Life history of the sooty beech scale (*Ultracoelostoma assimile*) (Maskell), (Hemiptera: Margarodidae) in New Zealand *Nothofagus* forests

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". . . one may return too often to past delights . . . . of honey dew in the summer time . . . . It is exuded by a tiny insect and sweats in transparent globules through a black, mossy parasite that covers the trunks of native beech trees in New Zealand."

Ngaio Marsh. *Black Beech and Honeydew* An Autobiography. 1965, Boston, Little, Brown.

ABSTRACT

Black beech *Nothofagus solandri solandri*, was sampled over 2 consecutive seasons at 2 separate South Island sites to provide life history information on *Ultracoelostoma*

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assimile (Maskell). There were 4 female instars and 5 male instars. Descriptions and diagrams of these stages are given. The 2nd and 3rd instar females and, to a lesser extent, the 1st instars produce honeydew. Adult females, 3rd and 2nd instar females are enclosed in a test on the host plant. They were present throughout the year with no significant seasonal changes of their proportions in the population. Eggs were found in tests in all months of the year, the highest number found was 232. Mobile male prepupae were found only in November. Adult winged males were found from December to March. Crawlers were present throughout the year with an increased production in summer when some wind dispersal occurred. Parasites recorded were a pteromalid (Hymenoptera) and its hyperparasite, and a melandryiid (Coleoptera). A clerid (Coleoptera) was found feeding on live scales. Caterpillars of the families Oecophoridae and Coleophoridae were found associated with scale tests but their role is uncertain. The life history is compared with other margarodids in New Zealand and other countries.

Keywords: Coccoidea, Margarodidae, sooty beech scale, *Ultracoelostoma assimile, Nothofagus solandri* var. *solandri,* biology, life history, distribution, phenology, fecundity, parasites, predators, honeydew, New Zealand.

INTRODUCTION

The sooty beech scale, *Ultracoelostoma assimile* (Maskell), produces copious honeydew as a result of its feeding activities providing important links in the ecological system of New Zealand southern beech forests ranging from honey feeding birds to minute organisms associated with sooty mould. Moreover, in recent years beekeepers have become aware of the potential of honeydew as a source for the commercial production of "bush honey". Previous studies of the sooty beech scale have been limited to taxonomic work (Brittin 1935, 1936; Cockerell 1902; Dumbleton 1967; Maskell 1889, 1891; Morrison & Morrison 1922; Morrison 1928; Oliver 1975) and investigations of honeydew production for the honeydew industry (Anon 1986; Belton 1976, 1978; Belton & Crozier 1979; Cook 1971a, 1971b, 1978a and b; Crozier 1978, 1981; Reid 1978; Smellie 1949; Smith 1980). Except for Belton (1978) and Moller *et al.* (1987), little attention has been paid to the ecology of the insect, to phenology, fecundity and the role of males. This study was undertaken in an attempt to fill this gap and was initiated in response to numerous requests for information on the biology of the sooty beech scale.

Sooty beech scale is found throughout the North and South Islands but the highest density populations occur around the northern half of the South Island, from the Nelson/Marlborough area to mid Canterbury, below altitudes of 780 m and in low to medium rainfall zones (Belton 1978; Crozier 1978).

In the South Island the scale is concentrated on the beech trunk whereas in central and southern areas of the North Island it is usually found in low densities on the twigs and branches. Beech is its main host, in particular black beech *(N. s.* var. *solandri)* and mountain beech *(N. s.* var. *cliffortiodes)* but it has also been found on *Weinmannia silvicola* and *Laurelia novae-zelandiae.* Maskell (1891) recorded it on *Phyllocladus trichomanoides* but this has not since been confirmed as a host record. There are records of sooty beech scale occurring on *Dracophyllum* species, mostly from the southern South Island, Chatham Islands, and the subantarctic Auckland Islands but these are based on specimens of another *Ultracoelostoma* species (Butcher unpublished).

In high density populations sooty beech scale will infest a beech trunk to such an extent that almost the entire surface can be encrusted with the beech scale tests which are a protective covering made by the scale as it grows. Inside the test the soft, pink, immature stage feeds on beech sap by means of a long stylet permanently lodged in the tree. A minute hole in the test allows excretion of alimentary waste fluid by way of an anal filament projecting about 5 mm from the beech trunk, on the end of which is often seen a droplet of honeydew. During summer, when high populations of beech scale are actively feeding the trunks are covered in a mat of dense hair-like, white waxy filaments with glistening droplets of suspended honeydew. The forest is filled with its aroma and many birds and insects feed from the droplets. Gaze *et al.* (1983) have demonstrated the importance of this food source for birds and Crozier (1978) has given accounts of its importance to beekeepers producing "bush honey" for export. Native parakeets, *Cyanoramphus auriceps auriceps*, have been observed cracking open sooty beech scale tests with their beaks and licking out the contents (Taylor 1985). Sooty mould is very commonly associated with honeydew and in high density populations of scale, beech trunks and the surrounding vegetation become blackened with a covering of this fungus which grows on the sugary concentrations of honeydew wherever it falls. There may be several different species of sooty mould present (Hughes 1966, 1972), *Capnocybe novae zealandiae* being a common species. The mould itself is a "mini-ecosystem" supporting populations of arthropods which in turn provide food for other forest insects and birds.

