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Seasonal Habitat Utilization and Food of the Ladybirds *Scymnodes lividigaster* (Mulsant) and *Leptothea galbula* (Mulsant) (Coleoptera : Coccinellidae)

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Abstract

Utilization of plant species by two ladybirds, the aphidophagous *Scymnodes lividigaster* (Mulsant) and mycophagous *Leptothea galbula* (Mulsant), was traced weekly for 3 y in a reserve near Sydney. *S. lividigaster* had a year-round association with *Glochidion ferdinandi* (J. Muell.) F. M. Bailey, the host plant of a prey species *Aphis eugeniae* van der Goot. The tree was utilized in dormant as well as breeding periods. In its breeding periods *L. galbula* utilized *Lonicera fragrantissima* Lindl. & Paxt. when this was infested with *Oidium* sp., powdery mildew fungus, but in its dormant periods it most utilized *Ficus rubiginosa* Desf. Many other plant species were also utilized at particular times; these are outlined. Gut analysis complemented data on habitat utilization; essential aphid or fungal foods were found in guts in breeding periods and a range of alternative foods, pollen, trichomes and other fungal spores at other times. Greatest food range and plant diversity utilized were in pre- and post-dormancy feeding periods.

Introduction

Evaluating the relationship between a ladybird and its habitat is fundamental during the investigation of seasonal cycles of development. The seasonal supply of food will affect survival and fecundity (Smith 1965, 1966); food quantity and quality can drastically alter the timing of reproductive and dormant periods (Hagen 1962; Iperti 1966; McMullen 1967).

Most ladybirds studied in the laboratory have a well defined food specificity (Blackman 1967), and field studies indicate that some have habitat specificity (Hodek 1973). Foods consumed, during their developmental cycle, that are related to reproduction have been called 'essential', and those related to body maintenance and fat deposition as 'alternative' (Hodek 1962). However, information on seasonal utilization of the field habitat and related food consumption is rare in ladybirds, particularly that on the role played by alternative foods (Hukusima and Itoh 1976).

In this study the seasonal and changing habitat preferences and type and range of food in the aphidophagous *Scymnodes lividigaster* (Mulsant) and the mycophagous *Leptothea galbula* (Mulsant) were investigated at Chinaman's Beach Reserve near Sydney. Data are related to the seasonal cycles of development. It has been determined that food specificity, and developmental cycles synchronized with abundance of essential food, characterize these species (Anderson 1979, 1980). *S. lividigaster* can reproduce on a number of aphid species, but most important in this study is *Aphis eugeniae* van der Goot, regularly infesting *Glochidion fer-*

Table 1. Host plants, and groups of host plants, utilized by ladybirds at Chinaman's Beach Reserve

Groups in order of weekly monitoring. Seasonality: Y, all year; Sp, spring; Su, summer; A, autumn; W, winter. Abundance, + + + abundant; + + common; + rare

Code	Species	Common name	Seasonality and abundance	Significance as a host plant for ladybirds	
				S. lividigaster	*L. galbula*
1*a*	*Glochidion ferdinandi* (J. Muell.) F. M. Bailey	Cheese tree	Y, + + +	Extensive use throughout, especially in breeding periods.	Sometimes used, but not in breeding periods.
2*b*	*Ipomoea indica* (Burm.) Merrill	Morning glory	Y + +	Regular use in 1975 and 1976, then cleared; not associated with breeding	
3*c*	*Ficus rubiginosa* Desf. ex Vent	Rusty fig	Y + +	Irregular use in prebreeding, breeding and dormancy periods, especially in 1975 and 1976	Extensive use in predormancy, dormancy and postdormancy periods
4*d*	*Ficus pumila* L.	Creeping fig	Y + +	Used in dormancy periods	Not used
5*e*	*Ligustrum lucidum* Ait.	Large-leaved privet	Y + +	Used when in flower to a small extent, but never for breeding	
	Ligustrum sinense Lour.	Small-leaved privet	Y + +		
6*f*	*Avena fatua* L.	Wild oat	A-Sp +		
	Briza maxima L.	Quaking grass	Sp-Su +		
	Digitaria didactyla Willd.	Queensland blue couch	Y + +	Regularly used according to season, but especially in late 1975 and 1976, when plant growth was lush; less often thereafter, particularly because of weed eradication projects; not associated with breeding	
	D. sanguinalis (L.) Scop.	Summer grass	Su +		
	Ehrharta erecta Lam.	Panic veldtgrass	Su +		
	Lolium rigidum Gaud.	Wimmera rye-grass	Su +		
	Paspalum dilatatum Poir.	Paspalum	Su + +		
	Ailanthus altissima (Mill.) Swingle	Tree of heaven	Y +		

