90-95

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NWRI CONTRIBUTION 90-95

RRB 90-61

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by

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NOVEMBER 1990
NWRI Contribution #90-95

EXECUTIVE SUMMARY

The management of agricultural land can greatly influence the composition and concentration of contaminants in agricultural runoff. In recent years, considerable interest has been expressed in conservation tillage practices which leave more crop residue on the soil surface and do not disturb the top soil matrix to the same extent as conventional tillage. The advantages of conservation tillage include control of soil erosion by reductions in surface runoff, decreased nutrient inputs to watersheds, increased efficiency of water use by crops and decreased labour and energy costs. The impact of conservation tillage on pesticide residues in watershed runoff is not as clearly defined and both enhancements and reductions of pesticides in such runoff from land with conservation tillage practices have been reported. In 1984, a demonstration study in an agricultural area near London, Ontario was established by the provincial government to compare the effects of conservation vs. conventional tillage on nutrient and sediment loadings in two branches of an agricultural stream, Kintore Creek. In 1988, the project was expanded by Environment Canada to determine residues of two pesticides (atrazine and metolachlor) in ambient and storm runoff events in the two watersheds and the effects on biota. This paper examines the effects of different land management practices on the secondary production of the benthic invertebrate communities (Trichoptera; Hydropsychidae: *Hydropsyche spp.*) occupying the two watersheds. Production estimates and densities of caddisflies were consistently higher in the watershed where conservation tillage was practiced (e.g., mean annual production of *H. slossonae* was 12.02 g ash-free dry weight (AFDW)/m^2 in the west branch vs. 2.45 g AFDW/m^2 in the east branch. Differing concentrations of herbicides, insecticides and nutrients in the two watersheds are discussed as possible explanations for this difference in productivity.

RÉSUMÉ POUR LA DIRECTION

La gestion des terres agricoles peut grandement influer sur la composition et la concentration des contaminants dans les eaux de ruissellement de ces terres. Ces dernières années, on s'est beaucoup intéressé aux pratiques de culture conservatrices du sol, qui laissent davantage de résidus de cultures à la surface du sol et qui ne perturbent pas autant la couche superficielle du sol, comparativement aux techniques classiques de culture. Parmi les avantages de ladite culture conservatrice ont peut citer les suivants : diminution de l'érosion du sol grâce à la réduction du ruissellement en surface; apport moindre d'éléments nutritifs aux bassins hydrographiques; rendement amélioré de l'utilisation d'eau par les cultures; coûts moindres en main-d'oeuvre et en énergie. L'effet de la culture conservatrice sur les résidus de pesticides dans l'eau de ruissellement du bassin hydrographique n'a pas été établi aussi clairement; les rapports font état aussi bien d'augmentations que de diminutions de pesticides dans l'eau de ruissellement de terres cultivées de façon conservatrice. En 1984, une étude-démonstration dans une zone agricole près de London (Ontario) a été entreprise par le gouvernement provincial pour comparer les effets des cultures conservatrice et classique sur les charges d'éléments nutritifs et de sédiments dans les deux bras d'un cours d'eau de zone agricole, le ruisseau Kintore. En 1988, le projet a été complété par Environnement Canada en vue de déterminer les quantités résiduelles de deux pesticides (atrazine et métachlore) dans l'eau de ruissellement des deux bassins après des orages ou dans des situations normales, et d'évaluer les effets sur les biocénoses. La présente communication

examine les effets de différentes pratiques de gestion des terres sur la production secondaire de communautés d'invertébrés benthiques (trichoptères; hydropsychidés : Hydropsyche spp.), qui occupent les deux bassins. La production et la densité de phryganes étaient systématiquement plus élevées dans le bassin à culture conservatrice (par ex. la production annuelle moyenne de H. slossonae était de 12,02 g, poids sec sans cendre (PSSC), par m^2 dans le bassin ouest, contre 2,45 g PSSC/m^2 dans la branche est. Les différences dans les concentrations d'herbicides, d'insecticides et d'éléments nutritifs des deux bassins sont évaluées quant à leur rôle dans l'écart de productivité.

ABSTRACT

Annual secondary production of four coexisting caddisfly species (Trichoptera; Hydropsychidae: *Hydropsyche spp.*) was estimated in two adjacent branches of Kintore Creek, Ontario, Canada. The west branch was located in a demonstration watershed where conservation tillage was practiced i.e., mulch-finishing of row crops, planting of forage and cover crops, some no-till practices, etc. Conventional agricultural land management occurred in the watershed which drained into the east branch i.e., corn-wheat-alfalfa rotation with fall moldboard ploughing. Production estimates and densities of caddisflies were consistently higher in the watershed where conservation tillage was practiced. For example, mean annual production of *H. slossonae* was 12.02 g ash-free dry weight (AFDW)/m^2 in the west branch vs. 2.45 g AFDW/m^2 in the east branch. Differing concentrations of herbicides, insecticides and nutrients in the two watersheds are discussed as possible explanations for this pronounced difference in productivity.

RÉSUMÉ

La production secondaire annuelle de quatres espèces de phryganes vivant ensemble (trichoptères; hydropsychidés : *Hydropsyche spp.*) a été évaluée dans deux branches adjacentes du ruisseau Kintore (Ontario). La branche ouest traversait un bassin de démonstration, où on pratiquait une culture de type conservatrice, soit la culture en ligne par paillis, la plantation de fourrage et les cultures de couverture, un peu de culture sans travail du sol, etc. Dans le bassin de la branche est, la gestion agricole classique des terres consistait en une rotation maïs-blé-luzerne, avec labour automnal à la charrue à socs. La production et la densité de phryganes étaient systématiquement plus élevées dans le bassin avec culture de type conservatrice. Par exemple, la production annuelle moyenne de *H. slossonae* était de 12,02 g PSSC/m^2 dans le bassin ouest, contre 2,45 g PSSC/m^2 dans la branche est. Les différences dans les concentrations d'herbicides, d'insecticides et d'éléments nutritifs des deux bassins sont évaluées quant à leur rôle dans cet important écart de productivité.

