Dow Chemical Inc.
Canadian Wildlife Service

Effects of Lawn Treatments with Chlorpyrifos (Dursban) on the American Robin (*Turdus migratorius*) in a Suburban Environment

Final Report

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ABSTRACT

Lépine, C., R. Décarie et J.-L. DesGranges. 1990. Effects of the spraying of lawns with chlorpyrifos (DURSBAN) on the American robin <u>Turdus migratorius</u> in a suburban area. GREBE Inc. for Environment Canada and Dow Chemical Inc. Technical report. Canadian Wildlife Service. Quebec Region. 46 pages + appendixes.

The purpose of this study is to establish if the immediate or repeated use of chlorpyrifos (DURSBAN) in a suburban area affects the use of lawns by the American Robin (<u>Turdus migratorius</u>) and the European Starling (<u>Sturnus vulgaris</u>), and if the repeated use of this insecticide has an effect on the productivity of the American Robin.

Four companies involved in lawn maintenance provided information on what was sprayed since 1986 on lawns in a sector of Duvernay, in Laval. The owners who were not customers of these companies provided information concerning their lawn. The abundance and frequency of presence of the American Robin and European Starling on these lawns were estimated on 17 occasions between July 4 and August 11, 1989. It seems that there are no effects of the repeated use of chlorpyrifos on the utilization of lawns by the robin or the starling although the abundance and weight of earthworms were reduced by the use of chlorpyrifos on the lawns (Coderre 1990). Earthworms are less active during this period of the summer, becoming less available on every lawn, treated or not. This is also the time that robins change their foraging activity towards fruits.

The productivity of 86 nests of robins was measured in 1988. The owners and the four associate companies provided information concerning the spraying of the lawns around the nests for the two years before the 1988 nesting season. It seems that there are negative effects of the repeated use of chlorpyrifos on this variable. The reduced availability of earthworms may explain this impact although it seems, according to the literature, that a diminished number of prey has no effect on productivity. However, the importance of missing information as to what was sprayed on each lawn surrounding the nests makes it necessary to study long-terms effects of chlorpyrifos on productivity.

RÉSUMÉ

Lépine, C., R. Décarie et J.L. DesGranges. 1990. Effets du traitement des pelouses au chlorpyrifos (DURSBAN) sur le Merle d'Amérique _Turdus migratorius_ en milieu urbain. GREBE Inc. pour Environnement Canada et Dow Chemical Inc. Rapport technique. Service canadien de la faune, région du Québec. 46 pages + annexes.

La présente étude vise à vérifier si l'usage immédiat ou répété sur plusieurs années de chlorpyrifos (DURSBAN) a un effet sur l'utilisation des pelouses en milieu résidentiel par le Merle d'Amérique (_Turdus migratorius_) et l'Étourneau sansonnet (_Sturnus vulgaris_) et si l'usage répété de cet insecticide sur les pelouses a un impact sur la productivité des nichées de Merle d'Amérique.

Quatre compagnies ont fourni les informations concernant l'entretien des pelouses depuis 1986 dans un secteur de Duvernay, à Laval et les propriétaires ne retenant pas les services de ces compagnies ont fourni l'information concernant leur pelouse. L'abondance et la fréquence de présence de Merles d'Amérique et d'Étourneaux sansonnets ont été notées sur les pelouses de ce secteur à 17 reprises du 4 juillet au 11 août 1989. Il ne semble pas que l'usage répété du chlorpyrifos ait un effet sur l'utilisation des pelouses par les merles et les étourneaux. Les lombriciens qui, eux ont subi une baisse de biomasse et d'abondance suite à l'utilisation de chlorpyrifos sur les pelouses (Coderre 1990) ont, à cette période de l'année, une activité réduite et sont donc moins disponibles quelque soit la pelouse. Dans le même temps, les merles voient leur régime alimentaire réorienté vers les fruits, les rendant moins tributaires des vers de terre.

La productivité de 86 nids de Merle d'Amérique a été mesurée à l'été 1988. Les propriétaires et les compagnies collaboratrices ont fourni les informations concernant les traitements de pesticides effectués lors des deux années précédentes autour de chacun des nids. Les résultats de cette étude semblent indiquer des effets négatifs de l'utilisation répétée de chlorpyrifos sur ce paramètre de nidification. La diminution de l'abondance et de la biomasse des lombriciens pourrait expliquer cet impact négatif bien que, selon la littérature, la diminution de proies ne semblent pas influencer la productivité. Par ailleurs, le grand nombre d'informations manquantes autour de chacun des nids commande d'étudier plus en profondeur les effets à long terme d'arrosages répétés au chlorpyrifos sur la productivité.

TABLE OF CONTENTS

PROJECT TEAM ii

ACKNOWLEDGMENTS iii

ABSTRACT iv

RÉSUMÉ v

TABLE OF CONTENTS vi

LIST OF TABLES viii

LIST OF FIGURES ix

LIST OF APPENDIXES x

LIST OF MAPS x

1.0. INTRODUCTION 1

2.0. CHLORPYRIFOS 2

3.0. PROCEDURE 3

3.1. Study Area 4
3.2. Biological Material 4
3.3. Treatment Schedule 5

3.3.1. Lawn Use 5
3.3.2. Productivity 7

3.4. Measurement Procedures 13

3.4.1. Measurement of Lawn Use by the American Robin and European Starling 13
3.4.2. Rival Hypotheses 14
3.4.3. Measurement of Productivity 16

3.5. Statistical Analysis 17

3.5.1. Lawn Use in Relation to Treatments 17
3.5.2. Characteristics of the Feeding Sites 21
3.5.3. Effect of Treatments on the Productivity of the American Robin 22

4.0. RESULTS 23

4.1. Lawn Use by the American Robin and European Starling . . 23
4.2. Effect of Treatments on Lawn Use by the American Robin and European Starling 24
4.3. Characteristics of the Feeding Sites 30

4.3.1. Grass Length 30
4.3.2. Area, Plant Stratification, and Extent of Enhancement for Human Use 32

4.4. Effect of Treatments on Productivity 37

5.0 DISCUSSION 41

6.0. BIBLIOGRAPHY 43

APPENDIXES

MAPS

LIST OF TABLES

Table 1 Percentage of Lots around the Nests for Which Treatment Information was Available for the Period from 1986 to 1988 11

Table 2 Comparison of the Specific Characteristics of Inferential and Exploratory Analysis 18

Table 3 Number of Lots with at Least One Sighting of American Robins or European Starlings during 17 Visits to the Duvernay Sector in the Summer of 1989 in Relation to the Types of Treatment Applied. 24

Table 4 Lawn Use by the Total Robin Population Observed as a Function of the Availability of Each of the Grass-Length Classes 30

Table 5 Lawn use by the American Robin as a Function of Enhancement for Landscaping and Man Use 35

Table 6 Comparison of Productivity as a Function of the Mean Percentage of Lots in Each Treatment Category 39

Table 7 Comparison of Mean Productivity as a Function of the Percentage of Lots in Each Treatment Category, according to Clutch Order 40

LIST OF FIGURES

Figure 1 Categories of Treatments Applied to Lawns in Duvernay (Laval) from 1986 to 1988 8

Figure 2 Categories of Lawn Treatments Applied from 1986 to 1989 Selected to Study Lot Use by the American Robin in the Duvernay Sector of Laval 9

Figure 3 Distribution of Lots by Category of Lawn Treatment Applied in the Duvernay Sector of Laval from 1986 to 1989 10

Figure 4 Categories of Lawn Treatments Applied from 1986 to 1988 Selected for Studying the Effect of Chlorpyrifos on the Productivity of the American Robin in 1988 in the Duvernay and St-Vincent-de-Paul Sectors of Laval 12

Figure 5 Correspondence Analysis Illustrating the Relation between the Highest Relative Abundance Values for American Robins and European Starlings Measured in the Summer of 1989 and Treatments Applied to the Lawns in Duvernay (Laval) from 1986 to 1989. 26

Figure 6 Percentage of Lots with at Least One Sighting of the Species Studied in the Course of 17 Visits in the Summer of 1989. Sex and Age Distribution as a Function of Treatments Applied in Duvernay (Laval) from 1986 to 1989. 28

Figure 7 Occurrence of American Robins and European Starlings in Percentage Values as a Function of Lot Availability in Each Treatment Category 29

Figure 8 Distribution of American Robin Sightings as a Function of Grass-Length Classes and Class Availability, as Determined on July 3, 1989 31

Figure 9 Percentage of Lawns with Short and Medium-Length Grass Used by the American Robin in the Summer of 1989 as a Function of Lawn Treatments in Duvernay (Laval) from 1986 to 1989 33

Figure 10 Percentage of Occurrence of American Robins as a Function of Availability of Lawns with Short Grass in Each Treatment Category 34

Figure 11 Correspondence Analysis Illustrating the Relation between the Occurrence of American Robins and European Starlings in the Summer of 1989 and Landscaping Enhancement in Duvernay (Laval) 36

Figure 12 Correspondence Analysis Illustrating the Relation between the Productivity of Robin Clutches in 1988 and Lawn Treatments in Duvernay (Laval) in 1986 and 1987. . . 38

LIST OF APPENDIXES

Appendix 1 Contributions associated with each of the values in the graphic representation of correspondence analysis illustrating the relation between the highest relative abundance values for American robins and European starlings measured in the summer of 1989 and lawn treatments in Duvernay (Laval) from 1986 to 1989 (Figure 5) 47

Appendix 2 Contributions associated with each of the values in the graphic representation of correspondence analysis illustrating the relation between the occurrence of American Robins and European starlings in the summer of 1989 and landscaping enhancement in Duvernay (Laval) (Figure 11) 48

Appendix 3 Contributions associated with each of the values in the graphic representation of correspondence analysis illustrating the relation between the productivity of American robin clutches in 1988 and lawn treatments in Duvernay (Laval) in 1986 and 1987 (Figure 12) 49

LIST OF MAPS

Map 1 Treatments employed on lawns in a sector of Duvernay: 1986-1989

Map 2 Sighting of American Robin on lawns in a sector of Duvernay, Laval: July 4th - August 11th, 1989

1.0 INTRODUCTION

Over the past few years, questions have been raised regarding the potential impact of phytosanitary pesticide applications in an urban setting on bird life. Many cases of bird mortality have been reported following lawn treatments with organophosphorus insecticides, such as diazinon and chlorpyrifos (Stone 1979, Coon 1983, Stone and Gradoni 1987). According to a study by Environment Canada, these are the two most commonly used insecticides in Quebec (Cossette et al. 1988).

There has been a trend away from these products ever since the new provincial pesticide act restricting their use went into effect on July 7, 1988 (Quebec 1989), but they are still widely employed in certain areas infested with chinch bugs (Blissus leucopterus) and other insect pests attacking turfgrass.

In a joint study, Dow Chemical and the Canadian Wildlife Service (CWS) set out to examine the effects of chlorpyrifos treatments in a residential area on the use birds made of lawns as feeding grounds and on the productivity of the American robin (Turdus migratorius).

Apart from the incidents noted above, this is the first time the effects of chlorpyrifos in an urban environment have been investigated. Brunet and Cyr (1990) recorded the impact of spraying the insecticide (in aqueous form) on the grass of cages containing American robins. Balcomb et al. (1984) administered granular chlorpyrifos orally to house sparrows (Passer domesticus) and red-winged blackbirds (Agelaius phoeniceus). Hurlbert et al. (1970) adopted a similar approach in their work with ducks confined to an enclosure (See also Kenaga 1974 and Hurlbert 1977). Clements and Bale (1988) tested various methods to study the effects of chlorpyrifos on grassland birds and mammals, while McEwen et al. (1986) focused on the effects of chlorpyrifos on the horned lark (Eremophila alpestris) and McCown's longspur (Calcarius mccownii) in anagricultural setting. In both instances, the species continued using the sites despite the application of chlorpyrifos.

Since the compound does not persist for long in the environment (Sears and Chapman 1979, Meikle et al. 1983, and Sears et al. 1987), two types of effects can be measured, i.e., the direct and immediate effects of spraying and the indirect effects of repeated use of the insecticide.

Immediate effects may either result in contamination of birds or elsecompel them to change feeding grounds temporarily to avoid ingesting contaminated prey or contact with chlorpyrifos residues. It was found in a laboratory experiment, for instance, that when ring-necked pheasants (Phasianus colchicus) or young mallards (Anas platyrhynchos) were given a choice, they generally preferred food that had not been contaminated with chlorpyrifos (Bennett and Prince 1981, Kenaga et al. 1981). In a natural setting, however, lawns that have just been sprayed with chlorpyrifos tend to attract European starlings

(*Sturnus vulgaris*) and hood crows (*Corvus corone*) because of the prey killed by the insecticide. There are no apparent immediate effects (Clements and Bale 1988).

Indirect effects may arise from a decline in prey numbers following repeated use of the insecticide. Earthworms are an important source of food for birds feeding from the ground in an urban environment (Kalmbach 1914 and Howell 1942 *in* Heppner 1965, Dolbeer *et al*. 1978). Coderre (1990) produced evidence that lots treated for several years with fertilizers, herbicides and chlorpyrifos yielded a reduced number and biomass of earthworms compared to lots treated solely with fertilizers and herbicides. As a result, birds eating this type of prey may avoid these sites where they will find fewer earthworms, or else may suffer a decrease in productivity as a result of fewer prey.

This study has three objectives:

1. Determine if chlorpyrifos applications have an immediate effect on lawn use by the American robin and European starling following the breeding season;

2. Determine if the repeated use (since 1986) of chlorpyrifos on lawns in a residential area has an impact on lawn use by the American robin and European starling following the breeding season;

3. Determine if the intensity of lawn treatments with chlorpyrifos in 1986 and 1987 affected the productivity of American robin nests in 1988.

2.0 CHLORPYRIFOS

Chlorpyrifos ($C_9H_{11}Cl_3NO_3PS$), also known as Dursban, Fosban or Lorsban, is an organophosphorus insecticide used to control insects, such as mosquitoes, termites, lice, cockroaches and various insect pests found in turfgrass and onornamental plants. It is used in emulsifiable concentrate, powder, granule or capsule form, or on various impregnated materials (Odenkirchen and Eisler 1988).

Chlorpyrifos rapidly breaks down by photodecomposition (half-life of 3 days) and volatilization (half-life of 8 hours) (Meikle *et al*. 1983). After 56 days, only 9 % of the solution applied to a lawn remains in the grass and stubble after 56 days. The stubble prevents the insecticide from penetrating the soil with the result that 2 % of the solution remains in the root area of the soil after 56 days and less than 1 % at a depth of 2.5 cm (Sears and Chapman 1979). In the soil, the half-life ranges from less than a week to over 6 months depending on soil moisture, microbial action, temperature and the clay and organic content of the soil (Kuhr and Tashiro 1978; Odenkirchen and Eisler 1988).

Chlorpyrifos is considered highly toxic for some bird species and moderately toxic for others following acute oral exposure (Smith 1987). The acute oral LD_{50} varies with the species and the author (Tucker and Haegele 1971, Schafer Jr. et al. 1983, Grolleau and Caritez 1986, Smith 1987, Odenkirchen and Eisler 1988):

Red-winged blackbird (*Agelaius phoeniceus*): 13 ppm
Common grackle (*Quiscalus quiscula*): 5.6 - 13.3 ppm
Japanese quail (*Coturnix japonica*): 13.3 - 15.9 ppm
Ring-necked pheasant (*Phasianus colchicus*): 8.4 - 17.7 ppm
House sparrow (*Passer domesticus*): 10 - 21 ppm
Rock dove (*Columba livia*): 10 - 26.9 ppm
American crow (*Corvus brachyrhynchos*) 32 ppm
Red-legged partridge (*Alectoris rufa*): 44 ppm
European starling (*Sturnus vulgaris*): 5 - 75 ppm
Northern bobwhite (*Colinus virginianus*): 32 - 108 ppm

There do not seem to be any data on acute toxicity in the American robin. There is reason to believe that it is similar to that recorded in the European starling, red-winged blackbird and common grackle.

Intoxication may result from ingestion or inhalation of the compound or from dermal contact. Like other organophosphorus insecticides, chlorpyrifos acts primarily by reducing cholinesterase activity levels in certain tissues like the brain and blood. Death usually ensues one hour to nine days after exposure (Odenkirchen and Eisler 1988, Brunet and Cyr 1990). Birds with reduced levels of cholinesterase activity may survive to recover (McEwen et al. 1986).

3.0. PROCEDURE

In order to achieve objectives Nos. 1 and 2, the study was divided into two parts. In an initial stage, the dates of treatments (chlorpyrifos, herbicides and fertilizers) applied to lots in a section of Laval in the period from 1986 to 1989 was established. This was followed by the measurement of lawn use in the area under study by birds feeding on ground-dwelling prey to determine whether use was influenced by chlorpyrifos treatments. Only treatments on front lawns were considered since the back yards were not accessible for daily observations.

For objective No. 3, the study likewise consisted of two parts. In the first, use was made of data collected in 1988 by Morneau et al. (1990) involving the productivity of the first and second clutches of

86 nests. In the second, the 1986 and 1987 treatment schedules were established for each of the 6 to 12 (front and back) lots surrounding the lot where a nest had been discovered.