	Capsella bursa-pastoris (L.) Medic.	Shepherds purse	Su+		
	Plantago lanceolata L.	Ribwort	Su+		
	Nasturtium sp.	Nasturtium	Y+		
	Verbena officinalis	Common verbena	Y+		
	Solanum nigrum L.	Blackberry nightshade	Y++		
7*g*	*Lonicera fragrantissima* Lindley & Paxton	Winter honeysuckle	Y+	Not used	Extensive use throughout the summer breeding period
8*h*	*Acacia longifolia* (Andr.) Willd.	Sydney golden wattle	Y+++	Used when in flower, but never for breeding; decreased in importance due to senescence and death of some trees, without replacement	
	A. (glaucescens) binervia (Wendl.) Macbride	Coast myall	Y++		
	A. maidenii F. Muell.	Maiden's wattle	Y+		
9*i*	*Bidens pilosa* L.	Pitchforks	Sp-A+++	Extensive use when in flower and when infested with aphid *Aphis gossypii*, especially in 1976; some breeding	Not used
10*j*	*Cassia* (*bicapsularis* L.) *coluteodes* Coll.	Cassia	Y+++	Spasmodic use for breeding when infested with aphid *Toxoptera ?aurantii*, especially in Apr. –May 1977	Spasmodic use when infested with powdery mildew; little breeding
11*k*	*Leptospermum laevigatum* (Sol. ex Gaertn.) F. Muell.	Coast tea-tree	Y++	Infrequently utilized and never for breeding	
12*l*	*Morus alba* L.	Mulberry	Y++	Regular use, particularly towards the end of the study as trees increased in size; not associated with breeding	Infrequently used

Table 1 (*continued*)

Code	Species	Common name	Seasonality and abundance	Significance as a host plant for ladybirds	
				S. lividigaster	*L. galbula*
13*m*	*Acetosa sagittata* (Thunb.) Johnson & Briggs		Y+		
	Araujia hortorum Fournier	Moth plant	Y+	Irregular use, increasing during predormancy feeding periods; not associated with breeding	
	Catharanthus roseus (L.) G. Don		Su+		
	Conyza albida Spreng.	Tall fleabane	Su-A+		
	Jasminum mesnyi Hance		Y+		
	Lonicera japonica Thunb.	Japanese honeysuckle	Y+		
	Nephrolepis exaltata (L.) Schott.	Boston fern	Y+		
	Pittosporum undulatum Vent.	Pittosporum	Y+++		
	Quercus robur L.	Oak	Y++		
	Thunbergia alata Boj. ex Sims	Black-eyed susan	Y+		
	Vibernum tinus L.		Y+		
14*n*	*Ilex cornuta* Lindl.	Horned holly	Y+	Irregular use; not associated with breeding	
15*o*	*Hibiscus* sp.	Hibiscus	Y++	Important host especially when infested with aphid *A. gossypii*, *but little breeding recorded*	Heavily utilized at end of study as growing close to *F. rubiginosa*, which was defoliated by limacodid caterpillars

dinandi (J. Muell.) F. M. Bailey, a tree common in the study area. *G. ferdinandi* also supports year-round populations of other predacious ladybirds, of which *Coelophora inaequalis* Fabricius, *Cryptolaemus montrouzieri* Mulsant, *Halmus chalybeus* (Boisduval) and *Rhyzobius ventralis* (Erichson) are the most numerous. In Queensland, other species of *Glochidion* were found to support high populations of many species of predacious ladybirds (Anderson, unpublished data). *L. galbula* is able to reproduce on *Oidium* sp., powdery mildew fungus, which regularly infests *Lonicera fragrantissima* Lindley & Paxton in the study area. Ladybird developmental cycles consist of periods of reproduction, predormancy feeding and dormancy, broadly outlined in Figs 1 and 6.

