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TRACING THE EPICENTERS OF TEAK DEFOLIATOR OUTBREAKS IN KERALA

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ABSTRACT

A study was made to test the hypothesis that the teak defoliator, *Hyblaea puera* Cramer (Lepidoptera, Hyblaeidae) outbreaks begin in small epicentres and spread progressively to extensive areas as a result of population built up in these epicentres. To gather relevant data, about 10,000 ha each of teak plantations at Nilambur and Konni were kept under observation during the outbreak period in 1993 and all outbreaks mapped. Interpretation of the spatial and temporal sequence of outbreaks yielded the following conclusions. In large teak plantation areas, *H.puera* outbreaks begin in comparatively small epicentres which may be 0.6 to 12 ha in area. These epicentres are not constant over the years and do not represent highly favourable local environments. Instead , they are sites where a group of immigrating moths or moths locally present but concentrated by as yet unknown phenomena assemble and lay eggs. Although many of the extensive outbreaks which occurred subsequently could be attributed to the pest population built up in these epicentres, all the outbreaks could not be attributed to locally built up populations. Immigration of moths from outside the Nilambur area was necessary to explain these. It appears that many of the large scale outbreaks can be prevented by controlling the small epicentre populations. However, the involvement of immigrating moths cannot be ruled out. An experimental study involving control of epicentre populations is recommended to examine the effectiveness of this approach to teak defoliator management. The study also revealed that teak plantations in all areas are not equally prone to defoliator attack. Incidence of outbreak appears to be strongly correlated with orographic features of the planted area, but more detailed studies are needed to elucidate the relationship.

1. INTRODUCTION

The teak defoliator, *Hyblaea puera* is recognised as the most important pest of forest plantations in Kerala. Earlier studies have shown that defoliation caused by this insect in plantations resulted in loss of about 44% of the potential volume increment in 4 to 9 year old trees (Nair *et al,* 1985). It was estimated that during the study period, the protected trees put forth a mean annual volume increment of 6.7 m^3/ha compared to 3.7 m^3/ha of unprotected trees, which amounts to a gain of 3 m^3/ha annually. Control of the teak defoliator can therefore lead to substantial gain in tree volume increment. Theoretically, protected trees will be ready for harvest in 26 years as they would accrue as much volume as unprotected trees will gain in 60 years, provided other necessary inputs are given (Nair *et al,* 1996)

There are two pre-requisites for practical control of this long recognised pest: availability of good control measures and the ability to predict the outbreak well in advance to mount the control efforts. A naturally occurring Nuclear Polyhedrosis Virus (NPV) has been identified as a promising control agent (Sudheendrakumar *et al,* 1988) and presently work is in progress to standardise the use of this NPV. The present investigation addressed the second pre-requisite, namely, proper timing of control operations.

Although defoliator outbreak is a regular annual feature in teak plantations throughout Kerala, it is extremely difficult to predict the exact time and places of occurrence of these outbreaks. Recent research has indicated that the outbreaks begin in small epicentres during the pre-monsoon season (Nair *et al,* 1994 : Nair and Mohanadas, 1996). Evidences obtained in earlier studies (Nair and Sudheendrakumar, 1986) indicated habitual, short-range, gypsy type movements of emerging moth populations, suggesting that these populations spread to larger and larger areas, generation by generation, affecting the entire teak plantations. On the other hand, early outbreaks were found strongly correlated with the occurrence of pre-monsoon showers. The important issue was therefore to determine whether outbreaks begin in small local epicentres and spread to larger areas locally through short-range movements of emerging moth populations or whether the so-called “epicentre” populations are in reality, small batches of migrant moth populations brought in through the pre-monsoon wind/cloud system from far - off places. Obviously our ability to prevent population build-up in a given area over successive generations will depend on whether there is local multiplication and spread or immigration from outside. . If outbreak epicentres occur in each large plantation area it will open up the possibility of controlling the insect by site specific application of control measures in these epicentres, in order to nip the problem in the bud. On the other hand, if long-range immigration of moths through the monsoon cloud front is involved, control will be more difficult. This project was therefore aimed at collecting very detailed information on the temporal and spatial distribution of early defoliator outbreaks in two large representative teak plantation areas (Nilambur and Konni), and use this data to test the hypothesis of outbreak "epicentres".

2. METHODS

2.1. Study area

The study was carried out at two major teak growing areas in Kerala- Nilambur and Konni. At Nilambur, an area of about 10,000 ha of teak plantations between latitudes 11o 10'N and 11o 25'N and longitudes 76o 10’E and 76o 25’E was observed. At Konni nearly 12,000 ha of teak plantations between latitudes 9^{o} 3'N and 9^{o} 19'N and longitudes 76^{o}51’E and 77^{o} 13’E were under observation.

For Nilambur, the plantation maps were prepared by interpreting the aerial photographs. Only the teak plantations were interpreted and mapped. The map was brought to the scale 1:50,000 and major features like drainage and roads were marked by superimposing it on Survey of India (SOI) topographic sheets of the same scale. For Konni area, the plantation map was prepared with reference to the SOI topographic sheets. At both the places, the area was divided into convenient Observation Units (OUs) based on natural boundaries of streams, roads and foot-paths. There were 149 OUs at Nilambur with an average area of 57.16 ha and 150 OUs at Konni with an average area of 85.19 ha.

2.2. Observations and recording of outbreak data

In addition to our own observations, trained field observers were deployed in the field to locate and record outbreaks. In Nilambur, observations started in the second fortnight of February 1993 and continued up to September 1993. At Konni, observations started in the second fortnight of March 1993 and ended in June 1993.

The immature stages of the teak defoliator is completed in about 19 days. Therefore observations at fortnightly intervals were made in each OU to ensure that no infestations were missed. This also gave an opportunity to collect live larvae or pupae from each of the outbreak sites to estimate the date of egg laying.

Each field observer was assigned one OU a day to cover by criss-cross perambulation. A maximum of ten OUs were assigned to a single observer to cover within a span of 14 days. Whenever an outbreak occurred, the approximate extent of infestation was marked in a map of the OU and collections of larvae were made from that site. The larvae were reared in the laboratory until they moulted to the next stage- either the next larval instar or pupa. Based on this, the date of egg laying was calculated using the duration of each instar. (preoviposition period- 2 days ,egg-1 day; instars 1 to 5- 2,2,3,3 and 3 days respectively; pupa -5 days). The approximate extent of outbreak was marked in the map of the study area.

