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Translocation and Monitoring Efforts to Establish a Second Population of the Rare *Megalagrion xanthomelas* (Sélys-Longchamps) on O'ahu, Hawai'i (Zygoptera: Coenagrionidae)[1]

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Abstract

The last remaining population of *Megalagrion xanthomelas* (Sélys-Longchamps) resides in a 100 meter reach of stream located on the grounds of Tripler Army Medical Center, O'ahu. Because actions may be taken that might jeopardize this only known O'ahu population, it has been considered imperative to establish a second population to prevent *M. xanthomelas* from going extinct on O'ahu. An attempt to establish this species at a stream in the Dillingham area of O'ahu was made in 1998, but unfortunately was unsuccessful. Because the Tripler population is so small and restricted in distribution, a second effort at translocation was attempted at a new location. We estimated the population size of *M. xanthomelas* at the Tripler site in 1997 and again in 2003 by mark-recapture and concluded that the Tripler population was stable and could withstand the removal and translocation of a small number of adults and larvae. A stream site located in Makiki Valley was selected for its lack of alien predators such as crayfish, prawns, and mosquito fish, and a number of adults and immatures were translocated to the Makiki site in August 2004. Monitoring of the Tripler and the Makiki sites is ongoing and an additional translocation of *M. xanthomelas* to Makiki is planned. Future conservation plans should also include the assistance of from the general public through avenues such as stocking of backyard ponds with *M. xanthomelas*.

Introduction

The native endemic damselfly *Megalagrion xanthomelas* (Sélys-Longchamps) inhabited lowland coastal wetland and the lowest reaches of streams on all the main Hawaiian Islands. *Megalagrion xanthomelas* is now severely restricted in range because lowland aquatic habitats over the past century have undergone major physical and biotic transformations. In contrast to some immature *Megalagrion* species having dagger-shaped or streamlined gills and being found in cascades and riffles, this species has round, paddle-shaped gills restricting it to areas with little or virtually no water current (Polhemus & Asquith,1996). Throughout Hawai'i, habitats containing still waters are generally found in the low elevation regions and are now quite limited.

Historic and current range of *Megalagrion xanthomelas*

Prior to 1993, it was speculated that *Megalagrion xanthomelas* existed on all the islands (Perkins, 1899), yet at that time there were no collections from Kaua'i, Lāna'i, or Kaho'olawe. Several specimens of *M. xanthomelas* collected from Kaua'i and Ni'ihau in the early part of the 20th century have been found in the Bishop Museum collection. It was not until 1993 that specimens of *M. xanthomelas* were collected on Lāna'i at two sites with unnatural water features (Polhemus, 1993). On O'ahu, this species was widely distributed and found in low elevation areas throughout the island, with historical collections starting in 1892 and ending in 1977 (Fig. 1) (Bishop Museum collection data). Surveys conducted by D.A. Polhemus in the 1990s found *M. xanthomelas* wide spread on Hawai'i Island where they are locally common in coastal wetlands in Puna, Ka'ū, and Kona districts (Polhemus, 1995). In 1997, *M. xanthomelas* was collected in 2 separate low-elevation locations on East and West Maui (Polhemus *et al.*, 1999).

1. Contribution No. 2007-006 to the Hawaii Biological Survey.

Megalagrion xanthomelas is now restricted to the islands of Hawai‘i, Moloka‘i, Lāna‘i, Maui, and O‘ahu. There are 4 populations known from Moloka‘i, and it was reported to be abundant in artificial golf course ponds on Lāna‘i (Polhemus, 1995). The last collection of this species from Lāna‘i was made in 1998 at the golf course ponds of Koele Lodge. However, in March 2005 *M. xanthomelas* was not sighted during a return visit to those ponds. The only other known population on Lāna‘i, located in Maunalei Gulch, was not visited during the present study and its status is currently unknown. Although once abundant on O‘ahu, *M. xanthomelas* is now only known from one population located at Tripler Army Medical Center (TAMC). Polhemus (1995) stated "The population of *M. xanthomelas* occurring at TAMC appears to be a remnant of a much larger and more continuous population that formerly occupied the wetlands along the inner margin of Pearl Harbor". The current populations on O‘ahu and Lāna‘i are supported by artificial water augmentation. In the case of TAMC, natural stream flow is augmented by water supplied by a hose 100 m above the stream. At Maunalei Gulch, Lāna‘i, the water was provided by vandals drilling holes in irrigation pipes, and presumably this population was originated by colonists from the ponds at Koele Lodge. Both the TAMC and Maunalei Gulch populations are at risk of extinction should these artificial water sources be cut off.

Conservation *in situ* of the remaining O‘ahu population

Believed to be extinct on O‘ahu since at least 1977, *Megalagrion xanthomelas* was rediscovered in 1994 by Neal Evenhuis of the Bishop Museum's Hawai‘i Biological Survey. A population was found residing in a small section of an unnamed tributary to Moanalua Stream at TAMC, adminstered by the U.S. Department of Defense (Fig. 1). Soon afterwards, attempts were made to locate additional populations on O‘ahu, but these efforts were unsuccessful. As this endemic species was formerly "a common insect in Honolulu gardens and lowland districts" (Perkins, 1913), it was imperative to preserve one of most conspicuous and beautiful components of the native Hawaiian aquatic fauna. Without the exceptional efforts of earliest researchers such as Perkins, later entomologists such as F.X. Williams (Williams, 1937), and more recently D.A. Polhemus (Polhemus, 1996), we would have had no idea that *M. xanthomelas* was threatened with extinction on O‘ahu.

