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MODE OF EXISTENCE AND SEASONALITY OF MIDGE LARVAE (DIPTERA: CHIRONOMIDAE) IN MAN-MADE LAKES IN THE COACHELLA VALLEY, SOUTHERN CALIFORNIA

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ABSTRACT. Over the past 2 decades, numerous man-made ponds and lakes constructed in country clubs and on golf courses in the Coachella Valley have become ideal habitats for various chironomid species. Large numbers of adult midges emerging from these water bodies pose nuisance and economic problems. During 1992 and 1993 we initiated comprehensive studies on the nature and scope of the nuisance midge problem in the valley. We sampled on a biweekly basis 2 lakes supplied with well water, 2 supplied with tertiary effluent water, and one supplied with a mixture of these 2 sources, to determine the midge larval fauna and the mode of existence, seasonal abundance, and population trends of these midges. Climbers, clingers, portable sand tube builders, and tube builders on plants predominated in well-water habitats with submerged vegetation and detritus bottoms. Tube builders and burrowers predominated in the tertiary water, which characteristically had a detritus bottom, devoid of vegetation. Habitats holding a mixture of the 2 water types with sandy bottoms supported midge larvae known to be sprawlers.

INTRODUCTION

During the past 2 decades, numerous country clubs and resorts with ponds and lakes on golf courses have been developed in the Coachella Valley, southern California. These aquatic habitats with sandy or mucky bottoms are shallow (1–3 m deep) and are supplied either with well water or tertiary effluent water or a mixture of both. High levels of eutrophication in some of these lakes, along with high temperatures in the valley, turn these lakes into ideal habitats for breeding large populations of aquatic chironomid midges. Adult midges cause a serious nuisance problem on the premises of these country clubs and resorts. There is evidence that chironomid midges affect human health, causing allergic manifestations such as asthma, rhinitis, and conjunctivitis (Cranston et al. 1981, Ito et al. 1986, Cranston 1988, Giacomin and Tass 1988).

Our study was undertaken to elucidate the midge larval fauna, and the mode of existence, seasonal abundance, and population trends of these midges in lakes supplied with well water, tertiary effluent water, and a mixture of both. For each habitat, modes of larval existence were characterized according to Merritt and Cummins (1978). Also, the index of species diversity (ST) and Sorensen coefficient of similarity (C) were calculated (Southwood 1991).

Because the Coachella Valley Water District (the sole water supplier in the valley) is planning to make tertiary effluent water available in the near future to most country clubs and resorts, our research was aimed at determining the potential increase of chironomid midge problems if and when tertiary effluent water is widely used for filling and replenishing the ponds.

MATERIALS AND METHODS

This research was conducted in the Mission Hills (Rancho Mirage) and Portola (Palm Desert) Country Clubs in the Coachella Valley in southern California. This valley has a characteristic desert climate with hot summers (up to 48°C), and mild winters with widely differing night (<0°C) and day (>30°C) air temperatures.

The Mission Hills Country Club covers *ca.* 728 ha and has 18 small and large lakes constructed 15–17 years ago. These 1–2-m-deep lakes are surrounded by residential units. The lakes were supplied with well water, which was used for irrigation of the golf courses. Of the 18 lakes, midge research was initiated in January 1992 on lake numbers 9 and 12. Lake 9 was 1 ha at the surface and was reconstructed and refilled with well water in November 1991. This lake was only 1 m deep in most areas but the maximum depth reached 2 m. In early April 1992, grass carp were introduced into this lake. Algae and weed growth in the lake were controlled with 2 or 3 treatments of copper sulfate ($CuSO_4$) and Cutrine Plus Granular® (copper alkanolamine complexes, 3.7% active ingredient) per year, usually in the summer.

Lake 12 was 16 years old with a 0.4-ha surface area composed of 2 basins. Both basins were 2 m deep, with the lower basin receiving water from the upper over a small waterfall. The upper basin was without fish or vegetation, the lower had fish (koi, bass, carp) and submerged vegetation.

The second study site was Portola Country Club, where 7 lakes were rebuilt 4–5 years ago and the bottoms were lined with plastic. Six of them were fed by tertiary effluent water; the remaining lake (lake 18) was fed with a mixture of well and tertiary effluent water. The bottoms of these lakes were covered with a 30-cm-thick mixture of sand and detritus, or only sand in lake 18, with sides lined with concrete. Each lake was connected directly to the main water supply. Water from all lakes was used for irrigation.