METHODS

STUDY SITES

The study was undertaken over 2 consecutive seasons at 2 separate sites. The first season's collections were made in the Maitai Valley near Nelson (NZMSI S20 688265) from July 1982 to July 1983. *N. s. solandri* (black beech) was the dominant species and 10 mature trees approximately 20-40 cm dbh (i.e. diameter of tree at breast height) were selected for sampling. The 0.5 ha site was on a steep south-facing slope. The second season's study site was situated at Craigieburn Forest Park (NZMS1 S66 192031) and was sampled from July 1983 to July 1984. This 1 ha site was on a northwest-facing slope. It was dominated by *N. s. solandri* and 30 trees were chosen for sampling. Five mature trees were selected for each monthly sampling occasion and these trees were sampled again 6 months later.

BARK SAMPLING

Sample locations were chosen to provide data on the life history rather than give precise population density estimates. Trees were selected semi-randomly with the qualifications that the trees should have a reasonably high population of live scales. The position of bark samples on each tree was chosen to ensure that each monthly sample would have some wax filaments present. More random sampling methods would have raised difficulties in producing enough live scales to study the life cycle because; 1), there is evidence of sooty beech scale concentrating on north-facing sides of tree trunks (Belton 1978); 2), there can be large areas of the trunk encrusted in empty tests; and 3), not every tree is infested.

Each month a 5 cm × 5 cm square of bark was removed by gently chiselling and peeling the bark down to the phloem layer. Samples were wrapped in damp tissue and plastic bags then airmailed to Auckland for assessment. Sooty beech scales on each bark sample were examined by gently cracking open the wall of the test with a sharp scalpel and recording the contents. Percentage area occupied by scales was determined by obtaining the average measure of the test of each stage, multiplying it by the number of tests present and expressing this total as a proportion of the area of the bark sample. Other arthropods present in the samples were noted and especially those which were found inside the tests or associated with recently dead scales.

STICKY TRAP SAMPLING

At the Maitai Valley site 5 sticky traps 1.5 m high were distributed randomly in the study site and run for 1 season concurrently with the bark sampling programme. The traps consisted of a metal pole with a cylinder mounted on the end. The exterior of this cylinder was wrapped with stiff cardboard 20 cm × 20 cm in area and covered in Tangle foot. (The Tanglefoot Co., Grand Rapids, Michigan, USA).

Each month the trap samples were collected (at the same time as the bark samples) and sent to Auckland for recording of numbers of crawlers and adult males of *U. assimile.*

RESULTS

Life History

Description of the life history stages

In this study no laboratory rearing was attempted to determine the length of instars, nor to investigate the breeding system.

The cast skins from each instar are left behind in the test, making it easy to determine the number of moults. From our sampling program we found that there were 4 female and 5 male instars (Fig. 1).

The female instars consisted of a mobile crawler, 2 intermediate feeding stages and the non-feeding adult female. These last 3 stages are immobile and enclosed inside the test. The male instars consisted of the mobile crawler, an intermediate non-mobile feeding stage, a mobile non-feeding prepupa, a sessile pupa and a non-feeding winged adult male.

