The Orangeblack Hawaiian Damselfly, *Megalagrion xanthomelas* (Odonata: Coenagrionidae): Clarifying the Current Range of a Threatened Species[1]

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Introduction

The Orangeblack Hawaiian Damselfly, *Megalagrion xanthomelas* Selys-Longchamps, formerly occurred in lowland aquatic habitats throughout all the high Hawaiian Islands. Although common at the turn of the century, the species began to experience a progressive decline after World War II, and by the early 1990s had not been seen on Oahu for over 20 years. This fact, coupled with the extensive alteration of lowland habitats in which the species formerly bred, led Polhemus (1993) to conclude that the species was probably extirpated on Oahu when he reviewed the conservation status of *Megalagrion* species for the U. S. Fish and Wildlife Service (USFWS). Based on this assessment, plus the apparent extirpation of the species on Kauai and Maui as well, USFWS (1994) proposed that *M. xanthomelas* be listed as a Threatened species and given protection under the Endangered Species Act.

Given this, it was of great interest when a remnant population of *M. xanthomelas* was discovered in the course of an environmental survey conducted by personnel from the Hawaii Biological Survey in March 1994 at the Tripler Army Medical Center (TAMC), on the outskirts of Honolulu. This population, so far as is known, is the last remaining colony of *M. xanthomelas* on Oahu, and thus a priority target for conservation efforts. The existence of the population was noted in a report to the R.W. Towill Corporation of Honolulu (Evenhuis & Cowie 1994); this report also concluded that the insects were confined to a small gully near the greenhouse at the lower end of the TAMC site, in an area that had the potential for being impacted by proposed construction activities further upslope. It was recommended that in order to ensure the continued survival of the TAMC *M. xanthomelas* colony the population should be relocated to a nearby site that would not be subject to construction impacts or other activities taking place on the TAMC grounds, a task that has recently been accomplished through the construction of an artificial refugium

In order to properly design the refugium for the TAMC population, it was necessary to conduct a detailed investigation of the biology of *M. xanthomelas*, which was poorly known at the time. This involved both detailed studies at TAMC (to be reported in a separate publication), and investigations at sites on other islands where populations of *M. xanthomelas* were still known to persist. This report details the results of those surveys, providing a statewide conservation assessment of this increasingly rare species.

Taxonomy and Historic Distribution of *Megalagrion xanthomelas*

Megalagrion xanthomelas was described by Selys-Longchamps (1876) based on specimens collected by G.F. Matthew of the Royal Navy, and labelled "Sandwich Islands", with no specific island within the group noted on the labels. The location of Selys-Longchamps' types is not currently known, although they may be in the Koninklijk

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Belgisch Instituut voor Natuurwetenschappen, in Brussels. The species has not been confused with others since its original description, thus its taxonomic history is relatively simple and devoid of synonyms.

The original distribution of *M. xanthomelas* within the Hawaiian Islands is a matter of some speculation. It seems unlikely that the species ever inhabited the small, dry island of Kahoolawe, and its presence on Kauai is open to question, although a single specimen is present from nearby Niihau (see below). Perkins (1899) stated that *M. xanthomelas* "Probably occurs all over the islands", despite the fact that he lacked any collections from Kauai and Lanai. Kennedy (1917), probably following Perkins' statement, listed *M. xanthomelas* from Oahu, Molokai, Maui, Hawaii, Kauai and Lanai, even though once again there were apparently no specimens at hand supporting the latter 2 records. It was only in 1993 that specimens were finally captured on Lanai (Polhemus 1993); and to date the species has never been taken on Kauai.

The ecology of *M. xanthomelas* was discussed anecdotally by Williams (1936), who also illustrated the immatures. They appear to have formerly bred in imponded sections of lowland streams, and in both natural and artificial ponds. The ability of this species to exploit artificial habitats was noted by Perkins (1913), who observed that *M. xanthomelas* was:

> "a common insect in Honolulu gardens and in lowland districts generally, not usually partial to the mountains, though in the Kona district of Hawaii it is common about stagnant pools up to an elevation of about 3000 feet. It is very numerous under conditions changed from the natural; perhaps it now finds more numerous breeding places, and a more abundant prey in the numerous insects that have been introduced by man in the region it frequents."

Williams (1936) also noted that *xanthomelas* bred abundantly in sugar plantation reservoirs at Waianae. Zimmerman (1948), by contrast, remarked that the introduction of *Gambusia* topminnows "has changed the lowland situation considerably in recent years, however, and the species is much less abundant than formerly."

The decline in populations of *M. xanthomelas* noted by Zimmerman in the years after World War II has continued to the present day. The species is now apparently extirpated on Maui, with no records from that island for the last hundred years, and reduced to single known population on Oahu (at TAMC). Molokai is known to support 4 populations, and the species is abundant in artifical golf course ponds on Lanai, although elsewhere on that island it retains only a tenuous foothold in small remnants of its former natural habitat. Only on Hawaii Island is the species still truly widespread, being commonly found in the coastal wetlands of the Puna, Kau and Kona districts.

In the sections below, the current distribution of *M. xanthomelas* is discussed on an island by island basis. The terminology used to describe aquatic ecosystems follows Polhemus *et al*. (1992).

Niihau

A single specimen of *M. xanthomelas* is in the Bishop Museum (BPBM) bearing a Niihau label, collected by L.D. Tuthill on 16 August 1947. No specific locality is given, but the specimen was probably collected along the margin of Halulu Lake, a permanent mixohaline pond fed by basal spring outflows, or from one of the perched springs that occur at Kaali and in Waiokanaio Gulch.

Kauai

Although *M. xanthomelas* was listed as occurring on Kauai by Kennedy (1917), there are no extant specimens from this island. The presence of the species on Niihau and Oahu, however, makes it virtually certain that it once occurred on intervening Kauai as well, even during historic times. The extensive alteration of basal spring wetlands on this island, particularly those formerly existing on the Mana plain near the present town of Kekaha (which were filled and converted to sugarcane cultivation beginning in the 1920s), appears to have led to the local extirpation of *M. xanthomelas* on Kauai. An extensive search by John Maciolek of the USFWS in the late 1970s failed to uncover any evidence of this species, and subsequent damselfly surveys on the island have been similarly unsuccessful in locating any populations.

Oahu

Tripler Army Medical Center

The present and historic distribution of *M. xanthomelas* on Oahu is summarized in Figure 1. As noted in the introduction, only a single population of this species is known to remain on the island, at the Tripler Army Medical Center (TAMC) on the outskirts of Honolulu. This population occupies a small gully shaded by koa haole (*Leucaena leucocephala*), with a bedrock channel that in this reach forces the base flow to the surface, creating a series of small pools connected by short, shallow runs. The flow into this reach originates from a 48-inch concrete pipe that drains the area around the main hospital buildings upslope, and disappears downslope into a similar culvert, making the Tripler habitat a small island of relatively natural stream channel within a sea of surrounding development. The survival of *M. xanthomelas* at this site appears to have been paradoxically favored due to the presence of the culverts, which have acted as filters to the introduced fishes that are abundant in the lower section of Moanalua Stream into which the Tripler gully eventually drains.

The *M. xanthomelas* population at TAMC appears to be a remnant of much larger and more continuous populations that formerly occupied the wetlands along the inner margin of Pearl Harbor. Five large basal springs previously emerged from the Koolau Aquifer in this area, these being from east to west the Kalauao, Waiau, Waimano, Waiawa and Waikele springs. The combined discharge of these springs in 1932 was over 80 million gallons a day (Stearns & Vaksvik, 1935), and their outflows formed extensive limnetic and mixohaline wetlands. The above authors noted that these springs issued forth in low, swampy areas along the margin of Pearl Harbor and were affected by tides. Similar types of habitats on Hawaii island currently support large populations of *M. xanthomelas*, and the former presence of this species in the Pearl Harbor area is confirmed by specimens in BPBM and the University of Hawaii.

