APPENDIX M: HEXHAM SWAMP MOSQUITO MONITORING PROGRAM – PROGRESS REPORT (FEBRUARY 2005)

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Summary Report: Mosquito investigations at Kooragang Island, Hexham Swamp and Tomago wetlands, 2002/2003 & 2003/2004.

A report prepared for Hunter and Central Rivers Catchment Management Authority

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EXECUTIVE SUMMARY

- Mosquito populations were sampled at three wetlands in the Lower Hunter Estuary in a continuation of the monitoring program commenced in 2002. The monitoring program is designed to assist the development of mosquito management strategies on Kooragang Island and provide baseline data for the assessment of habitat modification planned for the Hexham Swamp and Tomago wetlands.

- Adult and larval mosquito surveys were carried out in the three wetlands during two consecutive mosquito 'seasons', from December 2002 through until April 2003 and from December 2003 through until May 2004.

- The dominant factor influencing mosquito populations in both monitoring periods was the relatively low rainfall. As a result of the lack of substantial rainfall, many mosquito habitats were not inundated, or did not remain inundated for sufficient periods to allow mosquito breeding.

- The most abundant species was the saltmarsh mosquito *Ochlerotatus vigilax*. This species actively disperses great distances from breeding habitats, is a severe nuisance biting pest and is the most important vector of arbovirus disease in coastal regions of NSW. Populations of this species are closely linked to inundation of the wetlands with populations greatest when rainfall and tides combine to flood the wetlands.

- The freshwater mosquito, *Culex annulirostris,* was less abundant during these sampling periods compared to 2001/2002. The reduction in abundance of this species is directly related the low rainfall (2002/2003) and late season rainfall (2003/2004) failing to create substantial suitable breeding habitats in the three wetland areas. There was also a decrease in the overall diversity of freshwater mosquitoes collected as larvae and adults in 2002/2003 and 2003/2004 compared with 2001/2002.

- The re-establishment of tidal flow to the Hexham Swamp wetlands will increase potential habitats for *Oc. vigilax* but the resulting adult populations may not contribute to an overall increase in pest impacts in the lower Hunter estuary due to the prominence of breeding habitats in Kooragang Island and Tomago. The magnitude of population increases will be dependent on the tidal regime (frequency and duration of inundation) and changes in environmental variables such as vegetation composition (increased saltmarsh) and predator populations.

- Ongoing monitoring of adult and larval mosquito populations is recommended to assist future management of the wetlands.

INTRODUCTION

The Hunter-Central Rivers Catchment Authority commissioned The Department of Medical Entomology to undertake mosquito monitoring in the wetlands of Kooragang Island, Hexham Swamp and Tomago to assist wetland management across the lower Hunter estuary. The monitoring follows previous investigations by Turner (1999) and Flanagan (2001). The data collected in this monitoring will also form the basis of assessments of two habitat rehabilitation projects proposed to restore tidal flows to the wetlands of Hexham Swamp (via opening of floodgates at Ironbark Creek) and the landward habitats of the Tomago site west of Fullerton Cove.

There Lower Hunter River Estuary contains extensive areas of estuarine wetland that produce large populations of the saltmarsh mosquito, *Ochlerotatus vigilax,* following inundation by high spring tides and/or rainfall. Notwithstanding the severe nuisance biting impacts of these mosquitoes, there are also significant public health risks associated with large populations of both saltmarsh and freshwater mosquito species. A total of 932 human notifications of Ross River and Barmah Forest virus infections were reported by the Hunter Area Health Service from July 1996 until June 2003.