Because *M. xanthomelas* was now found only in approximately 100 m of habitat, concerns were raised about the continued existence of the Tripler population and possible loss of this species as a result of planned construction activities upslope from the site. To help ensure the survival of the damselfly population against possible watershed disturbances, it was decided to build 4 mitigation ponds just upslope of the stream (Fig. 2). Adult and larval damselflies were then transferred into the ponds from the stream to create a sub-population separate from but in close proximity to the stream. In October 1995, one month after the completion and filling of the mitigation ponds, a catastrophic flood eliminated the Tripler stream damselfly population, which survived only in the newly-filled mitigation ponds (Englund, 2001). The damselfly survived in the newly created ponds, and eventually recolonized the stream. Construction upslope of the stream then caused it to go dry, with as much as 40% of the 100-m Tripler stream channel having no water by May 1997 (Englund, 1998). The Veterans Administration then augmented water flow with a small garden hose, maintaining a low but fairly stable stream flow since 1997, which lead to a corresponding rebound in the Tripler *M. xanthomelas* population (Englund, 1998).

Difficulties of *in situ* conservation at TAMC

Examples abound regarding difficulties in preserving the remnant native Hawaiian flora and fauna (Banko *et al.*, 2001), and efforts in conserving the O‘ahu *M. xanthomelas* population have also been problematic. The mitigation ponds were not designed properly because they did not closely resemble the natural stream habitat, except to provide a fish-free body of water with water plants to provide substrate for egg laying. There was no attempt to provide vegetation around the ponds to allow for hiding and foraging by the females, as is their natural behavior at the stream site. Shade-cloth was added in order to simulate the overhead canopy found along the stream. The shade-cloth also lowered the pond's water temperature, which prior to that time was much higher than the adjacent stream temperatures, and this likely hindered larval damselfly development and subsequent recruitment. As a result of very slow water flow in the mitigation ponds, they soon became infested by large alien dragonflies such as *Tramea* spp., and a large notonectid bug predator *Notonecta indica*, which proliferated and almost certainly preyed on some *M. xanthomelas* larvae. In addition to the non-native predators, the very slow water flow and high light levels, due to insufficient shading, lead to excessive algal growth filling the ponds.

An additional threat to the entire stream population was discovered when *Tilapia* fish were purposely introduced into the mitigation ponds by the TAMC groundkeeping staff apparently to create their own private fishpond. This was a serious concern as the damselflies at the Tripler stream were located only 200 m directly downstream of these ponds. In March 2000, due to these continuing problems and after assurances from the Veterans Administration that all efforts to maintain the stream and flow would be undertaken, the decision was made to permanently drain the ponds (Englund, 2001). Once again, it was fortuitous that the Tripler damselflies survived, because a large storm caused the ponds to fill and overflow down slope into the stream soon after the ponds were drained and the *Tilapia* removed. If the *Tilapia* had washed into the stream and become established, they would have decimated the larvae and ultimately caused the extinction of *M. xanthomelas* on Oʻahu.

Conservation by relocation

Efforts focused on restoring portions of the endemic flora and fauna of the Hawaiian Islands have had a mixed record of success. In general, efforts in establishing additional populations to restore native plant species have been somewhat more successful than efforts to restore animals. Many examples of establishing new populations of endangered plants can be found, with the Mauna Kea silversword (*Argyroxiphium sandwicense*) a notable success story (Robichaux *et al*., 2000). However, establishment of additional populations of rare bird or insect species in Hawaiʻi has had a mixed record. There have been only a few notable successes such as the Nene (*Branta sandvicensis*), but mostly failures such as *ʻalalā* (*Corvus hawaiiensis*), or *palila* (*Loxioides bailleui*) (Banko *et al*., 2001). By far the vast majority of resources have been aimed at restoring bird populations, and with the exception of *M. xanthomelas*, we are not aware of any attempts in Hawaiʻi to establish additional populations of rare insects in order to preserve a species. Disease, low population sizes, and invasive species are just some of the major hurdles involving conservation efforts intended to restore populations in Hawaiʻi.

Because of the high continuing risk to *M. xanthomelas* at Tripler it was necessary to locate an alternate site suitable for translocation and establishment of a second population. The first attempt to translocate this damselfly species on Oʻahu, or anywhere in Hawaiʻi, was undertaken in 1998 (Johnson, 2001) when damselflies were translocated from the Tripler site to an unnamed stream near the Dillingham Airfield, Oʻahu. Although this effort was unsuccessful because of a crayfish introduction shortly after translocation was attempted (Johnson, 2001), it laid the groundwork for more successful future translocation attempts. After searching for a suitable site lacking invasive aquatic species, one was found in an area of upper Makiki Valley, Oʻahu. On 18 August 2003, a small number of adults and larvae were moved to an unnamed tributary of Makiki Stream. A comparison of the arthropods and riparian plants found at the Dillingham and Makiki translocation sites is given in Tables 1 and 2.

Study objectives

The objectives of the damselfly mark-recapture sampling efforts at TAMC were to 1) document recruitment of new individuals to the population between sampling efforts; 2) assess the relative abundance of damselflies between monitoring periods using a standardized methodology; 3) provide a quick means of determining if the TAMC *M. xanthomelas* population was threatened by disturbance or stream dewatering; and 4) determine if the TAMC population would be impacted by removing a subset of the population during translocation efforts to establish an additional population.

Table 1. Comparison of plant species found at TAMC, Dillingham Stream, and Makiki.

