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POPULATION ESTIMATION AND FEEDING BEHAVIOR OF ADULT CARABIDS IN JACK PINE STANDS, QUEBEC

by W. Tostowaryk

CENTRE DE RECHERCHES FORESTIÈRES DES LAURENTIDES
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ERRATUM

Q-X-27 "Population Estimation and Feeding Behavior of Adult Carabids in Jack Pine Stands, Quebec", by W. Tostowaryk should read Q-X-32. Please make appropriate corrections in both cover and title page.

Thank you.

Centre de recherches forestières
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ERRATUM

S.V.P. amender le Q-X-27 "Population Estimation and Feeding Behavior of Adult Carabids in Jack Pine Stands, Quebec", par W. Tostowaryk pour lire Q-X-32 sur la couverture et la page-titre.

Merci.

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INTRODUCTION

This report describes population and behavior studies of five species of adult carabids: *Pterostichus punctatissimus* Randall; *P. adstrictus* Eschscholtz; *P. pensylvanicus* LeConte; *P. coracinus* Newman; and *Sphaeroderus lecontei* Dejean. The purpose of the study was to show whether adult carabids, predators of cocoons of the Swaine jack pine sawfly, *Neodiprion swainei* Middleton, play an important role in the population dynamics of this pest in Quebec jack pine forests.

METHODS AND MATERIALS

Location

The study was made in 1971 in jack pine stands at Lac Cousacouta and Lac Normand, in the St. Maurice River watershed, Laviolette County, Quebec. The stand at Lac Cousacouta, consisted of pure jack pine, *Pinus banksianae* Lamb with a *Kalmia-Vaccinium* shrub layer and *Cladonia-Calliergon* ground cover; the degree of infestation by *N. swainei* was light and in a declining phase of an outbreak. The stand at Lac Normand was a mixture of black spruce, *Picea mariana* (Mill) BSP and jack pine, and the ground vegetation consisted of a *Kalmia-Vaccinium Liedum* shrub layer and *Calliergon-Cladonia-Hypnum* ground cover; the jack pine was lightly infested with *N. pratti banksianae* Rohwer and *N. swainei*. Populations of both species persisted at endemic levels from 1967, when monitoring of these insects began.

Population estimates

A capture-recapture method was used when estimating absolute numbers of adult carabids. At each locality a plot was established in a representative part of the stand, and 121 one quart cans were sunk in the soil to the rim in a square grid with 2.5 x 2.5 m spacing. Holes were punched through the bottom of each can, and 15 cm plywood boards were placed on wire stakes 10 cm above each can as protection from rain. Ten-centimeter diameter saucers were used as lids.

After each collection, the traps were closed and adult carabids separated into species and sexed, identification marks checked, marked if not already marked, and released. After 2 or more days of allowing marked to mix with unmarked insects, the traps were opened for approximately 24 hours. Collections were then made and the process repeated during the trapping period.

Each beetle was marked by a scrape on the interstrial spaces of the elytra (Murdoch 1963). As the marks are permanent, recaptures can be recorded without further marking. During marking the beetle was held in place within a dacron screen-topped Ampak No. 5 plastic vial fitted over an Ampak No. 3 glass vial (Fig. 1). Tension on the beetle was easily regulated with the fingers. Marks on the elytra were made with a sharp, pointed scalpel. Checking and marking were done under a microscope. It took approximately 2 min to place one beetle in position to check for former marks, determine the sex and/or mark.

To determine the effect of marking, several marked and unmarked adult carabids of each species were kept in the laboratory, and periodically examined for 4 months.

At Lac Cousacouta marking was done in the field to avoid transporting the beetles to the laboratory some 56 km away. At Lac Normand the marking was done in the field laboratory, near the plot. All beetles were released soon after marking, a point important in capture-recapture work. Each marked beetle was released in the center of the 2.5 m grid diagonally to the lower left of capture point.

The assumptions and techniques involved in capture-recapture work and analyses have been discussed by MacLeod 1958; Jolly 1963; Southwood 1966; Parr *et al.* 1968, and are not repeated here. In the present study the stochastic method of Jolly (1965) was used. Jolly's method involves at least three successive samples where both dilution and loss of animals may be occurring, but where there is no restriction of the length of time between samples. However, each sample taken is considered a random sample, and marked individuals are assumed to have the same probability as unmarked individuals of being captured in the next sample.

As this was a preliminary study, trapping was carried out only in June and July at Lac Cousacouta, and during July and August at Lac Normand. Ideally, trapping should be initiated in this area shortly after snow disappears and continued until late fall when snow returns, to correlate the number of adult carabids with available host cocoons, and to follow the trend of carabid populations during the year.