Lakes 2, 10, and 18 were investigated for midge larval fauna starting in January 1992. Lakes 2 and 10 had *ca.* 0.2 ha surface areas and were 0.5–1 m deep. Lake 18 was *ca.* 0.4 ha and 1.5 m deep. For algal control, $CuSO_4$ and potassium permanganate were applied biweekly during the summer.

For larval assessment 5 benthic mud samples were taken biweekly from each lake at the above mentioned sites during 1992 and 1993. A long-handled scoop sampler (handle = 2 m) was used to collect 15 × 15-cm and 5-cm-deep bottom mud from each lake. Midge larvae were separated from the bottom materials by the procedures described by Mulla et al. (1971) and were counted and stored in 70% alcohol. In most cases larvae were identified to species by associating larval and pupal exuviae with adult males according to Cranston et al. (1983), Fittkau and Roback (1983), Pinder and Reiss (1983), and Sawedal (1981). The larvae and adults were mounted in Euparol® mounting medium for identification, following the procedure of Pinder (1983).

During 1992, water samples (500 ml) were taken biweekly from each lake, and brought into the laboratory for estimating the amounts of ammonium, nitrate, and phosphate using the methods for the Hach (dr-er 2 model) spectrophotometer. Dissolved oxygen, water temperature, salinity, conductivity, and pH were measured at each site using a portable Orion oxygen meter (model 820) and a Hanna Instruments conductivity meter (Model HI 8033).

Species richness in lakes supplied with well, tertiary effluent, and a mixture of well and tertiary effluent waters was calculated by using the index of species diversity (ST) (Southwood 1991). The Sorensen coefficient of similarity (C) among the studied habitats was calculated by estimating species in common between the different water types (Southwood 1991).

Categorization of midge larval mode of existence was defined by examination of benthic mud samples and submerged vegetation in the laboratory. These samples were placed in a white enamel pan and filled with water to slightly overflow. A magnifying glass was used to examine a mode of larval existence for benthic mud samples. For submerged vegetation, a subsample of the vegetation was scanned under a dissecting microscope and the findings were compared with those given in Table 22A of Merritt and Cummins (1978).

RESULTS AND DISCUSSION

Twenty-two chironomid species in 16 genera were recognized in the 3 water types investigated (Table 1). At Mission Hills in lakes supplied with well water, 18 species in 13 genera were recorded. Of these, 7 species in 4 genera were recorded only at this location. At Portola, in tertiary water breeding sites, 10 species in 7 genera were recorded. *Nimbocera limnetica* (Sublette) was recorded only from this breeding site. In the lake at Portola with a mixture of well and tertiary water, 9 species in 9 genera were recorded. *Apedilum elachistus* Townes, *Cladotanytarsus viridiventris* (Malloch), and *Cryptochironomus* sp. were recorded only from this site. *Chironomus stigmaterus* Say, *Goeldichironomus amazonicus* (Fittkau), and *Procladius sublettei* Roback were collected in all 3 types of water habitats (Table 1).

Water quality data for the 3 habitats, as expected, indicated higher amounts of ammonium, nitrate, and phosphate in the tertiary effluent water lakes during summer 1992 (Table 2). The values of the other measured factors (dissolved oxygen, salinity, conductivity, and pH) were rather constant. In 1993 water samples were not taken because the data on water quality parameters in the previous year could not be correlated with changes in midge larval numbers.

The highest value for species diversity was for well water, ST = 18.83 and 20.29, for 1992 and 1993, respectively, followed by tertiary effluent water, ST = 7.50 and 11.72, and for the mixture of the 2 water types, ST = 7.05 and 10.26. Comparing these indices, the highest species diversity in all 3 water types was recorded in 1993, when the total production of midges was lower. In 1992, from May to September, a massive occurrence of *G. amazonicus* was noticed in the lake containing a mixture of well and tertiary water. At that time, *G. amazonicus* was the only species present in that lake. High numbers of *Goeldichironomus* larvae might have outperformed larvae of other species and caused lower species diversity. In 1993, however, during the same period as in 1992, *Goeldichironomus* was present in low numbers along with *Procladius, Polypedilum,* and *Chironomus.*