PLANT SPECIES	COMMON NAME	FAMILY	STATUS	Dillingham	Makiki	TAMC
Abutilon grandifolium	hairy abutilon	Malvaceae	Introduced			+
Adiantum raddianum	maidenhair fern	Pteridaceae	Introduced	+		
Aleurites moluccana	*kukui*	Euphorbiaceae	Introduced	+	+	+
Arthrostema ciliatum	everblooming lavender	Melanstomataceae	Introduced			+
Asystasia gangetica	Chinese violet	Acanthaceae	Introduced	+		
Carica papaya	papaya	Caricaceae	Introduced	+		
Caryota urens	white palm	Palmaceae	Introduced			+
Cedrela odorata	toona, Spanish-cedar	Meliaceae	Introduced		+	
Cestrum nocturnum	night cestrum	Solanaceae	Introduced		+	
Christella parasitica	downy wood fern	Thelypteridaceae	Introduced	+	+	
Cinnamomum burmannii	Padang cassia	Lauraceae	Introduced		+	
Clidemia hirta	Koster's curse	Melastomataceae	Introduced		+	
Coccinia grandis	ivy gourd	Cucurbitae	Introduced			+
Colocasia esculenta	*taro, kalo*	Araceae	Introduced	+	+	
Commelina diffusa	*honohono*	Commelinaceae	Introduced	+	+	+
Cordyline fruticosa	*ti*	Agavaceae	Introduced	+	+	+
Cycas circinalis	Sago palm	Cycadacae	Introduced			+
Cyperus papyrus	papyrus	Cyperaceae	Introduced			+
Digitaria insularis	sourgrass	Poaceae	Introduced			+
Dracena fragrans	happy plant	Agavaceae	Introduced			+
Dryopteris sp.	Driopteris fern	Dryopteridaceae	Endemic	+		
Erythrina sandwicensis	*wili wili*	Fabaceae	Endemic	+		
Ficus benghalensis	India banyan	Moraceae	Introduced			+
Ficus microcarpa	banyan	Moraceae	Introduced	+	+	+
Haematoxylum campechianum	bloodwood tree	Fabaceae	Introduced			+
Impatiens wallerana	impatiens	Balsaminaceae	Introduced		+	
Justicia betonic	white shrimp plant	Acanthaceae	Introduced		+	+
Leucaena leucocephala	*koa haole*	Mimosaceae	Introduced	+		+
Mangifera indica	mango	Anacardiaceae	Introduced		+	+
Momordica charantia	bitter melon	Cucurbitae	Introduced			+
Musa xparadisiaca	banana	Musaceae	Introduced		+	
Nephrolepis cordifolia	sword fern	Nephrolepidaceae	Indigenous	+		
Nephrolepis exaltata	common sword fern	Nephrolepidaceae	Endemic	+	+	

Table 1. (continued)

PLANT SPECIES	COMMON NAME	FAMILY	STATUS	Dillingham	Makiki	TAMC
Odontonema tubiforme	fire spike	Acanthaceae	Introduced		+	
Oplismenus hirtellus	basketgrass	Poaceae	Introduced		+	
Paederua scandens	*Maile pilau*	Rubiaceae	Introduced			+
Panicum maximum	Guinea grass	Poaceae	Introduced			+
Passiflora edulis	passion fruit	Passifloraceae	Introduced		+	+
Phlebodium aureum	hare's foot fern	Polypodiaceae	Introduced	+		
Philodendron lacerum	philodendron	Araceae	Introduced		+	+
Pimenta dioica	all spice	Myrtaceae	Introduced		+	
Pipturus albidus	*mamaki*	Urticaceae	Endemic		+	
Plumbago zeylanica	leadwort	Plumbaginaceae	Introduced	+		
Pouteria sandwicensis	*\`ala\`a, aulu*	Sapotaceae	Endemic		+	
Psidium_guajava	common guava	Myrtaceae	Introduced		+	+
Ricinus communis	castor bean	Euphorbiaceae	Introduced			+
Rivina humilis	coral berry	Phytolaccaceae	Introduced			+
Sapindus oahuensis	*\`aulu*, soapberry	Sapindaceae	Endemic	+		
Schefflera actinophylla	octopus tree	Apiaceae	Introduced		+	+
Schinus terebinthifolius	Christmas berry	Anacardiaciae	Introduced		+	
Senna surratensis	*kalamona*	Fabaceae	Introduced			+
Solanum americanum	popolo berry	Solanaceae	Introduced			+
Solanum seaforthianum	potato vine	Solanaceae	Introduced			+
Spathodea campanulata	African tulip tree	Bignoniaceae	Introduced	+	+	+
Synadenium grantii	African milk bush	Euphorbiaceae	Introduced			+
Syngonium sp.	arrowhead vine	Araceae	Introduced			+
Syzygium cumini	Java plum	Myrtaceae	Introduced	+		+
Terminalia catappa	false kamani	Combretaceae	Introduced			+
Thunbergia fragrans	white thunbergia	Acanthaceae	Introduced			+

Table 2. Arthropods recorded or observed from Tripler Army Medical Center compared to translocation sites (NSR = new state record).

TAXA		TAMC	Pinao'ula'ula	Makiki
ACARI (mites)				
ORIBATIDA				
Carabodidae	*Carabodes* sp.	+		
Cepheidae	Undetermined genus sp	+		
Galumnidae	*Pergalumna hawaiiensis* (Jacot)	+		
Hydrozetidae	*Hydrozetes* sp.	+		
Liacaroidea	*Liacarus* sp.	+		
Oppiidae	*Oppia* sp.	+		
Otocepheidae	*Dolicheremaeus* sp.	+		
Phthiracaridae	*Atropacarus* sp.	+		
Scheloribatidae	*Scheloribates* spp.	+		
Tryhypochthoniidae	*Hydronothrus cripus* Aoki	+		
MESOSTIGMATA				
Amerosiidae	*Ameroseius* sp.	+		
Ascidae	*Asca* spp.	+		
Laelapidae	*Echeronyssus* sp.	+		
Parasitidae	*Parasitus* sp.	+		
Podocinidae	*Podocinum pacificus* Leonardi	+		
Phytoseiidae	*Phytoseius* sp.	+		
Uropodidae	Undetermined genera spp.	+		
PROSTIGMATA		+		
Cheleytidae	*Bak deleoni* Yunker	+		
	Hemicheyletia bakeri (Ehara)	+		
Cryptognathidae	*Favognathus pictus* Summers & Chaudhri	+		
Cunaxidae	*Neocunaxoides andrei* (Baker & Hoffmann)	+		
Erynetidae	*Ceenus* sp.	+		
Eupodidae	Undetermined genus sp.	+		
Stigmaeidae	*Storchia robusta* Berlese	+		
ASTIGMATA				
Acaridae	*Tyrophagus putrescentiae* (Schrank)	+		
ARANEAE (spiders)				
Linyphiidae	Undetermined genus sp.	+		
Salticidae	Undetermined genus sp.	+		
DIPLOPODA (millipedes)				
Cambalopsidae	*Gyphyiulus granulatus* (Gervais)	+		
Julidae	Undetermined genus sp.	+		
Paradoxomatidae	*Oxidus* sp.	+		+
Polyxenidae	*Polyxenus* sp.	+		
CHILOPODA (centipedes)				
Geophilidae	Undetermined genus sp.	+		
Scolopendridae	*Scolopendra subspinipes* Leach	+		
ISOPODA (sow bugs, pill bugs)				
Oniscidae	*Oniscus* sp.	+		
AMPHIPODA (scuds, lawn shrimp)				
Undetermined family	Undetermined genus sp.	+	+	+
OSTRACODA (seed or mussel shrimp)				
Undetermined family	Undetermined genus sp.	+		
COPEPODA (copepods)				
Undetermined family	Undetermined genus sp.	+		