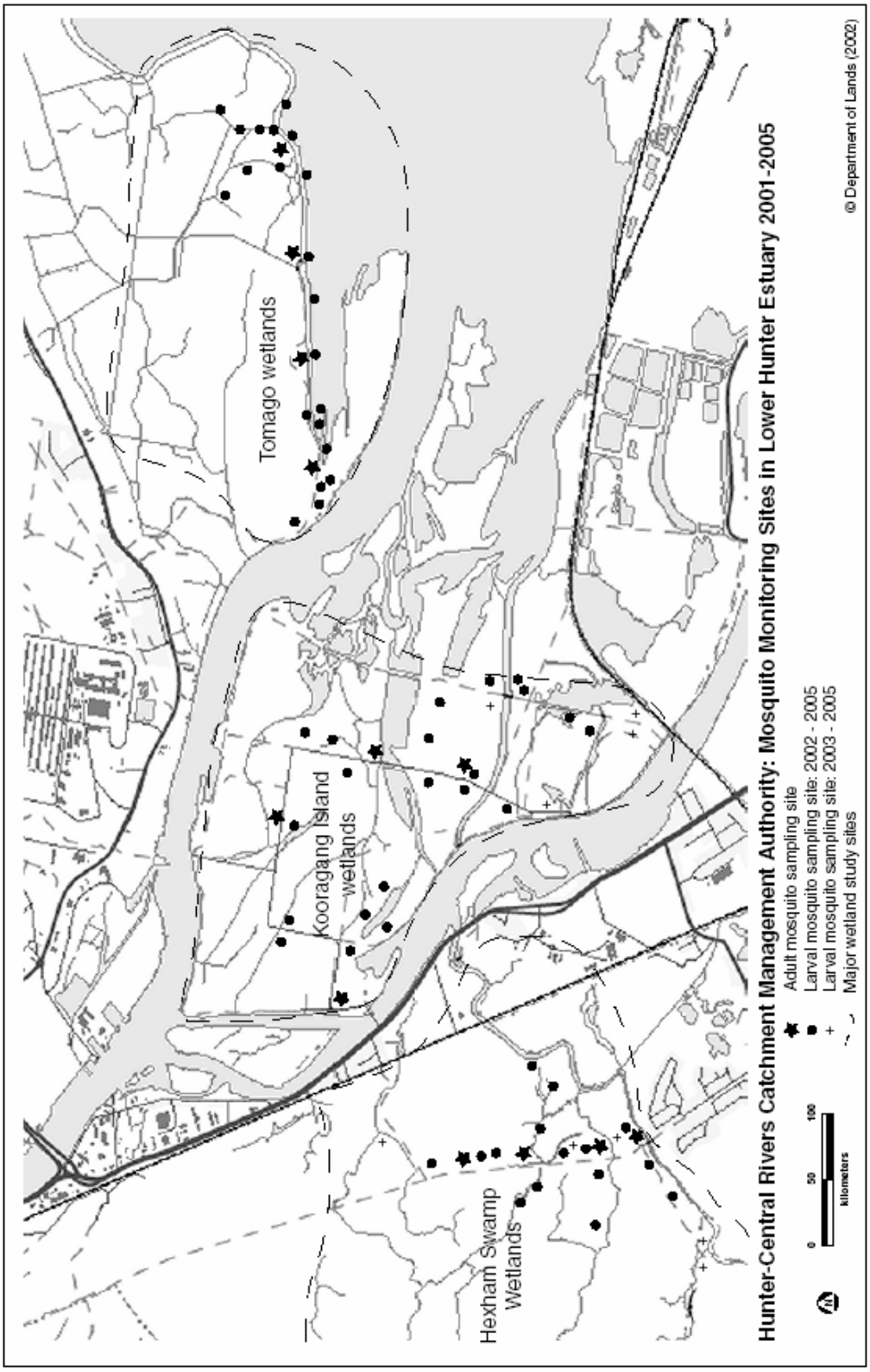
Mosquitoes associated with freshwater and brackish water habitats can also pose nuisance biting and public health risks. The freshwater mosquito, *Culex annulirostris*, is the major freshwater mosquito in the lower Hunter region with the most extensive habitats found in Hexham Swamp and inland areas of Tomago as well as small areas of habitat on Kooragang Island.

METHODS

Adult and larval mosquito sampling was undertaken in three wetland areas within the Lower Hunter River Estuary, Kooragang Island, Hexham Swamp and Tomago wetlands as described in the report of the 2002 monitoring program (Webb & Russell 2002). The location of all adult and larval sampling sites is shown in Figure 1.

