Recommendations for mosquito control in zoological parks to reduce disease transmission risk

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Recent studies in New Zealand have shown that zoological parks seem to provide an optimal environment for mosquito breeding (e.g. Derraik 2004a, b), most likely as a result of the high densities of large mammals and birds. Therefore, to reduce the risk of disease transmission to both humans and animals alike, the adoption of adequate mosquito control programmes in such facilities is necessary. A sound management programme would be particularly important in areas near captive rearing facilities, to prevent mosquito-borne disease outbreaks amongst endangered species.

Mosquito control efforts should be concentrated during the warmer seasons when mosquito populations commonly peak (e.g. Derraik & Slaney 2005), but should also be carried out less intensely during the colder months, as a basal population may persist throughout the year. Extra care should be taken when there is regular rainfall, as this is the single most important environmental factor contributing to mosquito-borne disease outbreaks (Kelly-Hope *et al.* 2004). Consequently, several management strategies are recommended to minimize mosquito breeding at zoological parks:

1. All types of water-holding debris, such as discarded tyres, containers, tubs and polythene sheets, should be moved to areas sheltered from the rain, where they should be kept dry. In the case of used tyres that are needed within animal enclosures, these should be individually managed to prevent build up of water. For example, tyres can be punctured or sliced longitudinally along one or both sides to allow water to drain (bearing in mind that falling debris such as leaves and twigs may lead to blockage and consequent water storage).

2. Animal enclosures should be adequately managed to ensure that drinking troughs are washed and have their full water content replaced at least once a week.

3. All storage tanks where stagnant water is kept should be covered. In cases where the water needs to be exposed to air, it should be covered with an adequate plastic insect mesh (1 mm). Where pools are covered with canvas or similar

water-proof materials, placing a floating device (e.g. large inner tube or buoy) underneath at the centre should prevent the pooling of rain water. Regular checks are advisable to ensure that no water build-ups are formed (and persist for over a week) to ensure that no mosquito breeding occurs. All ponds should have constant flowing water, as stagnant water creates ideal conditions for mosquito breeding. Nevertheless, it is important to keep in mind that some species may breed at the margins, where aquatic vegetation and/or rocks may provide shelter from the flowing current.

4. Gutters must be regularly cleaned to avoid blockage and retention of water, but covering with mesh is a better long-term solution. Such measures are important as in Australia for instance, gutters have been found to be common breeding grounds for disease vectors such as *Ochlerotatus* (*Finlaya*) *notoscriptus* (Skuse) and *Aedes* (*Stegomyia*) *aegypti* (Linnaeus) (Montgomery & Ritchie 2002). In New Zealand, *Oc. notoscriptus* also thrives in such larval habitats (personal observation)

5. Drains are the main breeding sites for some disease vectors such as *Culex* (*Culex*) *quinquefasciatus* Say, and management of these habitats is of particular importance for avian disease prevention. *Culex quinquefasciatus* is a vector of *Plasmodium relictum* (avian malaria) and avian pox viruses, and it is believed to have been the vector responsible for the outbreak amongst endangered birds at the Auckland Zoo (Derraik 2004a). Sewage and storm water drains should be covered with insect mesh (1 mm). The regular use of kitchen salt (sodium chloride) can be used as a cost-effective control against larval populations, and some public health authorities overseas recommend a concentration of at least 20g/L (SUCEN 2004). For best results it should be applied weekly.

6. In order to maximize the safety of endangered animals such as birds in captive breeding programs, it is important that contact with mosquitoes is reduced to a minimum. There are obvious constraints on this, but some measures should be adopted whenever possible, such as the use of insect meshes on all cages, enclosures and windows of facilities. The use of electronic devices to kill adult mosquitoes is popular, but there is no scientific proof that they reduce mosquito density or decrease the incidence of biting. In fact, numerous studies (see Coro & Suárez 1998 for a review) have shown that mosquito-repelling (Singleton 1977, Belton 1981, Foster & Lutes 1985, Schreiber 1991, Jensen 2000, Andrade & Bueno 2001) and electrocuting devices (Surgeoner & Helson 1977, Nasci *et al.* 1983, Frick & Tallamy 1996, Jensen 2000) are ineffective.

7. The control of natural breeding habitats is more complicated, as one cannot eliminate nor cover water reservoirs such as the leaf axils of bromeliads. In

addition, natural larval mosquito habitats within vegetated areas, such as tree holes and fallen nikau palm leaves, are not easy to find and monitor. Plants may nevertheless be treated with commercially available forms of *Bti* (*Bacillus thuringiensis israelensis*), which appears to be effective against mosquitoes. Its use has been deemed as one of the safer options for use against mosquitoes in New Zealand (Glare & O'Calaghan 1998). For tree holes, the World Health Organization recommends filling them up with sand or soil as a long lasting solution (WHO 1997). However, these may be washed out by heavy rain or by animal activity. Scholl & DeFoliart (1979) suggested a type of pipe insulating cement as the optimal solution, which they reported as light, relatively cheap, able to soak up water without breaking, very durable and its two main components (silica and slag) are not known to be toxic to plants. It should be pointed out that the control of mosquitoes breeding in natural containers within native forest habitats is very difficult to achieve. In the south of Brazil for instance, upon the discovery of bromeliad-inhabiting anopheline vectors of malaria early last century, the mosquito control solution adopted was to eliminate the breeding sites themselves (Avila-Pires 2000). This drastic measure resulted in extensive deforestation which destroyed 3,000 ha of pristine tropical forests adjacent to the most affected cities (Klein 1967). Any measure of this sort would be unimaginable nowadays, and other alternatives would obviously be necessary, but this example illustrates the complexity of the problem and the extent of the challenge. It has been suggested that a few hundred thousand people could be affected in the Auckland region alone as a result of an epidemic of Ross River virus (Kelly-Hope *et al.* 2002), and public health concerns may indeed override biodiversity issues. Nonetheless, since it is more likely that mosquito vectors in New Zealand would prefer anthropenically modified habitats, a targeted control strategy may be able to minimize potential deleterious effects on the native invertebrate fauna.

Following the above recommendations should lead to an effective mosquito control programme. Although it may require some initial investment of both time and money, it will almost certainly be cost effective in the long term, as the time staff would need to spend on control measures in the future would be greatly reduced. It is fundamental that all staff are educated on the importance of carrying out such measures. In addition, high profile organizations such as zoological parks could actually play a role in educating the general public in New Zealand, many of whom are largely ignorant on how to prevent mosquito breeding. This would be of vital importance not only to prevent the occurrence of a mosquito-borne disease outbreak, but also to reduce the general nuisance problem.

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