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THE ECOLOGY OF A MONTANE GRASSLAND IN SRI LANKA
VI. EFFECTS OF BURNING AND CUTTING

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SUMMARY

(1) The effects of different frequencies of burning and cutting on a montane grassland in Sri Lanka were investigated experimentally.

(2) Both treatments caused considerable changes in floristic composition and biomass. The main effects were to reduce the vigour of the predominant *Cymbopogon nardus*, to increase the occurrence of subordinate species, and, more importantly, to promote establishment of graminaceous and composite weeds, notably *Pennisetum polystachyon*. These effects became more severe with increasing frequency of treatment.

(3) The ecological implications of the results are considered, with particular emphasis on the possibility of modifications of the species spectrum of the grassland as a result of continued human interference.

INTRODUCTION

The effects of human interference on montane grasslands (patanas) of Sri Lanka have been emphasized by many workers (Broun 1891; Champion 1936; de Rosayro 1946a,b,c, 1961; Senaratne 1956; Perera 1967), and Pearson (1899) and Holmes (1951) regarded patanas as disclimaxes resulting from frequent burning of woody vegetation. Clearing for short-term cultivation, burning, removal of herbage for cattle-fodder and grazing by cattle are widespread on many patanas and cause floristic and habitat, particularly edaphic, changes (Mueller-Dombois & Perera 1971; Pemadasa & Mueller-Dombois 1979, 1981; Pemadasa 1981). However, very little experimental work has been carried out on the ecological effects of human impact on patanas.

The first two papers of this series (Pemadasa & Amarasinghe 1982; Amarasinghe & Pemadasa 1982) provided evidence of phytosociological and edaphic variations within a patana. Some of the variation

Note : The first five papers of this series were published in the *Journal of Ecology*.

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resulted from human interference, for burning is annual during January-February and forage removal for cattle is frequent, particularly at altitudes of 550 - 750 m. This paper describes experiments on the effects of burning and cutting on some selected samples of these patana communities.

METHODS

Effect of burning

Two homogeneous sites at 650 - 750 m altitude were selected: one of a recently disturbed community and a one in which there was little evidence of disturbance; these sites are hereafter referred to as 'disturbed' and 'undisturbed' respectively. The undisturbed site was predominantly of natural patana species such as *Cymbopogon nardus**, *Eulalia trispicata* and *Wickstroemia indica* with very few weeds; the eroded soil had a quartz-gravel upper layer containing little organic matter. The disturbed community had abundant composite and graminaceous weeds, notably *Pennisetum polystachyon*, and rather suppressed natural patana species; the soil was highly truncated with protruding rock outcrops and little organic matter.

At each site, twelve 2 x 2-m plots were arranged in three rows of four plots. There were 2-m wide strips between the plots; these were kept free of vegetation to prevent the spread of fire between adjacent plots.

Three burning frequencies (once, twice and three times per year) and an unburnt control were investigated by a randomized-block design with three replicates per treatment. Treatment commenced in the first week of January 1976 (to synchronize with the usual annual burning); subsequent burnings were carried out at intervals of two months.

Each plot was divided into a grid of one hundred 20 x 20-cm quadrats, of which twenty-five were selected systematically to make presence or absence records of each species; from these data percentage shoot frequency was calculated. Frequency records for each species and tiller counts of predominant grasses in each plot were taken prior to the commencement of treatments in January 1976 and then at intervals of two months. Recordings were made during the first week of the month. The experiments were planned to run for twenty months (January 1976 - August 1977) when it was intended to harvest the above-ground plant material for dry weight determination. Unfortunately, the undisturbed community was severely damaged by annual burning in February 1977 and the experiment had to be abandoned. The disturbed community was harvested in the first week of September 1977; shoots were cut about 5 cm above the ground-level, separated into species, and weight was determined after oven-drying (at 85 °C) for 72h.

* Nomenclature follows Abeywickrama (1959).

Effect of cutting

As in the burning experiment, a site representing an undisturbed community at 550 - 650 m altitude was selected. Twenty-one 2 x 2-m plots were arranged in three rows each of seven plots; 2-m wide access strips were employed.

Three cutting treatments (once, twice and three times per year) and a control in which the vegetation was not cut were studied by a randomized-block design with three replicates of each treatment. The cutting was carried out about 5 cm above ground level, using a sickle as in the process of forage removal for cattle. Treatment commenced in the first week of February 1976; subsequent cuttings were carried out at intervals of two months. The cut material was removed from half the plots; it was left lying on the ground in the others.

Vegetation records were as in the burning experiment. The experiment ran from February 1976 to December 1977 when the above-ground plant material was harvested and dry weight determined.