Table 2 (continued). (NSR = new state record)

TAXA		TAMC	Pinao‘ula‘ula	Makiki
INSECTA				
BLATTARIA				
Blaberidae	*Pycnoscelus indicus* (Fabricius)	+		+
Blattellidae	*Periplaneta americana* (Linnaeus)	+		+
COLEOPTERA				
Aglycideridae	*Proterhinus* sp.			+
Canthridae	*Caccodes oceaniae* (Bourgeois)	+		
Cerambycidae	*Sybra alternans* (Wiedemann)	+		
Cerylonidae	Ceryloninae sp.			+ (NSR)
Ciidae	*Cis* sp.			+
Coccinellidae	*Curinus coeruleus* Mulsant	+		
	Olla abdominalis (Say)	+		
Corylophidae	*Corylophodes suturalis* (Sharp)	+		
Curculionidae	*Dryophthorus* sp.			+
	Neotrichus latisculus (Fairmaire)			+
	Scotytinae sp. 1			+
	Scotytinae sp. 2			+
	Scotytinae sp. 3			+
Histeridae	*Baccanius* sp.			+
Elateridae	*Conoderus exul* (Sharp)	+		+
Nitidulidae	*Stelidota geminata* (Say)			+
	Undetermined genus sp.			+
Scarabeidae	*Adoretus sinicus* Burmeister	+		+
	Protaetia fusca (Herbst)	+		
Staphylinidae	*Neosorius rufipes* (Motschulsky)			+
	Osorius rufipes Motschulsky	+		
	Pselaphinae sp.			+ (NSR)
Tenebrionidae	*Amarygmus morio* (Fabricius)			+
	Undetermined genus sp.			+
COLLEMBOLA (springtails)				
Entomobryidae	*Entomobrya* sp.	+		+
	Lepidocyrtus sp.	+		
	Tomocerus minor (Lubbock)	+		+
Neelidae	*Neelus* (*Megalothorax* sp.)	+		
Sminthuridae	*Dicyrtoma* (*Papirioides*) *dubia* (Folsom)	+		+
DIPTERA (flies)				
Lauxaniidae	*Poecilominettia* sp.	+		
Phoridae	?*Spiniphora* sp.	+		
Psychodidae	*Psychoda* sp.	+		+
Sphaeroceridae	*Leptocera brevivenosa* Tenorio	+		
	Poecilosomella punctipennis (Wiedemann)	+		
Syrphidae	*Allograpta exotica* (Weidemann)	+		+
	Allograpta oblique (Say)	+		
	Simosyrphus grandicornis (Macquart)	+		
Tachinidae	*Trichopoda pilipes* (Fabricius)	+		
Tephritidae	*Bactrocera cucurbitae* (Coquillett)	+		
Tipulidae	*Limonia advena* (Alexander)	+		+
EMBIIDINA (web-spinners)				
Oligotomidae	*Oligotoma saundersii* (Westwood)	+		
HETEROPTERA (true bugs)				
Lygaeidae	*Cligenes marianensis* Usinger	+		
Notonectidae	*Buenoa pallipes* (Fabricius)	+		
	Notonecta indica Linnaeus	+		
Pentatomidae	*Brochymena quadripustulata* (Fabricius)	+		
	Nezara viridula (Linnaeus)	+		
Reduviidae	*Zelus renardii* Kolenati	+		+
Tingidae	*Leptodictya tabida* (Herrich-Schaeffer)	+		

Table 2 (continued). (NSR = new state record)

TAXA		TAMC	Pinao‘ula‘ula	Makiki
INSECTA				
HOMOPTERA				
Cicadellidae	*Agalliopsis* sp.	+		
	Homalodisca coagulata (Say)	+		
Clastopteridae	*Clastoptera* sp.	+		+
Flatidae	*Melormenis basalis* Walker	+		+
Psyllidae	*Heteropsylla cubana* Crawford	+		
Oligotimidae	*Aposthonia oceania* (Ross)	+		
HYMENOPTERA				
Agaonidae	*Odontofroggattia* sp.	+		
Anthophoridae	*Xylocopa sonorica* Smith	+		
Apidae	*Apis mellifera* Linneaus	+	+	+
Aphelinidae	Undetermined genus sp.	+		
Braconidae	*Apanteles trifasciatus* Muesebeck	+		
Eulophidae	Undetermined genus sp.	+		
Eurytomidae	*Eurytoma* sp.	+		
	Sycophobia sp.	+		
Formicidae	*Anoplolepis longipes* (Jerdon)	+		+
	Camponotus sp.	+		
	Cardiocondyla wroughtoni (Forel)	+		
	Leptogenys falcigera Rogers	+		
	Pseudomyrmex gracilis mexicanus Rogers	+		
	Solenopsis geminata (Fabricius)	+		
	Tapinoma melanocepohalum (Fabricius)	+		
Proctotrupidae	Undetermined genus sp.	+		
Sphecidae	*Scelipheron caementarium* (Drury)	+		
Trichogrammatidae	Undetermined genus sp.	+		
Vespidae	*Delta curvatum* (Saussure)	+		+
ODONATA				
Coenagrionidae	*Ischnura posita* (Hagan)	+		
	Megalagrion hawaiiense (McLachlan)		+	
	Megalagrion xanthomelas (Sélys-Longchamps)	+		
Libellulidae	*Nesogonia blackburni* (McLachlan)		+	
	Orthemis ferruginea (Fabricius)	+		
	Pantala flavescens (Fabricius)	+		
	Tramea abdominalis (Rambur)	+		
	Tramea lacerata Hagan	+		
ORTHOPTERA				
Acrididae	*Oxya japonica* (Thunberg)			+
	Schistocerca nitens (Thunberg)	+		
Gryllidae	*Laupala* spp.			+
Tettigoniidae	*Conocephalus saltator* (Saussure)	+		+
	Elimaea punctifera (Walker)	+		+

