Survival of insects in the wheel bays of a Boeing 747B aircraft on flights between tropical and temperate airports

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Mosquitoes (Culex quinquefasciatus), house flies (Musca domestica), and flour beetles (Tribolium confusum) located in cages within the wheel bays of a Boeing 747B aircraft, survived travel on the following normal commercial routes: Sydney–Melbourne; Melbourne–Singapore; Singapore–Bangkok; Bangkok–Singapore; and Singapore–Melbourne. Survival of all three species was high, averaging 84% for mosquitoes and higher for flies (93%) and beetles (> 99%). Although external temperatures were −42 °C to −54 °C for aircraft cruising at 10 700–11 900 m, minimum temperatures within the wheel bays ranged from +8 °C to +25 °C.

There is considerable concern among quarantine authorities about the international movement of insects that have medical, veterinary, or agricultural importance. Primarily because of its speed and frequency, international air transport provides the greatest potential for introducing many insect vectors or pests to countries.

In the Pacific region, a major concern is that vectors of malaria could be introduced and become established in areas where anopheline mosquitoes do not at present occur. There is also concern that Aedes vector species found in some islands could be transported to and become established in similar islands where they do not exist at present. Also, during the last decade, the spread of arboviruses has reinforced quarantine concerns and highlighted the importance of maintaining efficient preventive measures to minimize the chances of disease outbreaks.

Many countries have established rigorous quarantine precautions to prevent the introduction by aircraft of certain insects to areas where they are not indigenous, and disinsection of passenger cabins and cargo holds is often carried out. However, concern has been expressed that aircraft wheel bays may also provide a haven for insects and that these could then be transported in a part of the aircraft often not included in routine disinsection procedures.

During the Second World War, Cameron (1) noted that "... the retractable undercarriage offers a haven for winged insects, a haven which is automatically emptied before the plane lands and which must therefore be disinfected by mechanical devices while the machine is in flight." Such concern was reinforced by a report from Kenya that Anopheles gambiae mosquitoes in cages placed inside the wing of a flying boat survived a flight from Kisumu to Mombasa (2). Also, instances have been reported of moth-egg masses and of emerging larvae that survived on the external surfaces of aircraft as well as of beetles that survived international flights on the external fuselage of an aircraft (3). It has been assumed that the high speed of modern commercial passenger aircraft and their much greater cruising altitudes preclude this prospect today.

No evidence has appeared that insects can survive within the wheel bays of modern passenger aircraft, which fly at altitudes often above 10 500 m, where external temperatures are less than −40 °C. It is of interest to determine whether the conditions within the non-pressurized wheel bays are detrimental to most insects or whether some species might survive. A series of trials was therefore organized to investigate this, and the results are reported here.

MATERIALS AND METHODS

The trials were conducted on a Boeing 747B aircraft that operated between Sydney and Bangkok.
via Melbourne and Singapore, on 7 August 1986, and between Bangkok and Sydney via Singapore and Melbourne, on 9–10 August 1986.

Three species of insects were selected for the trial—the domestic mosquito (*Culex quinquefasciatus*), the house fly (*Musca domestica*), and the flour beetle (*Tribolium confusum*). The following numbers of insects were confined in plastic cups (185 ml) covered with plastic mesh ends: 10 mosquitoes per cup, 5 flies per cup, and 10 beetles per cup. In general, six cups (two of each insect type) were attached with adhesive tape to the internal walls of both the port and starboard inner wheel bays. A maximum–minimum thermometer was also attached to the wall adjacent to the insects to record extremes of temperature within the wheel bay. The flight engineer recorded external temperatures at the airports on departure and on arrival and also the external temperature at cruising altitude at intervals throughout the flight.

Insect survival was scored immediately on arrival following travel between Sydney and Melbourne, Melbourne and Singapore, Sydney and Singapore, Singapore and Bangkok, Bangkok and Singapore, and Bangkok and Melbourne. The maximum and minimum temperatures inside the wheel bay were also recorded at this time.

As a control for the insects “protected” within the plastic cups from the turbulence, *inter alia*, within the wheel bays, four cylindrical cages of wire mesh (17 cm × 5 cm), each containing 10 mosquitoes and five flies, were also attached within the wheel bays on the Singapore–Bangkok route. General survival controls (in plastic cups) for the three test species of insects were placed in insulated containers in the aircraft cabin during each flight. The mosquitoes and flies were maintained on sucrose solution when not involved in trials, while the beetles were not fed during the trial.

