# A Review of the New Zealand

# Mosquito Surveillance Programme

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**For the New Zealand Ministry of Health**
**May 2002**

*Juncus* swamp where SSM were found near Napier

International container ship at Napier port

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## EXECUTIVE SUMMARY

**Background:** This review was undertaken for the Ministry of Health (MoH) to assess the effectiveness of the current surveillance and exclusion programmes for exotic *Aedes* mosquitoes (e.g. *Ae. aegypti* and *Ae. albopictus*) entering at New Zealand ports, and for the introduced Southern Saltmarsh Mosquito (SSM - *Ochlerotatus camptorhynchus*) found in various coastal areas of the North Island, and to make recommendations on how the programmes can be improved. This review has been organised into two general sections covering the port programme and the SSM programme, respectively.

**1. Finding:** There are two separate components of a programme to preclude the entry of exotic *Aedes* mosquitoes through international ports: i) inspection and disinsection of vessels and cargoes, and (ii) surveillance of mosquitoes at and near seaports and airports. It was not widely recognised or accepted that both were critical, and at no New Zealand port were both well-maintained.

**1. Recommendation:** Further education of the Public Health Services (PHSs), Ministry of Agriculture and Forestry (MAF) and the port managers is required.

**2. Finding:** The MoH guidelines recommend surveillance practices, but there was little evidence that most PHSs undertook surveillance as recommended.

**2. Recommendation:** The disparate responsibilities for port surveillance and specimen identifications should be resolved towards a national uniformity of approach. There should be a greater inclusion of adult sampling in routine surveillance programmes, and the record keeping for surveillance at seaports and airports must be upgraded. Surveillance equipment and procedures should become relatively standardised and detailed recommendations are provided.

**3. Finding:** Disinsection of aircraft and inspection of incoming cargo is under the control of MAF, and appears to be done relatively effectively. The most important method of introduction of container-breeding mosquitoes, the international trade in used tyres, presents little concern to New Zealand as all used tyre imports undergo routine fumigation (providing the current method of fumigation or an alternative proven method is maintained). General cargo, particularly vehicles, and plant and equipment, appears to be the major concern for mosquito import. However, the large numbers of 'de-vanning' sites in various cities could be of concern where the contents of shipping-containers are not correctly notified.

**3. Recommendation:** There needs to be an upgrading of active anti-mosquito measures (e.g. ground surveillance and sanitation) within the port areas, in accordance with the requirements of Article 19 of the International Health Regulations.

**4. Finding:** The MoH guidelines also sought to provide for appropriate responses to interceptions and incursions. The procedures and time-frames for the various actions required were being followed in general terms by the PHSs. In some places where incursions had not yet been detected, the capability of local PHSs to undertake appropriate responses in a timely fashion had yet to be demonstrated, and the interactions with local authorities have yet to be tested.

**4. Recommendation:** There needs to be a formalisation of the responsibilities between PHSs and local authorities, MAF and commercial operatives. The 'national'

Memorandum of Understanding between MoH and MAF must ensure appropriate and adequate surveillance, effective communication, and provide for an appropriate and effective national response to interceptions and incursions. Additionally, ‘local’ MOUs should be developed between PHSs, port authorities and MAF to detail local responsibilities for surveillance and to formalise incursion response plans.

**5. Finding:** In general, the PHSs feel satisfied with NZ Biosecure. While there are some issues that need to be resolved, we have few reservations about the capability of NZ Biosecure to service the MoH and the PHSs' surveillance programmes adequately, and we believe NZ Biosecure is providing a commendable service.

**5. Recommendation:** NZ Biosecure could become the agent for training, and provision and maintenance of equipment, as well as being a centralised repository of data. One important issue that should be resolved relates to them receiving preserved larvae too young to be identified. We recommend that all larvae from SSM and port surveys be reared to $4^{th}$ instar in trays containing s-methoprene (1 pellet or granule/tray). Adults should only be reared in secure facilities approved by the MoH and MAF.

**6. Finding:** The PHSs generally have poor collections of local data, but some have a commendable assemblage of documentation for surveillance activities and incursion responses.

**6. Recommendation:** To maintain quality assurance, MoH should require copies of local MOUs and the associated surveillance and incursion response plans from the PHSs. Additionally, PHSs should be required to submit monthly data and provide annual reports to MoH. Biannual audits of PHS/Biosecure records should be undertaken. Seeding of mosquito collections with exotic larvae could be used to ensure quality assurance of the taxonomy processes at Biosecure.

**7. Finding:** While all PHSs conducted surveillance in response to the MoH request for SSM surveillance, inadequate planning, methods and outcome were achieved. Much of this was due to inadequate experience and training, coupled with too little time/resources and competing demands, to undertake the difficult task of surveying for SSM in remote and inhospitable areas.

**7. Recommendation:** The MoH should consider developing, in collaboration with PHSs, NZ Biosecure and recognised experts, procedures and protocols for SSM surveillance and control. A training course and new guidelines should be developed.

**8. Finding:** Too much emphasis has been placed upon larval surveys and collection of water samples by PHSs conducting SSM surveys.

**8. Recommendation:** More effort, including additional funding if needed, should be made to improve trapping for adult SSM mosquitoes.

**9. Finding:** NZ Biosecure has been instrumental in the successful eradication of SSM in Hawkes Bay. Their focus on the problem has enabled them to develop the necessary expertise to conduct thorough surveillance and control needed to eliminate the SSM. However, short-term contracts threaten staff stability, undermining their efficacy.

**9. Recommendation:** NZ Biosecure should be given more responsibility to assist PHSs with SSM surveillance in high-risk areas (particularly Auckland and Bay of Plenty), and should be co-opted immediately for appropriate interventions when new SSM populations are detected. These associations should be accompanied by increased funding, from either the individual PHSs or the MoH at the discretion of the MoH. Longer-term contracting should also be sought.

**10. Finding:** The MoH guidelines for surveillance were not entirely appropriate for either port or SSM monitoring; they did not adequately detail operational procedures.

**10.Recommendation**: A set of '*Recommended Standardised 'Best Practice' Procedures for Vector Monitoring at Ports'* and *'Recommended Standardised 'Best Practice' Procedures for SSM Surveillance System'* is provided as Appendix 1 and Appendix 2, respectively.

# INTRODUCTION

On 8 - 19 April 2002, Drs. Scott A. Ritchie and Richard C. Russell, accompanied by John R. Gardner, Senior Advisor Biosecurity, Ministry of Health (MoH), visited key ports and Public Health Services (PHSs) across New Zealand in order to provide a comprehensive review of mosquito surveillance in New Zealand. In particular, the review investigated strategies developed by the MoH and the Ministry of Agriculture and Forestry (MAF), and applied by PHSs and MAF, to survey and control exotic mosquitoes. These include programmes designed to detect and eradicate exotic *Aedes* mosquitoes at airports and seaports, along with specific programmes targeting the Southern Saltmarsh Mosquito (SSM), *Ochlerotatus camptorhynchus*.

Exotic *Aedes* and *Ochlerotatus* species had been recorded at New Zealand ports during the past decade. Large populations of the SSM were discovered near Napier in 1998, generating a comprehensive eradication campaign that was successful in the Napier/Gisborne area (Garner et al. 2001). Neither of the major *Aedes* species of concern (*Ae. aegypti* and *Ae. albopictus*) had managed to become established, but other populations of SSM have subsequently been found, most notably at the extensive Kaipaira Harbour estuary north of Auckland. The risk of establishment of the SSM in other estuarine habitats, such as the Manukau Harbour south of Auckland, is real, as is the threat of importation and subsequent outbreaks of Ross River virus (Kelly-Hope et al. 2002). The risk of importation of *Aedes* species to the country also remains – perhaps increasing as individual species spread throughout the Pacific.

The goal of this survey was to assess the effectiveness of the current *Aedes* mosquito surveillance and exclusion programmes at New Zealand ports, undertake a review of the SSM programme, and to make recommendations on how both programmes could be improved. For this review of the current surveillance programme, we visited selected District Health Boards through New Zealand where it was considered there were significant risks for the introduction of exotic species through major international sea- or airports, and for the establishment of container-breeding and wetland mosquitoes. This report presents a snapshot of status of NZ exotic mosquito surveillance and control relative to 1997 when it was last reviewed by Dr. Brian Kay and two general sections covering the port programme and the SSM programme. Within each, the following will be presented:

- a review of the PHSs' exotic mosquito surveillance and control programme, including methods, thoroughness and outcome;

- a review of the MoH Guidelines “Environmental Health Protection Manual, Section 5 Biosecurity”;

- proposals for improved exotic mosquito surveillance and control programme including approach, methods, and auditing system.

# EXOTIC SPECIES AND SURVEILLANCE IN NEW ZEALAND

### *Rationale for Mosquito Surveillance and Control at Ports*

- the prevention of the import, via sea vessels and aircraft, of exotic species of mosquito that constitute a national health concern for New Zealand (Hearnden, 1999; Hearnden et al., 1999; Kay, 1997; Laird, 1990, 1995; Laird et al., 1994; MoH, 1997).

- the prevention of the export of local mosquito species that might constitute an international health risk according to the International Health Regulations (WHO, 1983).

### *International Health Regulations and Mosquito Export*

Article 19 of the International Health Regulations (IHR) states, *inter alia*: "Every port and the area within the perimeter of every airport shall be kept free from *Ae. aegypti* in its immature and adult stages and the mosquito vectors of malaria and other diseases of epidemiological significance in international traffic. For this purpose active anti-mosquito measures shall be maintained within a protective area extending for a distance of at least 400 metres around the perimeter."

New Zealand is currently free from *Ae. aegypti* and other recognised vectors of dengue, malaria and other internationally significant mosquito-borne diseases; however, there remains the IHR obligation to maintain active anti-mosquito measures at seaports and airports.

### *National Concerns for Mosquito Imports*

The public health concerns for New Zealand relating to introduction of potential mosquito vector species such as *Ae. aegypti* (which arguably could not persist in New Zealand's climate) and *Ae. albopictus* (which arguably could extend and persist in much of New Zealand) which could result in the local transmission of dengue viruses, *Anopheles* mosquitoes which could bring a threat of malaria transmission, *Culex annulirostris* and various *Aedes* and *Ochlerotatus* species which could bring threats of transmission of various zoonotic arboviruses, have been well-documented over the past decade and are well-based in fact from local and recent international experience.

Overall, New Zealand has experienced the introduction and establishment of four exotic mosquito species: *Culex quinquefasciatus*, *Ochlerotatus australis*, *Ochlerotatus camptorhynchus* and *Ochlerotatus notoscriptus*. Historically, *Cx. quinquefasciatus* and *Oc. notoscriptus* were known to be established in the North Island by 1920, *Oc. australis* was evident in the South Island by the early 1960s, and *Oc. camptorhynchus* was first detected in the North Island in 1998. All species have expanded their distribution variously in the years since their introduction, which it is reasonably assumed occurred through ports receiving international sea vessels or aircraft.

There should be little doubt that a number of other exotic species have been imported to New Zealand but, unlike the above-mentioned mosquitoes, have not yet managed to become established. The following species have been detected at/near seaports in recent years: *Ae. aegypti, Ae. albopictus, Cx. annulirostris, Oc. japonicus, Tp. bambusa*, and *Tp. tasmaniensis.*

In a selective sampling survey of insects on international aircraft entering New Zealand from Pacific rim countries over a 12 month period during 1998/99 (D. Farr, MAF, Auckland International Airport), a total of 134 mosquitoes (19% of total insects collected) was taken from 73 aircraft. The mosquito species included: *Ae. aegypti*, *Ae. nocturnus*, *Cx. annulirostris*, *Cx. australicus*, *Cx. quinquefasciatus*, *Cx. sitiens*, *Oc. vigilax*, *Oc. vittiger*, and a species of *Tripteroides*.