As a result of species-specific dispersal patterns, the collection of adult mosquitoes cannot always be used to directly assess the mosquito productivity of that habitat. However, the collection of adults provides a much greater indication of overall diversity in the mosquito fauna and better assessments of onsite nuisance biting impacts. Adult mosquito abundance was recorded at 12 fixed trap sites across the three wetland areas using dry ice baited EVS traps (Rohe and Fall 1975). These traps use CO_2 as an attractant to host seeking female mosquitoes. Collections were returned to the Department of Medical Entomology and identified to species according to the taxonomic key of Russell (1993).

Figure 1. Location of adult and larval mosquito monitoring sites in the three wetlands areas of the lower Hunter estuary, 2002/03 and 2003/04.



Populations of mosquitoes associated with estuarine wetlands are closely linked to inundation of the wetlands by high tides and/or rainfall. Therefore, each of the three wetlands was sampled, where possible, within 5 days of inundation by high tides.

Larval populations were sampled at 66 sites (25 in Kooragang, 20 in Hexham and 21 in Tomago) using a standard dipping technique with a 300ml dipper. The number of larvae was recorded according to date and sampling site. Identification of larvae was undertaken in the field where possible; otherwise larvae were returned to the laboratory for identification to species using the keys of Russell (1993). Additional larval sampling sites were added in all three wetlands since the 2001/2002 monitoring period. In Hexham Swamp, sites were added based on the proposed areas of flooding under King and Spring tides (provided by Mr Philip Haines, WBM).

Temperature and rainfall data were taken from the Bureau of Meteorology (Newcastle) and the tidal data for the Hunter estuary from Manly Hydraulics.

RESULTS & DISCUSSION

Tides and Rainfall

The highest weekly tides and total weekly rainfall for Newcastle are presented in Figure 2. During January and February 2002, the total rainfall recorded was only 37.8mm, compared with the long term average of 198mm. It was not until the last week of February, when 76mm of rain was recorded that many freshwater habitats were inundated. The rainfall during January, February and March 2003 was much closer to average rainfall patterns. However, given the extended dry period during spring 2003, many of the freshwater habitats dried relatively quickly. The highest weekly rainfall event was March, when 148mm was recorded

Weekly tidal events between December and May, sufficient to inundate the estuarine wetlands of Kooragang Island (generally over 1.8m), occurred on 8 occasions in 2002/2003 but only 4 in 2003/2004 (Figure 1).

Larval populations

A total of 6 mosquito species was collected as larvae from the three wetlands during 2002/2003 (Table 1) and 8 species during 2003/2004 (Table 2). The most commonly collected species was *Oc. vigilax*. With the exception of *Oc. vigilax,* that was often found in high densities on Kooragang Island, the other species were recorded at very low densities and in some cases (eg. *An. annulipes* and *Oc. alboannulatus*), only a few individuals were collected.