**RESULTS**

The proportion of insects that survived the various flights, together with the temperature control records, are presented in Table 1. In general, on all routes survival of the insects was very good and, even though the mortality of the controls increased marginally towards the end of the study, there was little corresponding reduction in that of the test species. Insects on “double” flights (Sydney–Melbourne–Singapore and Bangkok–Singapore–Melbourne) also survived well compared with their single-flight counterparts. There was no significant difference in the survival of insects in port or starboard wheel bays or in that of insects attached to the rear, front, or side walls of the wheel bays.

The minimum external temperature during a flight was $-54^\circ C$ at 11 890 m between Melbourne and Singapore and also, at the same height, between Singapore and Bangkok. External temperatures were

<table>
<thead>
<tr>
<th>Route</th>
<th>Flight time (minutes)</th>
<th>Minimum temperature (°C)</th>
<th>C quinquefasciatus</th>
<th>M. domestica</th>
<th>T confusum</th>
<th>External</th>
<th>Internal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney–Melbourne</td>
<td>80</td>
<td>+14</td>
<td>97.5</td>
<td>100</td>
<td>100</td>
<td>95</td>
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<td>85.0</td>
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<td>82.5</td>
<td>90</td>
<td>100</td>
<td>+27</td>
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<tr>
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<td>87.5</td>
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<tr>
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<td>67.5</td>
<td>80</td>
<td>100</td>
<td>-49</td>
<td>+15</td>
</tr>
</tbody>
</table>

*Control mortality for *C. quinquefasciatus* or *M. domestica* never exceeded 20%, while that for *T. confusum* was always zero.*

*Influenced by the ambient temperature at take-off, before the bays were closed, as well as by any “in-flight” conditions.*

*Influenced by the ambient temperature upon landing at Melbourne as well as by any “in-flight” conditions.*
recorded hourly, and for the 6 hours at cruising altitude on the Melbourne–Singapore route. The minimum temperatures were as follows: −42 °C for 2 hours at 10 670 m, −48 °C for 2 hours at 11 280 m, and −54 °C for 2 hours at 11 890 m.

The minimum temperature within the wheel bays did not fall below +8 °C and was as high as +25 °C (Table 1). The lowest minimum temperature, +8 °C on arrival in Singapore from Melbourne and in Melbourne from Singapore, correlated with the ambient temperature in Melbourne, indicating that the temperature in the wheel bays during flight may have been considerably higher. There was no difference in the minimum temperatures when the thermometer was placed on the inner or outer walls of the wheel bay. The maximum temperature in the wheel bays was not above that at the respective airport, and the greatest range was from +8 °C to +28 °C between Melbourne and Singapore and from +28 °C to +8 °C between Singapore and Melbourne.

**DISCUSSION**

Laird cited an early report of Bert in 1877 that beetles recovered (although inert and apparently lifeless during the experiment) from 20 hours' exposure to pressures equivalent to those at approximately 15 250–18 300 m (4). Also, studies in aircraft indicate that Aedes notoscriptus mosquitoes become sluggish below 8–10 °C at altitudes above approximately 3000 m, while below 8 °C have no flight response (4). Laboratory studies confirmed that, at pressures equivalent to those at approximately 3000 m, mosquitoes showed no observable reactions, but voluntary movements ceased at pressures approximately equivalent to those above 9000 m; mosquitoes kept at a pressure equivalent to that at approximately 12 000 m for 48 hours resumed normal activity as soon as they were restored to pressures below that at 3000 m. In temperature trials, the mosquitoes could not be induced to fly below 8 °C, while those kept at −2 °C for 24 hours at normal pressure, and at pressures equivalent to those at approximately 3000 m and 9000 m, recovered normal behaviour within 10 minutes of return to favourable conditions; their survival was not affected thereafter (4).

The results of the present study indicate that insects can survive in the wheel bays of aircraft on international flights. Under the test conditions, the insects readily survived between tropical and temperate airports on flights of little more than 1 hour to at least 7 hours. The temperatures at Sydney and Melbourne were fairly typical for the time of year and were well below those at Singapore and Bangkok. However, temperatures before, during, and after flights were apparently not detrimental to the test insects. The take-off from Bangkok to Singapore occurred in heavy rain, and a considerable amount of water was sprayed into the wheel bays, but under these conditions the insects survived as well as they did under the dry conditions on other routes.