***The Situation Ten Years Ago - circa 1992***

In 1992, knowledge of the mosquito situation in New Zealand had been recently improved by surveys during 1988/89 (Laird, 1990) that revealed no new exotic species beyond the three previously known to be established – *Cx. quinquefasciatus*, *Oc. australis* and *Oc. notoscriptus* (Belkin 1968).

Following reports that mosquito larvae had been noticed in imported tyres at Auckland in 1992, a survey of samples of containerised tyres arriving in New Zealand from November 1992 to January 1993 revealed *Ae. albopictus*, *Oc. japonicus* and *Tp. bambusa* (from Japan) and *Tp. tasmaniensis* (from Australia), and imported tyres then became subject to inspection from February 1993 and mandatory fumigation from September 1993 (Laird et al., 1994). These findings also led to a more extensive survey from spring 1993 through autumn 1994, concentrating on container-type habitats, particularly tyres, but no new exotic species was found during that exercise (Laird, 1995). This perhaps confirmed the value of the recently installed measures targeting tyre imports, but there was still no routine surveillance programme in place at the ports to deal with introductions of exotic mosquitoes via other avenues.

***The Situation Five Years Ago - circa 1997***

During 1996-97, Dr B.H. Kay of the Queensland Institute of Medical Research, Brisbane, Australia, was commissioned by MoH to undertake a review of the New Zealand ‘programme for exclusion of exotic mosquitoes of public health significance’. He provided a comprehensive report of the risks for introduction of exotic mosquitoes, and the likelihood of their establishment and cause for public health concern in the various regions of New Zealand (Kay, 1997). He found a rudimentary and non-audited mosquito surveillance programme, and a general lack of expertise to deal with mosquitoes, their identification, monitoring and management. Aircraft disinsection covered potential importation to airports, and shipboard tyre imports were being fumigated, but other avenues of import to seaports existed and there was a particular border inspection deficiency with yachts. Additionally, with respect to both sea- and airports, it was clear that the New Zealand authorities were not fully complying with the IHR to which they were signatory.

Kay identified mosquito-borne disease scenarios associated with the introduction and local transmission of dengue (DEN) viruses, and Ross River (RR) and Barmah Forest (BF) viruses, principally because of the demonstrated laboratory competence of *Oc. notoscriptus* for the viruses, and he noted that introduction and establishment of a number of exotic vectors, *viz. Ae. aegypti*, *Ae. albopictus*, *Ae. polynesiensis*, *Cx.*

*annulirostris*, *Oc. camptorhynchus*, *Oc. japonicus*, and *Oc. vigilax* would be cause for concern.

Since the Kay report, *Oc. camptorhynchus* has become established at a number of sites in the North Island of New Zealand and is the subject of local eradication and containment programmes, and of the other species he mentioned, *Ae. aegypti*, *Ae. albopictus*, *Cx annulirostris*, *Oc japonicus* and *Oc vigilax*, have all been intercepted at New Zealand ports on at least one occasion.

At the time of the Kay review, the Crown Health Enterprises (CHEs) were not (with a few exceptions) undertaking routine surveillance for exotic mosquitoes, and those that were doing some surveillance were not carrying it out in a manner governed by recommended protocols, were limited by lack of appropriate training, and did not maintain adequate records and quality assurance measures.

The recommendations in the Kay report were intended *inter alia* to upgrade and formalise port surveillance activities, through provision of Ministry guidelines for surveillance and response activities, the provision of training for surveillance operatives, and the provision of a specialist resource for the identification of local and exotic mosquitoes.

# RESPONSES OF PUBLIC HEALTH SERVICES (PHS) TO MINISTRY OF HEALTH (MoH) REQUESTS FOR PORTS AND SOUTHERN SALTMARSH MOSQUITO (SSM) SURVEILLANCE PROGRAMMES

## 1. PORT SURVEILLANCE

During 1998-2000, the MoH issued guidelines and enhancement directives for the surveillance of exotic mosquito species. These indicated, *inter alia*, that the following species were not known to be established in New Zealand and were of public health significance: *Ae. aegypti*, *Ae. albopictus*, *Ae. polynesiensis*, *Anopheles* species, *Cx. annulirostris*, *Oc. camptorhynchus*, and *Oc. vigilax*.

The guidelines set out the rationale for exotic mosquito exclusion and outlined procedures towards that objective, including MAF inspection and notification responsibilities, and recommended surveillance activities to be undertaken by PHSs.

The recommendations for surveillance activities included:

(a) Ongoing ovitrapping, larval sampling and adult trapping in ‘high-risk’ locations, and sampling on a seasonal basis (October to May) in ‘low-risk’ locations.

(b) Surveys at least once per year in a 5km buffer zone surrounding ports and airports.

(c) Submission of all specimens collected during surveillance activities to the MoH taxonomy consultant (currently NZ Biosecure) by overnight courier.

(d) Larval habitats within the 400m zone of international seaports/airports be removed or treated with a range of ‘authorised’ mosquitocidal agents.

(e) A series of actions and timeframes for responding to interceptions, incursions and establishments of the exotic mosquito species.

***Regional Findings***

<u>Port of Napier (Hawkes Bay District Health Board)</u>

The port was relatively sanitary and offered few opportunities for imported mosquitoes.

Ovitraps (11) at the port were serviced weekly in summer and fortnightly in winter; the number and placement of ovitraps at the port was considered sufficient and appropriate, although one or two extra should be placed at nearby well-vegetated residential areas that could serve as harbourage sites for exotic mosquitoes leaving the port.

Ground surveys of container and surface larval habitats were undertaken occasionally, but these should become a monthly (at least) routine activity.

Adult traps (seven) were held, but not used routinely at port (or elsewhere), and adult sampling should become a part of the routine sampling with at least two traps rotated around the port on a weekly basis.

Species detected in the 12 months to March 2002 were *Oc. notoscriptus*, *Cx. pervigilans*, and *Cx. quinquefasciatus*. Larvae are sent to NZ Biosecure for identification.

Cooperation between the PHS and the Port of Napier Ltd appeared satisfactory for physical (source reduction) and chemical (ULV adulticiding) remedial operations in the event of an interception/incursion. However, there were access and legal enforcement issues with port tenants, lack of resources to cope with some habitats and others were thought to have no cost-effective solutions. The PHS should incorporate emergency procedures and practices into their contingency plan for an interception/incursion, and pass them through the port authority for recognition and approval so that operations will run smoothly when required.

The PHS had a 0.2 FTE for mosquito work, and maintained extensive documentation on their mosquito programme. This included an 'Exotic Mosquito Surveillance and Contingency Plan' that covered detection methods, including guidelines for ovi-/adult-trap surveillance, response procedures in the event of an interception that included details of stakeholders, a list of resources, bioprofiles on exotic mosquito species, a 'householder notice' and 'media release', and a report on potential habitat at the port (presented to the Port of Napier Ltd). The guidelines for ovitrap surveillance included appropriate treatment of paddles and pupae (unlike other PHSs), but did not cope with finding of immature larvae that were too young to be identified with certainty.

<u>Tauranga (Bay of Plenty District Health Board)</u>

The port was relatively sanitary, but a few tyres 'derelict' were observed lying about and should be removed. There was a number of large tyres positioned in the docks area (presumably to control traffic), and if these cannot be removed they should be filled with sand or cement to preclude mosquito breeding. Currently, sufficient tyre traps (21) were deployed appropriately at the port, and adult traps (three) were run continuously (although they reportedly broke down often because of the dusty conditions) for surveillance. Fewer tyre traps (perhaps 15) could be used if more adult traps (at least four) could be <u>effectively</u> employed throughout the port area.

The tyre traps were 'dipped' for larvae, but this is an inefficient technique and the tyres should be drained to better cope with the potential presence of low numbers and young stages of larvae. There was no evidence that ground surveys of container and surface pool habitats were undertaken routinely, although these were treated with the control agent *Bacillus thuringiensis israelensis* (Bti) during response activities. However, the use of s-methoprene has the benefit of not killing larvae which can be an advantage towards the identification of older stages and is thus recommended.

Larvae of the exotic species *Ae. albopictus* were found in an open-topped container holding refuse, including some tyres with water, from a ship ex Papua New Guinea in 1999. The container was treated, as was a delimiting area of 500m, and ovitraps were monitored for some weeks afterwards to ensure there was no local establishment. Larvae were sent to NZ Biosecure for identification.

The capacity of MAF to inspect and undertake immediate remedial action (with aerosol cans and 'pestigas' cylinders) appeared satisfactory, and MAF contacted the PHS within one hour of a finding; however, there was a concern for timely notification of 'risk platforms' moving between ports.

There should be a surveillance/control concern about the commercial areas bordering the docks, as these could provide container habitats that would be vulnerable to incursions of mosquitoes.

Whangarei (Northland District Health Board)

The Whangarei inner port was relatively sanitary; it receives mainly recreational yachts. The outer port receives large tankers but should be considered 'low risk'. The Bay of Islands ports (particularly Opua) receive 300-400 yachts and 30-40 cruise ships per year for 'first porting', and when visited independently by one of us (RCR) in February 2002 were also found to be relatively sanitary but deserve regular attention.

Ovitraps were not used for egg detection (checked for larvae only), but a sufficient number of tyre traps (18 sites) with drain holes were appropriately deployed and checked weekly (or fortnightly at the Bay of Islands). Typically, larvae that were collected were sent to NZ Biosecure for identification, although some young larvae were left in tyres to develop further - this is a risky practice and should cease. All young larvae should be removed for further development in the secure facility available at the PHS.

There were not enough adult traps available for port surveillance in the region. There were eight available and these were shared (run for one to three nights at a time) between the ports and the SSM programme, but at least two should be dedicated to weekly port surveillance on a rotational basis in Whangarei and at least one other deployed at Opua.

MAF reportedly have insufficient time during ship inspections to adequately deal with mosquito issues. PHS needs extra resources for someone to inspect the large numbers of yachts at Opua, and has very limited capability for incursion control (inspectors carry a 'kit' containing an aerosol pyrethroid insecticide for an initial response to positive containers) and would require involvement of commercial operators.

The Health Protection Unit has compiled an 'Exotic Mosquito Control and Exclusion Strategy' document which, despite including some minor errors of fact and interpretation (that were pointed out to Paul Reid), is a valuable compilation of strategic plans for surveillance and response, lists of stakeholders and resources, lists of equipment, and standard operating procedures for larval and adult sampling.

Auckland (Auckland District Health Board)

The Auckland seaports were found to be relatively sanitary. At commercial seaports, MAF undertake inspections of vessels and cargo and liaise with PHS, but the Ports of Auckland contract (entomologist consultant Gene Browne) for surveillance (with 15-20 ovi-/tyre traps). There does not appear to be any ground surveillance undertaken routinely and no routine adult trapping. According to PHS the seaport surveillance was not undertaken appropriately and was not reported in a correct (i.e. on recommended form) and timely manner; during a visit to the port only a few of the ovitraps could be located and the few tyre traps that were found were all dry. The current arrangement appears to be quite unsatisfactory.

Regrettably the Navy effort is somewhat erratic, the accountability for conducting surveillance is lodged with the Medical Branch but this organisation suffers from constant fluctuations in staffing that is reflected by a lack of continuity in surveillance effort. Its port should be considered to be vulnerable to incursions from the commercial ports, as well as having its own capacity to introduce exotic species, and it also has the only dry dock in Auckland and receives various international vessels for servicing.

The exotic species *Ae. aegypti, Ae. albopictus* and *Oc. japonicus* were intercepted at the seaport once or more during 1998, 1999, 2001. There were reports on the interceptions of *Oc. japonicus* and *Ae. aegypti* on 15/03/99 and 19/11/99, respectively. In the first instance the response reactions indicated there were issues to be resolved with respect to the relative roles, responsibilities and procedures of PHS and MAF. In the second instance all operations appeared to run smoothly although similar concerns were raised once more. Again, in April 2001, when live adults were noticed (but none collected) inside a shipping container that was promptly closed and eventually disinsected several days later by PHS, there was concern for the lack of a rapid disinsection response.