RESULTS

Effect of burning

Disturbed community

The luxuriantly-growing *Pennisetum polystachyon* contributed as much as 80% of the initial turf in all plots, with *Cymbopogon nardus* as the second most frequent species, and *Desmodium heterophyllum*, *D. triflorum*, *D. triquetrum*, *Eulalia trispicata*, *Lantana camara*, *Merremia angustifolia*, *Psidium guajava*, *Panicum maximum* and *Wikstroemia indica* as common subordinates; dicotyledonous weeds were rare. During the experimental period, control plots showed only slight floristic fluctuations, but in burnt plots progressively intensified changes occurred after successive fires (Fig. 1). All the species recovered readily after the first burning, despite considerable foliar-damage. In the twice and three times burnt plots, the frequency of *Cymbopogon nardus* was reduced drastically ($P < 0.01$), while *Eulalia trispicata* and *Wikstroemia indica* recovered slightly, and *Pennisetum polystachyon* more successfully. The frequency of dicotyledonous weeds *Ageratum conyzoides*, *Hedyotis* sp., *Mimosa pudica* and *Phyllanthus niruri* increased considerably after the first and second fires ($P < 0.05$), but decreased drastically after the third ($P < 0.05$).

The initial tiller density in both *Cymbopogon nardus* and *Pennisetum polystachyon* differed between plots, but the effects of successive burning were more considerable (Fig. 2). In control plots, the tiller density of *Cymbopogon nardus* showed slight changes during the experimental period, but that of *Pennisetum polystachyon* decreased progressively as a result of death of older tillers after flowering.

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In both species an enhancement of tillering occurred after the first fire ($P < 0.01$), but a substantial reduction after the second and third ($P < 0.05$). During the last six months of the experimental period, *Pennisetum polystachyon* had more tillers in plots given two and three burns, but the tillers were much larger and produced more inflorescences in the control and once-burnt plots. Increasing burning frequency was more deleterious to *Cymbopogon nardus* than to *Pennisetum polystachyon*; apparently, the weed was more fire-tolerant than the native species.

The effect of fire was to reduce the shoot dry matter of most species (Table 1), and this reduction became more drastic with increasing burning frequency, indicating their failure to produce biomass sufficient to compensate for the fire-damage; the reduced productivity is a result of reduced growth of tillers and leaves and of enhanced senescence. The only exception was *Eulalia trispicata* which produced more biomass in once and twice-burnt plots than in the control, presumably because of its improved growth in response to reduced competitive pressure of the predominant species; in plots given three burns, however, its dry matter was substantially reduced owing to intensive fire-damage.

Undisturbed community

Records of shoot frequency are given in Fig. 3; these were supplemented with regular visual observations. Initially *Cymbopogon nardus* and *Panicum maximum* predominated and, together, contributed more than 70% of the total cover; the next most frequent species were *Eulalia trispicata*, *Pennisetum polystachyon* and *Wikstroemia indica*. *Cymbopogon nardus* and *Panicum maximum* were vigorously growing, while *Pennisetum polystachyon* appeared rather suppressed.

The control plots showed very little floristic changes during the experimental year. *Cymbopogon nardus*, *Eulalia trispicata* and *Panicum maximum* grew progressively until flowering in November - December, when signs of senescence appeared; these species usually undergo a resting period during December-February (Mueller-Dombois & Perera 1971). The growth of *Pennisetum polystachyon* was slow, but some tillers flowered.

In contrast, the burnt plots showed distinct changes which became more marked with increased frequency of burning. Although a single fire completely burnt or highly parched the vegetative parts, particularly the leaves of *Cymbopogon nardus*, *Eulalia trispicata* and *Panicum maximum*, they recovered fairly rapidly and one year later there was little difference between these and control plots. However, in the plots given two or three successive burns all the species were severely damaged, and the rate of recovery was slow, particularly in *Cymbopogon nardus* and *Panicum maximum*. An increase in frequency occurred in weed species *Emilia scabra*, *Hedyotis* sp. and, to a lesser extent, *Pennisetum polystachyon* ($P < 0.05$). In all the species, inflorescence production was much less and leaf senescence during the resting period was more marked in plots burnt three times than in all the other plots.

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In control plots, the tiller density of both *Cymbopogon nardus* and *Pennisetum polystachyon* decreased later in the experimental year (Table 2) because of death of older tillers after flowering; tillering increased after the first fire ($P < 0.05$), but decreased after the second and third ($P < 0.05$). In *Pennisetum polystachyon* the initial tiller density was equally low in all plots; however, it produced more tillers in burnt plots than in the control indicating its enhanced growth in response to the reduced competitive pressure of *Cymbopogon nardus*.

Comparison of the two communities shows that initially *Cymbopogon nardus* grew better in the undisturbed community than in the disturbed one, while the reverse was true of *Pennisetum polystachyon*, and that burning further facilitated the establishment of the weed and handicapped the native species.

