EFFECT OF *FORMICA OBSCURIPES* (HYMENOPTERA: FORMICIDAE) ON THE PREDATOR–PREY RELATIONSHIP BETWEEN *HYPERASPIS CONGRESSIS* (COLEOPTERA: COCCINELLIDAE) AND *TOUMEYELLA NUMISMATICUM* (HOMOPTERA: COCCIDAE)

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The scale insect *Toumeyella numismaticum* Pettit and McDaniel occurred in small areas of heavy infestation in jack pine, *Pinus banksiana* Lamb., stands of southeastern Manitoba, where it was present in the same areas every year. The large populations of *Formica obscuripes* Forel present in the scale-infested areas lessened the effectiveness of the main predator of the scale, the coccinellid *Hyperaspis congressis* Watson, through interference with the *Hyperaspis* adults.

Résumé

Le Kermès-tortue du Pin, *Toumeyella numismaticum,* ravage fortement de petites superficies isolées dans les peuplements de Pin gris, *Pinus divaricata* (*Pinus banksiana*) dans le sud-est du Manitoba. Il se retrouve d'une année à l'autre aux mêmes endroits. L'auteur trouva que les fortes populations de *Formica obscuripes* trouvées avec les Kermès-tortues du Pin diminuaient l'efficacité du principal prédateur des Kermès-tortues du Pin: la Coccinelidée *Hyperaspis congressis* vu que leur action intefère avec celle des adultes *d'Hyperaspis.*

Introduction

The pine tortoise scale, *Toumeyella numismaticum* Pettit and McDaniel, has been present on jack pine, *Pinus banksiana* Lamb., in the Sandilands Provincial Forest of southeastern Manitoba every year since 1935. It produced severe and widespread infestations there in 1938 (Brown 1939) and has been abundant in some areas since (Annual Reports, Canadian Forest Insect and Disease Survey, 1940–68). The scale has persisted in small, widely scattered pockets of moderate to heavy infestation that occur in the same localized areas every year. Both large dominant and suppressed trees are infested, although the small amount of mortality now caused by the scale occurs mainly in the smaller trees.

The main natural control agent of the scale, the coccinellid *Hyperaspis congressis* Watson (*H. binotata* and *H. congener* of authors), is also present in the area every year.

Colonies of the ant *Formica obscuripes* Forel were much more numerous in the scale-infested areas than in the surrounding forest. Nests of *F. obscuripes* were counted a 1-ha block in the largest and most accessible pocket of scale infestation. This measured hectare, which included about half the area of the localized infestation, contained 64 nests, 43 of which were in its central 4000 sq. m. The nests were medium to large in size, with an estimated population of 40,000 ants each. No comparable concentrations of *F. obscuripes* occurred, except in other scale-infested pockets, although this ant was common in jack pine stands throughout the general area. Outside the scale pockets, *F. obscuripes* fed on small insects, and also on honeydew, when aphids and scale insects were present on the trees around a nest, as previously described (Bradley and Hinks 1968). The *F. obscuripes* nests were widely spaced, and nests of other ants were usually interspersed with them.

Rabkin (1940) remarked, "Evidence now indicates that ants are able to protect the remaining scale population from the few *Hyperaspis* that have persisted." This statement seemed true to the present author after observing the scale and the predator for several years, although casual observation seemed to provide conflicting evidence, i.e. that *Hyperaspis* larvae could be seen feeding on the scale in the presence of large numbers of ants, and were able to continue feeding, apparently unmolested, until maturity.

Two questions arising from the foregoing observations were: Why was the predator unable to completely eliminate the remaining scale in the area, and, conversely, why did the scale remain in the same small areas year after year without spreading and producing another large outbreak? Interference with the existing association of ants, scale insects, and predators, through removing the ants, followed by periodic observation of the results, was selected as the most promising approach in attempting to discover the answers.

Methods

Barriers were used to prevent ants climbing a series of scale-infested trees. Two types were used, each with Fluon (Polytetrafluoroethylene Dispersion, made by Imperial Chemical Industries, England). The first consisted of long interlocking strips of sheet metal 8 in. in width, placed on edge in a circle around the base of the tree. The lower 3 in. of the strips were dug into the soil, and the top 2 in. of the inner surface coated with Fluon. The second type, which was simpler and more effective, consisted of a few turns of wide masking tape wound around the trunk of the tree, after the bark scales had been removed by light scraping. The tape provided an even surface 5 or 6 in. wide, which, when painted with Fluon, became too smooth for the ants to cross.

The activities of the beetles and the ants on the banded and unbanded trees were observed at intervals. When a difference in the number of *Hyperaspis* adults present on the two classes of trees was noticed, counts were made to substantiate the observations. The counting was done by moving slowly around the tree and noting all the *Hyperaspis* that could be seen, without removing them, or jarring the branches.

