be undertaken as soon as possible, and any shortcomings be corrected in a timely manner; and
- Fiji's fruit fly host movement regulations/restrictions as they pertain to Rotuma be reviewed, and the appropriate enforcement be undertaken at all times.

1 Introduction

1.1 Background

1.1.1 Fruit Fly Fauna in Fiji

As originally noted in Tora Vueti *et al.* (1997a) and recorded on the Pacific Fruit Fly Web site (http://www.spc.int/pacifly), there are seven species of tephritid fruit flies known from the Fiji Islands (including Rotuma). These include: *Bactrocera xanthodes* and *B. distincta*, which are present in all Fiji Islands, including Rotuma; *Bactrocera passiflorae*, which is widespread in almost all the Fiji Islands, the exception being Rotuma; *B.* species near *passiflorae*, a light coloured form which is also present in the Fiji Islands but not Rotuma; *B. kirki* and *B. obscura*, which occur only on Rotuma; and, lastly, the non-economic *B. gnetum*, which has been reared from *Gnetum gnemon* in the Fiji island of Vanua Levu. Notably, only three species are considered to be economic species, namely *B. xanthodes*, *B. passiflorae* and *B. kirki*.

1.1.2 Exports of Fruit Fly Host Species from Fiji

Recently there have been reports suggesting that *B. kirki* has been discovered on the outer Fiji island of Vatoa in the southern Lau Group. Such reports, together with its presence on Rotuma, have raised concerns over the security of market access arrangements for exports of fruit fly hosts from the main island of Viti Levu.

Fiji currently exports a range of fruit fly host products from Viti Levu using a high temperature forced air (HTFA) post-harvest treatment for the two fruit fly species of economic concern (*B. passiflorae* and *B. xanthodes*) already present there. The HTFA treatment specification of 47.2°C fruit centre temperature for 20 minutes is the same as that approved for *B. melanotus* and *B. xanthodes* for the export of papaya from the Cook Islands to New Zealand in late 1993, and first applied commercially on 3 January 1994 (Waddell *et al.* 1997). Should *B. kirki* be introduced to Viti Levu, current exports would almost certainly be stopped until it could be demonstrated that the HTFA treatment was also effective against *B. kirki*. Heat tolerance data has previously been developed for *B. kirki* in Samoa. Presently it is not clear whether this data would be acceptable to Australia and New Zealand, and potential trading partners such as United States, or whether additional research would be required of Fiji to establish an acceptable phytosanitary treatment against *B. kirki*.

Similarly, equivalent phytosanitary measures have not been considered; establishing Fiji as a *B. kirki* free area is an option to be investigated. This option may involve eradicating the species from Fijian territories.

1.2 Required Fruit Fly Investigations

Due to the concerns over the security of existing market access for fruit fly hosts from the main island of Viti Levu, as well as providing information to the United States Department of Agriculture Animal and Plant Health Inspection Service (USDA-APHIS) as part of Fiji's papaya and breadfruit market access applications, the Fiji Market Access Working Group (MAWG) requires the following:

- Review the current status of *B. kirki* within Fiji territories based on analysis of trapping and fruit sampling data;

- Review the heat tolerance trials and data developed for *B. kirki* as part of the regional fruit fly project;
- If the data is considered suitable, develop a submission indicating that the current heat treatment used by Fiji for *B. passiflorae* and *B. xanthodes* will also kill *B. kirki*; and
- Conduct a scoping study to determine if *B. kirki* could be eradicated from Rotuma.

1.3 Current Activities

This report documents the findings from the activities listed in Section 1.2 (above). In addition, it outlines progress to date on negotiations by Biosecurity Authority of Fiji (BAF) with USDA-APHIS on Fiji's papaya and breadfruit market access applications.

The activities listed in Section 1.2 (above) have, in the main, involved reviewing fruit fly work (research findings and eradication programs/proposals) undertaken over a decade ago. Discussions with personnel undertaking this work and no longer involved, specifically Allan Allwood, Dr Jack Armstrong, Dr Chris Frampton, Dr Barney Stephenson and Barbara Waddell, have contributed to the findings documented in this report, and the resulting recommendations.

2 Current Status of *Bactrocera kirki* in Fiji

2.1 Fruit Fly Trapping and Host Surveys

Discussions held between 8 and 12 August 2011 with Ms Laisa Ralulu and Mr Anare Caucau (Fruit Fly Unit, Plant Protection Section, Research Division, Ministry of Agriculture and Primary Industries, Fiji) and a former member of the Unit, Mr Francis Wise, as well as reference to various Plant Protection Section records and reports have confirmed the distribution of *B. kirki* in Fiji. This includes data dispelling recent rumours that *B. kirki* had been discovered on Vatoa, one of the more remote islands located at the end of the southern Lau Group (to the east of Viti Levu).