INTRODUCTION

The management of agricultural land can greatly influence the composition and magnitude of contaminants in agricultural runoff (Leonard, 1988). In recent years, considerable interest has been expressed in conservation tillage practices which leave more crop residue on the soil surface and do not disturb the top soil matrix to the same extent as conventional tillage (Fox and Dickson, 1989). The advantages of conservation tillage include control of soil erosion by reductions in surface runoff, decreased nutrient inputs to watersheds, increased efficiency of water use by crops and decreased labour and energy costs (Francis *et al.*, 1985).

The impact of conservation tillage on pesticide residues in watershed runoff is not as clearly defined. Both enhancements and reductions of pesticides in watershed runoff from land with conservation tillage practices have been reported (Francis *et al.*, 1985; Chesters *et al.*, 1989). Increased use of pesticides as a substitute for mechanical cultivation of cropland, local rainfall characteristics, the time interval between pesticide application and rainfall, the properties of the pesticides, rates of application, soil texture and topography and the type and amount of ground cover have all been cited as possible reasons why pesticide residues in surface runoff from conservation tillage watersheds may vary (Willis and McDowell, 1982; Francis *et al.*, 1985).

In 1984, a demonstration study in an agricultural area near London, Ontario, was established to compare the effects of conservation vs. conventional tillage on nutrient and sediment loadings in two branches of an agricultural stream, Kintore Creek (Merkeley and Glasman, 1984; Merkeley, 1988). In 1988, the project was expanded to determine residues of two pesticides (atrazine and metolachlor) in ambient and storm runoff events in the two watersheds (Struger and Fischer, 1989). This paper examines the effects of different land management practices on the secondary production of the benthic invertebrate communities occupying the two watersheds. Caddisflies (Trichoptera; Hydropsychidae: *Hydropsyche*) were chosen for this study because of their importance in river and stream metabolism (Wallace *et al.*, 1977; Mackay, 1979), their predominance in both branches of Kintore Creek, the relative ease with which species could be identified and the abundance of information in the literature on the productivity of these species in southern Ontario (Mackay, 1979; Rutherford, 1986). The productivity of aquatic invertebrates in agricultural watersheds has been shown to be affected either directly due to the toxicity of contaminants, particularly pesticides, in surface and groundwater runoff (Muirhead-Thomson, 1987) or indirectly by changes in food resources and habitat caused by increased concentrations of suspended sediment, nutrients and pesticides in aquatic ecosystems (Dance and Hynes, 1980; deNoyelles, *et al.*, 1982; Dewey, 1986; Kettle *et al.*, 1987).

MATERIALS AND METHODS

Description of the Study Area

The study site was located on the two branches of Kintore Creek (43°10' N, 81°2' W) which flows into the middle branch of the Thames River with eventual discharge into Lake St. Clair (Fig. 1). The upper branches of Kintore Creek are formed by the Arthur-Vannatter and Logan-McKay Award Municipal Drains and serve as watershed of a suitable size for management purposes with similar land use, soil types and predictable erodibility (Table 1). Both the eastern and western watersheds originate in swampy headlands and flow through rolling cropland with silt, silt loam and/or sandy loam soils. Both streams are shallow and narrow, with widths between 2 and 4 m. Bottom substrates consist of coarse sand, cobbles, and pebbles in the riffle areas, and silty mud in the slower-moving areas. Extensive algal growth can be found on rocks at both sites. Historically, both watersheds were known to support cold water trout species but clearing of the land and poor land management practices have eliminated species of trout through accelerated surface erosion rates which have resulted in decreased water clarity and increased nutrient levels in the water.

In 1984, the Upper Thames River Conservation Authority in collaboration with the Ministries of the Environment, Agriculture and Food, and Natural Resources, initiated a long-term watershed study with the local farmers to assess the effects of land management practices on reducing upland soil erosion and consequently improving water quality (Merkeley and Glasman, 1984). In the western basin of the watershed, 12/15 farms became involved in a conservation tillage program which includes mulch-finishing of row crops, planting of forage and cover crops and some no-till practices. In addition, water and sediment control basins (termed WASCOBs) were constructed to control gully erosion by ponding runoff water during storm events and allowing slow drainage to a safe outlet via underground tile systems. Some stream banks were also reveted using rip-rap and filter cloth material to stabilize the slopes and trees were planted in some areas.

Landowners in the eastern basin (13 farms) continued to use conventional tillage practices (i.e., corn-wheat-alfalfa rotation with fall moldboard ploughing which leaves 0-15% surface crop residue).

A pesticide usage questionaire was completed by each landowner in both watershed basins in the spring and fall of 1988 (herbicides only) and the spring of 1989 (both insecticides and herbicides). The questionaire established the type and rate of pesticide use in each study area.

Water Quality Parameters

Selected water quality parameters were measured at monthly intervals in each branch of Kintore Creek i.e., temperature, dissolved oxygen (mg/L), alkalinity (as $CaCO_3$, mg/L), pH, conductivity (μmhos/cm), particulate organic carbon (POC) (mg/L), chlorophyll *a* (mg/L), nutrients (NO_2, NH_4-N, NO_3NO_2-N, total Kjeldahl nitrogen, total phosphorus, soluble reactive phosphorus (S.R.P.), total filtered phosphorus, and water flow at the riffles (m/sec). Analysis was conducted by the National Water Quality Laboratory, Burlington, Ontario Canada using standard methodology.

Determination of secondary production of invertebrates

Benthic invertebrate samples were collected monthly from 17 May 1988 to 12 May 1989, and biweekly from May 26 to July 7 in both branches of Kintore Creek. On each sampling date 5 replicate samples were collected from riffle areas at each site. A surber sampler (220-μm mesh) which encloses an area of 0.09 m^2 was used. The rocky substrate within this area was rubbed and cleaned in front of the net opening to collect the fauna. Contents of the net were transferred to glass jars and preserved in 10% buffered formalin.