Methods

The 6-ha study area contains grassy portions with scattered native and exotic shrubs and trees. On three sides are steep slopes, on the other is Middle Harbour. Vegetation is fully described in Anderson (1979).

Ladybirds were counted each week on various plants (Table 1). To ensure uniformity of sampling, the vegetation along a prescribed route approximately 550 m long was examined, according to standard methods, for 2 h in the morning. The route was chosen as it represented a selection of the plant species present in the habitat. Woody trees differed in size, but their presence was relatively constant, whereas annuals, weeds, grasses and low vegetation varied seasonally. However, the same areas were sampled each week. The rationale was to compare distributions of ladybirds within this fixed sampling area seasonally.

Each week some ladybirds from particular host plants were sampled; their guts were removed between oesophagus and rectum, mounted, examined microscopically as a whole to determine the relative position of the food, if any, and broadly classified as full or empty. Next, guts were squashed and re-examined for identification of hard parts by cross-matching with animal and plant material sampled from the habitat. Liquid contents were noted, but not identified further.

The Wilcoxon matched-pairs signed-rank test (Siegel 1956) and χ^2 tests (Moroney 1967) were applied to data.

Results

S. lividigaster (3836 specimens)

(i) *Host plant utilization and plant diversity*

S. lividigaster utilized *Glochidion ferdinandi* throughout (Fig. 1), except in March 1977, when only one ladybird was monitored. Utilization of *G. ferdinandi* was very high in breeding periods and tended to increase in some winter dormancies. During summer dormancy, pre- and postdormancy periods, utilization of *G. ferdinandi* was generally lower. In 1976, when populations of adult and immature ladybirds were high (Anderson 1981), *G. ferdinandi* was utilized by an average of 42% of the population, whereas in 1977, when populations were lower, average utilization was 30%.

Overall diversity of host plants utilized (Table 2) was highest in the winter and summer predormancy feeding periods (May, November) and the postdormancy–spring prebreeding period (August). The diversity of plants utilized was low in the summer postdormancy, summer–autumn prebreeding and breeding periods (January–March), spring breeding (October) and winter dormancy (June). The diversity of plants utilized was significantly different ($P < 0{\cdot}005$) in months of breeding, predormancy, and dormancy. Plant diversity utilized was significantly greater in 1976 than in the corresponding months of 1975 ($P = 0{\cdot}001$), and it was greater in 1977 than 1976, but the difference was not significant ($P > 0{\cdot}05$).

There was consistent utilization of plants other than *G. ferdinandi*, though the species concerned differed from season to season and year to year (Fig. 1; Table 1).