Tora Vueti and Leweniqila (2001) noted that in 1990, the Project on Regional Management of Fruit Flies in the Pacific (RMFFP) and the Ministry of Agriculture Fisheries and Forests and ALTA (MAFFA) Plant Protection Section initiated fruit fly trapping and host fruit surveys in the Fiji Islands. At first, fruit fly trapping and host fruit surveys were conducted to determine, among other matters, the species of fruit flies present in the Fiji Islands, their host fruit range and geographical distribution. However, in 1993 the initial emphasis on generating data on Fiji's fruit flies was shifted to "quarantine surveillance", where the data from these activities were used to monitor and detect any incursions of exotic fruit fly species. Currently, Fiji's quarantine surveillance for exotic fruit flies comprises over 150 trap sites, all of which include a cuelure and a methyl eugenol trap, while those in high risk areas such as ports of entry also include a trimedlure trap. Rotuma has nine trap sites, two of which (wharf and airport sites) have a trimedlure trap. The Biosecurity Officer (BAF) stationed on Rotuma checks the traps monthly and forwards trapped specimens to the Fruit Fly Unit, Koronivia, for identification.

Reports accessed relating directly to fruit fly trapping and host fruit surveys on Rotuma and Vatoa include:

- "Fruit Flies in Rotuma" (undated), which indicates that the Research Division's activities in Rotuma related to fruit flies began in 1996. The work confirmed the presence of four fruit fly species, namely *B. kirki*, *B. obscura*, *B. xanthodes* and *B. distincta*, two of which did not occur on any other Fiji Islands.
- "Report on Fruit Fly Trapping and Host Survey Conducted in Rotuma on 31 May – 7 June 1997" (dated 9 June 1997) refers to earlier work on fruit flies in Rotuma undertaken in 1992 revealing the presence of *B. kirki*, *B. obscura*, *B. xanthodes* and *B. distincta*. The report outlines the establishment of five permanent trap sites at Itumuta, Itutiu, Malhaha, Pepjei and Noatau. Each trap site had a cuelure trap and a methyl eugenol trap, while Noatau and Itutiu also had a trimedlure trap. Additionally, fruits were sampled from around the island, with samples being set up at the Agriculture Office in Ahau (Rotuma) in order to establish the host ranges of the fruit fly species present. Dead fruit flies reared from fruits, as well as those collected from traps, were taken back to Koronivia Research Station for identification.
- "Fiji Trapping Data" records for 2005 and 2007 show the predominance of the two cuelure-responsive fruit flies, *B. kirki* and *B. obscura*, in Rotuma.
- "Report of Fruit Fly Work in Rotuma 15 January – 9 February 2007" (coversheet dated 1 March 2007) reports on the continuation of host range work with fruit collections yielding *B. kirki* in breadfruit (*Artocarpus altilis*), ivi (*Inocarpus fagifer*), pineapple (*Ananas comosus*), papaya (*Carica papaya*), sweet orange (*Citrus sinensis*) and wi (*Spondias dulcis*).
- "Report of the Fruit Fly Work in Rotuma 11 March – 15 April 2007" (dated 18 April 2007) summarises the findings of the second visit to Rotuma by a Plant Protection Section's Fruit Fly Unit

staff member. Fruit collections involving samples from 'commercial' and rain forest fruits (69 species) were taken in order to further efforts to determine the host range of *B. kirki* and *B. obscura*. Of the 69 species sampled, nine were found to be infested with fruit flies – mostly *B. kirki* but a few *B. xanthodes*. *B. kirki* was reared from mandarin (*Citrus reticulata*), papaya, ivi, wi, sweet orange, avocado (*Persea americana*), mango (*Mangifera indica*), Thai guava (*Psidium guajava*) and local guava (*Psidium guajava*).

- "Follow up on a report provided by Research Division's Plant Protection Section in 2010 highlighting the presence of *Bactrocera obscura* on Vatoa, Lau" (coversheet dated 29 June 2011) summarises the findings of a one-month visit to Vatoa from 12 May – 17 June 2011. It includes results of host fruit collections and daily servicing of four trap sites, each with one cuelure, methyl eugenol and trimedlure trap. The trap results confirmed the presence of *B. passiflorae*, *B. xanthodes*, *B. distincta* and *B. obscura* on the 4.45 km^2 island of Vatoa.

In summary, available information confirms that the distribution of *B. kirki* in the Fiji Islands is restricted to Rotuma. As early as 1992, this fruit fly species was recorded from Rotuma so it cannot be regarded as a recent incursion. In addition, *B. obscura*, a non-economic species, has recently been discovered on Vatoa in the southern Lau Group. This recent discovery constitutes an expansion of the distribution of *B. obscura* in the Fiji Islands compared to that noted in Tora Vueti *et al.* (1997a) and recorded on the Pacific Fruit Fly Web site at this time.

2.2 Fiji Papaya and Breadfruit Market Access Applications

Fiji submitted market access applications to export papaya (*Carica papaya*) and breadfruit (*Artocarpus altilis*) to the United States in September 2008 and July 2009, respectively. Subsequently, BAF has endeavoured to respond to requests for further information related to these applications from USDA-APHIS. However, due in part to a number of key staff changes, follow-up with USDA-APHIS officials has not been proactive. Needless to say, potential exporters of papaya and breadfruit from Viti Levu to the United States are seeking an outcome on the applications as soon as possible.

In an effort to facilitate the continuation of negotiations with USDA-APHIS on Fiji's papaya and breadfruit market access applications, the correspondence between BAF and USDA-APHIS (Table 2-1) has been examined. In lieu of responding immediately to data requests from USDA-APHIS regarding thermo-tolerance data for *B. kirki*, BAF in its letter dated 27 September 2011 reiterated its earlier request of USDA-APHIS to consider the Fiji Islands **except** Rotuma as a pest-free area (PFA) for *B. kirki*. From 1993, Fiji has had a "quarantine surveillance" system for fruit flies in place (Tora Vueti and Leweniqila 2001). Furthermore, Fiji has an emergency response plan for fruit flies documented (Tora Vueti and Ratucicivi 1999). These initiatives support the request made of USDA-APHIS.

