Mosquito Life Cycles, Ecology and Behaviour “A E Wright 2002”

Background

Mosquitoes belong to the insect order *Diptera*, which include many common and familiar insects such as mosquitoes, midges and house flies.

Some are serious pests or vectors of disease while others are beneficial, and by virtue of their parasitic or predatory nature play an important role in regulating populations of many plants and animals that adversely affect human welfare.

Mosquitoes are abundant in this region of Australia. Adult female mosquitoes generally require a blood meal to effectively develop their eggs. A meal of protein in the form of blood is required to complete the reproductive process. These insects are opportunistic feeders that feed on many species of birds and mammals. Humans tend to be the most abundant source of food in many local areas close to wetland breeding areas favoured by these insects.

Problems therefore arise where human activities or habitation occur in proximity to these insect breeding areas. Extensive areas of both freshwater and tidal wetland provide ideal breeding areas for mosquitoes. As a result of the proximity of these wetland areas to residential and tourism development within the Ballina Council area, mosquito nuisance and/or disease risks are likely to occur in many areas within this district from time to time. These mosquito nuisance and health risks are likely to increase if developments continue to be allowed to encroach too close to wetland breeding areas.

As a general rule, the areas where mosquito problems will regularly create a nuisance/or health risk to our human populace will be within 1.6km of extensive breeding areas. Maps of known and suspected mosquito breeding areas have been produced for most of the populated coastal areas within Ballina Shire. (See Map A).

This information can be used to estimate those areas where potential biting insect problems will most likely occur. It should be noted that many wetland areas of the Ballina Shire have not yet been mapped for breeding grounds for mosquitoes. As well, habitat changes caused by some forms of development, such as creation of waterfront estates, reduced water quality through nutrient load or acidic runoff, altered drainage systems and filtration problems may expand mosquito problems.

Mosquitoes are an important group of blood sucking insects, not only because of the nuisance and annoyance of their bite but also because of the possibility of disease transmission to humans and other warm blooded animals. It is as vectors of disease that mosquitoes are often of most concern. An insect that transmits a disease-causing organism from one vertebrate host to another is called a disease vector. Examples of human disease agents transmitted locally by mosquitoes are Ross River virus and Barmah Forest virus. These viruses can cause debilitating disease symptoms in humans such as arthritic pain, chronic fatigue, fever, nausea and rash. These symptoms often persist for weeks and even months.

Mosquito Ecology

Mosquitoes are a particular group of insects, with an unequalled capacity to adversely impact upon human health and lifestyles. The ability of mosquitoes to blood feed, carry diseases, disperse widely and multiply rapidly under favourable conditions all contribute to this capacity.

Accordingly a basic outline of mosquito life cycles, ecology and behaviour is included here for the benefit of developers and other readers.

Common Mosquito Species in the Ballina Council Area

Ochlerotatus vigilax

This common salt marsh mosquito breeds in large numbers in temporary salt to brackish water pools left by the highest monthly tides. Eggs of this species are laid around the drying margins of these pools and may lie dormant for many months. Hatches may be triggered by tides or rainfall. Eggs may hatch in instalments as various environmental conditions in the breeding pools such as salinity and specific dissolved oxygen levels are met. *Oc. vigilax* is a savage biter by day or night so it is the species most likely to cause complaints throughout Ballina coastal areas. This mosquito also disperses widely from its breeding areas and appears attracted to the hill and ridgetops overlooking tidal flats, often many kilometres from its breeding source.

This species often reaches plague numbers during late summer, particularly when a long dry spell or drought has recently been broken by rainfall. Abnormally high tides caused by storm surges may also cause extensive *vigilax* egg hatches.

Oc. vigilax is the major vector of Ross River and Barmah Forest viruses in coastal areas of Australia (Russell et al, 1997a).

