A Five-Year Study of the Flying Beetles (Coleoptera) from a Grassland and an Adjacent Woods in Southern Québec (Canada)

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Abstract

During the entire snow-free season (April or May to October) in 2006-2010, we collected with four flight interception traps a total of 34629 individuals of 848 Coleoptera species belonging to 60 families in southern Québec (Canada). We caught mainly phytophagous and zoophagous beetles. The majority of species (621 or 73.2%) were represented by less than 10 adults over the five years; however, we collected at least 100 adults for 48 species, including four major species: *Meligethes nigrescens* Stephens (15.9% of the total catches), *Longitarsus luridus* (Scopoli) (10.6%), *Eusphalerum pothos* (Mannerheim) (9.1%) and *Acidota subcarinata* Erichson (5.9%). Between 39 and 47% of species from a trap were collected in one month only over the five years; whereas *E. pothos* and *M. nigrescens* flew mainly in May and June, and adults of *A. subcarinata* and *L. luridus* were collected mainly in September and October. Over 2006–2010, we caught a total of 9214 individuals of 439 species in the grassland, 7503 individuals of 519 species at the woods edge, 5943 individuals of 356 species in the woods, and 11969 individuals of 468 species near a ditch parallel to the woods. We consider that the curve of the cumulative number of species for each trap over 33 months in five years may indicate a good estimation of the flying beetle species richness in a site. Seven species were dominant in at least one trap over 2006–2010: *A. subcarinata, Bradycellus nigrinus* (Dejean), *Cercyon assecla* Smetana, *E. pothos, Isochnus rufipes* (LeConte), *L. luridus* and *M. nigrescens*. In a window trap, some dominant and subdominant species showed considerable fluctuation in percentage from year to year, particularly *E. pothos, L. luridus* and *M. nigrescens*. Also, we believe that, in the future, it will be important to explore variations of beetle biodiversity on long time.

Keywords: Coleoptera, flight interception trap, Québec.

The number of described beetle species on Earth is near 387 000 (Bouchard et al. 2017). To date, 8302 species of Coleoptera have been recorded in Canada (Brunke et al. 2019). The four most diverse families of beetles in Canada are the Staphylinidae (1774 spp.), Carabidae (983 spp.), Curculionidae (826 spp.) and Chrysomelidae (595 spp.). A total of 639 non-native beetle species have become established in Canada, with most species in the Staphylinidae (153 spp.), Curculionidae (107 spp.), Chrysomelidae (56 spp.) and Carabidae (55 spp.). Brunke et al. (2019) estimate that slightly more than 1000 beetle species remain to be reported from Canada, either as new records or undescribed species.

Beetles are important in most natural terrestrial and freshwater ecosystems, have a great effect on agriculture and forestry, and are useful model organisms for many types of science (Bouchard et al. 2017). Because of their greater diversity of species and trophic roles, and their great sensitivity to environmental perturbations, a better understanding beetle biodiversity will enhance our knowledge of the world and provide many practical applications. More information is needed on the habitat affinities of individual species.

We investigated the beetle biodiversity with diverse methods in southern Québec (Canada) over 2006–2012. In the first five years of this study, we explored the spatio-temporal variations of the composition and structure of flying beetle assemblages from a grassland and an adjacent woods, and also the edge effects.

Materials and Methods

Study site. We study beetles at Scotstown (45°32’00” N, 71°17’00” W, about 370 m a.s.l.), 10 km at north of Mont Mégantic, in southern Québec. This site, about 350 m by 60 m, includes a grasssland (pasture for horses during many years and abandonned since 2004) in its upper part (40%), and a

Table 1. Number of individuals and species for six trophic groups of beetles over 2006–2010