In the laboratory, formalin in the preserved samples was removed by rinsing each sample through a sieve (100-μm) with tap water. All invertebrates were sorted and separated under a dissecting microscope and stored in 70% ethanol. When samples contained large numbers of animals, a subsample was taken by dividing the sample into four equal portions. Caddisfly larvae were identified to species using taxonomic keys by Shefter and Wiggins (1986), and Mackay (1978). Head widths, color patterns and setal shapes were used for species identification of early hydropsychid instars (Mackay, 1978). Immature pupae were identified by associated larval sclerites in the pupal case, or by characteristics of the dorsal hook plates of the pupal abdomen (Rutherford, 1985). Following species identification of each larva, head capsule width at eye level was measured with an ocular micrometer to the nearest 10 um. From this, head width frequency histograms were constructed to separate larval instars.

Larval weights for each instar were estimated by weighing preserved larvae on an electrobalance to the nearest μg. Monthly estimates of larval weights were based upon weights of 5-12 individuals. For first, second and third instars, 5 or more larvae were weighed together and the mean weight was calculated. Preserved animals were placed in a drying oven at 55°C for 24 h, transferred to a dessicator for 24 h, then weighed to the nearest μg to obtain dry weight. The dried specimens were then ashed (500°C) for 1 h and then reweighed to obtain ash-free dry weight (AFDW).

Annual production of each species of *Hydropsyche* was estimated by the size-frequency method (Hynes & Coleman, 1968; Hamilton, 1969; Benke, 1979). This method was chosen because our species did not have well-defined cohorts and our number of samples per date was small. In the size-frequency method, species are first grouped into selected size categories (instars). For each instar, an annual mean numerical density is calculated from samples taken throughout the year. The resulting mean densities of each instar together comprise a mean size frequency distribution referred to as an "average cohort" (Hamilton, 1969; Benke, 1979; Benke and Waide, 1977). To estimate production of the average cohort the number of individuals lost due to mortality between successive size categories must first be calculated. By multiplying the number of individuals lost by weight, an estimate of biomass loss between size classes is obtained. The average cohort production is approximated by summing up all biomass losses. As suggested by Krueger and Martin (1980), the mean annual number of individuals in each instar was weighted for sampling interval length, and the larval weight at loss was estimated by the geometric mean of the weights of individuals in successive instars. All consecutive negative values from the first instar up to the third were omitted prior to summation as suggested by Benke and Wallace (1980). Two of the most important factors affecting production estimates are voltinism and length of aquatic life or CPI (Waters, 1979). If larval development time of a population is much more or less than a year, the production value obtained must be multiplied by 365/CPI, where CPI is the cohort production interval in days (Benke, 1979). When the species was univoltine, we assumed that the CPI was 365 days since no significant amount of time was spent in nonlarval stages (Parker and Voshell, 1983, Benke, 1984). If the species was bivoltine we assumed the CPI to be one half of 365 days, therefore the production estimate was adjusted by multiplying it by two according to Benke (1979). The method of Krueger and Martin (1980) was used to obtain 95% confidence intervals for the production estimates. These confidence limits permit evaluation of an estimate's reliability and allow us to compare estimates from both sites.

Estimates of fish populations

In order to determine the presence of potential predators on benthic invertebrates, a fish census on each branch of Kintore Creek was conducted by Ministry of Natural Resources personnel on Oct. 24, 1988. A branch was sectioned off with seine nets approximately 100 m apart and the area within these nets was intensively shocked using a portable electroshocker. Three separate passes were conducted at each site and a fishing effort of 30 min. was sustained at each pass. All fish were collected with dip nets, identified to species, measured (mm) and counted.

RESULTS

Pesticide Usage

Results from the pesticide questionaire (Table 2) indicate that more pesticides are used in the conservation tillage watershed than the conventional tillage watershed (22 vs. 13). More land is devoted to soybean production in the conservation tillage watershed (Table 1) and many of the additional pesticides used in this watershed pertain to this cultivation of soybeans. However, the kilograms applied and the hectarage covered by these additional pesticides are relatively minor in comparison to the total quantities of other pesticides (i.e., atrazine, metolachlor, EPTC, cyanazine, fonofos and terbufos) used in both watersheds.

Greater quantities of herbicides (with a few exceptions) were also applied in the conservation tillage watershed although this is dependent on the year of application (e.g., atrazine, metolachlor and dicamba were more heavily applied in 1988 in the conservation tillage watershed but not in 1989). However, the area of land to which these pesticides were applied is generally much larger in the conservation tillage watershed than in the conventional tillage watershed resulting in overall lower application rates (in kg/ha) and thus a more diffuse spread.

Although data are only available for the spring of 1989, the use of insecticides appears to be much higher in the conventional tillage watershed than in the conservation tillage watershed i.e., both in the number of pesticides used and the total kilograms applied. For example, the organophosphate, terbufos, was not used in the conservation tillage watershed but was applied at rates of 7.5 kg/ha in the conventional tillage watershed. Use of the organophosphate, fonofos, was much more extensive in the conventional tillage watershed.

Chemical parameters

Trends in water temperature and dissolved oxygen in both branches of Kintore Creek were similar throughout the study period although temperature was consistently 1.0-1.5 °C warmer in the conservation tillage branch (Fig. 2a) especially in the cooler months of the year. The presence of more forested area upstream in the conventional tillage watershed (Table 1) may provide more shading which in turn could result in slightly lower temperatures in this branch. Dissolved oxygen concentrations were always high and at saturation in both branches (2b).

The ranges in alkalinity, pH, conductivity, turbidity and particulate organic carbon were similar in both branches throughout the study period (Table 3). In contrast, levels of nutrients (particularly NO_3NO_2-N, NH_4-N and S.R.P) were consistently higher in the western branch in spite of the conservation tillage practices. Investigation of the watershed revealed that one farmer upstream of the conservation tillage area was allowing pig manure to contaminate the stream from his farm lagoon tile system. Chlorophyll *a* levels (Fig. 3) were also slightly higher in the conservation tillage branch especially during the growing season and could be the result of higher nutrient inputs.

Productivity of Hydropsychids

Species collected and abundance

Four species of *Hydropsyche* were found in both watersheds. In order of relative abundance these were *H. slossonae*, *H. betteni*, *H. bronta*, and *H. sparna*. Individuals of the genus *Cheumatopsyche* were also found but since there are no taxonomic keys to separate the species of this genus, they were not included in the study.