2.3. Behavioural observations

Moth movements were observed on several occasions during the study period. Some observations were fortuitous, but others were planned. Whenever an opportunity arose, the behavioural characteristics were closely observed and recorded. In planned observations, the number of moths in flight and the overall direction of movement was estimated with the help of field observers. Samples of moths were collected from the groups in flight or at rest to determine the sex ratio of the moth aggregations. All behavioural observations were made at Nilambur.

2.4. Data Analysis

The temporal data on outbreaks was examined to see whether each subsequent outbreak can be explained on the basis of the previous outbreak, *i.e.,* whether the progeny of a previous population could have caused the next outbreak. To examine this, the generation time from egg to egg was used. Based on the duration of each install given above, the egg to egg period works out to 21 days. Unpublished laboratory data had shown that a minimum of 20 days was required to complete the egg to egg period. For the period between February and May, when the temperatures are comparatively higher, 20 days was taken as the minimum ; and 23 days as the maximum egg to egg period. Beyond May, 23 days was taken as the minimum and 27 days a s the maximum egg to egg period.

The moths lay eggs continuously for a period of 5 days (Sudheendrakumar, 1994 Therefore if an infestation (egg laying) was observed between 20 to 28 days during February - May and between 23 to 32 days after May following an earlier infestation, it could be argued that the second infestation may have been caused, at least in theory, by the progeny of the first infestation.

3. RESULTS AND DISCUSSION

3.1. Outbreak characteristics

3.1.1. Nilambur

The temporal sequence of outbreaks at Nilambur in 1993 and the area infested during each outbreak are shown in Fig.1.

The first outbreak of the year occurred at Kariem-Muriem on 19 February (Fig.2.). There were two distinct patches of infestation, separated by a distance of about 3 km, one covering an area of 12.8 ha and the other, 1.7 ha. Prior to this, there was no visible evidence of presence of larvae although occasionally stray larvae could be located on careful search. General observations had indicated that in most areas, leaf fall was completed by the end of January and new flushes had started. The infestation which occurred on 19 February was dense and concentrated on the tree tops. We estimate that a minimum of 79,000 moths were required to cause this infestation (assuming 500 teak trees per ha., minimum of 50 infested leaves per tree, at least 20 larvae per infested leaf, and an average oviposition rate of 100 eggs per female on the day of oviposition). It is obvious that such a large population of moths could not have originated from the teak plantations at Nilambur all of a sudden, unless we assume that stray moths which were spread throughout the plantations got concentrated through some unexplained phenomenon. In that case, 8 moths per hectare could have made up 80,000 moths from the 10,000 ha of teak plantations at Nilambur. Wind aided concentration of airborne moths has been demonstrated in the case of the spruce budworm moth, *Choristoneura fumiferana* (Lepidoptera , Tortricidae) in Canada (Greenbank *et al,* 1980). Alternatively, the moths could have immigrated from outside the Nilambur area. In any case, the distinct patches of infestation indicate aggregation of moths and their movement as a group.

The second outbreak occurred on 26 February over a 5 ha area near one of the first outbreak patches (Fig.3.).The characteristics of this infestation were same as that of the first. Since only seven days had elapsed between the first and second outbreaks, it is obvious that the second outbreak was not caused by the progeny of the first. The 7-day gap between the two outbreaks also suggests that the second outbreak could not have been caused by the same group of moths which caused the first outbreak because

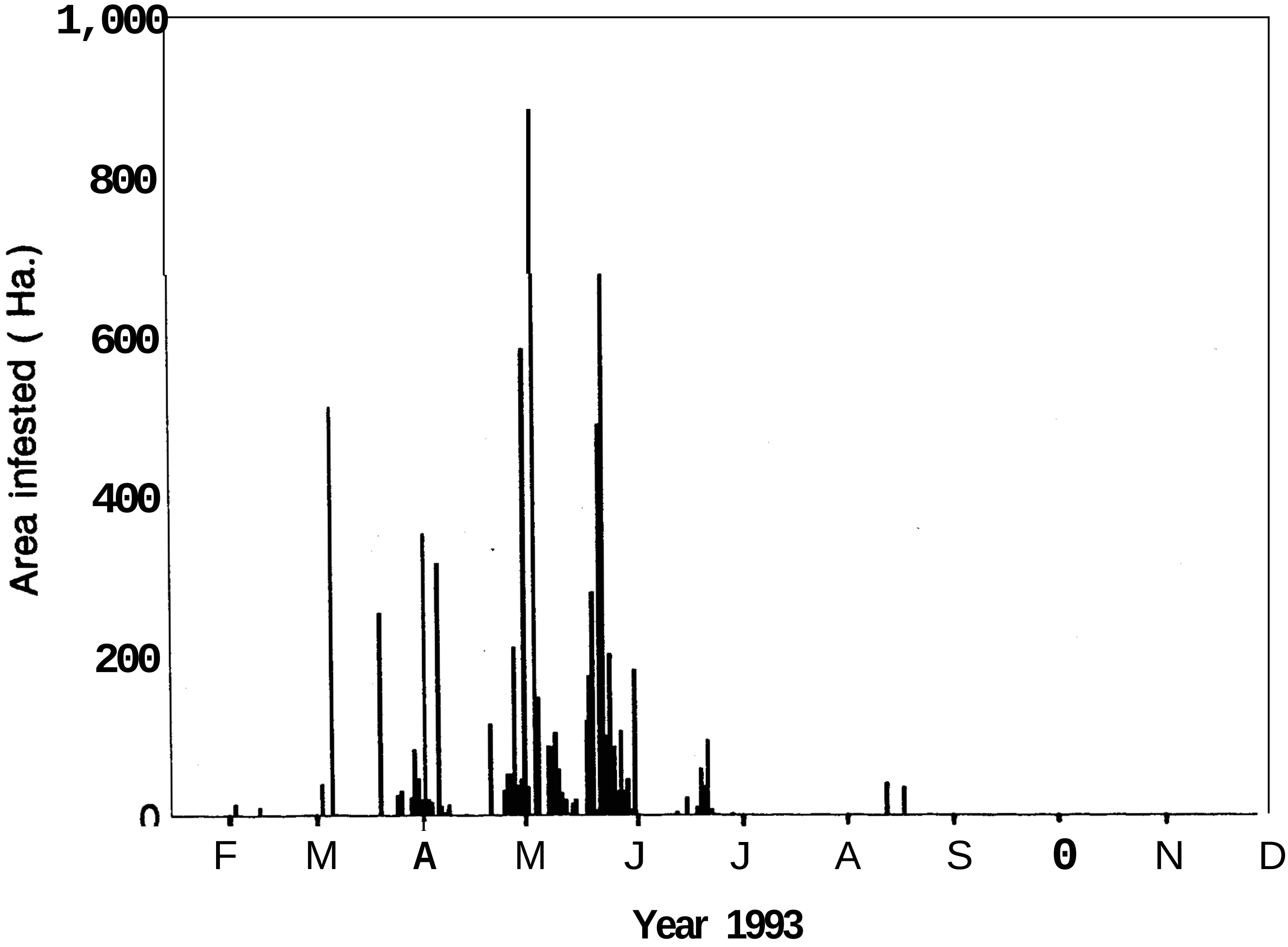

Fig.1. Temporal sequence of defoliator outbreaks and area infested during each outbreak at Nilambur, in 1993