Site descriptions

TAMC **—**The stream is located on leeward O‘ahu at 79 m elevation (Fig. 1), and flows for 95 m through a forest of introduced plants (Table 1). The wetted width of the stream is less than 1 m wide for most of its length, and has several pools that are 15–20 cm deep, though most of the stream is less than 10 cm in depth. A detailed description and map of the TAMC Stream study area can be found in Evenhuis *et al*. (1995), Polhemus (1996), and Pangelinan (1997). The TAMC stream now requires augmented water flow because construction in 1995 of a large Veterans Administration facility up slope of the TAMC stream disrupted the stream hydrology. The cement-lined mitigation ponds were constructed in 1995 drained in 2000, and were located approximately 200 m northwest

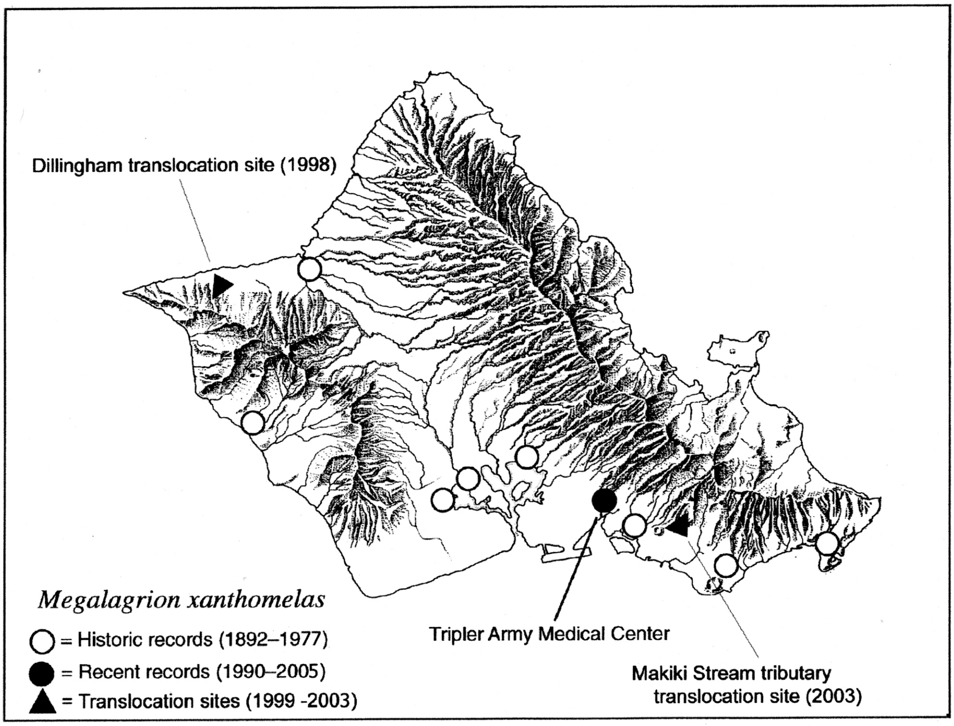

Figure 1. Map of O'ahu, Hawai'i showing locations of current and historic records for *Megalagrion xanthomelas* (modified from Evenhuis *et al*., 1995).

of the TAMC stream. The ponds measured 7.3 m long by 3 m wide and had an average water depth of 0.6 m. These ponds contained cobble substrate brought from the TAMC stream and aquatic plants such as algae, water lily (*Nymphaea* sp.), water lettuce (*Pistia stratiotes*), and the large aquatic sedge (*Cyperus alternifolius*).

Makiki —The upper reaches of Makiki Stream are quite low-flowing, but it is unclear how historical water diversions may have impacted the current stream flow because virtually all upper tributary reaches of Makiki Stream were diverted at one time. Makiki Stream and its associated tributaries maintain a permanent, albeit low, flow. The upstream Herring Springs found at upper Moleka Stream was apparently completely diverted by several Board of Water Supply box culverts until 1994. This area, prior to it being diverted, was an important collecting site in the 1890s and early 1900s by R.C.L. Perkins and others for several now extinct native Oahu damselfly species (Englund, 1999). An unnamed spring and short section of stream found between Kānealole and Moleka Springs in the upper (>290 m) Makiki watershed was chosen as the translocation site for *M. xanthomelas*. This is the only upper elevation stream area lacking alien fish species in the watershed. This is also the only section of stream found to lack the introduced shrimp *Neocaridina denticulata sinensis* and contain the native shrimp *Atyoida bisulcata*. A 6-m slanted waterfall appeared to be a barrier to introduced fish and crustaceans, which were observed at the bottom of the waterfall, approximately 15 m downstream of the relocation site. All other areas of Makiki Stream examined during this study were dominated by alien species. Feral pig activities (e.g., wallows and vegetation damage) around upper Makiki tributaries (e.g., Moleka Springs, Kānealole Stream) appeared to contribute sediment into the stream.

Figure 2. TAMC Mitigation ponds prior to drainage, February 2000.