Counts of *Hyperaspis* adults were started in May and continued at various intervals throughout the summer. Of necessity sampling was limited to periods of good weather, as the adult predators are inactive and shelter under bark scales during cool, cloudy weather. Under favourable conditions, however, the adults flew about freely in the infested area, as evidenced by the rapidity with which they appeared on a newly banded tree, a few hours of warm sunny weather being sufficient for them to become numerous.

Counts of *Hyperaspis* larvae and adults were also made from four branches of large trees, two from a banded and two from an unbanded tree. Each sample branch consisted of the terminal 18 in. clipped from a large lateral branch at a height of 15 ft above ground level.

Hyperaspis adults were transferred to trees on which ants and scale insects were numerous, and the resulting interaction between ants and beetles observed. Later in the season similar transfers of *Hyperaspis* larvae were also made.

Two nest populations of *Dolichoderus taschenbergi* (Mayr), a species of ant that also feeds on honeydew, nests of which are often found interspersed with those of *F. obscuripes,* were transplanted to a scale-infested area, and allowed to become established there behind protective metal strip barriers.

Results and Discussion

Hyperaspis adults were found to be much more numerous on banded than on unbanded trees (Table I). The absence of larvae, and the small number of adults on tree No. 1 (banded), resulted from the weakened condition of the tree, which had been severely attacked by the scale in previous years. There were relatively few scales on it in the early spring, and these had disappeared by June.

The abrupt disappearance of the *Hyperaspis* larvae from the banded trees, in contrast to their survival on the unbanded trees (Table 1B) was caused by starvation of the larvae when they were about half grown. *Hyperaspis* adults on the banded trees, undisturbed by ants, laid a large number of eggs. So many predator larvae resulted from these they had soon eaten all the scale insects on the trees, and so starved. On the unbanded trees, the few *Hyperaspis* larvae present had more than sufficient scale, and so continued feeding until they had completed their development.

On the sections of lateral branches clipped from the large trees, no *Hyperaspis* larvae or adults were found on either of the two branches from the unbanded tree, although scale insects were present in large numbers. On one branch from the banded tree there were 22 *Hyperaspis* larvae and one adult; on the other branch, 57 larvae and three adults.

When adult *Hyperaspis* were taken from banded to unbanded trees, each beetle was confronted by one or more ants almost at once, and reacted in one of three ways: (1) dropped from the branch; (2) took flight; (3) drew its legs and antennae under its body, and held itself tightly against the bark. In the latter case the ants milled around the beetle, trying unsuccessfully to grasp it with their mandibles. After this harassment had ceased, the beetle would proceed along the branch, only to drop off or take flight at the approach of another ant. The normal activities of

Table I. Number of *Hyperaspis congressis* adults (A) and larvae (B) on trees banded to exclude ants, and on adjacent, unbanded trees

	Banded tree number					Unbanded tree number				
Date	1	2	3	4	5	1	2	3	4	5
A										
May 6	12					0	0	0	0	0
May 13	24	2				0	0	2	0	0
May 15	20	2	25+			1	0	0	0	0
May 22	11	5	25+			0	0	0	0	0
May 23	1	6	25+			0	0	0	0	0
May 27	0	3	3	25+	25+	0	0	0	0	0
May 29	1	3	3	15	10	0	0	0	0	0
June 3	0	0	0	12	5	0	0	0	0	0
June 30	0	0	0	0	2	0	0	0	0	0
July 7	0	0	0	3	3	0	0	0	0	0
B										
June 30	0	12	40	3	10	0	0	0	0	0
July 7	0	25	50+	50+	50+	0	0	0	2	0
July 16	0	50+	50+	50+	50+	0	0	5	0	0
July 18	0	50+	50+	22	25	0	3	5	0	0
July 21	0	20	30	9	5	0	3	5	0	0
August 7	0	0	0	0	0	0	1	5	1	0

the beetles in searching for scale-infested branches, mating, and laying eggs, were apparently made nearly impossible by the great numbers of ants.

When *Hyperaspis* larvae were transferred to trees on which were large numbers of ants, they were attacked at once, the ants pulling off large wads of the cottony wax that covered their bodies. This wax, however, seemed to be an effective deterrent to successful attack. The larvae also exuded a sticky yellow secretion that stuck to the forelegs of the attacking ants. The wax covering and the secretion usually provided sufficient protection for the larvae, only a few of which were actually killed. Attacks by the ants gradually ceased, and the larvae were able to feed on the scale unmolested.