3.1. Study Area

Lawn Use

The Duvernay section of Laval (Quebec) was selected as the study site. Over the last few years, chlorpyrifos has been extensively used in this area, and home owners have shown a willingness to take part in this type of study (Don Gordon, President of Association Paysage Québec, personal communication). Because of the work involved in documenting the treatment schedules for each lot, it was decided to concentrate on a study site confined to a quadrangle comprising 2 275 lots within the Duvernay area.

The sector is made up of detached and, to a lesser extent, semi-detached houses. Only one street has dwellings with four apartments. The area of most of the lots in front of the houses ranges from under 50 m^2 to 150 m^2. Only a few are any larger. For a more detailed description of the area under study, consult the study by Morneau et al. (1990).

Productivity

The area where this portion of the study was conducted included the Duvernay and St-Vincent-de-Paul sectors of Laval. It is here that Morneau et al. (1990) located robin nests in the summer of 1988.

3.2. Biological Material

Lawn Use

The study focused on two of the bird species most commonly found in an urban setting, i.e., the American robin and European starling. The robin feeds on soft-bodied invertebrates, such as earthworms and insect larvae, hard-bodied invertebrates, such as coleoptera, orthoptera and lepidoptera, and berries or small fruit (Beal 1915 in Johnson et al. 1976, Hamilton 1935, Heppner 1965, Johnson 1969, Paszowski 1982, Tobin 1984, Swihart and Johnson 1986, Wheelwright

1986). The composition of this diet varies in the course of the year. There is a large consumption of invertebrates in spring during the nesting season and in the summer. Little by little, the shift is toward fruit which becomes the main source of food in the fall and winter (Johnson 1969, Wheelwright 1986). If chlorpyrifos has a serious impact on invertebrates in spring and summer, this may force robins to alter their patterns of lot use.

The European starling is a gregarious bird. Its diet is fairly similar to the robin's although more varied. Half consists of various invertebrates, but the bird also feeds on wild or cultivated fruits, seeds, plant waste and different grains, such as wheat and corn, when the individuals begin to gather in flocks in July and August (Kalmbach 1928, Dolbeer et al. 1978).

Productivity

The American robin was used to assess the effects of repeated use of chlorpyrifos on reproduction of the species.

3.3. Treatment Schedule

3.3.1. Lawn Use

Data Gathering

Four lawn-care firms (Chemlawn, Nature Plus, Pelouse Québec and Pelouse Santé) agreed to supply the information needed to establish the treatment schedule for the lots in the selected sector. The first step involved collating the data.

The number and type of treatments varied with the lot, depending on lot needs, the year and the lawn-care company.

The product application schedule for the customers of each of these four companies could not be completed for all of the lots since some of the property owners had changed companies since 1986. Others did not become customers of one of the four companies until 1988. In addition, data collection failed to yield any control lots, i.e., lots that had not received care since 1986, or lots that had been only minimally treated (fertilizers, but no herbicides or pesticides). It was therefore necessary to conduct a survey of property owners who did not use the services of these companies to determine the products that had been applied since 1986. A systematic sampling was carried out to pinpoint the lots that would be included in the survey. Every other house was visited (sometimes twice if the owner was absent at the time of the first visit). Treatments applied to rock gardens or trees and bushes were not included in the study.

The data collected in a survey may occasionally be incorrect orinaccurate. As a result, it was necessary in some instances to discard some of the information provided by the owners since it was not borne out by the condition of their lawns.

In this sector the four abovementioned companies had provided care for 41% of the lawns at least once since 1986. Twenty percent of the lots were maintained by the owners themselves, another company or a gardener. Sixty-eight lots (or 3%) were considered controls. Information was not available for the remaining 809 houses (36%) either because they were not included in the survey or else, the owners had not moved in until 1989.

Lawn Maintenance Method

Each of the four companies visit their clients' lots four times in the course of the summer. Fertilizers are applied each time. Prior to 1988, the companies applied one or more herbicides two to four times a year and an insecticide during the third visit. Since 1988, herbicides and pesticides have been applied only as needed. The first visit takes place in April, the second in June, the third in July and August and the last one in September and October. Up to 1.7 kg/100 m² of NPK fertilizer (16-2-6) are applied per year. Occasionally iron is added. The herbicides used are Killex (39 ml of active substance °2,4-D in solution with Mecoprop§ per 100 m²) or MCPA mixed with Mecoprop. Dacthal, a pre-emergence herbicide, is occasionally used once a year (up to 1.2 kg/100 m²). Chlorpyrifos (Dursban 4E) is applied in concentrations of 24 ml to 48 ml active substance/100 m² (Don Gordon, President of Association Paysage Québec, personal communication).

When the home owners hire the services of a gardener instead of one of the lawn-care firms, the gardener applies fertilizer and a granular herbicide two to four times a year and occasionally an insecticide. The owners adopt various approaches when they do the maintenance work themselves. Some apply exactly the same products as the abovementioned companies. Some occasionally apply a fertilizer or a herbicide or a pesticide, as required. Some treat the entire lawn, whereas others treat only portions. Some do not use any products. It often happens that the owners do not know what type of product has been used.

Data Processing

The lots for which the data obtained were fragmentary, irrelevant or ofdubious quality were eliminated from the study. Furthermore, none of the lots had been treated exclusively with chlorpyrifos. The types of treatments were therefore divided into homogeneous categories for a comparison of fertilizer- and herbicide-treated lots with lots treated with these same substances plus chlorpyrifos and with lots that had not been treated since 1986. Adopting thisapproach enabled us to isolate the effects of the pesticide.

Initially, the data were grouped into nine treatment categories for applications made either locally or over the entire lawn surface from 1986 to 1988 (Fig. 1).

Chlorpyrifos treatments in 1986 and 1987 were grouped together since it was impossible to determine whether the lots had or had not been treated with chlorpyrifos in 1987. To these nine categories were added the different treatment approaches adopted in 1989, i.e., the single or combined use of fertilizers, herbicides or the insecticide. Since chlorpyrifos was not always the pesticide used, and owners may have decided after three years to change the types of products or lawn maintenance firms, provision was made for increasing the number of categories to accommodate these various combinations.

However, very little chlorpyrifos was applied to the lawns in 1989 with the result that the number of treated lawns was too small for inferential analysis. The 1989 chlorpyrifos applications were therefore eliminated from the categories selected for this type of analysis, making it impossible to study the immediate effects of this insecticide. The data could be used, however, as a supplementary variable in certain exploratory analyses discussed later.

Since some of the categories were too poorly represented, only five of them were finally retained for statistical analysis (Fig. 2).

Fig. 3 shows the distribution of these categories in the sector under study.

3.3.2. Productivity

Data Gathering

Six to 12 owners of lots bordering the lot where each nest was discovered were surveyed to determine the treatments that had been applied to each of these lots in 1986, 1987 and early in 1988.

Figure 1 - Categories of Lawn Treatments Applied in Duvernay (Laval) from 1986 to 1988

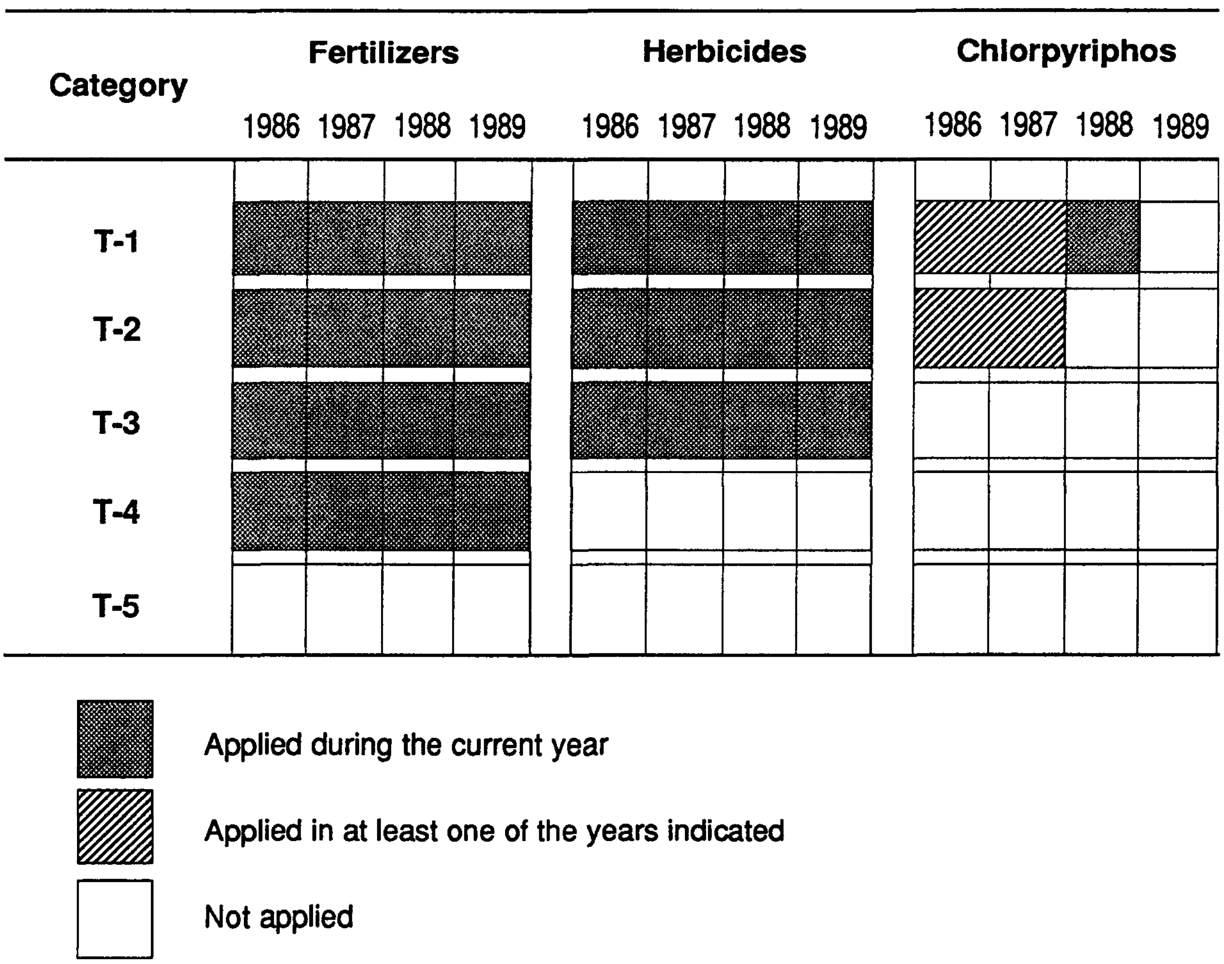
Category	Fertilizers			Herbicides			Chlorpyriphos			Other treatment(s)		
	1986	1987	1988	1986	1987	1988	1986	1987	1988	1986	1987	1988
1	■	■	■	■	■	■	□	□	■	□	□	□
2	■	■	■	■	■	■	▨	▨	■	□	□	□
3	■	■	■	■	■	■	▨	▨	□	□	□	□
4	■	■	■	□	□	■	□	□	□	□	□	□
5	■	■	■	■	■	■	□	□	□	□	□	□
6	■	■	■	■	■	□	□	□	□	□	□	□
7	■	■	■	□	□	□	□	□	□	□	□	□
8	□	□	□	□	□	□	□	□	□	□	□	□
9	□	□	□	□	□	□	□	□	□	▨	▨	▨

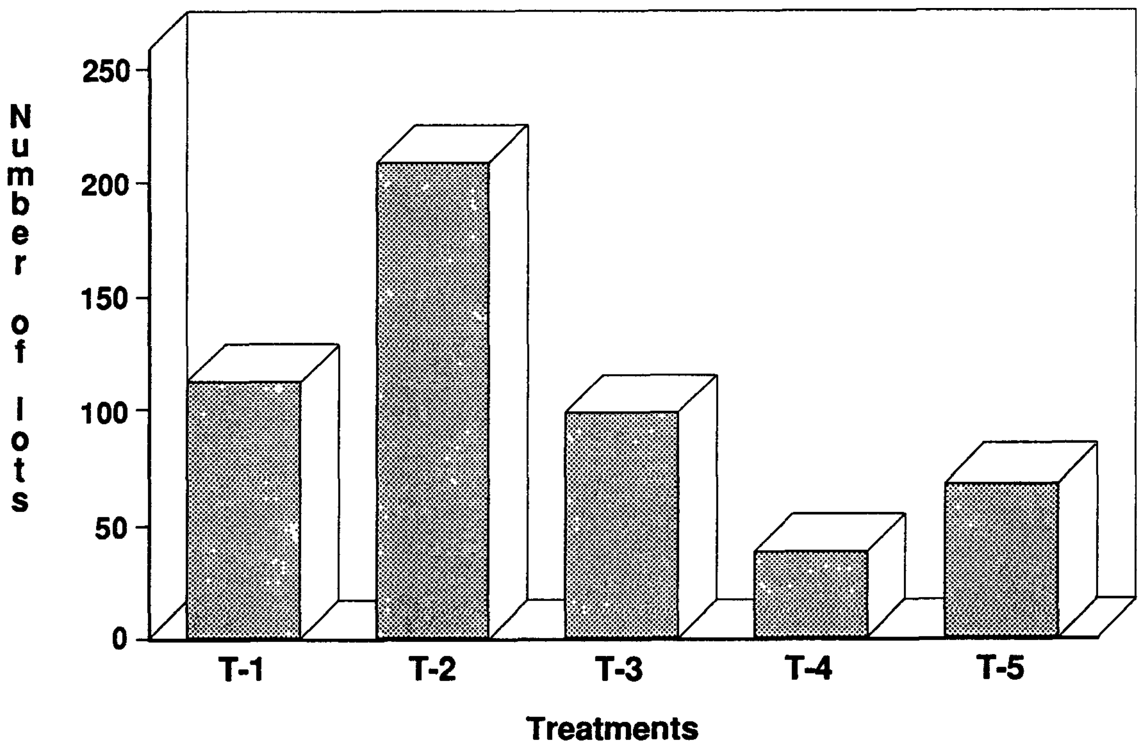
■ Applied during the current year

▨ Applied in at least one of the years indicated

□ Not applied

Figure 2 - Categories of Lawn Treatments Applied from 1986 to 1989 Selected to Study Lot Use by the American Robin in the Duvernay Sector of Laval





LEGEND

T-1 Fertilizers, herbicides from 1986 to 1989, chlorpyrifos in 1986 and / or 1987 and in 1988. n = 112

T-2 Fertilizers, herbicides from 1986 to 1989, chlorpyrifos in 1986 and / or 1987. n = 209

T-3 Fertilizers, herbicides from 1986 to 1989. n = 99

T-4 Fertilizers from 1986 to 1989. n = 38

T-5 No treatments from 1986 to 1989 (control). n = 68

Figure 3 - Distribution of Lots by Category of Lawn Treatments Applied in the Duvernay Sector of Laval from 1986 to 1989

Half an hectare around each nest adequately covers most of the feeding area of the American robin since the hunting grounds of this bird generally center around the nest (Howell 1942 and Young 1955 in Johnson 1969, Swihart and Johnson 1986) and usually extend over an area of about 0.12 hectare (Butts 1927, Young 1951 in Schoener 1968). Some individuals, however, fly as far as 1 km from their nests in search of food (Johnson 1969).

The same questions were asked as for the part of the study on lawn use. When the owners stated that they had retained the services of one of the four abovementioned companies, we consulted the archives to determine which treatments had been applied.

Data Processing

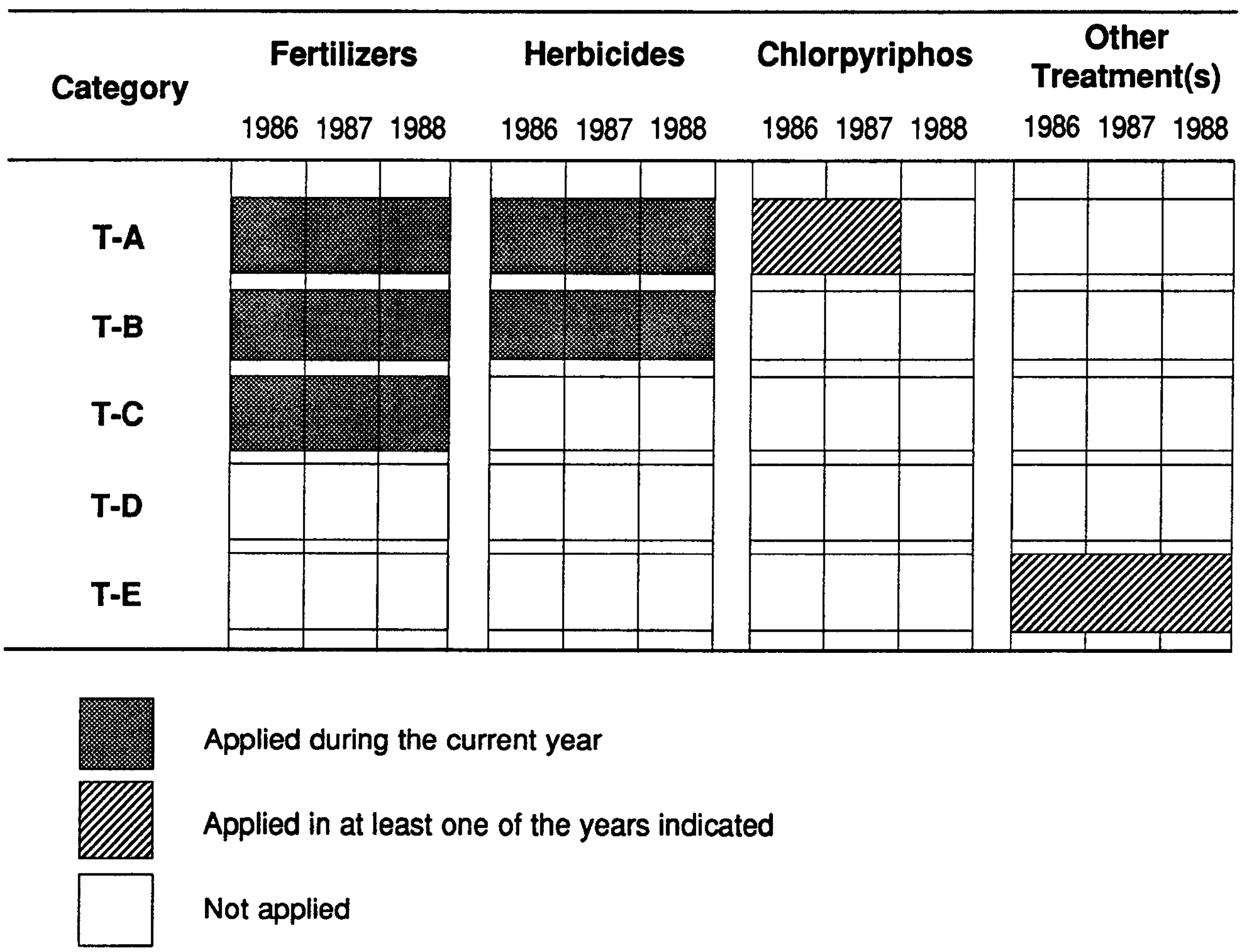
The treatment categories are the same as in Section 3.3.1. Since an estimate of productivity was made in the spring of 1988, categories of treatments effected after that period were not considered (Fig. 4).