Effect of cutting

Initially *Cymbopogon nardus* and *Panicum maximum* predominated on all the plots and together contributed about 70% of the total plant cover; *Eulalia trispicata* was the second most abundant species. The subordinate species were *Borreria hispida*, *Cassia kleinii*, *Desmodium triflorum*, *D. triquetrum*, *Fimbristylis* sp., *Ipomoea* sp., *Psidium guajava* and *Wikstroemia indica* which, together, contributed less than 15% of the total plant cover. Weed species were rare.

The results for the two treatments where the cut material was removed and not removed were pooled because there was no significant difference between them. In the control plots only slight floristic fluctuations were observed, while in the clipped plots the changes were considerable (Fig. 4). The frequency of *Cymbopogon nardus* decreased from the control and once-clipped plots, which showed little difference between them, through those given two clippings, to plots clipped three times, while the converse trend occurred in *Panicum maximum*. Successive cutting reduced the growth-vigour of *Cymbopogon nardus* and improved that of *Panicum maximum*; in fact, towards the end of the experimental period *Panicum maximum* appeared to flourish in plots given three clippings, where *Cymbopogon nardus* was severely suppressed. With increasing frequency of cutting the frequency of weed species *Cassia mimosoides*, *Emilia scabra*, *Hedyotis* sp., *Mimosa pudica* and *Vernonia cinerea* increased substantially ($P < 0.05$); there was also some indication of gradual invasion of clipped plots by *Pennisetum polystachyon* which was absent initially. A twenty-fold increase in shoot frequency of *Cassia mimosoides*, *Hedyotis* sp. and *Mimosa pudica* occurred in plots clipped three times, while in control plots their frequency never exceeded 5%.

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The changes in tiller density of *Cymbopogon nardus* during the experimental period was more marked in the clipped plots than in the controls (Table 3). Tillering was enhanced after the first clipping ($P < 0.01$), but reduced after the second and third ($P < 0.05$). However, although the clipped plants produced more tillers than did the controls, the tillers were less vigorous and produced smaller inflorescences. In all the plots tiller density decreased with time to a value similar to the initial one, presumably because of the death of older tillers after flowering and seed production.

The shoot biomass was significantly higher ($P < 0.01$) in the control plots than in the clipped ones (Table 4), and this is to be expected, because, unlike the former, the latter had no carry-over biomass. The species most affected was the predominant *Cymbopogon nardus*, which showed a drastic reduction of dry matter with increased frequency of clipping; *Panicum maximum* declined less. In *Eulalia trispicata* there was no significant difference between treatments.

DISCUSSION

That burning and cutting cause drastic changes in floristic composition, species-predominance and production in selected communities of the humid-zone dry patana in Sri Lanka is evident from the results presented. Such effects of fire and defoliation by cutting and grazing on the phytosociology of temperate grasslands are well known (e.g. Mueggler 1967; Daubenmire 1968; Lloyd 1968; Spedding 1971; Wells 1972; Vogl 1974).

The most obvious effects of burning were to destroy the existing vegetation so reducing abundance and vigour of native species, and, consequently, to promote ready establishment of graminaceous and composite weeds, notably *Pennisetum polystachyon*. The degree of fire-tolerance is known to be higher in grasses with deep rhizomes and root systems than in others (Jamson 1962). The underground organs are much deeper in *Pennisetum polystachyon* than in *Cymbopogon nardus*, *Eulalia trispicata* and *Panicum maximum*. In patana grasses seed production is restricted to the period November-February. In contrast, *Pennisetum polystachyon* sets seeds throughout the year, which are dispersed by wind. These characteristics, together with its ability to germinate readily and grow vigorously, enable it to flourish in places destroyed by fire. The composite weeds can establish rapidly also, because of the presence of a seed bank in the soil and of the availability of sites free of vegetation.

Burning caused a considerable reduction of subsequent production. Such effects of fire have been reported by Dix (1960), but Penfound & Kelting (1950), Kucera & Ehrenreich (1962) and Hadley & Kieckhefer (1963) observed the reverse. The effect of fire on grassland productivity is not only species-specific, but also depends on the severity, frequency and time of burning (Daubenmire 1968). In the present study, the successive

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fires were at the onset of resting (January) and growing (March) periods and in the middle of the actively growing period (May). Clearly, in addition to the initial destruction of the standing crop, burning during the growing season would reduce production. *Eulalia trispicata* was found to produce more in plots burnt once and twice than in the control, a feature attributable to its improved growth in response to reduced competition from fire-damaged *Cymbopogon nardus*; three successive fires, however, reduced its production because of severe fire-damage. It is clear that successive fires drastically reduce the productivity of the grassland.

