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Seasonal dynamic and larval distribution of *Chironomus* gr. *plumosus* and *C.* gr. *thummi* (Diptera: Chironomidae) in the Naviglio Canal of Modena. (*) ([1])

INTRODUCTION

In recent decades the growing impact of human settlements and activities on aquatic ecosystems has been creating increasing problems for the conservation of natural habitats and the management of man-made water bodies. The most common consequence observed in aquatic habitats affected by artificial effluents is an increase in the trophic level, with frequent, considerable changes in the fauna components.

Chironomid midges, largely found in natural and artificial water ecosystems, may take advantage of the nutrient resources available in eutrophic waters and play an important role in the circulation of organic matter, in the preservation of sediment quality, and in the depuration processes, contributing to the natural reduction of eutrophication (Armitage *et al.*, 1995).

In some situations, such as in highly polluted water bodies, they become infesting populations. Massive adult midges swarming in urban areas can cause serious nuisance, economic and even sanitary problems to the inhabitants (Grodhaus, 1963; Mulla, 1974; Ali, 1980; Ferrarese and Majori, 1985; Giacomin and Tassi, 1988; Ali, 1991).

It is well known that canals collecting domestic and industrial waste water can provide suitable conditions for the mass larval breeding of several chironomid species (Legner *et al.*, 1975; Pools *et al.*, 1975; Ali and Mulla, 1976b; Wilson and McGill, 1977; Cilek and Knapp, 1992).

The water treatment plant of the city of Modena, in Northern Italy, has a potential capacity of 1,500 l/sec equivalent to a population of 300.000 inhabitants. After its startup in 1984 the plant was modified several times to improve its depuration potential. In 1988 citizens living in Bertola, a town situated North of Modena near

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the depuration plant, started to complain about the nuisance caused by chironomid midges. In 1992 the Public Utility for the Management of Urban Waste (A.M.I.U.), responsible for the water depuration plant, appointed the Centro Agricoltura Ambiente to study the problem and recommend environmentally safe solutions.

Materials and Methods

The Modena municipal water treatment plant discharges depurated waters in the Naviglio Canal, a man-made canal which is 12 km long and carries water to the Panaro river. The width of the canal-bed ranges from 11 to 14 m, while depth varies from 70 to 130 cm in midstream and decreases progressively towards the banks. The speed of the water flow usually oscillates around 0.5 m/sec in midstream, while the water is almost stagnant up to a distance of 1-2 m from the banks.

85 m upstream the plant station outfall, a sluice gate separates depurated water from the polluted water from the city sewage system. Between the outfall and the sluice gate the water is usually stagnant, except when, to remove surface mud, the stream is inverted for a short time, recalling purified water by opening the sluice gate.

Moreover, the plant cannot handle the volume of water that collects in the sewage system after a heavy rainfall, which flows over the sluice gate. During such an exceptional downpour, the speed of the water flow increase to such an extent that it may come the erosion of the bottom of the canal.

The bottom of the Naviglio canal is predominantly clay, with consistent mud deposits of particulate organic matter up to 50 cm thick. The banks are steep and covered in vegetation used by adult chironomids as a resting site. Submerged water plants, prevalently *Potamogeton filiformis* Pers. and *P. pectinatus* L. grow in the canal.

The study was carried out from May 1993 to October 1994 along a stretch of approximately 1 km between the sluice gate and the residential area of Bertola, where the nuisance was greatest.

Larval sampling was conducted using a standard Ekman-Birge dredge capable of taking constant portions of bottom mud (225 square centimeters) (Ali and Mulla, 1976a). Five transversal transepts were selected: transepts 1 and 2 situated in the 85 m stagnant section, about 10 m apart; transepts 3 and 4 situated respectively 150 m and 250 m downstream from the plant outfall; transept 5 situated approximately 1 km from the outfall (Fig. I). At two week intervals, five samples were taken along each transept, at costant distances from one another considering the variations in the width of the canal. Each sample was placed in a plastic container and taken to the laboratory. Separation of the chironomid larvae from the sediments was achieved with the floatation method described in Nocentini (1985): the mud was poured into a PVC tank adding approximately 10 l of a 10% hydro-saline solution. By mixing the solution manually, the larvae were induced to leave their protective tubes and float to the surface where they were collected through a metal filter of about 400µm mesh size. This way the younger larvae were not collected, to reduce time consuming during counting. In the period between