Other interception reports indicated that the responses in follow-up with delimiting surveys and control activities beyond the perimeter were appropriate. The PHS can initiate a larviciding response to an incursion but need to involve a commercial operator for adulticiding. In the event of an incursion, the PHS undertake monitoring with ovitraps and adult traps, extending for 400-700m from the port with checking every three to four days for six weeks, with six persons involved initially but reducing to two persons as negative findings continue. There is satisfactory cooperation with the local council for this surveillance.

Identifications of the above-mentioned exotic species were done by Mark Bullians (Entomologist, MAF Lynfield) and/or Gene Browne (Consultant Entomologist). Currently, identification of introduced larvae detected at the seaport is done within the PHS (by Dick Thornton) before sending on to NZ Biosecure, but there were no secure facilities for maturing larvae or rearing adults and this is not a satisfactory situation.

At the airport, the airfield and terminal areas were relatively sanitary (although there were some drains with *Typha* sp. and other vegetation) and would provide little habitat for imported exotic mosquitoes, but some ornamental ponds within the adjacent commercial area could become an issue if they became heavily vegetated and were not monitored. The Auckland International Airport Ltd arranged for surveillance by MAF (which liaises with PHS) with 38 ovitraps and 10 tyre traps serviced weekly in the summer and fortnightly in winter. Adult traps (four) were run occasionally by MAF but not routinely, and no ground surveys were undertaken routinely. No routine sanitation programme was undertaken for container or ground habitats. Air transport cargo containers were checked only randomly (perhaps 1-5% inspected) and generally go off-site for opening. It is highly advisable that ground surveys are undertaken on a routine basis and, if necessary, the number of ovitraps could be reduced to provide time for effective ground and container surveys.

Surveillance data were apparently kept, but were not provided at the time. It was reported that no exotic species have ever been found (although *Oc. notoscriptus* was recorded occasionally), but the servicing procedures for the ovitraps were quite inadequate with the paddles not being checked for eggs or appropriately flooded to hatch eggs in the traps.

The PHS would like to take over seaport and airport surveillance from MAF to ensure diligence and effectiveness. There would need to be 1 FTE (currently 0.5 FTE) dedicated to the surveillance programme but perhaps PHS could charge the ports for services as is done by MAF. The PHS considers its funding for mosquito surveillance to be grossly inadequate; the funding provided for SSM has to be used for the port responses and this allocation could disappear in response to a single interception. The PHS considers surveillance at the ports more important than the SSM concern, but because of a lack of resources may have to drop port surveillance if on-going SSM surveillance is required. In our view, if there is such a genuine conflict/competition for resources then a rationalisation of the number of ovi-/tyre traps could be made at both the airport and seaport - as long as the revised surveillance schedule can be an effective as well as practical programme.

<u>Christchurch (Crown Public Health)</u>

Lyttelton seaport appeared to be relatively sanitary, but there was a variety of potential container habitats available on the docks associated with local and imported tyres, vehicles, plant and machinery (including imports from Japan and elsewhere in eastern Asia). Surveillance was undertaken weekly, and a sufficient number of ovitraps (16) were deployed appropriately. Although there has previously been no routine adult surveillance (with some undertaken following interceptions locally or at other ports), a single ‘Trappens’ adult trap is now placed ‘permanently’. At least one more adult light trap, baited with $CO_2$, should be deployed at the seaport.

The airport appeared to be ‘low risk’, as flights were mostly from Australia (with very few from Asia/Pacific) and it was relatively sanitary. Surveillance was undertaken weekly and there were sufficient ovitraps (16) deployed appropriately, but no ground surveys were undertaken for container habitats or ground pool habitats on the airfield or in adjacent sheep paddocks. There were ‘Bland’ adult traps (three) available for surveillance but these are not used routinely; only a single ‘Trappens’ adult trap was positioned for routine surveillance.

Unfortunately, the monitoring devices were not being serviced appropriately - the ovitraps were not being correctly assessed for eggs and the tyre traps were not being drained for larval inspection. There was also a concern that the type of adult trap used is less than appropriate; it would appear to have some advantages (e.g. attracting day-biting species such as *Ae. aegypti* and *Ae. albopictus*) but there are no data to support its effectiveness compared with the traps used elsewhere (e.g. 'Bland' traps), and if retained it should be augmented with carbon dioxide as bait (this applies also for the seaport trap/s).

There were some data available for the ovi- and tyre traps, with *Cx. pervigilans* and *Oc. notoscriptus* larvae being recovered from both the sea- and airport, but no exotic species have been found. However, a moribund specimen of *Oc. vigilax* was discovered following disinsection of an aircraft arriving from Australia in early 2002, and this indicated a level of vulnerability for the airport.

Typically, specimens collected by Crown Public Health are sent to NZ Biosecure for identification. However, the *Oc. vigilax* mentioned above was found by MAF officers, identified by a MAF entomologist at Lincoln, but was not seen by NZ Biosecure. We do not endorse this last practice and believe that all exotics should be posted to and confirmed by a recognised taxonomic facility (e.g. NZ Biosecure). Fortunately, in general, MAF undertake inspections of cargo as required and specimens are sent to the MAF entomologists for identification, with the PHS being notified of the results and the cargo treated appropriately when required.

PHS staffing for mosquito responses could comprise up to 10 persons but equated to 0.25 FTE, and there was good support from MAF personnel and a MAF entomologist.

<u>Wellington (Hutt Valley Health)</u>

Both ports were relatively sanitary although the 'control' tyres maintained near the seaport provided an unnecessary risk and should be removed. An annual risk assessment was undertaken at the sea- and airport, involving adult trapping and ground surveys, and biannual surveys for 400m around the perimeters. However, these were not comprehensive as access to commercial premises was not always available.

Routine surveillance involved ovitraps (four) and tyre traps (nine) at the seaport, and tyre traps (six) at the airport. Numbers and placement of the traps were all appropriate, although the procedures for servicing the ovi- and tyre-traps were not entirely adequate. Two adult traps were used for annual surveys only, and usage of adult traps should be upgraded to two traps rotated weekly around suitable sites at both the sea- and airport.

The exotic species *Ae. aegypti* was detected at the seaport in 1998, and the port traps have produced *Cx. pervigilans*, *Cx. quinquefasciatus* and *Oc. notoscriptus* in recent years.

A total of six PHS persons could be gathered together in case of an emergency response, although the usual commitment to mosquito work was a 0.7 FTE. The interception response strategy and procedures, involving delimiting surveys, cargo trace-back, disinsection practices, response evaluation, and supporting documentation, all appeared appropriate, but the prospects of dealing adequately with a local incursion were considered to be daunting.

The ports were seen as a major issue for the PHS. An extensive amount of documentation on the activities associated with the programme appeared to be well maintained. A comprehensive 'Regional Strategy Plan for Mosquito Surveillance and Response' had been drafted, and the PHS maintained a good relationship with MAF, the airport authorities and Centreport Ltd at the seaport.

New Zealand Biosecure Laboratory (National Exotic Mosquito Response Service (NEMRS))

The laboratory provides the national identification service for mosquito specimens submitted by the regional PHSs, a national database for the mosquito collection data in a standardised format, and a facility for training HPOs in surveillance activities. Additionally, it provides an on-going eradication programme against *Oc. camptorhynchus* on the east coast of the North Island of NZ, and a specialist capability to respond to interceptions elsewhere (ably confirmed with their response to the finding of *Oc. camptorhynchus* at Whitford near Auckland in March 2002, and their control and containment programme against *Oc. camptorhynchus* in the Kaipara following its detection there in February 2002).

The taxonomic service is conducted by trained personnel with demonstrated expertise, and has an international specialist confirmatory service provided by the Department of Medical Entomology, University of Sydney at Westmead Hospital, Australia.

NZ Biosecure concerns were for delays in receiving specimens from PHSs, particularly when there were attempts at identification within the PHSs, and when such samples were screened by the PHSs these results were not provided to Biosecure for verification and feedback. Additionally, Biosecure often received preserved immature (first and second instar) or damaged larvae that could not be identified with certainty.

Overall, there is a lack of a national standardised approach to surveillance and sampling, and data reporting and storage, although Biosecure prepare a quarterly report for MoH on the surveillance activities by region, and this is seen by the Technical Advisory Group (TAG). Unfortunately, the MoH quarterly reports do not clearly delineate the 'Nationwide Survey' from the SSM Response, and do not provide sampling method and efforts (e.g. number of trap nights, number of ovitraps). Within port surveillance, ovitraps and sentinel tyres need to be distinguished from light trap collections in separate tables. As the number of larvae in an ovitrap/tyre is not as important as presence/absence, we would prefer to see the number of ovitraps positive for larvae by species, along with the sampling effort involved (i.e. number of ovitraps set, number of weeks operated).

***Comments, Concerns and Conclusions***

Ministry of Health Guidelines

The MoH guidelines appropriately set out the reasons for maintaining mosquito surveillance at seaports and airports, with respect to national public health concerns and the IHR. They recommended surveillance practices, but there was little evidence that most PHSs undertook surveillance as recommended, particularly with respect to sampling of adult mosquitoes at ports.

Unfortunately, the guidelines did not adequately detail the procedures for servicing ovitraps and tyre traps. There was little knowledge amongst PHS operatives that eggs on paddles must be hatched as part of the surveillance procedure, either by removal for flooding or by flooding *in situ.* Additionally, there was a lack of awareness that detection of larvae hatching from oviposition in sentinel tyres should be undertaken by draining the water from the tyre and not by scooping (which is too likely to miss young larvae or low densities of larvae). If there is concern that tyre-traps may be potential or actual producers of mosquitoes (local or exotic) at sea- and airports, granules or pellets of the insect growth regulator s-methoprene could be placed in the tyres to prevent the production of adult mosquitoes (while maintaining live larvae for identification).

The MoH guidelines also clearly set out the requirement for active anti-mosquito measures within 400m of the port environs or airport perimeter, in accordance with the requirements of the IHR. However, we were not convinced that anti-mosquito measures other than surveillance were being undertaken at most ports. Certainly, most ports were in a relatively sanitary condition, but there was little evidence of active measures on the part of most PHSs to undertake routine inspection of container, sump, drain or surface water habitats within the ports to detect and eliminate breeding of exotic or native mosquito species.

The MoH guidelines also sought to provide for appropriate responses to interception and incursion detections. In general terms we have no objections to the tenets and timelines contained therein, and we recognise there needs to be room for some flexibility for PHSs to work within their separate jurisdictions. As far as we could discern, the procedures and time-frames for the various actions required for a response to an incursion were being followed in general terms by the PHSs, wherever local action had been required or where response plans had been prepared for the event of an incursion.

Port Surveillance

Monitoring equipment (egg-, larvae-, adult-traps) and operating procedures could become relatively standardised - ovitraps, tyre traps and dry ice-baited light traps need not necessarily be absolutely identical (although that would be highly desirable), but the operating protocols and critical servicing procedures should be uniform. For details see “***Recommended Standardised ‘Best Practice’ Procedures for Vector Monitoring at Ports”*** (Appendix 1). There should be a greater inclusion of adult sampling in routine surveillance programmes, and the record keeping for surveillance at seaports and airports must be upgraded.

NZ Biosecure should become the agent for training, and for the provision and maintenance of the standardised equipment if such usage is decided.