Densities of all four *Hydropsyche* species were significantly higher (ANOVA $p < 0.001$) in the conservation tillage branch compared to the conventional tillage branch on all sampling occasions (Fig. 4). Abundances of *H. bronta* and *H. sparna* were especially low in the conventional tillage branch suggesting unfavorable conditions for these two species.

Production estimates

The two aspects of larval growth which are essential for analysis of animal production are 1) biomass of each size category (instar), and 2) knowledge of life history or mean larval development time. Mean individual biomass was calculated for each of the five instars of each species with the exception of instar 1 for which only one specimen was found (Table 4). Instar frequency distributions were used to determine voltinism of the different species. When there was insufficient data to clearly document the actual life history of a species, we relied on literature values. We assumed *H. slossonae* and *H. betteni*, the two largest species to be univoltine with life cycles similar to other published accounts (Mackay, 1979; Rutherford, 1986). Although these species can potentially have a second generation under optimum conditions (Mackay, 1979), our instar frequency distributions did not indicate a second generation, and water temperatures in Kintore Creek were considerably lower (< 25.0 °C) than those considered essential for bivoltinism (27-28 ° C) (Mackay, 1979). Although instar frequency distributions for *H. bronta* and *H. sparna* were not as clearly defined, they were both assumed to be bivoltine, as described in the literature (Mackay, 1979; Fuller and Mackay, 1981; Mackay, 1984; Rutherford, 1986). *H. bronta* and *H. sparna* are both smaller larvae than *H. slossonae* and *H. betteni*, thus requiring less time to mature. For this reason these two species usually exhibit bivoltinism and, in some cases, trivoltinism (Rutherford, 1986).

Production calculations are illustrated for *H. slossonae* in Table 5. Since *H. slossonae* was a univoltine species the production estimate did not need adjustment. Production estimates for the four *Hydropsyche* species are summarized in Table 6. In all cases production was higher in the conservation branch of Kintore Creek. For example, production of *H. slossonae* in this branch was 12.02 g AFDW/m^2, compared with 2.45 g AFDW/m^2 in the conventional tillage branch. With the exception of *H. betteni*, confidence intervals did not overlap between the production estimates for the two branches suggesting that significant differences in annual production exist between the two sites.

<u>Fish Census</u>

Species of fish captured in the electroshocking census were similar in the two branches of Kintore Creek with the exception of the presence of the American brook lamprey (*Lampetra appendix*) and the fathead minnow (*Pimephales promelas*) in the conservation tillage watershed (Table 7). More individuals were captured in the conservation tillage watershed than the conventional tillage watershed for a similar catch-per-unit-effort.

DISCUSSION

Annual secondary production of *Hydropsyche spp.* was substantially higher in the western branch of Kintore Creek where conservation tillage practices are in operation. Many factors can influence the life-history patterns of aquatic insects (Sweeney, 1984) particularly the two components responsible for secondary production i.e., biomass and rate of growth of species. Temperature, nutrition, habitat complexity, photoperiod and biological interactions (i.e., predation, parasitism, competition, etc.) can all affect production (Fuller and Mackay, 1981; Krueger and Waters, 1983; Parker and Voshell, 1983; Benke, 1984).

The fish population census indicated that enhanced predation by fish in the conventional tillage watershed was not a factor in explaining the differences in productivity. In fact, greater abundances and more species of fish were found in the conservation tillage watershed than the conventional tillage watershed and most of these species are known to feed on benthic invertebrates (Scott and Crossman, 1973).

The composition of the benthic invertebrate communities other than caddisflies were also similar in each of the branches (R. Sallenave, personal observation) and consisted of crayfish (*Orconectes sp.*), leeches (Erpobdellidae, Glossiphoniidae), snails (*Physa sp.*), stoneflies (Nemouridae), mayflies (Heptageniidae, Baetidae), oligochaetes (Tubificidae), beetles (*Optioservus sp.*, *Stenelmis sp.*), and Diptera (Chironomidae, Empididae).

A consistently higher temperature of 1.0-1.5 °C was recorded in the conservation tillage watershed. Nebeker (1971) has suggested that even a small increase in water temperature (≈ 1.0 °C) may allow insects to grow faster and emerge earlier as adults thus increasing their productivity; however, few studies have substantiated this. Mackay (1979) found that water temperatures of 27-28 ° C were necessary before a significant increase in productivity of *H. slossonae*, *H. sparna*, and *H. betteni* could occur. As temperatures in both branches of Kintore Creek rarely exceeded 25 °C, it is unlikely that temperature can account for the pronounced differences in productivity between the two sites.

Differences in food quality and quantity can also be a controlling factor in the growth and productivity of *Hydropsyche* species (Fuller and Mackay, 1981). Members of this genus can occupy all trophic levels from detritivore to carnivore but they depend largely on suspended material in streams. The composition of their gut usually reflects that of the seston composition in the stream flow with most species ingesting very high percentages of detritus with lower percentages of diatoms and animal material (Fuller and Mackay, 1980).

However, Fuller and Mackay (1981) demonstrated that diatoms, which originate from well-developed periphyton communities, contribute the most to larval growth of *H. slossone*, *H. betteni* and *H. sparna* with detritus being of lesser importance in the nutrition of these species. The quality of the suspended particulate matter in both branches of Kintore Creek was not examined in detail in this study but chlorophyll *a* measurements from the water column (Fig. 3) indicate that more microalgae were present in the water in the conservation tillage branch compared to the conventional tillage branch during the summer months and may be contributing to increased secondary productivity. High nutrient levels in the form of S.R.P., NO_3NO_2-N and NH_4-N caused by the spillage of manure into this watershed may provide the explanation for greater primary productivity during 1988-89. Krueger and Waters (1983) found that nitrates were positively associated with invertebrate production in three Minnesota streams because the presence of increased nitrate levels produces a favourable environment for microorganisms which in turn produces a higher-quality food. However, a return to the Kintore Creek study sites in the summer of 1990 indicated that densities of caddisfly species were still considerably higher in the conservation tillage branch vs. the conventional tillage branch even though nutrient inputs in the conservation tillage watershed were being controlled (K.Day, unpublished data).