		Individuals		Species	
Trophic Groups	**Year**	**N**	**%**	**n**	**%**
Zoophagous	2006	1879	26.4	190	39.6
	2007	1911	24.9	156	34.8
	2008	1324	20.4	155	36.4
	2009	1064	20.6	135	37.0
	2010	1133	13.8	168	40.4
Phytophagous	2006	3951	55.6	167	34.8
	2007	4540	59.3	167	37.3
	2008	4020	61.8	154	36.2
	2009	3397	65.7	129	35.3
	2010	6098	74.5	133	32.0
Saprophagous	2006	791	11.1	53	11.0
	2007	912	11.9	61	13.6
	2008	935	14.4	54	12.7
	2009	532	10.3	44	12.1
	2010	610	7.5	54	13.0
Fungivorous	2006	428	6.0	52	10.8
	2007	260	3.4	52	11.6
	2008	170	2.6	44	10.3
	2009	105	2.0	36	9.9
	2010	182	2.2	48	11.5
Xylophagous	2006	12	0.2	10	2.1
	2007	14	0.2	5	1.1
	2008	17	0.3	13	3.1
	2009	15	0.3	10	2.7
	2010	9	0.1	7	1.7
Others	2006	46	0.6	8	1.7
(non-feeding,	2007	25	0.3	7	1.6
unknown)	2008	39	0.6	6	1.4
	2009	58	1.1	11	3.0
	2010	152	1.9	6	1.4

mixed woods dominated by alders (*Alnus* sp.) in its lower part (60%). A ditch, generally partially or totally shaded by shrubs and trees, is parallel to the grassland and the woods.

Five-year study. During the entire snow-free season (April or May to October), in 2006–2010, we used flight interception traps (FIT) of the type ''window trap'', with a transparent acrylic sheet (1.2 m height, 0.6 m width), white pan traps on both sides and the use of a germicid detergent. A FIT at the soil level was located at the woods edge, in the grassland at 50 m from the edge, in the woods at 50 m from the edge, and also near the ditch in its lower part (at about 150 m from the River au Saumon).

Trophic groups. Alike Didham et al. (1998), and Grimbacher and Stork (2007), we assigned beetles to six trophic groups: 1) zoophagous (predators and parasitoids), 2) phytophagous (herbivors; feeders of algae, bryophytes, pollen or seeds), 3) fungivors, 4) saprohagous (including dung beetles and detritivors), 5) xylophagous (including xylomycetophagous), and 6) others (non-feeding or unknown). Where only one feeding biology was known for a family, all species were assigned to that trophic group. In other cases, where multiple feeding biologies were known to occur, species were assigned on an individual basis using published details of the feeding biology of the genus or of related genera. The feeding behavior of carabids as a group is difficult to characterize; of the approximately 40 000 described species of

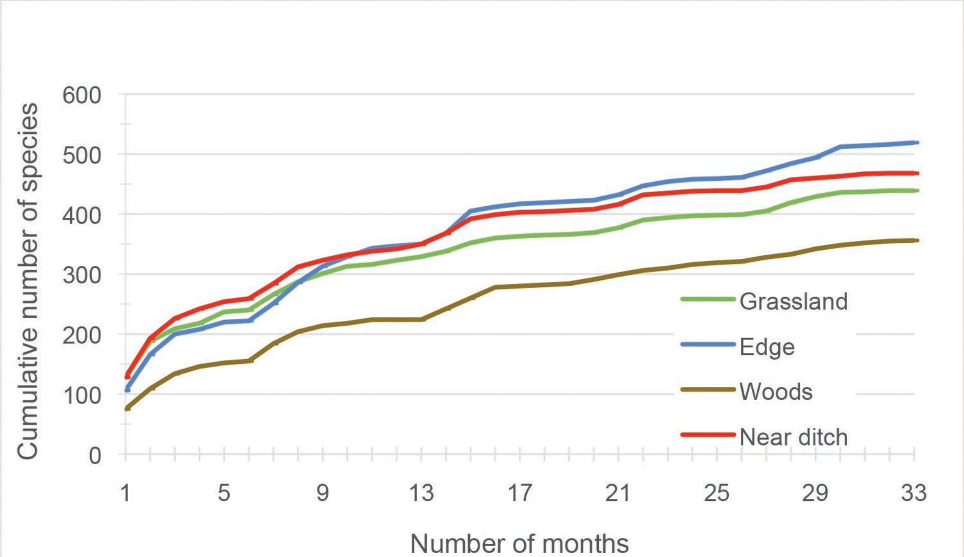

Figure 1. Cumulative number of beetle species for each trap over 33 sampling months in 2006–2010

Carabidae, feeding habits are only described for 2.6% of species; carabids range from nearly complete carnivory (as in most Carabini) to nearly complete herbivory (as in some Harpalini, Zabriini) (Lundgren 2009). Klimaszewski (2000) has presented a synthesis on the feeding habits of rove beetles; most Staphylinidae are generalist predators on other arthropods, but some are specialized to utilize other food resources (as mushrooms, pollen, algae, decomposing organic material). In northern Nearctic forests, about 80% of rove beetle species are predators (Pohl et al. 2008).