On the whole, information was available for only a small percentage of the lots surrounding the nests (Table 1). This was due to the fact that the choice of lots was determined by nest location.

Table 1 Percentage of Lots around the Nests for Which Treatment Information was Available for the Period from 1986 to 1988

Percentage of lots for which information was available	Number of nests
0 to 19%	20
20 to 39%	39
40 to 59%	21
60 to 79%	6
80 to 100%	0

Figure 4 - Categories of Lawn Treatments Applied from 1986 to 1988 Selected for Studying the Effects of Chlorpyrifos on the Productivity of the American Robin in 1988 in the Duvernay and St-Vincent-de-Paul Sectors of Laval



3.4. Measurement Procedures

3.4.1. Measurement of Lawn Use by the American Robin and European Starling

1) Variables

In order to measure lawn use by the American robin and European starling, the presence and number of individuals from each species as well as their sex (in the case of the robin) and stage of maturity (i.e., immatures vs. adults) were recorded during 17 visits in the abovementioned sector. It is known that immature birds do not necessarily select the same feeding sites as the adults (Ficken and Ficken 1967, Howe 1974, and Dunn and Nol 1980 in Gochfeld and Burger 1984). Likewise, the males may behave differently from the females. These measurements served as a basis for calculating the relative abundance (mean number of robins or starlings seen on a lot during the 17 days of observation) and frequency of occurrence (number of days the birds were sighted on a given lot) for each of the lots in relation to the various treatment categories. The house number, street and grass length were also recorded.

2) Itinerary and General Mode of Operation

The itinerary was laid out ahead of time for the sake of objectivity. For each observation run, two observers covered half of the sector, using bicycles. They rode at a constant speed, keeping movement and noise to a minimum so as not to startle the birds.

The observer scrutinized a single side of the street at a time for consistency in the observation procedure. He would scan an area from the fifth house ahead of him to the lawn at his side, thereby increasing the chances of sighting the birds. By adopting this approach, it was possible to detect the more timid individuals which fly off well before the observer reaches the site.In order to minimize the risk of disturbance, the other side of the street was scrutinized after the observer had proceeded to another block.

As the day unfolds, the light intensity increases and the human noise level rises. Bird activity may be influenced by these factors (Welty 1975). Each observer therefore modified his rounds each time, beginning the count at a at a different place in the itinerary.

There were few lots with robins. In order to increase the numbers, a note was made of any robin or starling sighted on the itinerary once the observation run was completed, using a different code from the one employed for the regular observations. Sightings under these conditions were less likely to occur and could not be used for the same analyses, but they provided additional information on lawn use by the American robin and European starling.

3) Observation Time

After a few days, it became clear that the best time for observing the birds was between 5 and 8 o'clock (Eastern daylight saving time) since this was when the target species were the most active. This also corresponded to the time of earthworm activity. Earthworms occur at the surface of the ground mainly at dawn and dusk and after a rainfall or after watering and it is then that the robins are most likely to find them (Heppner 1965).

4) Observation Dates

In order to determine whether chlorpyrifos had an immediate effect on the target species (Objective No. 1), the observation period had to be selected from the time of year when the lawns were sprayed (July, August and September). This period also favoured achievement of Objective No. 2. However, it is essentially during the nesting season and shortly thereafter that robins and starlings feed on earthworms and other arthropods (Johnson 1969, Wheelwright 1986). All of the lots in the sector were therefore systematically observed in the period from July 4 to August 11 to obtain an optimum number of birds as well as an optimum number of lawns with birds since later in August the nesting season would be over and there would be fewer sightings of robins and starlings (Johnson 1969, Morneau et al. 1990).

At that time of year, however, there is fairly little precipitation (Environment Canada 1989). Staggering the observations over several daysincreased the chances of having rainfall which, in turn, would cause the earthworms to rise to the surface (Heppner 1965), thereby attracting the robins.

3.4.2. Rival Hypotheses

There is a plausible hypothesis that treated lots are mown more often than others. It is safe to assume that people concerned with having nice lawns will spare no effort. These lots may therefore be the best groomed (short and freshly mown lawn), the largest, etc. In order to eliminate the effects of these rival hypotheses, certain other parameters were measured.

Grass Length

According to Eiserer (1980), the first few minutes after a lawn has been mown are favourable to the American robin since prey is then exposed to the predator's view. Likewise, short and/or sparse grass help the bird to spot the prey (Heppner 1965, Eiserer 1980).

On July 3, just prior to the observation runs, the length of the grass in the front yard of one out of every four lots was measured. Grass length was divided into three classes:

short: under 5 cm
average: 5 to 8 cm
long: over 8 cm.

The observer made a note if the lawn appeared to have been cut within the previous 24 hours. In addition, lawn density (thick or sparse growth) was recorded. As the growth of over 95% of the lawns were considered dense, this variable was eliminated from the analyses.

These observations were recorded once only. They provide some idea of the distribution of the grass-length classes. A comparison between the availability of each class and use by the birds, as recorded during the series of observations, is possible only if it is assumed that the distribution pattern recorded on July 3 remained the same throughout the week and all during the summer. If this assumption is true, then it can be determined if grass length influences lot use by the robin and if it masks or magnifies the effect of chlorpyrifos. It is likely, however, that there is some variation in the distribution. Caution is therefore needed in interpreting the results.

Areas, Plant Strata and the Extent of Enhancement for Human Use

Several parameters may influence an animal's choice of a site as a feeding ground. It is generally accepted that landscaping strongly influences bird species, especially the Passeriformes, in their selection of a site, since it provides nesting sites, song perches and hiding places (Smith and Shugart 1987). In an urban area, the following factors may influence site selection: lawn size, plant stratification and the intensity of enhancement for landscaping and human use.

One hundred and twenty-five lots where no robins were detected during the observation runs and 125 lots where robins were sighted once only were selected by means of a simple random sampling procedure. All of the 153 lots where robins were observed at least twice were retained. In the front of each of the lots, the following three variables describing the landscaping were measured.

Area Classes for Front Lawns Visible from the Street

1- under 50 m^2

2- between 50 and 150 m^2

3- over 150 m^2.

Plant Stratification Classes

1- no vertical structure
2- presence of one or more trees and/or one or more decorative bushes under 3 meters tall
3- presence of trees over 3 meters tall but no bushes
4- presence of a few trees over 3 meters tall and bushes
5- presence of several trees over 3 meters tall, bushes, hedges, flowers, etc.

Classes Describing Enchancement for Lanscaping and Human Use

Elaborate: lot containing an extensive rock garden with many flowers and rocks, a very large driveway, a broad walk;

Moderate: lot with ordinary landscaping, a simple driveway, a small walk, etc.

If one of these parameters is significant in the robin's choice of feeding sites, its potential for masking or magnifying the effect of chlorpyrifos can be determined.

3.4.3. Measurement of Productivity

Nest productivity has been defined as the number of young birds that are still alive at the time of dispersal. This variable was measured in the nests discovered in the Duvernay and St-Vincent-de-Paul sectors of Laval from May 11 to June 23, 1988 when the fledglings were roughly 11 days old (Morneau et al. 1990). The number of fledglings surviving at the time of dispersal is related to environmental conditions and to the adult females as well as to the number of eggs laid. It has been shown that the latter decreases as the nesting season progresses (Howard 1967, Welty 1975). In 1988, it was established that the robins had produced two clutches, with an average of nearly 4 eggs in the first and of 3 eggs in the second (Morneau et al. 1990). The two clutches were therefore considered separately in the statistical analysis of productivity. Morneau et al. (1990) also suggested that diazinon probably affected productivity. Diazinon-treated nests were therefore eliminated from the study.

3.5. Statistical Analysis

3.5.1. Lawn Use in Relation to Treatments

The relative abundance of robins and starlings and frequency of occurrence were calculated for the immature birds and adults (females and males in the case of the robins) and for the total number of both species of birds found on all the lots where at least some information on treatment (or the absence of treatment) was available.

Two types of analysis were selected to make optimum use of most of the data. Inferential analyses (chi square and other types) were applied for a comparison of the frequency of occurrence of the birds in the five treatment categories chosen in Section 3.3.1 (Fig. 2). Restricting analysis to these categories meant that only the observations recorded in 526 of the 2 275 lots (23%) in the sector could be used. For exploratory purposes, correspondence analysis was carried out to reveal differences that might exist between the relative abundance values for different treatments that were not grouped by class or year. This type of analysis makes it possible to visualize the interrelations between qualitative or semi-quantitative variables (Benzecri et al. 1973, Legendre and Legendre 1984). Table 2 provides a comparison of these two types of analysis.

Table 2. Comparison of the Specific Characteristics of Inferential and Exploratory Analysis

	Inferential Analysis	Exploratory Analysis
Type of analysis	Comparison of frequency	Correspondence analysis
Objectives	Compare lawn use in relation to categories of treatment with and without chlorpyrifos	Show different degrees of lawn use in relation to each treatment (fertilizers, herbicides, chlorpyrifos and control) for each year.
Categories used	Treatment categories T-1 to T-5 (Table 2)	Individual treatments for each year
Variables used	Frequency of occurrence	Mean of relative abundance values
Number of lots	526 lots (23% of lots in the sector)	1 482 lots (65% of lots in the sector)
Specific characteristics	Only lots consistently treated over the 4 years were considered	All of the lots for which there were some data on the products applied were considered
	Probability associated with the results	No probability associated with these results. The analysis reveals trends.

Exploratory Analysis

In order to be able to observe temporal relationships with correspondenceanalysis, it was necessary to transform the data matrix. The original data table contained the treatments applied each year (even if the information was occasionally incomplete), the frequency of occurrence and relative abundance of the immature and adult robins and starlings. In the case of the robins, both the males and females were considered separately. All of the treatments for a single year were grouped into one variable for each of the lots. To illustrate:

TREATMENTS				ABUNDANCE								FREQUENCY OF OCCURRENCE							
				Robins				Starlings			2 species	Robins				Starlings			2 species
1986	1987	1988	1989	Im	M	F	Tot	Im	Ad	Tot	Total	Im	M	F	Tot	Im	Ad	Tot	Total
First address																			
F	FI	FHI	F	2	1	0	3	0	0	0	3	1	1	0	1	0	0	0	1
Second Address																			
FHI	FH	FH	FH	0	0	0	0	3	3	6	6	0	0	0	0	1	1	2	2
.																			
.																			
.																			

In order to separate the various treatments applied each year, a new datamatrix had to be constructed. The above example then became:

FIRST ADDRESS

	ABUNDANCE								FREQUENCY OF OCCURRENCE							
	Robins				Starlings			2 species	Robins				Starlings			2 species
	Im	M	F	Tot	Im	Ad	Tot	Total	Im	M	F	Tot	Im	Ad	Tot	Total
F86	2	1	0	3	0	0	0	3	1	1	0	1	0	0	0	1
H86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F87	2	1	0	3	0	0	0	3	1	1	0	1	0	0	0	1
H87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I87	2	1	0	3	0	0	0	3	1	1	0	1	0	0	0	1
R87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.																
.																
.																

SECOND ADDRESS

	ABUNDANCE								FREQUENCY OF OCCURRENCE							
	Robins				Starlings			2 species	Robins				Starlings			2 species
	Im	M	F	Tot	Im	Ad	Tot	Total	Im	M	F	Tot	Im	Ad	Tot	Total
F86	0	0	0	0	3	3	6	6	0	0	0	0	1	1	2	2
H86	0	0	0	0	3	3	6	6	0	0	0	0	1	1	2	2
I86	0	0	0	0	3	3	6	6	0	0	0	0	1	1	2	2
R86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F87	0	0	0	0	3	3	6	6	0	0	0	0	1	1	2	2
H87	0	0	0	0	3	3	6	6	0	0	0	0	1	1	2	2
I87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.																
.																
.																

The mean value for relative abundance and the mean value for frequency of occurrence were then calculated for each treatment and each year. The variables for this new matrix then became the mean values for frequency of occurrence and relative abundance on the lots (16 variables). The elements became the treatments that had been applied (fertilizers, herbicides, chlorpyrifos, no treatment) each year (14 lines):

	ABUNDANCE								FREQUENCY OF OCCURRENCE							
	Robins				Starlings			2 species	Robins				Starlings			2 species
	Im	M	F	Tot	Im	Ad	Tot	Total	Im	M	F	Tot	Im	Ad	Tot	Total
F86	0,0059	0,0084	0,0085	0,0248	0,0023	...										
H86	0,0058	0,0083	0,0078	0,0241	0,0023	...										
.																
.																
.																

A lot may have been treated with herbicides and fertilizers in the course of a given year, thereby making these input lines interdependent. Correspondence analysis is still valid since it is used only to reflect the way data are organized in relation to one another. If the data are not independent, the analysis will show the relationship between them while bringing to light other relationships that are difficult to detect by a simple observation of the data table (Benzecri *et al*. 1973).

Inferential Analysis

In order to determine whether the American robin or European starling used treated and untreated lots in different proportions, the frequency of occurrence of the robins and starlings in each treatment category was subjected to a chi-square analysis. When differences were detected, a contrast test revealed preferred or rejected categories. Since the proportion of lots was not the same in all of the treatment categories, either or both of the species may have used some treated or untreated lot categories in equal or different proportions as a result of differences in availability. The proportion of availability was therefore calculated for each treatment category and compared to the proportion of use by the robins (sensitivity test). When differences emerged, Bonferroni's z-test (Neu et al. 1974) pinpointed preferred or less-used categories.

3.5.2. Characteristics of the Feeding Sites

Grass Length

A sensitivity test was applied to determine whether the American robin favoured certain grass lengths. In this case the proportion of availability of each class of grass length, as determined on July 3, was compared to theproportion of use by the American robin. When test results showed significant differences between observed and theoretical proportions, the preferred proportion was determined by means of Bonferroni's z-test.

Subsequently, when a preference was found for a grass-length class, analysis determined whether this masked a greater or lesser use of treated lots. This hypothesis was tested by means of a G-test, followed by a contrast test, to find which class was more or less favoured than the others.

The number of robins of all ages on lots with short, medium, long and freshly cut grass was used for this analysis.

Area, Plant Stratification, Extent of Enhancement for Human Use

Exploratory Analysis

In an initial phase, the relationship between lawn area, plant stratification, and extent of enhancement, on the one hand, and lawn use by the American robin and European starling, on the other, was established on a descriptive basis. The variables were qualitative (plant stratification, extent of enhancement) or semi-quantitative (lawn area, relative abundance and frequency of occurrence). Correspondence analysis was therefore carried out to so that the interrelations among the variables could be visualized.

Inferential Analysis

Chi-square analysis to determine whether American robins preferred certain types of enhancement was followed by a contrast test when there were significant differences between observed and theoretical proportions. For these analyses, use was made of only the frequency of occurrence of robins of all ages since it was on the basis of this information that lots had been selected to measure the enhancement variables (See Section 3.4.2). When differences were observed, the same analyses were applied to test the potential of these types of enhancement for masking or magnifying the effect of one type of treatment or another.

3.5.3. Effect of Treatments on the Productivity of the American Robin

For each nest, the proportion of lots per treatment category was calculated.

Exploratory Analysis

On an exploratory basis, correspondence analysis was performed to establish the relations between treatment intensity and productivity.

Inferential Analysis

Kendall's rank coefficient (Kendall's tau), which determines the correlation between semi-quantitative variables, was measured to quantify the relationship between productivity, clutch order and intensity of treatments around the nests (Scherrer 1984). The Wilcoxon-Mann-Whitney test was also used to compare the mean percentage values of chlorpyrifos-treated lots with poor productivity (0, 1 and 2) and of those with high productivity (3 and 4) (Scherrer 1984).