Alternate explanations for reduced productivity in the conventional tillage watershed may include a reduction in food resources and habitat due to the effects of herbicides on the primary producers, particularly the attached algal community. Struger and Fisher (1989, 1990) reported higher levels of the herbicide, atrazine, in both the ambient water and during storm runoff events (ca. 90 μg/L) in the conventional tillage branch of Kintore Creek compared to the conservation tillage branch. Higher application rates of other herbicides were also reported in this watershed. Concentrations of atrazine ranging from 50 to 500 μg/L have been shown to cause *in situ* reductions in phytoplankton and periphyton photosynthesis as well as changes in species composition (deNoyelles *et al.*, 1982; Brockway *et al.*, 1984; Kosinski, 1984; Herman *et al.*, 1986; Hamilton *et al.*, 1988). Day *et al.* (1989; Day, unpublished data) found that ash-free dry weight (AFDW) of periphyton on artificial substrates placed in both branches of Kintore Creek was reduced in the conventional tillage branch compared to AFDW in the conservation tillage branch. In addition to feeding on diatoms in the stream flow (which originate through sloughing of the periphytic community), net-spinning hydropsychids utilize the periphyton as a habitat and graze on the epilithic material in the winter months when the larvae shift from filter-feeding to scraping (Fuller and Mackay, 1980). Thus a reduction in primary productivity in the summer months due to the effects of herbicides may result in less available food in both the summer and the winter months. Dewey (1982) and Kettle *et al.* (1987) both suggest that indirect effects through alterations of algal food resources and habitat rather than direct toxicity were responsible for their observed declines in benthic insect communities and zooplankton in pond ecosystems contaminated with 20 μg atrazine/L although Lynch *et al.* (1985) reported that atrazine had no significant or lasting effects on the structure of macroinvertebrate populations in model stream ecosystems.

Another possible factor in explaining the differences in productivity between the two branches may lie in a comparison of the quantities and types of insecticides used in each watershed. The organophosphate insecticides, fonofos and terbufos, are known to be highly toxic to aquatic invertebrates in the μg/L range (Mayer, 1987; Worthing and Walker, 1987). Larger quantities and higher application rates of fonofos were used in the watershed practicing conventional tillage and terbufos was also applied in this watershed. If, as suggested by Struger and Fisher (1989; 1990), higher concentrations of herbicides occur in surface runoff from the conventional tillage watershed in Kintore Creek vs. the conservation tillage watershed, higher concentrations of insecticides may also be occurring in this watershed (although residues were not measured). The continuous input of higher concentrations and greater numbers of organophosphate insecticides into the conventional tillage watershed vs. the conservation tillage watershed may result in decreased productivity of the aquatic invertebrates found in this ecosystem due to detrimental sublethal effects. Further research would be necessary to substantiate this.

In conclusion, it is difficult to attribute the differences observed in secondary production of benthic macroinvertebrate species between the two branches of Kintore Creek to any one explanation. For example, limited availability of high quality food due to lower levels of nutrients and to a lesser extent, higher concentrations of herbicides in the ambient waters of the conventional tillage watershed may be contributing to a decrease in secondary production. However, heavier use of insecticides in this watershed may also result in reduced growth and biomass. It is likely that a combination of both environmental and anthropogenic factors may be affecting the biomass and rate of growth of the benthic invertebrate community.

ACKNOWLEDGEMENTS

We would like to thank the landowners in the Kintore Creek basin, particularly the Aarts family and the Logan family, for access to their private properties for sampling purposes. A special thanks goes also to the Upper Thames River Conservation Authority for establishing the study sites in the first place and the Ministry of Natural Resources, Alymer, Ontario for their fish census data. We wish to thank Pat Schefter for her help in identifying some larval specimens. Jane Rutherford gave valuable advice on interpreting instar frequency distributions. Financial support was provided by Department of the Environment funding (PESTFUND) to K.E. Day.

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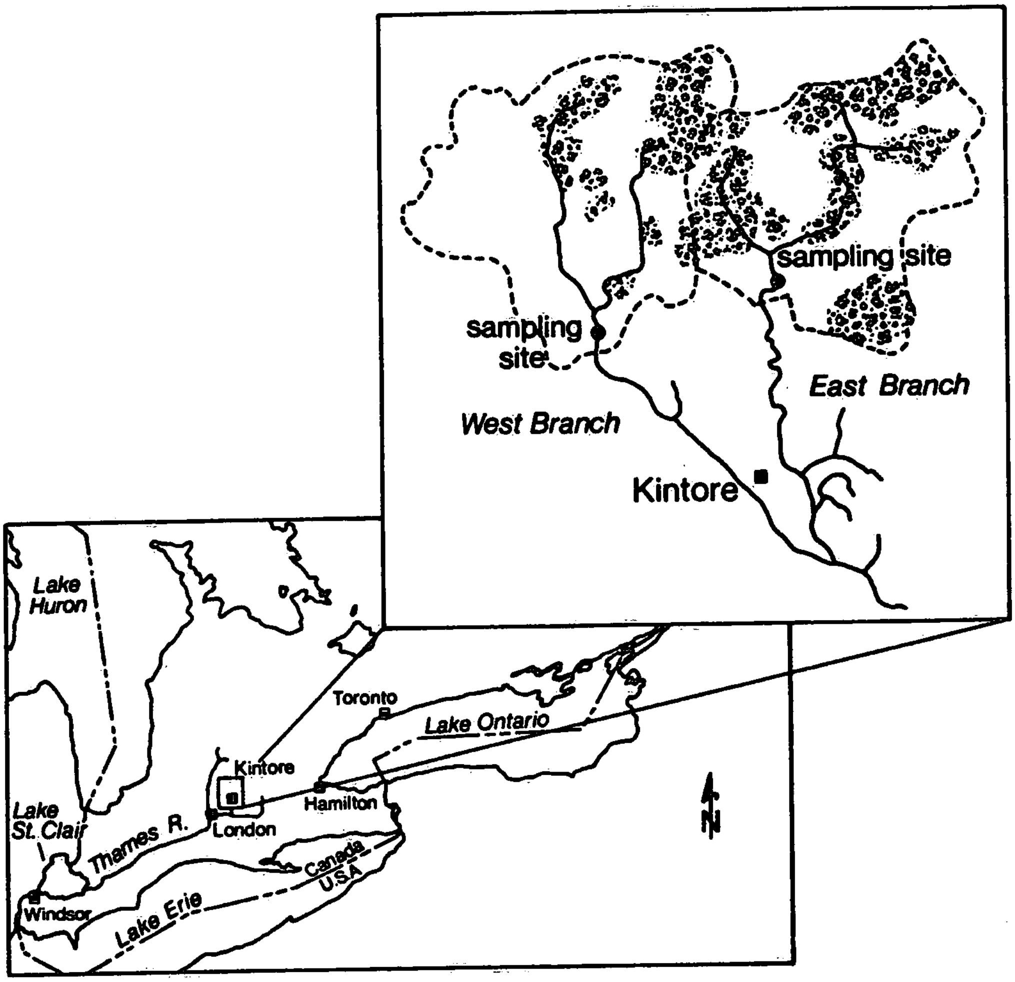
LIST OF FIGURES