Adult carabid feeding response

The functional response of the adult carabid to varying densities of cocoons of *N. swainei* and to puparia of calliphorid flies was tested in the field laboratory at Lac Normand. The species of predator and prey, and the duration and replication of each experiment was as follows:

Predator species	Prey species	Replicates	Duration (days)
P. punctatissimus	sawfly cocoons	7	35
P. punctatissimus	fly puparia	6	8
P. adstrictus	sawfly cocoons	8	30
P. pensylvanicus	sawfly cocoons	8	30

The density of sawfly cocoons and fly puparia varied from 1 to 10 per 930 sq cm (approx. 1 sq ft) and the number of predators per arena held at unity. The arena was a 30.5 x 30.5 x 8 cm wooden tray half-filled with moist sand. Clean *Cladonia* was placed on the sand and the tray covered with transparent plastic to maintain high humidity.

RESULTS

Population estimates

Of the four carabid species recovered at Lac Cousacouta only two, *P.adstrictus* and *P. pensylvanicus*, were sufficiently abundant to be measured (Table 1). Only an expert can quickly differentiate the external morphology of *P. adstrictus* and *P. pensylvanicus* (Barlow *et al.* 1969). As both species occupied the same habitat, appeared at the same time, and caused approximately the same degree of predation on sawfly cocoons, they were combined for the purpose of this study. The low numbers of *P. punctatissimus* and *S. lecontei* at Lac Cousacouta precluded population estimates.

In addition to *P. adstrictus* and *P. pensylvanicus* (Table 1), *P. punctatissimus* was also abundant in the black spruce-jack pine forest at Lac Normand. Numbers of *S. lecontei* and *P. coracinus* were too low at Lac Normand to obtain population estimates.

Because of the small number of recaptures (Table 1) the standard error of population estimates are high, (Tables 2,3) and so the reliability of the population estimates is questionable. Presumably a greater number of captures and recaptures could be obtained by increasing the density of traps; however, there is a danger in spacing the traps too closely because much of the ground cover may be trampled during installation and subsequent examinations resulting in an excessively disturbed habitat. The traps were spaced 2.5 m apart based on preliminary evidence of adult carabid movement; but information from this current study now suggests that traps could be spaced closer, probably 1.5 m, without appreciably damaging the habitat.

There is also high temporal variation in the numbers of carabids per plot (Tables 2,3). This variation may be real because of dilution and losses, but it may also be due to variable carabid activity. During inclement weather the number of captures and recaptures was lower. Thus it may be necessary to keep traps open longer than the 24 hr period for each sampling.

Adult carabids moved extensively in each plot (Table 4) and the higher movement rate of *P. adstrictus* and *P. pensylvanicus* in the Lac Normand stand can probably be attributed to sparse ground cover. In the same stand, marked individuals of *P. punctatissimus* were captured in traps located 10 m away from the sample plot. Hence much immigration and emigration to and from the plot probably occurred.

Marking did not appear to affect the behavior, or cause mortality in adult carabids. All individuals marked in May and June, and kept in the laboratory until October, remained in good condition. Also at Lac Normand, traps reopened in October 1, yielded two recaptures of *P. pensylvanicus* and *P. adstrictus* marked on July 8 and 11, and one recapture of *P. punctatissimus* marked on August 12.

Adult carabid mortality

Adult carabids were susceptible to predation by shrews, *Sorex* spp. and toads, *Bufo* spp. In June and early July, a small number of shrews and toads were found in pitfall traps. Where shrews were found there was an occasional elytra of an adult carabid, presumably victims of shrews. Toads do not usually leave evidence of predation, but 87 toads, collected from pitfall traps during previous experiments at Lac Cousacouta, were dissected and

and the stomach content examined. Results (Table 5) showed that toads preyed on several species of adult carabids, so in future it may be necessary to provide refuge for the carabids in the traps to prevent predation by toads and shrews.

Functional responses

The functional response of *P. punctatissimus* to increasing densities of sawfly cocoons and fly puparia (Fig. 2) follows a density-dependent type response (Holling 1959), and that of *P. adstrictus* and *P. pensylvanicus* an inverse density-dependent type response. Predation by the three species of carabids on sawfly cocoons in the laboratory, in the absence of alternate prey was low ranging from 1 to 3% of the cocoons offered, or approximately 0.2 cocoons a day, which agrees with earlier findings (Tostowaryk 1972). Predation on fly puparia by *P. punctatissimus* in the laboratory was considerably greater, ranging from approximately 30 to 64% of puparia offered.