A search was made of these Pearl Harbor springs for *M. xanthomelas* during damselfly conservation status surveys funded by USFWS, and the results are germane to the present study, since they indicate the absence of other *M. xanthomelas* populations in proximity to TAMC. The closest of the springs to TAMC is the Kalauao Spring, which now forms a watercress farm lying between the Kamehameha Highway and the Pearlridge shopping mall. This spring has been extensively modified by watercress cultivation, and contains large numbers of introduced fish and prawns. A search for *M. xanthomelas* here on several occasions during 1994 and 1995 proved fruitless. The Waiau Spring lies imme-

diately upslope of the Kamehameha Highway and behind a Zippy's restaurant. It is also given over to watercress cultivation, and contains numerous introduced fish species. The Waimano Spring formerly emerged at the site now occupied by the Waiau electrical generating station, built in 1945, which exploits the spring's water for cooling. The Waiawa Spring lies below a bluff occupied by the Leeward Community College, in a degraded area containing the Pearl City Peninsula landfill, a highly contaminated EPA Superfund site; it too supports watercress production, and forms an extensive wetland on its seaward side that has yet to be completely surveyed. The Waikele Springs emerge from the east bank of Waikele Stream upstream from the H-1 freeway bridge; these springs are partially diverted by the Oahu Sugar Company, although significant outflows still emerge, providing the majority of base flow in the terminal reach of Waikele Stream. This area was intensively surveyed by Englund (1993), who found high densities of tilapia, *Rana cateseiana*, and other introduced aquatic vertebrates, but no indication of *M. xanthomelas*. Based on current knowledge, it thus appears that all the basal spring wetlands in the Pearl Harbor area that formerly could have supported *M. xanthomelas* are now physically altered or biologically degraded to the point that they no longer harbor this species. Examination of *M. xanthomelas* specimens in BPBM shows that the last date of collection for this species at Waipahu was in 1925, although a specimen was taken at Pearl City as late as 1977.

Basal spring wetlands similar to those that occurring at Pearl Harbor are also present on the north shore of Oahu to the east of Haleiwa, near the mouth of the Anahulu River. One of these wetlands, surrounding Emerson Spring, is still relatively intact, although it is now traversed by the recently constructed Haleiwa Bypass highway project. An investigation of these wetland systems by Adam Asquith of the USFWS in early 1995 found them to be dominated by alien aquatic species, and to lack populations of *M. xanthomelas*, although specimens taken at Waialua in 1892 are present in BPBM.

Recent surveys thus indicate that *M. xanthomelas* has been extirpated from suitable lowland habitats throughout Oahu, and reinforce the view of the Tripler population as an isolated remnant that has survived through fortuitous circumstances. Since some of the basal spring wetlands formerly occupied by this species still exist, it might be possible in the future to reintroduce this species to suitably managed sites in the Pearl Harbor and North Shore areas, provided that the Tripler population can be maintained in the interim.

Molokai

Pelekunu Valley

Pelekunu Stream is a swift, rocky, perennial stream that begins as a set of plunging streamlets at elevations near 120 m on the sheer northern face of the Molokai Crest. The catchment takes the form of a giant bowl, ringed by peaks including Kaunuohua, Olokui and Kamakou, the latter at 1515 m being the highest point on Molokai. The headwater reaches are nearly vertical, with the stream profile making an abrupt transition to a more moderate gradient at ca. 915 m elevation, which is interpreted as the head of the midreach. From this elevation downstream to the mouth the channel exhibits a moderate but continuous gradient, with numerous riffles and small cascades, and thus retains a midreach character completely to its seaward terminus.

The extreme lower section of Pelekunu Valley consists of a vegetated debris fan, laced by various stream channels that are continually cut off and reoccupied. These aban-

doned channels in many cases contain pools with weak flow that are fed by seepage through the pore spaces in the coarse surrounding alluvium. At the mouth of the stream the debris fan forms a transverse barrier of water-rounded rocks and cobbles, behind which the stream pools to form a small pond before entering the sea via a small rapid. The size of the terminal pond varies according to spates and other stream fluctuations, and at certain times of year a black sand beach is also exposed seaward of the cobble bar that impounds it.

Further upstream at the head of the debris fan the bed narrows and vertical walls of coarse volcanic conglomerate occasionally confine the channel. The basic channel substrate throughout this terminal section consists of rounded cobbles averaging 20–40 cm diameter, alternating with beds of coarse gravel. Except for the large pool at the mouth, the stream profile is composed primarily of erosional zones formed by rapids and riffles. In the first kilometer upstream from the mouth numerous streamlets and rheocrenes enter from the east bank off the steep flanking wall of the Olokui massif, forming swampy areas at the base of the eastern valley wall. To the west of the stream mouth is an extensive complex of abandoned taro fields, now dry and heavily overgrown by introduced grasses.

During an initial visit to lower Pelekunu Valley in 1991, the author captured individuals of *M. xanthomelas* along the margins of the terminal pond formed behind the cobble bar at the stream terminus (Polhemus 1991). This bar was high enough and steep enough that the waves did not overtop it, and thus retained a limentic character despite its proximity to the sea. The adults observed here did not range far from the pond, flying low and perching amid vegetation on the stream margins which offered protection from the sea breeze, and since the species was not encountered elsewhere in the lower valley it was assumed that this terminal pond was the breeding site.

This area was revisited in late August of 1995 and showed a number of changes from its aspect in 1991. The alluvial delta bordering the terminal pond was now heavily overgrown with tall stands of Job's tears (*Coix lachryma-jobi*), and the riparian vegetation further up the valley was also much denser. This revegetation appears to indicate recovery from a major flood that took place immediately prior to the initial 1991 survey. The stream channel itself also exhibited a different configuration, splitting into a D-shaped loop just before its seaward terminus. The previously ponded section now occupied a small area along the outside curve of the D near the point where this side branch rejoined the main channel. The pond, which in its present configuration could more properly be considered a deep, flowing pool, was bordered along its seaward side by the terminal cobble bar covered with *honohono* (*Commelina diffusa*), along its eastern side by a steep bedrock face, and along its remaining margins by cobble bars overgrown with Job's tears and Guinea grass (*Panicum maximum*). The pond was measured and found to be 11 m in length and 9.5 m in width, with an inflow width of 5.3 m. The maximum depth of the pond was 1.4 m, and the depth at the inflow was 0.5 m. The substrate of the pond consisted of stream-rounded rocks and cobbles sitting on coarse, dark gravel. The water chemistry of this site is summarized in Table 1.

Megalagrion xanthomelas was found once again at the mouth of Pelekunu Valley during the 1995 survey, but only in a small area along the seaward margin of the reduced terminal pond. At least 4 males were observed perching amid marginal vegetation and making short forays over the open water; no females were seen. A detailed search was made of the leaves of the *honohono* that bordered the pond but no oviposition scars were

found, although tissues of this plant are known to be a favored oviposition sites for *M. xanthomelas* at TAMC. Other Odonata co-occurring with *M. xanthomelas* at the terminal pond included the introduced damselfly *Ischnura ramburii* (Selys-Longchamps), which was not seen during the 1991 surveys and may be a recent invader in the valley, and the indigenous dragonflies *Anax junius* (Drury) and *Pantala flavescens* (Fabricius).

Of particular note at Pelekunu was the short time duration of *M. xanthomelas* activity during the day. When the survey team arrived at 0900, the weather was clearing after a brief rain shower and the sun was just rising above the rim of the Olokui massif. Although fair and sunny conditions prevailed for the next several hours after this, no *M. xanthomelas* were observed. In the absence of any activity, surveys were made a short distance up the main stream to see if populations might be present there, but none were found, although 3 other *Megalagrion* species, *M. pacificum* McLachlan, *M. blackburni* McLachlan and *M. hawaiiense (McLachlan)*, were observed. The survey party returned to the pond area at ca. 1130 and at this point found adult *M. xanthomelas* to be active, allowing the capture of several specimens. By 1230, a brief shower passed over and activity ceased. Although the remainder of the day was characterized by alternating periods of sun and light showers, no additional *M. xanthomelas* were observed. At this site the total duration activity on the day that surveys were made thus appeared to be ca. 1 h during midday when the valley received its most direct sunlight. This preference for high light conditions corresponds to similar observations made at the Koele Lodge on Lanai (see following section).