sampling site
sampling site
East Branch
West Branch
Kintore
Lake Huron
Toronto
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Hamilton
Lake St. Clair
Thames R.
London
Canada
U.S.A.
Windsor
Lake Erie
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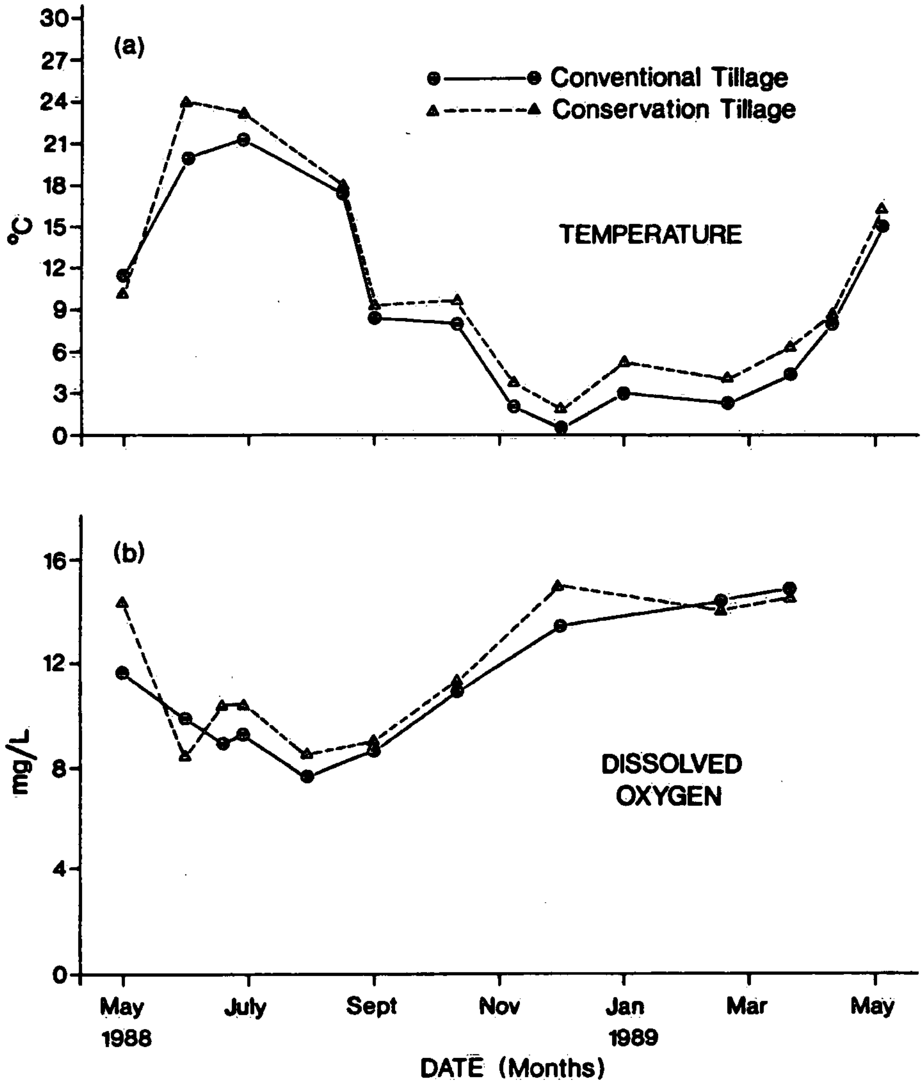
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Conventional Tillage
Conservation Tillage
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30
27
24
21
18
15
12
9
6
3
0
(b)
DISSOLVED OXYGEN
mg/L
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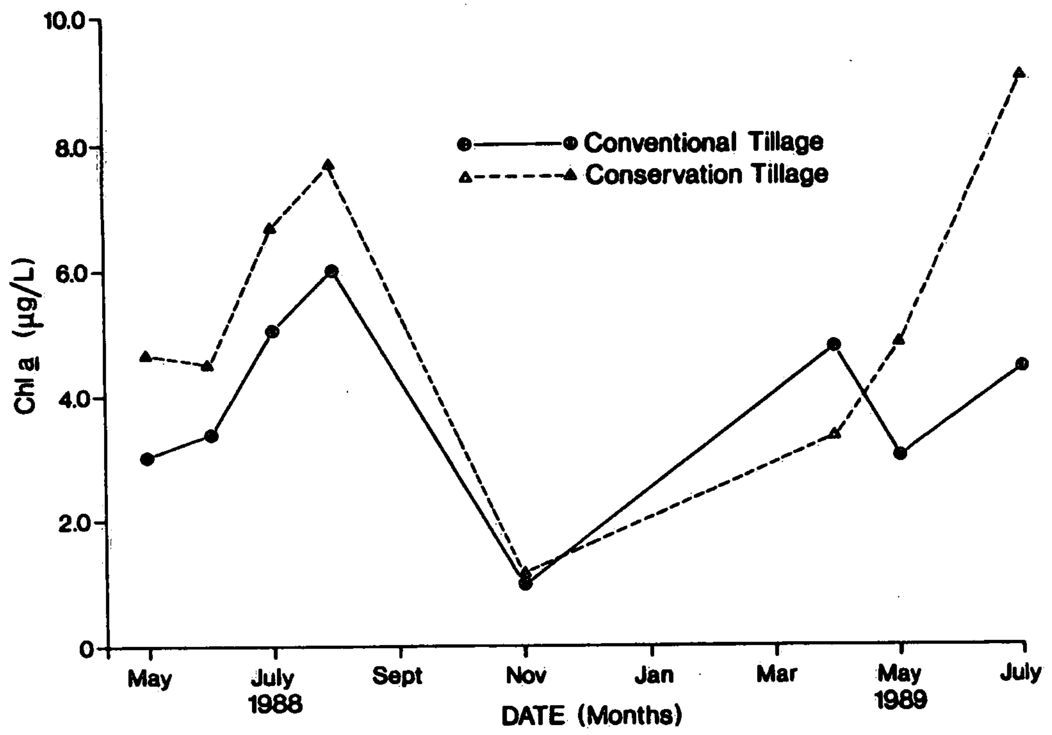
12
8
4
0
May 1988
July
Sept
Nov
Jan 1989
Mar
May
DATE (Months)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Chl a (µg/L)
Conventional Tillage
Conservation Tillage
May
July
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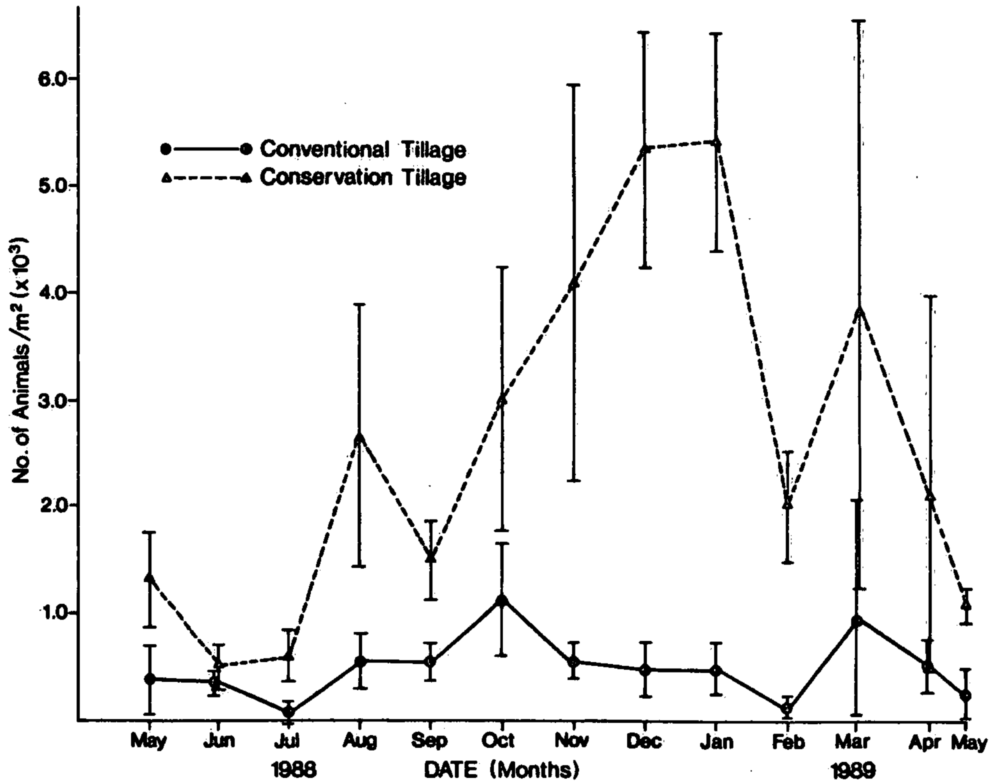
1989
July
DATE (Months)