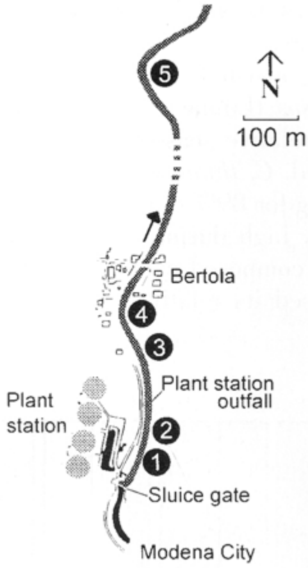


Fig. I - Diagram of the Naviglio Canal where the study was conducted. Numbers locate the position of the transepts.

July 1993 and October 1994 a pool of 150-200 individuals for each sample data was preserved in alcohol 70° for species determination.

Adults were collected weekly during the summer months, and every two weeks during the rest of the year, in the bank vegetation by means of 3 sweeping nets between transepts 3 and 4.

Depurated water was sampled continuously once an hour and analyses were performed daily on the sample resulting from the 24 mixed sub-samples.

Results

For the duration of the study the water of the Naviglio Canal was usually very eutrophic as shown by the chemical and physical parameter values reported as a variation range in Tab. 1. Water temperature ranged from 20 to 26 °C during

Tab. 1 - Naviglio Canal: main chemical and physical parameters of water discharged by the depuration plant (PMP-AUSL Modena and IDARU laboratories; analysis methods: IRSA-CNR and Standard Methods for analysing water and waste water).

pH		7.1 - 8.1
COD	[mg/l]	13.0 - 92.0
BOD_5	[mg/l]	5.0 - 17.0
Phosphates	[mg/l of P]	0.2 - 8.0
Ammonia	[mg/l]	0 - 34.5
Nitrites	[mg/l of N]	0 - 0.6
Nitrates	[mg/l of N]	0 - 22.9
Total Suspended Matter	[mg/l]	0 - 93.0
Chlorides	[mg/l]	109.0 - 210.0
Sulphates	[mg/l]	126.2 - 441.0
Fluorine	[mg/l]	0.2 - 13.0

the summer months, from 14 to 18 °C in the spring and autumn, reaching a minimum of 12 °C in January.

The larval population consisted almost exclusively of two Chironominae species: *Chironomus plumosus* (Linnaeus) and *C. thummi* Kieffer (= *C. riparius* Meigen). Fig. II shows the relative seasonal larval abundance of the two species in the canal segment studied. *C. thummi* was the most numerous species during the entire season, accounting for 89% of the larval population. Its relative density was found to be particularly high during the autumn, winter and spring months, when several samples were composed exclusively of this species. In the summer months *C. plumosus* increased its relative density up to a maximum of 39% in August.