Waikolu Stream

Waikolu Stream is a swift, rocky perennial stream occupying an elongate, sheer-sided valley on the northern, or windward, side of eastern Molokai. As in nearby Pelekunu Valley, the Waikolu drainage begins with a steep headwall section dropping rapidly from an encircling rim at ca. 1067 m elevation to the beginning of the midreach at ca. 305 m elevation. This midreach section continues for several km to the stream mouth, following a moderate gradient with numerous small waterfalls and rapids, with the stream entering the sea across a steeply sloping cobble bar. The stream profile throughout the midreach is thus composed primarily of erosional zones, along with a few deep pools found primarily below old water diversion structures, and in the area immediately behind the cobble bar at the stream terminus. The basic channel substrate throughout the mid- and terminal reaches consists of large stream-rounded boulders averaging 1–2 m in diameter, alternating with beds of cobbles and coarse gravel. The stream is shaded in its upper reaches by a closed canopy forest of kukui and guava, but becomes progressively more open as one proceeds downstream. Numerous small tributary rivulets and rheocrenes enter along the midreach, particularly in the area immediately below the pumping station. These spring fed ecosystems provide stable aquatic habitats that are not subject to the sudden and unpredictable variations in discharge rate that characterize the main stream, and thus support diverse aquatic insect communities including some taxa not commonly seen along the main channel. Water temperatures in along the main channel sampled range from 18 °C at 180 m to 21 °C at 80 m, while the water temperature in the spring fed tributaries is 19 °C (Polhemus 1992).

Individuals of *M. xanthomelas* were observed by Adam Asquith along the terminal reach of Waikolu Stream at midday on 19 July 1995. The insects were not abundant, and

flew along the margins of five slow, shallow stream pools lying behind the terminal bar. In general aspect this habitat is thus very similar to Pelekunu.

Palaau Wetland

An extensive basal spring wetland is present at Palaau, 3 km east of Kaunakakai on the southern coast of central Molokai (Fig. 2). At least 6 individual spring outflows of varying sizes are present in this area, many being marked by stands of bulrushes (*Schoenoplectus* sp.), bordered peripherally by expanses of pickleweed (*Batis maritima*), and others emerging along the margins of shallow coastal basins to form large, horizontally stratified mixohaline ponds, most notably the Kaluaapuhi Pond. Most of the larger springs that emerge above sea level have been boxed, although their outflows still reach the ponds, and water from others is being used to supply an expanding series of aquaculture projects, and for cooling and steam generation at the local power plant. The vegetation of the area is highly altered from its original state, being a kiawe (*Prosopis pallida*) savannah along the inland margins, and bearing a thick band of mangroves seaward, the latter having become established after World War II. A more complete vegetative description of this ecosystem type may be found in Wagner *et al*. (1990). Although the Palaau wetland is still partially intact, the continued spread of aquaculture facilities, which are being actively promoted and funded by the County of Maui, will likely alter this area in the near future, both by reconfiguring the mixohaline pools and marshes, and by diverting the spring waters upon which these systems depend.

Megalagrion xanthomelas was present here along the along the inland margins of the wetland, in company with 2 introduced damselfly species, *Ischnura ramburi* and *Ischnura posita*, and 2 larger dragonfly species, *Anax junius* and *Orthemis ferruginea*. Individuals of *M. xanthomelas* were observed along the back edge of Kaluaapuhi Pond, in the nearby mangroves along a flooded trail, and emerging as tenerals from small water pockets at the base of an isolated *Schoenoplectus* clump. Measured salinities in Kaluaapuhi Pond varied from 2 ppt at a small spring inflow to 3 ppt in middle of the pond away from this inlet. Stearns & Macdonald (1947) noted that the entire basal lens underlying west and central Molokai is brackish, thus all basal springs in this area are saline to some degree. The fact that *M. xanthomelas* is breeding in the Palaau wetland, which is supplied by such brackish springs, clearly indicates that the species can tolerate salt concentrations of at least 2 ppt.

This conclusion was reinforced by the discovery of *M. xanthomelas* at a small pond adjacent to the Molokai Sea Farms aquaculture facility at western end of the Palaau wetland complex. This pond occupied an elongate, steep sided basin bordered by pickleweed (*Batis maritima*) and other introduced weeds. The waters of the pond were heavily covered with a layer of duckweed (*Lemna aequinoctialis*), which was maintained by the aquaculture farm as a means of deterring algal growth. The steep sides and elongate form of the basin suggest that it is an artificial modification of a former spring outflow.

Megalagrion xanthomelas was present at this small pond, in association with the same damselfly and dragonfly species seen at Kaluaapuhi pond, but did not occur at the adjacent aquaculture ponds, which lacked floating or marginal vegetation. Individual males were seen perching on sticks and weeds that projected over the water, and a tandem pair was observed ovipositing on the thick duckweed mat. The salinity of the water in this pond was taken and found to be 2 ppt, the same as that of the springs at Kaluaapuhi Pond

(the water chemistry of these sites is summarized in Table 1). This once again clearly demonstrates that *M. xanthomelas* can breed in mildly saline waters.

Kauhako Lake

A single immature specimen of *M. xanthomelas* (which was reared to adulthood at BPBM to confirm its identity) was taken by Dr. Robert Kinzie of the University of Hawaii in late March 1995 along the margins of Kauhako Lake, lying in Puu Uao crater on the Kalaupapa Peninsula of northern Molokai. The salinity of the lake is 15 ppt (R. Kinzie, pers. comm.), although freshwater inflows presumably enter at certain points due to percolation through the volcanic cone, creating a system reminiscent of a very large anchialine pool. The lake is over 250 m deep (Maciolek 1982), and its steep, rocky margins lack emergent aquatic vegetation, although they are heavily shaded in some areas by overhanging tree limbs. No adults were seen at the time the immature was collected.

Table 1: Summary of water chemistry and other physical data for sampling sites on Molokai

Site	**Soil pH** (2/site)		**Water pH** (2/site)		**Air Temp.** (°C)	**Soil Temp.** (°C)	**Water Temp.** (°C)	**Salinity** (ppt)
Palaau:								
Kaluaapuhi	—	—	7.2[1]	7.2[1]	—	—	24.5	2.0[1]
			7.1[2]	7.1[2]				3.0[2]
Palaau:								
Molokai Sea Farms Pond	—	—	6.6	6.6	—	—	31.0	2.0
Pelekunu Val. breeding site	—	—	8.2	8.3	—	—	23.0	0.0

[1] inlet; [2] boat

The distributions of the Molokai populations discussed above are summarized in Figure 2.

Lanai

Koele Lodge

One of the largest populations of *Megalagrion xanthomelas* outside of Hawaii island occurs in a set of ornamental streams and pools at the Koele Lodge on upland Lanai. These habitats, lying at 580 m above sea level, are also the highest elevations from which the species has been recorded in this century. The existence of this population remained undetected until 1993, although the species presumably occupied the ranch pond that was constructed at this site in the late 1800s. The fact that *M. xanthomelas* has been able to colonize an artificial habitat that was constructed within the last 5 years with no consideration to damselflies whatsoever had an important bearing on the situation at TAMC, since it indicated that construction of similar habitats at TAMC might be sufficient to mit-

igate the present threats to the species at this latter site.