Results

Abundance and species richness. Over 2006-2010, we collected with FIT a total of 34 629 individuals of 848 Coleoptera species belonging to 60 families. Seven families were more abundant: Staphylinidae (9743 individuals; 276 species), Nitidulidae (6209; 22), Chrysomelidae (5221; 65), Carabidae (2607; 94), Elateridae (2564; 33), Curculionidae (2425; 83) and Hydrohilidae (1894; 23); these families represented 88.5% of individuals and 70.3% of collected species. We observed the presence of 40 Holarctic species (19.1% of individuals) and 126 adventive species (19.3% of individuals). In FIT, we caught mainly phytophagous (about 35% of species) and zoophagous beetles (near 40%) (Table 1); the relative variations for six trophic groups from year to year were of small amplitudes.

We collected a total of 7107 individuals of 482 species in 2006, 7662 individuals of 446 species in 2007, 6505 individuals of 425 species in 2008, 5171 individuals of 366 species in 2009, and 8184 individuals of 416 species in 2010. The number of individuals by species over the five years ranged from 1 to 5498 adults. The majority of species appeared as singletons (276 species, 32.5%) or in small numbers (2–9 adults; 345 species, 40.7%). Some species in low numbers in window traps may be collected in large numbers with other methods.

Over 2006–2010, we collected a total of 9214 individuals of 439 species in the grassland, 7503 individuals of 519 species at the woods edge, 5943 individuals of 356 species in the woods, and 11969 individuals of 468 species near the ditch. We present the curve of the cumulative number of beetle species collected by each trap over 33 months in 2006–2010 (Fig. 1). At the end of the first sampling year (2006), we have recorded only 240 species in the grassland, 222 species at the woods edge, 155 species in the woods, and 259 species near the ditch; thereafter, over 2007–2010, we observed near 300 other species at the woods edge, and near 200 additional species in the three other window traps. After five years of trap operation, the curve of the cumulative number of species for each trap may indicate almost the final total of species in the surroundings of a trap. The most frequent species were *Longitarsus luridus* (Scopoli) and *Atomaria lewisi* Reitter

Table 2. Total catches of dominant and subdominant beetle species in each trap over 2006–2010, and variations of annual percentages

Species	FAM.[a]	N	%	MIN.%–MAX.%
		Grassland		
Meligethes nigrescens Stephens	NIT	3156	**34.3**	10.3 – 59.6
Longitarsus luridus (Scopoli)	CHR	659	**7.2**	1.7 – 23.7
Hydrothassa vittata (Olivier)	CHR	445	4.8	1.7 – 8.2
Dalopius pallidus Brown	ELA	308	3.3	1.3 – 6.7
Acidota subcarinata Erichson	STA	209	2.3	1.4 – 3.8
Bradycellus nigrinus (Dejean)	CAR	191	2.1	1.8 – 2.4
		Woods edge		
Isochnus rufipes (LeConte)	CUR	1193	**15.9**	8.8 – 34.0
Eusphalerum pothos (Mannerheim)	STA	1061	**14.1**	1.1 – 35.2
Bradycellus nigrinus (Dejean)	CAR	418	**5.6**	2.9 – 7.2
Cercyon assecla Smetana	HYD	399	**5.3**	3.0 – 8.1
Longitarsus luridus (Scopoli)	CHR	385	**5.1**	0.2 – 19.7
Acidota subcarinata Erichson	STA	234	3.1	1.2 – 5.3
Dalopius vagus (Brown)	ELA	200	2.7	1.3 – 5.2
Meligethes nigrescens Stephens	NIT	166	2.2	0.7 – 3.1
Bradycellus semipubescens Lindroth	CAR	165	2.2	1.5 – 3.4
		Woods		
Eusphalerum pothos (Mannerheim)	STA	1184	**31.7**	8.6 – 55.3
Cercyon assecla Smetana	HYD	594	**10.0**	5.0 – 20.2
Bradycellus nigrinus (Dejean)	CAR	239	4.0	1.9 – 7.6
Tachinus luridus Erichson	STA	224	3.8	1.4 – 7.3
Bisnius blandus (Gravenhorst)	STA	189	3.2	2.7 – 4.4
Catops basilaris Say	LEI	157	2.6	1.4 – 4.4
Acidota subcarinata Erichson	STA	155	2.6	0.2 – 7.9
Bradycellus semipubescens Lindroth	CAR	149	2.5	0.8 – 4.8
Dalopius vagus (Brown)	ELA	146	2.5	1.5 – 4.2
Isochnus rufipes (LeConte)	CUR	128	2.2	0.1 – 3.3
		Near ditch		
Longitarsus luridus (Scopoli)	CHR	2561	**21.4**	4.5 – 37.0
Meligethes nigrescens Stephens	NIT	2139	**17.9**	6.0 – 37.0
Acidota subcarinata Erichson	STA	1435	**12.0**	8.2 – 18.3
Ctenicera tarsalis (Melsheimer)	ELA	475	4.0	3.0 – 6.1
Cercyon assecla Smetana	HYD	455	3.8	0.6 – 11.5
Dalopius pallidus Brown	ELA	395	3.3	2.0 – 5.8
Dalopius vagus (Brown)	ELA	247	2.1	1.3 – 3.2

