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SEX RATIOS OF ADULT *SCYMNODES LIVIDIGASTER* AND *LEPTOTHEA GALBULA* [*COL.: COCCINELLIDAE*], SAMPLED IN THE FIELD

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A 3 year field study of *Scymnodes lividigaster* (MULSANT) adults near Sydney indicated sex ratios close to 50 : 50, ♀ : ♂. Ratios deviated between samples collected in various periods of year and in individual years. Deviation was related to collecting methods, environmental conditions and behaviour of sexes in different developmental phases. Sampling *Leptothea galbula* (MULSANT) in 2 different habitats indicated all sex ratios biased towards ♀; ratios apparently not related to collecting methods and with little seasonality. In laboratory sex ratios of *L. galbula* were close to 50 : 50.

A sex ratio of close to 50; 50, ♀ : ♂, is considered to be normal in most insects (ENGELMANN, 1970), though deviations are commonly encountered (CHAPMAN, 1969; SUOMALAINEN *et al.*, 1976), including ladybirds, where high ♀ bias has been recorded (SMITH, 1966; HONEK, 1975; MATSUKA *et al.*, 1975; HALES, 1978). However no seasonal evaluations are available.

Parthenogenesis leading to production of high numbers of ♀ is common in insects according to IMMS (1960) and sex ratio bias has been attributed to environmental conditions such as temperature, humidity and wind speed (DYER & SWIFT, 1979), food supply (STEVENS *et al.*, 1977) and to genetic factors which are heritable (MATSUKA *et al.*, 1975).

A field study (1975-1978) of aphidophagous *Scymnodes lividigaster* (MULSANT) and mycophagous *Leptothea galbula* (MULSANT) in the Sydney area indicated both species were facultatively multivoltine; *S. lividigaster* had 2 breeding periods per annum, in spring (October) and summer-autumn (February-May). A summer (December-February) and winter reproductive diapause separated breeding periods (fig. 1). *L. galbula* had summer-late autumn breeding and winter diapause (ANDERSON, 1979; a, b; ANDERSON & RICHARDS, 1977).

METHODS

S. lividigaster and *L. galbula* were monitored weekly at Chinaman' Beach Reserve near Sydney; as was *L. galbula* in a garden at University of New South Wales, on a less regular basis. Study areas are described in ANDERSON (1979, a, b).

S. lividigaster can be easily and reliably sexed at a glance; as ♂, but not ♀ have a yellow frons; *L. galbula* sex can be reliably determined by dissection only.

Ladybird numbers were followed by using hand net and beating tray, From June 1975 to July 1977 the only *S. lividigaster* sexed were those randomly collected and brought into the laboratory for dissection. Thereafter, all *S. lividigaster* collected were sexed. *L. galbula* sex ratios from study areas were derived entirely from samples brought into the laboratory and dissected.

Culturing *L. galbula* provided laboratory sex ratio data. Cultures were kept in constant light, temperature 22 ± 2° C and fed ample fungal food, *Oidium* sp. from cucurbits; techniques detailed in ANDERSON (1979 a). There is no laboratory data for *S. lividigaster*. All ratios are expressed ♀ : ♂.

RESULTS

S. lividigaster

Yearly sex ratios in 1975 and 1976 were 49 : 51, slightly in favour of ♂ : in 1977 46 : 54 and 1978 41 : 59, a swing towards ♂ (table 1a, fig. 1). However ♀ bias in certain periods was recorded in all years, but least in 1977.

Distribution of sex ratios monthly displayed signs of seasonality. Lower % of ♀ were found in many breeding periods; in March 1976, March-April 1978 and in October 1975, 1976. Females were also low in some diapause periods: June and December 1975, July 1976 and December 1977, but generally not as low as in the breeding periods cited. Higher % of ♀ were found in some winter pre- and postdiapause feeding periods; in November 1975, May 1976 and 1978, August 1976, January and February 1977.

L. galbula

Yearly sex ratios were characterised by high proportions of ♀ ; in the Reserve (table 1b) 64 % in 1975, 71 % in 1976, 58 % in 1977 and 54 % in 1978 ; in the University garden (table 1c), 55 % in 1977 and 64 % in 1978 ; with a mean of 62 % in the Reserve and 60 % in the garden. In only 5 cases did the % of ♀ fall below 50 %. Twice, however, it remained near to 50 %. Distribution of sex ratios fluctuated monthly, but showed little if any, seasonal regularity between years, except for an increase in ♀ % in the Reserve in postdiapause periods (August-September).