The resort complex at Koele, consisting of The Lodge at Koele and The Experience at Koele golf course (referred to subsequently as the Koele Lodge) was constructed in 1990 on the site on the former Koele ranch, at an elevation of 580 m. The development includes ten separate aquatic features, including a large reflecting pool and ornamental stream complex behind the lodge building itself, a putting course nearby with several small ornamental streams, and 8 large ponds scattered around the golf course to serve as water hazards. All of these individual habitats were surveyed, and their water chemistries are summarized in Table 2. For purposes of this study the reflecting pool and inflow stream behind the lodge building were treated as a single aquatic feature, as were the two large ponds at Holes 8 and 9 that are connected by a cascading ornamental stream. Several of these water features are also fed by shared recirculating water systems. Most notable among these are the ponds at Holes 4 and 18, which are widely separated topographically and elevationally (Hole 4 lies at 610 m, Hole 18 at 580 m), but connected hydraulically. Such connections would allow potential transfer of *M. xanthomelas* eggs and immatures from one site to the other. All the water features on the golf course are internally recirculating with the exception of the pond at Hole 17. The pond and streams behind the lodge, Holes 4, 8–9, and 18, and the putting green streams occupy sheltered locations at the base of Lanaihale mountain and are surrounded by tall stands of *Araucaria* and other introduced trees. By contrast, the ponds at Holes 12, 15, 16 and 17 are more exposed to the wind and lack shelter from either topography or trees.

The large pond and its associated inflow streams behind the lodge building, referred to subsequently as the Lodge Pond, has a capacity of 3.5 million gallons, and is not currently subjected to any water treatment protocol. The pond is equipped with a downflow biofilter system, but this has never been used in the 6 years since its emplacement due to technical problems. A high rate sand filter is also installed, but like the biofilter is not currently in use. Instead, occasional treatments of potassium permanganate at 5 ppm concentrations are applied to retard the growth of algae. The pond occupies the site of a previous storage reservoir used by the former Koele Ranch to water cattle, indicating that an artificial aquatic feature has been continuously present at this site for over a century.

The recirculating inflow stream feeding the Lodge Pond originates in a small lily pond upslope from the lodge. This pond occupies a roughly circular basin approximately 4.5 m in diameter and 1 m deep. The surface is covered with numerous floating lily pads, and the western margins are composed of set rock walls bearing a growth of ferns, whose roots hang into the water. This pond previously received applications of Aqua Shade to retard algal growth, but this practice has been discontinued for the last 2.5 years.

The several small streams present on the putting green, immediately east of the lodge building, are swift and unshaded, originating in small ponds lined with ornamental rock walls. They are lined by plantings of exotic flowering plants, and receive an application of Aqua Shade once a month to eliminate algae.

None of the other water features on the golf course are currently subjected to filtration or chemical treatments. Carp were present in the Lodge Pond and at Hole 12, guppies were seen at Holes 12 and 15, and apple snails were present at Hole 15. Apart from this, and the exotic Odonata noted in Table 3, the water features at Koele Lodge seem to be relatively free of introduced aquatic biota.

Table 2. Summary of water chemistry and other physical data for sampling sites on Lanai.

Site	Soil pH (2/site)		Water pH (2/site)		Air Temp. (°C)	Soil Temp. (°C)	Water Temp. (°C)	Salinity (ppt)
Lodge pond	—	—	8.6	8.6	19.1	19.0	21.6	0
Lodge pond	—	—	9.3	9.4	20.3	19.5	20.7	0
Putting course	—	—	9.1	9.1	20.9	19.0	21.9	0
Hole 12			8.8	8.9	18.5	19.0	20.1	0
Hole 15			9.8	9.9	18.7	20.0	20.3	0
Hole 16			9.0	9.1	18.1	19.0	20.0	0
Hole 17			9.1	9.2	17.4	19.5	20.4	0
Maunalei Gulch			8.0	8.1	22.5	21.0	24.5	0

Table 3. Distribution of Odonata at sampling sites on Lanai.

	Locality									
Taxon	**LG**	**PC**	**4**	**8–9**	**12**	**15**	**16**	**17**	**18**	**WW**
M. xantho	x	x	x	x	-	-	-	x	x	-
E. civile	x	x	x	x	x	x	x	x	x	x
I. ramburii	-	-	-	-	x	-	-	x	-	x
A. junius	x	x	-	-	x	x	x	x	x	x
O. ferru	x	-	x	x	x	-	-	x	-	-
P. flaves	x	-	x	x	x	x	x	x	-	-

Explanation of locality codes:

LG = Lodge reflecting pond; PC = putting course, 4 = 4th hole, 8–9 = 8th and 9th holes; 12 = 12th hole; 15 = 15th hole; 16 = 16th hole; 17 = 17th hole; 18 = 18th hole; WW = wastewater treatment plant.

Explanation of taxon codes:

M. xantho = *Megalagrion xanthomelas*; E. civile = *Enallagma civile*; I. ramburii = *Ischnura ramburii*; A. junius = *Anax junius*; O. ferru = *Orthemis ferruginea*; P. flaves = *Pantala flavescens*

Populations of *M. xanthomelas* were found at the Lodge Pond and its inflow streams, Holes 4, 8, 9, 17, and 18, and at the small streams on the putting course, but the species was absent at the ponds adjoining Holes 12, 15, and 16 (see Table 3). It was evident that the insects preferred the more sheltered sites, an observation congruent with that made at Ninole Springs in Kau (see following section). Numerous other Odonata were also found in these artificial systems, including the introduced damselflies *Enallagma civile* and *Ischnura ramburi*, and the dragonflies *Anax junius*, *Pantala flavescens* and *Orthemis ferruginea*. No clear correlation was evident between the presence of any of these other species at a site and the absence of *M. xanthomelas*, indicating that competitive interactions are not structuring the Odonata guilds in this system.

Detailed observations were made regarding *M. xanthomelas* behavior at several of the Koele sites. The most robust population appeared to be in the lily pond at the source of the ornamental stream feeding the Lodge Pond. Females were seen oviposting here on floating lily pads, which exhibited numerous brown oviposition scars, and immatures were taken from the submerged roots of ferns that grew on the rock wall bordering the pool. Adults were also observed emerging from their immature casings at this site. Emergence took 30–60 min, after which the insects flew away from the water to perch in sheltered spots amid vegetation, presumably to allow their cuticle to harden. By contrast, adults in later stages of maturity were active around and above the pond, with males aggressively defending territories ca. 2 m in diameter. These adults quickly ceased activity if the sunlight was interrupted by passing clouds, indicating that *M. xanthomelas*, at least at this elevation, is very photosensitive.

At the Hole 8–9 complex, tandem pairs of *M. xanthomelas* were observed ovipositing in collapsed lily stems that hung into the water, while at Hole 4 a female was observed ovipositing on algal mats in the lowermost of three inflow basins below an ornamental waterfall. The pond at this latter site had relatively open, grass-lined banks, and in this area adults were observed only in areas where small irregularities in the shore line, such as coves formed by large rocks, provided some form of shelter.

Maunalei Gulch

The population of *M. xanthomelas* currently extant at the Koele Lodge occupies artificial habitats that did not exist prior to the early 1990s. The source of the *M. xanthomelas* population that colonized this site must thus lie elsewhere. It is possible that the insects colonized the former Koele Ranch cattle pond from populations inhabiting small springs emerging at the base of Lanaihale mountain, but no such outflows are mentioned by Stearns (1940). Instead, the most logical source from which the colonists could have come is Maunalei Gulch, a deep canyon on the northern side of Lanai that previously contained the only perennial stream on the island. A survey of the upper reaches of this gulch by the author in 1993 revealed that three species of *Megalagrion* damselflies, *M. hawaiiense* (McLachlan), *M. blackburni* McLachlan and *M. calliphya* (McLachlan) still persisted in in this catchment, but *M. xanthomelas* was not seen. In 1994, however, a specimen of *M. xanthomelas* was taken in dry forest near the mouth of Mauanlei Gulch by Dr. Richard Baumann, a visiting entomologist from Brigham Young University. This discovery indicated that a colony of *M. xanthomelas* did indeed persist somewhere in the lower Maunalei system, and an attempt was thus made to locate it during the current investigations on Lanai.