The disparate responsibilities for port surveillance and specimen identifications should be resolved towards a national uniformity of approach. Additionally, data collection should be centralised, notwithstanding collection and collation regionally/locally. There is value in centralising the identifications with a specialist expertise, despite the risk of losing the national expertise if the consultant company collapses or lose its major sustaining activity (e.g. SSM surveillance/management). PHSs should not be responsible for ultimate identification of exotic species. The question of PHSs screening samples before sending suspect specimens to NZ Biosecure has to be resolved with respect to the issues of local 'ownership', the quality of the result and dissemination of nationally relevant data, and a capacity for the PHS to hold immature larvae until they reach an identifiable stage ($4^{th}$ instar) before sending to NZ Biosecure. These issues vary with each PHS. Additionally, in some places (e.g. Christchurch), MAF have taxonomy resources and do not notify the PHS/MoH of the detection of an exotic specimen until its identification has been completed by the MAF entomologist, and there is no arrangement for the specimen to be seen and confirmed by NZ Biosecure or their consultant specialist.

There needs to be a formalisation of the requisite response activities between PHSs and local authorities, MAF and commercial operatives. The 'national' Memorandum of Understanding (MOU) between MoH and MAF must ensure appropriate and adequate surveillance, effective communication, and provide for an appropriate and effective national response to interceptions and incursions. Additionally, 'local' MOUs should be developed also between local PHSs, local port authorities and MAF to detail local responsibilities for surveillance and to formalise incursion response plans.

Disinsection of aircraft and inspection of incoming cargo is under the control of MAF, and there is no reason to suspect that it is not being done effectively (although it was mentioned that in some ports there is only a limited amount of time available for MAF seaport inspectors to devote to mosquito searching). The most important method of introduction of container-breeding mosquitoes, the international trade in used tyres, should present little concern for New Zealand. Currently, all used tyre imports are identified and fumigated routinely. However, the current use of methyl bromide for fumigation is somewhat under question internationally and if this treatment was to become unavailable then a proven alternative must be utilised (Bill Crowe and Brian Read of Australian Quarantine and Inspection Service indicated that no proven alternative is currently available). General cargo, particularly vehicles and plant and equipment, appears to be the major concern for mosquito import and these appear to be well inspected on a routine basis. However, the large numbers of "de-vanning" sites in various cities (e.g. reportedly >400 sites in Auckland) could be of concern where the contents of shipping-containers from seaports and airports are not correctly notified.

Incursion Responses

The MoH guidelines' attempts to provide for appropriate responses to interception and incursion detection appeared to have been accorded due acceptance in principle by the various PHSs, although the detail included in the Regional Response Plans we saw did vary extensively. Most impressive were the Hawkes Bay DHB's 'Exotic Mosquito Surveillance and Contingency Plan' that closely followed the MoH guidelines, and the Hutt Valley DHB's 'Regional Strategy Plan for Mosquito Surveillance and Response' that was an impressive document and provided very extensive detail that would allow an appropriate response. Where incursion responses had been undertaken (e.g. Auckland, Tauranga and Wellington), they were undertaken in a generally appropriate and timely fashion, if not exactly as prescribed by the MoH guidelines. We consider that while time-frames for response actions are important (and in some instances critical) for appropriate responses to prevent establishment of an exotic mosquito outside the immediate port area, there appears to be little reason to demand a national blueprint that might not take adequate account of local operational considerations - providing there is continuing evidence of appropriate and timely responses following interception and incursions.

In some places, the capability of local PHSs to undertake appropriate responses in a timely fashion has yet to be demonstrated, and the fluidity of the interactions with the various local authorities that will be required have yet to be tested. To this end the establishment of local MOUs (as mentioned above) and protocols will be critical.

Is there a need for standardised protocols for port surveillance and incursion response?

In our view there is a strong case for MoH insistence on relatively standardised equipment and protocols for surveillance at airports and seaports. Equipment selection, procurement and disbursement should be the responsibility of MoH (or NZ Biosecure as its agent), and the protocols could be drawn up from the ***Recommended Standardised "Best Practice" Procedures for Vector Monitoring at Ports*** (Appendix 1).

Whether a standard protocol for responses to incursions is required is less certain, at least with respect to the detail to be included. Although we would recommend that there is a necessity for the various actions to be completed within a timely fashion, and we agree in general with the actions and time frames set out in the MoH guidelines, we feel there needs to be some flexibility to cope with local circumstances, such as the scope and operational aspects of the port and surrounding urban areas, and the competing interests of the various stakeholders. We emphasise, however, that careful consideration of control strategies be undertaken, with a view towards using residual products such as s-methoprene (pellets or granules) and aerosol pyrethroid insecticides to respectively treat potential containers and harbourage areas near the interception (see Ritchie et al. 2001a,b). However, given that we have recommended the establishment of local MoUs between PHSs and local authorities and other stakeholders, and that any MoH-issued standard protocols would need to take these into consideration, we generally endorse the response measures and time frames currently promulgated in the MoH guidelines.

Taxonomy Facility

We have few reservations about the capability of NZ Biosecure to service the Surveillance programmes adequately, and generally speaking they are providing a commendable service.

However, there are some issues that should be resolved:

(i) The submission of preserved first and second instar larvae for which identification will be uncertain or impossible because of their immature stage of development - NZ Biosecure should collect/construct descriptions/diagrams of immature larvae of local mosquitoes (at least the common species) so that exotic species can be better detected (even though the identification of immature exotic larvae may remain uncertain).

(ii) The lack of adequate access to scientific literature - the Medical Entomology laboratory of the University of Sydney is assisting with provision of relevant literature, but computer assisted access to local and international journals through a New Zealand University library should be sought as a priority objective.

(iii) The delays in getting specimens and data from the PHS routine surveillance activities.

(iv) The lack of a national standardised approach to data collection, reporting and storage.

(v) The lack of reference of specimens collected by MAF and identified by MAF entomologists to NZ Biosecure for sighting and confirmation.

(vi) Although the respective PHSs were happy with the general service and turn-around-time for the identification service provided by NZ Biosecure, many considered that filling in the required forms was too time-consuming and involved unnecessary duplication / repetition that could be eliminated if NZ Biosecure could maintain details of the sites and receive only the simplest collection details.

(vii) The ‘short-term’ duration of the contract with MoH hinders forward-planning and investment and, in particular, places the retention of trained staff in some jeopardy. NZ Biosecure needs to be maintained and sustained to provide an on-going expert capability in mosquito identification, surveillance and control, training activities for PHS and other interested personnel, and the provision and maintenance of recommended or standardised surveillance equipment.

Quality Assurance

MoH should require copies of local MOUs and the associated surveillance and incursion response plans from the PHSs, and (if local circumstances allow) in a format that will allow a comparative assessment for effective auditing. Additionally, PHSs should be required to provide directly to MoH their monthly surveillance data in a standardised spreadsheet format, and these can be compared with the monthly data reports received from Biosecure. PHSs should also be required to provide MoH with an annual summary report that can be audited against a similar report required from Biosecure. With respect to interception responses, the PHSs should provide to MoH individual detailed reports of the activities and time-frames that pertained when each interception or incursion was followed up as directed.

With respect to maintaining quality assurance of the surveillance activities at the various ports, aside from the ‘planting’ of particular larvae (a non-exotic species but perhaps one not usually found in container habitats) to check for effectiveness of detection, which may occasionally be desirable but perhaps difficult to arrange, we suggest that audits be undertaken biannually of the relevant PHS records along with the associated NZ Biosecure records for comparison. Consequently, it is important that all specimens that might be identified by any local public health staff with appropriate training be promptly forwarded to NZ Biosecure for confirmation.

With respect to the taxonomic services, we suggest that NZ Biosecure should receive occasional samples of larvae and adults ‘spiked’ with dead exotic (and perhaps unusual local) species so as to audit the quality of their identification services. We believe this procedure will provide for an educative process that goes beyond a quality audit, and as such is strongly recommended. We do not believe that this should be done without the consent of NZ Biosecure, and Steve Garner (Manager, NZ Biosecure) has indicated he is amenable to such an occasional process for overall quality assurance.

## 2. SOUTHERN SALTMARSH MOSQUITO SURVEILLANCE

***Routine SSM Surveillance by PHS's***

The detection of large populations of the Southern Saltmarsh Mosquito (SSM) in brackish habitats near Napier in 1998 generated an extensive eradication campaign to prevent its establishment in NZ (Garner et al. 2001). The SSM can disperse tens of kilometres (Lee et al. 1984), is a very efficient vector of Ross River virus (Russell, 2002) and also involved as a vector of Barmah Forest virus (Russell and Dwyer, 2000). Many coastal areas of New Zealand would be under threat of outbreaks of RR disease should the SSM become established (Kelly-Hope et al. 2002).

This sections details surveillance programmes for the SSM, highlighting deficiencies and outlining methods of improvement. The 'Snapshots' of situations 5 and 10 years ago are not really relevant as the SSM was not present then, although clearly the preparedness for general mosquito surveillance and control have improved markedly since the arrival of the SSM.

Upon the recognition of the SSM at Napier in New Zealand in 1998, the MOH sent a request for enhanced surveillance for SSM to PHSs across New Zealand. These requests entailed sampling suspected habitat by larval dipping and light trapping after king tides or heavy rain. A GIS-derived map of suspected saltmarsh habitat was produced by Landcare and distributed to the PHSs. Three populations of SSM have been found post-Napier using this approach: Gisborne, Whitford east of Auckland and in the extensive Kaipara Harbour north of Auckland. The later represents the most serious incursion, with several populations of SSM found along either side of this large inlet. Extensive mosquito control has begun in the area by NZ Biosecure. But clearly the spread and magnitude of SSM breeding in the Kaipara indicates that the surveillance programme did not successfully detect SSM before they had spread throughout the region. This section details the strengths and weaknesses of the SSM surveillance programme. The surveillance methods employed by the PHSs visited are summarised in Table 1.

<u>Identification of High-risk Areas</u>

Land-care New Zealand produced a GIS-based map of habitat likely to support SSM breeding that was used by all PHSs interviewed. This map, derived from a combination of satellite data and ground-truthing, basically showed areas that were subject to inundation by high tides. Thus, most of the habitat consisted of low marsh dominated by mangrove with scattered *Juncus* and *Sarcocornia* marshes. Surveys of the Gisborne, Napier and Kaipara areas by NZ Biosecure indicated that much of the SSM breeding has been inland of these areas, with significant breeding in stock paddocks and disturbed land adjacent to but above the saltmarsh. Clearly, the Landcare map did not directly highlight areas with the highest risk of SSM breeding. Rather, it identified low marsh that was subject to too much tidal inundation to support SSM breeding. However, adjacent low areas inland of these sites could be productive and should be targeted for SSM breeding. Fortunately, most PHSs realised this shortfall.