Methods

The entire length of wetted stream was sampled starting at the upstream end of the man-made culvert where stream flow originates. Methods used were identical to previous research conducted on the *M. xanthomelas* TAMC population (Pangelinan, 1997; Englund, 1998). For this study, damselflies were marked and recaptured from May–July 1997, and March–August 2003. At least two observers collected adult damselflies while slowly walking down the stream. Each observed damselfly was netted and its wings marked with a permanent black extra fine felt tip marker. The number was recorded if a captured damselfly had been previously marked. After completing the slow downstream walk, which would average 3 hours, we returned slowly upstream to collect and mark any previously unmarked damselflies. Collection and observation times were consistent during each monitoring event to standardize sample effort. Only netted, marked individuals were counted as recaptures. New captures were marked, sexed, measured, and held at the stream sections where they were collected. All individuals were released later the same day, at the conclusion of the survey. Individual numbers were recorded with their sex noted and abdomen lengths measured, and recaptures were recorded and tandem pairs were noted as to whether any were previously marked. Population estimates were obtained by using the Petersen estimate of population size (Caughley, 1980). Although the Petersen estimate will in the long run result in an overestimation of population size (Caughley, 1980), we use it here because our mark-recapture studies in 1997 and 2003 were relatively short in duration, and they provide a relatively good estimate of damselfly population size.

Pond sampling (from 1997 until there draining in March 2000 was identical to Englund (2001). This involved thirty-minute damselfly counts being conducted at each of the four concrete mitigation ponds, with damselfly sex and behavioral activity was recorded during each thirty-minute count. Individual adults were not counted unless they were captured and the wings marked with a number. Quantitative aquatic net samples were taken at the ponds starting during the November 1997 monitoring. Three aquatic net sweeps approximately 1.25 m in length were taken at the surface, middle, and bottom of each pond. The net contents were then placed in a 500-µm sieve and inspected for immature damselfly naiads (Englund, 2001).

Table 3. **Sample dates and recaptures during the 1997 mark-recapture study at TAMC stream and mitigation ponds**.

Date	No. recapture / day (stream + ponds)	No. new captures / day (stream + mitigation ponds)	Total captures / day
11-May-1997	0	17	17
17-May-1997	12	3	15
18-May-1997	17	4	21
22-May-1997	15	10	25
13-Jun-1997	13	26	39
6-Jul-1997	8	42	50
10-Jul-1997	21	47	68
13-Jul-1997	43	77	120
Total	129	226	355

Table 4. **Sample dates and recaptures during the 2003 mark-recapture study at TAMC stream only**.

Date	No. recapture / day	No. new captures / day	Total captures / day
21-Mar-2003	0	111	111
25-Mar-2003	30	86	116
1-Apr-2003	39	93	132
8-Apr-2003	59	82	141
15-Apr-2003	58	74	132
23-Apr-2003	48	58	106
29-Apr-2003	54	57	111
6-May-2003	45	64	109
13-May-2003	43	73	116
20-May-2003	41	77	118
27-May-2003	75	62	137
3-Jun-2003	67	80	147
10-Jun-2003	79	62	141
1-Jul-2003	14	42	56
8-Jul-2003	6	5	11
29-Jul-2003	11	69	80
8-Aug-2003	26	72	98
15-Aug-2003	47	62	109
Total	742	1229	1971

TAMC Population Study Results

From May to July 1997, 355 damselflies were marked, with 129 recaptures made during the study period (Table 3). *Megalagrion xanthomelas* population estimates ranged from a low of 18 to a high of 221 individuals in 1997 (Fig. 3). Over a period of 148 days between March and August 2003, 1167 individual damselflies were captured and marked, with 742 recaptures during this period (Table 4). A high of 147 individuals were collected on 21 June 2003 and a low of 11 captured on 8 July 2003. As a result of more stable and higher stream flows, population estimates in 2003 increased on average more than in 1997 and ranged from 75–535 individuals (Fig. 4). Capture success was determined by the weather with results being better on clear, sunny days. In 2003, the population estimate was quite consistent with the exception of a marked decrease in July 2003 when numbers were exceptionally low. The July

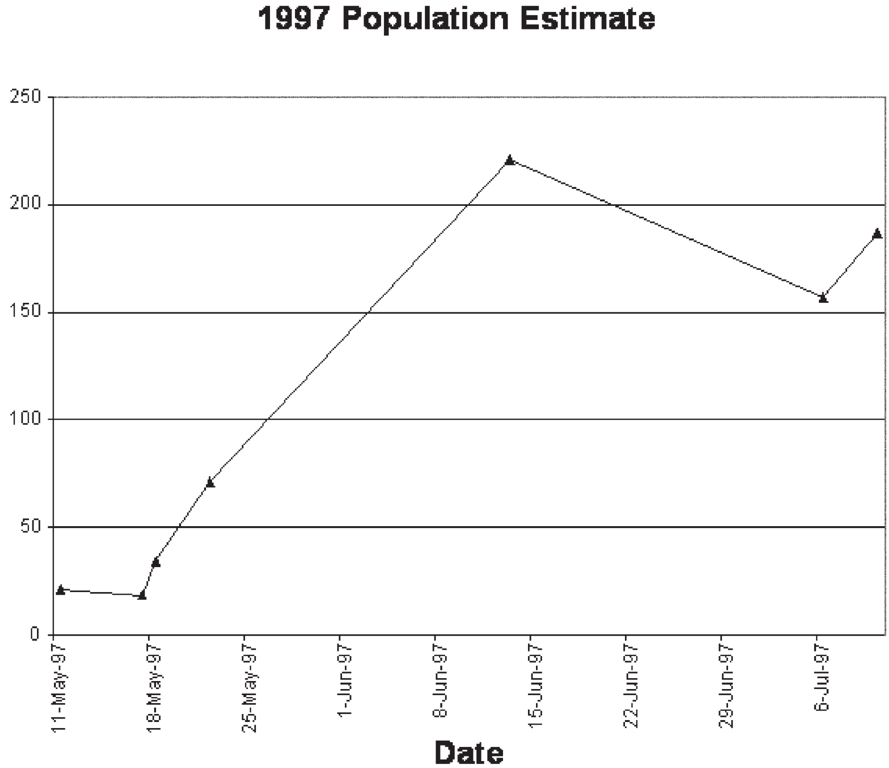

Figure 3. Population estimates from 1997 mark-recapture study at TAMC Stream and mitigation ponds.