Verralina funerea

This species breeds in shaded fresh to brackish ponds, often with emergent reed vegetation or under the cover of mangrove, casuarina, tea tree or palm thickets. It is a savage biter by day or night, often biting in large numbers, though it tends not to travel far from heavily shaded areas surrounding its breeding sites. *Ve. funereus* is often found breeding in areas slightly more elevated than *Oc. vigilax* breeding sites, particularly where springs or creeks feed into brackish water habitats. Eggs are laid around the drying margins of pools and may remain dormant for many months awaiting hatching stimuli. Residential areas in close proximity to these sites are often affected by these mosquitoes for several weeks following heavy rainfall, particularly if corridors of thick vegetation are continuous between breeding sites and residential areas.

Culex sitiens

The third major salt marsh mosquito pest in the district is *Cx. sitiens* which breeds in fresh to brackish ponds in similar habitat to *Oc. vigilax*, though it prefers a lower salinity. This species usually reaches population peaks during late summer when rainfall has diluted salinity in tidal salt marsh pools and flooded lowland agricultural flats.

Eggs of this species are deposited in rafts on the surface of the water. *Cx. sitiens* is slower than the two previous species to build up population peaks, due to the fact that *Ochlerotatus* and *Verralina* mosquitoes eggs are already awaiting hatching stimuli in their preferred larval habitat prior to the pool flooding. (See Appendix).

Culex sitiens feeds mainly at night and may disperse widely from its coastal breeding areas.

Culex annulirostris

This species breeds in sunlit freshwater pools, especially when thick marginal or emergent vegetation is present to provide protection from fish, dragonfly larvae and other predators. *Cx.annulirostris* will also breed in freshwater bodies which are nutrient enriched e.g. water polishing ponds, (i.e. artificial wetlands constructed with thick emergent vegetation to remove nutrients).

In temperate areas of Australia adult *Culex annulirostris* are usually active from late spring through summer to late autumn. In warmer, tropical areas of Australia this species is active year round. This species feeds on humans as well as a wide variety of mammals and birds and is crepuscular in its biting habits, feeding most actively for about two hours after sunset and then again around dawn. *Culex annulirostris* can disperse widely (up to ten kilometres) (O'Donnell et al, 1986) in search of bloodmeals. *Culex annulirostris* is the major vector of Murray Valley encephilitis, and Kunjin viruses throughout Australia (Broom et al 1997), it is also a major vector of Ross River (RR) and Barmah Forest (BF) viruses in areas away from the coast (Russell et al, 1997a).

Coquillettidia linealis

This species breeds in freshwater wetlands which contain thick emergent vegetation e.g. Typha, Baumea orJuncus reeds. The larvae of this species (and others of the genera *Coquillettidia* and *Mansonia*) attach to the stems of this emergent vegetation, obtaining oxygen without the more hazardous necessity of staying on the water surface to breathe the air like other mosquitoes. Adult *Cq. linealis* are active through the warmer months of the year from mid-spring until autumn, although periods of peak abundance vary considerably with regional rainfall patterns. This species readily and viciously bites humans, as well as other animals, and is mainly nocturnal although it will bite during the day in shaded conditions.

Coquilettidia linealis readily disperses up to three kilometres in search of bloodmeals and may be an important secondary vector of RR and BF viruses (Russell et al, 1997a).

Ochlerotatus notoscriptus

This species breeds in a wide variety of domestic container situations where rainfall collects, especially where dead leaves also accumulate e.g. blocked gutters, stock troughs, rainwater tanks without effective screening, pot plant drip trays etc. However it does not appear to breed in polluted water e.g. septic tanks, or in natural ground pools. It does however breed in natural "containers", e.g. treeholes and rock pools.

This species bites viciously at night and by day in shady areas, however it does not appear to disperse widely away from breeding sites (i.e. less than 500 metres).

This species may be a secondary vector of RR and BF viruses in urban and suburban areas (Doggett and Russell, 1997a).

Ochlerotatus procax

This species is common in coastal areas of northern New South Wales and S.E. Queensland, where it breeds in ground pools in bushland and riparian areas following heavy rainfall.

This species bites humans readily, although it does not appear to disperse widely away from its breeding areas. RR and BF viruses have been isolated from this species, however its status as an effective vector is not known.