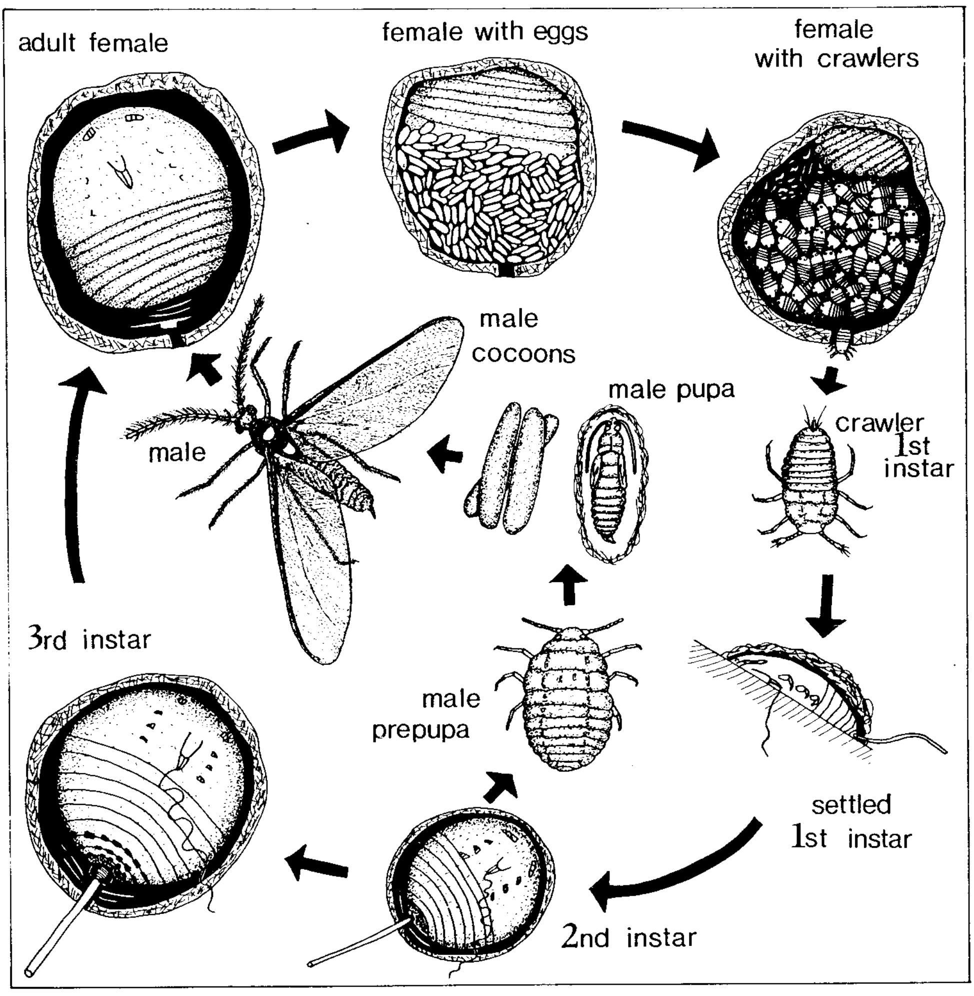

Fig. 1: Diagrammatic representation of the life history of sooty beech scale. Crawler 1.0 mm, 2nd instar 1.0-1.6 mm, 3rd instar 2.5-4.5 mm, adult female 3.0-5.0 mm, male prepupa 3.0-4.0 mm, male cocoons 5.0 mm, adult male 3.0-4.0 mm.

Female

First instar (crawler)

The crawlers are about 1 mm long and 0.5 mm wide, bright pink with well developed legs and antennae. They settle in crevices on the bark, begin feeding by inserting their stylets into the host tissue and produce the characteristic anal filament to excrete their waste products. Their body becomes enveloped in a fluffy, white, waxy covering which later hardens to form a test. This test is secreted by epidermal glands (Fig. 8). The female is now settled in this position for the rest of her life.

Second instar

The scale is now 1.0-1.6 mm in diameter and covered by the protective hard test. The legs and antennae are reduced and the body has become spherical and tightly pressed to the inside of the test. The last abdominal segment is more sclerotised than the rest of the body and appears as a dark cap at the anal end.

Third instar

This instar ranges between 2.5-4.5 mm in diameter. The last abdominal segment has become extremely heavily sclerotised to the extent that part of this segment appears as a raised thick ring surrounding the anus (Fig. 7). There is also a ring of sclerotised tissue separating the last abdominal segment from the previous segment and 3 concentric rings of angular patches of dense intersegmental sclerotisation surround the anus. The size and segmentation of the antennae and legs are further reduced.

Fourth instar

The adult female is from 3-5 mm in diameter with reduced non functional mouthparts and vestigial legs. Because she has stopped feeding she no longer produces honeydew from the anal filament, although the filament sometimes remains intact. There are no heavy sclerotisations on her body. Eggs are laid inside the test and the female slowly shrivels and dies. All the skins from the previous moults remain in the test pushed against the posterior end but the anal aperture remains open.

The eggs are about 0.70 mm × 0.50 mm, oval and bright pink with a dusting of fine powdery white wax. When examined under the electron microscope, the wax appears as circular parings (Fig. 9), similar to that found by Gerson (1980) on the eggs of another margarodid, (*Icerya* sp.). The larvae hatch inside the test and emerge through the anal filament aperture.

Male

First instar (crawler)

Same as in female.

Second instar

There is no visible difference between the male and female 2nd instars. In this study 4 male 3rd instars (prepupae) were found inside 2nd instar tests together with the 1st and 2nd instar moulted skins confirming that the prepupal male is formed after the 2nd instar moult. The walls of these tests appeared to be thinner and softer than those of other 2nd instar tests and although no observations were made, it was assumed that the newly moulted male 3rd instar emerged from the anal filament aperture of the test.

Third instar (prepupa)

The male prepupa is an active crawling stage about 3-4 mm long and 2-3 mm wide. It is a bright brick-red colour with well developed legs, antennae and ocelli. Although this active stage was not collected in our sampling, except in the examples mentioned above, one of the authors (AKW) has observed it crawling on beech trunks in great numbers from ground level to about 2-3 m during late November at Lake Rotoiti, Nelson Lakes National Park. Smith (1980) refers to a belief among beekeepers that the adult females crawl on the host bark and mentions that they may have mistaken them for mealy bugs or ladybird larvae. It could be that they had observed the behaviour of male prepupae and assumed they had seen adult females, or they may have seen adult females of the closely related *Coelostomidia* species which are mobile and are often seen crawling on tree trunks in the summer months.

Fourth instar (pupa)

From field observations and laboratory rearing it was found that the prepupa settles and rapidly pupates amongst the masses of sooty mould which have often accumulated on small shrubs at the base of the trees. The pupa is enclosed in a long, narrow, white, fluffy cocoon which is about 5 mm in length.