Table 1. Chironomid species recorded in different water types in lakes at Mission Hills and Portola Country Clubs in the Coachella Valley (1992–93).[1]

Species	Water type		
	Well	Tertiary	Mixture
Chironomus stigmaterus	+	+	+
Tanypus neopunctipennis	+	+	−
Tanypus grodhausi	+	+	−
Tanypus imperialis	+	+	−
Caladomyia pistra	+	+	−
Nimbocera limnetica	+	−	−
Polypedilum parvum	+	+	−
Goeldichironomus amazonicus	+	+	+
Dicrotendipes californicus	−	+	+
Cladopelma forcipis	+	−	−
Crypthochironomus sp.	−	−	+
Cladotanytarsus viridiventris	−	−	+
Psectrocladius vernalis	+	−	+
Apedilum elachistus	−	−	+
Apedilum subcinctum	+	−	−
Procladius sublettei	+	+	+
Parachironomus hirtalatus	+	−	−
Parachironomus monochromus	+	−	−
Parachironomus directus	+	−	−
Cricotopus sylvestris	+	−	−
Cricotopus bicinctus	+	−	−
Ablabesmyia cinctipes	+	−	+

[1] + = present, − = absent.

The highest value of the Sorensen coefficient of similarity between compared habitats was for well and tertiary water lakes, C = 0.36 with 8 species in common. The values of this coefficient for well water and the mixture of well and tertiary water were similar, C = 0.26 (5 species in common) and C = 0.23 (4 species in common), respectively (Table 1). The majority of the species in common among the 3 habitats were burrowers and sprawlers, species with less specific modes of existence.

Study of the 3 types of water habitats indicated that composition of midge larval species depended primarily on the type of bottom substrate. Originally the lake bottoms were covered with sand. Over time the lakes receiving tertiary and well water developed a mixture of detritus and sand at the bottom. The richness of the bottom substrate in the tertiary effluent water was caused by a high content of organic matter and periodic blooms of the planktonic algae *Anabena, Chlorella,* and *Scenedesmus* and the filamentous algae *Spirogira* and *Cladophora.* During the summer of 1992, high quantities of ammonium, nitrate, and phosphate, reaching up to 9, 19, and 12 mg/liter, respectively, were recorded in the lakes supplied with tertiary effluent water (Table 2). The richness of the bottom substrate in the well water lakes was caused by disintegration of submerged vegetation, such as in lake 12 at Mission Hills, where mostly *Najas minor* combined with filamentous and the attached–erect algae *Chara,* built a thick layer of detritus mixed with sand over a period of years.

In contrast, the lake with a mixture of well and tertiary effluent water, devoid of submerged vegetation, had a sandy bottom. Contents of ammonium, nitrate, and phosphate reached values of 3, 6, and 4 mg/liter, respectively (Table 2).

Because of the similar bottom substrate, well water and tertiary water lakes had the highest Sorensen coefficient of similarity for chironomid midge larvae when bottom mud samples were taken.

Mode of larval existence: Larvae of *G. amazonicus* were found in lake 12 at Mission Hills (supplied with well water) on submerged vegetation. After we observed a number of *G. amazonicus* larvae moving slowly in their fine sand tubes from one part of the plant to another, we categorized *G. amazonicus* as a portable sand tube builder. Although these movements in the laboratory were probably due to disturbance, in natural habitats such movements are related to conditions such as crowding, reduced resources, or other unfavorable environmental conditions (Oliver 1971). Larvae of *G. amazonicus* were also found in their portable sand tubes on the

Table 2. Water quality parameters of 3 types of water habitats in recreational–residential lakes in the Coachella Valley, 1992.