Although not as detrimental as burning, cutting also caused considerable phytosociological changes, but its effects were rather selective; it reduced the growth-vigour of *Cymbopogon nardus*, increased the growth of the subordinate *Eulalia trispicata* and *Panicum maximum*, facilitated the colonization of weeds, and reduced the overall production. The severity of the effects of cutting depends on the frequency and time of cutting, the height at which it is carried out, and the extent to which shoot apices are damaged (May 1960; Dittmer 1973). Unlike *Panicum maximum*, with shoot apices lying close to the soil surface, *Cymbopogon nardus* has its apices 5-10 cm above the ground-level; thus, cutting is likely to cause more apical damage to it than to *Panicum maximum*, and this may explain their differential degree of recovery and subsequent growth. The enhanced establishment of weeds is undoubtedly a result of reduced competition from the vegetation, the availability of suitable microsites, and of the presence of a seed bank in the soil.

It seems reasonable, therefore, to suppose that continued human interference would modify the floristic composition of the patana in favour of weeds, notably *Pennisetum polystachyon*, at the expense of the natural species; such floristic changes are already evident, particularly at lower altitudes of the grassland (Pemadasa & Amarasinghe 1982; Amarasinghe & Pemadasa 1982). Therefore, proper management is essential for the conservation of this ecosystem.

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Table 1. Effect of different frequencies of burning on above-ground biomass (g M^{-2}) in the disturbed community of the humid-zone dry patana in Sri Lanka. $n = 3$

	Control	Burnt once	Burnt twice	Burnt thrice	L.S.D. at $P = 0.05$
<i>Cymbopogon nardus</i>	242.5	174.3	129.0	30.5	6.7
<i>Eulalia trispicata</i>	5.0	16.0	18.5	3.0	2.9
<i>Pennisetum polystachyon</i>	686.0	218.0	110.5	73.5	11.5
<i>Wikstroemia indica</i>	38.0	2.5	3.8	2.2	0.9
Other species	31.5	11.7	5.0	3.5	2.1
Total	1003.0	422.5	266.8	112.7	15.7

TABLE 2. Effect of different frequencies of burning on the course of tiller density (\pm S.E.) per tussock of *Cymbopogon nardus* and *Pennisetum polystachyon* in the undisturbed community of the humid-zone dry patana in Sri Lanka. $n=30$

Months after Burning	Control	Burnt once	Burnt twice	Burnt thrice
<i>Cymbopogon nardus</i>				
0	31.6 \pm 2.1	25.0 \pm 3.2*	32.3 \pm 3.4*	29.3 \pm 3.4*
2	34.6 \pm 3.3	50.1 \pm 5.6	56.3 \pm 6.5**	48.7 \pm 3.9**
4	32.0 \pm 3.4	34.0 \pm 4.1	37.3 \pm 3.5	39.2 \pm 4.2***
6	30.2 \pm 3.2	32.1 \pm 3.4	31.5 \pm 2.8	26.3 \pm 2.1
8	20.6 \pm 2.3	27.4 \pm 2.4	25.3 \pm 2.1	16.9 \pm 1.9
10	19.5 \pm 1.7	23.6 \pm 2.3	20.2 \pm 1.7	15.3 \pm 1.2
12	18.3 \pm 1.2	18.3 \pm 1.5	17.9 \pm 1.5	14.3 \pm 1.8
<i>Pennisetum polystachyon</i>				
0	10.1 \pm 2.1	8.1 \pm 1.2*	11.2 \pm 1.2*	9.3 \pm 1.9*
2	12.3 \pm 2.3	34.1 \pm 3.8	29.6 \pm 4.1**	35.7 \pm 3.9**
4	14.6 \pm 1.9	26.4 \pm 3.2	18.9 \pm 2.3	20.9 \pm 2.1***
6	13.2 \pm 2.0	20.3 \pm 2.3	17.6 \pm 2.3	14.9 \pm 1.7
8	10.3 \pm 1.2	17.3 \pm 2.1	14.5 \pm 2.0	13.2 \pm 1.2
10	9.6 \pm 1.8	15.6 \pm 1.2	14.2 \pm 1.7	12.0 \pm 1.2
12	9.3 \pm 1.2	14.9 \pm 1.4	13.9 \pm 1.3	12.4 \pm 1.4

*, **, and *** indicate times of first, second and third fires respectively.