**Table 1. Methods employed by New Zealand PHSs to survey for SSM.**

| | NZ Biosecure (includes Napier, Gisborne) and Hawkes Bay PHS | Auckland | Bay of Plenty | Northland | Hutt Valley | Christchurch |
|---|---|---|---|---|---|---|
| Identification of SSM habitat | Landcare map, aerial survey, ground survey, GPS, GIS mapping | Landcare map, Limited ground survey, GPS/GIS mapping | Landcare map, ground survey, aerial photos | Landcare map, ground survey | Landcare map, aerial survey, ground survey, GPS, GIS mapping | Landcare map, ground survey, GPS/GIS |
| Monitoring of trigger events | Rain gauges, local sentinels | Tide charts, NZ Biosecure | Rain gauges, local knowledge | Local knowledge | Local knowledge | Local knowledge |
| Larval surveys | Routine monitoring, aerial and ground by experienced, trained staff | Ad-hoc; part-time student; NZ Biosecure has taken over in Kaipara &, in part, Whitford | Routine ground surveys by 2 fulltime students | Ground surveys upon flooding; 3 staff + 1 in northern marshes. (1 person also at Kaitaia but area too large to sample adequately) | Annual ground survey by 2 staff 5 days after flooding rain or tide | Four ground surveys/year 5 days post flooding – tide or rain by 2 staff. |
| Adult surveys | Routine sentinel light traps, $CO_2$ + octenol; several standard light traps; trap new areas. | Ad-hoc; variety of traps, dry-ice limiting and sometimes not used; NZ Biosecure has taken over | Routine sampling by 3 sentinel light traps with $CO_2$ | Trap 10 days post flood 3 nights; $CO_2$ + octenol; traps rotated with sites at ports | Limited trapping after flooding; 2 traps set for 3 nights with $CO_2$ | No adult trapping of saltmarsh |

Most PHSs identified high-risk areas on foot, using the Landcare map and HPOs or unskilled labour (Table 1). This process was largely ad-hoc and dependent upon the experience of the field crew. A+ in Auckland employed a part time student during the summer. The Bay of Plenty PHS used students (2 at any one time) to conduct ground surveys. Those who had helped with the Napier and Gisborne programmes (e.g. Bay of Plenty) undoubtedly benefited from the experience. This method could be useful in identifying disturbed areas that do not contain classic saltmarsh habitat but are capable of breeding SSM. Some PHSs mapped high-risk sites, employing a hand held GPS to reference location, even taking digital images of suspected sites for field reference (e.g. Hutt Valley). Calibration problems with GPS were described for the helicopter survey conducted in the Auckland region.

Based upon the site visits and discussions with PHSs and NZ Biosecure staff, several areas represent a high risk for introduction and establishment of the SSM. These include the saltmarsh habitat near Auckland (including Manukau Harbour as well as isolated habitats in the Kaipaira and east of Auckland including the Whitford area where SSM was recently found), the northern marshes of northland, and the Bay of Plenty, especially barrier islands near Tauranga.

<u>Monitoring of SSM Triggering Events</u>

The SSM, along with its close relative, *Oc. vigilax*, are, in essence, floodwater mosquitoes. Eggs are laid in moist soil along the edge of depressions or pools. These may be anything from a large, hectare size pond, a clogged drainage ditch, a hoof print, or even a flat area with slight relief that allows water to pool when flooded. Note that with the SSM, these are typically high (salt) marsh sites, but also include nearby brackish and freshwater pools, especially if livestock are present. Eggs are ready to hatch after a 3-4 day maturation process that hardens the chorion. This eggshell is desiccation-resistant, enabling the eggs to survive dry periods for up to several months. Inundation of previously dry pools by flooding tide and/or rain results in synchronous hatching of saltmarsh eggs, creating large broods that typically emerge within 7-10 days in summer but longer in winter.

Thus, the presence of larvae and pupae is usually restricted to a few periods following inundation of a dry marsh by an exceptionally high tide or heavy rain. These flooding events can be termed SSM triggering events, and their sporadic nature implies that they must be carefully monitored for timely detection of SSM broods.

SSM triggering events were not systematically monitored by the PHSs. No tidal data were recorded. Tide charts were often relied upon, backed up by observations of flooding in local marshes (so called “local knowledge”). For some, this consisted of consulting residents or even NZ Biosecure. Unless the height of a triggering tide is known, the tide charts are of little help beyond pinpointing the likely highest tides of the year. Most mosquito control programmes elsewhere that target saltmarsh mosquitoes measure tides and know the minimum height to flood mosquito habitat. Rain gauges were employed by some PHSs but, overall, measuring of triggering events was not undertaken and PHSs generally relied upon local observations. For a PHS with limited staff/resources, this is adequate provided the observers are located near high-risk sites, prove to be reliable, and employ appropriate equipment (eg., rain gauges) and quality observations. Nonetheless, we recommend that some form of formal data be collected to prevent being reliant upon, and provide a backup to, "local knowledge".

SSM Surveillance: Larval Sampling

Most ground surveys for SSM larvae have employed acceptable sampling methods, such as dippers, although sample size could have been increased at dip sites. However, because triggering events were not always recognised, timing of surveys was likely amiss. Clearly, the extensive SSM breeding now recognised in the Kaipara suggests that little in the way of extensive appropriate ground surveys were conducted in the Auckland area. Thus, the wetlands associated with Manukau Harbour south of Auckland are a concern.

Obviously, much of the saltmarsh habitat is remote, requiring off road transport using boats or helicopters. The time and expense of doing so likely has prevented a timely and full assessment of SSM breeding in New Zealand following the detection of SSM in Napier.

Some of the PHSs (e.g. Bay of Plenty) had conducted extensive routine surveys of marsh areas but their resources could have been better-spent conducting surveys after triggering events.

Larval samples sent to NZ Biosecure were delivered and processed adequately. However, many of the larvae were too young to accurately identify. MoH will have to develop a procedure for rearing larvae to $4^{th}$ instar for identification. Paul Reid of Northland addressed this issue by rearing larvae in a secure room. Furthermore, screening of samples by PHS staff delays the system and may damage delicate specimens, resulting in errors. Until the MoH is confident in the training and skills of these staff, we cannot recommend this procedure.

NZ Biosecure clearly had the best SSM surveillance programme. The use of a specialist, well-trained unit focussing strictly on mosquito control has enabled NZ Biosecure to develop the expertise and organisation skills necessary to locate and successfully treat SSM despite the isolated nature of SSM populations. High-risk saltmarsh sites were identified from aerial photos and helicopter surveys. These were then inspected on the ground. To monitor rainfall, residents living near the site were given a rain gauge and contacted by phone to obtain timely rainfall data. While no tide gauge data were used, residents living near high-risk sites provided observations on sentinel marshes. While such a programme is not quantitative and is prone to 'subjective error', it does provide timely, local information on marsh flooding. Finally, the residents used were largely farmers who know their property intimately and routinely keep an eye on it. This method may be inadequate in remote areas, especially barrier islands. Fortunately, most coastal areas of the North Island are well populated. Again, NZ Biosecure would benefit from more intimate measuring and knowledge of tides.

Because the SSM can travel far on the wing, and can inhabit inland brackish swamps (eg. Mildura ca. 363 km inland (Lee et al.1984)), inland brackish swamps should not be overlooked. Hutt Valley PHS should be commended for identifying and inspecting saline pools inland of Wellington (they were negative), and the Landcare map indicated similar areas in the Central Otago region of the South Island.

In summary, larval surveys were neither timely nor thorough enough to cover most of the potential SSM habitat. This reflects limited resources, both in personnel and money, for the proper conduct of thorough surveys. The lack of expertise, coupled with the multiple responsibilities of HPOs, also hindered their efforts. Furthermore, the remoteness of many sites prohibited easy surveying. *The MoH should not be fooled by colourful GIS maps. While the use of GPS/GIS systems is admirable, and delivers a pretty, high-tech image, the adage 'garbage in - garbage out' applies. There is no substitute for competent ground surveys.* And clearly not all appropriate habitat has been recognised and adequately surveyed for SSM. The uneven quality of the SSM surveys that the different PHSs have provided to date raises the risk that other cryptic breeding sites may exist.

SSM Surveillance: Adult Trapping

Most PHSs conducted some form of adult trapping, using a variety of methods. While most mosquito traps were employed correctly, the relatively limited number set indicates that coverage, in time and space, was relatively poor. In response to the MoH surveillance directive in 1999, the Auckland District Health Board gave light traps baited with only octenol to school children in rural areas north of the city. Traps were presented to 8-9 schools for trapping over 4-5 months. Octenol, by itself, is not attractive to mosquitoes (Kemme et al. 1983). Thus, this was clearly a public relations exercise, and a waste of time and resources. Ironically, a larval survey detected SSM in the nearby Kaipara in Feb. 2001.

Other PHSs used a few sentinel traps that ran for several days before sample collection. While this may adequately reflect mosquitoes at nearby sites, it may not help delimit the population. Sentinel sites are fine if high-risk sites are limited, or to monitor sites with a history of SSM production. But locating new foci of SSM requires expanding the search into new areas. Clearly, most PHS need more traps set at more locations, especially unexplored ones near high-risk areas. Again, new areas with SSM could still await discovery.

Finally, there were problems with trap procedures and access to $CO_2$, especially dry ice. Dry ice was only available in major cities and transport logistics, including courier service, were expensive. There is room for provision of standardised traps, along with trapping procedures. NZ Biosecure should develop a training course incorporating a MoH approved protocol for SSM surveillance for PHS staff. They should also consider being the lead agency for procurement of mosquito surveillance and control materials. Nonetheless, because of the difficulties in adequately sampling wetlands for SSM larvae, an emphasis should be placed upon adult trapping to locate SSM in novel areas.

Data Analysis, Record Keeping and Reporting, and Overall Performance

Most PHSs sent surveillance data to NZ Biosecure for compilation. A quarterly report was then prepared and sent to the MoH. PHSs maintained files of records and most produced annual reports summarising their efforts and findings. Most were quite useful (e.g. Hutt Valley) but the lack of a standardised approach limited their broad application.

The MoH quarterly reports are valuable information and a great aid to keep everybody up to date. However, the headings for SSM Response and the Nationwide Survey are different and may cause confusion. The ‘Nationwide Survey’ should be clearly delineated from the SSM Response, and there should be a separate section on ‘Seaport and Airport Surveys’ where appropriate. Furthermore, the Nationwide Surveys do not provide sampling method and efforts (e.g. number of trap nights, number of ovitraps). For the SSM response, quarterly reports would be better served if the table of surveillance included the number of sites sampled and the number of sites positive for SSM.

A map of the areas inspected should be provided, showing sites positive for SSM larvae and adults. This would be especially important to highlight new foci and the current distribution of SSM (perhaps the latter can be done in an annual report), along with treated areas.

Overall, the SSM surveillance programme conducted by PHSs, despite great efforts on the part of most, has been inconsistent and generally inadequate. New foci of SSM have been found, but the extent of SSM in the Kaipaira reflects the inadequacy of surveillance efforts in the area. This is not all the fault of individuals running the PHS mosquito programmes. As discussed in ‘Proposed SSM Surveillance System’, surveillance for something that “probably isn't there” - and lives in remote and often inaccessible areas - is exceedingly difficult. More importantly, it is very time demanding. The multiple responsibilities of the environmental health branch of PHSs, from shellfish monitoring to restaurant inspections, leaves little time for comprehensive SSM surveys.

The urgency of the situation - the need to respond - forced PHSs to undertake surveillance despite being inexperienced with mosquito work, inadequately trained and under resourced. This has created scenarios such as the octenol traps in north Auckland and ad-hoc marsh surveys by keen but undertrained students. The situation is exacerbated by the difficulty of the survey work in remote areas. Staff turnover and loss of ‘institutional memory’ was also as a problem identified by some PHSs. It comes as no surprise that surveillance and control activities have been taken over by NZ Biosecure in some areas.

It should also be noted that Hawkes Bay PHS must plan for starting surveillance for SSM in the Napier region once the Biosecure ‘eradication contract’ concludes and the current surveillance stops.

*Critique of MoH Guidelines*
## *"Environmental Health Protection Manual, Section 5 Biosecurity"*

This manual outlines general responsibilities, procedures for surveillance and sampling of mosquitoes. Regulations and laws are clearly defined. Appendices 1-2 describe sampling methodology including larval dipping, ovitrapping and adult trapping.

The section on incursion response (section 5.3) clearly identified timeframes, roles and responsibilities should an incursion of an exotic mosquito occur. This Incursion Action Plan is very thorough and is commended. Incursions of SSM are distinguished from container and freshwater breeding species. Table 5.3 outlines appropriate zones for surveillance and control.

A shortcoming of the manual is that it does not spell out specific plans for SSM surveillance and eradication. Most of the procedures are combined as 'Exotic Mosquitoes', which blurs the distinction that must be made when monitoring and controlling mosquitoes at a port vs a SSM scheme in marshlands. A separate SSM Surveillance and Control Strategy should be developed (it is, in practice) and included in updated MoH guidelines.