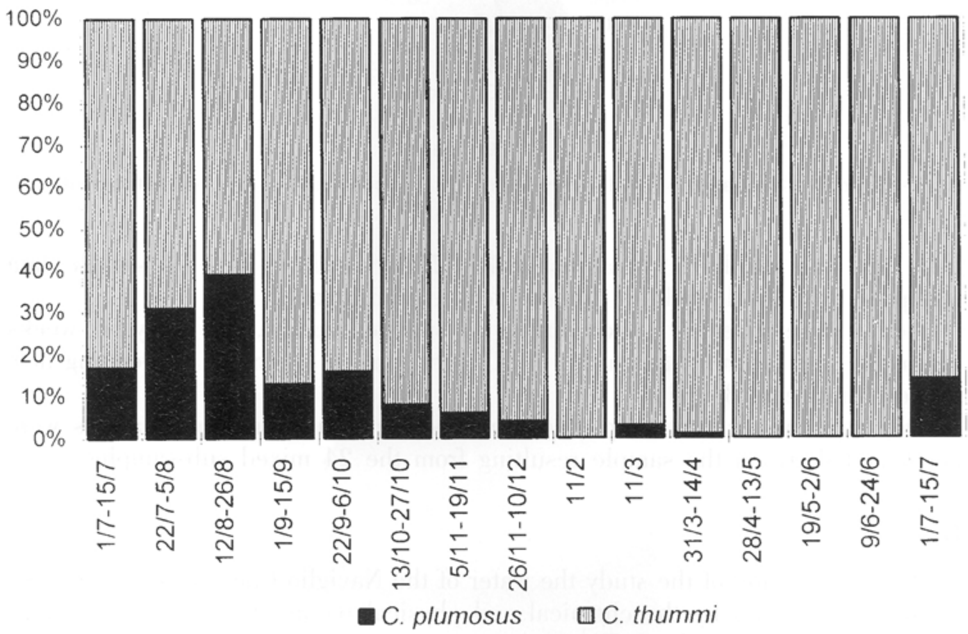


Fig. II - Relative abundance of *C.plumosus* and *C.thummi* larvae during the period July 1993-October 1994 in the Naviglio Canal segment under study.

The seasonal dynamic of the larval population density are shown in Fig. III as an average, considering all samples collected in every transept at the time intervals reported. The total mean density was higher in the autumn 1993, reaching a peak of 50,222 larvae/ m^2 in late November-early December. During the winter, population density decreased and reached a minimum of 1374 larvae/ m^2 at the beginning of March. After a peak in April, density dropped in May and June to an absolute minimum value of 1,080 larvae/m^2. This was due to the natural high larval mortality noticed in the samples and was to some extent confirmed by the numerous drifting dead larvae. Unfortunately, it was not possible to establish the cause of such mortality.

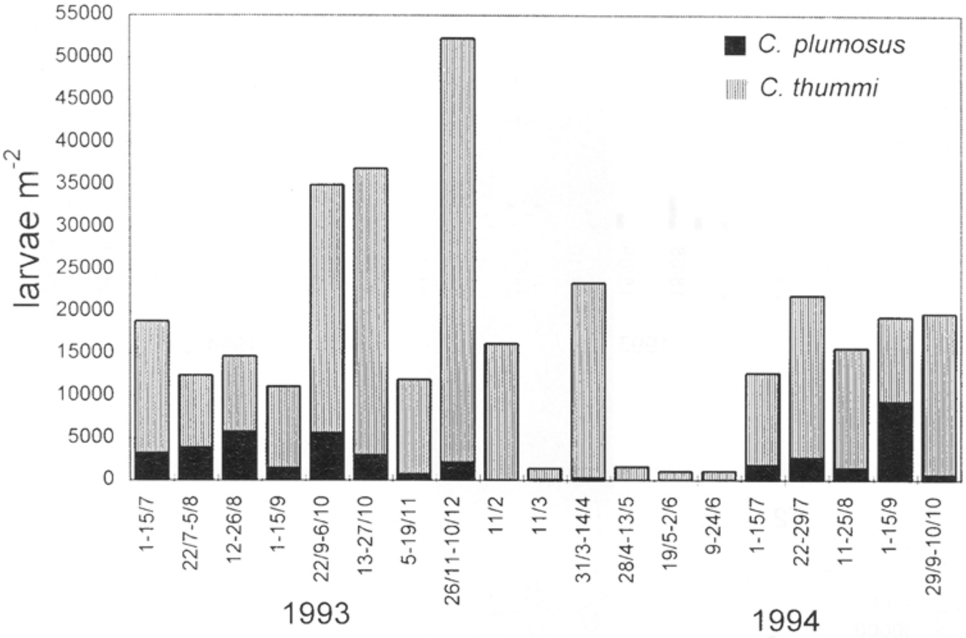


Fig. III - Seasonal dynamic of Chironomid larval density in the Naviglio Canal segment under study.

In July 1994 the population returned to the same density levels recorded in 1993.