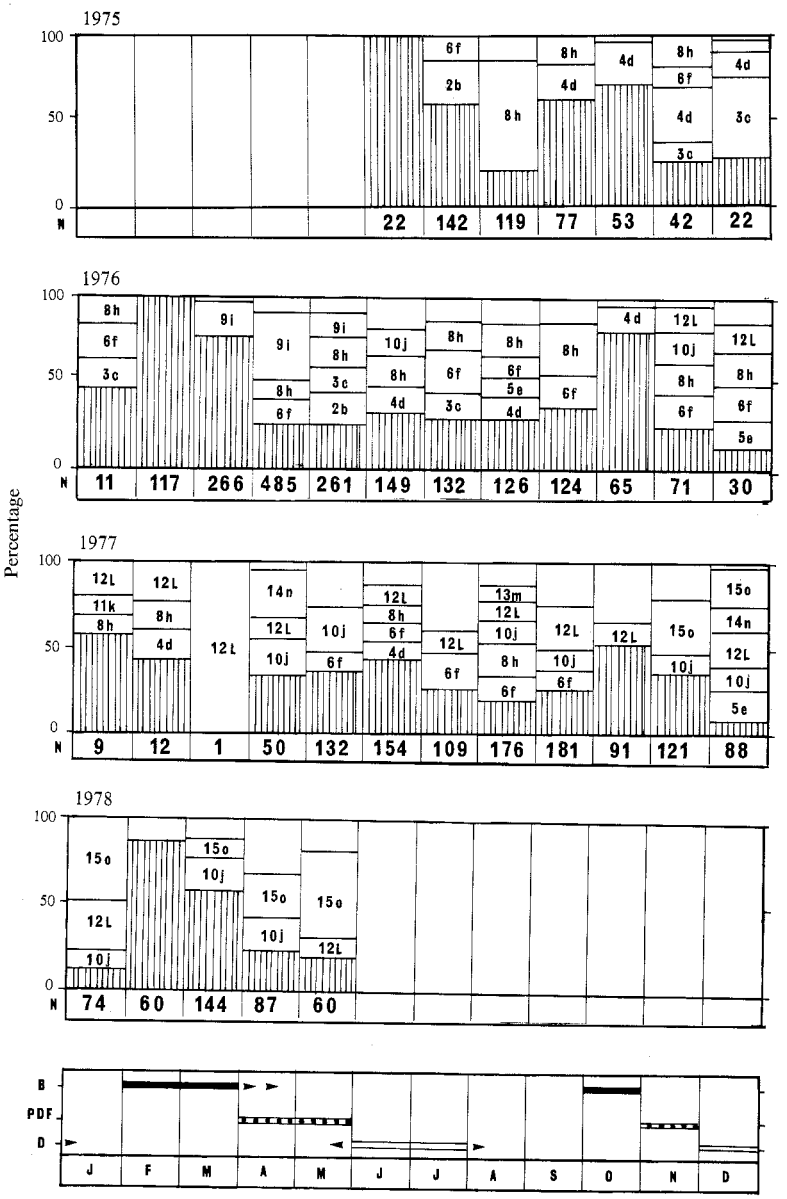

Fig. 1. Monthly utilization of habitat by *S. lividigaster* at Chinaman's Beach Reserve, expressed as percentages of ladybirds recorded on the plants and plant groups listed in Table 1. Vertical hatching, *Glochidion ferdinandi* (No. 1*a*). Unidentified blocks, plants utilized by < 9% of the population. **N**, number of ladybirds analysed. **B**, principal breeding season. **PDF**, predormancy feeding. **D**, dormancy.

(ii) *Gut contents*

The percentage of the population with full guts (Table 2) was greatest in breeding periods (February, March, October) and least in dormancy (June, July, December).

Gut samples had significantly different contents in months of breeding, predormancy feeding and dormancy ($P < 0{\cdot}005$).

Gut contents during breeding consisted of a blackish green liquid and large quantities of aphid parts: *A. eugeniae* when ladybirds were on *G. ferdinandi*; *A. gossypii* when on *B. pilosa* or *Hibiscus* spp.; *T. ?aurantii* when on *C. bicapsularis*.

Table 2. Diversity of host plants utilized, and percentage of specimens with food in the gut, from 1975 to 1978

Diversity is represented by the number of different plants or groups of plants (Table 1) on which the species was recorded. Values in parentheses are sample sizes