Fifth instar (adult male)

The adult male emerges from the pupa and has well developed wings, legs, antennae and compound eyes. It is about 3-4 mm long with a wing span of about 8 mm, and a deep reddish pink body. The wings are a clear purplish pink with the costal margin thickened and coloured deep pink, and discally with an indistinct, solitary, pink sinuous longitudinal vein. The males of this species have a longer penis sheath than the closely related and similar looking *Coelostomidia* males.

We did not observe mating, but it has been observed by H. Moller (pers. comm.).

Phenology

Data from both sites (Fig. 2) show that the female instars of the sooty beech scale are present throughout the year. Fluctuations in density are erratic in all samples, with large error values (standard errors of density estimates averaged 34% of the means). This emphasises the spatial heterogeneity of the population at both sites, and indicates that very much larger samples would be needed to obtain reliable estimates of seasonal population fluctuations. Apart from the crawlers (Fig. 3), male 3rd and 4th instars and adult males (Fig. 6), all of which appeared to show an increase during the summer months, there are no significant changes in proportions of life history stages through the year at either site (Fig. 2).

Densities of live scale were low at both sites, reaching 10% or more of the bark areas in only 2 months at Craigieburn, and peaking at 6% of the bark area at Maitai (Fig. 4). In contrast, empty scale tests were much more abundant than tests containing live scales at both sites (Fig. 4). Empty scale tests were particularly abundant at Craigieburn, with up to 54% of the bark surface being occupied by them. The abundance of empty scale tests suggests that they remain on the bark for a long time after the death of the insect, and may be a factor limiting new scale settlement. It was noticed that scales often settled in the cracks in bark, and that the smooth, unbroken areas of bark appeared unsuitable for crawler settlement. Thus, it is possible that 5-10% of bark coverage by live scales actually represents a much higher percentage occupation of available settlement sites for scales, and future scale settlement may be limited by the presence of empty tests.

Fecundity

Counts of eggs inside scale tests occupied by live gravid females showed no significant seasonal pattern, although mean egg number was higher between August and December than between January and June (Fig. 5).

Unfortunately, the numbers of gravid females in most of the monthly samples was too small for these estimates to be reliable. Eggs were present throughout the year, and the maximum number counted within 1 scale test was 232. This could be close to the maximum total fecundity, though more precise determination would require work on the rate of egg production and the likelihood of eclosion and crawler dispersal from the female test before the completion of oviposition.

Activity of crawlers and adult males

Crawlers

Crawlers were caught on sticky traps from October to June with peak numbers in January and February (Fig. 6). This shows that they are capable of wind dispersal as

