A description of those scenarios considered most likely to have contributed to the spread of southern saltmarsh mosquito to different areas in New Zealand

As indicated in the discussion above and by the information contained in Tables 8-10, there are a number of pathways that may have contributed to the spread of *Oc. camptorhynchus* to different areas in New Zealand. Despite undertaking a systematic examination of the possible pathways of entry and spread, the mystery remains as to whether there have been one or more introductions of *Oc. camptorhynchus* into New Zealand. Moreover, although the spread of this mosquito invader from Kaipara Harbour to Mangawhai and Whangaparaoa Peninsula, Wairau Lagoons to Lake Grassmere, and possibly Napier to Mahia, may be accounted for through wind-assisted dispersal, the spread of this species from Napier to Gisborne and Porangahau, also Napier or Kaipara Harbour to Whitford, and the arrival of *Oc. camptorhynchus* to the top of the South Island (i.e., non-contiguous distribution) cannot be readily explained.

Notably, the discovery of *Oc. camptorhynchus* in the South Island post-dated the eradication[1] of the mosquito from Napier and Mahia (Maungawhio Lagoon), and a period of at least 18 months of no detections of adult or immature *Oc. camptorhynchus* following treatment at Gisborne (Wherowhero Lagoon and Sponge Bay), Porangahau, Mangawhai and Whitford. Given the biological characteristics of *Oc. camptorhynchus* and means of spread discussed in the previous sections, as well as the rapid population decline of this mosquito in treated areas, there is no biologically plausible explanation for the spread of this mosquito to Wairau estuarine area/Lake Grassmere. This obviously raises the question of whether a second introduction occurred. However, with reference to Tables 6-7, such an event in itself is a very remote possibility.

Consequently, the possibility of the deliberate illegal introduction/spread of *Oc. camptorhynchus*, whatever the motive, cannot be ignored.

[1] After two years of no finds

Table 9: *Areas of Oc. camptorhynchus infestation in New Zealand and the corresponding stage of any eradication/control programme in those areas*

Area of infestation	Month/year *Oc. camptorhynchus* infestation confirmed	Stage of eradication/ containment programme	Distance from nearest known infestation in New Zealand
Napier (~650 ha)	December 1998	Eradication declared July 2002[1]	Not applicable
Gisborne (including Wherowhero Lagoon and Sponge Bay) (~85 ha)	October 2000	Last detection September 2002, eradication programme completed[1] September 2004	~120 km from Napier
Porangahau (~35 ha)	November 2000	Last detection August 2002, eradication programme completed[1] August 2004	~85 km from Napier
Maungawhio Lagoon, Mahia (~63 ha)	November 2000	Eradication declared November 2003[1]	~95 km from Napier
Kaipara Harbour (~2700 ha)	February 2001	Last detection February 2004, eradication programme due to be completed[1] February 2006	~385 km from Napier and Gisborne
Mangawhai (similar to Whitford)	April 2001	Last detection December 2002, eradication programme completed[1] December 2004	~30 km from Kaipara Harbour
Whitford (~1 ha)	March 2002	Last detection November 2002, eradication programme completed[1] November 2004	~60 km from Kaipara Harbour
Whangaparaoa Peninsula (~22 ha)	January 2004	Last detection March 2004, eradication programme proceeding	~35 km from Kaipara Harbour
Wairau Lagoons near Blenheim/Lake Grassmere (~960 ha)	May 2004	Eradication programme proceeding	~545 km from Kaipara Harbour [~330 km from Napier[2]]

[1] Following two years of no finds

[2] However, *Oc. camptorhynchus* had not been detected in Napier since mid 2000 suggesting that the low, if not zero, populations were nevertheless an unlikely source of the Wairau Lagoons/Lake Grassmere infestation (which may have been present for two years or longer according to SSM TAG (28 June 2004 meeting)).