When fly puparia and sawfly cocoons were offered to *P. punctatissimus* only 1% of the food eaten was sawfly cocoon, indicating preference for fly puparia. Pupal case structure and size could cause this preference. The wall of the fly puparium is thin and fragile, whereas the cocoon is thick and fibrous. Carabids took only a fraction of second to open a fly puparium by crushing it with their large, curved mandibles. Sawfly cocoons however were opened by tearing the wall, and this took several minutes. Occasionally cocoons were abandoned after several unsuccessful attempts.

Size appeared to be important in the selection of fly puparia over cocoons. In density response experiments, the ratio of male to female cocoons offered was 4:6, simulating normal field conditions; however, significantly more male cocoons were consumed (Table 6). Measurements of sawfly cocoons and fly puparia (Table 7) also show that the width of the male cocoons was significantly less than that of the female cocoons, and the width of the fly puparia was significantly less than that of the cocoons. Width appears to be the important criterion, as the adult carabids invariably opened cocoons and puparia transversely to the long axis.

The opening of the spread mandibles in *P. punctatissimus* measured 3.4 mm, and in *P. adstrictus* and *P. pensylvanicus* 2.5 mm. These three carabid species consistently selected more male cocoons than female cocoons in the density-response experiments, and when presented with fly puparia as alternate food consistently preferred fly puparia. Also, because *P. punctatissimus* has larger mandibles, it could be expected to prey on more female cocoons than the other species. This was confirmed by observation (Table 6). In another experiment pupae of *Petrova albicapitana* (Busck) (Lepidoptera) were offered as alternate prey. The size of the pupae was similar to male sawfly cocoons, but the pupal skin was fragile. The carabid preyed only on the lepidopterous pupae. Thus, host size and thickness of the integument or cocoon wall appear to be important factors in the selection of prey by adult carabids.

DISCUSSION AND CONCLUSION

This preliminary study has partially revealed the influence of adult carabids on several pine sawflies, particularly *N. swainei*. *Pterostichus adstrictus* and *P. pensylvanicus* were the only abundant species of carabid preying on cocoons of *N. swainei* in a pure jack pine stand at Lac Cousacouta, where periodic eruption of *N. swainei* have occurred. The numerical responses have not been explored. Population estimates of carabids during a gradation of the sawfly population, to determine the nature of the numerical response would be pertinent to this study. However the low numbers of *P. adstrictus* and *P. pensylvanicus*

(Table 1), their non-regulative type of functional response to increasing densities of cocoons (Fig. 2), low predation pressure on the sawfly cocoon population, and the abundance of alternate prey (Table 8), indicate that these two species play only a minor role in the population dynamics of *N. swainei*.

The density-dependent type of functional response of *P. punctatissimus* (Fig. 2) indicates this predator offers potential in regulating populations of its prey. However, when the prey consisted of sawfly cocoons, the degree of predation was low, and in the presence of alternate prey, such as dipterous and lepidopterous pupae, no cocoons were consumed. In the spruce-pine stand at Lac Normand *P. punctatissimus* was the most abundant carabid species feeding on sawfly cocoons. Populations of the sawflies *N. pratti banksianae* and *N. swainei* have been maintained at endemic levels for several years in this stand. As *P. punctatissimus* may be playing an important role in maintaining the populations of this sawfly at low levels, more research is required on this species to fully determine its ecological impact on sawflies.

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Table 1. Summary of adult carabid capture-recapture data, Lac Cousacouta and Lac Normand, 1971

Locality	Species	Total captured	Total marked and released	Total recaptured	% recaptured
Lac Cousacouta					
	P. adatrictus & *P. pensylvanicus*	208	194	30	15.5
	P. punctatissimus	1	1	0	0.0
	S. lecontei	17	16	2	12.5
Lac Normand					
	P. adstrictus & *P. pensylvanicus*	60	58	4	6.9
	P. punctatissimus	70	69	13	18.8
	P. coracinus	1	1	0	0.0
	S. lecontei	4	4	0	0.0

Table 2. Population estimates of *P. adstrictus* and *P. pensylvanicus* in a jack pine stand at Lac Cousacouta, Quebec, based on Jolly's (1965) capture-recapture method

Date	Estimated number per plot	Estimated number per hectare
June 14	114.8 ± 78.1*	1595
June 22	152.3 ± 105.5	2116
June 29	170.2 ± 189.9	2365
July 6	44.3 ± 28.4	616
July 9	30.0 ± 22.5	417
July 12	72.0 ± 63.4	1000

* Standard error of mean.