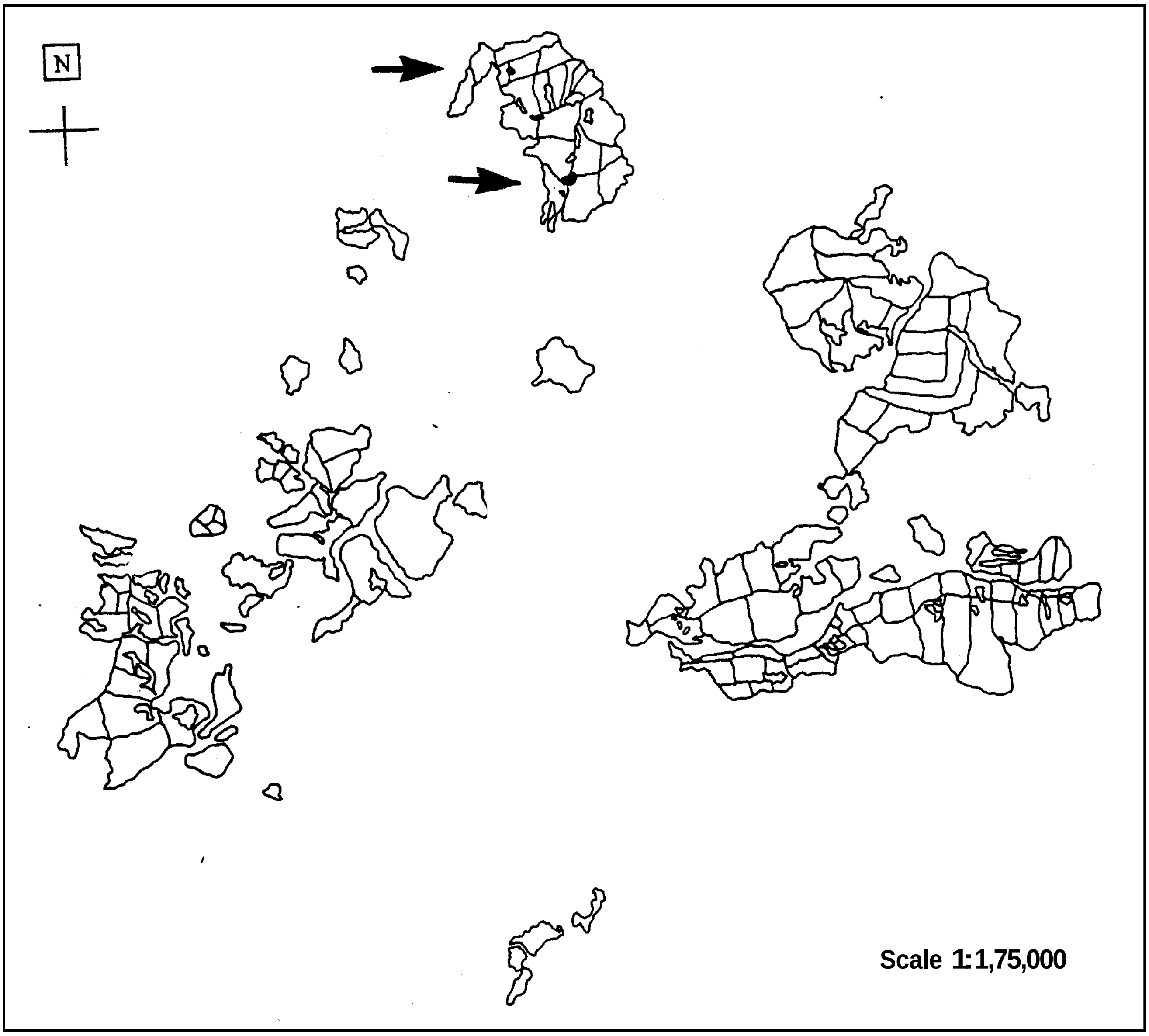

Fig.2. Map of Nilambur teak plantations showing the locations of the first outbreak in the year 1993 on 19 February