Ochlerotatus multiplex

This species is locally common within the Ballina area where it breeds in shaded ground pools, especially in forested areas, following heavy rainfall. This species bites humans but does not appear to disperse widely away from its breeding areas. This species is not known to be a vector of diseases.

Mosquito Borne Diseases (see also www.medent.usyd.edu.au/arbovirus)

Ross River virus (RRv)

RRv is endemic in this region. This virus causes outbreaks or sporadic cases of an epidemic polyarthritis in humans in most years. During the period 1998 –2002, 50 cases of RRv disease were notified from within Ballina Council area. (J.Terry, PHU Lismore). For reasons of underreporting, underdiagnosis and undernotification this figure almost certainly underestimates the true incidence of RRv disease. While the disease has no associated mortality, the symptoms can be extremely painful and debilitating, often resulting in severe lifestyle constraints and substantial economic losses. The mosquito suspected of being the major vector of this disease in this area is *Ochlerotatus vigilax. Culex annulirostris* is the major vector of RRv in inland and northern areas of Australia. Ross River virus has also been isolated from *Verralina funerea, Culex sitiens, Coquillettidia linealis andAedes procax*. (Russell et al, 1997a). These latter species are not considered major vectors, however experimental transmission studies (Ryan and Kay, 1997) suggest that both *Verralina funerea* and *Ochlerotatus procax* can be effective vectors when conditions are suitable.

Barmah Forest virus (BFv)

This mosquito-borne virus is closely related to RRv, although it is generally less prevalent and less well recognised, having been more recently discovered. BFv causes a similar human disease to that caused by RRv and is carried by similar species of mosquitoes. It also occurs in both outbreaks and sporadic cases of human disease; sometimes these outbreaks occur concurrently with RRv, sometimes separately. *Ochlerotatus vigilax* and *Culex annulirostris* are considered to be the major vectors of BFv, although it has also been isolated from a number of different mosquito species. (Russell et al, 1997b). During 1998 –2002, 27 cases of BFv disease were notified from within Ballina Council areas (J.Terry – PHU Lismore).

General Life Cycle

The mosquito starts life as an egg, which hatches into a larva, or wriggler. The larva is the growth stage of the mosquito; it actively feeds and moults four times. The four larval stages are called instars. On the last moult the larva becomes a pupa, a mobile, non-feeding stage which generally only lasts 2-4 days. Both the larval and pupal stages of the mosquito life cycle are aquatic although they both breathe air through the surface of the water via a siphon (larvae) or a trumpet (pupae); they simply must have appropriate water which lasts long enough (at least 6 days, often more – see below) for these stages to be completed. The requirements of the egg stage vary with different species and genera of mosquitoes (see below).

Inside the pupa the adult mosquito forms and then hatches through a split in the back of the pupa. It climbs on to convenient emergent vegetation, expands and dries its wings and then usually flies off to feed on plant nectar. Male mosquitoes tend to assemble in swarms, into which female mosquitoes fly, whereupon they mate with one of the males. Female mosquitoes mate only once and store sperm to fertilise each batch of eggs (see below).

Variations in Mosquito Life Cycles

Ochlerotatus and Verralina mosquitoes lay dessication resistant eggs above the waterline of appropriate temporary or seasonal water bodies. These eggs remain dormant until water levels rise due to either rainfall, flooding or tidal inundation (see below), whereupon most hatch and develop synchronously, emerging as a sudden plague of biting adults about a week later in summer; (this process takes longer under cooler conditions). These plague levels of adults persist for a week or so then progressively decline due to natural factors (dessication, predation). After three or four weeks very few, if any, remain alive unless subsequent water level rises and resultant egg hatches have generated one or more new, overlapping generations of mosquitoes.