An initial reconnaissance of the coast revealed no wetlands that might support the species. A foray was then made up the lower reaches of Maunalei Gulch, which is at this point a dry bed shaded by kiawe forest. A leak was eventually discovered in a small water pipeline at ca. 120 m above sea level, which created a limited outflow on a bench above and to the south of the gulch bed. *M. xanthomelas* was relatively abundant along this seepage, with many mating pairs present. The water at this site was found to have the following characteristics: temperature, 24.5 °C; salinity, 0.0 ppt; pH, 8.0. This habitat is extremely limited, and could easily be eliminated by repair or replacement of the currently leaking pipeline.

Lopa Fishpond

A good series of *M. xanthomelas* was taken from this remote fishpond near the eastern tip of Lanai by Steve Montgomery of the Bishop Museum in August 1994. Montgomery (pers. comm.) reports that the fishpond was filled with mangroves, and that the damselflies were taken along its inland margin in an area where deer were coming down to water. These observations, coupled with the presence of *M. xanthomelas*, indicate that a permanent mixohaline aquatic habitat at exists at this site, probably due to weak basal spring percolation into the fishpond basin.

Keomoku

A tandem pair of *M. xanthomelas* was taken by Montgomery at this site on the same day as the specimens from Lopa were captured. The distance between these localities is over three miles, indicating the presence of two separate populations. The only water source at Keomoku is a covered well (Montgomery, pers. comm.), which seems an unlikely breeding habitat for *M. xanthomelas*, although its plumbing system may be providing artificial habitat in a manner similar to the leaking pipeline in Maunalei Gulch. It seems more likely, however, that the species is breeding in small pockets of fresh or brackish water present somewhere in the general area surrounding Keamoku. The water table along the section of the coast between Lopa and the mouth of Maunalei Gulch lies only a few meters above sea level, and in certain areas fresh water can be seen running into the sea at low tide (Stearns, 1940). Some of this water may be collecting in small natural depressions, or in the remnants of trench wells dug by settlers, and thus providing habitat for *M. xanthomelas*.

The distributions of the Lanai populations discussed above are summarized in Fig. 3.

Maui

The only specimens of *M. xanthomelas* known from Maui are four individuals in the BPBM by R.C.L. Perkins from the "West Maui Mountains" in 1894 and 1895. Perkins gave no further locality data, and one can only speculate as to the precise areas he sampled. Since Perkins' collections on West Maui during May 1894 were made entirely in the vicinity of Iao Valley, it seems likely that his specimens of *M. xanthomelas* taken in this year came from the wetlands and sand hills of the Wailuku Plain at the valley mouth, which prior to urban development in this century supported some of the most extensive sets of taro fields in Hawaii.

Another area that appears to have been capable of supporting *M. xanthomelas* was the Loko o Mokuhinia marsh at Lahaina, a basal spring wetland that was filled in for development in 1913. Pictures of Loko o Mokuhinia taken in the mid-1890's (the period when Perkins' collections were made) show a pond with floating vegetation and emergent bulrushes, similar to coastal habitats on Hawaii island in which *M. xanthomelas* breeds at the present time (Klieger *et al*., 1995).

Recent surveys on Maui have found no evidence of *M. xanthomelas* populations, even at potentially suitable sites such as the coastal Kealia and Kenaha ponds. A complete circuit of the West Maui coastal lowlands was conducted in mid-1995, but failed to uncover any remaining populations, although potential habitat was available at the mouths of Makamakaole, Kahakuloa and Honokohau streams. Surveys of coastal wetlands on leeward Haleakala and at various stream mouths along the Hana Coast have been similarly

unsuccessful. Based on these results, it seems possible that *M. xanthomelas* may have been locally extirpated on Maui.

Hawaii (Big Island)

Ninole Springs

Scattered populations of *M. xanthomelas* are known from coastal wetlands in Puna, Kau and North Kona on Big Island, where limnetic groundwater percolates seaward and mixes with the inland percolating marine water table to form horizontally stratified mixohaline systems. The largest of these coastal *M. xanthomelas* populations is found in a set of limnocrenes, rheocrenes, and mixohaline marshes located at Ninole, Kau, where downslope subsurface percolation from the Ninole Hill drainages emerges just above sea level at the mouth of Ninole Stream. This is the second largest basal spring complex on the island of Hawaii (the largest being Waiakea Pond at Hilo), discharging over 20 million gallons per day in 1946 (Stearns & Macdonald, 1946), although this flow may have been subsequently modified by withdrawls from wells to irrigate sugar cane fields upslope. The water originates from lava tubes in the Kau volcanic series, and represents the subterranean outflow from ancient valleys in the nearby Ninole Hills that were filled by subsequent eruptions from Mauna Loa. Due to its origination in catchments upslope the water is quite cold, with an emergent temperature of 19 °C. This groundwater surfaces along the inland sides of coastal lava basins that have some degree of connection to the sea, creating horizontally stratified mixohaline systems with a zone of freshwater marsh along their inner margins. Similar basal spring wetlands are found at several other points along the Kau coast, including Punaluu, the mouth of Hilea Stream at Hawa Bay, Hawa Springs, and Whittington Beach Park.

The Ninole Spring wetland complex contains an extensive set of limnetic to mixohaline marshes, ponds and creeks lying at the stream mouth and in the area directly to the east, between the Sea Mountain golf course parking lot and the lava coastline. Numerous cold freshwater springs emerge just inland of the coast at the base of an a'a flow, some flowing directly into tidepools, others feeding large ponds and sloughs. One large pond with thick beds of watercress along its margins occupies a lava basin immediately east of the stream mouth, and is separated from the sea by a wall of lava ca. 3 m high, which large waves occasionally overtop. A second, even larger pond lies further to the east, in a basin just above sea level, and enters the ocean via a swift freshwater creek ca. 1 m wide and 15 cm deep. The inland margins of both these ponds grade into marshes dominated by bulrushes (*Schoenoplectus* sp.) and *honohono*; similar marshes are also present in the area between the ponds, in association with smaller spring outflows. The eastern pond also contains water hyacinth (*Eichornia crassipes*) along its inland margin.

Surveys undertaken during early May 1994 found *Megalagrion xanthomelas* to be abundant at Ninole Springs, breeding in all suitable habitats. Numerous mating pairs were observed, and many newly emerged adults were seen along the margins of the westernmost pond. A mating pair was also captured above the standing pool formed behind the cobble bar at the mouth of the stream itself. In addition, the introduced damselflies *Enallagma civile* and *Ischnura ramburi* were present along the margins of the eastern pond, especially in seaward areas exposed to the wind, but *M. xanthomelas* was clearly the dominant damselfly species across the entire Ninole system. In general the introduced damselflies seemed more abundant in open areas, while *M. xanthomelas* flew amid the

shelter of vegetation along the slough channels, which were difficult to investigate, being heavily vegetated and often over 1 m in depth. The large dragonflies *Anax junius* and *Pantala flavescens* were also seen throughout the Ninole area.

The salinity of the aquatic features at Ninole Springs varied from limnetic (less than 0.7 ppt) at the outflows to fully euhaline (at least 30 ppt) at the shore, with all degrees of intermediate salinity encountered throughout the ponds and marshes. It is clear from other investigations on Molokai (see previous section) that *M. xanthomelas* can tolerate salinities of at least 2 ppt, thus it is able to breed along much of the inland margin of the Ninole wetland system.

The estuarine marshes and limnocrenes at Ninole Springs and other coastal wetlands in Kau provide extensive breeding habitats for *M. xanthomelas* that are not currently duplicated on the other high islands, although similar systems may once have existed at Pearl Harbor on Oahu prior to its urban development. Throughout such coastal situations, both here and in North Kona, *M. xanthomelas* is typically found in company with the alien *Ischnura ramburi* and *Enallagma civile*, but the competitive interactions among these species, if any, do not seem to preclude the continued presence of *M. xanthomelas* at these sites.