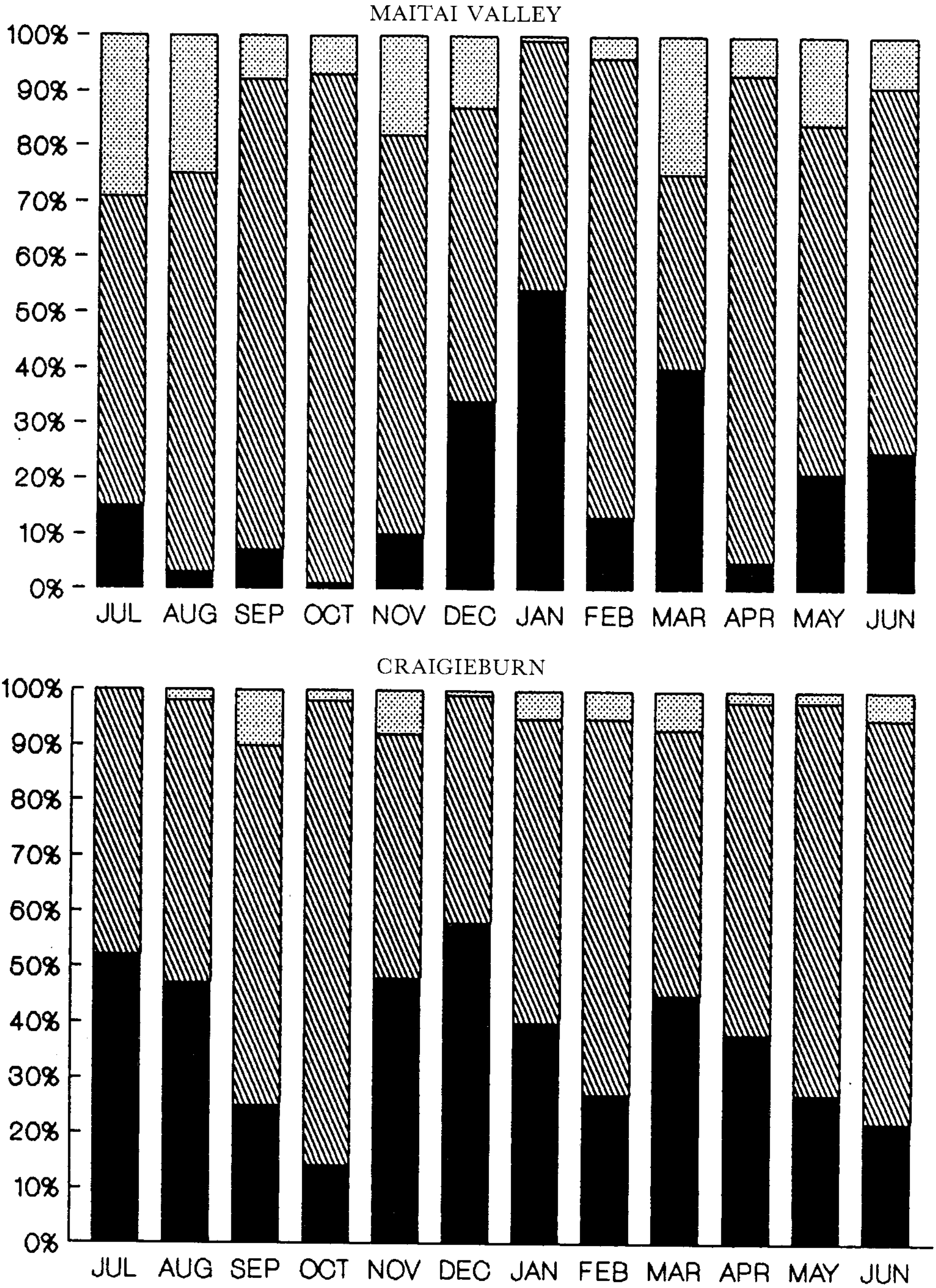

Fig. 2: Proportional composition of the sooty beech scale population.
1st instar 2nd & 3rd instars Adults

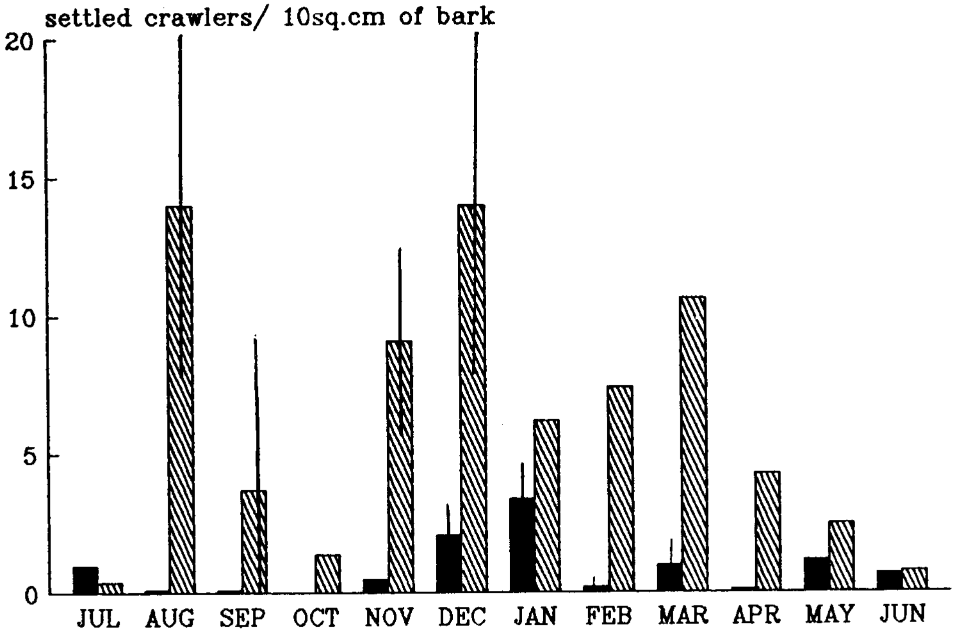

Fig. 3: Mean seasonal sooty beech scale crawler densities at Maitai and Craigieburn, plus selected 95% confidence intervals.