2003 decrease was attributed to poor weather conditions that resulted in low damselfly capture rates, and not a decrease in real population size. Population estimates increased again to between 224–293 in August 2003 with the return of sunny sampling conditions.

Males were collected in higher numbers than females because their bright orange color made them easier to see and they were more inclined to fly when approached (Fig. 5). Males defended oviposition sites and stayed closer to the water, perching on rocks, twigs, and branches in the stream. Females are more cryptically colored and tend to sit still on vegetation or rocks when approached. Single females were not readily seen unless flying about, however tandem pairs were very noticeable, thus we collected most females when they were in tandem with a male. Single females tended to be at greater distances from the water than single males and only came to the water to mate and lay eggs.

Search and selection of suitable sites for translocation

In conjunction with monitoring of the TAMC damselfly population, an extensive search was carried out on O‘ahu to locate potential relocation sites for *Megalagrion xanthomelas*. Suitable sites needed to be free of alien predators, particularly poeciliid fish, prawns, and crayfish. During this study only two O‘ahu sites were located that met these requirements. One site was located on private lands and could not be used because of access issues. Another site free of alien fish was also located in Makiki Valley, and was located at an unnamed tributary of Makiki stream, roughly 75 m below Herring Springs and was also remote enough to discourage human disturbance. The lack of predators resulted from a natural barrier created by an approximate 6-m waterfall located downstream of the site. The Makiki site was assessed for water quality, stream corridor vegetation, and available

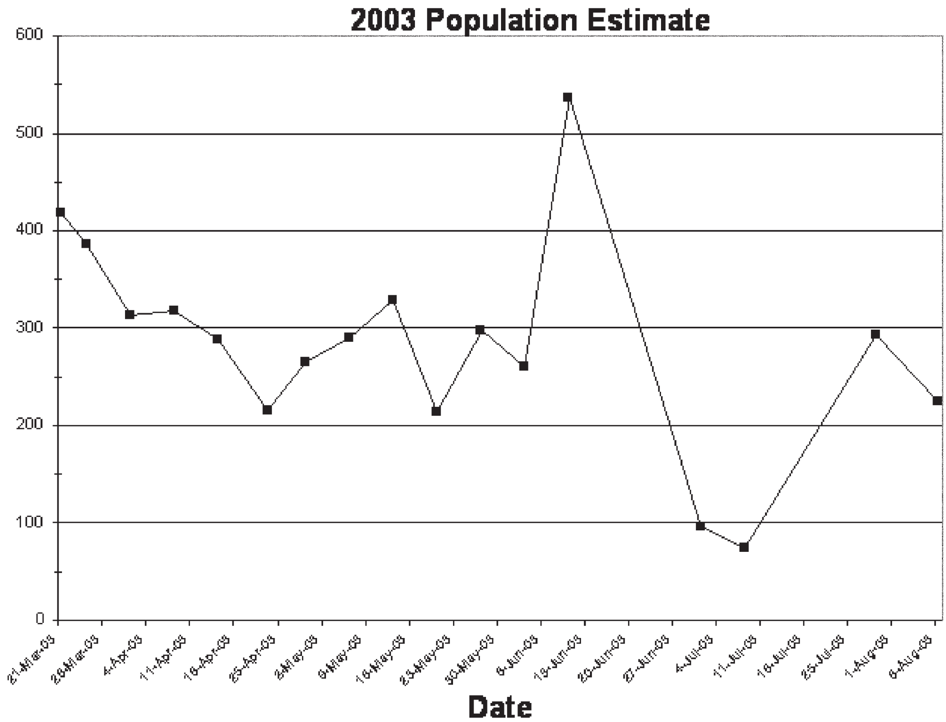

Figure 4. Population estimates from 2003 mark-recapture study at TAMC Stream only.

food resources. Stream bank vegetation, algae, and detritus, all used for oviposition, were comparable to the TAMC site. The Makiki site had denser vegetative over-story. The streambed at Makiki was sufficiently varied both in vegetation and benthic substrate and should provide adequate usable habitat for the larvae and adults. It should be noted that the Japanese wrinkled frog (*Rana rugosa*) was abundant at the Makiki site and was of some concern. However, this frog is common in most streams where damselflies still occur and does not seem to be a significant threat (Englund, 1999).

Translocation of *Megalagrion xanthomelas*

Damselflies are most active during sunny and warm periods of the day thus collecting was planned for good weather. On the morning of 18 July 2003, 35 adult (21♂, 14♀) *M. xanthomelas* and 30 larvae were collected from TAMC. Lone adults were numbered and placed singly into plastic snapcap vials while tandem pairs were placed together in the vials. Late instar damselfly larvae were collected from the TAMC Stream and placed singly in water containers. The adults and larvae were kept in a small soft-sided cooler containing a small amount of ice which kept the adults and larvae still and also prevented overheating during transportation to the Makiki site. Damselfly larvae were released at several pools within the Makiki site, and 5 larvae were released in each pool. Pools were assessed to make sure they contained enough macroalgae and a varied substrate to allow the larvae to find cover and search for prey. Adults were released at points between adjacent pools where the larvae were placed. A second collection of 33 adults (17♂, 16♀) was made at TAMC on 25 August 2003, of which 9 pairs were collected in tandem or were mating when captured. Larvae were not collected for this second phase of the translocation. Our population estimates clearly indicate that removing these individuals from the TAMC Stream did not negatively impact the damselfly population here. For example, the damselfly population estimates increased between mark-recapture studies