Mean Densities of Caddis Flies (4 spp of Hydropsyche)

TABLE 1. KINTORE CREEK WATERSHED CHARACTERISTICS - 1988-89

	Conventional (East Kintore Ck.)	Conservation (West Kintore Ck.)
Size of Watershed	5.60 sq. km	6.56 sq. km
Soil Types	silt loam, sandy loam, muck	silt loam
Soil Erosion Potential	medium to high	medium to high
Area understudy	628 ha	633 ha
Area tile drained	30%	55%
No. major landowners	13	15
Total forest cover	296 ha	106 ha
Total crop area	301 ha	467 ha
corn	172 ha	241 ha
soybean	9 ha	66 ha
grain	55 ha	40 ha
alfalfa	65 ha	119 ha
Area Under Conservation Tillage	-	157 ha (34%)

TABLE 2. PESTICIDE USE IN CONVENTIONAL AND CONSERVATION TILLAGE WATERSHEDS DURING 1988 AND 1989 GROWING SEASONS.

Pesticide	Conventional Tillage Total kg Applied	Conventional Tillage Total Area Covered (ha)	Conservation Tillage Total kg Applied	Conservation Tillage Total Area Covered (ha)
<u>Herbicides</u>				
* atrazine	330[a]	140	339	219
	430[b]	236	321	202
*/**metolachlor	175	75	479	230
	71	37	54	47
*EPTC	173	63	38	12
	-	-	221	50
*bromoxynil	21	60	17	70
	14	35	19	60
*dicamba	28	46	130	147
	21	34	32	62
*MCPA	17	48	3	5
	-	-	18	5
*2,4-D	8	20	26	52
	49	30	12	33
2,4-DB	-	-	-	-
	6	5	1	9
*cyanazine	21	7	62	72
	31	34	242	108
*/**glyphosate	9	10	-	-
	13	15	30	45
butylate	77	19	-	-
	67	17	8	2
**bentazon	-	-	62	66
			32	14
**linuron	-	-	41	36
			9	8
**sethoxydim	-	-	3	17
			1	8
**trifluralin	-	-	11	16
			30	32

(TABLE 2 cont'd next page)

TABLE 2. (cont.)