Parameter (units)	Habitat	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
O_2 conc. (mg/liter)	Tertiary	9.7	9.7	9.8	8.2	8.5	10.2	8.4	9.6	8.0	7.2	9.4	9.0
	Well	10.7	10.6	9.7	10.1	10.4	12.5	8.6	8.8	8.7	9.5	9.2	9.4
	Mixture	9.7	10.0	8.7	8.1	10.5	9.7	9.8	9.0	8.3	8.9	9.2	9.4
pH	Tertiary	9.0	8.9	8.4	8.6	8.7	8.6	9.2	9.8	9.4	9.2	10.0	9.1
	Well	9.7	9.8	9.1	9.5	9.7	9.7	9.6	9.5	9.7	9.7	9.7	9.7
	Mixture	8.8	9.1	8.8	8.9	9.5	8.8	8.7	8.9	8.6	8.9	9.2	9.5
Conductivity (mhos)	Tertiary	700	686	592	546	542	598	597	536	626	833	726	738
	Well	625	838	640	666	675	663	626	696	648	740	786	700
	Mixture	792	777	802	766	753	829	806	799	885	908	881	981
Salinity (ppm)	Tertiary	0.27	0.29	0.34	0.29	0.26	0.30	0.29	0.27	0.31	0.42	0.35	0.33
	Well	0.42	0.41	0.31	0.32	1.33	0.34	0.31	0.34	0.31	0.36	0.35	0.39
	Mixture	0.39	0.33	0.30	0.39	0.39	0.36	0.37	0.37	0.46	0.43	0.41	0.39
Ammonium (mg/liter)	Tertiary	2.9	2.3	3.9	8.7	3.2	7.7	6.9	9.0	2.7	1.9	1.4	1.3
	Well	0.3	0.2	0.3	0.6	0.6	0.6	0.4	0.5	0.4	0.3	0.2	0.2
	Mixture	1.7	1.1	0.4	0.6	1.0	3.0	2.9	3.0	2.6	2.3	2.0	2.0
Nitrate (mg/liter)	Tertiary	8.4	6.2	8.8	10.7	7.6	9.4	10.3	19.1	6.7	3.6	2.0	2.3
	Well	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.2	0.0	0.0	0.0	0.0
	Mixture	0.9	1.2	1.1	1.0	1.3	3.4	5.2	6.0	4.2	3.2	3.0	2.9
Phosphate (mg/liter)	Tertiary	6.0	6.5	6.9	7.0	6.8	12.0	9.0	12.0	7.1	3.1	1.9	2.1
	Well	0.3	0.2	0.2	0.3	0.2	0.6	0.3	0.3	0.3	0.2	0.2	0.3
	Mixture	2.0	2.4	3.3	3.0	3.5	3.9	3.0	4.0	4.1	2.0	1.1	1.4

Table 3. Mode of existence of chironomid midge larvae recovered from the lakes at Mission Hills and Portola Country Clubs in the Coachella Valley (1992–93).

Species	Mode of existence						
	Burrowers	Tube builders	Climbers	Clingers	Sprawlers	Tube builders on plants	Portable sand tube builders
Chironomus stigmaterus	+	+					
Tanypus neopunctipennis					+		
Tanypus grodhausi					+		
Tanypus imperialis					+		
Caladomyia pistra			+	+			
Nimbocera limnetica			+	+			
Polypedilum parvum			+	+			
Goeldichironomus amazonicus	+						+
Dictrotendipes californicus	+						
Cladopelma forcipis					+		
Crypthochironomus sp.	+				+		
Cladotanytarsus viridiventrus	+						
Psectrocladius vernalis					+		
Apedilum elachistus				+			
Apedilum subcinctum				+		+	
Procladius sublettei					+		
Parachironomus hirtalatus					+		
Parachironomus monochromus					+		
Parachironomus directus					+		
Cricotopus sylvestris			+	+			
Cricotopus bicinctus		+	+				
Ablabesmyia cinctipes					+		

bottom surface in lakes supplied with tertiary water at Portola (Table 3).

At lake 12 at Mission Hills, supplied with well water and with substantial stand of submerged vegetation, climbers (*Nimbocera, Polypedilum*), clingers (*Caladomyia, Nimbocera, Cricotopus*), portable sand tube builders (*Goeldichironomus*), and tube builders on plants or other objects (*Apedilum*) were noticed in large numbers, in contrast to the genera known to be burrowers and bottom sand tube builders. As vegetation was controlled in lake 12 with 2 applications of Cutrin Plus Granular® (applied at the rate of 10 lb/acre with a hand-cranked fertilizer spreader) during July 1993, chironomid species associated with submerged vegetation decreased in numbers, whereas species of burrowers and bottom sand tube builders (*Chironomus*) increased.