Finally, the manual is quite heavy going, with a predominance of bureaucratic regulations and language. A user-friendly version for field staff should be made and incorporate a key and photographs of habitats typical of different species, dippers and traps, colour plates of exotic species of concern and common local species. The key could include photographs or drawings and should be of 4$^{th}$ instar larvae and adult females of common NZ species and high-risk exotics such as *Ae. albopictus* and *Cx. annulirostris.* NZ Biosecure would be best suited to produce this, in collaboration with MoH. An interactive CD could be produced, and used in a general training course. A poster containing common New Zealand species, along with high risk exotics (e.g., *Ae. aegypti, Ae. albopictus* and *Oc. camptorhynchus*), could be produced for PHSs and MAF with the assistance of the Medical Entomology Dept. at Westmead Hospital, NSW (Mr. S. Doggett).

Other specific comments:

Appendix 1, Sampling methodology:

Section 1.2, Larval Sampling. Larvae sampled for ID should be 4$^{th}$ instar if possible. Otherwise, they should be collected live and reared to 4$^{th}$ instar in trays containing a pellet or granule of s-methoprene. Only facilities with in an approved, secure enclosure should rear larvae to adults.

Section 1.2.1 Ground Water Habitats. Granted it is important to traverse the entire pool edge. But why determine the source of water in a pool by entry and exit points? This is very impractical. Monitoring of rain and tide should tell you mechanism of flooding Also, SSM will breed in the pool regardless of how it was flooded.

We are concerned about the use of permanent sampling points. For SSM hunting, it is better to thoroughly hunt for larvae around the edge, and to watch the water for larval movements. Sampling permanent points runs the risk that technicians will only sample those points, and not take time to search new areas - distribution of SSM larvae in open pools is influenced by wind and water movement. In heavily vegetated water bodies and pastures, SSM may be hidden by/amongst marsh plants or grassy sods. In tidally affected areas, sampling also needs to be coordinated with rainfall events as well as tides.

Section 1.3: Adult traps

Section 1.3.1 An insulated metal bucket for dry ice is not essential, dry ice wrapped in newspaper and placed in a ziplock plastic bag securely shut with tape or string. One-two small holes can be made in the bag with a pen or pencil. The bag can then hung above or next to the top of the trap.

Section 1.3.2.d: For SSM, we recommend baiting traps with $CO_2$ and octenol if possible/available, using a vial with a pipe cleaner wick (Van Essen et al. 1994).

Section 1.3.2.i: check battery; could be 'flat' or hooked up incorrectly.

Section 1.4 Assessment of the variables listed (dispersal, availability of nectar sources, hosts, light, etc.) is beyond need for general surveillance. Simple notes such as "next to cow paddock, wooded site, GPS coordinates" are all that is needed beyond basic trapping date, and location data. The 1st two paragraphs of this section seem redundant.

Again, separate ovitrapping and tyre traps into a separate section from light traps.

Section 1.6: Emphasise collection of 4th instar, or collection of live younger instars that can be reared to 4th instar in trays treated with a granule or pellet of s-methoprene. Rearing larvae to adults will require a secure facility approved by MoH and MAF.

### *Final Comments on SSM Surveillance and Control*

The ability for SSM to disperse and rapidly increase in numbers necessitates a complex, comprehensive surveillance and control programme. Furthermore, the surveillance programme cannot be done in isolation from a control programme - if eradication is the goal. Thus, the complexity of the programme outlined requires experience and skill, in addition to adequate researching. In our history with mosquito control programmes, these demands can only be effected by a dedicated mosquito control organisation. NZ Biosecure has proven with the Hawkes Bay SSM eradication effort that it is capable of running such a programme. However, NZ Biosecure's expertise should be coupled with the local knowledge and logistical advantage that PHSs offer. Thus, it would be advisable for PHSs, if they are keen to do so, to continue to conduct SSM surveillance work, augmented by training and collaboration with the MoH and NZ Biosecure. This allows the PHSs to retain some expertise in mosquito monitoring in the advent, albeit unlikely, that NZ Biosecure would "disappear". However, NZ Biosecure should be called in whenever SSM is found as only they have the necessary expertise and resources for the appropriate interventions.

The security of NZ Biosecure should be improved. NZ Biosecure is constrained by short, annual contracts. The lack of long-term job security increases the risk that staff - well-trained and experienced - will move on to more secure employment. This should be avoided at all costs by ensuring that NZ Biosecure has a more secure future with longer contracts. Additionally, privatisation of mosquito control has been successfully employed in the USA (Clarke's Mosquito Control). The MoH should consider expanding NZ Biosecure's role to encompass SSM surveillance and control in positively identified and potential high-risk areas, particularly the Auckland and Bay of Plenty region, in collaboration with existing PHSs.

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# APPENDIX 1.

## *Recommended Standardised Guidelines and 'Best Practice' Procedures for Vector Monitoring at Ports*

There are two separate components of a programme to exclude exotic mosquitoes; both should be recognised as critical and both should be well-maintained:

(i) inspection and disinsection of vessels and cargoes to deter incursions of exotic species and

(ii) surveillance of mosquitoes at and near seaports and airports to detect incursions of exotic species of concern for import or any presence of local species of concern for export.

**(i)Vessels and cargo inspection/disinsection**

The inspection of sea vessels arriving at seaports and the disinsection of aircraft arriving at airports, and inspection of their high-risk cargo, are the first lines of defence against importations of exotic mosquito species.

**(ii) Port surveillance**

The monitoring of mosquito populations at seaports and airports is the backup defence against importations of exotic mosquito species.

There is a voluminous literature on mosquito sampling, summarised by Service (1993) who described the many and various techniques for sampling eggs, larvae and adults. The generic monitoring methodologies currently employed variously across the range of seaports and airports are egg-traps (ovitraps), larval-traps (ovitraps and sentinel tyres), larval surveys (ground pools and receptacles) and adult-traps (dry ice-baited light traps), and all are acceptable but not stand-alone techniques.

There are a number of questions and issues that cloud considerations of the procedures that could be recommended for standardised monitoring. For instance, should there be a national standardising of a surveillance system with consistency of equipment and methodology at all ports or should a variety of methods be available and selected to suit the local circumstances? Notwithstanding the decision, there should be detailed guidelines with stepwise instructions for the various monitoring methodologies.

**Egg sampling**

For the detection of *Ae. aegypti* at airports and seaports, the standard practice advocated by WHO (1972) has been the deployment of ovitraps, and these sentinel habitats will also attract *Ae. albopictus* and other container-breeding mosquitoes introduced to the port.

However, if ovitraps are used routinely as larval traps (i.e. there is no assessment of eggs on paddles), and *Ae. albopictus* is a target species, then sentinel tyres should be used in parallel with ovitraps (perhaps eventually replacing them). Tyres hold water for longer periods than ovitraps, and could replace ovitraps in ports where ovitraps are not deployed or not serviced adequately.

The attractiveness of ovitraps and sentinel tyres should be enhanced by supplementing the water with organic attractants (e.g. grass infusion or rat food pellet, particularly one that is lucerne-based (Ritchie 2001a)), and this can allow fewer but more attractive traps to be deployed.

**Ovitraps –**

Black plastic (or glass) containers of approximately 750ml with a vertical paddle of roughened wood (masonite strips or tongue depressors are ideal) and stabilised (e.g. set within a dark coloured concrete block or tied to a support), should be deployed indoors or outdoors in sheltered and shaded sites, preferably near vegetation, and from ground level to 1m above ground. The imprinted surface on masonite provides a very attractive surface for egg laying, but tongue depressors roughened by sandpaper are also suitable and provide a light surface against which eggs can be more readily seen (Ritchie 2001a).

This combination of smooth container and rough paddle is designed to focus the mosquito for laying its eggs on the paddle. At each weekly visit the paddles should be removed and clean replacements inserted, and the container topped up with clean water to which a little grass infusion has been added. A pellet or granule of s-methoprene can be added weekly to prevent the emergence and escape of adults, with the side benefit of maintaining live larvae for identification.

The paddle can be inspected for eggs (a small hand lens will be a useful aid), either at the site or after return to the office / laboratory. Any paddles containing eggs should be dried for two days (to ‘condition’ the eggs) and then submerged in water aged with a little grass infusion or very dilute yeast solution to promote hatching. The resulting larvae can be reared through to fourth instars, adding a granule or pellet of s-methoprene to the tray, for identification (being fed on small amounts of fish food to supplement the grass infusion if necessary). The temperature of the rearing facility should be kept preferably at 25-28 degrees Celsius to promote rapid development.

Non-inspection of the paddle for eggs, and checking only for larvae in the water, can delay the early warning of an incursion of an *Aedes* or *Ochlerotatus* species. If this procedure is nonetheless followed, the ovitraps must be filled to the same level on each occasion so that eggs laid previously will be covered by water for hatching and not left above the water line, and this is facilitated by an internal marking if the container is glass or a drainage hole if it is plastic).

**Sentinel tyres -**

Used automobile or light aircraft tyres (<500mm diameter) should be placed outdoors in sheltered shaded areas, near vegetation if possible, upright or at an angle of no less than 60$^{o}$, secured and/or marked so that the vertical alignment can be maintained, and filled with at least 1 litre of aged water, or preferably to a drainage hole. The water should be provided with a small volume of grass infusion or lucerne pellets as an attractant. Because of the great risk that sentinel tyres will breed large numbers of mosquitoes, a pellet of s-methoprene should be added weekly to prevent the emergence and escape of adults.

The tyres should be inspected weekly and all the water should be removed for larval inspection. Any larvae detected should be collected and reared through to fourth instars with s-methoprene pellets or granules. The tyres can be sampled most effectively by pouring the water from within through a drainage hole in the tread or the sidewall. Scooping for larvae in sentinel tyres is not recommended, because larvae have a habit of diving to the bottom when startled and young larvae or low numbers may well be missed.

The vertical alignment of the tyre should be marked so it can be replaced in the same aspect and filled with water to the same marked level (or to the drainage hole) on each occasion. This will ensure that eggs laid previously will be covered for hatching and not left at another position aside from or above the water line. Chaining or otherwise fixing the tyre in position, as recommended below for security purposes, will facilitate this positioning.

Tyres, when deployed as sentinel habitats and used as larval-traps, whether in parallel with or as replacements for conventional ovitraps, should be placed in similar situations to those used for ovitraps (i.e. close to the activity wishing to be monitored, and protected from the wind when outdoors). The tyres should be fixed in position (e.g. chained) and distinctively marked (e.g. painted red - which the mosquitoes will see as dark), if their security is a concern.

**Larval sampling**

Natural (e.g. tree-holes, leaf axils) and artificial (e.g. tyres, drums) receptacles, ground pools, ponds, sumps, drains, and marshes (fresh and saline), and any other accumulation of water within the 400m exclusion zone for seaports and airports should be sampled for mosquito larvae regularly (preferably weekly during warm seasons but at least fortnightly) using dippers, pipettes and/or nets.

**Dippers** - the standard soup ladle-type dipper of approximately 400-500ml is used widely and is acceptable and effective for sampling various habitats, particularly surface water accumulations, depending on the relative size.

**Pipettes** - large (turkey baster) and small (laboratory transfer-type) pipettes are useful for removing larvae from smaller receptacles and/or transferring larvae from ladles to rearing containers, and from collection or rearing containers to alcohol for preservation for identification.

**Nets** - there is evidence that in many situations, and particularly in larger receptacles, a small light wire framed net can be more effective in collecting larvae than a dipper, which is more disturbing in the habitat. Tyres are difficult to sample with a dipper, cannot easily be emptied if not holed, and a net with an appropriately shaped or flexible frame to fit the tyre profile can more readily provide a useful sample than a dipper (Tun-Lin et al., 1994).