4.0. RESULTS

4.1. Lawn Use by the American Robin and European Starling

A count of birds detected along the designated route in accordance with the measurement procedure yielded 806 sightings of American robins on 399 different lots out of the 2 275 lawns in the sector during the series of observations conducted from July 4 to August 11, 1989. Robins were observed 184 times on 142 of the 526 lots classified as T-1 to T-5 (Table 3).

The European starling was sighted 54 times on 43 of these 526 lots and both species were spotted 234 times on 168 of the 526 lots (Table 3). All throughout the observation campaign, the observers also recorded the presence of robins on all of the lots, including those in front of which they had already passed or lots on the other side of the street. This increased the number of robins from 142 to 197 on the 526 lots falling into one of the T-1 to T-5 categories.

There were fewer robin sightings on the lawns in the study sector than anticipated. There may be several reasons for this, most of them related to the observation period selected. In their study conducted during the nesting season, in May and June, 1988, Morneau et al. (1990) found a large number of robin nests in the sector under study. There were many robins on the lawns and large numbers of males sang to defend their territories. It was erroneously assumed that there would be as many, if not more, robins on the lawns in July because of the new crop of young.

This time of year, however, corresponds to slackened earthworm activity due to a reduction in available decomposable food and lower soil moisture levels (Gérard 1967, Lee 1985, Garceau et al. 1988). During the series of observations, the Dorval weather station recorded only 8.4 cm of precipitation, 60% of which fell after August 4 (Environment Canada 1989). It is also at this point in the summer that the American robin begins to change its feeding habits. It consumes fewer invertebrates and more fruit (Johnson 1969, Wheelwright 1986). As a result, there may have been fewer robins on the ground than in the fruit trees. During the observation period, for instance, 30 sightings of robins were made in fruit trees (ornamental cherry and apple trees). Furthermore, in the northeastern part of North America, fruit seems to make up a larger proportion of the diet of immature robins than of the adults in the period from June to September (Wheelwright 1986). The immatures we expected to find on the lawns had probably moved to more favourable feeding grounds (Johnson 1969).

Table 3 **Number of Lots with at Least One Sighting of American Robins or European Starlings during 17 Visits to the Duvernay Sector in the Summer of 1989 in Relation to the Types of Treatment Applied[1]**

Species	T_1[2]	T_2	T_3	T_4	T_5	Total
Juv. robins	11 (15)	13 (20)	6 (10)	4 (4)	5 (8)	39 (57)
Robins	17 (27)	23 (37)	11 (13)	4 (4)	6 (12)	61 (93)
Robins	11 (15)	29 (39)	6 (13)	8 (8)	8 (13)	62 (88)
Tot. robins	35 (45)	56 (83)	22 (32)	11 (11)	18 (26)	142 (197)
Tot.Starlings	9	14	10	1	9	43
Tot. birds	42	63	29	11	23	168

1. The figures in parentheses represent the total number of robins counted along the itinerary both in accordance with the measurement procedure and without applying the procedure. Since this type of count was not used for the starlings, there are no figures in parentheses for total starling numbers and total bird numbers.
2. T_1- fertilizers, herbicides from 1986 to 1989, chlorpyrifos in 1986 and/or 1987 and in 1988
   T_2- fertilizers, herbicides from 1986 to 1989, chlorpyrifos in 1986 and/or 1987
   T_3- fertilizers, herbicides from 1986 to 1989
   T_4- fertilizers from 1986 to 1989
   T_5- no treatment from 1986 to 1989 (control)

4.2. Effect of Treatments on Lawn Use by the American Robin and European Starling

No chlorpyrifos was sprayed prior to the observation campaign and during the campaign proper, only 10 lawns were sprayed with the chemical. It was therefore not possible to check the immediate and direct effects of the compound (Objective No. 1). Only the effects of repeated use over the previous summers could be examined (Objective No. 2).

Exploratory Analysis

For purposes of analysis, the data for chlorpyrifos applications from 1986 to 1988 were grouped to give added weight to this type of treatment (Fig. 5). Chlorpyrifos applications in 1986-1987 and 1988 were, nonetheless, represented in the figure as supplementary variables although they did not contribute to the analysis. The 1989 application was also represented, but its position could not be interpreted because of the small number, i.e., 10, involved in the calculation of mean relative abundance values.

Relative abundance values were recoded as binary variables for classification in a logical table with only 0 and 1 values. 0 represented low abundance values and 1, high values. Each class interval was determined by means of a frequency diagram to give a relatively equal weight to each class (similar numbers).

With an analysis of this type (Fig. 5), certain trends emerged. Appendix 1 shows the contributions made by each parameter in the construction of each of the axes. The first two factor axes alone account for 73% of the variability of the scatter of points. This projection is therefore a very good representation of the arrangement of the data. It brings out the temporal structure of the treatments by separating them according to year, so that they occur in succession on an arc on axes 1 and 2. The factor representation shows that the fertilizer used one year was often applied concurrently with a herbicide since both elements always appeared very close together on the graph. These treatments were also associated, although not so intimately, with chlorpyrifos applications in the same year, thereby reflecting the fact that each pesticide selected was rarely used alone. In addition, this representation also shows that treatments carried out one year were also linked to treatments applied in the year before and after. Customers generally retain the services of a company for at least 2 consecutive years. This suggests therefore that a greater number of 1986 customers still engaged the services of these firms in 1987 than in 1989.

The analysis also suggests that immature robins and starlings were more frequently sighted than the adults on lawns that had either never been treatedwith fertilizers or herbicides or else, had only recently (1989) been treated with these substances. Adult female robins were observed more often on lots treated in 1986 and 1987 with fertilizers and herbicides and probably chlorpyrifos, too, since at that time, more liberal use was made of pesticides. On the graph, the total pesticide parameter indicates the position of chlorpyrifos applications over three years. This parameter, along with other pesticide parameters, i.e., chlorpyrifos applications in 1987 and chlorpyrifos applications in 1988, (supplementary variables[1]) occur relatively near the great

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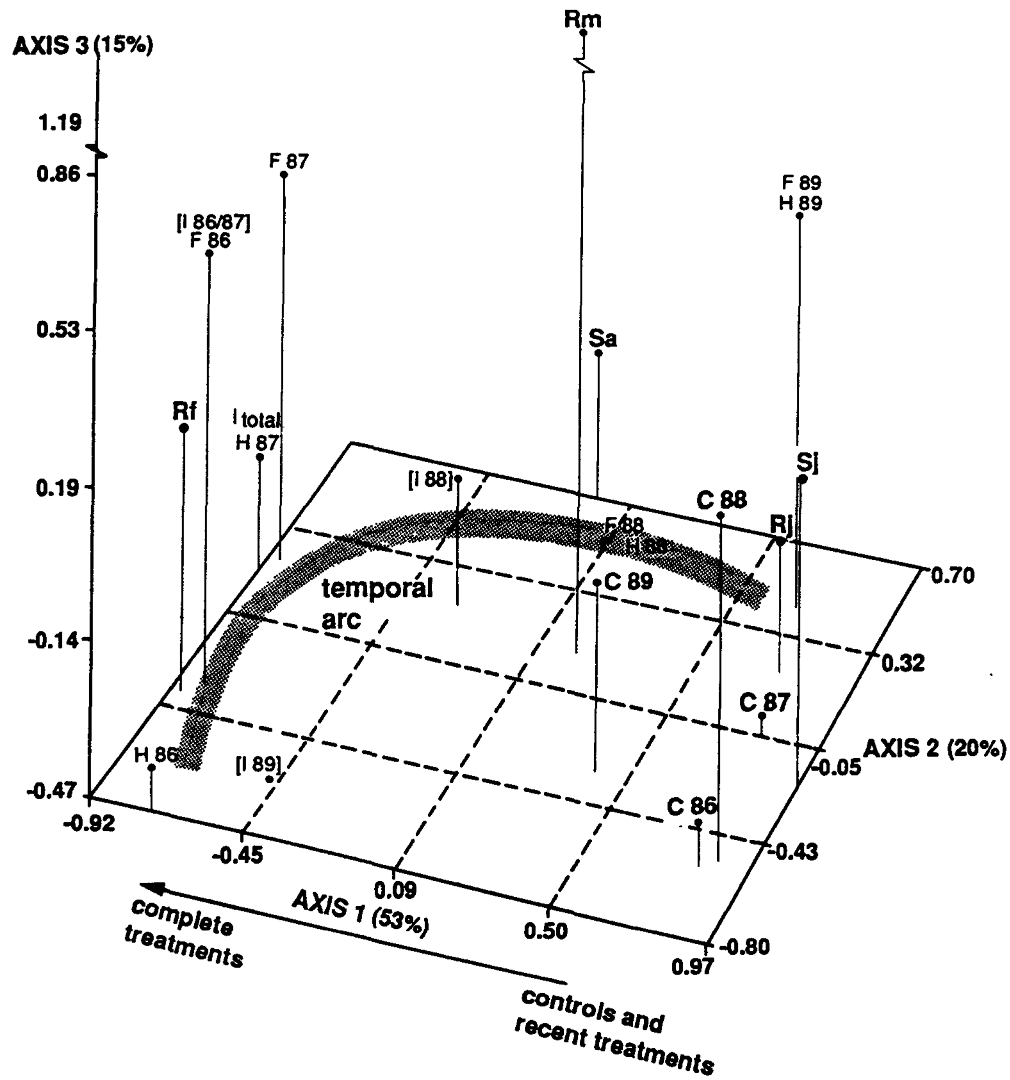
[1] Only the total pesticide parameter contributed to formation of the axes. The position of the parameters, I_{87} and I_{88}, was calculated and projected on the graph in relation to the other parameters, but the position of the other parameters was not calculated from these two parameters.



LEGEND

Rj	Juvenile robins	**F 86**	
Rf	Female robins		Treatment year
Rm	Male robins		Treatment
Sj	Juvenile starlings	F	Fertilizer
Sa	Adult starlings	H	Herbicide
		I	Chlopryrifos
		C	No treatment
[ ]	Supplementary variables	I_{total}	Total for period from 1986 to 1988

Figure 5 - Correspondence Analysis Illustrating the Relation between the Highest Relative Abundance Values for American Robins and European Starlings Measured in the summer of 1989 and Treatments Applied to the Lawns in Duvernay (Laval) from 1986 to 1989

abundance of females, suggesting a positive relation. There were more sightings of adult starlings on lawns treated in 1988. Adult male robins failed to display a preference for any treatment since as a group they occurred in the middle of the graph and did not contribute to the formation of either of the two axes.

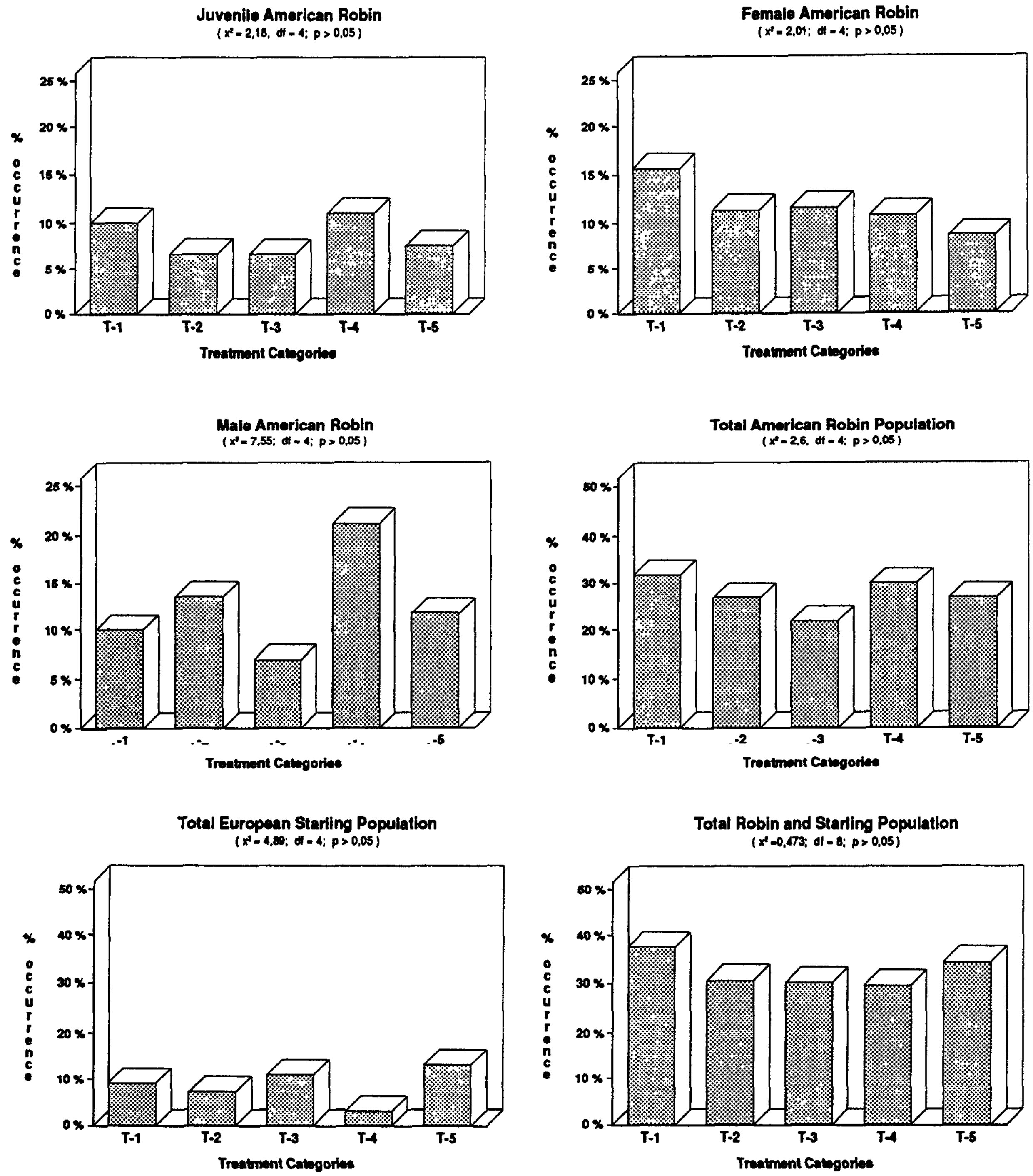
These trends cannot be tested by inferential analysis since it wasimpossible to create a treatment category from existing data. Too few lots were treated with fertilizers and herbicides in 1986 or 1987 alone for statistical analysis. Moreover, the very process of correspondence analysis(recoding of data into two classes with similar numbers) tends to maximize variation in the phenomena.

Inferential Analysis

On the basis of counts conducted with and without the measurement procedure, chi-square analysis comparing the proportion of birds occurring in each treatment category failed to reveal a clear preference for or rejection of any particular treatment category by immature or adult robins and starlings. Furthermore, the bird count by the measurement procedure revealed virtually the same proportion of birds in the different categories (Fig. 6), except in the case of the male robin which seemed to favour T-4 lots (lots treated solely with fertilizers). The preference was insignificant.

The proportion of lots was not the same for each treatment category. One or both of the bird species may have used certain treated or untreated lot categories in different or similar proportions as a result of this difference in availability. A sensitivity test was applied (Scherrer 1984) in order to determine if use of the lawns in the various treatment categories by the robins differed from the proportion of availability. None of the trends shown provedsignificant (Fig. 7).

It should be pointed out that by grouping the lots into 5 major treatment categories, it was not possible to analyse separately the relations between each of the applications and differential use of the lots by each of the groups of birds.