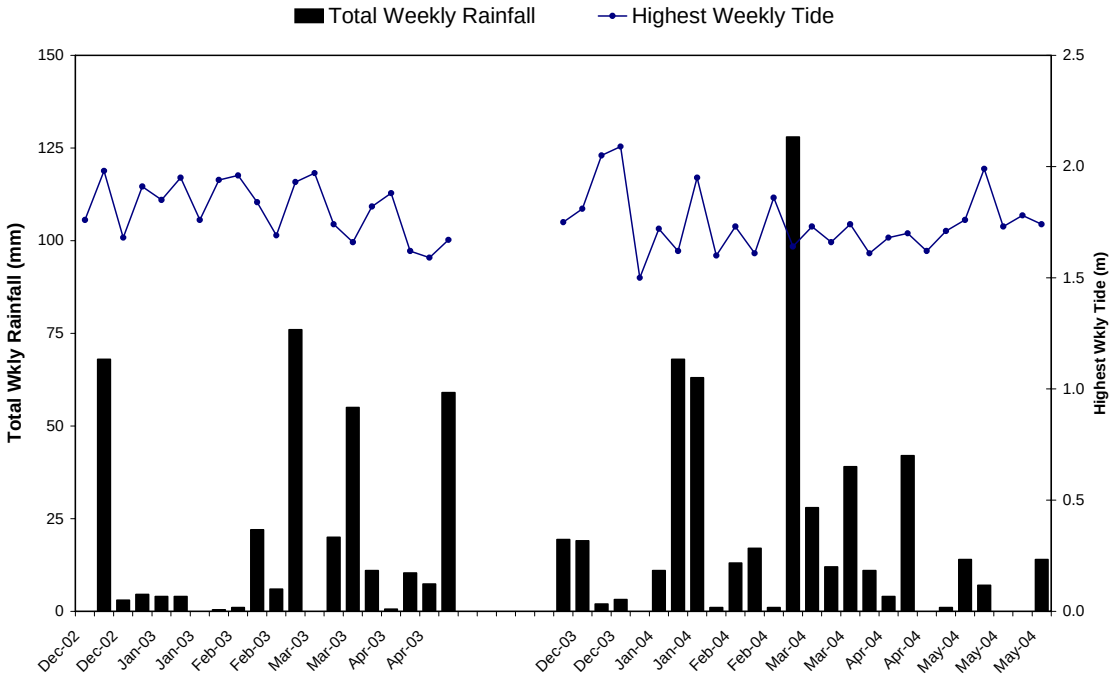


FIGURE 2. Total weekly rainfall and highest weekly tide in the Hunter Region (recorded at Newcastle Met. Station) from December 2002 to April 2003 and December 2003 to May 2004.

TABLE 1. Mosquito species collected as larvae from habitats within the three wetlands, December 2002 until April 2003.

Species	**Kooragang**		**Hexham**		**Tomago**	
	Saline[1]	Fresh	Saline	Fresh	Saline	Fresh
Cx. annulirostris				+		
Cx. australicus		+		+		+
Cx. quinquefasciatus				+		
Cx. sitiens	+	+	+		+	
Oc. alternans	+		+		+	
Oc. vigilax	+		+	+	+	
total	3	2	3	4	3	1

[1] Saline habitats include all habitats with salinity >3ppK

TABLE 2. Mosquito species collected as larvae from habitats within the three wetlands, December 2003 until May 2004.

Species	Kooragang		Hexham		Tomago	
	Saline[1]	Fresh	Saline	Fresh	Saline	Fresh
An. annulipes		+		+		
Cx. annulirostris				+		+
Cx. australicus		+		+		+
Cx. quinquefasciatus		+		+		
Cx. sitiens	+	+		+	+	
Oc. alboannulatus						+
Oc. alternans	+			+	+	
Oc. vigilax	+		+	+	+	+
total	3	4	1	7	3	4

[1] Saline habitats include all habitats with salinity >3ppK

The decreased diversity in the larval mosquito fauna during these two sampling periods, compared to the 10 species collected in 2001/2002, reflects the reduced habitat available due to the lack, or only small amount of rainfall during these two sampling periods.

Larval densities of *Oc. vigilax* were greatest following inundation of the wetlands by high tides and/or rainfall when pooling of water was common on the marsh. Overall, the larval populations of *Oc. vigilax* were consistently greatest in small to medium sized shallow pools on Kooragang Island lined with *Sarcocornia quinqueflora* or *Sporobolus virginicus* (Figure 2). Moderate to high densities of larvae were also collected from pools associated with mangrove stands. However, this was only in circumstances where the area was poorly flushed and, generally, the mangroves were in poor health with saltmarsh vegetation on the margins of the pools. Larger pools and areas of extensive inundation supported lower densities of larvae, usually collected from vegetated margins.

Ochlerotatus vigilax was found across a wide range of salinities ranging from 2ppk (Hexham Swamp) to some pools on the saltmarsh of Kooragang Island >40ppk. Larvae of *Oc. vigilax* were rarely collected from habitats with salinity <5ppk despite, being located within the estuarine wetlands of Kooragang Isand adjacent to saltmarsh pools containing high densities of larvae.