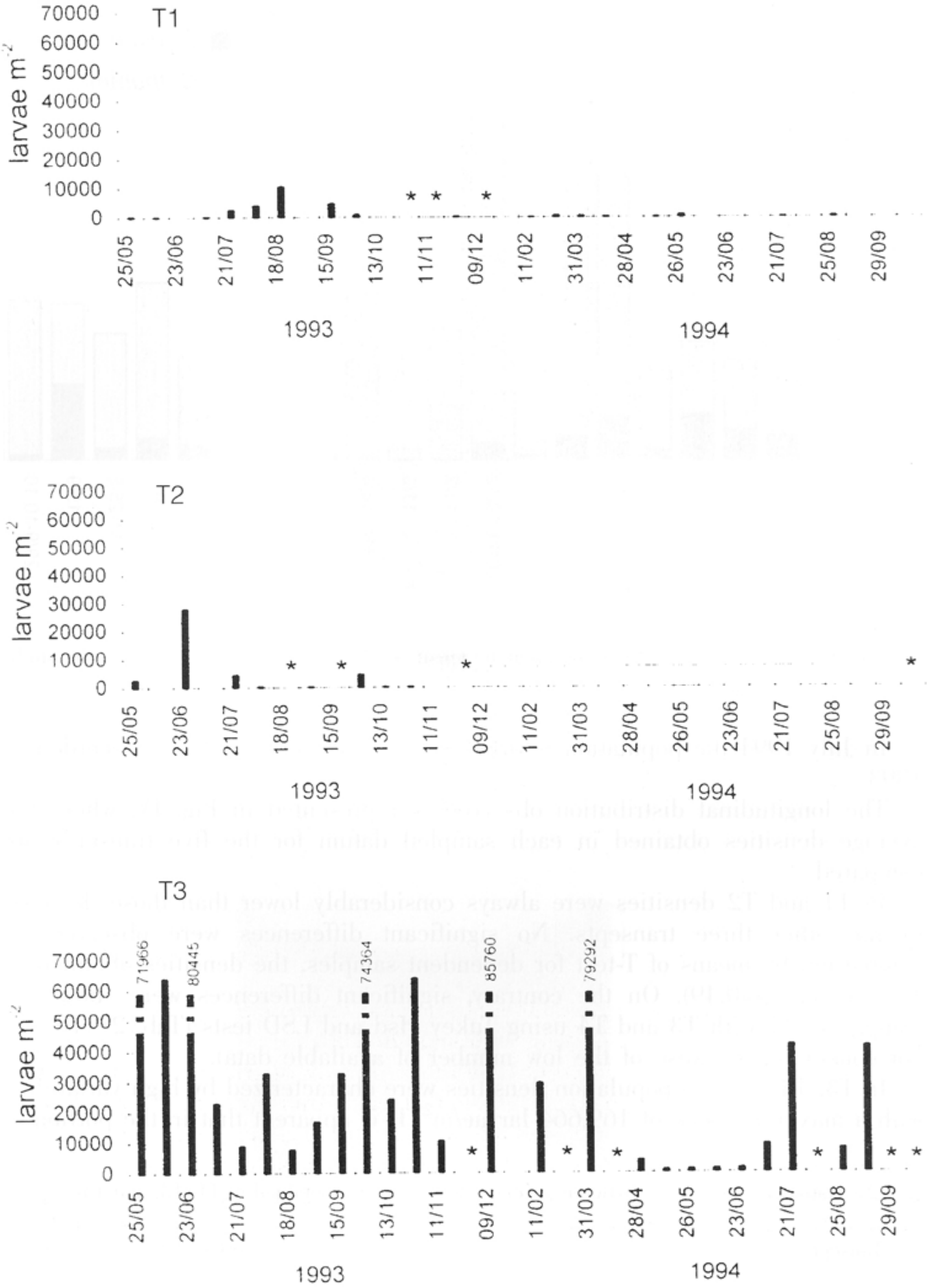
The longitudinal distribution observed is represented in Fig. IV, where the average densities obtained in each sampled datum for the five transepts are compared.

In T1 and T2 densities were always considerably lower than those detected in the other three transepts. No significant differences were observed by comparing, by means of T-test for dependent samples, the densities obtained in T1 and T2 ($p=0.49$). On the contrary, significant differences were shown by comparing T1 with T3 and T4 using Tukey Hsd and LSD tests (Tab. 2) (T5 was not considered because of the low number of available data).

In T3, T4, and T5 population densities were characterized by high variability, with a maximum peak of 169,664 larvae/m^2. It is apparent that in the portion of

Tab. 2 - Statistical comparison between average larval densities obtained in T1, T3, and T4.