LÉGENDE

T-1 Fertilizers, herbicides from 1986 to 1989, chlorpyrifos in 1986 and / or 1987 and in 1988. n = 112

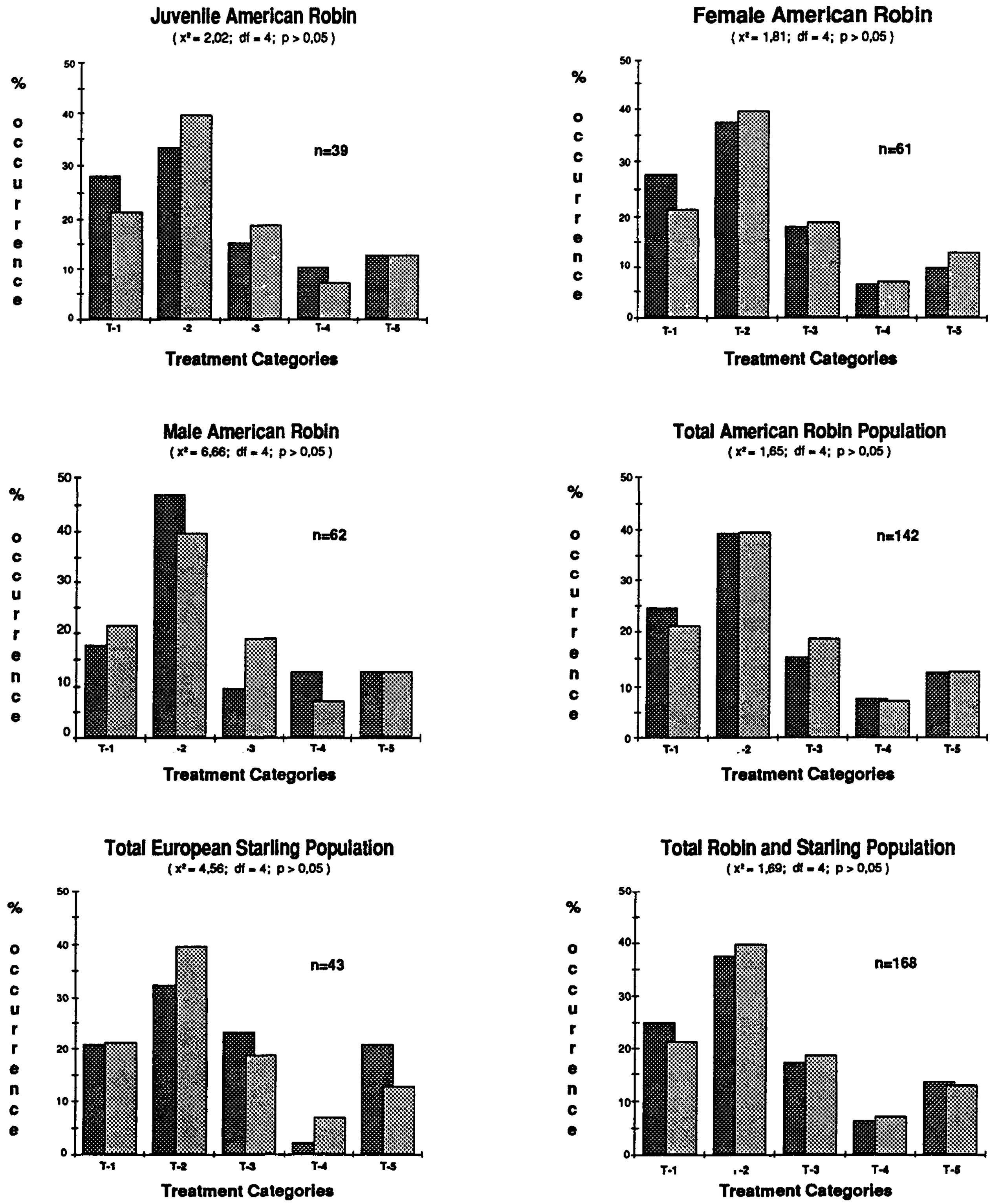
T-2 Fertilizers, herbicides from 1986 to 1989, chlorpyrifos in 1986 and / or 1987. n = 209

T-3 Fertilizers, herbicides from 1986 to 1989. n = 99

T-4 Fertilizers from 1986 to 1989. n = 38

T-5 No treatment from 1986 to 1989 (control). n = 68

Figure 6 - Percentage of Lots with at Least One Sighting of the Species Studied in the Course of 17 Visits in the Summer of 1989. Sex and Age Distribution as a Function of Treatments Applied in Duvernay (Laval) from 1986 to 1989.



LEGEND

T-1 Fertilizers, herbicides from 1986 to 1989, chlorpyrifos in 1986 and / or 1987 and in 1988

T-2 Fertilizers, herbicides from 1986 to 1989, chlorpyrifos in 1986 and / or 1987

T-3 Fertilizers, herbicides from 1986 to 1989

T-4 Fertilizers from 1986 to 1989

T-5 No treatment from 1986 to 1989 (control)

Observed proportions

Available proportions

Figure 7 - Occurrence of American Robins and European Starlings in Percentage Values as a Function of Lot Availability in Each Treatment Category

4.3. Characteristics of the Feeding Sites

4.3.1. Grass Length

In order to determine the proportion of availability of each class of grass length in the sector, grass length was systematically recorded on every fourth lot (567 lots in all) on July 3. The proportions consequently represent the state of the grass on only one given day in the study period. During the observation rounds, this parameter was also recorded whenever a robin was spotted on a lot, thereby providing the means for comparing the use of different grass lengths with their availability, i.e., availability, as recorded on July 3, which we assumed to be representative of the situation existing throughout the study in the field (Fig. 8). Since observation rounds were carried out on every day of the week and not just on a Monday, as was the case for the July 3 observation, the comparison can only serve as an indication of trends.

The robins did not use the lawns in the proportions in which they were available (Table 4). Compared to the availability of lawns with short grass, the robins made significantly higher use of this lawn class (Bonferroni's z-test, $\alpha = 0.05$). Conversely, they were sighted on lawns with medium-length and tall grass in proportions that were significantly lower than anticipated ($\alpha = 0.05$). On freshly cut lawns, they were observed in proportions corresponding to availability ($\alpha > 0.05$).

Table 4 Lawn Use by the Total Robin Population Observed as a Function of the Availability of Each of the Grass-Length Classes ($X^2 = 51.77$; df = 3; $p < 0.01$)

Lengths	Observed frequencies	Observed proportions (%)	Theoretical frequencies	Theoretical proportions (%)	Confidence intervals for the observed proportion[1] (p = 0.05)
Short	660	82.1	568.4	70.7	$0.7872 \leq p \leq 0.8548$
Medium	118	14.7	194.6	24.2	$0.1158 \leq p \leq 0.1782$
Tall	8	1.0	18.5	2.3	$0.0012 \leq p \leq 0.0188$
Freshly cut	18	2.2	22.5	2.8	$0.0091 \leq p \leq 0.0349$
Total	804	100	804	100	

1. These intervals were compared to the theoretical proportions. If the theoretical proportions were included in the interval, the class was neither preferred nor rejected.

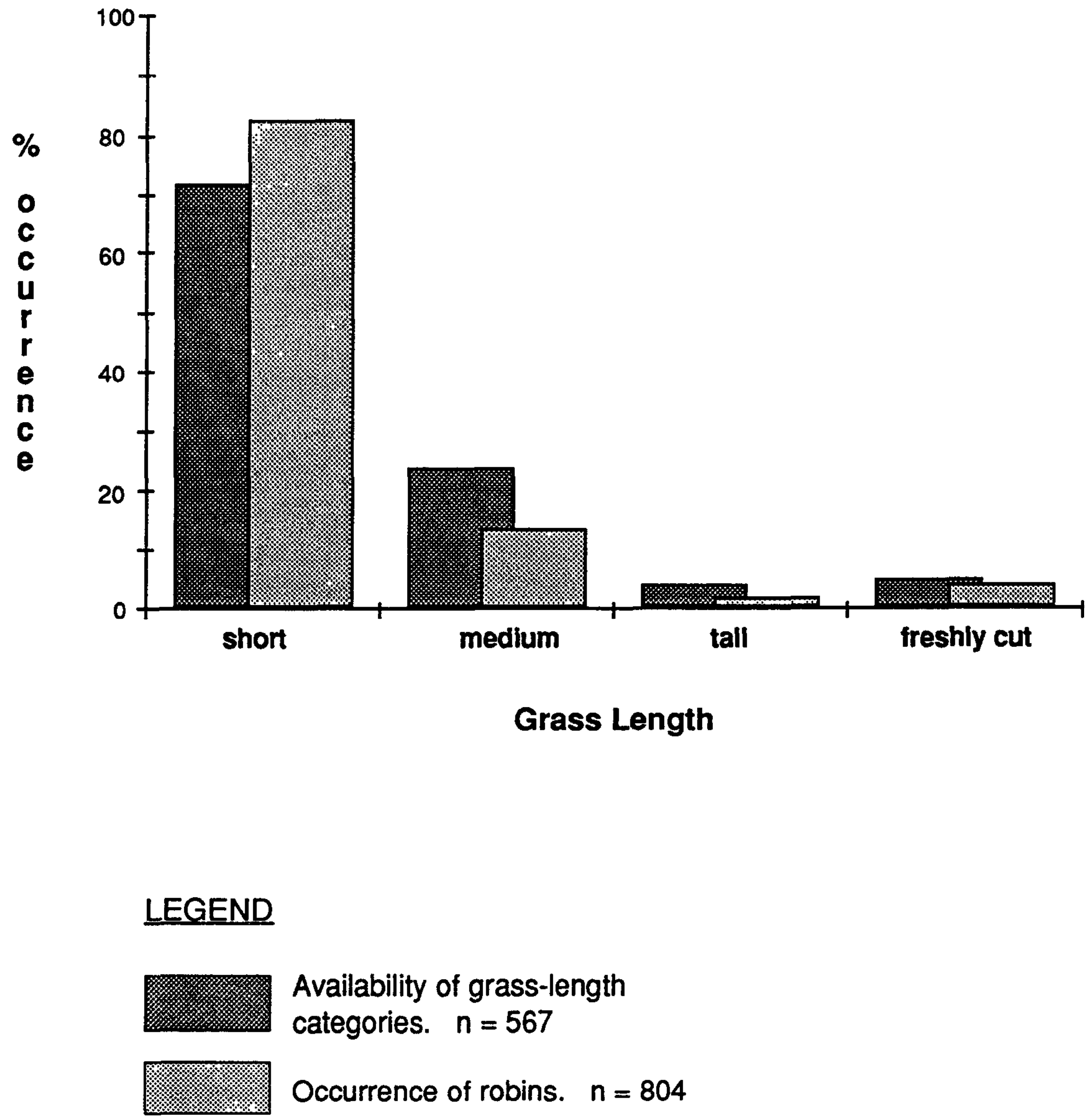


Figure 8 - Distribution of American Robin Sightings as a Function of Grass-Length Classes and Class Availability, as Determined on July 3, 1989

In order to determine whether there was a homogeneous distribution of grass heights among the lawn-treatment categories, only the short-grass and medium-grass classes were retained. All of the other grass classes were too poorly represented. Short- and medium-grass classes were not evenly distributed among the various treatment categories (Fig. 9). In fact, compared to the proportion of medium-grass lawns, there was a significantly higher proportion of short-grass lawns in treatment category 1 than in treatment category 3.

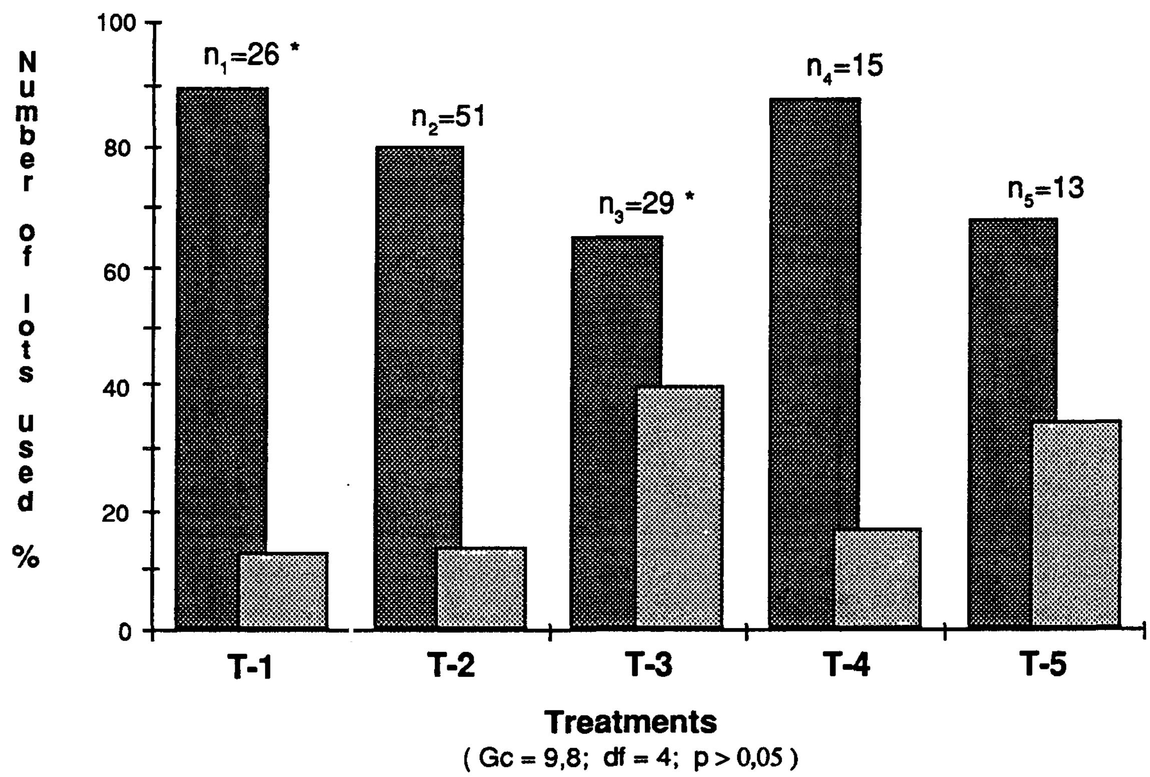
These findings suggest that robins use lawns with short grass more often than lawns with medium-length or long grass. Since the grass in the T-1 lawns was generally shorter and the grass in the T-3 lawns, medium in length, this would explain, in part at least, why the robins did not seem to favour or avoid any of the categories. Thus, in order to determine if grass length masked or magnified the effect of chlorpyrifos, only observations recorded on lawns with short grass were retained. By means of a new sensitivity test, it was possible to compare lawn use by treatment category with the proportion of available lots with short grass in each of the treatment categories (Fig. 10). Once again, the robins did not seem to favour or avoid the lawns in any particular treatment category.

4.3.2 Area, Plant Stratification, and Extent of Enhancement for Human Use

Lawn areas, plant stratification and the extent of enhancement for landscaping and human use were measured in the front yards of 396 houses (Table 5). Forty-four percent of these yards were less than 50 m^2. Forty-nine percent ranged in area from 50 to 150 m^2 and the remaining 7% exceeded 150 m^2. There were several trees and bushes on 61% of the lots, whereas 32% had only a few trees or bushes. In most of the yards (88%), enhancement for landscaping and human use was moderate, whereas in the others, it was more elaborate with double driveways, elaborate rock gardens and large walks.

For correspondence analysis to reveal the data structure more effectively, the variables were first assigned to one of two classes. For frequency of occurrence, 0 represented the absence of birds and 1, the presence of birds. Class intervals were selected to maximize the conditional probability profile.

Since the enhancement variables had already been assigned to classes, 0 represented the weakest classes for each variable and 1, the strongest. The data matrix did not undergo any further transformations since it represented 396 lots for which each of the variables (enhancement, frequency of occurrence and relative abundance of the bird species) had been measured.



* Lawns with short and medium-length grass in treatment categories **T-1** and **T-3** were used in significantly different proportions.

LEGEND

T-1 Fertilizer, herbicide from 1986 to 1989, chlorpyrifos in 1986 and / or 1987 and in 1988

T-2 Fertilizer, herbicide from 1986 to 1989, chlorpyrifos in 1986 and / or 1987

T-3 Fertilizer, herbicide from 1986 to 1989

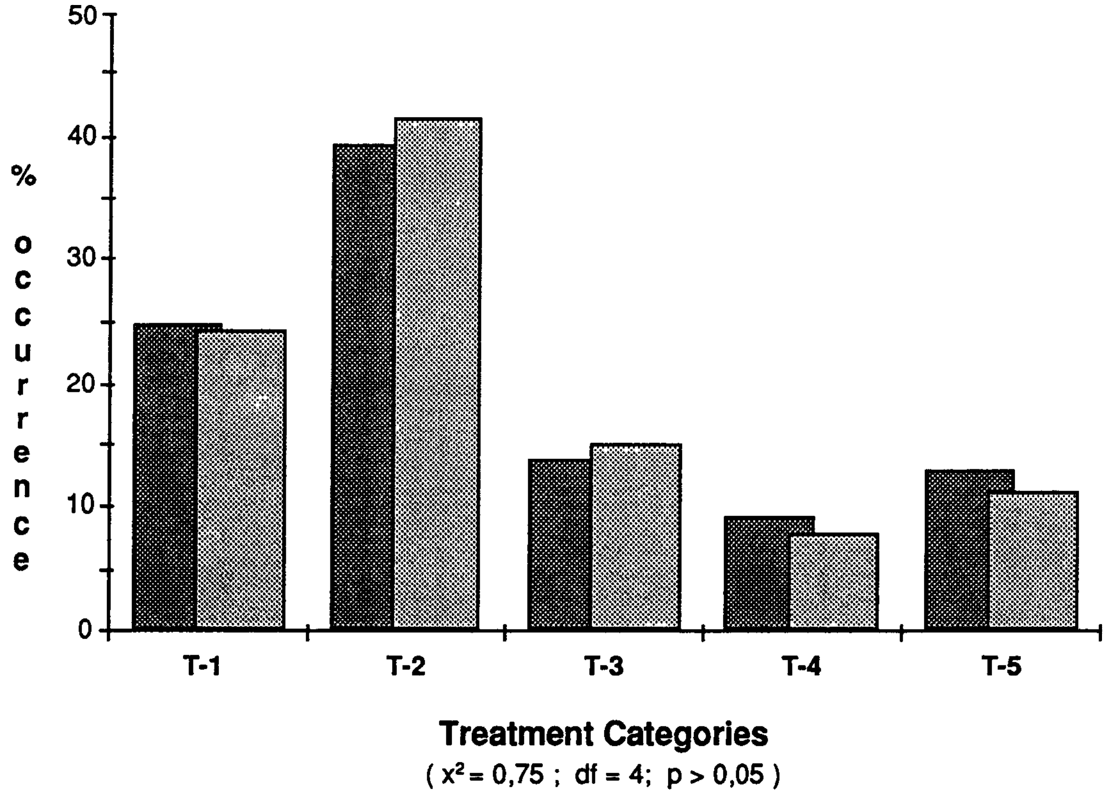
T-4 Fertilizer from 1986 to 1989

T-5 No treatment from 1986 to 1989 (control)