Figure 3. An example of productive *Ochlerotatus vigilax* habitat on Kooragang Island

Larvae of *Oc. vigilax* were also collected from Hexham Swamp. Larval densities were low and only recorded following inundation of the wetland by the heavy rainfall in March 2004. Larvae were collected from shallow pools within the remnant stands of saltmarsh (Figure 3) and grassy pools within *Juncas* stand close to Ironbark Creek. The breeding by *Oc. vigilax* in Hexham Swamp was considered minor compared with breeding on Kooragang Island and Tomago, and, generally, the wetland is not considered an important breeding site for *Oc. vigilax*.

Hexham Swamp supported extensive breeding by a range of freshwater species in 2001/2002 but due to the dry conditions during these two sampling periods, the abundance of larvae was greatly reduced. While briefly inundated in early December 2002 (Figure 4), the majority of habitats in Hexham remained dry until March 2003. However, even following the inundation at this time, and the persistence of inundation for many weeks, no larvae were collected at high densities. This result was most likely due to the timing of inundation as the build up of freshwater mosquitoes may required that the wetlands are inundated in January or early February to allow sufficient time for population buildup.

Figure 3. Remnant saltmarsh habitat in Hexham Swamp, east of the water pipeline. When flooded with rainfall, low densities of larvae were collected from small pools.

There was a great disparity in the larval populations recorded from the Tomago site either side of the levee bank. While the river side of the levee bank contains extensive saltmarsh and mangrove areas, larvae were only occasionally collected and at only low to moderate densities. These areas, as well as being well flushed, generally supported more abundant fish populations.

Moderate to high densities of *Oc. vigilax* larvae were collected from the saltmarsh lined drainage channels (Figure 5) landward of the levee bank and ring drain. While generally remaining dry, these channels, once flooded by heavy rainfall, supported abundant larvae. The small shallow pools and channels run through remnant mangrove and saltmarsh areas and while covering only a small area, have the potential to produce large numbers of adult mosquitoes.

There are likely to be many more freshwater and brackish water habitats on the landward side of the levee bank. The site covers an extensive area and access was difficult and time consuming, limiting the opportunity to survey new areas. Larval populations in this area may be underestimated using the current sampling sites and, as reflected in some adult collections, this site may make a significant contribution to the overall mosquito impacts in the local area.

Figure 4. Flooded freshwater habitat in Hexham Swamp suitable for *Culex annulirostris*, *Culex australicus* and *Culex quinquefasciatus*.

Figure 5. An example of channels running landward from the ring drain at Tomago. The channels contain saltmarsh vegetation and, when flooded, high densities of larvae.

Adult mosquitoes

Across the three wetlands, adult collections recorded a total of 9 species in 2002/2003 and 12 species recorded in 2003/2004. The most abundant species across the three wetlands were *Oc. vigilax*, *Cx. annulirostris* and *Cx. sitiens*.

There were fewer species of mosquito collected in these two sampling periods compared with 2002 when 19 species were recorded. The decrease was a direct result of the generally low rainfall during the 2002/2003 and 2003/2004 monitoring periods. There was, however, a relatively diverse range of mosquitoes collected including species associated with saltmarsh habitats (*Cx. sitiens*, *Oc. alternans, Oc. camptorhynchus* and *Oc. vigilax*), brackish/freshwater ephemeral habitats (*An. annulipes*, *Oc. procax* and *Ve*. Marks#51), permanent freshwater habitats (*Cq. linealis*, *Cx. annulirostris*, *Cx. australicus*, *Cx. orbostiensis* and *Ma. uniformis*), highly polluted habitats (*Cx. molestus*, *Cx. quinquefasciatus*) and tree-hole/container habitats (*Oc. notoscriptus*). It is interesting to note that *Oc. camptorhynchus* was collected in May 2004 from Kooragang Island. This species is usually associated with estuarine habitats along the coastline of the southern states and the Hunter is close to the northernmost distribution of this species and was not collected during the 2001/2002 or 2002/2003 sampling periods.

The abundance of adult *Oc. vigilax* across the three monitoring periods is shown in Figure 6. Populations of this species were generally similar between the two monitoring periods with no exceptionally large population increases as recorded in February 2002. Overall, the greatest abundance of *Oc. vigilax* was recorded at Tomago with collections consistently two to three times as great as collections in Kooragang or Hexham Swamp.