### Adult sampling

Dry ice-baited light traps are useful for collecting adult mosquitoes of most pest and vector species, although they are not a particularly sensitive technique for day-biting *Aedes* species such as *Ae. aegypti* and *Ae. albopictus* (Freier and Francy, 1991; Service, 1993). Light traps similar to the EVS or CDC types (and the local `Bland' traps) are appropriate for general monitoring when baited with dry ice. The addition of octenol as an auxiliary attractant can further increase catches of certain species but its use is not necessarily warranted. These traps should be hung from tree branches or other supports sited in sheltered areas away from competing light sources and animal hosts, and operated from at least one hour before sunset to at least one hour after sunrise. Traps should not be in direct contact with vegetation, and the string or chain can be coated with vaseline, to prevent ants from getting into the trap and destroying the collection. Traps should be sited upwind of any major mosquito habitats in the area, and multiple traps should be separated by at least 50m.

Adult trapping as a monitoring technique cannot be used effectively at seaports where security of the traps is a problem, and for others where the exposed nature of the site creates unfavourable conditions for adult trapping. At the major airports, security is not usually a problem, but the exposed and windy nature of the airport environment is often not conducive to effective trapping.

### Trap positions

In the view of the authors, there are few reasons for ovitraps, tyres and/or adult traps to be always sited routinely at the same location, rather than moving them around the port area or rotating them around different sites in order to more comprehensively sample the local or introduced fauna. Fixed site monitoring is usually undertaken to monitor relative abundance in an area, rather than to detect the presence/absence of particular species, and where the latter is the principal objective, the rotation of traps between sites within a locality can give a more effective coverage of risky areas if it is compatible with the workforce. Well-vegetated harbourage areas should be sought out for trap placement but traps should not be placed directly within dense shrubbery.

### Identification of specimens

All collections, larval or adult, should be labelled with date and site of collection, collecting technique, and type of larval habitat (if appropriate), before transport for identification.

Accurate identification of exotic mosquitoes intercepted at importation on vessels or after introduction to ports, should be seen to be a critical component of the programme. The effectiveness of remedial actions will be dependent on the efficiency of the reporting system that, in turn, is dependent on the veracity of the identification process.

Therefore, the question of local identification of samples, and the provision of training and other resources for that objective, is an issue of concern. Notwithstanding the undoubted enthusiasm displayed by many of the MAF/PHS personnel associated with the programmes, and that there is an argument for the retention of some identification resources within the local MAF/PHS facility, it is obvious that in general the facilities, resources and competencies at the local PHS level are not sufficient for the identification of larvae of exotic species (nor in some cases for the identification of many local species). The importance of accurate identification cannot be stressed enough, and there must be a confidence within the system that the reported identifications from all sites are accurate.

**Recording and reporting monitoring data**

All collection data should be recorded locally in accordance with a uniform system and reported nationally in accordance with a national database. Currently there appears to be a diversity of forms used in the surveillance system, and there is a need for some degree of uniformity.

Notwithstanding the obvious arguments for uniform reporting of collection data, it is not essential for local hard copy records (e.g. field collection forms) to be uniform, providing the following details are recorded consistently: locality, date, collector's name, sampling site, type of collection, number of mosquitoes, sex of mosquitoes, species of mosquitoes, population index (number of larvae per trap or dip, number of specimens of target species per trap night), and prevailing meteorological and characteristic habitat data.

For established target populations, the local surveillance results should be critically examined internally at least monthly, to determine underlying causes for variations and whether the variations can be attributed to any known variables. The local surveillance programme should be examined critically each year for seasonal and other patterns of abundance, and the reasons for the variation. Annual reports should be compiled and should outline all aspects of the programme, and should include updated monitoring maps, changes in procedures and equipment, and details of all remedial operations. Assessments and conclusions about the surveillance programme and any control operations undertaken locally should be made so that the programme can be modified if required.

There should be a biennial or triennial review of the national data by an experienced medical entomologist, or expert working group comprising MoH personnel and at least one experienced mosquito biologist.

**Remedial Action**

It is explicit within Article 19 of the International Health Regulations (WHO, 1983) that when mosquito habitats are detected within the 400m exclusion zones, they will be removed or eliminated, or at least modified or treated to make them unproductive of mosquitoes. MAF should initiate and take responsibility for pursuing and ensuring this action, and should liaise with the relevant local port and other relevant authorities to resolve the issue.

Habitats that could be removed from ports include discarded receptacles such as tins and bottles, tyres and drums, and plastic sheeting that can hold water. Habitats that might be otherwise eliminated include blocked sumps, drains and roof gutters, waterlogged and poorly draining land, and surface depressions holding rainwater. Habitats that might need to be treated with anti-mosquito agents include marshes, ponds, channels, drains and sumps - treatment options (depending on circumstances) include biorational (biocides such as *Bti*, and insect growth regulators such as s-methoprene) and chemical (organophosphate and pyrethroid) pesticides, oils (kerosene/castor oil mix) and biological agents (fish). Essential containers that cannot be removed, filled with sand, or otherwise precluded from offering a larval habitat for exotic mosquitoes at ports can be periodically treated with s-methoprene or residual pyrethroids (Ritchie, 2001b; Ritchie et al., 2001b).

At some airports and at most seaports, urban development and/or naturally vegetated areas exist within the 400m zone prescribed in the International Health Regulations. As MAF/PHS authority does not extend to cover these areas, the cooperation of local authorities should be sought with respect to an extension of surveillance and intervention activity if so required. However, the realities of this situation should serve to further emphasise the importance of the border control procedures, particularly vessel inspection and port sanitation with respect to receptacles.

# APPENDIX 2.

## *Recommended Standardised Guidelines and 'Best Practice' Procedures for SSM Surveillance*

### *Introduction*

Sampling coastal habitat for SSM, especially considering its scarcity, requires a strategic approach. This is summed up as: sampling the habitats at risk at the most appropriate time with the greatest coverage possible. Thus, the four general steps required are:
1. Identify and map habitat suitable for SSM breeding;
2. Monitor events that will trigger a large hatch of SSM (trigger events; rainfall and tide);
3. Conduct larval surveys within 2-7 days post flooding and
4. Conduct adult surveys 10-17 days post flooding (later in winter).

We will describe "best practice" options, although alternative approaches will also be listed. **It is also important to couple this system with a SSM Emergency Response Plan if SSM are located.** The MoH guidelines on mosquito surveillance and control "Environmental Health Protection Manual, Section 5 Biosecurity", along with the Mosquito Control Association of Australia's "Australian Mosquito Control Manual" also detail operations and should be consulted.

### *I. Strategic preparation for SSM Surveillance*

Preparing the necessary resources

The tools for sampling SSM are relatively simple - a few dippers, gumboots and adult traps - but the logistics of thoroughly and accurately detecting the presence of mosquitoes, especially when rare (not abundant and/or not widely distributed), are daunting. The search for the SSM is, in most cases, looking for the proverbial 'needle in a haystack'. Thus, careful planning of resources, equipment and personnel must be made. Things to consider are

- Organising travel to remote sites

- Procuring adequate sampling equipment

- Freeing adequate staff for 1-3 weeks of field sampling 2-3 times/year

- Obtaining accurate maps of likely SSM habitat

- Rearing and identification of mosquito samples

- Field collation of the data and, most importantly

- Tailoring the survey to your budget (or, increasing funding to do the work).

Thus, a strategic SSM surveillance plan incorporating larval and adult surveillance should be designed to detail exactly what you will do and when. Resources should be identified. And, it would be advisable if an agreed standard “methodology” could be used by all at-risk PHSs. Mosquito identification and control procedures should be made in collaboration with the MoH and NZ Biosecure.

**Identification of SSM habitat**

Preliminary mapping should be conducted to identify areas that can be ground-truthed and surveyed. The Landcare GIS map of suspected habitat provided a rough idea of coastal habitat to investigate, but largely incorporated low marsh mangrove habitat not suitable for saltmarsh breeding. However, upon recognising this fact, areas adjacent to extensive marsh habitat should be investigated. Topographic maps that indicate areas of tidal inundation or low coastal relief should also be inspected. Some PHSs have archives of aerial photos that can be very useful in depicting vegetation type and even areas subject to flooding such as drains and pools that can directly breed SSM. Both topographic maps and aerial photographs also indicate roads and trails for accessing the sites. Aerial photographs have the benefit of identifying coastal agricultural areas, such as paddocks, which are prone to produce SSM.

Finally, aerial surveys, if feasible, are extremely useful, especially if conducted by helicopter. They provide a current snapshot of the area and, with helicopters, the site can be visited on foot. Photographs and GPS coordinates can also be taken. **Ensure that the GPS is correctly calibrated!** High-risk areas should then be visited on foot. Transport ranges from quad bikes and 4X4 vehicles to boats and helicopters. Look for saltmarsh pools with vegetated banks, clogged ditches and spoon drains in adjacent paddocks. Disturbed areas with reclaimed saline soils are a high risk. NZ Biosecure should endeavour to produce a CD containing pictures of habitats where they have encountered SSM. A map of high-risk sites should be produced for reference and action when a triggering event occurs.

***II. Monitoring Triggering Events***

The hunt for new foci of SSM does not require sampling after every flooding tide or heavy rain event. What it does require, especially for an agency with limited resources and manpower, is a selective sampling (verification) after triggering events most likely to provide a SSM hatch over a broad area. In this way, the majority of high-risk sites can be sampled within a fortnight. Besides significant flooding events, you need to have an idea of whether the marsh was dry before the potential triggering event. A tide that floods a marsh that was already flooded by rain will not hatch many additional eggs - they were already hatched by the previous flood event! The largest hatch will be when the site has been dry for several weeks before a major inundation.

Monitoring a marsh for dryness.

Ideally, the site can be directly observed, but this is not practical for remote areas (e.g. barrier islands) that may only be surveyed 1-2 times/year. For tides, sentinel marshes that are practical to observe (located near PHS base, etc.) can be monitored by simply recording if they are flooded or dry. Care should be taken to restrict this to highest sections of the marsh. For rainfall, rain gauges near the site, especially if residents can be used to collect data, are useful. Better yet is to actually have local observers who can report on risk-sites, as is done by NZ Biosecure in the Kaipara. Sentinel marsh status should be tabulated and updated weekly if possible.

<u>Monitoring SSM triggering events</u>

The primary triggering events of rainfall and tide need to be monitored. Again, while local sentinel sites can serve as a proxy for remote marshes, this can be misleading, especially for rainfall, which can be very localised. Tides can be grossly predicted using tide charts or books. But because tides are affected by wind direction and air pressure (and rainfall in estuary catchments), actual tidal data should be collected if possible. Most significant ports presumedly record tide data and efforts should be made to access this. Modern gauge data may be able to be accessed via a telephone, fax or potentially by e-mail. Simple tide gauges can also be constructed, but these have to be calibrated against a known standard. Again, nothing beats direct observation of marshes at risk, reiterating the call to develop a network of residents who can observe sentinel sites. If this is not possible, proxy sentinel marshes that can be easily and conveniently observed could be employed.

Because of the variable nature of rainfall, sentinel rain gauges near the high risk should be established and monitored by local cooperators. Bureau of Meteorology data can also be useful for nearby sites. While smaller rainfalls will hatch some SSM eggs, they may not flood significantly large parts of the habitat. Rainfall of at least 50 mm within 24-48 hr should serve as a general threshold for sampling. Following especially dry periods, and in fast draining soils, even heavier rains may be needed to flood a site. Keep in mind that many disturbed areas, and paddocks capable of breeding SSM, may not flood due to tide but will flood from rainfall. **Thus surveys should not be limited to being triggered by tidal flooding only.**

If a significant triggering event occurs, the SSM surveillance plan developed earlier should be evoked.