Short grass


Medium-length grass

Figure 9 - Percentage of Lawns with Short and Medium-Length Grass Used by the American Robin in the Summer of 1989 as a Function of Lawn Treatments in Duvernay (Laval) from 1986 to 1989



LEGEND

T-1 Fertilizer, herbicide from 1986 to 1989, chlorpyrifos in 1986 and / or 1987 and in 1988

T-2 Fertilizer, herbicide from 1986 to 1989, chlorpyrifos in 1986 and / or 1987

T-3 Fertilizer, herbicide from 1986 to 1989

T-4 Fertilizer from 1986 to 1989

T-5 No treatment from 1986 to 1989 (control)

Observed proportions

Available proportions

Figure 10 - Percentage of Occurrence of American Robins as a Function of Availability of Lawns with Short Grass in Each Treatment Category

Table 5 Lawn use by the American Robin as a Function of Enhancement for Landscaping and Man Use

Number of occurence	Lawn area			Plant structure[1]					Landscaping enhancement[2]	
	- 50 m²	50 à 150 m²	+ 150 m²	1	2	3	4	5	ordinary	elaborate
0	65	56	6	4	17	27	74	5	110	17
1	54	62	6	4	20	24	69	5	107	15
2	48	64	8	0	19	18	75	8	107	13
3	5	8	6	1	1	1	16	0	17	2
4	1	4	3	0	0	1	7	0	8	0
Total	173	194	29	9	57	71	241	18	349	47
	(X^2 = 32.81; df = 6; a < 0.01)			(X^2 = 4.69; df = 6; a > 0.05)					(X^2 = 0.91; df = 3; a > 0.05)	

1. Plant Structure

1- no vertical structure
2- presence of one or more decorative trees and/or one or more bushes less than 3 m tall
3- presence of trees over 3 m tall; no bushes
4- presence of a few trees and bushes
5- presence of many trees and bushes, hedges, flowers, etc

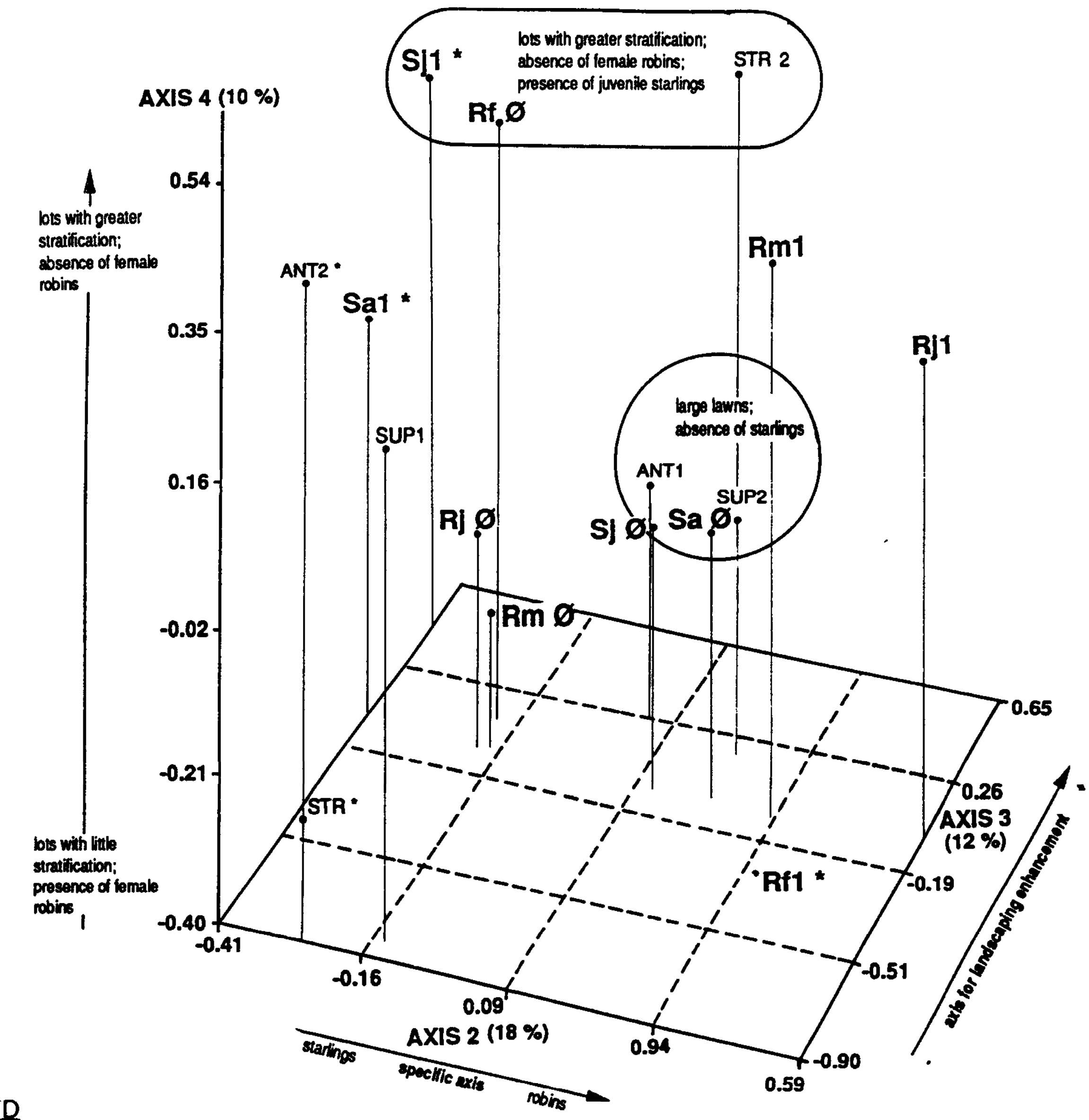
2. Enhancement for Landscaping and Human Use

Elaborate: lot with a substantial rock garden with many flowers and rocks, a large driveway and wide walk;

Moderate: lot with ordinary landscaping, simple driveway, small walk, etc.

Examination of contributions attributed to the variables in the formation of the first five axes indicated that the variables for the relative abundance of robins and starlings were in a larger measure responsible for the total inertia of the scatter of points than the enhancement variables (Appendix 2). Some relationships emerged, however, from the graphic representation of axes 2, 3 and 4 (Fig. 11). This representation provides the best explanation for the relations between abundance values and landscaping enhancement variables (39% of the total inertia of the scatter of points).

Axis 2 separates high abundance values for the robins and starlings. Axis 3 links the landscaping enhancement variables. In view of the fact that both of these axes are orthogonal, the relative abundance of male and immature robins and the relative abundance of immature and adult starlings (virtually parallel to axis 2) are only minimally related to lawn area (parallel to axis 3), as these variables form a right angle.



LEGE_D

SUP1 Small lawn area (-50 m²)
SUP2 Large lawn area (+50 m²)

STR1 Little plant stratification
STR2 Considerable plant stratification

ANT1 Moderate enhancement for human use
ANT2 Substantial enhancement for human use

R j Ø

R	American Robin	**S**	European Starling
Ø	Absence	**1**	Occurrence
j	Juvenile	**f**	Female
m	Male	**a**	Adult

* The coordinates for these variables were brought closer to the others as they were very far on one or the other of the axis.

Figure 11 - Correspondence Analysis Illustrating the Relation between the Occurrence of American Robins and European Starlings in the Summer of 1989 and Landscaping Enhancement in Duvernay (Laval)

The graph suggests that male robins and immature robins and starlings generally occurred on the most highly stratified lots. Female robins, however, avoided these lawns. According to our analysis, there were fewer sightings of adult and immature starlings on large lawns and on lots with moderate enhancement for human use.

The only variable for which the relation to lawn use by the American robin seemed to be significantly different from expectations involved lawn areas (Table 5). A contrast test (Scherrer 1984) showed that robins had a significant preference for lots of more than 150 m^2 ($p < 0.05$). Correspondenceanalysis failed to reveal this difference since the lots of over 150 m^2 were grouped in the 50 m^2-to-150 m^2 class of lots to weight each class more or less equally. Robins may prefer large lawns, but it is equally possible that a larger area simply increases the chances of finding robins on the lots in question.

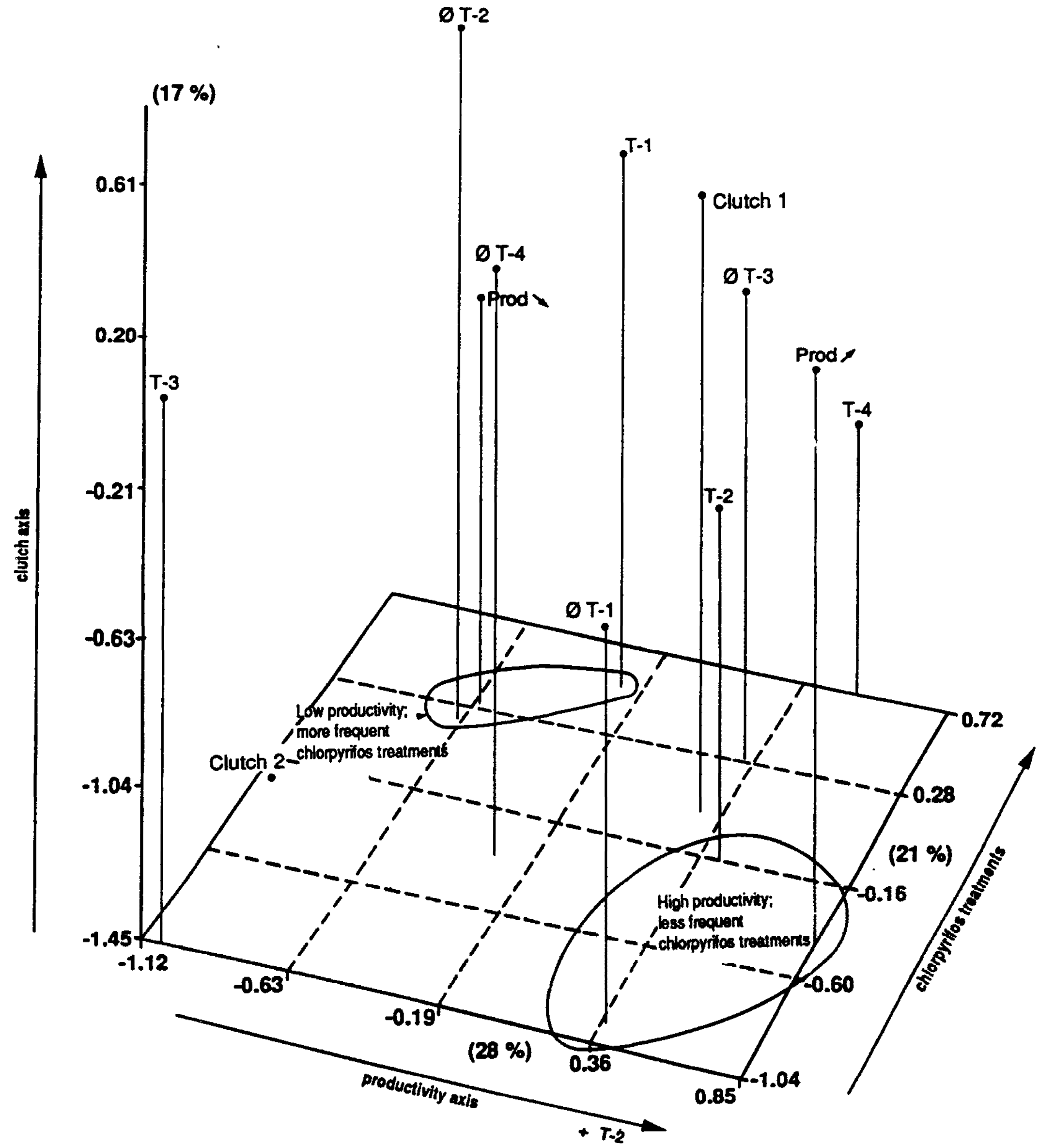
Dividing the coefficient for the occurrence of robins (number of robins sighted/number of lots in the area class) by the coefficient for the area class yielded the relative density per lot by cancelling the area effect. This calculation suggested that robins were found more often on large lawns simply because the chances of sighting them were greater. This class was poorly represented, and the risk coefficient, demonstrating that the class of lots in excess of 150 m^2 was used differently from the class grouping lots 50 to 150 m^2 in size, was just below the level of significance ($G_c = 13.6$ vs $G_{\alpha = 0.05} = 12.05$). Normally, we should check if large lots were available in different proportions for the various treatment categories, but the large-lawn class was too small for this type of analysis.

4.4. Effect of Treatments on Productivity

Productivity declined as the season progressed. It is often related to the number of eggs laid. The average size of the first clutch was found to be 3.9 eggs and of the second, 3.2 eggs (Morneau et al. 1989).

Exploratory Analysis

Correspondence analysis was undertaken to test the relations between productivity, clutch order and the intensity of previous chlorpyrifos applications around each of the nests (Fig. 12). The input table included the number of young produced, clutch order and the proportion of lots in each treatment category. These data were recoded to yield a logical table (0 and 1 values). For each treatment category, 0 represented the absence of any lots from this category and 1, the presence of lots. In the case of productivity, the 0 value represented productivity of less than 4, and the 1 value, productivity of 4. Clutch 1 was assigned the 0 value and clutch 2, the 1 value.



LEGEND

Prod. ↘	Productivity: 0, 1, 2 or 3 offspring
Prod. ↗	Productivity: 4 offspring
T-A	Fertilizer, herbicide from 1986 to 1988, chlorpyrifos in 1986 and / or 1987
T-B	Fertilizer, herbicide from 1986 to 1988
T-C	Fertilizer from 1986 to 1988
T-D	No treatment from 1986 to 1988
Ø	None of the lots for which information was available received this treatment

Figure 12 - Correspondence Analysis Illustrating the Relation between the Productivity of Robin Clutches in 1988 and Lawn Treatments in Duvernay (Laval) in 1986 and 1987

Axes 1, 2 and 3 most satisfactorily demonstrated the relation between productivity, lots that had received one or more chlorpyrifos treatments and control lots (52.35% of the total inertia of the cluster of points) (Appendix 3). The graphic representation clearly revealed a negative relation between productivity and clutch order. It also revealed higher productivity for nests surrounded by lots treated with fertilizers and herbicides but not with chlorpyrifos.

Inferential Analysis

Productivity was negatively correlated with the size of chlorpyrifos-treated lots (category T-A) (Tau = -0.2348; n = 86; p = 0.0097). Also, the mean percentage of T-A category lots was significantly higher around nests in which productivity was low (Table 6). These findings should be viewed with caution since a high proportion of the lots did not fall into categories T-A to T-D. It should also be pointed out that more information was available for nests with the lowest productivity and nests built on lots treated with chlorpyrifos in 1986 and/or 1987 (Table 7). The most reliable results were therefore obtained for these nests.

Table 6. Comparison of Productivity as a Function of the Mean Percentage of Lots in Each Treatment Category

Productivity	n	T_A[1] (% x)	T_B (% x)	T_C (% x)	T_D (% x)	T_E (% x)
With diazinon						
0, 1 and 2	13	20.4	12.5	4.5	1.7	60.9
3 and 4	73	11.9	10.6	3.1	4.9	69.5
Z	--	1.99	0.45	0.19	-1.48	-1.46
P_z	--	**0.047**	0.652	0.851	0.140	0.144
Without diazinon						
0, 1 and 2	9	20.2	13.4	3.7	2.5	60.2
3 and 4	66	11.1	11.4	3.2	4.7	69.6
Z	--	1.66	0.01	-0.01	-0.81	-1.30
P_z	--	**0.097**	0.993	0.991	0.418	0.195

1. T_A- fertilizers, herbicides from 1986 to 1988, chlorpyrifos in 1986 and/or 1987
   T_B- fertilizers, herbicides from 1986 to 1988
   T_C- fertilizers from 1986 to 1988
   T_D- no treatment from 1986 to 1988 (control)
   T_E- treatment unknown

Nests for which the supports were treated with diazinon were eliminatedto avoid a combined effect with chlorpyrifos, since Morneau et al. (1990) suspected diazinon of affecting productivity. The negative correlation between productivity and the number of chlorpyrifos-treated lots (T-A) remained significant (Tau = -0.2004; n = 75; p = 0.0422). On the other hand, the mean percentage of chlorpyrifos-treated lots was no longer significantly greater around the nests with low productivity (Table 6).