TABLE 3. Effect of different frequencies of cutting, on the course of tiller density (\pm S.E.) per tussock of *Cymbopogon nardus* in a community in the humid-zone dry patana in Sri Lanka. $n = 30$

Months after Clipping	Control	Clipped once	Clipped twice	Clipped thrice
0	22.1 \pm 3.4	24.2 \pm 2.1*	34.2 \pm 3.1*	43.2 \pm 3.4*
2	25.2 \pm 2.9	60.3 \pm 3.4	83.1 \pm 5.3**	95.4 \pm 6.5**
4	33.2 \pm 2.3	54.1 \pm 3.2	77.0 \pm 4.5	80.2 \pm 5.4***
6	35.3 \pm 2.7	43.2 \pm 4.1	49.2 \pm 3.4	40.2 \pm 3.2
8	24.1 \pm 2.1	32.2 \pm 3.2	32.2 \pm 3.2	33.5 \pm 3.6
10	23.1 \pm 2.9	28.4 \pm 2.8	36.6 \pm 2.9	26.4 \pm 2.5
12	21.2 \pm 1.9	23.4 \pm 2.4	32.4 \pm 1.9	28.5 \pm 3.9

*, **, and *** indicate times of first, second and third cutting respectively.

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TABLE 4. Effect of different frequencies of cutting on above ground biomass ($g M^{-2}$) in a community of the humid-zone dry patana in Sri Lanka. $n = 3$

	Control	Clipped once	Clipped twice	Clipped thrice	L.S.D.at $p = 0.05$
<i>Cymbopogon nardus</i>	2004.0	1360.0	412.0	266.0	23.6
<i>Eulalia trispicata</i>	33.2	34.4	32.5	38.0	3.4
<i>Panicum maximum</i>	164.2	78.3	80.5	137.2	9.6
other species	27.5	44.5	28.5	86.0	33.7
Total	2228.9	1517.2	553.5	527.2	33.8