In lakes with tertiary effluent water with mostly detritus bottoms, burrowers and tube builders, such as *Chironomus*, were predominant. Others, known as sprawlers (*Ablabesmyia, Tanypus, Procladius, Psectrocladius*) and climbers or clingers (*Nimbocera, Polypedilum*) were present in small proportions.

The habitat with a mixture of well and tertiary effluent water, having a sandy bottom, was dominated by sprawlers (*Ablabesmyia, Tanypus, Procladius, Cryptochironomus, Psectrocladius*). Bottom burrowers, such as *Dictrotendipes* and *Cladotanytarsus,* were recorded in small numbers.

Previous data on the spatial distribution of chironomid midge larvae on 5 substrate types in a concrete-lined channel in southern California (Ali and Mulla 1976) showed a positive correlation between *Chironomus* spp. and sandy or algal bottoms and between *Cricotopus* spp. and detritus. However, in the Santa Ana River Basin, southern California, *Cricotopus* spp. and *Tanytarsus* spp. are predominant in sandy substrates, and *Chironomus* spp. are associated with a muddy bottom (Ali and Mulla 1978). In Westlake, CA, where the bottom substrate is mud with a small portion of sand and gravel, *Chironomus* larvae are predominant in the muddy portion of the lake (Kramer et al. 1977).

Our sampling data and larval numbers showed that *C. stigmaterus* larvae were mostly associated with a detritus type of bottom in lakes supplied