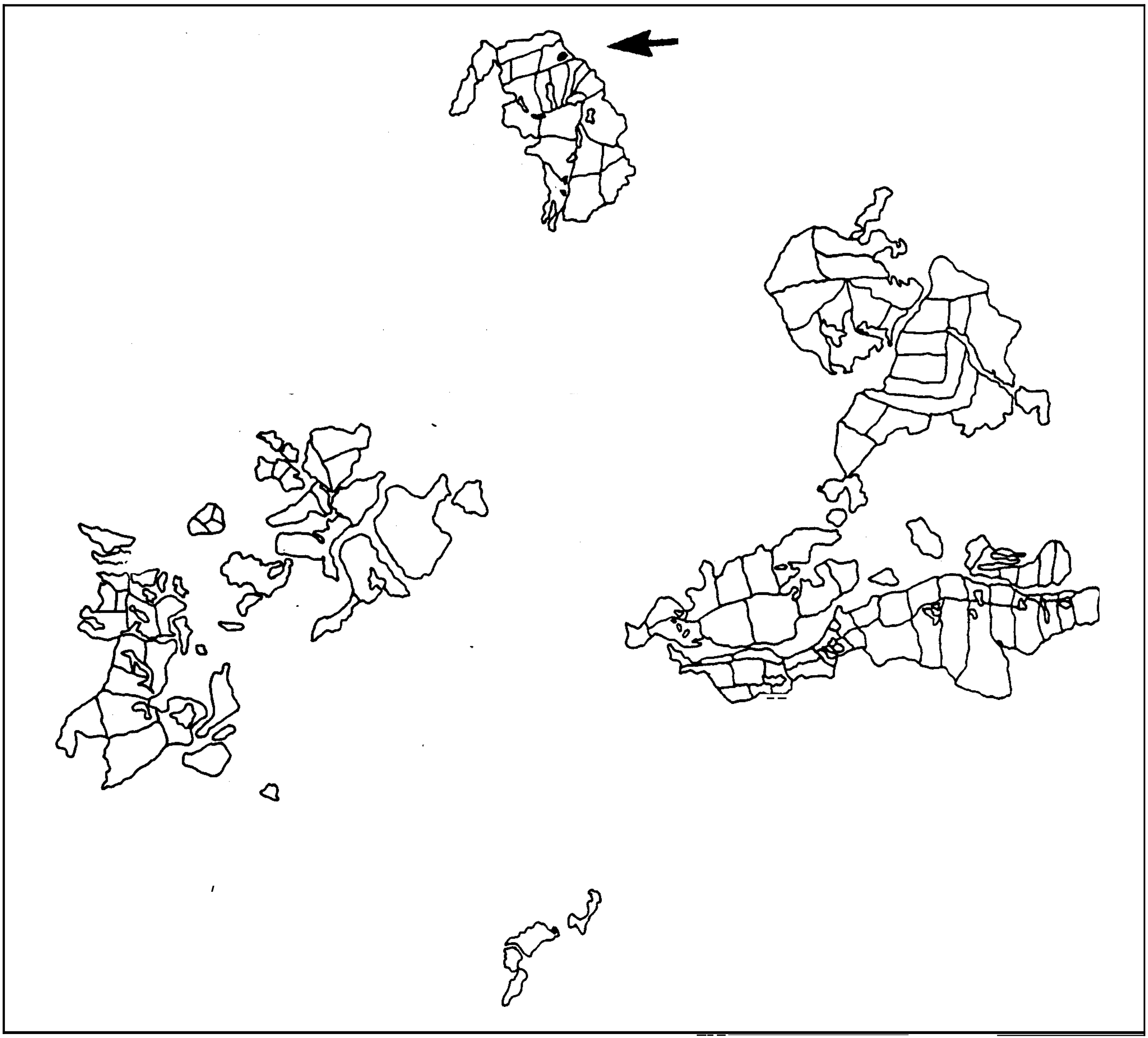

Fig.3. Map of Nilambur teak plantations showing the locations of the second outbreak in the year 1993 on 26 February

the normal egg laying period is only 5 days. In view of the above facts, the origin of the second infestation cannot be explained except in the same manner as the first.

The third outbreak occurred on 17 March in a different plantation (Fig.4.) and covered an area of 38.8 ha. The moths which caused the infestation could be the progeny of the first population (moth population at Serial No. 1,Table 1.).

The fourth outbreak occurred on 20 March and covered an area of 512 ha in the general location where the first two outbreaks occurred (Fig.5.). This was the first large-scale infestation wherein over 500 ha were infested on a single day. This infestation could be attributed to the progeny of the moth population at Serial No. 2; Table 1.

The fifth infestation was noticed on 21 March and covered an area of 1.7 ha in a different location (Fig.6.). In theory, this could also be attributed to the progeny of population No.2 which caused the large infestation on the previous day at a different location. However, the very small area of this outbreak has some similarity to the first two infestations of unexplained origin.

The sixth outbreak occurred on 26 March in a new area (Fig.7) and covered only 0.12 ha. In theory, this can also be attributed to the progeny of population No. 2, but the very small area of infestation and the gap between the current and the previous infestation indicates that this is unlikely. As in the previous infestation, the similarity of the infestation to the first two of unexplained origin is striking.

The seventh outbreak occurred on 3 April in the same general area where the first two outbreaks occurred and covered a substantial area of about 254.4 ha (Fig.8.). This was the second major infestation of the year in terms of area coverage. The origin of this infestation could not be attributed to any of the previous populations within Nilambur (Table 1).

In the following period , a very large area (934 ha) was infested from 7 to 20 April. It was not possible to distinguish the area infested on each day within this interval (Fig.9.). There were 24 distinct patches of infestation, which included some very small patches similar to the initial infestation patches. All these infestations can be explained, in theory, as caused by the progeny of previous populations (Table 1).