[a] Families : CAR Carabidae; CHR Chrysomelidae; CUR Curculionidae; ELA: Elateridae; HYD Hydrophilidae; LEI Leiodidae; NIT Nitidulidae; STA Staphylinidae

/ *A. fuscata* Schönher (during 30 months) in the grassland, and *Bradycellus nigrinus* (Dejean) (during 30 months) at the woods edge; however, between 39 and 47% of species from a trap were collected in one month only.

Dominant and subdominant species. A dominant species represented at least 5% of catches in a trap, and, a subdominant species, between 2 and 5%. Seven species were dominant in at least one trap over 2006–2010 (Table 2): *Acidota subcarinata* Erichson near the ditch, *B. nigrinus* at the woods edge, *Cercyon assecla* Smetana at the woods edge and in the woods, *Eusphalerum pothos* (Mannerheim) at the woods edge and in the woods, *Isochnus rufipes* (LeConte) at the woods edge, *L. luridus* in the grassland, at the woods edge and mainly near the ditch, and *Meligethes nigrescens* Stephens in the grassland and near the ditch. In a trap, some dominant and subdominant species showed considerable fluctuation in percentage from year to year; for examples, between 8.6 and 55.3% for *E. pothos* in the woods, between 4.5 and 37.0% for *L. luridus* near the ditch, and between 10.3 and 59.6% for *M. nigrescens* in the grassland.

Table 3. Total catches, habitat preferences, biogeography, trophic groups, activity months and female ratio of the most abundant species over 2006-2010