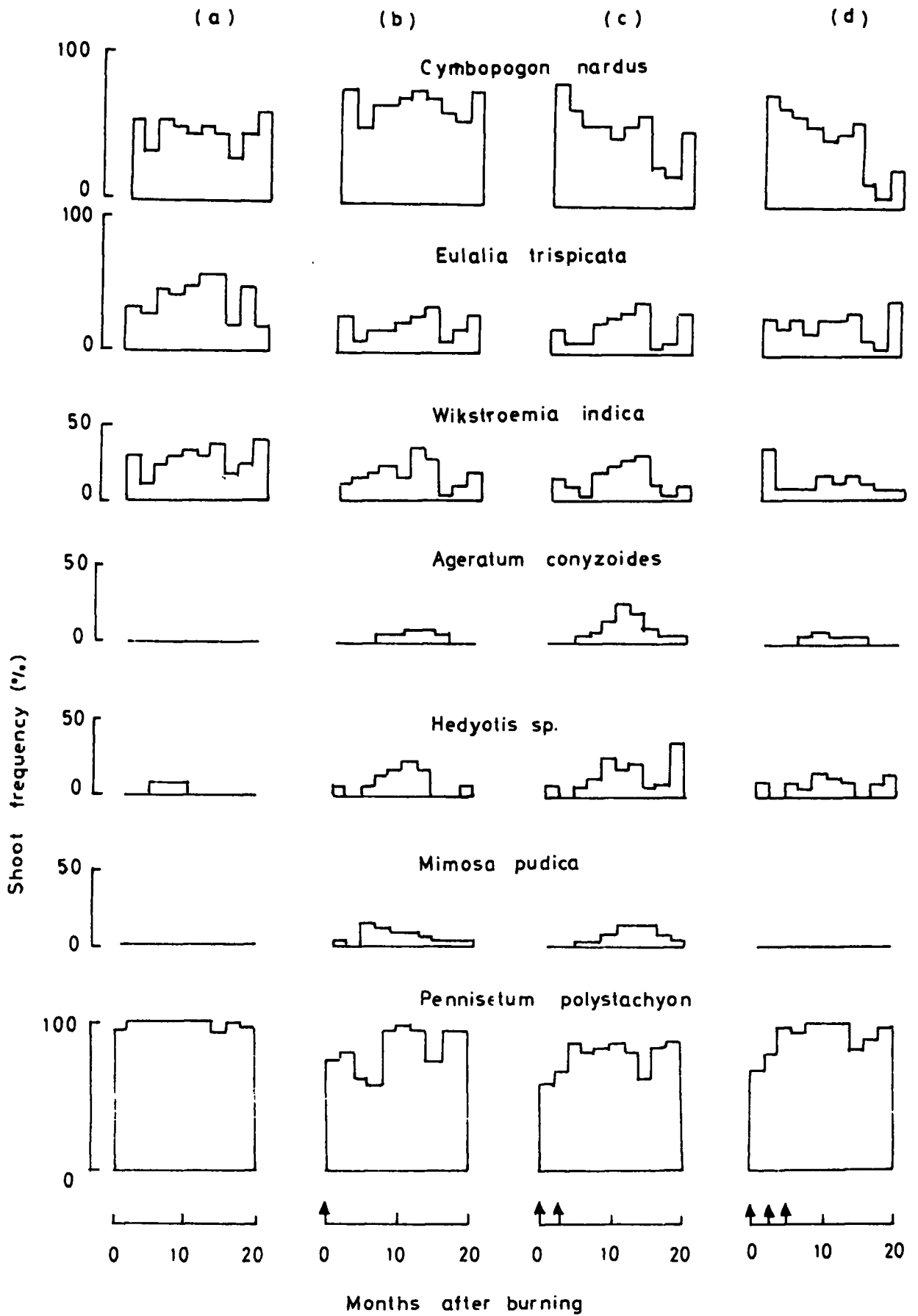
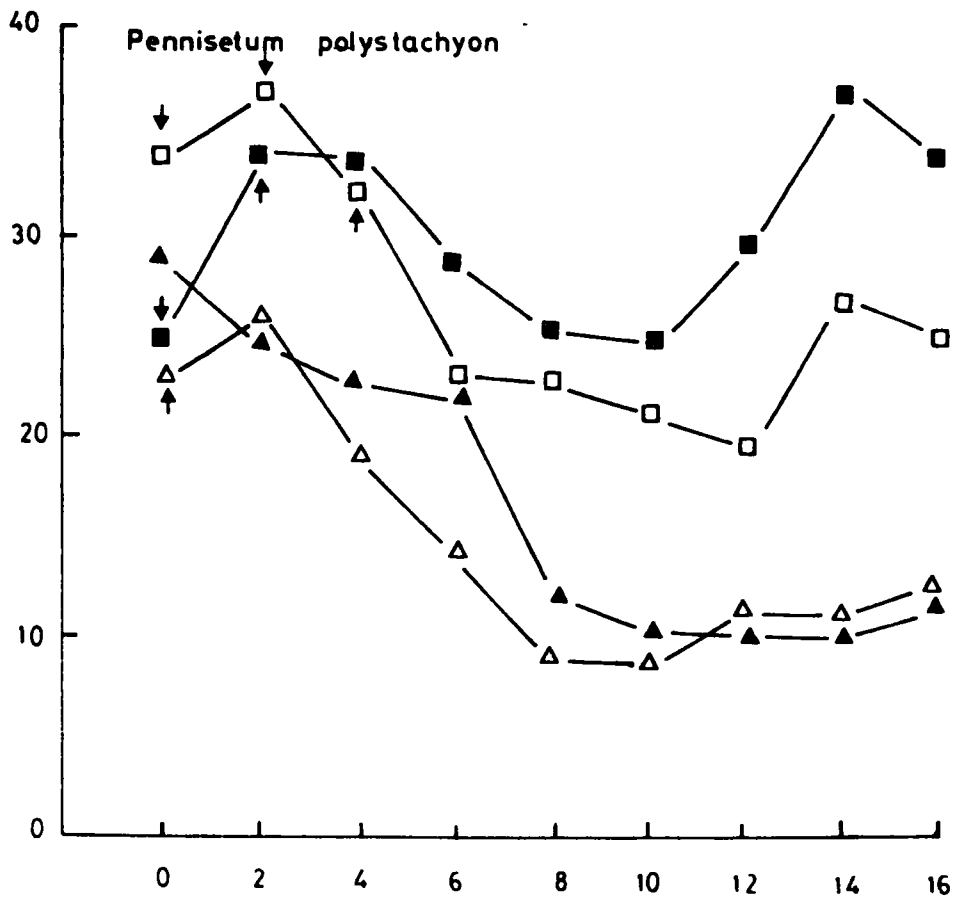