Hilea

A coastal wetland similar in form and origin to that seen at Ninole but of smaller extent occurs at the mouth of Hilea Stream, approximately one mile to the southwest on the opposite (western) side of an intervening lava flow. The habitat consists of several elements, beginning with a long, deep mixohaline pool at the mouth of the stream channel, which runs parallel to the base of the lava flow. This pool is separated from the sea by a cobble bar that is occasionally overtopped by high swells, and experiences a weak tidal flux. No damselflies were seen along this pool. West of the stream mouth are several small limnetic ponds bordered with sedges, grasses, and *honohono*; these ponds supported *Megalagrion xanthomelas*, *Enallagma civile*, *Ischnura ramburi*, *Anax junius*, *Pantala flavescens*, and *Tramea lacerata*. Even further to the west is a large basin, connecting directly to the sea via a narrow mouth, but with a zone of bulrushes at the back, bordered even further inland by an extensive, apparently limnetic marsh thickly overgrown with tall grasses. No damselflies were seen at this latter basin, but it seems likely that *M. xanthomelas* may occur in the marsh.

When this site was visited on 4 June 1994, water was being pumped from the western marsh by squatters, who were using it to irrigate small taro fields. One of these squatters claimed that the mouth of Hilea Gulch previously consisted of a large, swampy estuary, but that a major flood 4 or 5 years earlier had washed in a large amount of sediment, producing the current configuration.

Hawa Springs

This habitat consists of a small limnetic spring outflow emerging at the base of an eroded lava flow, and flowing into a linked series of progressively more saline ponds scattered along a sinuate depression behind the shoreline. The overall impression is one of an interrupted tidal creek, bordered by grasses and sedges. During a survey on 4 June 1994 the limnetic pools near the head of this system supported populations of *Megalagrion xanthomelas* and *Anax junius*; no introduced damselflies were seen. The area appears to be in a relatively natural condition, and does not appear to be frequently visited.

Whittington Beach Park

A single large pond behind the shoreline at Whittington Beach Park receives limnetic inflow along its inland margin, while connecting to the sea via a narrow mouth along the ocean side. A mixohaline gradient appears to exist across the width of this pond, with the seaward portion being essentially euhaline, but changing to mixohaline as one progresses inland. The basin here is similar in extent to the large eastern pond at Ninole, but is not raised above sea level as in the former case. The back margin of the Whittington pond is bordered with low grasses and bulrushes, indicating that a narrow freshwater zone exists as a result of limnetic downslope percolation into the basin. *Megalagrion xanthomelas* was found here on 4 June 1994, with adults flying low amid the shelter of the vegetation along the back edge of the pond. No individuals were seen along the front edge of the pond nearer to the sea. Cattle have disturbed this system, but do not appear to pose a threat to the long term stability of the marsh.

Kaloko Fishpond

A large fishpond and many other smaller anchialine pools are found in this area. David Foote of the National Biological Service, Hawaii Volcanoes National Park, has taken numerous specimens of *M. xanthomelas* from this site and documented their occurrence in the various habitats present.

Kiholo Bay

A complex of wetlands containing numerous anchialine ponds and pools occurs along the margins of Kiholo Bay. Access is difficult due to private ownership, and the area remains poorly surveyed. During the present study it was possible to walk down the shore along the northern end of the bay and sample a large, apparently mixohaline pond that lay immediately behind the beach ridge. One specimen of *Megalagrion xanthomelas* was taken here, in company with *Ischnura ramburii*, which was abundant.

Anaehoomalu Bay

One of the most extensive sets of anchialine pools known on the North Kona coast formerly occurred along the northern margin of Anaehoomalu Bay, at a site now occupied by the Waikoloa resort. These pools were bulldozed in the course of resort development, but similar systems, though smaller in extent, still exist along the southern margin of the bay, in a complex owned by Parker Ranch and known as the "Parker Ponds". In this area the shore forms a high dune ridge, behind which lie a series of depressions, marked by palms, containing mixohaline marshes and bordered by low, halophytic vegetation, predominantly pickleweed (*Batis maritima*). A specimen of *M. xanthomelas* was taken along the margin of one of these basins on 7 June 1994, in company with the introduced *Ischnura ramburi*, which was abundant. Although the salinity of these marshes was not ascertained, females of *Anax junius* were seen ovipositing in them, indicating that in at least some sections it must be quite low.

Beyond the marshy basins to the southwest lies a set of rock rimmed anchialine pools, some forming large ponds with bulrushes along their margins. No damselflies were seen in this area, but two dragonfly species, *Anax junius* and *Tramea lacerata*, were observed. The overall Parker Pond system is relatively undisturbed, and further surveys in the area would be useful in order to localize the sources of limnetic inflow, around which

M. xanthomelas would be likely to congregate. The area has recently been sold by the Parker Ranch, but alteration of the pools and marshes should be discouraged if possible, since they represent the last remaining undisturbed portion of the formerly extensive Anaehoomalu anchialine pool complex, which was described in detail by Maciolek & Brock (1974).

The large Kuualii and Kahapapa fishponds at the Waikoloa resort were also surveyed, along with a complex of smaller adjacent anchialine pools containing red shrimps. All these habitats proved either too saline or too ecologically altered to support damselfly populations, and a search for further, more limnetic habitats in the general area was unsuccessful. A few *Anax junius* and *Pantala flavescens* were observed, but these may have been strays from populations breeding in nearby golf course ponds. An extensive set of anchialine pools formerly occurred to the north of this site, near Waiulua Bay (Maciolek and Brock, 1974), but these were destroyed in the course of resort development and no longer exist.

Leleiwi Point

A population of *M. xanthomelas* was found breeding in an anchialine pool system at Leleiwi Point by David Foote when he surveyed the area on 20 March 1995. Foote reports that the site consists of a large anchialine pond with a lava rubble and coral sand bottom. The submerged rocks are covered by a layer of light brown algal growth, and the pond margins are set with a dense growth of California grass (*Bracharia mutica*) that form floating mats in several places. A small patch of *Wedelia trilobata* also occurs along the shore in an area shaded by hau (*Hibiscus tiliaceus*). Water conductivity ranged from 4.86–6.52 mS, and the water temperature averaged 19 °C, indicating the pond is fed by a basal spring. Males of *M. xanthomelas* were observed along the pond margins, along with 1 tandem pair. Other Odonata at this site included the introduced damselflies *Enallagma civile* and *Ischnura ramburii*, and the dragonfly *Anax junius*.

The pond at Leleiwi is part of a very large system of anchialine pools and estuarine limnocrenes that extends from this point westward along the coast to Hilo, and includes Waiakea Pond, the largest basal spring in Hawaii. Individuals of *M. xanthomelas* were observed at Liliuokalani Park within Hilo itself in October 1995, and historical collections are present from Coconut Island immediately offshore, suggesting a long-standing population of *M. xanthomelas* in this area.

Onomea Stream

This is a relatively short catchment heading at approximately 275 m elevation and flowing for 3 km to a seaward terminus in Onomea Bay, north of Hilo. The stream exhibits a steep profile typical of drainages on the Hamakua Coast, descending stair-step fashion via waterfalls in a bed of hard basalt. The seaward terminus, lying within the Hawaii Botanical Garden, consists of a long, flowing freshwater pool impounded behind a cinder beach, with a waterfall at its head. Progressing upstream one encounters a series of falls and plunge pools heavily shaded by introduced figs, palms and bamboo, until the bridge on the Pepeekeo Scenic Drive is reached. Immediately above this road crossing the stream is less confined, and forms long, partially shaded flowing pools, which continue to the base of another high waterfall.

The terminal reach and lower midreach of this system both up and downstream of

the Pepeekeo Scenic Drive were surveyed on 8 June 1995. *Megalagrion xanthomelas* and *M. hawaiiense* were found along the pooled midreach section of the stream at 55 m elevation, just upstream from the road, but no damselflies were seen along the terminal reach in the botanical garden. Individuals of *M. xanthomelas* were observed perching on low ferns, dead palm fronds, and bare rocks along the channel margins. Immatures were not found, but are likely to inhabit the trailing submerged root mats that are well developed here.