Family and species	N	Hab.[a]	Biog.[b]	Gr.[c]	Activity months[d] A M J J A S O	Fem. (%)
Carabidae						
Bradycellus lugubris (LeConte)	128	G		P	A **M** J	62
Bradycellus neglectus (LeConte)	116	G		P	A **M** J A S O	56
Bradycellus nigrinus (Dejean)	1067	G		P	**A** **M** J J A S O	55
Bradycellus semipubescens Lindroth	507	G		P	**A** **M** J J A S	56
Chrysomelidae						
Altica corni Woods	124	F		P	A **M** **J** J A S O	69
Hydrothassa vittata (Olivier)	569	O	H	P	A **M** J J A S O	na
Longitarsus luridus (Scopoli)	3660	O	A	P	A M J J A **S** **O**	44
Coccinellidae						
Harmonia axyridis (Pallas)	152	O	A	Z	A S **O**	59
Cryptophagidae						
Atomaria ephippiata Zimmernann	281	O		F	M **J** J A S	60
Atomaria lewisi Reitter / *A. fuscata* Sch.	264	O	A/H	F	A **M** **J** J A S O	na
Curculionidae						
Eutrichapion cyanitinctum (Fall)	252	O		P	A M J J A **S** **O**	67
Isochnus rufipes (LeConte)	1363	F		P	A M **J** **J** A **S** O	65
Phyllobius oblongus (L.)	157	G	A	P	M **J** J	na
Elateridae						
Ctenicera tarsalis (Melsheimer)	566	O		P	A **M** J	20
Dalopius pallidus Brown	740	O		P	A **M** **J** J A	29
Dalopius vagus (Brown)	721	G		P	M **J** **J** A S O	35
Hypnoidus abbreviatus (Say)	143	O		P	A **M** J J	59
Hydrophilidae						
Cercyon assecla Smetana	1534	G		S	A M J J **A** **S** O	59
Lampyridae						
Ellychnia corrusca (L.)	309	G		Z	A **M** **J** J A S O	37
Leiodidae						
Catops basilaris Say	236	F		S	M J **J** A S	48
Sciodrepoides teminans (LeConte)	137	G		S	M J **J** A	60
Mordellidae						
Mordellina sp. S	242	O		P	J **J** **A** S	49
Nitidulidae						
Carpophilus brachypterus (Say)	138	O		S	A **M** **J** J A	54
Conotelus obscurus Erichson	168	O		P	J J **A** **S** O	55
Glischrochilus quadrisignatus (Say)	259	G		S	A **M** **J** J S	na
Meligethes nigrescens Stephens	5498	O	H	P	A **M** **J** J A S O	9
Pedilidae						
Pedilus canaliculatus (LeConte)	226	O		P	**M** **J** J	38
Scirtidae						
Cyphon variabilis (Thunberg)	242	G		?	A **M** J J A S O	64
Silphidae						
Necrophila americana (L.)	189	O		S	M **J** **J** A	33
Staphylinidae						
Acidota subcarinata Erichson	2033	G		Z	M J **S** **O**	11
Acrotona sp. S4 + *Mocyta luteola* (Er.)	109	O		Z	A **M** J J A S	na
Amischa analis (Gravenhorst)	242	O	A	Z	A **M** **J** J A S O	100
Anotylus rugosus (Fabricius)	113	O	A	S	A **M** J J A	66
Atheta crenuliventris Bernhauer	247	O		Z	M J **J** **A** S O	40
Atheta districta Casey	157	F		Z	M J **J** **A** S O	51
Bisnius blandus (Gravenhorst)	229	F		Z	A M J **J** **A** S	52
Carpelimus sp. S02	100	?		S	A **M** J J A S O	na
Eusphalerum pothos (Mannerheim)	3159	F		P	**M** **J** J A	53
Gabrius subnigritulus (Reitter)	101	O	A	Z	A **M** J J A S O	72
Mocyta fungi (Gravenhorst)	244	O	A	Z	A **M** J J A S O	na
Ontholestes cingulatus (Gravenhorst)	175	O		Z	A M **J** **J** A S	46
Oxytelus laqueatus (Marsham)	109	F	A	S	M **J** J **A** S O	55
Philhygra clemens Casey	101	O		Z	A **M** **J** J A S O	na
Philonthus carbonarius (Gravenhorst)	119	O	A	Z	A **M** J **J** A S O	54
Philonthus cyanipennis (Fabricius)	114	F	H	Z	M **J** **J** A	57
Quedius curtipennis Bernhauer	121	O	A	Z	A **S** O	55
Tachinus luridus Erichson	326	F		Z	M J **J** A S	54
Tachyporus dispar (Paykull)	150	O	A	Z	A **M** **J** J A S O	58

[a] Habitat preferences: F forest; G habitat generalist; O open site; ? indetermined
[b] Biogeography: A adventive species; H Holarctic species
[c] Trophic groups: F fungivorous; P phytophagous; S saprophagous; Z zoophagous; ? unknown
[d] At least 25% of catches during months in bold

On the basis of the species richness and idendity of the dominant and subdominant species, the composition of the beetle assemblage at the woods edge was intermediary between the assemblages in the grassland and in the woods; whereas the composition of the beetle assemblages in the grassland and near the ditch were more similar.