Month	Number of plants utilized				Percentage with food in gut			
	1975–76	1976–77	1977–78	Mean	1975–76	1976–77	1977–78	Mean
			Scymnodes lividigaster					
June	1	8	10	6	47 (*17*)	52 (*21*)	28 (*25*)	42
July	3	8	10	7	33 (*27*)	65 (*26*)	57 (*35*)	52
Aug.	7	10	10	9	45 (*22*)	78 (*27*)	84 (*25*)	56
Sept.	3	8	14	8	65 (*27*)	92 (*25*)	79 (*24*)	78
Oct.	3	5	10	6	90 (*31*)	88 (*24*)	100 (*16*)	93
Nov.	7	9	11	9	80 (*20*)	52 (*21*)	96 (*26*)	76
Dec.	6	8	9	8	39 (*18*)	32 (*22*)	90 (*21*)	54
Jan.	4	4	6	5	79 (*14*)	60 (*8*)	58 (*19*)	67
Feb.	3	4	5	4	96 (*44*)	0 (*5*)	96 (*25*)	64
Mar.	5	1	8	5	96 (*22*)	71 (*7*)	81 (*21*)	83
Apr.	9	6	8	8	79 (*62*)	91 (*22*)	71 (*24*)	80
May	10	14	7	10	50 (*16*)	53 (*15*)	69 (*26*)	57
Total No. of plants utilized	1976: 90		1977: 103					
			Leptothea galbula					
July	3	4	6	4	11 (*19*)	22 (*23*)	50 (*8*)	28
Aug.	4	3	6	4	46 (*24*)	59 (*22*)	75 (*4*)	60
Sept.	2	5	8	5	100 (*7*)	88 (*16*)	60 (*5*)	83
Oct.	2	4	6	4	100 (*2*)	70 (*10*)	100 (*2*)	90
Nov.	2	2	4	3	100 (*9*)	100 (*20*)	74 (*27*)	91
Dec.	1	5	4	3	67 (*12*)	74 (*31*)	95 (*19*)	79
Jan.	1	1	3	2	100 (*12*)	– (*0*)	100 (*9*)	100
Feb.	1	2	2	2	100 (*4*)	100 (*1*)	88 (*8*)	96
Mar.	2	1	5	3	100 (*7*)	75 (*8*)	100 (*8*)	92
Apr.	3	2	3	3	74 (*35*)	100 (*4*)	0 (*3*)	58
May	5	5	4	5	10 (*10*)	66 (*3*)	64 (*11*)	47
June	7	7	–	7	73 (*7*)	80 (*22*)	0 (*10*)	51
Total No. of plants utilized	1976: 43		1977: 52					

In periods of dormancy, guts were often empty and reduced to a narrow thick-walled tube, or contained a small quantity of amorphous brown-black sludge-like material. In some, air bubbles were present. There was evidence of feeding in others; crops were filled with clear liquid of varying colours, often containing plant trichomes, fungal spores and pollen. Red trichomes of *F. rubiginosa* (Fig. 2)

predominated in gut samples collected on or near these trees. *Acacia* spp. pollen (Fig. 3) was present in guts concurrently with flowering.