Alakahi Stream

This is a short, steep catchment approximately 2 km long, heading at about 230 m elevation and terminating in Onomea Bay adjacent to Onomea Stream. The stream presents a steep profile, descending through a bed of mossy boulders, heavily shaded by a forest of introduced trees. The terminal reach and lower midreach of this system upstream of the Pepeekeo Scenic Drive were surveyed on 8 June 1995. *Megalagrion xanthomelas* and *M. blackburni* were found between 55 and 75 m elevation, up to a point where hau (*Hibiscus tiliaceus*) begins to heavily overtop the stream; the former species was found even in areas of dense shade, an unusual habitat preference (see comments under sections on Lanai and Molokai). No damselflies were seen along the lower section of the stream below the road, in the area where it passes through the Hawaii Botanic Garden, despite the presence of suitable habitat, including a large ornamental pond adjacent to the stream itself.

Kawainui Stream

This is a large volume catchment that flows through a steeply dropping basalt bed and reaches the sea in an incised fjord south of Pepeekeo. At 60 m elevation the stream flows through a natural archway formed by an old lava tube. The lower midreach of this system immediately downstream of the Pepeekeo Scenic Drive was surveyed on 8 June 1995. *Megalagrion xanthomelas* adults and immatures were taken at small side pools in bedrock adjacent to the main channel, and bordered by clumps of yellow flowering *Wedelia trilobata*. Other adults were taken next to seepage fed pools on bedrock shelves along the south bank of the stream immediately across from these side pools. Heavy rains several days later caused the stream to rise appreciably, completely covering the side pool habitats with swiftly flowing water (although the seeps were not affected). It thus appears that at this site *M. xanthomelas* is exploiting temporary habitats on an opportunistic basis.

This and other *M. xanthomelas* populations found along drainages entering Onomea Bay probably represent a northward extension of the populations centered around the estuarine limnocrenes at Hilo. To date *M. xanthomelas* has not been found to the north along the Hamakua Coast past Pepeekeo Point, despite surveys at suitable stream mouths between there and Honokaa. Most of the streams in the Hamakua area end in terminal falls, and of those few that do not the following have been surveyed: Kolekole, Hakalau, Honolii, and Laupahoehoe. Several others, such as Maulua and Nanue, still await surveys, but it is considered unlikely that they harbor *M. xanthomelas* populations based on current findings.

Kapoho

An extensive series of anchialine and mixohaline wetlands fed by basal springs is found along the shoreline to the east of Kapoho Crater, in Puna, developed amid a series of recent lava flows that have been subject to coastal subsidence. Searches were made along the seaward edge of this system between 8 and 9 June 1995, both north and south of Kapoho Point. *Megalagrion xanthomelas* was found in the former area, which is being developed into residential subdivisions, with adults patrolling along the margins of moderately saline (8.0–8.5 ppt) pools. Current USGS maps do not correctly reflect the coastline profile and adjacent wetlands in this area, since extensive subsidence took place after their last update in 1981.

The interior of nearby Kapoho Crater contains a water filled basin known as Green Lake, which has no outlet and appears to be fed by seepage from the surrounding crater walls. This lake, which is essentially circular and ca. 100 m across, has silty, greenish waters with a temperature of 27 °C, and supports an overwhelmingly alien aquatic biota including frogs, topminnows, and numerous introduced aquatic plants. The shores are thickly lined with bamboo, kukui, breadfruit, mango and other exotic vegetation. Two males of *M. xanthomelas* from this locality, taken by F.X. Williams in 1936, are present in the collection of the Hawaii State Department of Agriculture. A survey of the lake and its surroundings in good weather failed to detect any sign of this species, although the introduced damselflies *Ischnura ramburii* and *Enallagma civile* were abundant, in company with the dragonflies *Anax junius* and *Pantala flavescens*. It is assumed that the introduction of alien fishes and frogs at Green Lake has led to the extirpation of this population of *M. xanthomelas*.

The distributions of the Hawaii populations discussed above are summarized in Figure 4.

Summary

The present surveys of *M. xanthomelas* demonstrate that the species occupies a wide range of habitats and has broad ecological tolerances. The most common habitats in which this species occurs are coastal wetlands fed by basal springs, as seen in the Puna, Kau and North Kona districts of Hawaii, at Palaau on Molokai, and formerly at Pearl Harbor on Oahu. This species also occasionally breeds along the terminal and lower midreaches of perennial streams, as illustrated by the populations at Pelekunu and Waikolu streams on Molokai, and at Onomea Bay on Hawaii island. Given the absence of introduced aquatic biota, *M. xanthomelas* can also breed in reservoirs and ornamental ponds, as recorded previously by Williams (1936), and currently documented at the Koele Lodge on Lanai. The species will also opportunistically exploit temporary habitats, as shown by its occupation of ephemeral side pools bordering flashy streams on Hawaii island, and pipeline seepages on Lanai.

Although *M. xanthomelas* has a recorded elevational range of 0–1000 m above sea level (Perkins, 1899), it is generally a lowland species, with most of the known populations now occurring below 60 m, and the highest recent records coming from 610 m, in artificial settings on Lanai. Results from salinity readings taken at Palaau, Molokai demonstrate that the species can tolerate salt concentrations of at least 2 ppt, and circumstantial evidence from habitats in Puna and North Kona indicates that the tolerance may be as high as 8 ppt. Based on results from Lanai the species also does not seem to be

adversely affected by commercial anti-algal treatments such as AquaShade and copper sulphate, which are commonly used in hotel and golf course water features. The species was found breeding in habitats with water temperatures ranging from 20–31 °C, and with pHs ranging from 6.6–9.2.

In terms of interactions with alien aquatic species, *M. xanthomelas* seems to be able to tolerate the presence of carp and apple snails, but does not do well in habitats containing guppies or top minnows. There is no indication of adverse competitive interactions between *M. xanthomelas* and the widespread introduced damselflies *Ischnura ramburii*, *Ischnura posita*, and *Enallagma civile*, with which it frequently co-occurs.

Despite its broad range of ecological tolerances, *M. xanthomelas* is becoming increasingly rare in Hawaii, having apparently been extirpated from two islands, Kauai and Maui, on which it previously occurred, while being perilously close to extirpation on Oahu. Based on our current understanding of the species' biology, this loss of *M. xanthomelas* populations is linked more to the introduction of alien aquatic biota than to outright habitat alteration or destruction. On one hand this is a source of optimism, since this pattern of decline can perhaps be stablized through protection of remaining natural habitats or construction of suitable refugia. On the other hand, it is also a source of pessimism, since the continuing onslaught of alien aquatic species in Hawaii shows no signs of abatement (Eldredge 1994).

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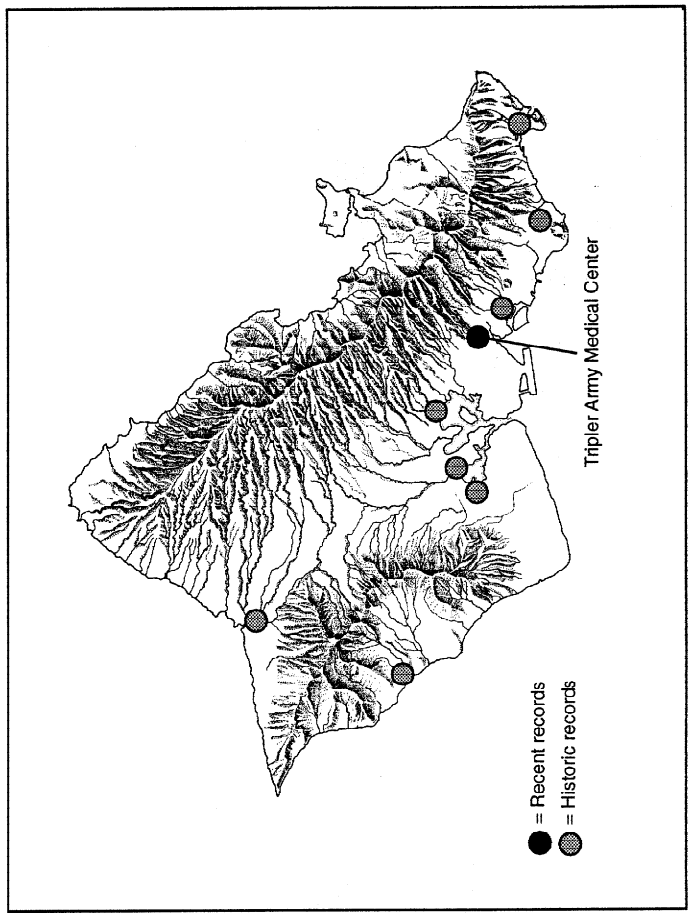

Fig. 1. Map of Oahu, showing locations of current and historic records for *Megalagrion xanthomelas*.