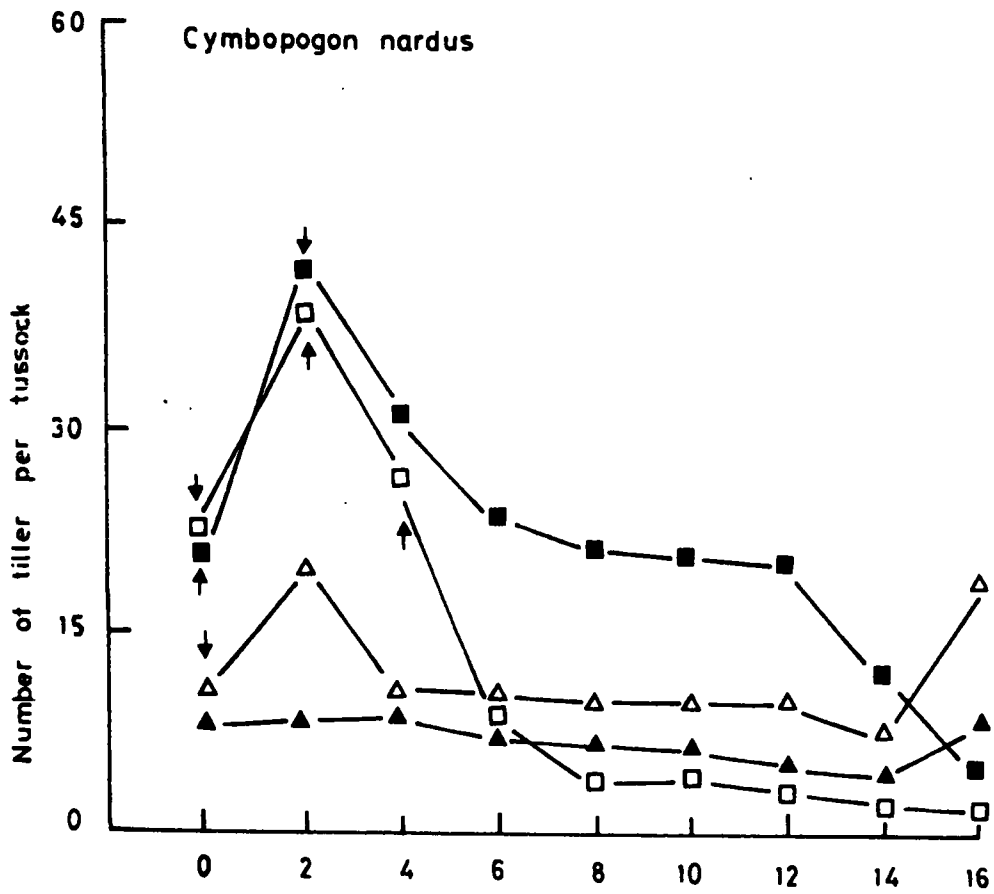