Table 10: *Means of spread and measures in place to minimize the risk of Oc. camptorhynchus spreading via these means*

Means of spread	Measures Adopted to Prevent or Reduce the Spread of Mosquitoes via this Means	Any Additional Measures that may be considered to Prevent the Spread of Mosquitoes via this Means
Natural spread by adults from an infested area	Timely treatment (with *Bacillus thuringiensis israelensis* or S-methoprene) of infested areas	–
Immature stages in a water receptacle (e.g. used and/or spare tyres) transported between an infested area and an uninfested area	No enforceable measures available.	Ministry of Health mosquito awareness programmes may assist.
As adults on light aircraft flown from an infested area to an uninfested area	Disinsection of aircraft [Aircraft disinsection was undertaken for all flights departing Napier Airport from January 1999 (Ruud Kleinpaste *pers. comm.*) to December 2000 (SSM TAG Notes of 4 December 2000 Meeting); Aircraft disinsection was instigated for flights departing Gisborne in October 2000 (SSM TAG Notes of 13 October 2000 Meeting.]	–
As adults inside vehicles (cars, trucks) or caravans with the road transport of people or livestock	No enforceable measures available.	Ministry of Health mosquito awareness programmes may assist.
As adults inside the cabins of boats moved from an infested area to an uninfested area	No enforceable measures available.	Ministry of Health mosquito awareness programmes may assist. Perhaps s131 (Declaration of controlled area) of the Biosecurity Act could be utilized to good effect in regard to this means of spread.
Deliberate illegal (man-instigated) spread	No person shall knowingly communicate, cause to be communicated, release, or cause	–

Means of spread	Measures Adopted to Prevent or Reduce the Spread of Mosquitoes via this Means	Any Additional Measures that may be considered to Prevent the Spread of Mosquitoes via this Means
	to be released, or otherwise spread any pest or unwanted organism (s52 Biosecurity Act 1993). It is an offence under the Biosecurity Act 1993 if one fails or refuses to comply with s52 (s154(m) Biosecurity Act 1993). *Oc. camptorhynchus* was declared to be an unwanted organism in January 1999 (Ministry of Health *pers. comm.*). Penalties, in the case of an individual person convicted of such an offence are imprisonment for a term not exceeding five years, a fine not exceeding $100,000, or both. Such penalties should operate as a deterrent to spreading *Oc. camptorhynchus*.	
Wind dispersal of adults	None possible (although timely treatment (with *Bacillus thuringiensis israelensis* or S-methoprene) of infested areas will obviously reduce the probability).	Not applicable.
Inadvertent transport of eggs by bird watchers or duck shooters	No enforceable measures available.	Ministry of Health mosquito awareness programmes, in conjunction with organizations like Fish and Game New Zealand may assist.
Inadvertent transport of eggs by migratory birds	None possible (although timely treatment (with *Bacillus thuringiensis israelensis* or S-methoprene) of infested areas will obviously reduce the probability).	Not applicable.

Recommendations

While there is no obvious pathway of entry and only some of the spread of *Oc. camptorhynchus* is readily accounted for by wind assisted natural dispersal of adult mosquitoes, the following additional measures specifically identified in this report in Tables 6 and 10 would further enhance New Zealand's management of exotic mosquitoes, and hence it is recommended that they be implemented:

- Enforcement of compliance with the **pre-shipment** import requirements stipulated in the IHS for used forestry and agricultural equipment (26) to reduce the incidence of exotic mosquitoes (particularly container-breeding species such as *Ae. albopictus* and *Oc. japonicus*) entering New Zealand.

- If the IHS for treated used vehicles (28) is retained, ensure that the heat treatment effectively kills desiccation-resistant mosquito eggs which may go unnoticed during the inspection for visible contamination.

- With reference to the IHS for soil and water (27) and the vessel inspection procedures followed by inspectors, suitable treatments (e.g., spraying with a 1% chlorine solution (19)) should be specified in detail. In addition, the definition of contamination (at least in the context of potential mosquito habitat) needs to be clarified to mean "any surface of a receptacle or other item containing water, or dry but likely to have held water".

- Proposed changes to the International Health Regulations pointing to a greater emphasis on ship sanitation, including the requirement for "every conveyance leaving a point of entry situated in an area where vector control is recommended shall be disinsected and kept free of vectors" (71) should be vigorously supported.

- With reference to the IHS for sea containers (30), indicate that the supply of dual-action aerosol insecticide referred to in section 7.1 needs to be on-hand when opening the door of any shipping container for unpacking or inspection.