Subsequently, BAF has corresponded with USDA-APHIS on information related to thermo-tolerance research undertaken on *B. kirki* forwarded directly to Dr Karen Ackerman, USDA-APHIS Trade Director for Australia, New Zealand, and the Pacific Islands, on 18 September 2011 by Dr J.W. Armstrong, Quarantine Scientific Limited. Among other related matters, Elvis Silvestrini (Chief Executive Officer, BAF) informed USDA-APHIS that BAF is aware of the data package submitted directly by Dr J.W. Armstrong and while it is not its usual procedure, it appreciates the submission as a contribution towards facilitating Fiji's access negotiations. Heat tolerance data for *B. kirki* is discussed in Section 2.3 (below).

Table 2-1 Correspondence between BAF and USDA-APHIS

Correspondence to	Correspondence from	Dated	Subject
USDA-APHIS	Mr Hiagi Foraete, Director Quarantine, Fiji Ministry of Agriculture & Primary Industry	1 July 2008, submitted September 2008 (refer breadfruit application)	Application to export papaya (*Carica papaya)* to the United States
Mr Craig Fedchock, Assistant Deputy Administrator, Phytosanitary Issues Management, Plant Protection and Quarantine, USDA-APHIS	Mr Hiagi Foraete, Director Biosecurity, Agriculture Quarantine & Inspection Division, Fiji Ministry of Agriculture & Primary Industry	29 July 2009	Application to export breadfruit (*Artocarpus altilis)* to the United States
Mr Hiagi Foraete, Director Quarantine, Fiji Quarantine Inspection Division, Ministry of Primary Industries	Luis E Forero, Risk Analyst, USDA-APHIS Plant Protection and Quarantine (PPQ), Center for Plant Health Science and Technology (CPHST) – Colombia	7 August 2009	Email request for reference related to pest risk assessment (PRA) of papaya from Fiji into the United States – Nafus (1997). Insect Survey of the Federated States of Micronesia, and Palau. Technical paper No. 210. South Pacific Commission, Noumea, New Caledonia.
Mr Hiagi Munivai Foraete, Director, Quarantine and Inspection Division, Ministry of Agriculture, Fisheries and Forest, Suva, Fiji Islands	Murali Bandla, Assistant Deputy Administrator, Phytosanitary Issues Management, Plant Protection and Quarantine, USDA-APHIS	13 September 2010	Letter, notifying Mr Foraete that "we have identified three fruit flies as quarantine pests associated with Fiji papaya that will require treatment: *Bactrocera kirki*, *Bactrocera passiflorae*, and *Bactrocera xanthodes*" and requesting research studies demonstrating the efficacy of the proposed HTFA treatment for the three fruit flies.
Dr Murali Bandla, Assistant Deputy Administrator, Phytosanitary Issues Management, Plant Protection and Quarantine, USDA-APHIS, Riverdale, Maryland	Ilaitia Boa, Acting Chief Executive Officer, Biosecurity Authority of Fiji, Ground Floor, Takayawa Building, GPO Box 18360, Suva, Fiji Islands	27 January 2011	Letter accompanying a report and a publication containing thermo-tolerance data and analysis for *Bactrocera passiflorae* and *Bactrocera xanthodes*, as a response to the request from USDA-APHIS (of 13 September 2010). In addition, a publication reporting on the fruit fly fauna of Fiji was provided as evidence of the limited distribution (on Rotuma Island only) of *Bactrocera kirki*.

Correspondence to	Correspondence from	Dated	Subject
Mr Hiagi Munivai Foraete, Director, Quarantine and Inspection Division, Ministry of Agriculture, Fisheries and Forest, Suva, Fiji Islands	Murali Bandla, Ph.D., Assistant Deputy Administrator, Phytosanitary Issues Management, Plant Protection and Quarantine, USDA-APHIS	27 July 2011	Letter accompanying draft PRA "Importation of Fresh Papaya Fruit, *Carica papaya* L., from Fiji into the Continental United States" for review and comment, together with a request for research studies demonstrating the efficacy of the proposed HTFA treatment for *Bactrocera kirki* **or** information confirming that *B. kirki* is found only on Rotuma Island AND fruit fly trapping and fruit fly host movement regulations are in place. *Note:* The letter also states that "The information provided in your submission to support this treatment did not include research studies demonstrating that the proposed treatment is efficacious in killing the two fruit flies: *Bactrocera passiflorae* and *Bactrocera xanthodes*."
Dr. Murali Bandla, Assistant Deputy Administrator, Phytosanitary Issues Management, Plant Protection and Quarantine, USDA-APHIS	Elvis Silvestrini, Chief Executive Officer, Biosecurity Authority of Fiji, GPO Box 18360, Suva, Fiji Islands	27 September 2011	Letter notifying USDA-APHIS of the establishment of BAF and introducing the CEO, reiterating the request for the Fiji Islands **except** Rotuma to be considered a PFA for *Bactrocera kirki* and indicating that heat tolerance data had been forwarded with the correspondence dated 27 January 2011.
Dr. Murali Bandla, Assistant Deputy Administrator, Phytosanitary Issues Management, Plant Protection and Quarantine, USDA-APHIS	Elvis Silvestrini, Chief Executive Officer, Biosecurity Authority of Fiji, GPO Box 18360, Suva, Fiji Islands	Due to be dispatched 17 October 2011	Letter informing USDA-APHIS that BAF is aware of the data package submitted directly by Dr J.W. Armstrong and while it is not its usual procedure, it appreciates the submission as a contribution towards facilitating Fiji's access negotiations. A request is made for consideration of "the Fiji Islands **except** Rotuma to be considered a PFA for *Bactrocera kirki*" to be given priority by USDA-APHIS. Similarly, a request is made for an update on USDA-APHIS's progress on Fiji's applications to export papaya and breadfruit to the United States.