Only small numbers of *Oc. vigilax* larvae collected in larval surveys at Tomago during 2001/2002, but more extensive sampling of landward sites along channels during the 2002/2003 and 2003/2004 monitoring periods have shown that extensive breeding can often occur in these areas and will definitely contribute to the high mosquito abundances. However, adult populations were still high despite these landward habitats remaining dry and the adult *Oc. vigilax*, on these occasions, may be moving into the area from habitats on Kooragang Island, including the extensive estuarine wetlands within the Kooragang Nature Reserve that extend from the north-eastern edge of the island and into Fullerton Cove.

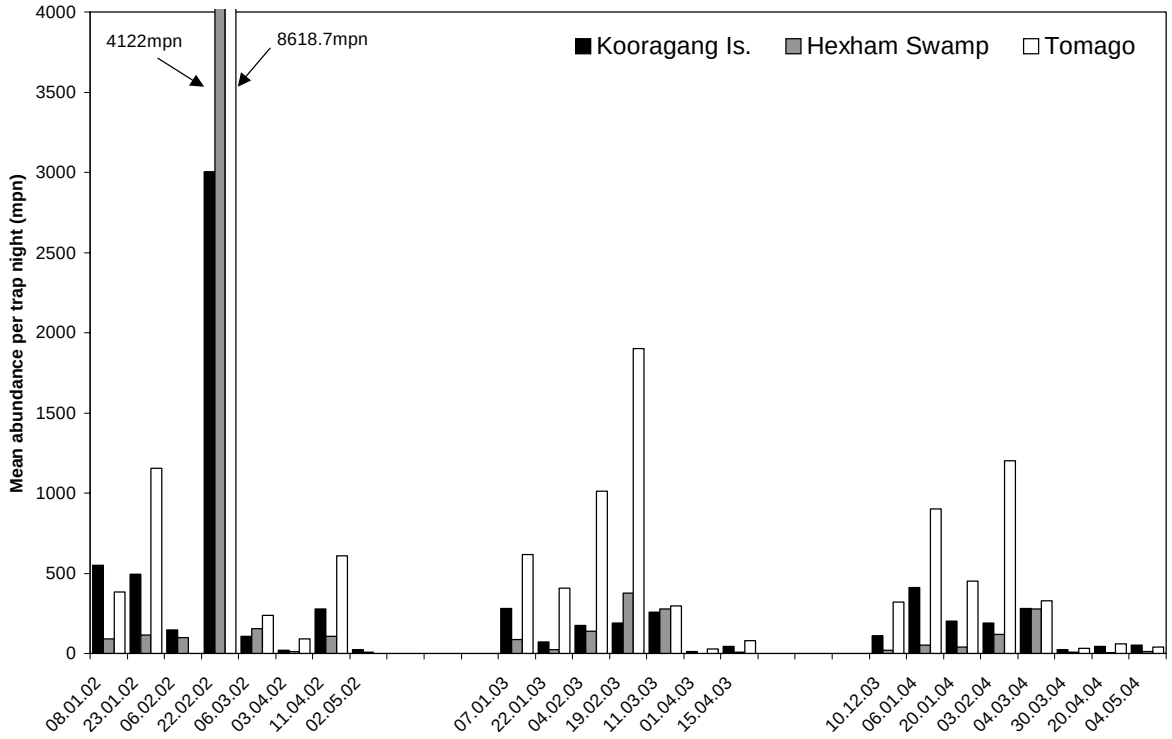


FIGURE 6: Mean number of *Ochlerotatus vigilax* collected per trap at Kooragang Island, Hexham Swamp and Tomago Wetlands over three sampling periods from January 2001.

Despite the absence of extensive breeding habitats in Hexham Swamp, the abundance of *Oc. vigilax* in this area highlights the ability of *Oc. vigilax* to actively disperse from breeding sites. The majority of adult mosquitoes collected in this wetland, while on occasion may have been contributed too by production from small on-site breeding sites, are likely to have dispersed into the area from the considerably more productive habitats at Kooragang Island and Tomago.