This life cycle strategy is highly responsive to the presence of suitable breeding sites and usually results in greater fluctuations in adult mosquito numbers than is the case for *genera* that breed in more permanent breeding sites (e.g. *Culex, Coquillettidia, Mansonia* species). (See Fig.1)

Culex mosquitoes lay their eggs on the surface of suitable standing water in rafts consisting of between 50 and 500 eggs. These eggs are not dessication resistant and do not lie dormant, instead they hatch within a few days. Consequently *Culex* mosquitoes require continuous standing water to survive at a given breeding site; if the site dries up, *Culex* mosquitoes must recolonise the site when it is again filled with water. However if the breeding site does retain water *Culex* mosquitoes can continue to breed without the requirement of a rise in water level to hatch their eggs (in contrast to *Ochlerotatus or Verralina* species). Because water bodies colonised by *Culex* mosquitoes generally persist for longer, they are more likely to be also colonised by predators of mosquito larvae such as dragonfly larvae, water beetles and even fish. The net effect of these factors is that Culex mosquito populations rise and fall less dramatically than those of *Ochlerotatus and Verralina* mosquitoes (See Fig.1)

The larval stage of *Culex* mosquitoes usually lasts 8-12 days at high temperatures because there is less natural selection pressure to complete larval development quickly than is the case with *Ochlerotatus* and *Verralina* mosquitoes breeding in more ephemeral water bodies.

Coquillettidia and Mansonia mosquitoes lay their eggs singly on the underside of suitable emergent or floating vegetation (reeds, waterlilies etc.) by dipping the end of their abdomen through the surface of the water. These eggs are also neither dessication resistant nor dormant, so these mosquitoes require more persistant water bodies which have existed long enough to allow the colonisation and proliferation of appropriate vegetation. Their life cycles are often of several weeks duration as there is no natural selection pressure to complete life cycles quickly (again, in contrast to *Ochlerotatus and Verralina* mosquitoes). Consequently, like *Culex* mosquitoes their populations rise and fall less dramatically than *Ochlerotatus* and *Verralina* mosquitoes (See Fig 1).

Adult mosquito feeding behaviour

All adult mosquitoes feed on plant nectar, a source of concentrated carbohydrate to provide ideal energy for flight. Most, but not all, adult female mosquitoes also blood feed, engorging themselves until they have more than doubled their weight with high protein liquid food. The bloodmeal is then digested and converted into egg yolk. Bloodfeeding is therefore a behaviour which evolved and became almost ubiquitous amongst mosquitoes because it enables female mosquitoes to lay far more eggs than would be the case if they had to rely upon protein reserves remaining from the main feeding stage ie. the larva.

When an adult female mosquito inserts its biting mouthparts (proboscis) into a host it secretes saliva into the host. This saliva contains an anti-coagulant without which it would not be possible to blood-feed; the blood would simply clot whilst travelling up the extremely narrow feeding tube within the mosquito proboscis. The secretion of saliva by adult female mosquitoes is the basis of human problems with, and hence interest in, mosquitoes. The saliva is recognised as “foreign” by the host immune system because of the large protein molecules it contains. The immune system reacts (far more strongly in some individuals than others – hence the wide range of itch responses), causing the hot, inflamed, itchy welts we associate with mosquito bites. This is also the mechanism by which mosquito borne diseases are transmitted. Any pathogen (disease causing agent) which is effectively transmitted by mosquitoes has the ability to multiply within the salivary glands of mosquitoes. This enables the delivery of an infective dose of the pathogen concerned and creates the risk of disease in the bloodmeal host . Obviously, and for a variety of different physiological reasons, not all mosquito species can do this, and those that can transmit, for example, Ross River virus, are not all equally effective at doing so.

After bloodmeal feeding the adult female mosquito retreats to a cool humid refuge, digests the bloodmeal and develops a batch of 100-500 eggs. These are then laid as described above, the mosquito usually obtains a feed of nectar and then seeks another bloodmeal host. It does not need to mate again, having stored enough sperm from its single mating to fertilise as many batches of eggs as it lives long enough to produce. Mosquitoes vary widely as to the time of day that they bite. Many mosquitoes are nocturnal (night feeding) or crepuscular (peaks of biting behaviour at sunset/dusk and then again at dawn). However some are also diurnal (daytime) feeders, especially those living in either cool climates, the wet tropics or shaded forests generally.