2.3 Heat Tolerance Data for *Bactrocera kirki*

Both published and unpublished works relevant to the assessment of heat tolerance in *B. kirki* have been accessed and reviewed (refer second bullet point, Section 1.2). These include: Alderson *et al.* (1999), Foliaki and Armstrong (1997), Fonoti and Tunupopo (1997), Frampton and Evans (1996), Saili and Laiti (2004), Tora Vueti *et al.* (1997b), Appendices 4 and 5 from Tora Vueti and Leweniqila (2001), and Waddell *et al.* (1997). Some of these reports/publications present data and/or reiterate findings already reported to a particular audience. The key studies allowing the comparison of the heat tolerance of immature *B. kirki* with *B. passiflorae* and *B. xanthodes* were described in Frampton and Evans (1996), and Fonoti and Tunupopo (1997) but results accessed from Alderson *et al.* (1999).

In investigating the mortality response of Samoan *B. kirki* to water bath heat treatments of 43, 45, 47 and 48°C, and comparing the results with Samoan *B. xanthodes*, Fonoti and Tunupopo (1997) found that at 47°C, the maximum observed time for 99% mortality (LT99) for Samoan *B. kirki* was **6.1 minutes** (5.4 – 6.9 95% confidence interval [CI]) for mature eggs, while the maximum LT99 for

Samoan *B. xanthodes* was 5.5 minutes (4.7 – 6.5 95% CI) for late third instar larvae (Table 2-2). Fonoti and Tunupopo (1997) compared their results with those of Waddell *et al.* (1997) for *B. melanotus* in the Cook Islands and reported that at all temperatures, mature eggs of *B. melanotus* were significantly more tolerant than the tested life stages of Samoan *B. kirki*. At 47°C, the maximum observed LT99 for *B. melanotus* mature eggs was **9.8 minutes** (9.0 – 11.0 95% CI).

Frampton and Evans (1996) in their analyses of heat tolerances of immature stages of *B. passiflorae* and *B. xanthodes* in Fiji reported that at 47°C, the maximum observed LT99 of **9.249 minutes** (7.721 – 10.778 95% CI) was for *B. passiflorae* eggs less than 10 hours old. At the same temperature, the maximum observed LT99 for Fijian *B. xanthodes* of 2.316 minutes (2.106 – 2.526 95% CI) was for first instar larvae. These results for 47°C and similar findings from other heat tolerance studies conducted in Tonga are summarised in Table 2-2.

Table 2-2 Comparison of estimated lethal times for 99% mortality (LT99) and their 95% confidence intervals for the most heat tolerant stage of economic fruit fly species present in Fiji, Cook Islands, Samoa and Tonga immersed in hot water at 47°C

Fruit fly species	Life stage	LT99 (minutes)	95% CI
Bactrocera facialis[1] (Tonga)	Third instar (non-feeding)	6.366	Not able to be estimated
Bactrocera kirki[2] (Samoa)	Mature egg	6.1	5.4 – 6.9
Bactrocera melanotus[3] (Cook Islands)	Mature egg	9.8	9.0 – 11.0
Bactrocera passiflorae[4] (Fiji)	Early egg (<10 hours old)	9.249	7.721 – 10.778
Bactrocera xanthodes[1] (Tonga)	Third instar (feeding)	3.482	3.015 – 3.949
Bactrocera xanthodes[2] (Samoa)	Late third instar	5.5	4.7 – 6.5
Bactrocera xanthodes[3] (Cook Islands)	Mature egg	6.5	6.0 – 7.1
Bactrocera xanthodes[4] (Fiji)	First instar	2.316	2.106 – 2.526

[1] Foliaki and Armstrong (1997); [2] Waddell et al. (1997); [3] Alderson et al. (1999); [4] Frampton and Evans (1996)

In summary, as clearly shown in Fonoti and Tunupopo (1997), Frampton and Evans (1996) and Waddell *et al.* (1997), the lethal time for 99% kill (LT99) is temperature dependent, as is the most heat tolerant life stage for the various *Bactrocera* species studied. From the published and unpublished works reviewed to compare the heat tolerance of immature *B. kirki* with *B. passiflorae* and *B. xanthodes* in Fiji, it appears that at 47°C the most heat tolerant life stage of Samoan *B. kirki* is less tolerant than the most tolerant life stage of the most tolerant species (*B. passiflorae*) in Fiji. Furthermore, Samoan *B. kirki* is significantly less tolerant than Cook Islands *B. melanotus* (Fonoti and Tunupopo 1997). Additionally, as reported in Tora Vueti *et al.* (1997b), a comparison carried out on the heat tolerances of the late egg stage of *B. melanotus*, the most heat tolerant species and stage in the Cook Islands, with the early eggs of *B. passiflorae* showed that *B. melanotus* late eggs are more tolerant than *B. passiflorae* in Fiji. Incidentally, at temperatures of 45, 47 and 48°C, the LT99s for the most heat tolerant life stage of Samoan *B. kirki* were invariably less than those for Fijian *B. passiflorae* (Alderson *et al.* 1999; Frampton and Evans 1996).