Table 3. Population estimates of *P. punctatissimus*, *P. adstrictus*, and *P. pensylvanicus* in a black spruce-jack pine stand at Lac Normand, Quebec, based on Jolly's (1965) capture-recapture method

Species	Date	Estimated number per plot	Estimated number per hectare
P. punctatissimus	July 11	105.0 ± 118.1*	1459
	July 14	253.0 ± 302.6	3515
	July 26	130.5 ± 153.8	1813
	July 29	192.5 ± 232.8	2675
	Aug. 1	21.7 ± 19.5	301
	Aug. 10	105.0 ± 142.3	1459
P. adstrictus & *P. pensylvanicus*	July 11	97.8 ± 129.1	1355

* Standard error of mean.

Table 4. Distances traversed by adult carabids based on capture-recapture data

Species	Locality	Number of beetles	Mean (m) per day	Range (m) traversed between captures
P. adstrictus & *P. pensylvanicus*	Lac Cous-acouta	30	0.5	2 - 26
P. adstrictus & *P. pensylvanicus*	Lac Normand	4	4.7	15 - 25
P. punctatissimus	Lac Normand	13	0.9	2 - 25

Table 5. Stomach analyses of 87 toads, *Bufo americanus americanus* and *B. a. copei*, collected from pitfall traps at Lac Cousacouta in June and July, 1965.

Classification of arthropod faune	Number of specimens	Per cent of total
Formicidae	1377	59.4
Chrysomelidae	269	11.6
Carabidae		
Calathus ingratus	167	7.2
Agonum	50	2.1
Notiophilus aeneus	22	0.9
Pterostichus adstrictus & *Pterostichus pensylvanicus*	5	0.2
Sphaeroderus spp.	4	0.2
Scaphinotus bilobus	1	0.1
Ichneumonidae	39	1.7
Staphylinidae	21	0.9
Elateridae	15	0.6
Curculionidae	5	0.2
Pentatomidae	4	0.2
Diptera	2	0.1
Larval forms (Lepidoptera)	159	6.8
Araneae (Spiders)	121	5.2
Unknown	58	2.5
Totals	2319	99.9

Table 6. Proportion of male and female sawfly cocoons opened by adult carabids in density response experiments

Carabid species	Number cocoons opened		Ratio
	male	female	male:female
P. punctatissimus	33	9	3.7:1
P. adstrictus	38	8	4.8:1
P. pensylvanicus	33	7	4.7:1
Totals	104	24	4.3:1

Table 7. Measurements of male and female sawfly cocoons and fly puparia offered to adult carabids in density response experiments

	Number	width(mm)	length(mm)
Sawfly cocoons			
female	24	4.1 ± 0.06	8.6 ± 0.06
male	25	3.2 ± 0.04	6.8 ± 0.08
fly puparia	30	2.9 ± 0.05	7.5 ± 0.14

Table 8. Composition of arthropod fauna collected from emergence traps in jack pine stands, Lac Cousacouta, 1966 to 1970

Classification	Number of specimens	% composition
Diptera	4822	38.4
Hymenoptera	2877	22.9
Coleoptera	1969	15.6
Lepidoptera	1792	14.2
Hemiptera	325	2.6
Neuroptera	97	0.8
Homoptera	134	1.1
Orthoptera	46	0.4
Other insect families	39	0.3
Araneae (spiders)	467	3.7
Totals	12568	100.0