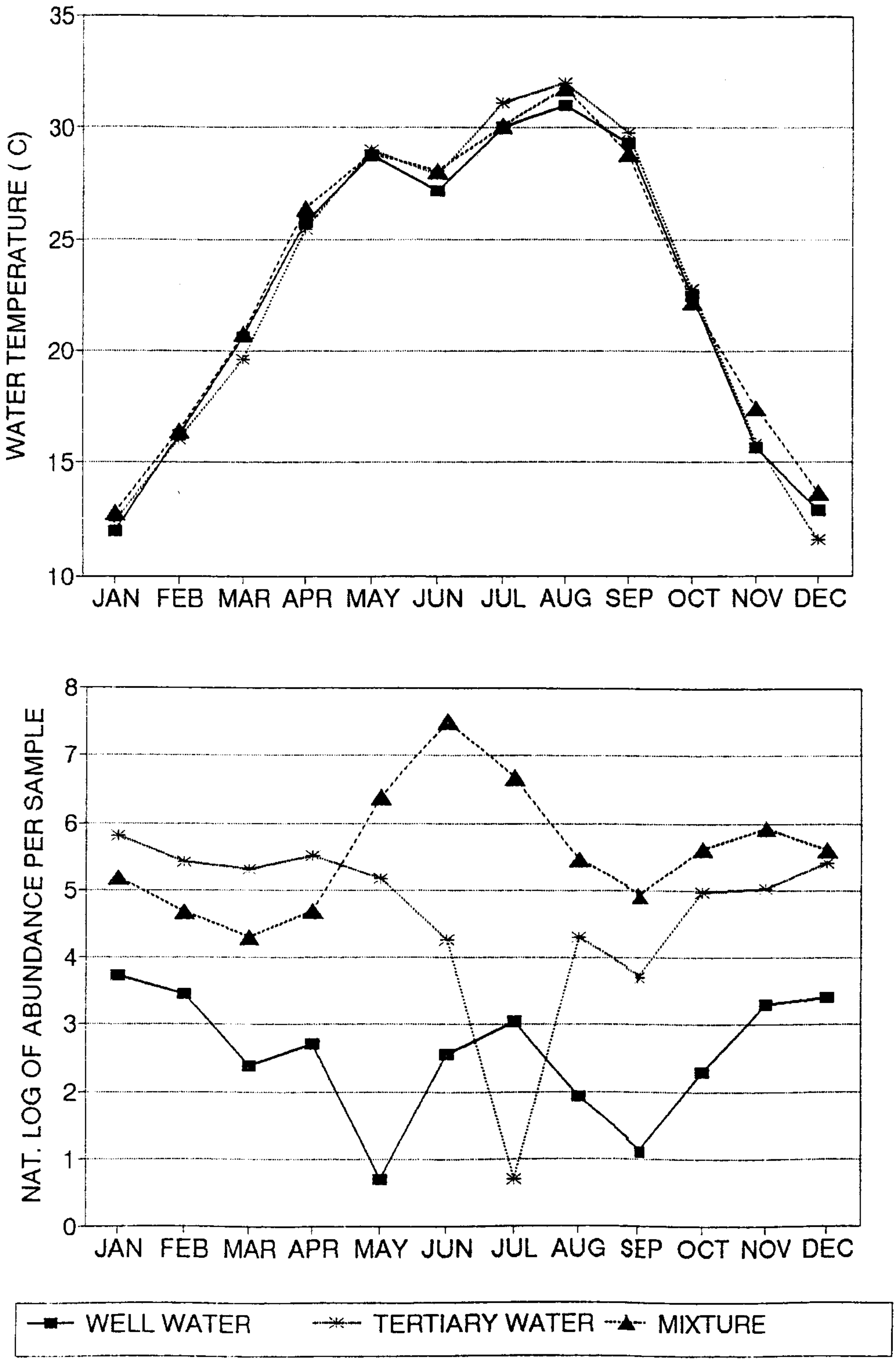

Fig. 1. Seasonal abundance of chironomid midge larvae in 1992, as related to water temperature and type of water.