In conclusion, evidence from all the available studies leaves little doubt that the HTFA treatment of 47.2°C fruit centre temperature for 20 minutes – the treatment used for *B. melanotus* and *B. xanthodes* for the export of papaya from the Cook Islands, and that used for *B. passiflorae* and *B. xanthodes* for the export of a range of fruit fly host products from Viti Levu, Fiji – will also kill *B. kirki.* The findings (Table 2-2) highlight the possibility that a regional submission be developed in

accordance with the requirements set out in International Standards For Phytosanitary Measures (ISPM) No. 28: *Phytosanitary treatments for regulated pests* and forwarded for consideration by the Technical Panel on Phytosanitary Treatments for this HTFA treatment for approval by the Commission on Phytosanitary Measures as a 'generic' treatment for fruit flies from the Pacific Island countries of Fiji, Cook Islands, Samoa and Tonga.

It important to note that all pertinent information on the heat tolerance of *B. kirki* was contained in Dr Armstrong's information package forwarded to USDA-APHIS in September 2011 (refer Section 2.2 above). As a consequence (and with reference to the third bullet point, Section 1.2 (above)), development of another submission indicating that the "current heat treatment used by Fiji for *B. passiflorae* and *B. xanthodes* will also kill *B. kirki*" is negated.

2.4 Eradication of *Bactrocera kirki* from Rotuma: Scoping Study

2.4.1 Rotuma

Rotuma is an isolated group of volcanic islands in the South West Pacific, the name deriving from the main island which is about 14.5 km in length and 4 km wide, with an area of 46 km^2. Other than the main island, there are eight small islands that lie within Rotuma's reef, none of which are inhabited by humans. Between 4 and 11 km off the west coast of the main island, and beyond the reef, there are three other volcanic islands: Uea, at about 1 km^2, is the largest and nearest of these islands; Hatana is in the middle; and Hofliua is the farthest away. Some details on Rotuma's geography and vegetation are provided in Table 2-3.

The islands 2000 inhabitants are mostly of Polynesian descent (2007 Population Census of Fiji, Fiji Islands Bureau of Statistics). In 1881, when the chiefs of Rotuma decided to cede their island to Britain, the island was considered too small and isolated to justify its own governor-general. The chiefs were persuaded to cede themselves instead to the larger Melanesian islands, Fiji, the closest country in the region that had already become a member of the British Empire. Rotuma's closest neighbour is Niulakita, the southern island of the Tuvalu group, lying about 350 km to the north, while the other islands of Fiji lie some 450 km to the south.

Aside from its geographical isolation, Rotuma is far from the international trading routes between larger Pacific Islands, Asia and the Americas. Once a month, a boat goes from Suva to Rotuma (a 2–3 day trip), while a weekly domestic flight service (with no more than 10 passengers each with 15 kg baggage limit) from Nadi resumed in March this year. The flight service is currently operated by Pacific Sun and a one-way flight costs FJD 626.00 (Pacific Sun Ticketing Desk, 14 October 2011). Flights can be cancelled when the airstrip on Rotuma is waterlogged. Visitors to Rotuma are mostly friends or relatives of local residents. Tourist interest is negligible so, as such, there is no infrastructure supporting a tourism industry. With no hotels and no restaurants or other tourist facilities, tourists make "homestay" arrangements with families on Rotuma.

According to www.rotuma.net (accessed 13 October 2011):

> *Rotumans cultivate a range of starchy staple crops, including taro, yams, sweet potatoes, cassava, breadfruit, and bananas, as well as coconuts, numerous varieties of fruit and assorted vegetables. Most Rotuman households keep chickens and pigs, and some raise a few goats or cows as well. Meat from these animals, or fish, shellfish and seaweed from the surrounding waters, are eaten as accompaniment to the basic starchy foods. Rotuman households are generally self-sufficient,*

although a cultural value of generosity, especially towards kin, promotes frequent reciprocal assistance and sharing of food and other resources.

2.4.2 Fruit Fly Eradication Programs in the Pacific

As significant pests of fruit and fleshy vegetables, exotic fruit flies have been the target of eradication or suppression programs to rid countries or parts of countries of these introduced pests. Notably, in the Republic of Nauru an eradication program of four introduced species of *Bactrocera* – namely Oriental fruit fly (*B. dorsalis*), Pacific fruit fly (*B. xanthodes*), melon fly (*B. cucurbitae*) and mango fly (*B. frauenfeldi*) – has been implemented (Allwood *et al.* 2002). In the Republic of Palau a similar eradication program was proposed to eliminate what was initially identified as Oriental fruit fly (now confirmed to be *B. philippinensis* and *B. occipitalis*, also species belonging to the *dorsalis* complex (Pest Alert No. 23, Plant Protection Service, Secretariat of the Pacific Community)) and breadfruit fly (*B. umbrosa*) (McGregor 2000). Together, these eradication programs provide a useful comparison to scope the technical feasibility of a fruit fly eradication program on Rotuma. A comparison of the attributes of Nauru, Palau and Rotuma relevant to fruit fly eradication is summarised in Table 2-3.