Maitai Craigieburn

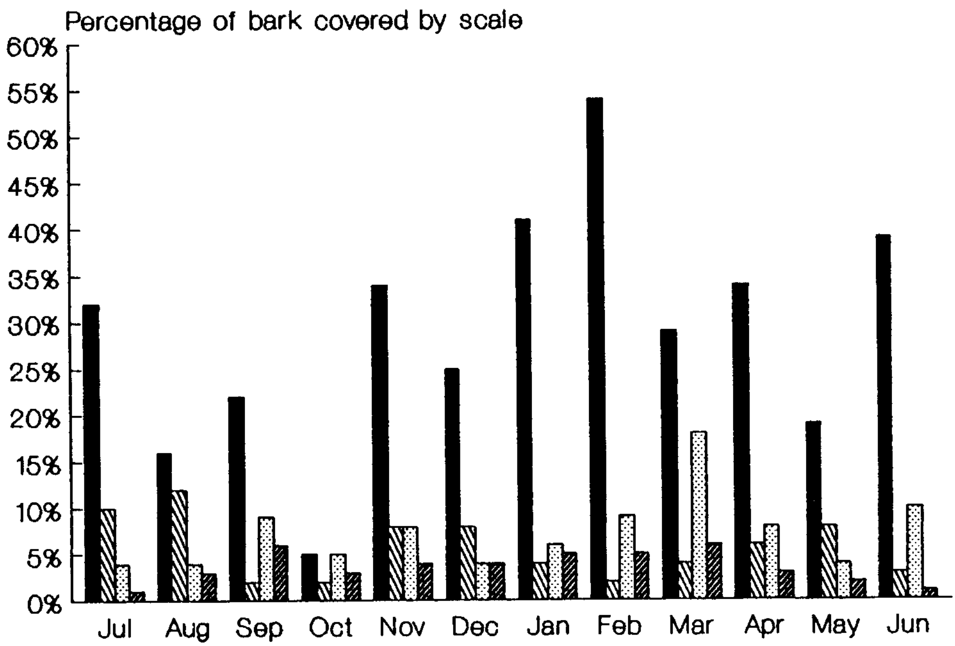

Fig. 4: Percentage of the area of bark sampled which was occupied by a covering of live or dead sooty beech scale at each of the sites.

Craigieburn empty Craigieburn live Maitai empty Maitai live

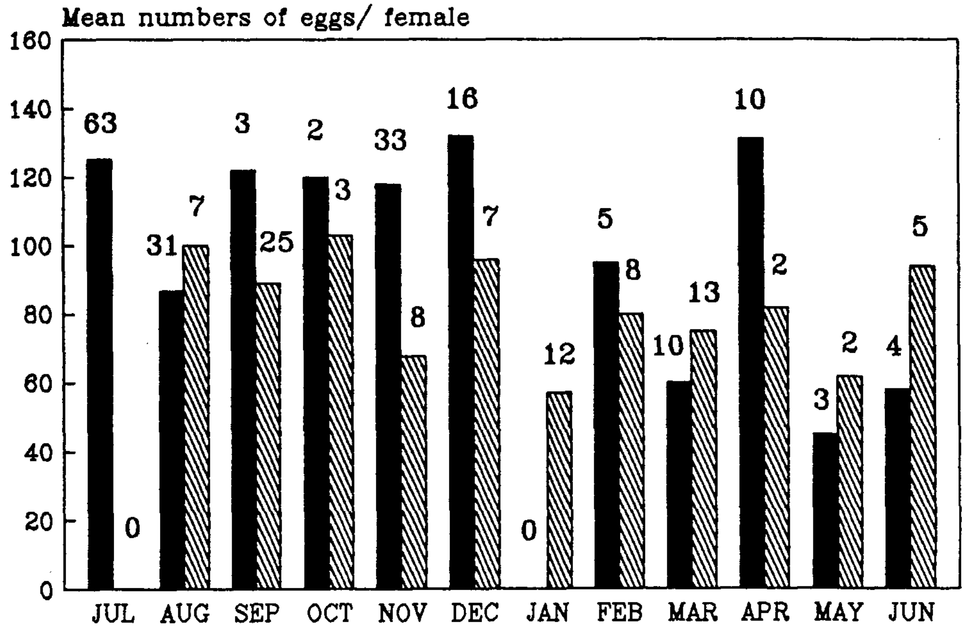

Fig. 5: Mean numbers of eggs per gravid female sooty beech scale throughout the year at both sites. Figures above bars are sample sizes.

■ Maitai ▨ Craigieburn

in another margarodid, *Icerya seychellarum* Westwood (Hill 1980). In the bark samples there was a corresponding peak emergence of crawlers at Maitai Valley in January (Fig. 2), but they were also present in varying numbers throughout the year.

Adult males

Males were caught on the sticky traps from December to March with peak numbers in December (Fig. 6). Adult males were not collected during the bark sampling programme, neither were male prepupae except in the few samples mentioned in the **Life history** section above.

Parasites and predators

There appear to have been no previous records of parasitism or predation on this species. In this study 2 parasites were found in low numbers. First, a parasitic wasp belonging to the Pteromalidae (Hymenoptera: Chalcidoidea) was found on 3 occasions at Maitai Valley, but unfortunately it could be reared only to the pupal stage. Other incidences of parasitism and hyperparasitism by Hymenoptera have been found at Christchurch (L. Emms pers. comm.). Second, a predatory beetle *Doxozilora punctata* Broun (Coleoptera: Melandryiidae), was found newly emerged inside a complete test. The beetle is about 5 mm long and 2 mm wide and a dull blackish purple colour with a smooth body. At Oxford, Canterbury, a beetle larva, *Metaxina ornata* Broun (Coleoptera: Cleridae), has been found feeding on live sooty beech scale inside a test (L. Emms pers. comm.).

We found many other arthropods associated with the scale/sooty mould complex. The most common lepidopterous larva was of *Stathmopoda coracodes* Meyrick (Oecophoridae). This pale pink and fawn mottled caterpillar was found in most areas of the bark, sooty mould and inside tests. Another lepidopteran, *Batrachedra agaura* Meyrick (Coleophoridae) was frequently found inside tests with recently dead scales and on the bark. The larvae of some species in the genera *Stathmopoda* and *Batrachedra* are recorded as being predatory on scale insects (Common 1970) and it is possible that *S. coracodes* and *B. agaura* could be sooty beech scale predators although we never recorded these larvae feeding on live scales. Likewise, *Salpingus unguliculus* (Salpingidae), a small, brown, variegated beetle was found in the samples and is a suspected predator of scale insects (J. C. Watt pers. comm.).