L. galbula reared in the laboratory had a sex ratio of 49 : 51 (n = 1220), close to normal, where adult mortality during 1 month experiments was < 4 % and larval mortality was very low. Hatchability of eggs in different temperatures (15-27°C) and light regimes (LD 8 : 16 to LL) was 75 % (n = > 5 000).

DISCUSSION

A 50 : 50 sex ratio operates in the life cycle of *S. lividigaster*. Seasonal deviations in results can be explained by ladybird behaviour and collecting methods. Behaviour is reported to affect collecting data (GREENSLADE, 1964; SOUTHWOOD, 1966). From June 1975-July 1977, the only *S. lividigaster* sexed were those randomly collected for dissection. These were beaten or swept from vegetation and results were close to 50 : 50. Thereafter, all *S. lividigaster* sighted and collected were sexed, which resulted in an increasing % of ♂ recorded. This bias is probably the result of their greater activity. Activity of ♂ carabid beetles caused a sex ratio bias of up to 35 : 63 (GREENSLADE, 1964). In field, *S. lividigaster* ♂ were nearly always seen on leaf surfaces, moving rapidly towards apices of branches, etc., whereas ♀ spent most of their time in close proximity to aphid colonies, shel-

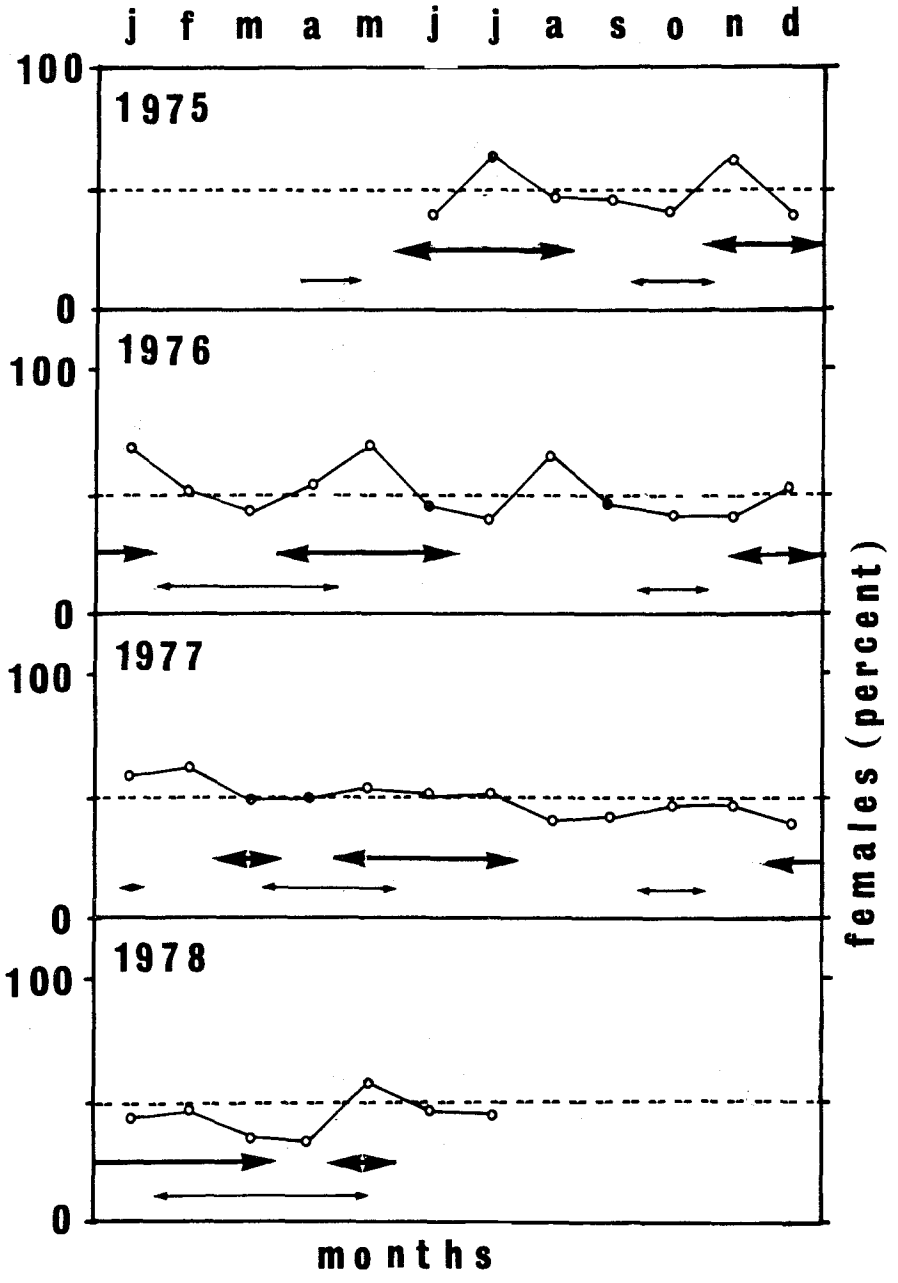

FIG. 1. *Scymnodes lividigaster*. Seasonal sex ratio data. Graph shows % of females in the population per month. Diapause periods represented by large arrows; based on intense gonotrophic regression of female ovaries. Breeding periods represented by small arrows; based on presence of immatures (larvae, pupae).

TABLE I

Sex ratio data. Tables show number ladybirds sampled monthly(n)