Nauru eradication program

A program to eradicate four introduced *Bactrocera* species from the Republic of Nauru was implemented between October 1998 and December 2000 (Allwood *et al.* 2002). Although the Nauru Fruit Fly Eradication Programme (FFERAD) belonged completely to the Government of the Republic of Nauru, technical and financial support was provided through the Food and Agriculture Organization / United Nations Development Programme / AusAID / Secretariat of the Pacific Community RMFFP. (Note: The third and final phase of RMFFP concluded in December 2000.) Visits to Nauru by the Chief Technical Advisor of RMFFP in February, May and September 1998 largely contributed to the planning of the program, but also provided opportunities to inform government staff and members of the public about fruit flies, their economic significance and the appropriate methods to eradicate fruit flies from Nauru (Allwood and Stephenson 1999). Allwood and Stephenson (1999) indicated that the program's "success would improve the availability of locally grown fresh fruits and vegetables to Nauruans while reducing a serious threat to other Pacific Island countries and territories (PICTs)." In addition, the program provided the opportunity to train government personnel from various Pacific Island nations in fruit fly eradication and emergency response techniques – in fact, over 40 plant protection and quarantine staff from 18 PICTs spent 2–4 weeks in Nauru undergoing field training during the eradication program, thereby increasing the technical capacity in fruit fly eradication across the Pacific for some years subsequently.

As described in Table 2-3, both male annihilation and protein bait application techniques were used to effect eradication in this program. The fibreboard blocking campaigns were repeated every eight weeks. Notably, the Nauru Government arranged ground teams for blocking from the Departments of Youth, Health, and Works, and from the Nauru Phosphate Corporation and Buada Lagoon Community (Allwood *et al.* 2002) for much of the program. In areas that were readily accessible by the ground teams, such as in urban or village areas, and in areas of high incidence of fruit flies, blocks were distributed at densities of up to 1500–1700 blocks per square kilometre. Generally, however, a density of 400–700 blocks per square kilometre was found to be acceptable (and effective) in urban and accessible 'native' vegetation areas. In the accessible mined area known as Topside, blocks were distributed at 50 m intervals along all roads, train tracks, and motorcycle and walking tracks that radiated from a central point and along roads that ran around the coastal edge of the escarpment. In

mined, inaccessible areas on Topside, blocks were thrown or fired from slingshots into 'native' vegetation patches, giving an overall density in these areas, because of the terrain, of 60–135 per square kilometre, a density much lower than the target of at least 300 per square kilometre. Nevertheless, by December 2000 three of the four species – namely *B. dorsalis*, *B.xanthodes* and *B. cucurbitae* – were declared eradicated. Populations of *B. frauenfeldi* still persisted. It should come as no surprise that a cuelure-responsive species remained – as noted by M.A. Bateman and reported by Allwood *et al.* (2002), the effectiveness of cuelure in the application of the male annihilation technique is recognised as being less than that of methyl eugenol. Consequently, remaining residual fly populations may result in continuation of the species unless other forms of fruit fly management such as protein bait sprays or sterile insect technique are incorporated into a program.

The exact costs of FFERAD in Nauru could not be readily accessed. The approximate cost of the program as recalled by B.P. Stephenson (pers. comm.) amounted to several hundred thousand dollars rather than millions. McGregor (2000) referred to a total estimated cost of AUD330,000 for FFERAD. From Allwood and Stephenson (1999), it is apparent that RMFFP financial support at that time had amounted to AUD127,000; funding managed through the Crawford Fund for International Agricultural Research, including the Australian Government's Office of the Chief Plant Protection Officer, Bronson and Jacobs and Rhone Poulenc Rural (Australia), amounted to AUD 100,000; and the New Zealand Government contribution amounted to AUD40,000. The Government of the Republic of Nauru contributed much in kind, as noted above.

Proposed eradication program in Palau

McGregor (2000) undertook a full economic feasibility study of the proposed eradication of Oriental fruit fly (*B. dorsalis,* but according to the Pacific Fruit Fly Web site now known to be *B. occipitalis* and *B. philippensis*) and breadfruit fly (*B. umbrosa*) from the Republic of Palau. This followed a technical feasibility assessment conducted in August 1999 by Allan Allwood and others, who essentially concluded that it would be feasible to eradicate the methyl eugenol-responsive fruit fly species from Palau at an estimated cost of USD1.21 million by adopting the male annihilation technique that was used in Nauru, supplemented by protein bait spraying and the release of parasitoids to reduce the populations to be eradicated (McGregor 2000). McGregor (2000) stated that the major difference in the program proposed for Palau was the use of a helicopter for distribution of the fibreboard blocks due to the difficult terrain and numerous islands that would have to be covered. Costings for the proposed program were based on commercial rates for a helicopter to be brought from Guam every eight weeks for eight blocking campaigns spread over an 18-month period.