The timing of mosquito feeding behaviour has a lot to do with the limitations of mosquito physiology; mosquitoes are relatively fragile and subject to dessication (drying out), so they tend to be most active in humid, shaded conditions. They are also not active if temperatures are too low; as “cold-blooded” animals whose body temperature (and hence metabolic rate) is governed by ambient temperatures they are simply not able to function if it is too cold, instead resting or dying.

Individual mosquito species will also vary their activity levels (including blood feeding) according to conditions. For example *Culex annulirostris* mosquitoes are usually crepuscular or nocturnal in hot weather, however on cloudy, milder days they will also bite during daylight hours, especially in the shade.

Some mosquito species are highly opportunistic, biting day or night under all but the worst conditions of hot sun, strong winds or heavy rain (all of which are rather life-threatening for mosquitoes). The best example of these is *Ochlerotatus vigilax*, the ubiquitous coastal saltmarsh mosquito.

Another way in which mosquito biting behaviour varies considerably is the choice of bloodmeal hosts. Some mosquitoes are strongly anthropophilic (human biting), others are ornithophilic (bird biting) and never bite humans at all. The members of one genus of very small mosquitoes *(Uranotaenia)* are almost exclusively frog feeders. Many mosquitoes will blood feed from a variety of different hosts. All other things being equal (i.e. abundance, physiological capability etc.), this attribute increases the risk of transmission of arboviruses such as Ross River virus. Arboviruses which can cause human disease in Australia are mostly zoonotic diseases. This means that the pathogen concerned circulates naturally between mosquitoes and wildlife or domestic animals, and that humans are only incidentally infected. In other words humans are not essential to the ongoing survival of the pathogen concerned.

As outlined above, the blood feeding habits of mosquitoes are highly variable. Both care and knowledge is essential to the accurate interpretation of mosquito collection data. A mosquito trap index of for example, one hundred *Ochlerotatus vigilax* is far more significant in both nuisance and disease risk terms than even a thousand *Culex orbostiensis* because the latter only feeds on birds at night. An understanding of the blood feeding habits of each significant mosquito species present in an area is essential to any efforts to reduce the nuisance or disease risk impacts of the mosquitoes concerned.

Mosquito Dispersal

Another very variable aspect of mosquito behaviour which significantly effects the degree to which mosquitoes can impact human lifestyles is their ability to disperse away from breeding sites in search of bloodmeals. At one extreme many domestic mosquito species such as *Ochlerotatus notoscriptus* only disperse tens, or at most hundreds of metres. At the other end of the spectrum we have *Ochlerotatus vigilax* (in Australia) and many other similar saltmarsh mosquito species elsewhere in the world which readily disperse up to fifty or more kilometres. This aspect of mosquito behaviour is critical to considerations of buffer zones between mosquito breeding areas and proposed residential or resort developments.

Mosquito dispersal distances also vary greatly according to the type of terrain to be traversed. Ginsberg (1986) showed that an American salt marsh mosquito *(Ochlerotatus, sollicitans*) dispersed many kilometres through wooded areas, but less widely across open, cleared areas and less widely again across open water. Whilst such detailed studies have not been carried out in Australia observations by various mosquito workers suggest that similar patterns of behaviour by salt marsh mosquitoes also occur here.

Mosquito breeding sites

These are the aquatic environments selected by the female mosquito on the basis of olefactory stimuli (i.e. smell) as being suitable for oviposition (egg-laying) and subsequent larval developments (See above).

Different mosquito species will choose different types of standing water in which to lay eggs. These vary from plant leaf axils to extensive wetland areas (like the Ballina Nature Reserve), to mangrove swamps to rainwater tanks to badly maintained septic tanks (and all points in between). Whilst varying enormously these breeding sites have one thing in common i.e. water must stand for a minimum of six or seven days for larval development to be completed (longer at lower temperatures). Contrary to popular mythology, mosquitoes do not breed in long green grass, although they often choose such places to rest and shelter from sun, wind or rain.