Fig. 1



Months

Fig. 2

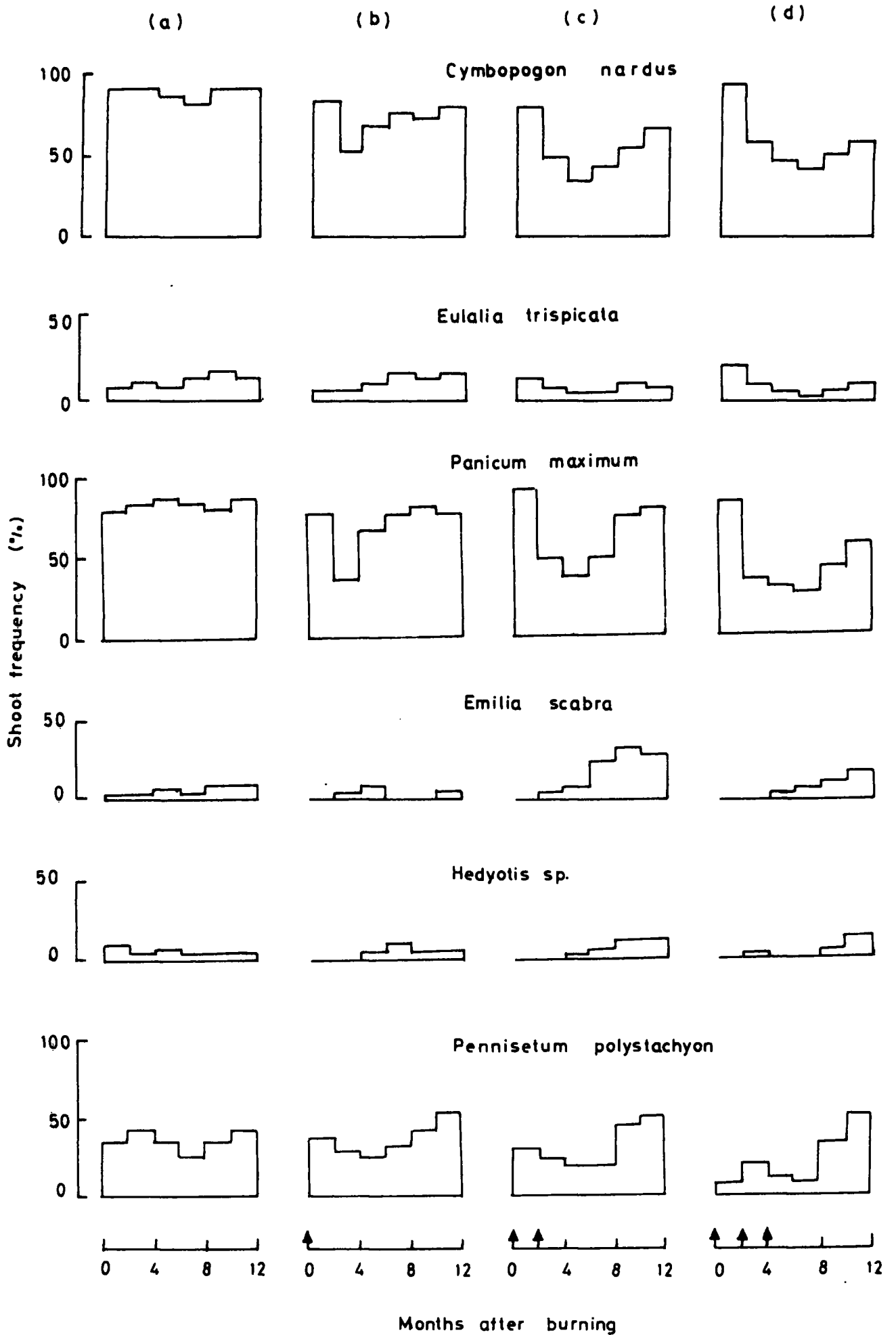


Fig. 3

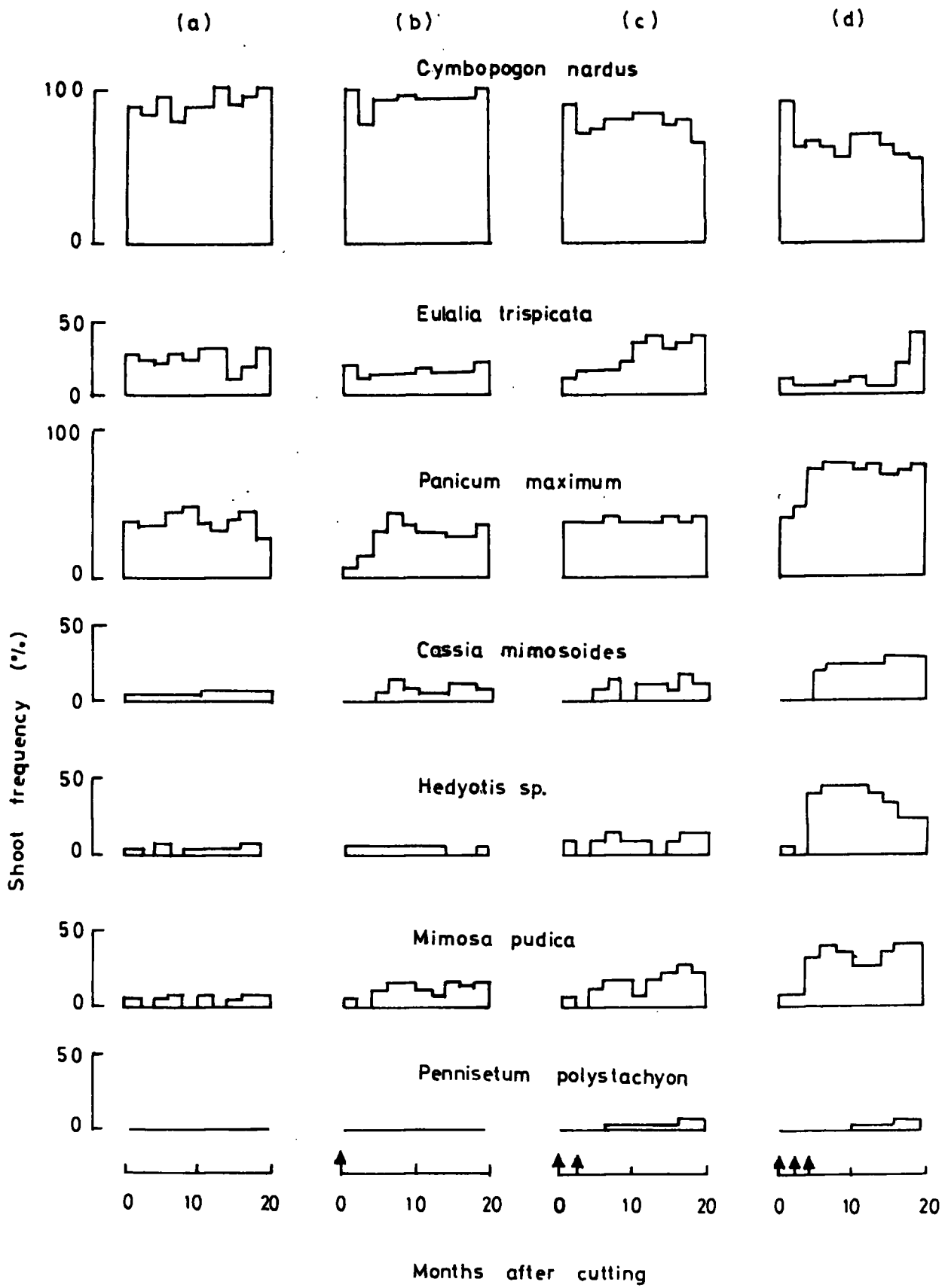


Fig. 4