Table 7 Comparison of Mean Productivity as a Function of the Percentage of Lots in Each Treatment Category, according to Clutch Order

Productivity	n	T_A[1] (% x)	T_B (% x)	T_C (% x)	T_D (% x)	T_E (% x)
Clutch 1						
0	2	40.3	18.1	0	6.3	35.4
1	2	16.1	5.0	11.1	0	67.9
2	4	14.4	7.5	2.8	2.5	72.8
3	21	13.1	9.7	5.3	4.1	67.7
4	33	10.4	12.0	1.4	5.7	70.5
Clutch 2						
0	1	11.1	44.4	0	0	44.4
1	0	---	---	---	---	---
2	0	---	---	---	---	---
3	9	11.6	6.2	3.9	3.7	74.7
4	3	3.7	31.5	6.5	0	58.4

1. T_A - fertilizers, herbicides from 1986 to 1988, chlorpyrifos in 1986 and/or 1987
   T_B - fertilizers, herbicides from 1986 to 1988
   T_C - fertilizers from 1986 to 1988
   T_D - no treatment from 1986 to 1988 (control)
   T_E - treatment unknown

There was a significantly negative correlation between productivity and clutch order (Tau = -0.3053; n = 86; p = 0.0029). In order to eliminate this effect on the relation between chlorpyrifos treatments and productivity, the data for each clutch were separated for analysis, and Kendall's tau was calculated for each. There were too few second-generation clutches (1 in the lowest productivity classes versus 12 in the highest productivity classes) to analyse the relation between treated and untreated lots. In the case of the first clutches, there was no longer any relation between productivity and the number of chlorpyrifos-treated lots (Tau = 0.1927; n = 62; p = 0.076). The percentage of lots treated with chlorpyrifos (T-A) was not significantly higher around the nests with low productivity (Wilcoxon-Mann-Whitney test: z = 1.628; p = 0.1094; low productivity n = 8; high productivity n = 54).

5.0 DISCUSSION

Chlorpyrifos was rarely used in 1989, and the persistence of this insecticide is low. As a result, it was not possible to measure the direct effects of the compound on the American robin. Only its indirect effect, as determined by the decrease in prey due to repeated use, could be analysed.

Our findings suggest that repeated use of chlorpyrifos has very little effect on lawn use by the American robin and European starling. In a study conducted in the fall on the same site, Coderre (1990) showed that the abundance and biomass of earthworms was negatively affected by the repeated use of chlorpyrifos. There are two interrelated reasons why the decrease in this resource did not influence lawn use by the robins: 1) earthworms are less active during the period in the summer when the study was under way (Gérard 1967, Lee 1985, Garceau et al. 1988) and consequently are less available, irrespective of the lawn where they occur, and 2) robins change their feeding habits at that time of the year and are less dependent on earthworms (Johnson 1969, Wheelwright 1986). Both of these factors could account for the small number of robins observed on the lawns during that period, compared to the nesting season. This may have also made it impossible to detect the effect of chlorpyrifos.

Corrrespondence analysis indicated that female robins had a preference for lawns with a longer history of treatment with fertilizers, herbicides and chlorpyrifos. Young robins and starlings, on the other hand, seemed to prefer lawns that either had never been treated or else, had only recently been treated. Differences in behaviour between immatures and adults have also been recorded in some Passeriformes in which the immature birds do not choose the same feeding sites as the adults (Ficken and Ficken 1967, Howe 1974, Dunn and Nol 1980, in Gochfeld and Burger 1984). Gochfeld and Burger (1984), however, failed to find any significant difference in the choice of feeding sites by American robins according to their stages of maturity.

Robin productivity seemed to be affected by repeated use of chlorpyrifos. It is known that during the breeding season, earthworms constitute a majorsource of food (Wheelwright 1986). Their decrease in number and biomass (Coderre 1990) may account for reduced productivity. DeWeese et al. (1979), on the other hand, did not observe any effect on productivity despite a 70% decline in the prey population. Similarly, Powell (1984) failed to observe any changes in productivity and the growth rate of young red-winged blackbirds despite lower prey numbers. The females made the same number of trips the same distance from the nests as the females in the control group, but they sometimes spent more time looking for food. Bednarek and Davidson (1967) recorded a drop in productivity. In this instance, it was not due to a smaller number of prey but to the direct effect of carbaryl.

The possibility of a combined diazinon-chlorpyrifos effect should not be overlooked. If the nests in diazinon-treated trees are excluded from the analysis, the difference between the percentages of chlorpyrifos-treated lots around nests with large and small clutches is no longer significant. Further research is needed to determine the interrelationship between the two compounds.

Because of the high percentage of lots next to nests for which no information was available, considerable circumspection is needed in interpreting our findings. Despite this cautionary note, the trend detected warrants further study because of the possible effects of reduced productivity on robin populations in a residential area.

Furthermore, chlorpyrifos-treated lots rarely form homogeneous groups. Instead, they constitute a mosaic of several types of treatments, which may reduce the impact of the pesticide. Chlorpyrifos may therefore be harmless, provided that it is not used on a large proportion of lots in the same sector.

We recommend a further study during the nesting season in sites for which treatment schedules are more fully documented, and feeding sites, their distance from the nests and the abundance of prey are recorded.

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Appendix 1 Contributions associated with each of the values in the graphic representation of correspondence analysis illustrating the relation between the highest relative abundance values for American robins and European starlings measured in the summer of 1989 and lawn treatments in Duvernay (Laval) from 1986 to 1989 (Fig. 5)

Name of Variables	Contribution				
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
Juvenile robin	0.5	0.4	18.3	2.1	0.1
Female robin	0.0	1.6	1.8	17.9	2.0
Male robin	0.2	0.4	41.4	2.5	0.1
Juvenile starling	6.6	4.6	0.0	1.5	23.9
Adult starling	4.3	2.2	1.3	19.6	1.4

Name of elements	Contribution				
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
Fertilizers 1986	10.3	4.0	15.2	0.0	15.9
Fertilizers 1987	11.3	1.4	11.8	3.3	1.9
Fertilizers 1988	0.0	13.9	11.6	0.4	15.6
Fertilizers 1989	6.7	7.4	11.7	0.0	1.5
Herbicides 1986	7.8	25.0	5.2	4.5	0.0
Herbicides 1987	12.3	0.8	1.4	1.1	9.1
Herbicides 1988	0.0	13.9	11.6	0.4	15.6
Herbicides 1989	6.7	7.4	11.7	0.0	1.5
No treatment 1986	10.1	11.9	5.2	0.1	0.1
No treatment 1987	9.1	0.1	7.6	4.7	25.4
No treatment 1988	11.0	9.9	5.5	9.8	3.9
No treatment 1989	2.3	3.7	0.0	74.6	0.3
Total insecticides	12.3	0.8	1.4	1.1	9.1

Appendix 2 Contributions associated with each of the values in the graphic representation of correspondence analysis illustrating the relation between the occurrence of American Robins and European starlings in the summer of 1989 and landscaping enhancement in Duvernay (Laval) (Fig. 11)

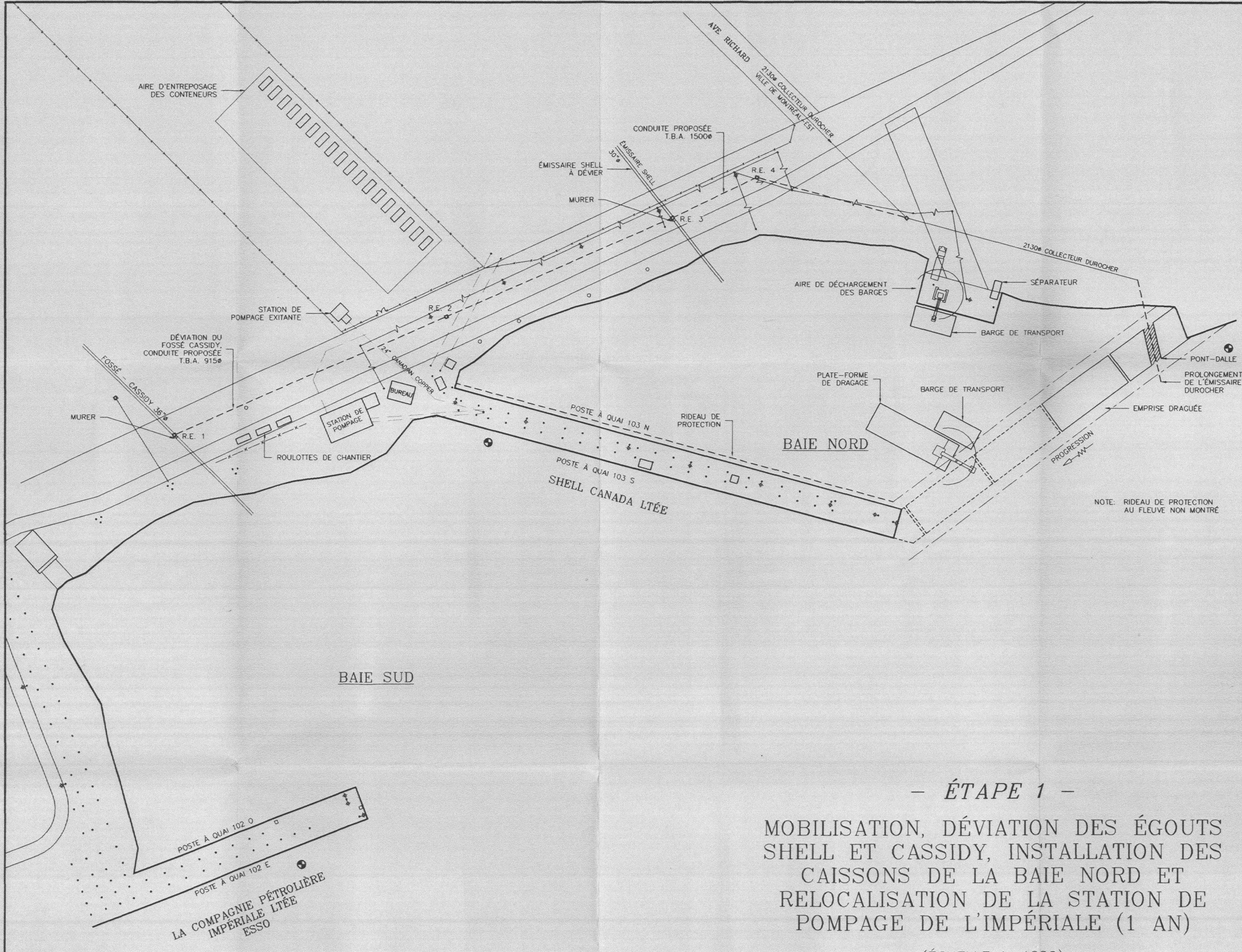
Name of variables	Contribution				
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
Lawn area					
(- 50 m^2)	0.6	0.5	23.5	2.8	0.1
(+ 50 m^2)	0.5	0.4	18.3	2.1	0.1
Plant stratification					
(slight)[1]	0.1	3.0	3.4	33.9	3.7
(substantial)	0.0	1.6	1.8	17.9	2.0
Enhancement for human use					
(moderate)	0.0	0.1	5.6	0.3	0.0
(elaborate)	0.2	0.4	41.4	2.5	0.1
Abundance young robins					
(none)	2.3	1.6	0.0	0.5	8.3
(occurence)	6.6	4.6	0.0	1.5	23.9
Abundance female robins					
(none)	2.5	1.3	0.7	11.2	0.8
(occurence)	4.3	2.2	1.3	19.6	1.4
Abundance male robins					
(none)	2.6	1.0	0.0	2.2	20.2
(occurence)	4.9	1.9	0.0	4.2	37.8
Abundance young starlings					
(none)	0.3	0.7	0.0	0.0	0.0
(occurence)	6.2	15.1	0.7	0.6	0.1
Abundance adult starlings					
(none)	0.9	2.4	0.0	0.0	0.1
(occurence)	8.6	22.8	0.0	0.3	0.9

[1]. The five plant stratification classes described in Section 3.4.2 were grouped into 2 classes distinguishing slight stratification (no plant structure with trees over 3 meters tall; no bushes) from substantial stratification (presence of trees and bushes, hedges, etc.)

Appendix 3 Contributions associated with each of the values in the graphic representation of correspondence analysis illustrating the relation between the productivity of American robin clutches in 1988 and lawn treatments in Duvernay (Laval) in 1986 and 1987 (Fig. 12).

Name of Variables	Contribution				
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
Productivity					
(0, 1, 2 ou 3 young)	13.1	4.6	1.0	0.0	6.0
(4 young)	18.2	6.4	1.4	0.0	8.4
Clutch					
(first)	3.7	0.1	10.1	0.1	0.0
(second)	15.0	0.3	40.9	0.3	0.1
T-1[1]					
(no lots)	2.9	25.3	3.4	14.6	15.5
(1 or more lots)	1.7	14.3	1.9	8.2	8.7
T-2					
(no lots)	10.1	1.6	14.4	24.0	1.3
(1 or more lots)	6.6	1.0	9.4	15.7	0.9
T-3					
(no lots)	4.7	6.1	0.1	0.4	10.2
(1 or more lots)	15.4	20.0	0.2	1.3	33.6
T-4					
(no lots)	2.8	6.6	5.6	11.6	4.9
(1 or more lots)	5.7	13.7	11.7	24.0	10.2

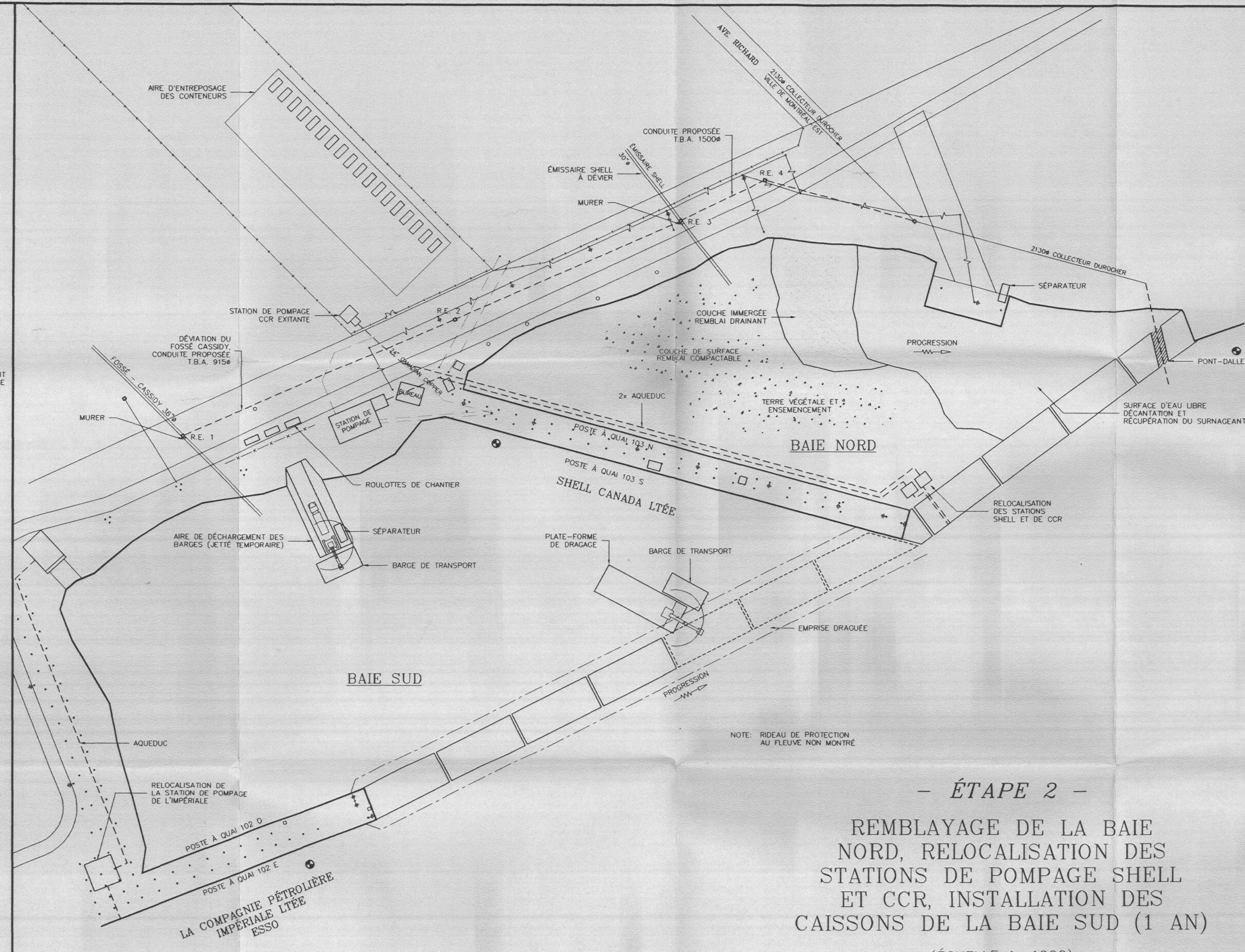
1. T_1- fertilizers, herbicides from 1986 to 1988, chlorpyrifos in 1986 and/or 1987
   T_2- fertilizers, herbicides from 1986 to 1988
   T_3- fertilizers from 1986 to 1988
   T_4- no treatment from 1986 to 1989 (control).