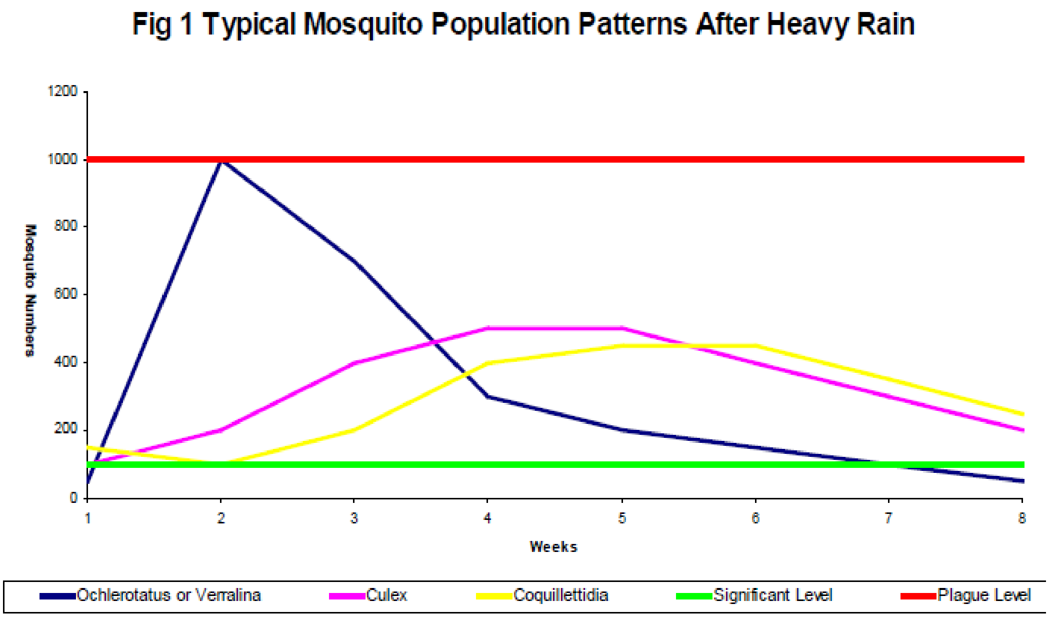
Another feature of mosquito ecology which is not always widely understood is the ability of some mosquito species to breed in saltwater pools remaining after high tides which flood mangrove or saltmarsh areas. The most important of these in Australia is *Ochlerotatus vigilax*, the vicious-biting, widely dispersing major vector of Ross River virus.