Transept	n° data	average (larvae/m^2)	S.D.	Tukey HSD	LSD
1	17	1,476	2,748	a	a
3	17	21,170	23,324	ab	b
4	17	32,513	42,509	b	c


T1
larvae m-2
70000
60000
50000
40000
30000
20000
10000
0
25/05
23/06
21/07
18/08
15/09
13/10
11/11
09/12
11/02
31/03
28/04
26/05
23/06
21/07
25/08
29/09
1993
1994
T2
larvae m-2
T3
larvae m-2
71966
80445
74364
85760
79292

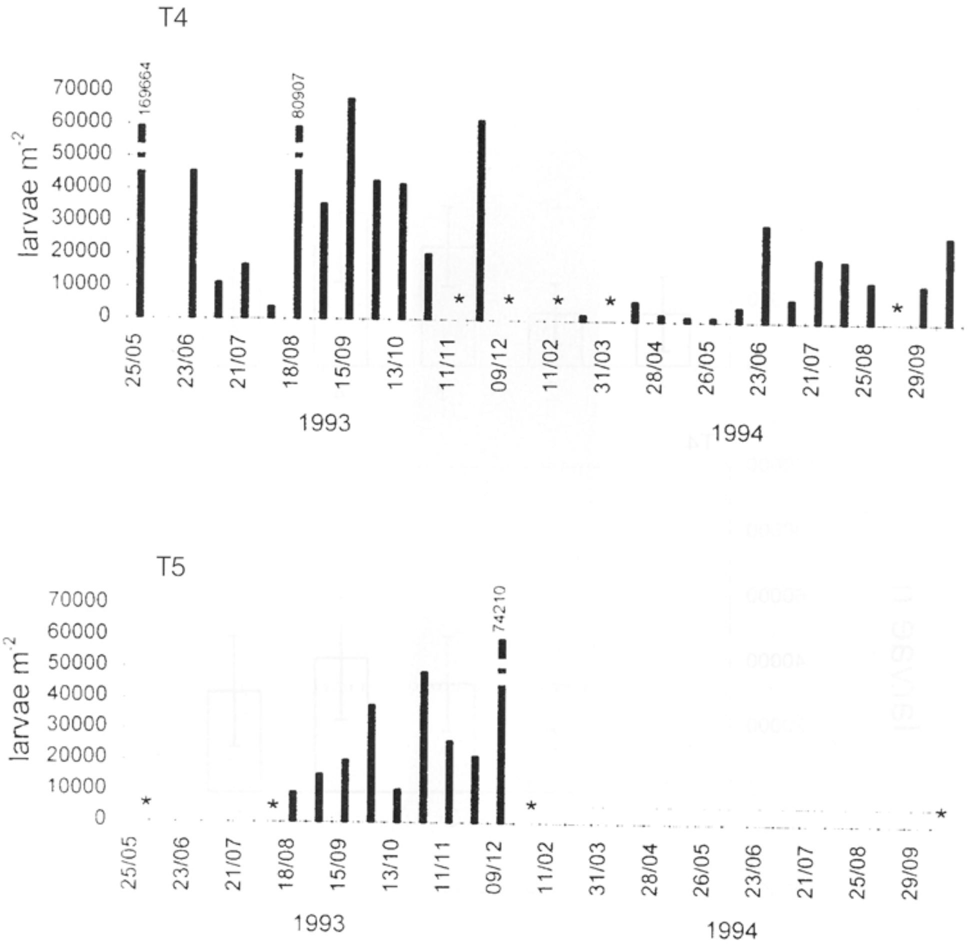


Fig. IV - Larval densities observed in the five transepts sampled (* samples not collected).

the canal downstream the outfall, the Chironomid larvae found optimal breeding conditions, consequently achieving enormous densities.

T3, T4 and T5 showed different transversal density distribution (Fig. V). The seasonal average larval densities obtained at each transept sample point were compared inside each single transept and as a cumulative mean, using the Duncan test separation means, but no significant differences were noticed. Larval distribution across the canal confirms evidence that the entire canal bed is colonized, with no apparent relation to water depth, current speed and position on the transept.