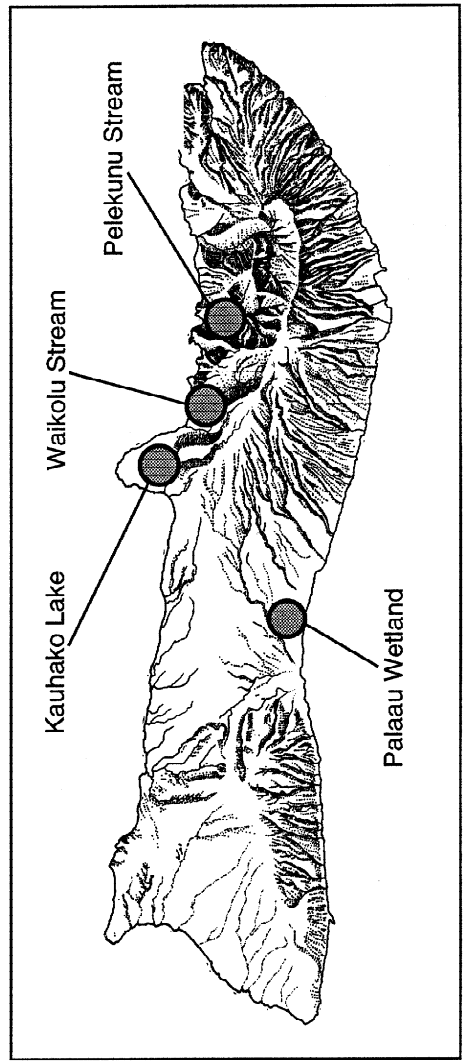

Fig. 2. Map of Molokai, showing currently known populations of *Megalagrion xanthomelas*.

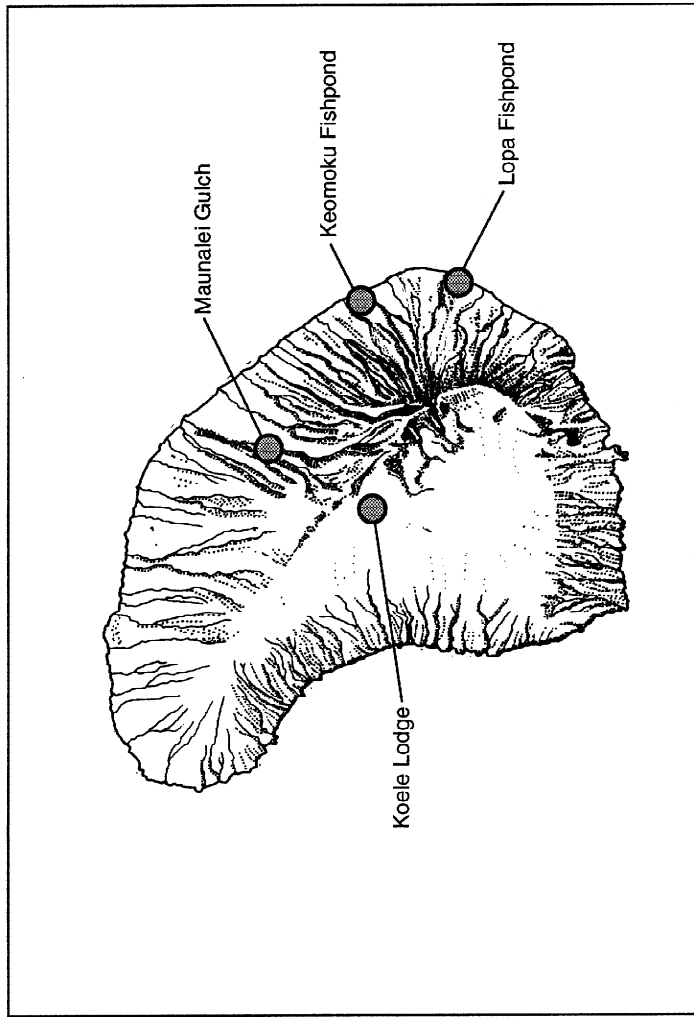

Fig. 3. Map of Lanai, showing locations of current and historic records for *Megalagrion xanthomelas*.

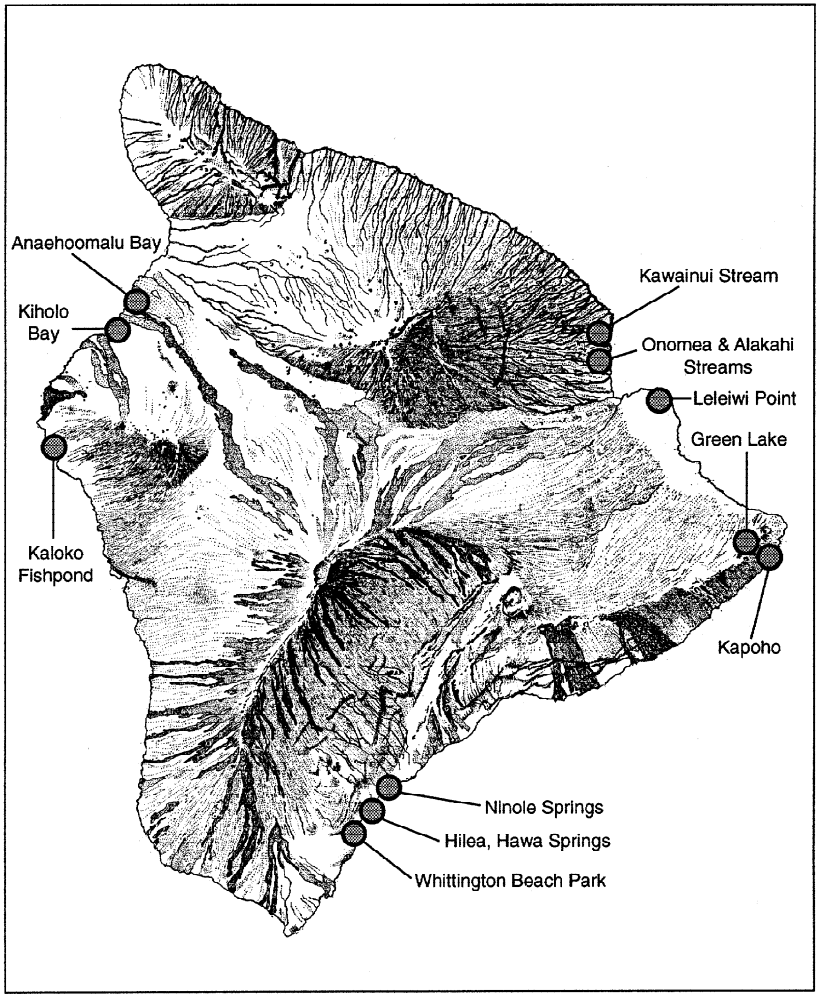

Fig. 4. Map of Hawaii Island (Big Island), showing known populations of *Megalagrion xanthomelas.*