The most abundant species. We collected at least 100 adults for 48 species, representing 80.7% of beetles in the four traps over 2006–2010 (Table 3), including four major species: *M. nigrescens* (15.9%), *L. luridus* (10.6%), *E. pothos* (9.1%), and *A. subcarinata* (5.9%). We believe that nine species were forest species (predominantly occurring in forests), 12 were habitat generalists, and 26 species were generally in open sites and / or in boundary (woods edge or near the ditch). Among the 48 most abundant species, 15 taxa are Holarctic or adventive, including three very abundant phytophagous species (*Hydrothassa vittata* (Olivier), *L. luridus* and *M. nigrescens*), and an adventive species (*Quedius curtipennis* Bernhauer) recently recorded in southern Québec. These species included two fungivorous taxa, 19 phytophagous species, nine saprophagous species, 17 zoophagous species and one species of unknown trophic group. We observed a wing polymorphism in *L. luridus* (Chrysomelidae Alticini): 5.5% of individuals were macropterous; whereas adults of 47 other abundant species were all macropterous. Two species, *E. pothos* and *M. nigrescens*, were mainly active in May and June; however, adults of *A. subcarinata* and *L. luridus* were collected mainly in September and October. We observed generally the flight of females and males in similar numbers, but we caught mainly males (~90%) of *A. subcarinata* and *M. nigrescens* (Table 3).

Discussion

Owen (1993) used a flight interception trap in studying the beetle fauna of a Surrey (UK) woods over a three year period. He collected a total of 10581 individuals belonging at 499 species (average of 320 species / year). The number of individual by species over the three years ranged from 1 to 841. The majority of species appeared as singletons (132 species) or in small numbers (2–10 individuals, 238 species). Many species were trapped in one year but were not caught in either of the two other years. The extrapolation of the cumulative total of species at the end of each year of this survey indicates that the final total achieved with the trap (after many years of operation) would be in the range of 580 species. Some species showed considerable fluctuation in number; very few showed an uniform abundance over the three years. More beetles and species occurred in the warmer months of the year; 82% of the total catches and 61% of species were trapped in April-September; certain species occurred over relatively short periods whereas others had an extended season.

In a previous study, we investigated the flight of beetles in a raspberry agro-ecosystem at Johnville (about 50 km from Scotstown, southern Québec) over 1987–1989 (Levesque and Levesque 1992, 1993a, 1993b, 1994a, 1994b, 1995a, 1995b, 1995c, 1996, 1997, 1998). We used four FIT, three near raspberry plants (two in open sites, one at a woods edge), and one in an adjacent pine woods. The species composition of beetle assemblages was quite similar over the years in each trap, except at the woods edge because of variations in the relative abundance of species flying either in open sites or in wooded sites. Among the 42 most abundant species (excluding Aleocharinae) in FIT at Scotstown, at least 27 species were also collected at Johnville. Our observations for these 27 species on the phenology patterns, female ratio, wing polymorphism and habitat preferences were quite similar over 1987–1989 and 2006–2010. The total number of *L. luridus* catches from Johnville was increased by a factor of 6.5 between 1987 and 1989, this difference mainly associated with the new generation adult activity during the autumn (Levesque and Levesque 1998). However, we did not observe important differences for *E. pothos* and *M. nigrescens* captures from year to year at Johnville (Levesque and Levesque 1992 and 1996).

Generally, our observations on beetles from Scotstown were quite similar at these of Owen (1993) and Levesque and Levesque (1992–1998). Species-level responses driven probably by differences in behavior, dispersal ability, ecological interactions, abundance of ephemeral habitats, microclimate, or spatial heterogeneity in food quality and quantity (Maguire et al. 2014).

Community composition of Coleoptera varied significantly by trap height and time in the north-temperate forests (Barsulo and Nakamura 2011, Hardersen et al. 2014, Irmler 1998, Maguire et al. 2014, Normann et al. 2016), and also in agricultural landscapes (Boiteau et al. 1999, 2000a, 2000b, Stein 1972). Highest abundance and species richness were observed in the lowest stratum at all sites, where phytophagous and predators were more abundant.

One of the factors associated with FIT data is that many species are wide-ranging "tourists" that are sometimes found in habitats where they do not reproducte or develop (Zeran et al. 2006). The combined influence of structural and compositional habitat heterogeneity at stand (within a 11.3 m radius) and landscape scales (within 400 or 800 m radius) best explained richness patterns in flying beetles in a matrix of old-growth boreal forest in Québec (Janssen et al. 2009).

In last years, some researches have focused on the biodiversity of beetles from many sites during one or two years. However, we believe that this type of research could explore more often variations on long time, particularly in the study on influences of climatic changes, because 1) the difficulties to estimate the real species richness of flying Coleoptera in a site, even after a five-year sampling, and 2) the possible considerable fluctuation of annual percentages for the most abundant species in a flight interception trap installed in an undisturbed site.

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