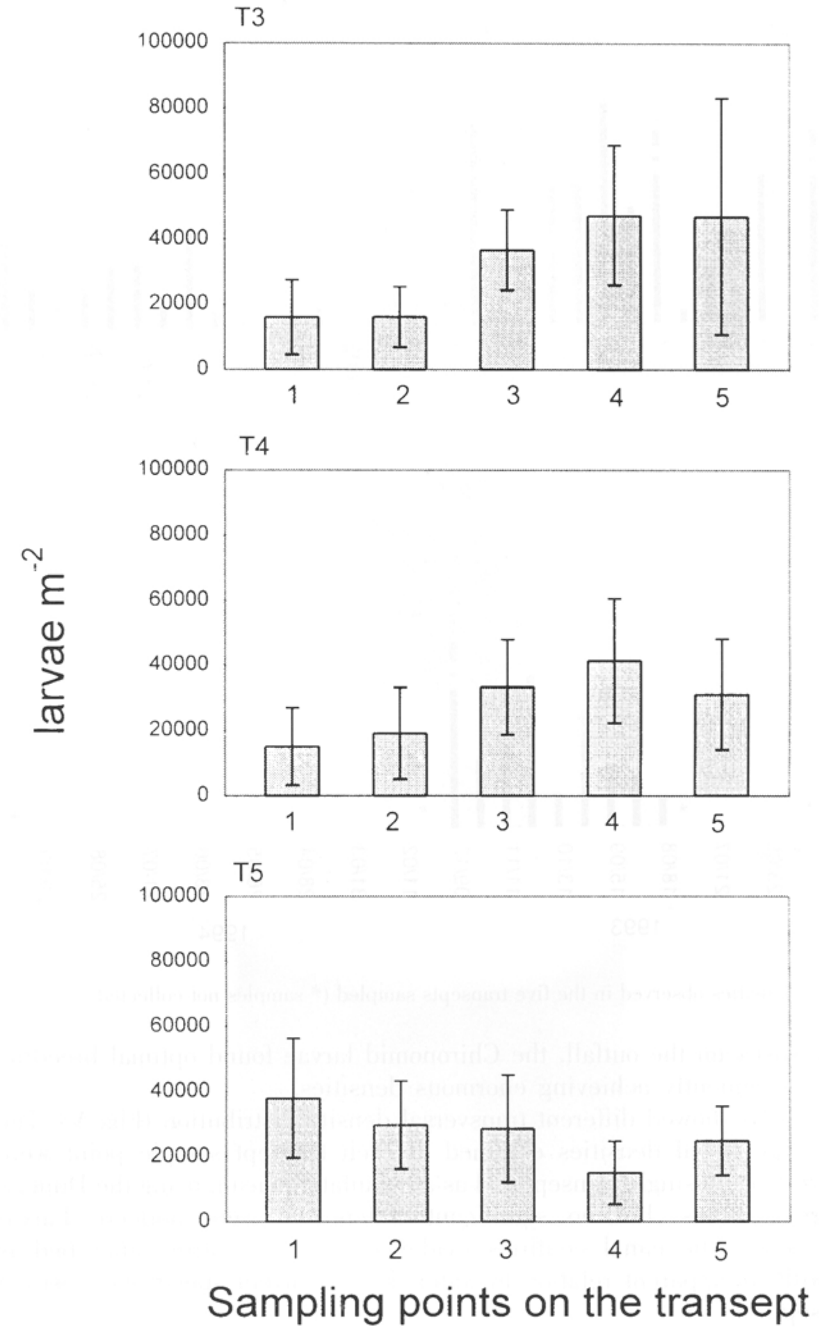


Fig. V - Average larval distribution obtained during the study period across the canal bed in the three most densely colonized transepts.
1 : 1-1.5 m from the left bank; 2 : 2.5-3.5 m from the left bank; 3 : middle of the canal; 4 : 2.5-3.5 m from the right bank; 5 : 1-1.5 m from the right bank

Adult population dynamic is shown by using the mean monthly densities, calculated excluding weekly values biased by the effect of adulticide measures (Fig. VI). In June 1993 a peak was registered, followed by a decrease in July and a stable presence during the summer and autumn months. Only in December did the population decline. In 1994 densities were very low until June, with similar dynamic to those observed in the larval population. In July the population increased slightly while a very important peak was detected in September (without any comparable trend in larval density), then it declined progressively, reaching a minimum in December.