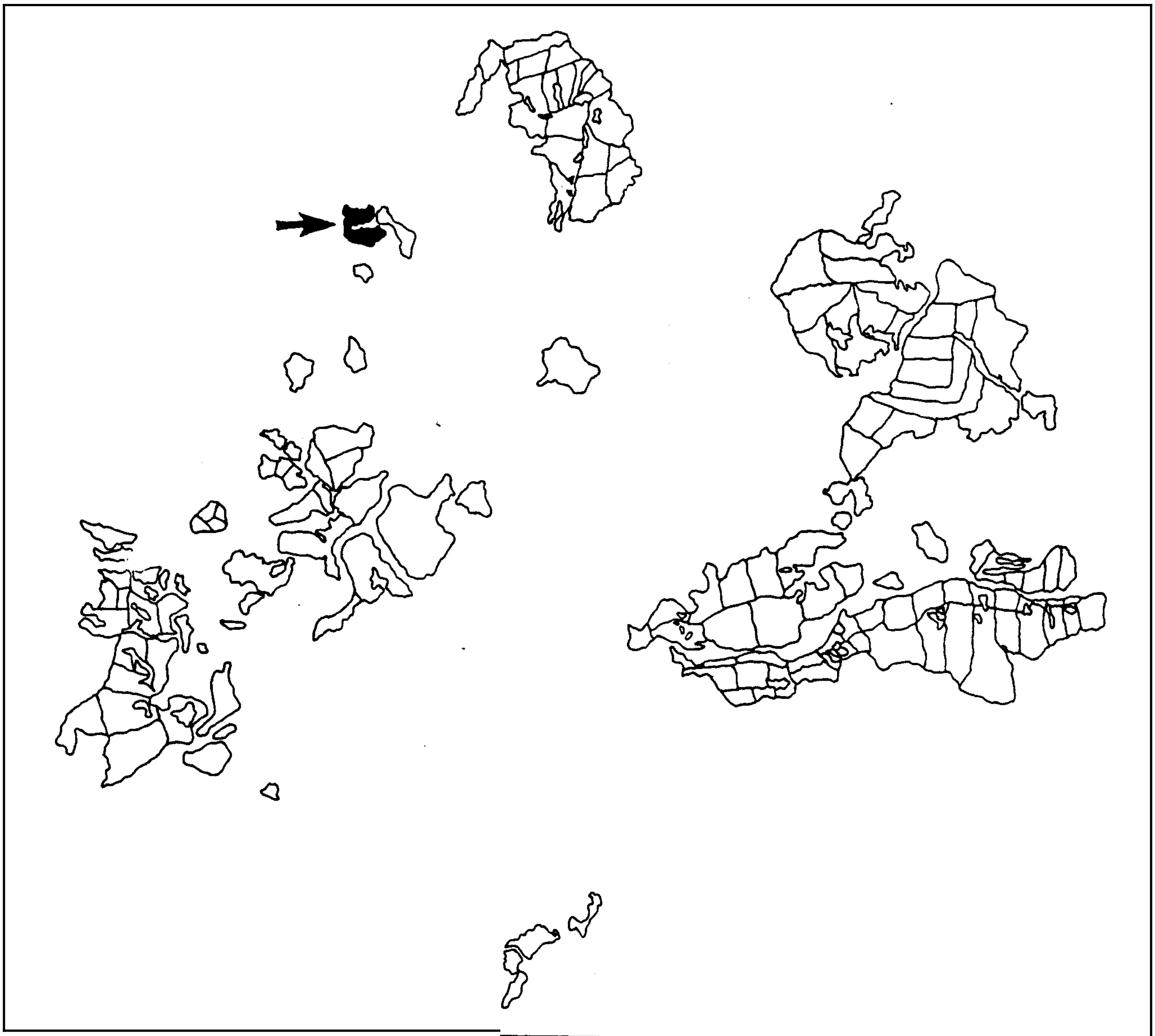

Fig.4. Map of teak plantations showing the locations of the third outbreak in the year 1993 on 17 March

Table 1. Chronology of *H. puera outbreaks* at Nilambur in this year 1993.

Serial No.	Date of egg laying	Infested area (ha.)	No. of patches	Expected egg laying period of progeny
1	19 Feb	14.3	2	11-19 Mar
2	26 Feb	10.0	1	18-26 Mar
3	17 Mar	38.8	1	6-14 Apr
4	20 Mar	512.0	1	9-17 Apr
5	21 Mar	1.7	1	10-18 Apr
6	26 Mar	0.12	1	18-23 Apr
7	3 Apr	254.4	3	23 Apr-1 May
8	7-20 Apr	934.4	24	27 Apr-18 May
9	23 Apr	11.9	1	13-21 May
10	25-26 Apr	18.1	4	15-24 May
11	28 Apr	1.5	2	18-26 May
12	5 May	114.7	3	25 May-2 June
13	8-30 May	2498.9	47	28 May- 27 June
14	2-16 Jun	2531.5	67	22 June- 18 Jul
15	28 Jun	4.25	1	21-30 Jul
16	1 Jul	22.4	1	24 Jul-2 Aug
17	4-11 Jul	208.6	16	27 Jul- 12 Aug
18	14 Jul	2.65	1	6-15 Aug
19	18 Jul	0.5	1	10-19 Aug
20	27Aug	40.6	1	19-30 Sep
21	1 Sep	35.7	3	24 Sep-2 Oct
22	3-6Sep	1.3	4	26 8 Oct
23	8-9 Sep	1.6	3	1-11 Oct

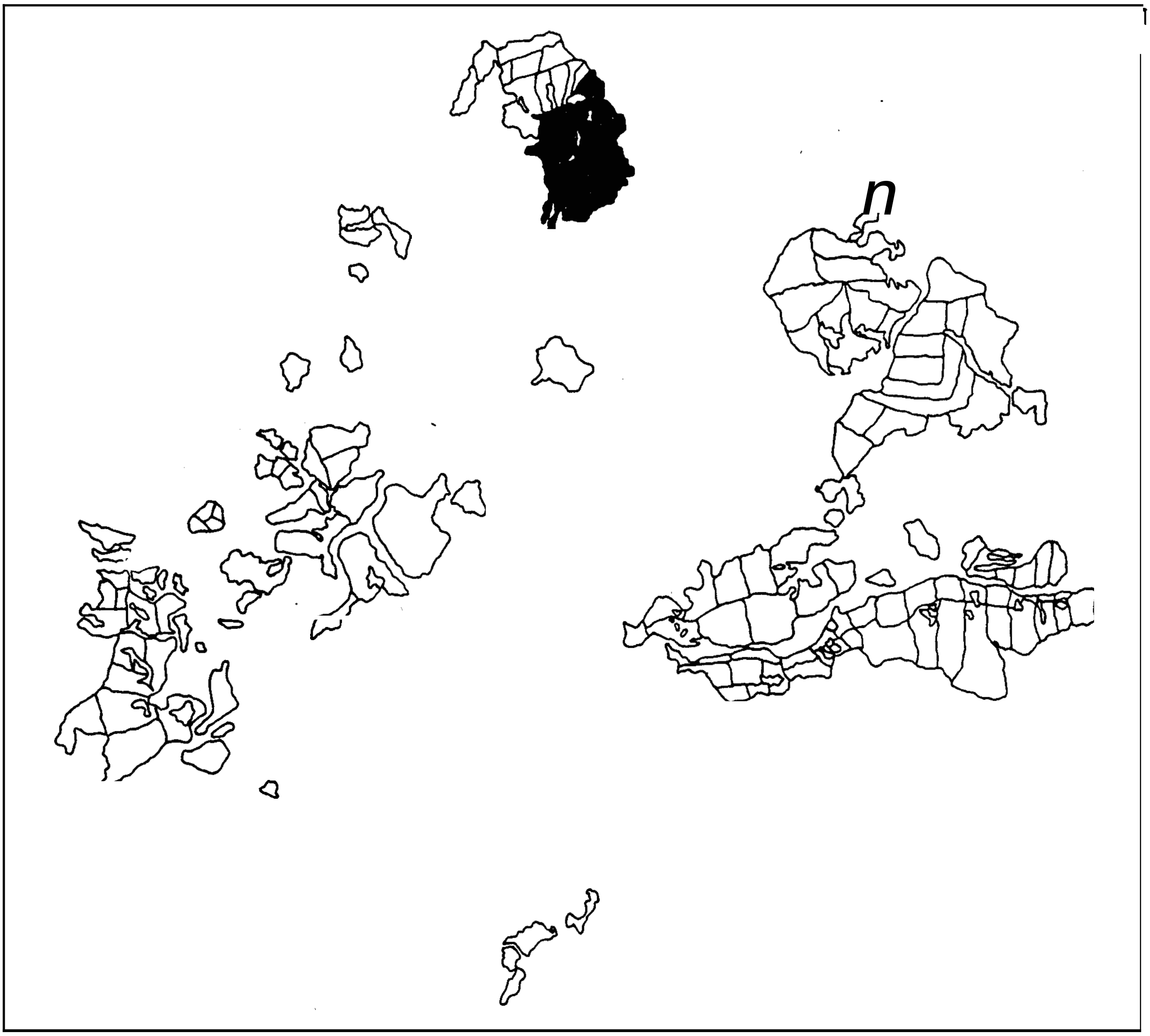

Fig.5. Map of Nilambur teak plantations showing the locations of the fourth outbreak in the year 1993 on 20 March