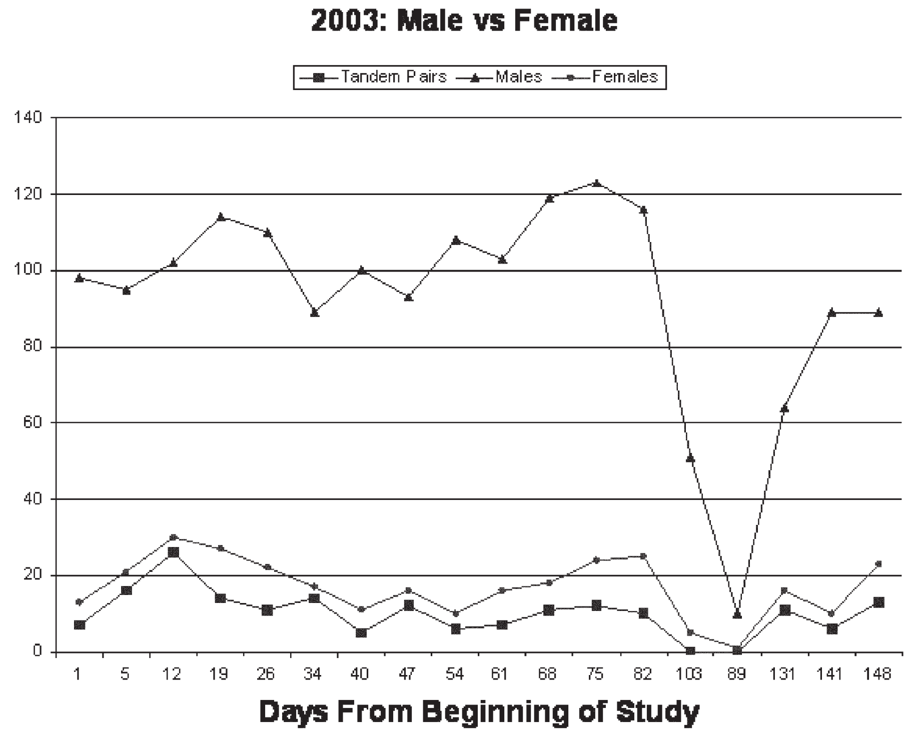

Figure 5. Number of individual males, females, and tandem pairs captured in 2003 at Tripler stream.

conducted between 29 July and 8 August 2003 (Fig. 4), several weeks after the first translocation efforts conducted on 18 July 2003 when 35 adults and 30 late instar larvae were removed from the TAMC Stream.

Three visits to the Makiki site after the translocation in August, September, and November of 2003 failed to detect any recruitment of *M. xanthomelas*. Unusually heavy flooding in this region on 30 October 2004 may have hindered damselfly recruitment. Although damselfly recruitment was not documented at the Makiki translocation site, a very important finding of long-term adult survival of the translocated damselfly adults was documented during this study. One individual marked adult male damselfly translocated from the TAMC Stream on 18 August 2003 was resighted and recaptured on 25 August 2003, though no larvae were observed. Because adult *Megalagrion* damselflies will not survive without food for more than a few days, this finding indicates that adequate forage existed at the Makiki site for this damselfly to persist for at least a one-week period. Unfortunately funding did not allow for long-term monitoring of the Makiki site but monitoring of the TAMC site continues. Mark-recapture population studies at the TAMC Stream have not been conducted since 2003, but we have determined through visual observations that the TAMC population remains stable at this time. Future translocations are planned for June of 2005 when the TAMC population should be at a high enough level to withstand a 10–20% loss of adults to a translocation site.

Discussion

The only O‘ahu population of *M. xanthomelas* was monitored since 1997, with intensive mark-recapture studies conducted in 1997 and 2003. The conclusion here is that the size of the TAMC *M. xanthomelas* population is a direct result of usable habitat size, and as this habitat is extremely limited, another population must be established elsewhere. The continued survival of the *M. xanthomelas* population has been due to an astonishing series of events, but stochastic events such as large rainstorms or chemical spills will eventually eliminate the TAMC damselfly population because it is so severely restricted and small in size.

The population estimates from 1997 and 2003 indicate an increase in damselfly numbers since nearly 40% of the TAMC Stream habitat was lost from dewatering in early 1997. Excluding the July population estimate data that were taken during suboptimal cloudy and rainy conditions, the 2003 estimates indicate a relatively stable population ranging from 250–350 adults. Negative impacts from removing a small portion of the TAMC stream population were not observed, even though approximately 10–20% of the estimated adult population (and a corresponding number of larvae) were removed from the TAMC stream for translocation to the Makiki site on two separate occasions.

The TAMC stream is an extreme case of a restricted habitat, where a small section of usable damselfly habitat is bounded by channelization at the lower end and by drainage culverts at the upper end, with habitat regulated by water availability. If the area of useable habitat were to be reduced, the larvae might become crowded and start to cannibalize each other thus reducing the adult numbers. This reduction in adult numbers would then be reflected as a reduction of eggs being produced and therefore an overall reduction in population size.

Because low-elevation natural stream and wetland areas lacking alien fish and crustaceans species on O‘ahu are virtually nonexistent, another option that should be pursued is the use of artificial habitats for translocation sites. *Megalagrion xanthomelas* used to be “a common insect in Honolulu gardens and in lowland districts” (Perkins, 1913), and it once again could be found in urban habitats and gardens of Honolulu. Areas such as backyard ponds, golf course waterways, and even hotel or landscaping waterfalls or water gardens could be stocked with damselfly larvae. It would be necessary to make sure these habitats were free from alien fish or crustacean species, but this could be encouraged with small grants or technical assistance in the form of aid to remove the aliens prior to damselfly stocking. There are precedents for this in the Hawaiian Islands, and a similar technique is currently being used where private citizens are encouraged and allowed to propagate endangered plants in their backyards. School groups or other educational institutions could also be encouraged to propagate native damselflies, in ways similar to the Honolulu City and County “Adopt-A-Stream” program that encourages regular cleaning of urban streams. The continued existence of the TAMC population of *M. xanthomelas* in <100 m of stream habitat illustrates the fact that large swaths of pristine habitat are not necessary for this species’ continued existence. It is of great urgency that actions are taken prior to another major disturbance to the last remaining O‘ahu population.

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