(a) Scymnodes lividigaster *at Chinaman's Beach Reserve*

Month	J		F		M		A		M		J		J		A		S		O		N		D		$\bar{x}$	Σn
year	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	(%)	
1975	—	—	—	—	—	—	—	—	—	—	37.5	16	63.0	27	47.3	19	47.8	23	44.8	29	60.0	20	38.8	18	49	152
1976	71.4	14	50.0	30	38.5	26	52.7	55	73.1	16	46.2	26	41.2	131	60.2	98	47.2	53	42.4	33	41.9	31	51.2	41	49	554
1977	57.1	14	51.1	18	50.0	4	50.0	50	52.0	50	50.0	34	51.0	111	40.0	187	43.4	184	47.3	93	47.9	121	37.5	88	46	954
1978	41.0	75	48.0	61	33.5	137	34.3	90	56.5	62	47.8	23	46.6	15	—	—	—	—	—	—	—	—	—	—	41	463

(b) Leptothea galbula *at Chinaman's Beach Reserve*

1975	—	—	—	—	—	—	—	—	—	—	57.0	7	52.6	19	75.0	24	57.1	7	0.0	2	71.4	7	75.0	12	64	78
1976	75.0	12	75.0	4	57.1	7	65.7	35	100.0	10	72.5	40	73.1	41	77.2	22	76.9	26	69.2	13	66.6	18	58.1	31	71	259
1977	54.8	42	66.6	6	75.0	8	52.0	25	50.0	28	58.6	29	62.5	8	81.8	11	60.0	10	78.6	14	47.3	55	62.9	35	58	271
1978	52.4	21	80.0	5	40.9	22	55.6	9	58.6	29	55.0	20	57.1	14	—	—	—	—	—	—	—	—	—	—	54	120

(c) Leptothea galbula *in University garden*

1977	70.6	34	—	—	—	—	56.7	30	34.4	32	46.4	28	80.0	15	—	—	—	—	—	—	—	—	—	—	55	201
1978	74.3	35	50.0	30	71.8	39	56.5	23	50.0	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	64	137

, % ♀ of monthly population, %, annual total number ladybirds sampled,(Σn), and mean annual % of ♀ in sampled population, $\bar{x}$ (%).

tering in flower petals, calyxes, leaf buds and curled leaves. In laboratory, ♂ were nearly always found on top of cages; ♀ further down in more sheltered positions. Males were more often seen to fly off in the field and were more often lost in laboratory because of rapid takeoff.