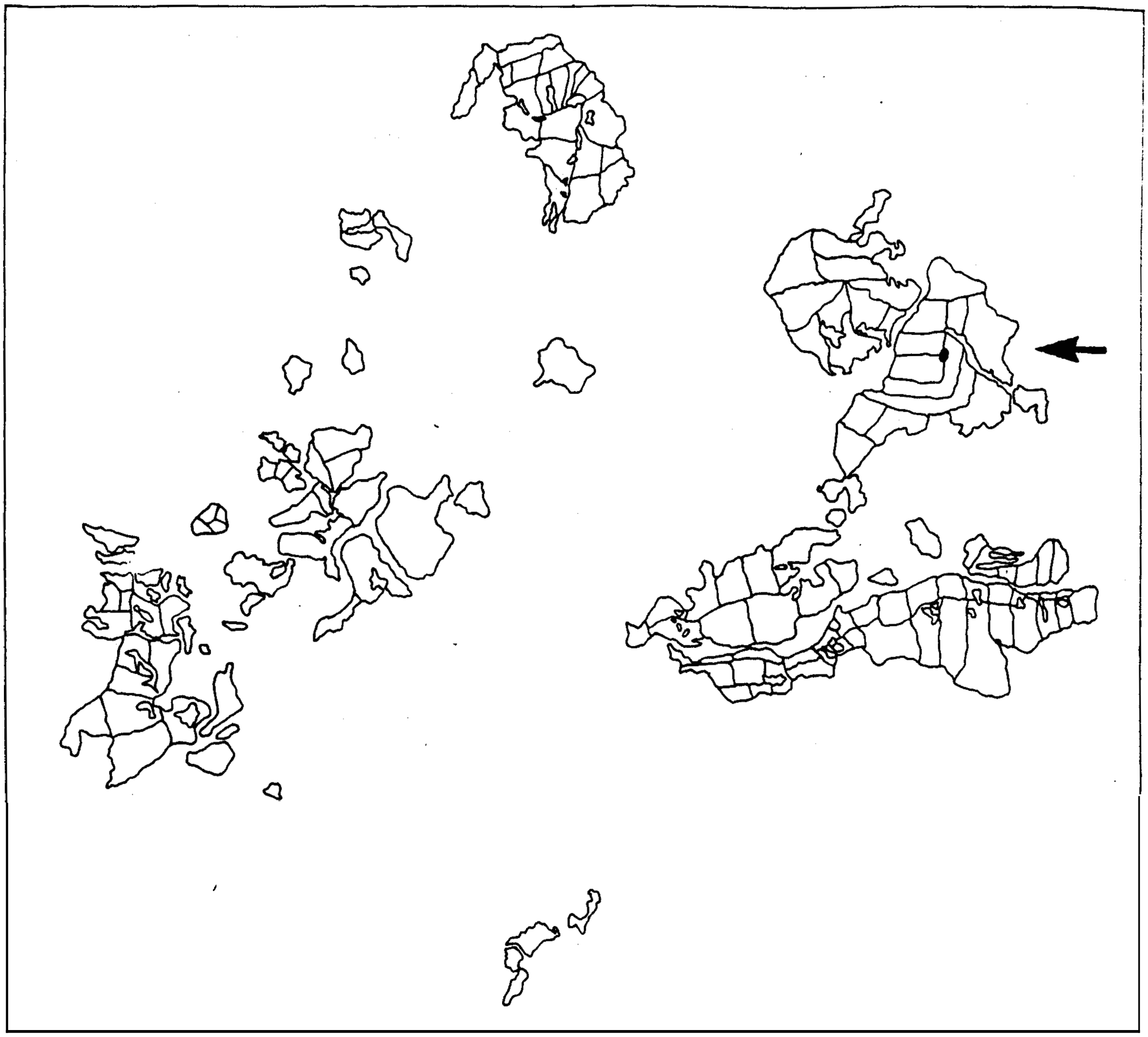

Fig.6. Map of Nilambur teak plantations showing the locations of the fifth outbreak in the year 1993 on 21 March

Fig.7. Map of Nilambur teak plantations showing the locations of the sixth outbreak in the year 1993 on 26 March

Fig.8. Map of teak plantations showing the locations of the seventh outbreak in the year 1993 on 3 April