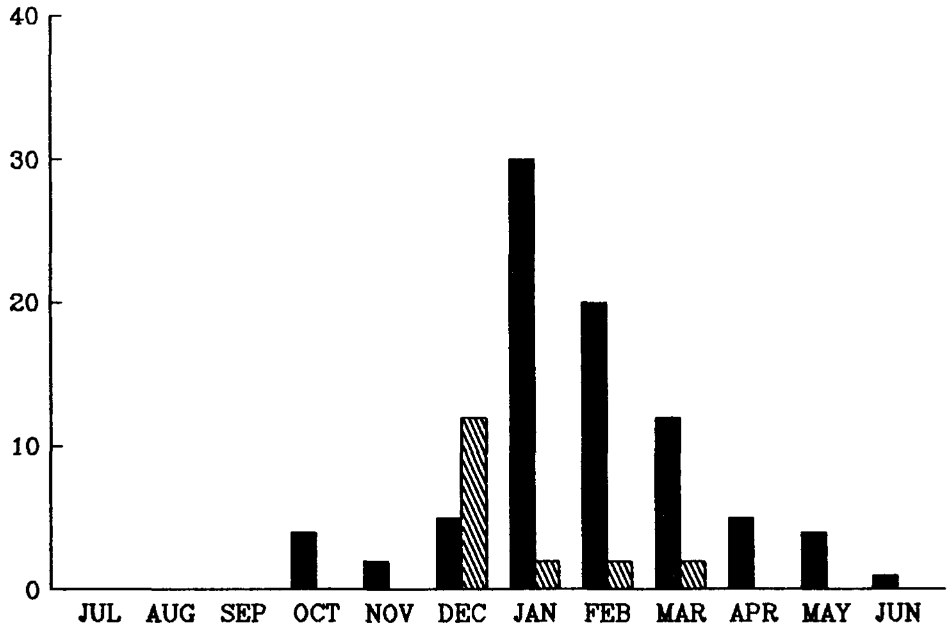

Fig. 6: Sticky trap catches of crawlers and adult males of sooty beech scale.
Crawlers Males

Other arthropods which were often encountered were spiders, anthocorid bugs, pseudoscorpions, mites, thrips and fungal feeding beetles. Bladder mites were found feeding on caterpillars inside the tests.

DISCUSSION

Although Brittin (1935) made an accurate estimate of 5 male instars, he observed only 3 female instars. He collected male prepupae emerging from 2nd stage tests, and thinking they were small adult females, kept them in the laboratory. After several weeks they developed into adult *U. assimile* males. In the field he noted 1 large emergence of males at the same time that most of the females are in their 2nd instar and concluded that mating must take place at this time because eggs were found several weeks later. Although Dumbleton (1967) reported an accurate estimate of 4 female instars he suggested that in the apparent absence of males, *U. assimile* was probably parthenogenetic. Our studies confirmed the presence of males, but the breeding system in *U. assimile* remains a mystery. Many margarodids have complicated breeding systems. In *Icerya* sp. the females become hermaphrodites in the 2nd instar and may produce males from unfertilised eggs. Self fertilisation is assured by protandry of the hermaphrodite and the resulting offspring are hermaphrodite unless there has been fertilisation by a male which results in both males and hermaphrodites being produced (Hughes *et al.* 1966). Further study of the breeding system in New Zealand Margarodidae will provide an interesting comparison with that of *Icerya* sp.

Dumbleton (1967) commented that mating was unlikely to occur in the 2nd instar female. He suggested that it would be difficult because the anal filament aperture of the female test is occluded with the cast skins of previous stages and that it would be almost impossible for the male prepupa to emerge from tests similar to those of the female since these are hard and have a small aperture. But our discovery of male prepupae enclosed in soft tests and observation of mating (H. Moller pers. comm.) negates Dumbleton's conclusions. There are several species of Margarodidae outside New Zealand which form tests on their host plant, but detailed biological studies have been done only on those which are in other subfamilies to the New Zealand fauna. In the Xylococcinae, *Matsucoccus* *gallinicola*, a pest of pines in the U.S.A., the mobile adult female has been observed emerging slowly from a small hole in the hardened 2nd instar test (Parr 1939). The legged prepupal male of *Xylococcus betulae* emerges from the test of its previous apodous stage. The adult females are confined to the test and when mating is about to occur a small aperture appears in the anal end (Shigo 1962).

Another New Zealand margarodid, *Coelostomidia wairoensis*, in the same subfamily as *U. assimile*, has a mass emergence of male prepupae in March, when individuals emerge from soft 2nd instar tests. Adult males mate with the females while the latter are enclosed in the test (Butcher unpublished).