The abundance of *Cx. annulirostris* was considerably lower in 2002/2003 and 2003/2004 compared to 2001/2002 (Figure 7). The lower adult populations resulted from the low rainfall and lack of suitable habitat. The largest collections of *Cx. annulirostris* were recorded from Hexham Swamp with populations generally higher during 2003/2004 than 2002/2003.

The production of pest mosquitoes in Hexham Swamp is highly dependent on the quantity and frequency of rainfall. In the absence of regular rainfall and/or high rainfall events, the mosquito production from this wetland would be considered relatively low. However, following heavy rainfall events, there will be some breeding by *Oc. vigilax* in suitable habitats (e.g. saltmarsh) but there may also be by

freshwater 'floodwater' species such as *Oc. alboannulatus*, *Oc. procax* and *Ve*. Marks sp#52. If water persists in these habitats for extended periods, and the salinity remains low, they will become suitable for the production of species such as *Cx. annulirostris* and *Cx. quinquefasciatus*. However, while these situations may result in increased mosquito production, the populations of these freshwater species, and the small quantities of *Oc. vigilax*, are unlikely to result in significant increases in the overall pest impacts experienced in the lower Hunter estuary region.

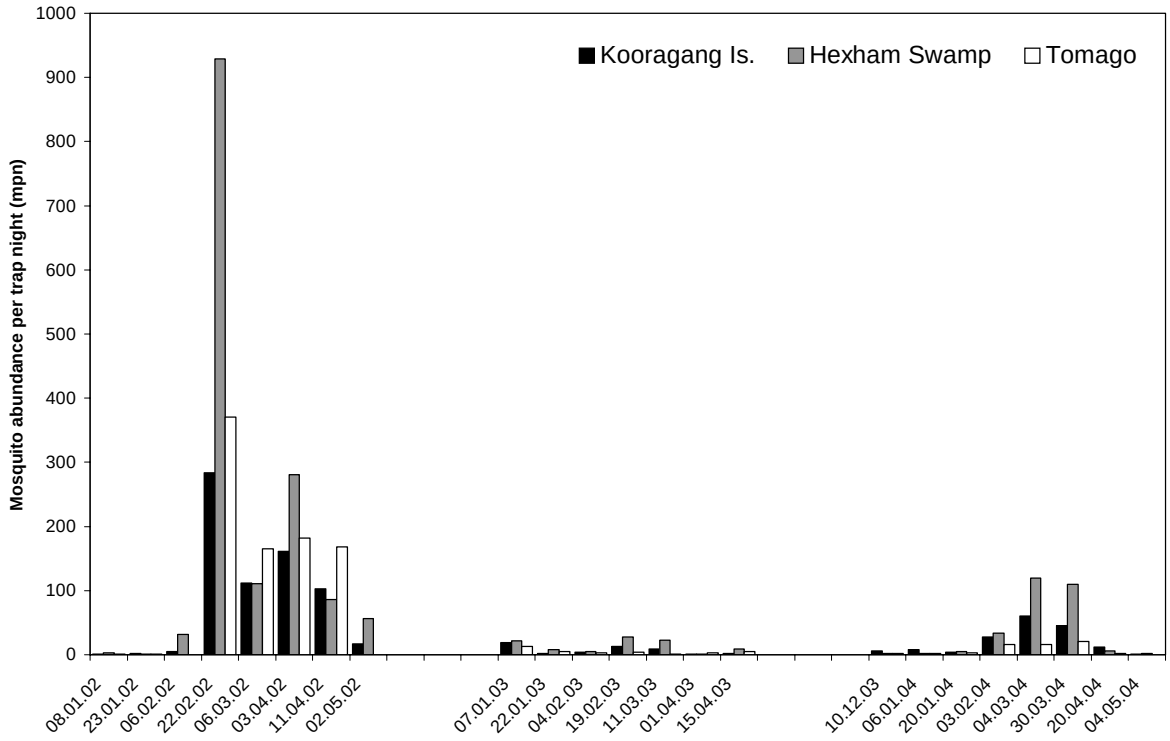


FIGURE 7: Mean number of *Culex annulirostris* collected per trap at the Kooragang Island, Hexham Swamp and Tomago wetlands on the 8 sampling nights.