In assessing the economic feasibility of eradication, McGregor (2000) acknowledged that the risk of fruit fly re-entry soon after a successful program was very real for Palau, which lies in close proximity to southeast Asia and Papua New Guinea. Costs associated with managing this risk were therefore taken into account when comparing economic costs with the benefits of fruit fly eradication in Palau. As for the benefits from the proposed eradication program, some of those to which a dollar value could be assigned related to tourism. Palau's economy consists primarily of tourism, subsistence farming, and fishing. In 2007, business and tourist arrivals numbered 85,000 (World Factbook, www.cia.gov (accessed 4 November 2011)) and long term prospects for the tourist sector have been enhanced by the expansion of air travel in the Pacific. McGregor (2000) ultimately concluded that the value of benefits to Palau significantly exceeded the costs of the proposed eradication program.

Comparing Rotuma to Nauru and Palau

As recorded in Table 2-3, a combination of male annihilation and bait application techniques is recommended as the most appropriate fruit fly management option for eradication of target fruit flies in Nauru, Palau and Rotuma – especially for cuelure-responsive flies. As a single, small, low-lying island, Nauru was a technically easier proposition than Rotuma, a small isolated group of volcanic islands, or the many, scattered islands of the Republic of Palau. Similarly, the geography, geology and vegetation of Rotuma and Palau present greater challenges to obtaining good coverage of the lure- and insecticide-impregnated fibreboard blocks at the required densities than in Nauru. These challenges can be largely overcome in Palau by using a helicopter for the distribution of the fibreboard blocks; however, given the isolation of Rotuma and limited infrastructure to support aerial operations, aerial application of the blocks is not an option for Rotuma. In addition, the methods employed on Nauru in mined, inaccessible areas whereby blocks were thrown or fired from slingshots into 'native' vegetation patches would be inadequate for achieving appropriate densities and distribution of the blocks, given the steep terrain and lush vegetation present in areas of Rotuma.

Further to the above considerations for a fruit fly eradication program on Rotuma, it must not be overlooked that, unlike Nauru and Palau, the target of any eradication program on Rotuma is a cuelure-responsive species. Methyl eugenol-responsive species, especially those in the *dorsalis*-complex, are more amenable to eradication using the male annihilation technique. As mentioned above, it is usually necessary to incorporate other forms of fruit fly management (such as protein bait sprays or sterile insect technique) into any program. The difficulties with applying such techniques in Rotuma are several orders of magnitude higher than male annihilation. As a consequence, without more effective attractants for cuelure-responsive species, at this time the technical feasibility of an eradication program for *B. kirki* on Rotuma is questionable.

In addition, the economic feasibility is likely to be marginal. One of the benefits shared by Nauru and Palau of eradication of the introduced fruit fly species is the improved nutrition and food security for the residents on the islands because of the production of locally grown fruit. In Palau, economic benefits from the production of locally grown fruit would also accrue from the tourist market. It was thought that the proposed eradication program would eventually enable the selling of fruit to tourists while in Palau and selling of fruit to tourists departing Palau (McGregor 2000). Neither of these benefits could be attributed to the eradication of *B. kirki* from Rotuma – "Rotuman households are generally self-sufficient" (www.rotuma.net (accessed 13 October 2011)) and there is limited tourist interest in Rotuma. With very little tourist-related infrastructure on Rotuma and with Rotuma's isolation from major trading/transport routes, there are severe constraints to any future development of a substantive tourist industry, let alone the export of fresh fruit and fleshy vegetables.

The same constraints as those applying to the development of a tourist industry on Rotuma may prove to be hurdles in the implementation of an eradication program. For example, there may be difficulties encountered in the procurement and timely supply of the necessary resources for eradication and providing for short-to-medium visits from technical and operational staff involved in planning and implementing an eradication program. However, an enthusiastic and supportive local community can achieve much (as was observed during FFERAD in Nauru) and such hurdles should not be viewed as insurmountable for Rotuma.

Table 2-3 Comparison of the attributes of Nauru, Palau and Rotuma relevant to fruit fly eradication

	Nauru **(Source: Allwood *et al.* 2002)**	**Palau** **(Source: McGregor 2000)**	**Rotuma**
Fruit fly species present/Male lure **Note: Species listed in bold = eradication targets**	***Bactrocera dorsalis*** (Methyl eugenol) ***B. xanthodes*** (Methyl eugenol) ***B. cucurbitae*** (Cuelure) ***B. frauenfeldi*** (Cuelure)	Oriental fruit fly complex (*dorsalis* complex): ***B. occipitalis*** (Methyl eugenol) ***B. philippinensis*** (Methyl eugenol) ***B. umbrosa*** (Methyl eugenol) *B. frauenfeldi* (Cuelure) *B. calophylli* (NOT methyl eugenol or cuelure)	***B. kirki*** (Cuelure) *B. distincta* (Cuelure) *B. obscura* (Cuelure) *B. xanthodes* (Methyl eugenol)
Geography	Uplifted limestone island with a narrow coastal belt encircling a limestone escarpment reaching 30–70 m above sea level.	The Palau archipelago comprises 343 islands with a total area of 488 km^2. The four largest islands – Babeldaob, Arakabesan, Koror and Malakal – are volcanic, with the highest elevation being 242 m. Except Kayangel, a low atoll, the remainder are raised coral limestone islands.	An isolated group of volcanic islands – there are eight small islands that lie within the reef of the main island, as well as three other islands that lie between 4 and 11 km off the west coast of the main island. Rotuma's highest peak is Mt Suelhof at 256 m. Topographically, the main island consists of three terraces; the first is littoral, then there is a narrow coastal terrace, while the third starts along the slopes of hills that form a central plateau of gentle undulations (30–60 m in elevation) from which remnant volcanic cones arise abruptly (Zug *et al.* 1988). The central plateau occupies the entire centre of the island. There is a coastal road, along which villages are spread out, and there are some walking tracks to the interior.
Area affected	21.2 km^2	488 km^2 (Babeldaoh, the Big Island, is 396 km^2)	44 km^2
Population of the fruit fly-affected area	12,350 (2002 estimate)	20,956 (July 2011 estimate (World Factbook))	2,002 (2007 Population Census of Fiji)