It is perhaps questionable as to whether insects not “protected” by enclosure within the test cups or cages would remain in the wheel bays during aircraft taxiing or be driven from the wheel bays by air turbulence during take-off. Although the insects in wire cages survived as well as those in cups, indicating that they were not subject to detrimental buffeting, their “confinement” probably offered some relative degree of protection. Similarly, whether insects that survived in the wheel bays would be driven from the bays by air turbulence when the undercarriage was lowered, or would leave of their own volition during or after taxiing, or remain and be available for “on-arrival” disinsection, also remain unresolved. The possibility that insects could escape from wheel bays after landing but before “on-arrival” disinsection has been recognized for some time, and disinsection of aircraft wheel bays as close as possible to the departure time has been recommended (5–8).

Data on mosquitoes collected from aircraft have been reviewed by Smith & Carter (9), who also detailed reports of diseases transmitted by the introduction and establishment of mosquitoes in areas where they were previously not indigenous. Recent cases of “airport malaria” in Europe, caused by infected Anopheles mosquitoes from Africa, have renewed interest in aircraft disinsection (10); although cabins and cargo holds are usually pre-eminent in discussions on disinsection, the results reported here point to the risk associated with wheel bays.

Aerosol disinsection of wheel bays immediately prior to departure would assist in preventing transport of many insect types, depending on insecticide formulation. In contrast, aerosol disinsection immediately after arrival may have limited value. In this respect, use of residual insecticides to provide a toxic substrate deposit within wheel bays is problematic, primarily because of build-up of films of grease and oils on the surfaces of the bays.

The results reported here indicate that disinsection of aircraft wheel bays should be considered. Aerosol disinsection at the last departure airport is recommended as the most appropriate technique, unless an “automatic disinsection device” can be incorporated into the bays.
ACKNOWLEDGEMENTS

The trials were undertaken with the willing cooperation and assistance of Qantas flight and ground staff. The Qantas Facilitation Manager at Sydney, Mr R. Millward-Grey, provided logistical and technical assistance during the trial, and his contribution is gratefully acknowledged.

RÉSUMÉ

SURVIE D’INSECTES TRANSPORTÉS DANS LES LOGEMENTS DE ROUES D’UN BOEING 747B ENTRE UNE RÉGION TROPICALE ET UNE RÉGION TEMPÉRÉE

Pour éviter le transport involontaire de moustiques et autres insectes, on soumet généralement les avions assurant des liaisons internationales à une désinsectisation préventive dans le cadre des procédures générales de quarantaine, mais si la cabine et les soutes sont régulièrement traitées, il en est rarement de même pour les logements de roues. La présente étude visait à déterminer si des insectes peuvent survivre dans ces compartiments sur un avion moderne de transport de passagers. Trois espèces d’insectes ont été choisies pour l’expérience: un moustique (Culex quinquefasciatus), la mouche domestique (Musca domestica), et une blatte (Tribolium confusum). Les insectes ont été placés dans des cages fixées sur la surface interne des logements de roues d’un Boeing 747B et leur taux de survie a été contrôlé à la fin de chaque étape sur l’itinéraire suivant: Sydney — Melbourne, Melbourne — Singapour, Singapour — Bangkok, Bangkok — Singapour et Singapour — Melbourne.

Sur chaque étape, les trois espèces ont très bien survécu, de même que les insectes qui ont effectué l’aller-retour. Le taux de survie des moustiques a été en moyenne de 84%, tandis que celui des mouches et des blattes a été encore plus élevé (93% et >99% respectivement). Bien que la température extérieure ait varié entre -42 °C et -54 °C, pour des durées de vol comprises entre un peu plus d’une heure et sept heures, à une altitude de croisière de 10 700 m à 11 900 m, la température minimale à l’intérieur des logements de roues est restée comprise entre +8 °C et +25 °C. Les conditions étaient donc propices à la survie des trois espèces.

L’étude montre que des insectes peuvent survivre dans les logements de roues d’un avion lors d’un vol international, si l’on admet que les conditions observées lors de cet essai sont représentatives et que les insectes ne sont pas expulsés par la turbulence de l’air au décollage.

REFERENCES