– ÉTAPE 1 –

MOBILISATION, DÉVIATION DES ÉGOUTS SHELL ET CASSIDY, INSTALLATION DES CAISSONS DE LA BAIE NORD ET RELOCALISATION DE LA STATION DE POMPAGE DE L'IMPÉRIALE (1 AN)

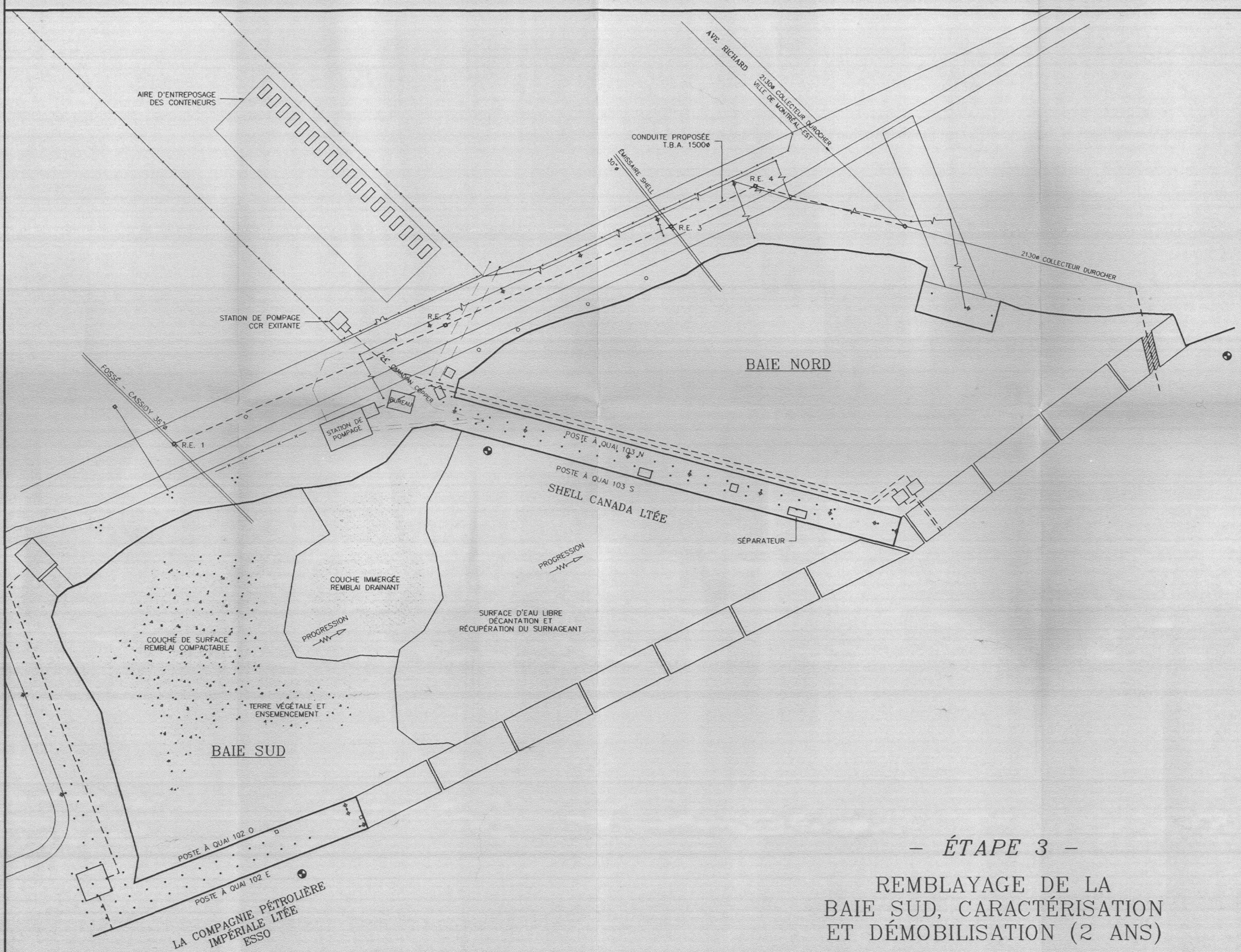
(ÉCHELLE 1: 1000)



– ÉTAPE 2 –

REMBLAYAGE DE LA BAIE NORD, RELOCALISATION DES STATIONS DE POMPAGE SHELL ET CCR, INSTALLATION DES CAISSONS DE LA BAIE SUD (1 AN)

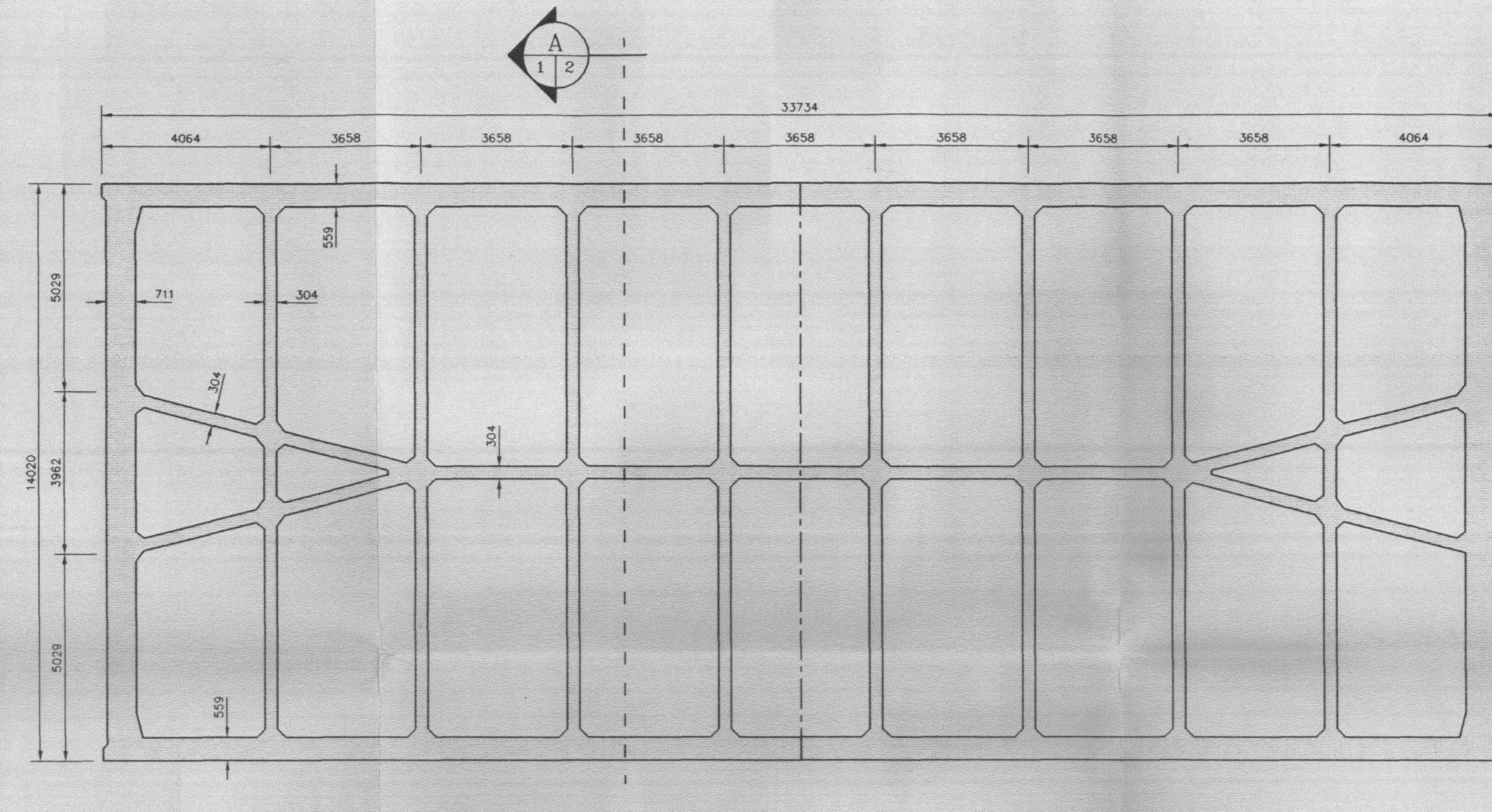
(ÉCHELLE 1: 1000)



– ÉTAPE 3 –

REMBLAYAGE DE LA BAIE SUD, CARACTÉRISATION ET DÉMOBILISATION (2 ANS)

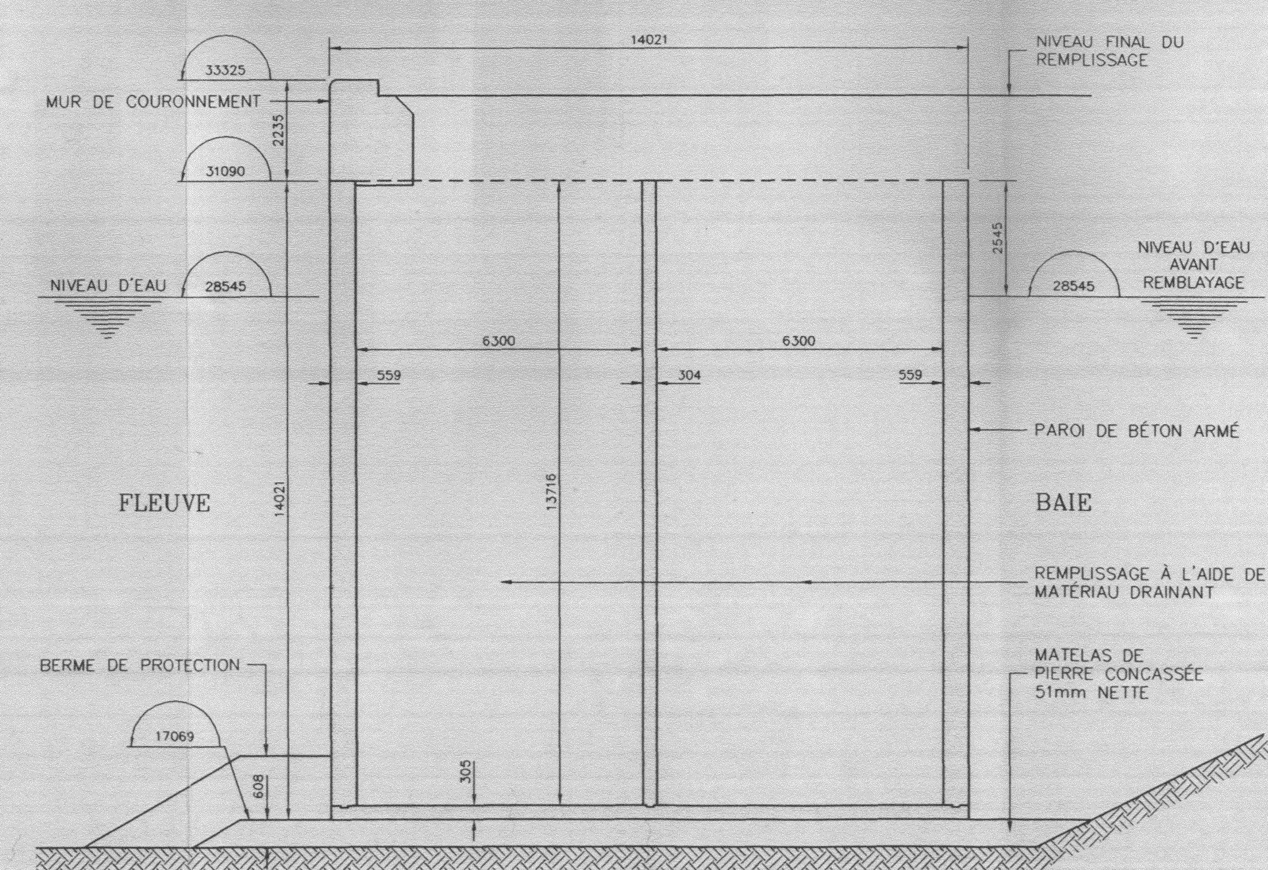
(ÉCHELLE 1: 1000)



– PLAN TYPE D'UN CAISSON (1960) –

ÉCHELLE 1:100

SURFACE TOTALE = 470,24m²
SURFACE DU BÉTON = 102,36m²
SURFACE DU REMBLAI = 367,88m²



– COUPE-TYPE –

ÉCHELLE 1:100

NO.	REVISION (S)	DATE

ADS GROUPE-CONSEIL INC. ENVIRONNEMENT

1441, BOULEVARD RENÉ-LÉVESQUE OUEST, BUREAU 500, MONTRÉAL, H3G 1T7
TÉL: (514) 875-1441
MONTRÉAL, QUÉBEC, OTTAWA/HULL

Conçu par: M. VERMETTE	Dessiné par: D. GRANT
Vérifié par: M. VERMETTE	Approuvé par: R. FONTAINE

Titre du projet:
RESTAURATION DES BAIES SITUÉES DE PART ET D'AUTRE DU QUAI 103

Titre du dessin:
SCÉNARIO No. 5: CONSTRUCTION D'UN POSTE À QUAI ET REMBLAYAGE DES BAIES ÉTAPES DE MISE EN OEUVRE

Échelle: INDIQUÉES	Dossier no.: 17-36-849	Feuille no.: 1 / 2
Date: 96/07/11	Figure no.:	

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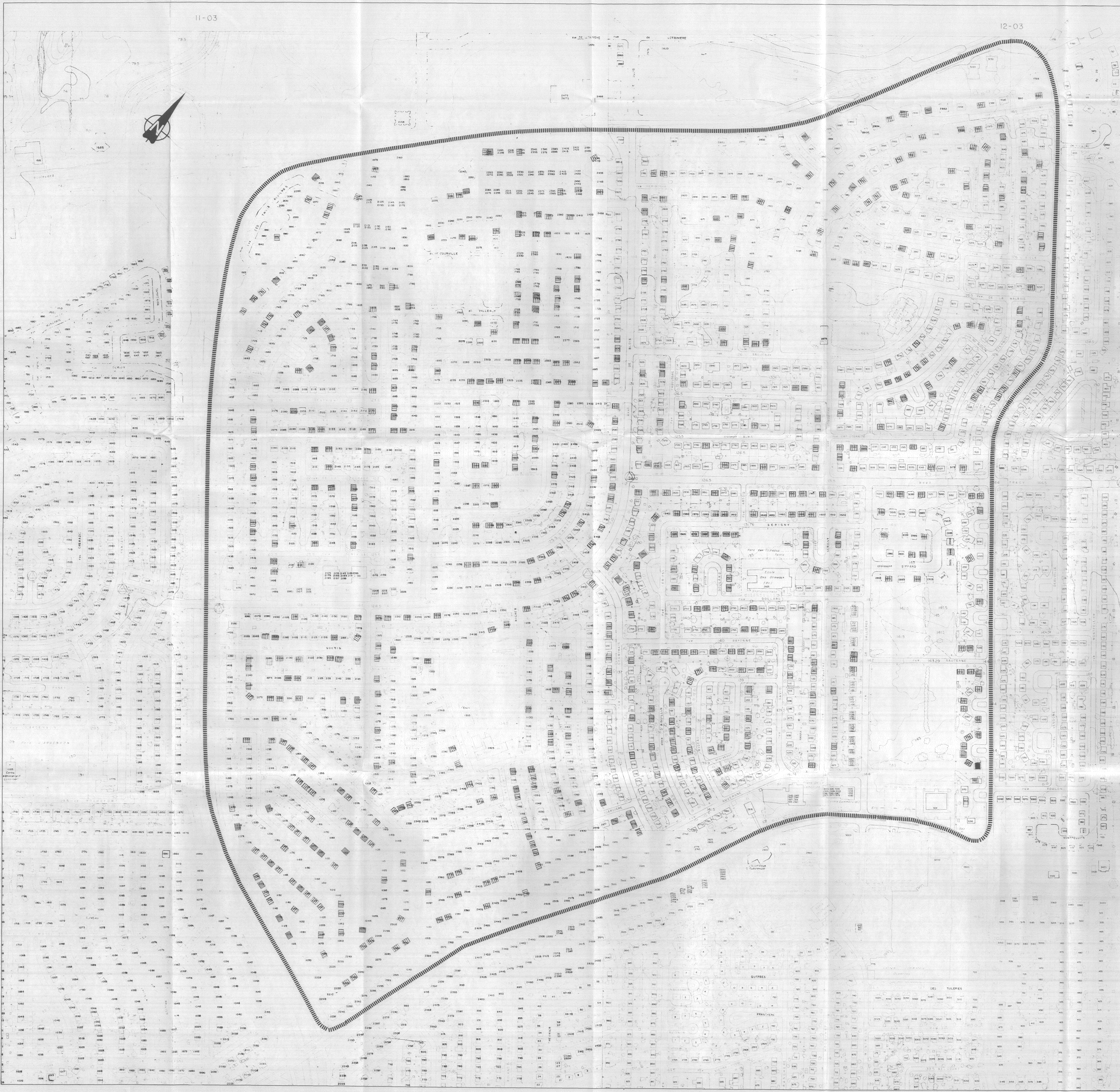

LÉGENDE LEGEND

Fréquence de présence		Frequence of sightings (number of times)
aucune		never
1		1
2		2
3		3
4		4
5		5

Sceaux

Client

Service Canadien de la Faune
Canadian Wildlife Service

Dow Chemical Inc.

G.R.E.B.E. inc. 1134, rue Sainte-Catherine Ouest, Montréal, Québec H3B 1H4 (514) 871-9221 Télécopieur: (514) 397-9750

Projet

Effets du traitement des pelouses au chlorpyriphos, sur le Merle d'Amérique (Turdus migratorius) en milieu urbain

Effects of chlorpyrifos used on lawns over several years on the American Robin (Turdus migratorius)

Dessin

Observation de Merles d'Amérique sur les pelouses d'un secteur de Duvernay, Laval: 4 juillet au 11 août 1989

Sighting of American Robin on lawns in a sector of Duvernay, Laval: July 4th - August 11th, 1989

Préparé	C. L.	Dessiné	B. V.
Vérifié	R. D.	Approuvé	R. D.
Échelle	1 : 2 400	Date	JANVIER 1990

Client	Projet	Activité	No feuillet	Rév.
1 0 5 9	1 1 0	0 0 0	0 0 0 2	