	Nauru **(Source: Allwood *et al.* 2002)**	**Palau** **(Source: McGregor 2000)**	**Rotuma**
Vegetation	Flora is poor relative to other Pacific Islands (493 species or hybrids), partly due to the extensive phosphate mining activity.	The islands have diverse flora. Almost 75% of the land mass remains under forest cover, with eight classes of forest delineated. This means there is an abundance of host fruits on which the exotic fruit flies thrive.	Rotuma's original vegetation was forest (Mueller-Dombois and Fosberg 1998). What little original forest remains, on steep slopes and cinder cones, is really altered primary forest, because most of the terrain is too steep to have ever been properly cleared. The central plateau was an area of intense agriculture – much of the land is occupied by dense coconut plantations, together with taro, cassava and yam gardens. Copra was the principal cash crop. Now many of the plantations have been neglected and have reverted to mature secondary forest. An undergrowth of *Hibiscus tiliaceus* and *Lantana camara* is prevalent amongst most of the plantations. The terrestrial flora of the Rotuma island group consists of over 500 species of indigenous and introduced plants (McClatchey *et al.* 2000) and has been described as "lush".
Methodology for eradication	A combination of male annihilation and bait application techniques. Male annihilation technique involved distributing fibreboard blocks impregnated with male fruit fly lure (methyl eugenol and/or cuelure) and the insecticide Fiprinol in a loose grid resulting in at least 300 blocks per km^2 over Nauru. Bait application technique involved spraying host fruit trees in hot spot areas with protein insect lure and Fiprinol gel on a weekly schedule.	Male annihilation technique, supplemented by protein bait spraying and the release of parasitoids. BUT, unlike on Nauru, helicopter to be used for the distribution of the fibreboard blocks due to the difficult terrain and numerous islands to be covered.	A combination of male annihilation and bait application techniques. Note: Aerial application of fibreboard blocks is not an option.

	Nauru **(Source: Allwood *et al.* 2002)**	**Palau** **(Source: McGregor 2000)**	**Rotuma**
Implementation of the program	Program implemented between October 1998 and December 2000. Three of the four species were declared eradicated, namely *B. dorsalis* (in October 1999), *B. xanthodes* (in October 2000) and *B. cucurbitae* (in October 1999). Note: *B. frauenfeldi* still persisted. Informal reports received by the Secretariat of the Pacific Community in May 2004 confirm that *B. cucurbitae* and *B. xanthodes* have re-occurred on Nauru.	Recommended for implementation in October 2001, subject to funding support.	

Conclusion

There is little doubt that fruit fly management techniques available today have enabled the suppression or eradication of populations of introduced pest fruit flies from whole countries or parts of countries. Nevertheless, wide-area suppression and eradication attempts are not simple operations – any program can be likened to a military campaign and, as stated by McGregor (2000), "good leadership with the required technical and management skills is essential". The present scoping study to determine if *B. kirki* could be eradicated from Rotuma has drawn on the experiences of two fruit fly eradication 'programs' in the Pacific: the successful Nauru Fruit Fly Eradication Programme (FFERAD) implemented between October 1999 and December 2000, and the similar one proposed for the Republic of Palau. However, matters such as the high level of management capability required for planning and implementing an eradication program and the approval of the insecticide Fipronil for use in a program using male annihilation and protein bait application have not been taken into account. These matters were conditional to the finding that the proposed program for Palau was technically feasible (McGregor 2000), based on their significance to the success of FFERAD. Even without taking these matters into account for Rotuma, this study concludes that, at this time, without more effective attractants for cuelure-responsive species, the technical feasibility of an eradication program for *B. kirki* on Rotuma is questionable. Furthermore, the value of the benefits is unlikely to exceed the costs.

Regardless of whether an attempt to eradicate *B. kirki* from Rotuma is undertaken, the importance of Fiji's quarantine surveillance for exotic fruit flies ((including the trapping/monitoring on Rotuma) must be emphasised, especially to support the BAF request of USDA-APHIS to accept the Fiji Islands **except** Rotuma as a PFA for *B. kirki*. If accepted by USDA-APHIS, the PFA will require ongoing maintenance involving appropriate fruit fly trapping and monitoring. It will also require enforcement of fruit fly host movement regulations/restrictions. It is, therefore, recommended that:

- An independent audit of all aspects of Fiji's quarantine surveillance system for fruit flies be undertaken as soon as possible, and any shortcomings be corrected in a timely manner; and
- Fiji's fruit fly host movement regulations/restrictions as they pertain to Rotuma be reviewed, and the appropriate enforcement be undertaken at all times.

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