The duration of life span of margarodids varies. Some of those which are enclosed in a test for the intermediate instar but which have mobile females, have 1 to 2 generations per year (McKenzie 1942; Bean & Godwin 1955), or in others e.g. *Stomatococcus*, there are 3 generations per year (Ferris 1917). However in *X. betulae* which has intermediate and adult female instars enclosed in a test there is 1 generation every 3 years (Shigo 1962).

Recent estimates of the seasonal variation of honeydew production of sooty beech scale have been done by counting the number of honeydew filaments (Crozier 1978) or honeydew droplets (Gaze *et al.* 1983). Crozier (1978) found there was an autumn peak and a summer low in wax filament density and proposed that there may be another peak in spring, possibly indicating 2 generations of the insect a year. A high spring peak and a lesser autumn peak in honeydew droplet production was reported by Gaze *et al.* (1983). Most such estimates have assumed that there was only 1 instar of the insect responsible for honeydew production, when in fact there are 2. Our studies found no significant differences in proportions of the life history stages throughout the year and without further study the relationship between seasonal filament and honeydew production and the life history stages of the insect remain unclear. Smith (1980) suggested that there may be up to 4 cycles because all the preadult stages were present throughout the year. Brittin (1935) found all the life history stages present at any time of the year and concluded that the life cycle must last more than 1 year. In our view accurate estimates of the number of annual generations must await development rate studies on individual scale insects *in situ* on the plant.

CONCLUSIONS

There are 4 female and 5 male instars in the life history of *U. assimile*. Mobile male prepupae emerge from 2nd instar tests in November. Winged adult males are found from December to March with greatest numbers in December. Crawlers can be carried in the wind and are found throughout the year with peak numbers in January. The 2 intermediate female instars which produce most of the honeydew were not shown to have peaks in seasonal abundance. Adult females are present in low numbers in all months of the year. Eggs are produced all year round. The length of the life cycle and the number of generations is uncertain, but this insect seems to have completely overlapping generations. Two coleopterous predators and 1 hymenopterous parasite of this insect are recorded for the first time.

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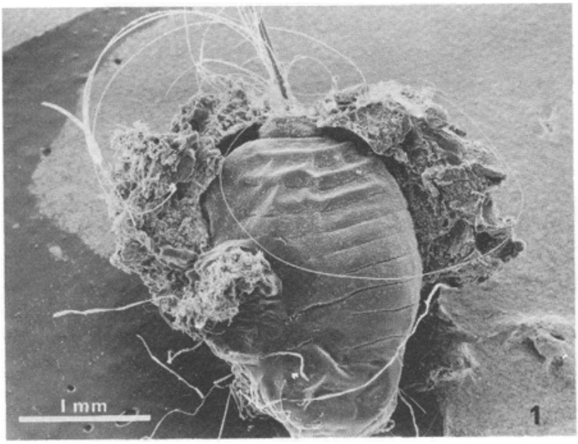

Fig. 7: S.E.M. of 3rd instar female sooty beech scale with test removed to show anal end with its sclerotised ring of tissue and filament.

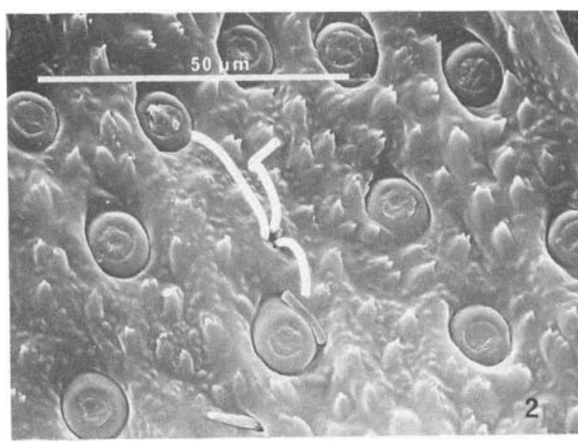

Fig. 8: S.E.M. of details of 3rd ins tar female sooty beech scale epidermis showing wax glands and 1 seta.

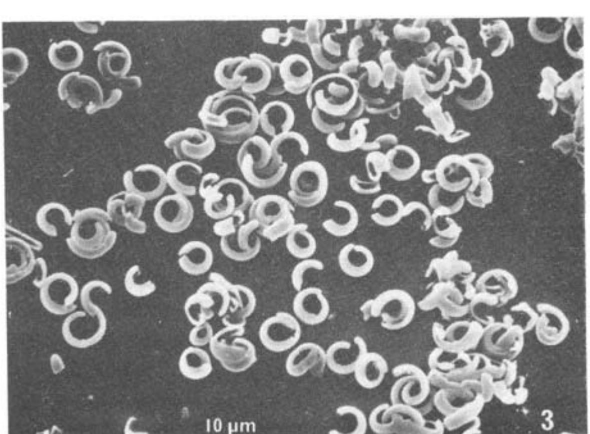

Fig. 9: S.E.M. of surface of egg of sooty beech scale to show wax parings.

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Erratum

A footnote was omitted from Morales, C. F.; Hill, M. G.; Walker, A. K., 1988: *New Zealand entomologist 11:* 24-37. It was to read: C. F. Morales, formerly Butcher.