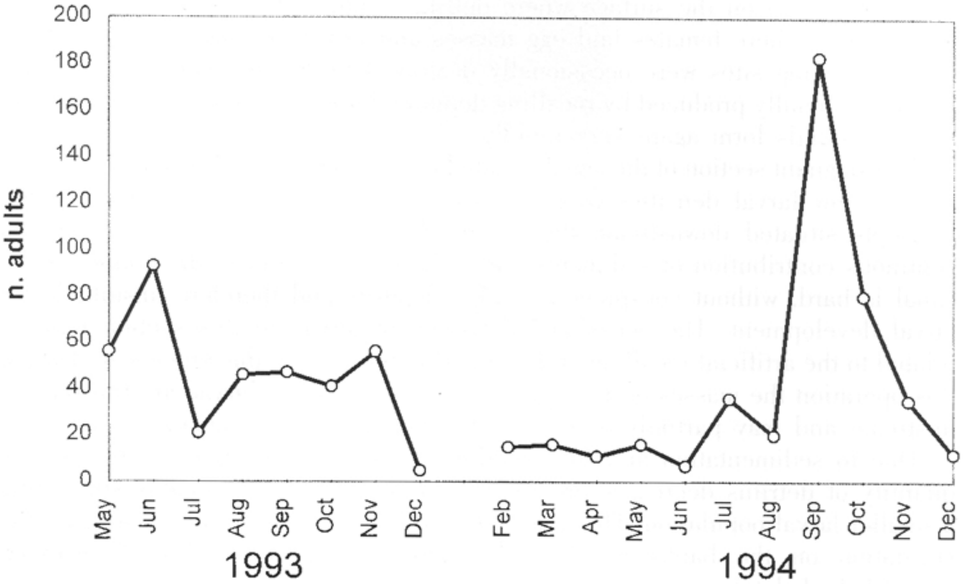


Fig. VI - Adult population dynamic obtained by weekly sampling the vegetation on the banks of the Naviglio Canal with the sweeping net.

While collecting adults resting in the vegetation, we were able to catch a few specimens of species such as: *Smittia* spp., *Cricotopus trifascia* Edwards, *C. bicinctus* (Meigen), *Dicrotendipes nervosus* (Staeger). Due to the low number, tiny body and poor flying ability, these species may be considered as non noxious in the Naviglio area.

Discussion

The two major Chironomid species found in the Naviglio Canal are well known indicators of water bodies with heavy concentrations of organic matter (Lindegaard, 1995).

The distribution of larvae in the portion of the canal studied clearly shows that larval density is related to the continuous contribution of organic detritus and other food materials transported in the water discharged by the plant station. Analogous distribution patterns, though with lower densities, were observed in a canal receiving treated municipal sewage by Polls *et al.* (1975); in concrete-lined canals draining waste water in Southern California by Ali *et al.*, (1976); in flood control urban canals by Ali and Mulla (1976b) and in polluted creeks by Cilek and Knapp (1992).

In this work it was not possible to establish accurately to what depth the larvae penetrate the sediments, but considering that densities as high as 16 larvae cm^{-2} were detected, larvae must colonize the mud to a depth of some cms.

Larval colonization was not restricted to the bottom of the canal, as larvae were widely scattered on the surface where detritus retained by *Potamogeton* formed mud islands where females laid egg masses and larval development took place. These breeding sites were occasionally destroyed by the inversion of the water stream artificially produced by recalling depurated water into the depuration plant, but the islands form again very rapidly.

The stagnant section of the canal situated upstream the outfall was characterised by very low larval densities in comparison with the densities observed in the transepts situated downstream the outfall. In the upstream section, where no continous contribution of sediments and nutrients takes place, the bottom of the canal is hard, without conspicuous sludge deposits and therefore unsuitable for larval development. The occasional detection of larvae in this section may be related to the artificial recalling of depurated water through the sluice gate. During this operation the masses of mud colonised by Chironomid larvae are transported upstream and may partially deposit on the bottom of the stagnant section.

Due to sedimentation and filter-holding action of submerged vegetation, the quantity of detritus decreases progressively downstream, presumably supporting a smaller larval population. This was confirmed by observing adults resting on the vegetation on the banks which were almost absent a few km downstream (unpublished data).