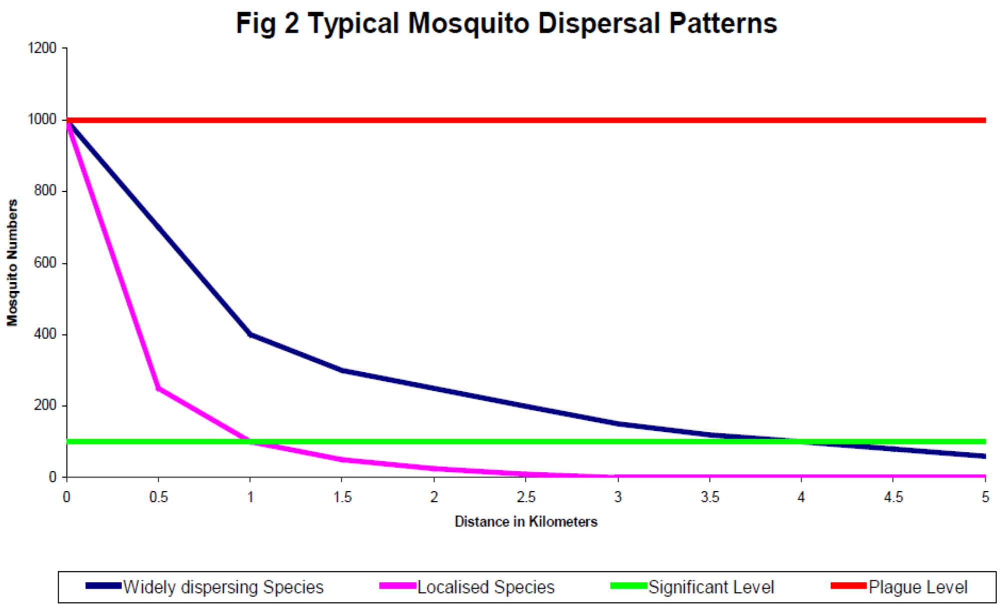
Seasonality and Weather

Most mosquito populations vary enormously according to both seasons and weather. Temperature effects both growth rates and blood-feeding behaviour as already mentioned. Rainfall usually has prolonged effects on the creation, maintenance and suitability of breeding sites. This is especially the case with *Ochlerotatus* and *Verralina* mosquitoes, numbers of which can change from negligible to plague levels in the space of a couple of days one week or so after flood rains. Humidity has very significant effects on mosquito blood-feeding behaviour (See above) and also mosquito survival; adult mosquitoes will live much longer (up to several weeks) under ideal warm, humid, cloudy conditions, than they will under either hot or cold windy conditions.

This variation in survival has prolonged effects on the transmission of mosquito-borne diseases. Adult female mosquitoes which live several weeks (and take several bloodmeals) are much more likely to ingest an arbovirus (e.g. Ross River virus), incubate it and then pass it on at a subsequent blood feed. Conversely mosquitoes living in hot, windy conditions are likely to perish due to dessication long before they have had a chance to ingest, incubate and transmit any pathogen.

All of the above factors vary greatly from both season to season and from one year to the next. Mosquito activity levels and consequently nuisance levels, disease risks and the need for and cost of mosquito control also vary greatly as a result. This can create considerable problems, especially if understanding is lacking and expectations are consequently unrealistic on the part of either those in decision making positions or the general public.





Glossary of Terms

This section is included to provide working explanations of mosquito related jargon which may not be familiar to some readers.

Anthropophilic	a mosquito which bites humans
arbovirus	arthropod borne virus e.g. Ross River virus
arthropod	a phylum of animals with external skeletons which includes insects and is used in this context because some exotic arboviruses are transmitted by ticks, not insects
crepuscular	peaks of activity at dusk and dawn
duirnal	peaks of activity during daylight
endemic	always present in an areas (a pathogen)
entomologist	someone who studies insects
ephemera	ecological term referring to occurences in nature which happen quickly or don't last long
genus (plural genera)	a group of related species e.g. *Ochlerotatus*
instar	the growth stage of a mosquito larva between moults; mosquito larvae have four instars
larva (plural larvae)	growth stage, wriggler; the mosquito equivalent of a caterpillar
larvicide	an insecticide which targets larvae
larvivorous	feeding on larvae

mosquito breeding areas - aquatic environments where larvae live

nocturnal	peaks of activity at night
olefactory	smell
ornithophilic	a mosquito which bites birds
oviposition	the act of laying eggs (by an insect)
pathogen	a bacterium, virus or protozoan which causes disease
pupa (plural pupae)	the insect stage between larva and adult
species	a population which can breed with other members of the same species, but not other species

vector an insect or arthropod which can carry disease organisms from one host to another

zoonotic term describing a human disease organism which survives in cycles between vectors and animal hosts independently of humans e.g. Ross River virus