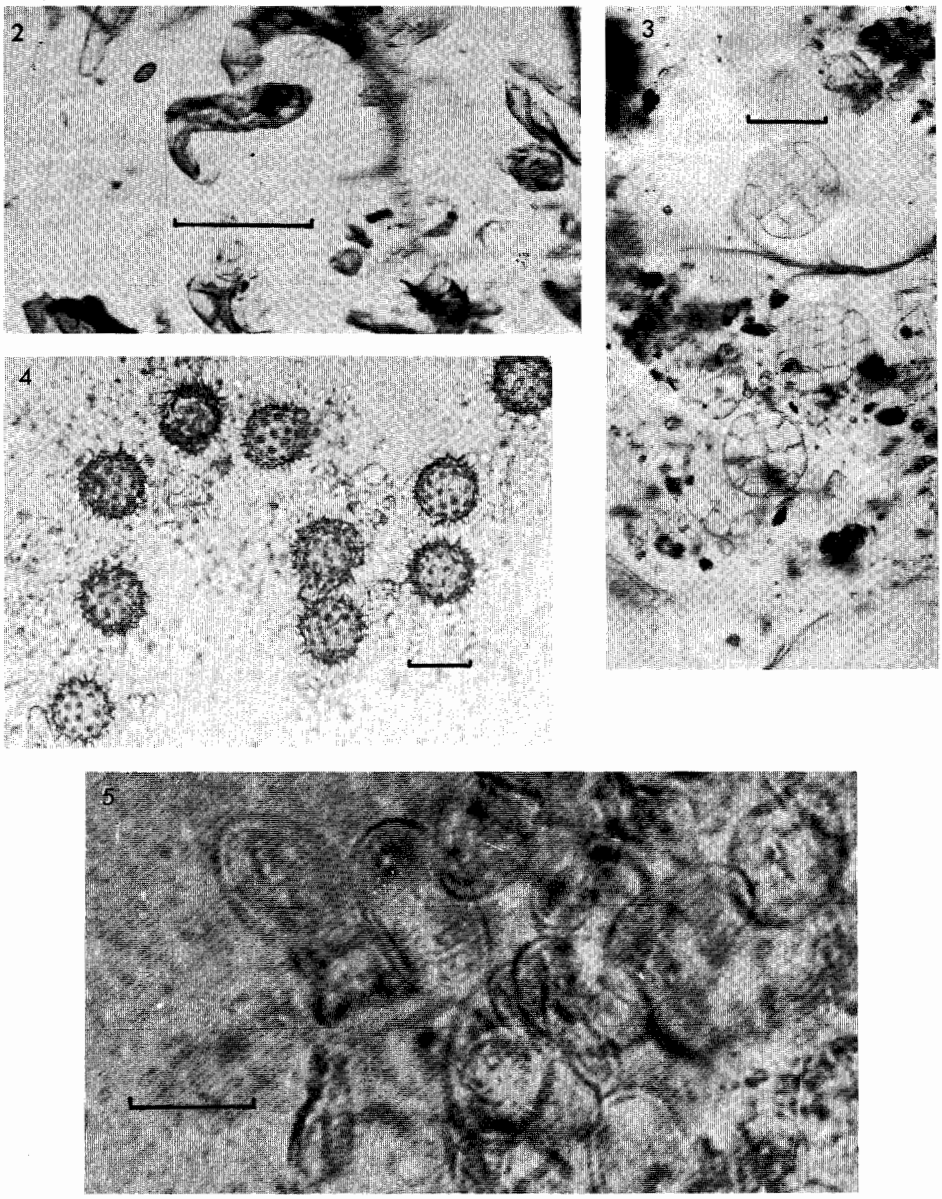

Fig. 2. Trichome of *Ficus rubiginosa* from *L. galbula* gut, August 1977. Scale line, 0·1 mm.
Fig. 3. Pollen of *Acacia* sp. from *L. galbula* gut, September 1976. Scale line, 0·05 mm.
Fig. 4. Pollen of *Bidens pilosa* from *S. lividigaster* gut, March 1976. Scale line, 0·03 mm.
Fig. 5. Conidia and hyphae of *Oidium* sp. on zucchini in *L. galbula* gut, November 1977. Scale line, 0·02 mm.

In periods of predormancy, guts contained an array of materials, largely of plant or fungal origin, but often including balls of insect parts in rectums. Pollen of *B. pilosa* (Fig. 4) was common, but much material appeared semi-digested and was hard to identify.

During postdormancy and prebreeding, guts were on the whole a little less full than during predormancy, and were initially predominantly liquid. Later, pollen (especially *Acacia* spp. and *B. pilosa*), trichomes (especially *F. rubiginosa*) and