The seasonal evolution observed in the density of the larval population may be influenced by water temperature and photoperiod combinations (Danks, 1978). During the summer months, as a result of the increase in water temperature, the larval development period is shorter than in other months, leading to the underestimation of densities observed. Conversely, in the colder months, the larval cycle is much longer, causing an overestimation of larval density. Furthermore, in winter, larval dormancy induced by a temperature-photoperiod combination may strongly inhibit pupation and emergence (Fischer, 1974). The usual spring infestation which the inhabitants of Bertola complained of could be caused by the simultaneous emergence of overwintering and spring developing larvae. As pointed out by Mundie (1957) overwintering larvae need cumulative degree days exceeding the species specific requirement thus causing emergence peaks.

Another factor that may influence larval density is food availability during the season. Due to the collector-gatherers feeding mechanism of *C. thummi* and *C. plumosus* larvae, which is mainly non selective, possible seasonal variations of the nutrient resources may be responsible for changes in the larval diet, in the rate of growth and therefore in population dynamics (Provost and Branch, 1959; Hilsenhoff, 1967; Ward and Cummins, 1979; Ali,1990). This possibility has not been investigated in relation to the conditions under study but seasonal changes in the microfauna occurred in depuration plant (Madoni *et al.*, 1993; Azzoni, 1995).

The catastrophic decline registered in larval density during May-June 1994 led to the hypothesis that an epidemic outbreak may have occurred. Such an important natural event must be carefully assessed in consideration of the interest the isolation of a potential biological control agent may have.

Moreover some larvae were found infested by a single Mermithid larva that was found to be *Hydromermis contorta* (Kohn). However, for the duration of the entire study the parasitization observed was sporadic.

Due to the slow current speed and to the shape of the canal section the entire submerged bed is colonized by Chironomids, thus creating an important substratum for Chironomid larval development.

The ecological conditions created in the Naviglio Canal by the outfall of the sewage treatment plant are ideal for Chironomid larval development. Studies to improve the depuration plant performance and to reduce the effluent sediments must be undertaken to prevent massive Chironomid production.

At present larval and adult control methods should be used to reduce the noxious problems lamented by the inhabitants.

The feasibility of alternative methods such as the rearing and collecting the larvae for economic purposes must also be considered (Bouguenec and Giani, 1992).

ABSTRACT

The Naviglio canal, which collects water depurated by the municipal treatment plant, supports the breeding of *Chironomus* gr. *plumosus* and *C.* gr. *thummi* which often become a serious noxious problem for the nearby inhabitants. Chironomid larvae were found to be present throughout the year with a peak of more than 50,000 larvae/ m^2 in the autumn.

Transversal sampling showed that the whole canal bed is colonised by Chironomid larvae, with no apparent relation with water depth and current speed.

Longitudinal sampling clearly demonstrated that larval density was very low upstream the plant outfall, while it reached maximum values downstream, thus confirming the role of organic detritus deposited on the canal bottom, as larval food and substratum.

The adult population sampled on the vegetation of the banks showed great and rapid variability with higher densities concentrating in the spring and autumn months.

Dinamica stagionale e distribuzione larvale di *Chironomus* gr. *plumosus* e *C.* gr. *thummi* (Diptera: Chironomidae) nel canale Naviglio di Modena.

RIASSUNTO

Il canale Naviglio, che raccoglie le acque reflue del depuratore della città di Modena, risulta fortemente colonizzato da *Chironomus* gr. *plumosus* e *C.* gr. *thummi* che raggiungono spesso densità tali da rappresentare un serio problema di nocività per gli abitanti della zona.

La popolazione larvale è risultata presente durante l'intero arco stagionale e ha raggiunto la densità media massima di oltre 50.000 larve/ m^2 durante l'autunno.

Campionamenti lungo sezioni trasversali del canale hanno mostrato che la colonizzazione riguarda l'intero letto senza relazioni evidenti con la profondità dell'acqua e la velocità di corrente.

Campionamenti longitudinali hanno confermato il ruolo dei detriti organici scaricati con l'acqua depurata quale fonte alimentare e substrato di sviluppo larvale. Infatti nella parte a monte dello scarico le densità larvali sono sempre risultate basse, mentre nel tratto a valle hanno raggiunto valori molto elevati.

La densità di popolazione degli adulti, stimata mediante campionamenti con retino entomologico sulla vegetazione riparia, è risultata molto variabile con concentrazione dei valori elevati in primavera ed autunno.

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