Lower proportions of ♀ *S. lividigaster* were recorded in breeding seasons because ladybirds remain close to food sources and oviposit near them (BLACKMAN, 1965; HODEK, 1967), so are concealed. Males in breeding periods are very active searching for mates and more are observed. Slight increases in ♀ prior to winter and summer dormancy is probably because prediapause feeding on a range of alternative foods, a common ladybird behaviour pattern (HAGEN, 1962; MCMULLEN, 1967), is practised by *S. lividigaster*. While feeding, ladybirds spread themselves in the habitat. Females are as visible as ♂, but because of their greater energy requirements, evidenced by greater biomass and fat accumulation at this time (ANDERSON, unpublished data), ♀ feed longer and more are observed.

Little seasonal deviation in *S. lividigaster* sex ratio in 1977 compared with other years, may be explained by environmental and human factors. In 1977, alternative food was in short supply due to drought and excessive ground cover removal in weed eradication projects, so that normal habitats available for prediapause feeding were absent. Consequently ladybirds were not visible and had to be beaten from their habitat, resulting in a ratio close to 50 : 50.

Female predominance in *L. galbula* sex ratios in all years and in 2 very different habitats is not likely to have been caused by collecting methods, for sampling in both habitats was unbiased. Sex could not be determined except by dissection and ladybirds were collected at random by a combination of methods.

Seasonal variations in *L. galbula* sex ratio present an array of contradictions. In the Reserve in 1975, a high proportion of ♀ was recorded at peak breeding (November-December); but not in other years. Certain months of late summer-autumn reproduction in 1976 and 1978 were associated with high ♀ %, but the same period in 1977 was associated with lower %. There was no increase in ♀ % in any of the prediapause feeding periods in the Reserve, but there was an increase in the postdiapause, when ladybirds emerged from dormancy and searched for food. This may indicate greater nutritional needs of ♀, displayed by increased dispersal before breeding seasons, but more likely, a demise of some ♂ over winter. Lower ♂ survival in difficult environmental conditions is indicated by seasonal fat analysis (ANDERSON, unpubl. data). Here, ♂ showed less ability than ♀ to accumulate and maintain their reserves. SMITH (1966) suggested that greater food requirements of ♀ ladybirds and their enhanced longevity affected sex ratios.

Another likely explanation of ♀ predominance in *L. galbula* is a different method of sex determination. Abnormally high proportions of ♀ have been found in laboratory cultures of the ladybird, *Harmonia axyridis* PALLAS and suggest parthenogenesis, for some ♀ produced only ♀. At times spontaneous restoration of normal sex ratio occurred (MATSUKA *et al.*, 1975). However, no ♀ increase occurred in laboratory cultures of *L. galbula*, where survival was high and where sex ratio approached 50 : 50; however, cultures were kept in constant light; other photoperiods were not tested.

When comparing the 2 ladybird species, differences are great. *S. lividigaster* sex ratio approximated 50 : 50, with regular seasonal fluctuations attributed to collecting methods and seasonal changes in behaviour of the adults; *L. galbula* had a predominance of ♀ and often displayed inexplicable variation in seasonal sex ratio pattern. Investigation of *L. galbula* genetics, breeding in different photoperiods; temperatures and with different food supplies, could explain some of these deviations. A method by which sex could be

manipulated could be advantageous when rearing ladybirds for experiments or mass release.

This study indicates certain sampling methods may give erroneous sex ratio data. Correct interpretation of data must involve regular and long term studies of the population; including seasonal cycles of development, habitat preferences and behaviour patterns.

RÉSUMÉ

Proportion des sexes chez les adultes de *Scymnodes lividigaster* et *Leptothea galbula* [*Col. : Coccinellidae*] dans la nature

Trois années d'étude de *Scymnodes lividigaster* (MULSANT) dans les conditions naturelles près de Sydney ont montré que la proportion des sexes était 50 : 50. Les proportions varient selon les échantillons prélevés à différentes périodes de l'année et suivant les années. Les variations dépendent des méthodes de prélèvement, des conditions de milieu et du comportement des sexes aux différentes étapes de leur développement. L'échantillonnage de *Leptothea galbula* (MULSANT) dans 2 habitats différents a mis en évidence des proportions des sexes favorables aux femelles, sans relation apparente avec les méthodes de collecte et avec peu de dépendance avec la saison. Au laboratoire la proportion de sexes de *L. galbula* était voisine de 50 : 50.

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