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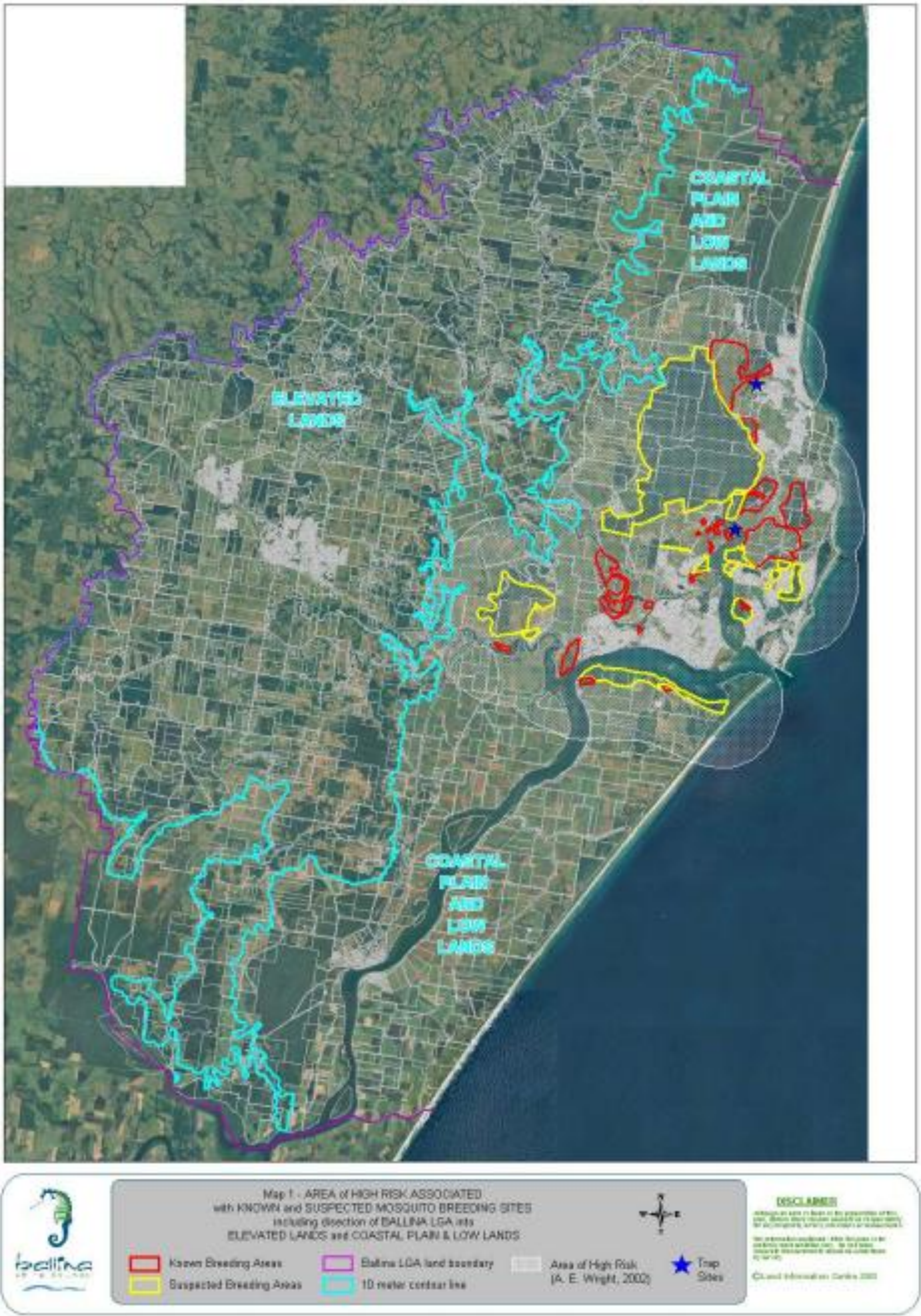
Further Information

Please contact Council's Regulatory Services Group on telephone 02 6686 1210.


COASTAL PLAIN AND LOW LANDS
ELEVATED LANDS
COASTAL PLAIN AND LOW LANDS
Map 1 - AREA of HIGH RISK ASSOCIATED
with KNOWN and SUSPECTED MOSQUITO BREEDING SITES
including disection of BALLINA LGA into
ELEVATED LANDS and COASTAL PLAIN & LOW LANDS
Known Breeding Areas
Suspected Breeding Areas
Ballina LGA land boundary
10 meter contour line
Area of High Risk (A. E. Wright, 2002)
Trap Sites
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