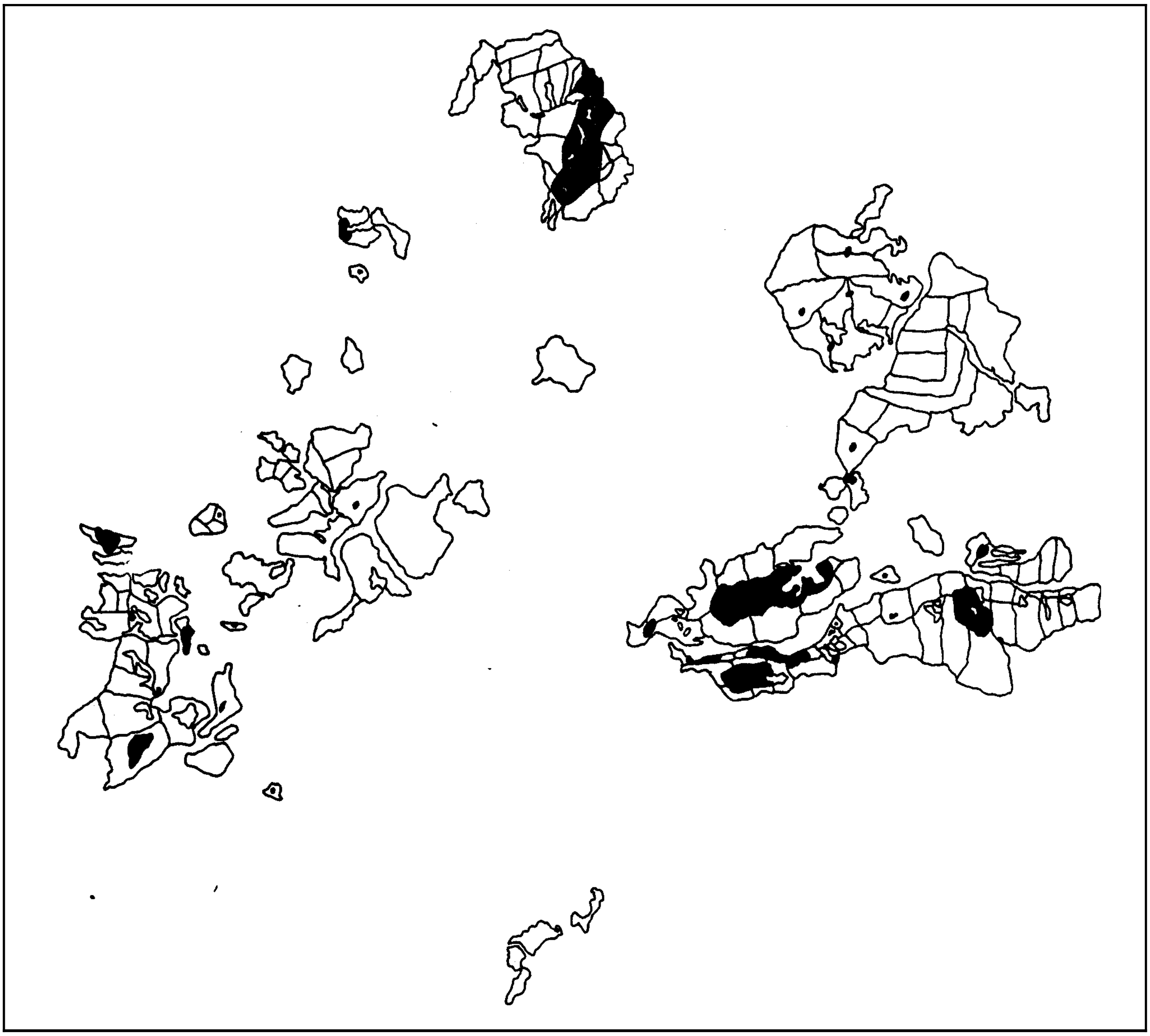

Fig.9. Map of teak plantations showing the locations of the eighth outbreak in the year 1993 during 7-20 April

From our analyse of the first seven outbreaks which occurred on single days the following conclusions can be made.

1. Three of them (1st 2nd and 7th) cannot be attributed to the progeny of pre-existing populations within the study area consisting of about 10,000 ha of teak plantations. This clearly shows either immigration of moths from other areas or aggregation of dispersed moths. The 5th and 6th infestations, covering very small areas may also fall in this category, as indicated above.

2. All the infestations occurred in discrete patches in spite of the existence of contiguous infestable plantations. This indicates aggregation and movement of moths as a group.

All the subsequent infestations which occurred from 7 April to 18 July (serial No. 8 to 19 in Table 1) were attributable (in theory) to the progeny of previous populations within the area. However, the possibility of immigration or local concentration cannot be ruled out. These infestations (Serial No. 8 to 19) constitute the major part of the infestations covering an area of 6349 ha out of the total infested area of 7180 ha.

The last four infestations of the year from 27 August to 9 September (Fig. 10) (serial No. 20,21,22 and 23 in Table 1) were not attributable to previous populations. This also indicates either immigration of moths from outside the study area or aggregation of stray moths from within the area.

Fig. 11 is an overlay of areas infested in all the outbreaks during 1993 ; green areas were not infested at all ; each infestation frequency is indicated by a different colour.

It may be seen that large areas of teak plantations were not infested during the year. At the same time, some areas were repeatedly infested, upto seven times. It is clear that all plantations were not equally prone to defoliator outbreak. Plantations in the two locations viz., Kariem- Muriem, and Sankarangode-Nedumgayam-Kanjirakkadavu were the most heavily infested in 1993.