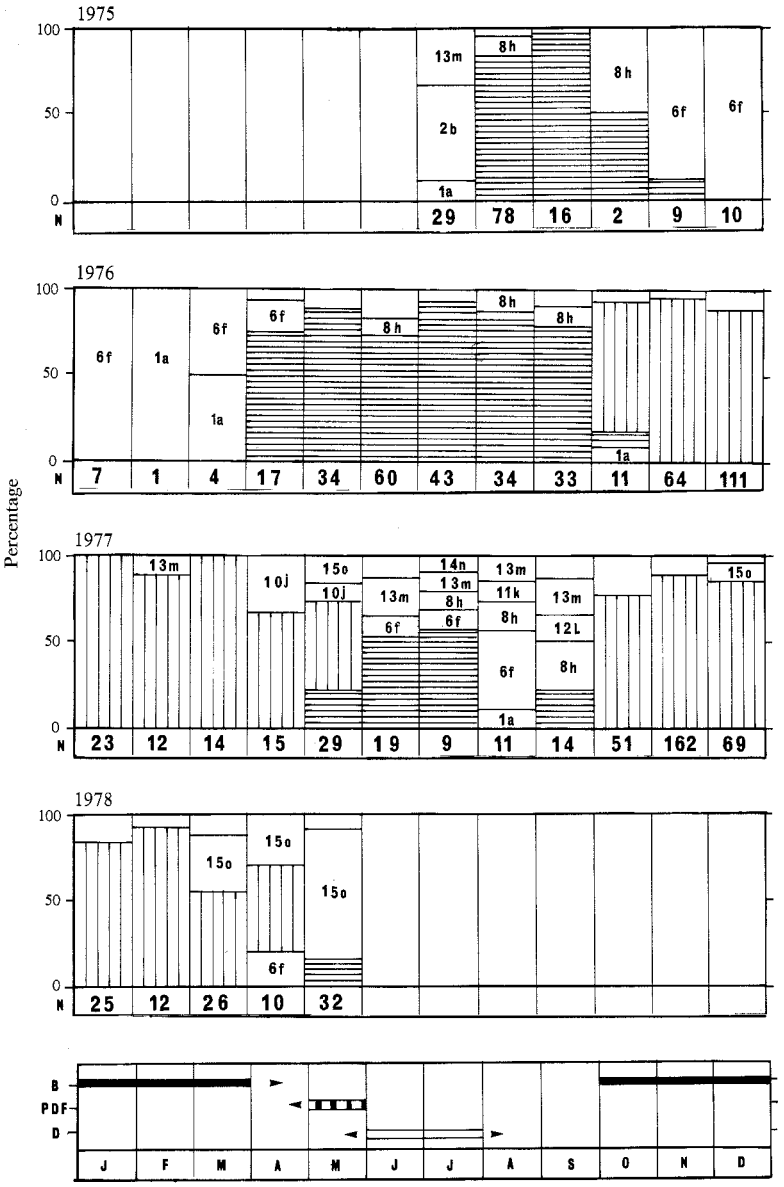

Fig. 6. Monthly utilization of habitat by *L. galbula* at Chinaman's Beach Reserve, expressed as percentages of ladybirds recorded on the plants and plant groups listed in Table 1. Vertical hatching, *Lonicera fragrantissima* (No. 7*g*). Horizontal hatching, *Ficus* spp. (Nos 3*c*, 4*d*). Other conventions as in Fig. 1.

fungal spores in quantity, rarely animal parts, were present. Ladybirds on *G. ferdinandi* had guts distended with bright orange liquid.

Debris (sand, charcoal etc.) was common in guts throughout the annual cycle.

Leptothea galbula (1096 specimens)

(i) *Host plant utilization and plant diversity*

Two plants played a major role in the annual cycle (Fig. 6): *Lonicera fragrantissima*, when infested with powdery mildew, from October to May (except 1975), i.e. the breeding period, and *Ficus rubiginosa* from May to September, i.e. the predormancy, dormancy and postdormancy periods. However, due to limacodid caterpillar attack, *F. rubiginosa* was not continuously occupied, particularly in 1977–78; instead, other hosts were utilized.

The diversity of host plants utilized was greatest during predormancy and early dormancy (May, June) and postdormancy (September) (Table 2), whereas it was least during breeding (October–April) and late dormancy (July). As well, many other plant species were utilized (Fig. 6; Table 1).

(ii) *Gut contents*

The percentage of the population with full guts (Table 2) was generally highest in the prebreeding (September) and breeding periods (October–April), and generally lower in the predormancy and dormancy periods (May–July). There were some irregularities in results, which may be attributed to small samples in certain months.

During breeding periods the gut contents consisted mainly of conidia and hyphae of *Oidium* sp. (Fig. 5); often a yellow clear liquid was associated with utilization of *L. fragrantissima*. Sometimes small quantities of pollen of various types, other fungal spores and large quantities of debris were associated with breeding.

Throughout dormancy guts typically contained large air bubbles, with semi-digested and collapsed pollen grains, plant trichomes and debris in early dormancy (April), and increasing quantities of red *F. rubiginosa* trichomes during May–July).

In postdormancy and prebreeding (late July–October) variously coloured liquids swelled guts with increasing quantities of pollen (*Ligustrum* spp., *Acacia* spp.).

Discussion

Diversity in food consumption cannot be assumed from observation of ladybirds on different species of plants, because ladybird adults are very mobile and visit many places in search of food (Hodek 1973). Observation of adults and larvae feeding on prey on particular host plants suggests that the prey is essential food; if ladybirds are seen on flowers, they may perhaps be feeding on them. However, such assumptions can lead to incorrect conclusions about feeding habits (Hodek 1973).