The two colonies of *D. taschenbergi* that were placed in a scale-infested area established new nests, and the ants began feeding on honeydew from scale on the small jack pines that had been enclosed inside the barriers with them. When the barriers were removed, however, these nests were soon overrun and their populations killed or dispersed by the overwhelming numbers of *F. obscuripes*.

The crawler stage of the scale had become established on the new shoots by 30 June. *Hyperaspis* larvae were also present at this date. It was apparent that the development of the predator and the scale insect were synchronized. This observation is in agreement with Hagen (1962), who concluded that coccinellids which attack sedentary prey, such as scale insects, display close synchrony with the prey. Some of the *Hyperaspis* larvae were in the first instar at this date, while others were already in the second and later instars. This variation was caused by fluctuations in the temperature during oviposition by the *Hyperaspis* adults. Since these were only active on warm days, the eggs were deposited at irregular intervals in the variable weather of early spring.

The young scales on the banded trees were eaten by the *Hyperaspis* larvae soon after they had settled on the new shoots. Their empty skins, from which the body contents had been removed, remained attached to the bark of the shoots. It seemed clear that the predator, in the absence of ants, would soon overpopulate the scale-infested trees, and destroy itself through starvation.

It was apparent that a very large ant population was prerequisite to maintaining the scale in the infested areas, since it was only the presence of great numbers of ants on the trees that affected the predator. It seemed apparent also that *F. obscuripes* needed the large supply of honeydew, provided in this case as a by-product of scale feeding, to build up its population to the density at which the scale would be protected.

In removing the honeydew for food, the ants maintained the scales and their feeding sites on the branches in a clean, dry condition. For a few days after the ants were excluded, the scale insects on the banded trees continued to produce large quantities of honeydew, which accumulated in large sticky droplets on the needles and branches. Large numbers of dipterous and hymenopterous insects were attracted to it, but did not remove it fast enough to prevent the accumulation. The honeydew was later washed off by rain, and the scale insects, in the absence of ants, seemed to stop producing it in such large quantities.

Within each small area of scale infestation the predator had little effect on the population of the prey, because of the influence of the ants. In the area surrounding the localized infestations, however, it seemed to be highly effective, since the perimeter of each infested area remained in the same location from year to year. Although the local infestations were undoubtedly serving as foci for the spread of the scale, the annual windborne dispersal of scale nymphs was only effective within a 3-mile radius, as discovered by Rabkin and Lejeune (1954). Predation by *H. congressis* in these surrounding areas, away from the influence of the large ant populations, prevented the scale from overpopulating the new locations. This observation is in accord with the conclusions reached by Huffaker (1958) concerning the sometimes greater significance of predators in areas surrounding infestations.

Food conditioning, brought about through the effect of scale feeding on the trees, seemed to be an important factor in limiting scale density. The new shoots of the perennially infested trees were stunted, those of the most heavily attacked, suppressed trees being reduced to a few millimetres in length, and shoots of the dominant trees were also greatly shortened. Since the new shoots are the preferred location for the crawler stage of the scale to settle, it seemed likely that lack of space on the shoots limited the number of scales that were able to establish themselves successfully on a tree. This factor, together with parasitism and predation, was apparently enough to keep the number of scale insects feeding on the large trees below the limit of the carrying capacity of the trees, since only a few had succumbed to scale attack. There seemed to be little danger, therefore, of extensive tree mortality in the scale-infested areas.

Elimination of the scale from the local areas of heavy infestation would seem desirable from the standpoint of managing the forest. It was clear that this could be done by destroying or reducing the ant populations in the scale-infested pockets, a relatively easy procedure, since the ant nests are conspicuous, and grouped in a few small areas. In upsetting the balance between predator, prey, and ants, however, elimination of the predator as well as the scale might result, leaving the forest susceptible to future scale outbreaks. It would seem better, therefore, to preserve the localized infestations as propagation centres for the predator, and to accept the small losses caused in them by *T. numismaticum* as insurance against larger outbreaks.

Conclusions

The questions asked at the beginning of the experiment can now be answered. The predator cannot eliminate the remaining *T. numismaticum* infestations because of interference by the ants. The scale cannot spread from the infested local areas to produce a new outbreak because of the strong predator population that is maintained from year to year.

In the interaction between *T. numismaticum, H. congressis,* and *F. obscuripes* there is a direct trophic relationship between the ant population and that of the scale insect, and a direct predator–prey relationship between *H. congressis* and *T. numismaticum.* Coaction between *F. obscuripes* and *H. congressis,* although having important consequences for the populations of the predator and the scale insect, and, through them, for the ant population as well, is much less direct, depending only on the attraction of ants and predators to the same scale-infested trees. The interaction of *T. numismaticum, H. congressis,* and *F. obscuripes* is thus an interesting example of how the population of one species can have an important effect on the populations of other species merely through being present in the same space and time.

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