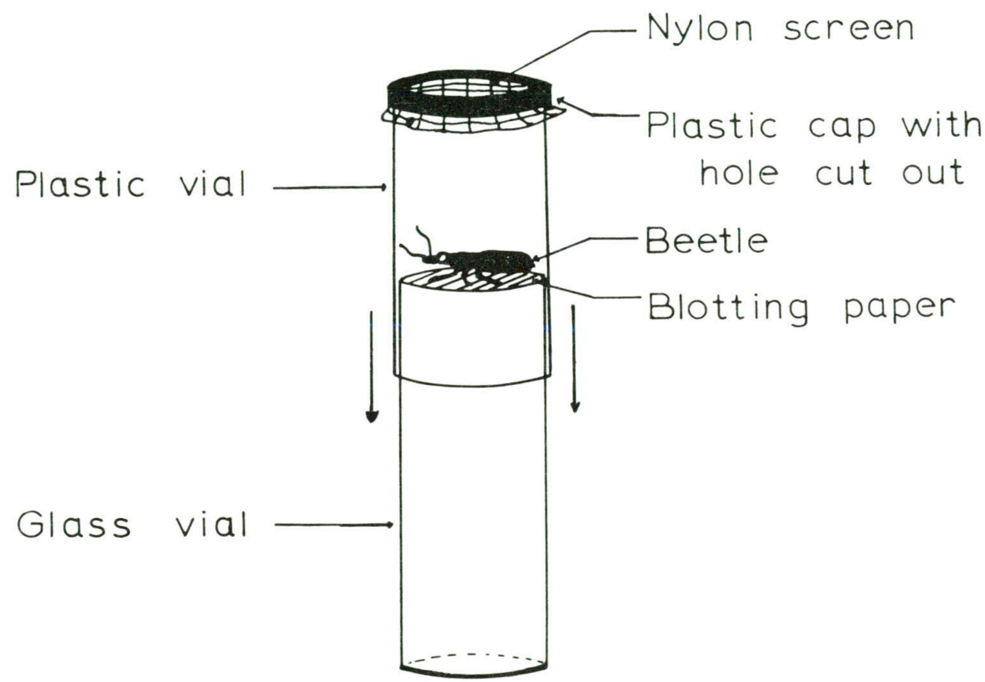

Fig. 1. A device for holding a carabid beetle in place during marking.

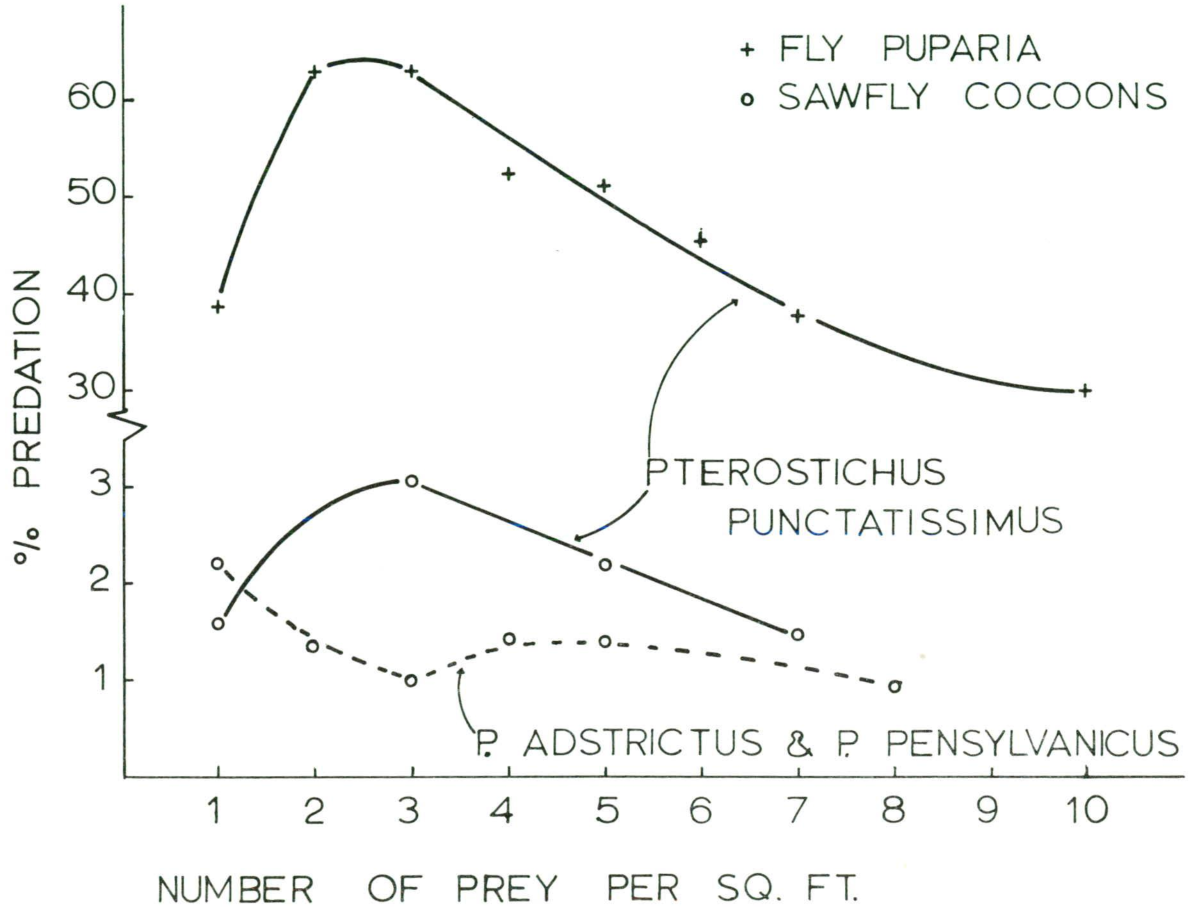

Fig. 2. Functional response curves of adult carabids to varying densities of sawfly cocoons and fly puparia.