Implications for the re-establishment of tidal flushing in the Hexham Swamp Nature Reserve and Tomago wetlands and future monitoring

As outlined in by Webb and Russell (2002), the re-establishment of tidal flushing in these two wetlands would result in significant changes to mosquito breeding habitats with a general increase in the availability of suitable habitat created following the re-establishment of tidal flooding.

With increased salinity, and the resulting changes in vegetation, habitats will become more suitable for *Oc. vigilax*. However, the magnitude of population increases will be dependent on a number of factors. Production of *Oc. vigilax* is likely to be greatest if tides only inundate the wetland on the highest tides of the month and pooling of water remains for at least 7- 10 days. If the water drains or soaks away over a shorter period of time, mosquitoes will be unable to complete development, and if the habitats remain inundated for longer periods of time, then predator populations will increase and access to suitable oviposition sites will be decreased, resulting in lower larval densities.

In Hexham Swamp, the increase in salinity may enhance breeding habitats for *Oc. vigilax* but will also result in the reduced suitability of habitats for *Cx. annulirostris* and other freshwater species. However, habitats beyond the reach of tidal inundation will remain as potentially productive freshwater mosquito habitat.

It is difficult to predict the extent of saltmarsh mosquito habitat that may be created following the opening of the Ironbark Creek floodgates. However, the relatively flat topography will probably result in large areas of inundation with only minor increases in tidal height. The proposed areas covered by Spring and King tides, as provided by Philip Haines of WBM Oceanics Australia, has been projected to cover a relatively large area of wetland. Due to the uncertainty of how the wetland will respond to tidal inundation, and consequently mosquito populations, it is strongly recommended that the first flooding events are undertaken during the winter months to significantly reduce the possibility of producing unusually large mosquito populations.

As with Hexham Swamp, restoring tidal flooding of the lands to the west of Fullerton Cove in Tomago, through the removal of floodgates and decommissioning of the levee bank, will significantly alter the wetland and mosquito production. The limited tidal exchange along channels in this area already indicate that there is potentially highly productive habitat (albeit over a relatively small proportion of the area) and a greater influence of tidal flushing may increase the existing saltmarsh habitat. More extensive surveys of this area are required to identify actual and potential mosquito breeding habitats and an increase in the number of sampling sites should be considered following modeling of expected inundation within this area.

To effectively assess the impact of restored tidal flushing to the Hexham Swamp and Tomago wetlands, continued monitoring of adult and larval mosquito populations, as well as actual and potential mosquito habitat, is strongly recommended.

The current network of adult traps and larval sampling points should enable the collection of adequate information on the impact of re-established tidal flushing on mosquito populations. These monitoring sites should remain fixed. However, additional sampling sites may need to be added in Hexham Swamp in response to surveys following the opening of the floodgates and initial assessments of wetland area to be flooded by both King and Spring tides.

It is important that the area of wetland covered by larval sampling sites includes areas expected to be inundated on a range of tidal heights as well as beyond the reach of tidal influence. These sites should also include habitats containing remnant saltmarsh vegetation as well as those currently vegetation with freshwater aquatic reeds and rushes as well as pasture/grasslands. There is some uncertainty as to the productivity of “freshwater” habitats while in transition to “saltwater” habitat and the associated changes in salinity and vegetation composition.

The timing and frequency of larval population sampling is an important consideration for saltmarsh mosquitoes. As larvae in the estuarine wetlands can hatch from eggs and complete development to adults within 7-10 days, monitoring programs must ensure sampling is undertaken with a week of wetland inundation.

The adult trap collections provide the only reliable method to identify the mosquito species responsible for nuisance biting impacts. It is not unusual, even close to estuarine wetlands, that the species causing nuisance biting impacts may have originated from brackish water, freshwater habitats or domestic habitats and in this instance, the biting impacts should be disassociated from habitats in Hexham Swamp.

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