### *III. Sampling for Larvae*

<u>Where and when to sample</u>

Larval sampling of high-risk sites identified above could technically start the day after a triggering event. However, because the larvae would be only 1st instars, they could be easily missed, especially at low densities (1-5/dip). Sampling should be delayed until 2-3 days after flooding. Larvae should be large enough (2-3 instar) to be readily seen, and this allows sufficient time to monitor most areas before the brood emerges (7-10 days post flood). More importantly, it allows for control efforts to be initiated if a brood is located. Sampling should not be delayed beyond the larval + pupal developmental period - otherwise the late stage larvae and pupae which are not susceptible to the control agents will have formed, or the adults may have already emerged and the entire generation will have escaped control.

Larval sampling, better yet, larval hunting, requires careful consideration of where larvae are likely to be. Younger instars are generally concentrated in thick vegetation at edges of pools or depressions.

<u>How to sample</u>

At least 20 dips (300 ml white dipper attached to ca. 1 m of doweling) should be taken around the edge of these pools, concentrating on thick vegetation at the waters edge. For larger instars (3-4 instars and pupae; approx. day 4+ post trigger), again take dips but take time to carefully observe the pools for larvae. Polarised sunglasses are a help. Continue this for all potential habitats in the area, taking care to sample adjacent inland sites, especially paddocks. Sequential sampling to cover as many risk habitats as possible can continue for up to 7 days post trigger. *There is no need to take water samples for salinity (or other) analysis.* SSM will happily grow in a range of salinities from fresh through to 100% seawater (or potentially saltier) and can breed in freshwater swamps near coastal areas (Lee et al. 1984).

If larvae are encountered, they should be placed into a vial (5 ml sample vial with label), labelled with date, location (e.g. GPS or map name) and collector. Take up to 10 larvae/site if available. They should be not be overheated; thus samples kept in a hot vehicle should be placed in a small chilly-bin or esky (but not with ice as it can kill larvae!). The site should then be treated with a larvicide, preferably s-methoprene pellets, granules or briquets (the latter can be used singly to treat entire small pools) as they provide residual control while leaving larvae for additional sampling/identification if needed.

It is now important to sample nearby pools to determine the range of the infestation (delimiting survey). If possible, especially if a large infestation is found, supervisors should be notified so that the larval identification can be fast tracked and an emergency response prepared. If the infestation is larger than you can treat by hand, and are likely SSM, the MoH and the SSM Emergency Response Plan will need to be evoked. SSM are suspected (over *Culex*) when 1. flooding is due to high tides; 2. the larvae are of a comparable age and size rather than a mix of all 4 instars and 3. the larvae have a short, stout siphon tube.

When returned to the lab, young larvae should be reared to 4$^{th}$ instar in 20% seawater and maintained on fishfood in trays containing a pellet (or granule) of s-methoprene to ensure that adults do not develop. Rearing of adults should only be conducted in an approved, secure rearing environment (see appropriate rearing procedures developed by MoH or NZ Biosecure). Do not send dead 1-2 instar larvae if possible. Pupae will have to be reared out to adults in a secure facility, then dead adults sent to NZ Biosecurity for identification. If pupae are collected in the field, endeavour to find 4$^{th}$ instar larvae for identification purposes and selectively collect these. Because 4$^{th}$ instar larvae can be preserved in 70% ethanol, quarantine rearing arrangements are avoided. Arrangements should be made to send specimens to NZ Biosecure (or other acceptable taxonomic source) as soon as possible. While we encourage staff to learn to identify SSM larvae and adults, specimens must be sent to an approved, experienced person for identification. Furthermore, the specimens must be in good condition, avoid excessive handling of the specimens as they can destroy fine larval hairs used for identification. Retain some of the larvae in case the couriered samples are lost (yes, it does happen!).

Most sites will be negative. Datasheets should be designed to ensure speedy yet accurate recording. Thus, rather than recording each -ve dip, simply record number of dips and that the site was -ve. A palmtop computer would speed up data transfer but may not be practical in a saltmarsh habitat. All positive sites should be marked on the site map. **It is critical to update the database and site maps when the identifications are confirmed, highlighting areas with SSM.**

### *IV. Sampling for SSM adults*

Because SSM larvae are likely to be hard to locate, and the habitat difficult to access and sample thoroughly, a greater emphasis needs to be placed upon adult trapping. Even if a small foci of larvae is not detected, a light trap set in the area will likely catch some adults. More thorough larval sampling can then be planned for the next trigger event to locate the likely breeding site(s).

Where and when to sample

While SSM, and most salt marsh mosquitoes, can travel considerable distance from the breeding site, greatest densities will be found within 1-5 km of the larval habitat. Using the larval habitat risk map and, especially, aerial photographs, identify areas nearby that could harbour mosquitoes. Things to target are 1. wooded areas, especially downwind; 2. farms with livestock. Mark these on a map similar to the larval site map.

SSM may complete their larval and pupal development in approx. 7-10 days in summer but longer in winter. Adult mosquitoes must mate and disperse before bloodfeeding, and most bloodfeeding (and attraction to dry ice-baited traps) may not begin in earnest until approx.10 days post hatch (i.e., at triggering event), and continue for approx. a week before the generation may markedly or completely disappear.

Sampling methods

Several methods can be used to sample for adult SSM. If, when investigating a public complaint or conducting larval dipping or adult trapping, mosquitoes are attracted to the collector, they should be collected for identification. The simplest and cheapest is to simply collect mosquitoes attracted to you (or a colleague) using a net (treated with residual insecticide to knock down mosquitoes) or aspirator. SSM are aggressive day biters, and if heavily wooded areas near a suspected saltmarsh are visited, adult SSM could be biting and should be collected.

A variation on the theme is to obtain mosquitoes, or reports of mosquitoes, from the public. The original outbreak in Napier was discovered via public complaints. To be effective, only areas near SSM habitat should be selected. Mosquitoes can be trapped overnight or collected with nets or even from residents. Keep in mind that many of the call-ins will be for other mosquitoes; in Christchurch, such a programme elicited numerous investigations of *Oc. notoscriptus* infestations. Furthermore, such a programme will not be sensitive to low-level populations. Thus, we cannot recommend solely relying upon this method for detection of SSM.

Most jurisdictions will probably employ light traps. These traps are baited with $CO_2$ (either dry ice or gas), a small light, and sometimes octenol. Octenol is an alcohol extracted from ox breath that is highly attractive to bloodfeeding insects that feed on large mammals, especially ruminants. Other saltmarsh mosquitoes, such as *Oc. vigilax* (Kemme et al. 1993, Van Essen et al. 1994) and *Oc. taeniorhynchus*, are known to be highly attracted to octenol when used with $CO_2$. The SSM is likely no different. See Van Essen et al. (1994) for methods. Most light traps function by sucking mosquitoes attracted by the $CO_2$ and light into a collection bag with a small fan. A variety of light traps are available, and we noted some 'homemade' styles (e.g. Bland trap) in New Zealand. Most were just variations on the basic theme.

There are new traps that offer 'stand alone' service, collecting mosquitoes for several days or even weeks without servicing. The MegaCatch™ employs a programmable timer to start and stop the trap and the $CO_2$ cylinder. The MosquitoMagnet™ and Mosquito Eradicator™ catalyse propane to power the trap and provide $CO_2$ and heat as an attractant; these traps can run continuously for 4 weeks or more. These stand-alone traps are expensive and are not useful for the 'hit and run' trapping need to provide wide coverage. However, they would be of use in monitoring sentinel sites, especially areas with a history of SSM activity, and in documenting and verifying eradication efforts.

Trapping strategy when hunting for new foci of SSM

As was the case for SSM larvae, trapping for new foci of SSM is literally hunting. Adult females will disperse from the breeding sites, seeking a bloodmeal, within 7-10 days post hatch. Generally, they will harbour in well-vegetated areas within 5 km of the breeding site. Livestock will also serve as an attractant. Traps should be set in identified high-risk sites. Priority trapping sites are:

1. areas < 5 km downwind of SSM habitat 10-17 days post hatch;

2. areas that are well-forested;

3. areas where livestock are nearby (traps can be set immediately downwind of paddock, thus using the animals as a bait – but still use $CO_2$ with trap!);

4. areas near where SSM larvae were detected;

5. new areas not addressed or negative by larval survey (this way, risk areas that were not sampled for larvae can be examined for adult mosquitoes). However, this does not exclude trapping in areas sampled for larvae).

Trapping protocol

The following outlines methods in a trapping strategy for novel SSM sites using standard light traps:

a. prepare traps for trapping (charge batteries, check that traps work, prepare octenol wicks; calibrate $CO_2$ regulators);

b. plan on setting traps 10-17 days after flooding event (you should have a 3-4 day break between larval surveys and start of adult surveys);

c. set up map of proposed trapping areas, concentrating on areas where SSM larvae were found and high risk areas described earlier.

d. plan on moving traps, on a nightly basis, to different areas, setting at least 2 traps at least 50m apart at each localised area. This way, 5 areas can be sampled on a given day.

e. Pack traps, batteries, battery chargers, octenol, torch, etc.

f. If using dry ice, order in advance (and use block ice if possible as it lasts longer than pellets and less can be used - thus it is more economical). Things to consider are
   1. buy enough for daily use (0.5 kg/trap) if possible;
   2. for remote areas, ca. 50 kg could service 10 traps for 3 nights, and
   3. keep in a large, well-made 'chilly bin' for transport and storage

g. set light traps in well-vegetated areas protected from the wind, at chest height (ant proof if needed – see Appendix 1), baited with $CO_2$ and octenol in late afternoon;

h. pick up traps in early morning (7-9am);

h. kill trap collections in freezer;

i. recharge batteries and prepare for that days trapping;

j. screen frozen trap collections for mosquitoes, and placing them in a small jar or vial, label (date, location, GPS) and then posting to NZ Biosecure.

Each day, a new area should be targeted. Keep moving until 1-2 weeks trapping is completed, the weather becomes too cool (< $15^oC$) or windy (> 20 km night), SSM are encountered or the target areas are covered. $CO_2$ and octenol should be employed. **While field staff cannot provide a confirmed identification, they should be trained to recognise a suspected SSM in the field. This enables them to conduct further trapping in the area and to even examine local marshes for residual larvae/pupae.**

Post survey analysis

A post survey analysis should be conducted for both surveys and include

a. Tabulated specimen IDs from NZ Biosecure into database;

b. Upgraded survey maps with areas surveyed and confirmed identifications;

c. Discussion and plan for response if SSM are found and

d. Upgraded protocols and reprioritise target areas for next survey.

A formal report, addressed to the MoH, should be written up and include survey data and maps. Lessons learned with recommendations should be incorporated.

Audit

The key to successfully auditing a SSM surveillance and control programme would first involve a review of each PHS's SSM surveillance plan, including maps of high risk areas and protocols to measure triggering events and to sample larvae and adults. Deficiencies can be identified and rectified, in collaboration with the PHS, before the programme is initiated. These protocols will identify measures that can be audited such as:

1. Triggering events - data from rain and tide gauges; sentinel marsh observations;

2. Larval surveys - areas adequately sampled after a triggering event, number of sites dipped, number of dips, larvae encountered and a map of areas sampled. In this case, the timing and the areas covered are more important than just raw number of dips;

3. Adult trapping - areas trapped and dates; number of trap nights, again with an emphasis on coverage, maps of areas trapped, identification of adults collected;

4. Post survey analysis - overall result of surveys highlighting status of SSM in area, control efforts, completeness of the surveys, and areas to be targeted next time.

Because triggering events may not occur each quarter, the MoH should be looking for evidence that triggering events are being reliably monitored. There should not be an emphasis to undertake extensive surveys, for the sake of "having data for the quarterly report", if a *bona fide* triggering event (flooding of a dry marsh) has not occurred. Keep in mind that the annual highest tide, along with heavy rain events, should ensure that at least one, and likely more, surveys are conducted per year.