Herbicides				
**chloramben	-	-	40	16
			51	20
**metobromuron	-	-	-	-
			7	14
**diquat	-	-	-	-
			7	14
**ethalfluralin	-	-	-	-
			2	4
**metribuzin	-	-	-	-
			4	4
**fenoxaprop-ethyl	-	-	-	-
			2	14
Insecticides				
*fonofos	-	-	-	-
	527	73	216	77
*terbufos	-	-	-	-
	354	47	-	-

* pesticides used in corn production
** pesticides used in soybean production

[a] 1988 (insecticide information not requested)
[b] 1989

TABLE 3. WATER QUALITY PARAMETERS IN CONSERVATION VS. CONVENTIONAL TILLAGE WATERSHEDS.

Parameter	Conservation Tillage	Conventional Tillage
Temperature °C	2.0 - 23.0	0.5 - 21.0
Dissolved oxygen mg/L	8.4 - 14.8	7.5 - 13.4
Alkalinity ($CaCO_3$) mg/L	208 - 254	237 - 243
pH	7.54 - 8.15	7.79- 8.16
Conductivity (mμs/c)	580 - 647	474 - 584
Turbidity	0.16 - 4.4	0.33 - 3.1
Particulate Organic Carbon mg/L	0.33 - 1.42	0.34 - 2.75
Chlorophyll *a* μg/L	1.8 - 9.2	0.1 - 5.5
Cl mg/L	16.1 - 27.2	7.1 - 11.4
NO_2 mg/L	0.027 - 0.077	0.008 - 0.043
NH_4-N mg/L	0.017 - 3.74	<0.005 - 0.062
NO_3NO_2-N mg/L	3.74 - 7.56	1.24 - 2.91
S.R.P.-Phosphorus mg/L	0.0034 - 0.279	0 0016 - 0.0406
TP-Phosphorus mg/L	0.0263 - 0.345	0.0249 - 0.0665
TFP-Phosphorus mg/L	0.0179 - 0.270	0.016 - 0.0460
TKN-Phosphorus mg/L	0.270 - 0.507	0.230 - 0.476
Water Flow M/sec		
Riffle Areas	0.65 - 1.10	0.65 - 0.81
Sediment Zones	0.22 - 0.50	0.12 - 0.49

TABLE 4. MEAN MONTHLY BIOMASS[a] FOR INSTARS OF *Hydropsyche spp.*

	Instar				
Species	I	II	III	IV	V
H. slossonae	0 (1)[b]	0.04 (47)	0.16 (98)	0.77 (100)	5.17 (126)
H. betteni	-	0.02 (2)	0.17 (83)	0.95 (103)	5.65 (117)
H. bronta	-	-	0.13 (73)	0.47 (90)	2.66 (100)
H. sparna	-	0.05 (9)	0.16 (12)	0.43 (58)	2.25 (85)

[a]ash-free dry weights for instars I and II were converted using the accepted conversion of 0.9 (Waters, 1977)

[b]total number of larvae weighed

TABLE 5. EXAMPLE OF CALCULATING PRODUCTION BY THE SIZE-FREQUENCY METHOD (*H. slossonae* at conservation tillage site).

Instar	Annual mean density (no./m^2)	Mean indiv. biomass (mg AFDW)	Annual mean biomass (mg/m^2)	Indiv. lost (no./m^2)	Indiv. biomass at loss (mg)	Biomass loss (mg/m^2)	Correct. factor *5
I	1.70	0.00	0.00				
				-259.60	0.00	-0.47	-2.34*
II	261.30	0.04	9.41				
				-251.28	0.08	-19.19	-95.95*
III	512.58	0.16	83.04				
				42.73	0.35	14.95	74.77
IV	469.85	0.76	355.21				
				11.96	1.98	23.63	118.15
V	457.89	5.17	2365.46				
				457.89	5.17	2365.47	11827.35
	N = 1703.32[a]		B = 2813.11[a]				P = 12020.27[a]

* Not included in production summation; see text
[a] N = mean density, B = mean standing stock biomass, P = production

TABLE 6. SUMMARY OF MEAN VALUES FOR PRODUCTION PARAMETERS OF 4 SPECIES OF *Hydropsyche* AT CONSERVATION (WEST) VS. CONVENTIONAL (EAST) TILLAGE BRANCHES OF KINTORE CREEK, ONTARIO.

Species	Site	N ($No./m^2$)	B (g/m^2)	P (g/m^2)	95% Confidence Interval
H. slossonae	West	1703.32	2.81	12.02	10.221 - 13.77
	East	228.12	0.72	2.45	1.80 - 3.10
H. betteni	West	398.55	1.15	4.19	3.11 - 5.27
	East	220.98	0.82	2.70	1.90 - 3.50
H. bronta	West	559.29	0.79	5.76	4.88 - 6.64
	East	3.74	0.007	0.05	0.046 - 0.054
H. sparna	West	87.11	0.13	0.85	0.62 - 1.08
	East	1.28	0.010	0.001	0.00 - 0.002

TABLE 7. KINTORE CREEK FISH CENSUS DATA, OCT. 24, 1988

Common name	Scientific Name	Conservation Tillage		Conventional Tillage	
		No.	Range in Length (mm)	No.	Range in Length (mm)
Lamprey family					
American brook lamprey	*Lampetra appendix*	6	161 - 191	-	-
Sucker family					
Common white sucker	*Catostomus commersoni*	18	36 - 70	8	37 - 151
Minnow family					
Common shiner	*Notropis cornutus*	17	60 - 84	23	48 - 114
Bluntnose minnow	*Pimephales notatus*	13	54 - 80	20	44 - 82
Blacknose dace	*Rhinichthys atratulus*	52	22 - 74	36	24 - 75
Creek chub	*Semotilus atromaculatus*	46	34 - 119	29	35 - 160
Fathead minnow	*Pimephales promelas*	1	67	-	-
Stickleback family					
Brook stickleback	*Culaea inconstans*	8	35 - 48	2	35 - 36
Perch family					
Fantail darter	*Etheostoma flabellare*	8	30 - 75	18	32 - 65
Johnny darter	*E. nigrum*	2	41 - 42	2	58 - 64
Number of species		10		8	
Number of individuals		171		138	

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