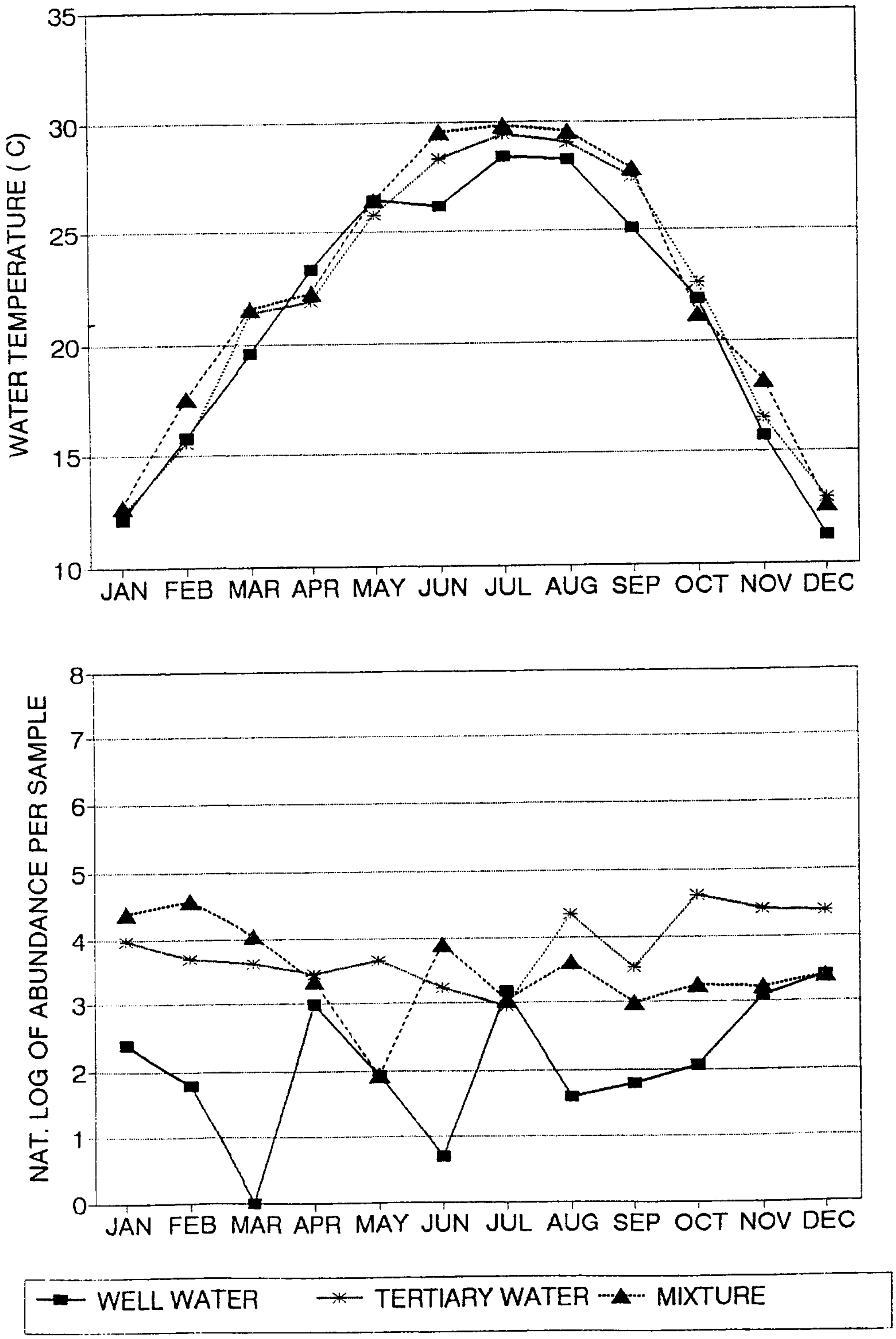

Fig. 2. Seasonal abundance of chironomid midge larvae in 1993, as related to water temperature and type of water.

with well or tertiary effluent water. In the lake supplied with a mixture of well and tertiary water and with a sandy bottom, *Chironomus* larvae were rarely recorded.

According to these results it seems that presence and composition of chironomid larval species depend to a great extent on the type of the bottom or other substrate and may vary from one situation to another. It is widely recognized (Wirth and Stone 1956, Curry 1965, Pinder and Reiss 1983) that most species of *Chironomus* prefer soft mucky bottoms, but reasons for the distribution of larvae of other species must be found in a combination of factors, rather than in a single factor. It is most likely that in some habitats the distribution of larvae may be primarily limited by temperature and food, whereas in another type of habitat, substrate, submerged vegetation, or current (in the streams) can be influencing factors.

Larval seasonality: Overall higher numbers of midge larvae were recorded in tertiary effluent and a mixture of well and tertiary water, in contrast to well water alone (Fig. 1). During our research, highest midge densities in these lakes averaged 300 larvae per sample, which equates to 25 million midge larvae per hectare. In 1992 extremes of more than 2,000 larvae of *G. amazonicus* per sample, equating to 150 million larvae per hectare, were recorded in the lake supplied with a mixture of well and tertiary effluent water during May, June, and July (Lothrop et al. 1993).

Total larval population regardless of the type of water was higher in 1992 than in 1993. This increase was primarily caused by a massive population of *G. amazonicus* in the lake containing a mixture of well and tertiary water (Figs. 1 and 2).

Data from both years indicated high larval populations during December and January at all 3 habitats. Water temperature during these months in 1992 and 1993 was below 15°C (Figs. 1 and 2). According to Oliver (1971) the effect of lower temperature and short day conditions drove certain species of midge larvae to an inactive state with no or very low emergence. Due to lack of emergence, the larval population reached higher density levels than in the summer months. We assumed that these factors were the main reasons for abundant overwintering populations, which accumulated until more suitable conditions accelerated their development and emergence. In overwintering populations, in the lakes with tertiary effluent water, *Chironomus* was predominant over *Tanypus, Cryptochironomus*, and *Goeldichironomus*. In the lakes with well water, *Tanypus* and *Cryptochironomus* occurred in higher numbers than *Chironomus* and *Procladius*. In the mixture of well and tertiary effluent water *Cryptochironomus* and *Goeldichironomus* were recorded.

Seasonal patterns of larval abundance in the lakes at Mission Hills and Portola Country Clubs were different in 1992 and 1993. In 1992 chironomid larval abundance in well and mixture waters was greater in May, June, and July, but decreased in tertiary water during July. In 1993, in well water, 2 peaks were registered, in April and July. In tertiary water, August and October had high numbers, whereas larval counts from the mixture of well and tertiary water indicated high numbers in June and August (Figs. 1 and 2). Such a diversity in larval seasonality from year to year indicated the influence of many still unknown factors, requiring further research.

Our studies indicated that the well water lakes had a higher species diversity of chironomid midge larvae and lowest abundance, whereas tertiary water habitats had more widely found species, mostly bottom dwellers and sprawlers, but higher chironomid larval abundance. The site with a mixture of well and tertiary water was characterized with the highest abundance and widely found chironomid midge larval species.

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