- With reference to the IHS for sea containers (30), open shipping containers (specifically those that have an open top, covered by removable canvas) should be deemed to be high risk, and therefore subject to external inspection (for evidence of water collected in the soft top), fumigation with methyl bromide, or decontamination by an

approved method. In addition, the definition of contamination (at least in the context of potential mosquito habitat) needs to be clarified to mean "any external surface of the shipping container containing water, or dry but likely to have held water".

- While the IHS covering the importation of nursery stock (34) includes basic conditions requiring that all whole plants and cuttings be treated for insects, the effectiveness of each of the three treatments against mosquitoes (especially desiccation-resistant eggs) should be confirmed.

- Incorporate *Ae. albopictus* in Appendix 1(a) of the IHS for cut flowers and branches of *Cordyline* and *Dracaena* species. Also the IHS covering all other cut flowers and branches (33) should require that cut flowers and branches shall not be shipped or contained in free-standing water. Furthermore, in the standard covering the clearance of fresh cut flowers and foliage (32), specific mention of mosquitoes (especially mosquito eggs) in the **Inspection** section could usefully be made, so that any wet/damp packing material is appropriately **treated**. Inspection will not result in the detection of mosquito eggs even if they are present.

- Although no enforceable measures are available, Ministry of Health mosquito awareness programmes could assist in reducing the risk of immature *Oc. camptorhynchus* being spread in water receptacles transported between an infested area and an uninfested area.

- Similarly, Ministry of Health mosquito awareness programmes would assist in lowering the probability of adults being transported inside vehicles or caravans with the road transport of people or livestock.

- Also, Ministry of Health mosquito awareness programmes, in conjunction with organizations like Fish and Game New Zealand may help reduce the inadvertent transport of mosquito eggs by bird watchers or duck shooters as well as the transport of adult mosquitoes inside the cabins of boats moved from an infested area to an uninfested area.

Research suggestions

In the course of this review it was apparent that some matters could not be resolved with reference to currently available information, publications or calling upon the experience of long time Australian medical entomologists such as Brian Kay, Mike Lindsay, Scott Ritchie, Richard Russell and Peter Whelan. However, some matters could be further informed through

additional research. For example, the duration of egg survival of a floodwater species like *Oc. camptorhynchus* does not appear to favour successful spread through the inadvertent carriage by bird watchers or duckshooters from site to site. Nevertheless, the frequency that such carriage is suggested as a means of spread indicates that further investigation may be warranted. Indeed some laboratory studies examining the possibility of *Oc. camptorhynchus* being picked up on footwear and carried to another site could be considered. Needless to say, such studies could include variables such as different egg densities required for carriage to be initiated, varying lengths of time of carriage and any effects on the viability of eggs carried in such a manner.

Secondly, recovery of the saltmarsh species, *Oc. vigilax*, from rock pools (Peter Whelan, *pers. comm.*) raises the possibility that breeding of saltmarsh species such as *Oc. camptorhynchus* may occur, albeit very infrequently, in open structures where salt water has ponded. This possibility may also warrant field and laboratory research involving critical examination of the range of *Oc. camptorhynchus* breeding sites, including large open receptacles that receive some salt spray.

Lastly, as stated earlier, the question "do the areas of *Oc. camptorhynchus* infestation represent more than one introduction from Australia?" needs to be addressed if eradication efforts are not to be wasted. Despite this review, this question has not been answered. Some would say that molecular diagnostic techniques could be put to good use for this purpose, or to determine the location of the source population in Australia. Unfortunately, this is not the case – at least not in the short term and not in regard to all the North Island infestations for specimens have not been retained. More recently, protocols for the preservation and retention of specimens have been amended. Consequently, some *Oc. camptorhynchus* material from the Wairau Lagoons and Lake Grassmere may be analysed using molecular diagnostic techniques in the future. Firstly, however, baseline analyses need to be conducted on Australian *Oc. camptorhynchus* populations to establish whether there is sufficient population-level variation to be useful in identifying source populations of new incursions. Establishing such baseline information should be a research priority if resolution of such matters as "has there been more than one introduction of *Oc. camptorhynchus* into New Zealand" is to be progressed at all.

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