At Chinaman's Beach Reserve *S. lividigaster* is a 'typical species' (Klausnitzer 1966), for it showed marked seasonal and annual constancy in habitat selection and food consumption. Its seasonal cycles of development depended on the indigenous perennial euphorbiacean, *G. ferdinandi*. Within the habitat ladybirds moved onto and off *G. ferdinandi* according to season, particularly during breeding, pre- and postdormancy. This species was often seen on *G. ferdinandi* even when aphids were absent. The orange liquid found consistently in guts of ladybirds on this tree when aphids were absent indicated that they were using another food, possibly extra-floral nectar associated with glands on the leaves (C. J. Quinn, per-

sonal communication). *S. lividigaster* was also able to shelter in leaves curled by lepidopteran larvae.

Only one host plant other than *G. ferdinandi* affected breeding. An infestation of *T. ?aurantii* developed on *C. bicapsularis* in April 1977 after a small autumn breeding of *S. lividigaster* on *A. eugeniae* had ended. Much of the ladybird population had entered dormancy when this new essential food appeared, but many individuals returned to reproduction. This type of facultativeness or lability in the life cycle of ladybirds has been reported (Hagen 1962; Hodek 1973) and enables maximal use of ephemeral food supplies.

A wide range of other host plants was utilized outside of breeding seasons, and a wide range of food types was found in guts. Hard parts such as pollen and plant trichomes were identified, and the relationship between such hosts as *Acacia* spp., *F. rubiginosa*, *B. pilosa* and *C. bicapsularis* was established. However, no identification of the liquid contents of guts was attempted. These plants were considered to supply alternative foods, for they were associated with non-reproductive states. In breeding experiments (Anderson 1980) no evidence was found to suggest that any food other than specific aphid species could act as essential food for *S. lividigaster*.

Throughout, both observation and analysis of gut contents showed that food consumed was related to host plant utilization; the data could be used to delineate the seasonal cycles of development in every year of the study. Annual utilization of the habitat, and diversity of plants utilized, differed markedly, associated with some human interference in the habitat, accentuated by excellent environmental conditions and large populations of ladybirds in 1976 (Anderson 1981) and poorer conditions in 1975 and 1977, including periods of low rainfall. Despite this, the range of food within guts showed little annual variability. It seems that the population of *S. lividigaster* adjusted its numbers rather than its way of life in response to differing food supplies in the habitat, particularly to the supply of alternative food.

The annual cycle of habitat preference of *L. galbula* alternated between the breeding host, the deciduous *L. fragrantissima*, which supported powdery mildew, and *F. rubiginosa*, the major host during dormancy. The pattern of diversity of host plants utilized was much simpler than that of *S. lividigaster*. Also, the numbers of *L. galbula* monitored were fewer, indicating that the habitat was less suitable for *L. galbula*.

Gut analysis showed that *L. galbula* ate *Oidium* sp. during breeding seasons, and large quantities of *F. rubiginosa* trichomes during dormant periods. The significance of the trichomes was not determined, and it could be that they were ingested accidentally along with latex, honeydew or water.

Differences in host preference between the two ladybird species were striking and almost entirely due to the food specificity of each and the life history of the host plant.

Data on gut contents fully supported data on host preferences in both species, and indicated that specific essential foods were consumed during breeding and a wide variety of other material was consumed during pre-, postdormancy and prebreeding. In dormancy, a high proportion of guts were empty, reduced to a narrow tube or filled with air bubbles. However, certain individual ladybirds did feed during dormancy.

This study indicates the need for both essential and alternative food as well as shelter, if ladybirds are to remain in an area. *G. ferdinandi* supplied all these to *S. lividigaster*, consequently *S. lividigaster* was found in the reserve in high numbers throughout the study (Anderson 1981); the supply of food and shelter for *L. galbula* was less reliable, and this was reflected in its pattern of host plant utilization and its population dynamics (Anderson 1981).

A search for perennials like *Glochidion* spp., which have year-round attractions for beneficial insects, could be a fruitful line of research, with the objective of developing a practice of planting refuges for beneficial insects between areas of monoculture.

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