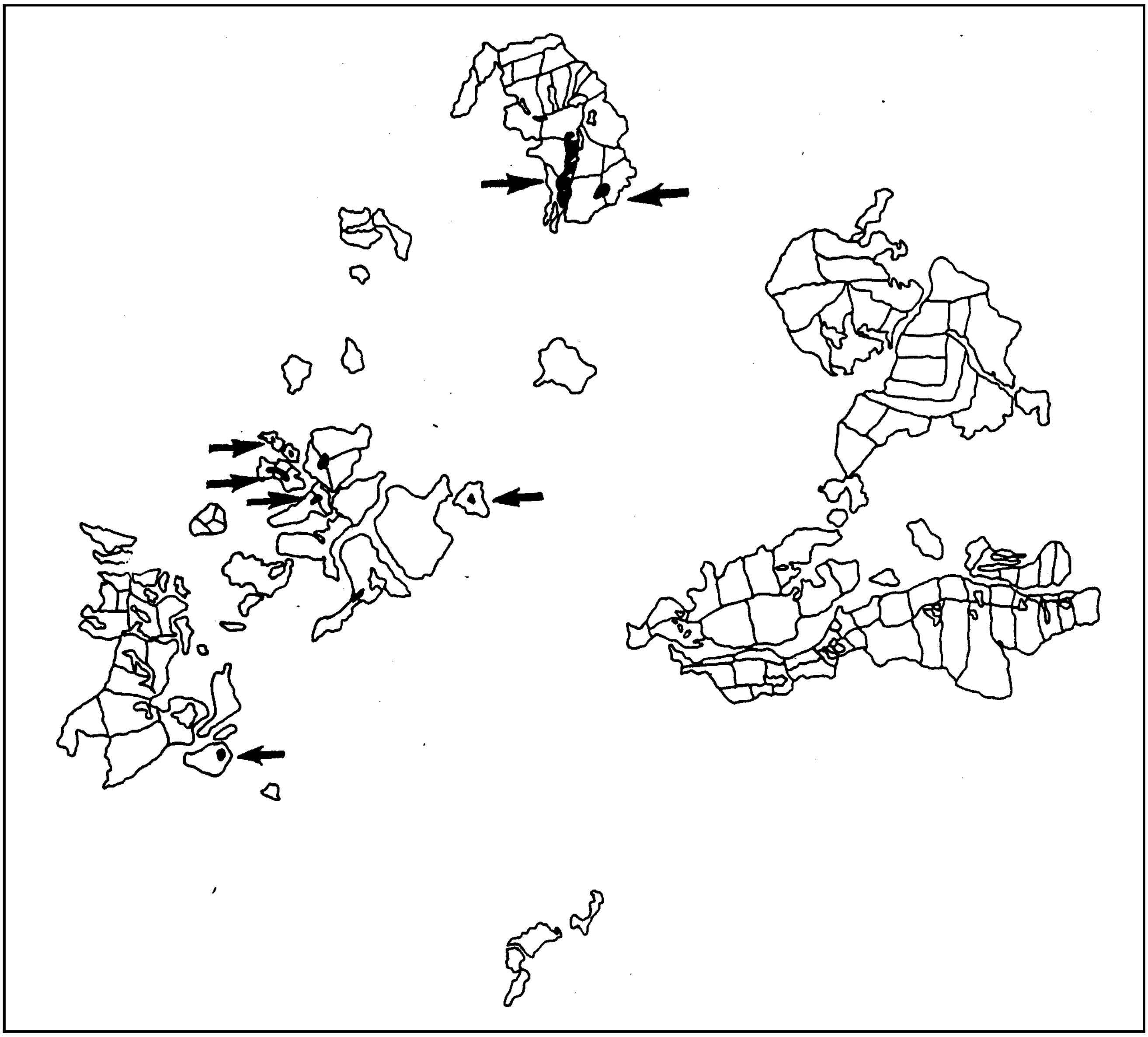

Fig. 10. Map of Nilambur teak Plantations showing the locations of the last four infestations from 27 August to 9 September in 1993

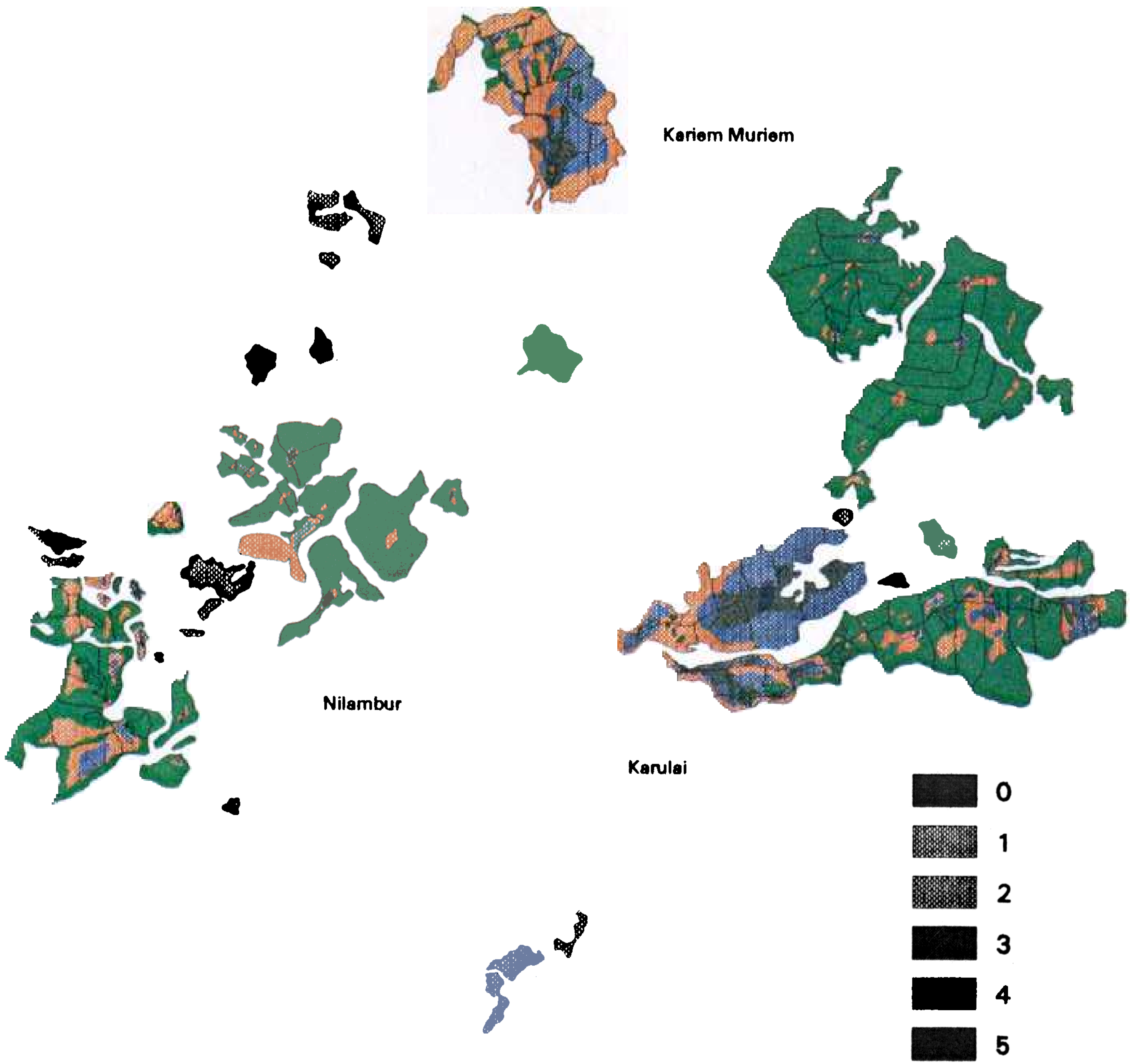

Fig.11.Spatial contour of outbreak frequency at Nilambur in 1993.

3.1.2. Konni

The temporal sequence of outbreaks and the area infested in each outbreak at Konni are shown in Table 2. By the time the observations started on 15 March at Konni, some outbreaks had already occurred. This was evident from the presence of defoliated trees, but the exact date of oviposition could not be determined. The total area infested before 18 February was estimated at 584 ha; the distribution of infested patches is shown in Fig.12. The characteristic small patch infestation, as in the early outbreaks at Nilambur is evident. Extensive outbreaks occurred starting about 10 March and they spread over vast areas in quick succession. Since we missed recording the dates of early outbreaks, analysis similar to that for Nilambur was not possible, although the later infestations can be attributed, in theory, to the progenies of earlier populations. The observations were terminated in June.

The data also indicates that at Konni, peak outbreaks occur earlier than at Nilambur.

Table 2. Chronology of H. *puera* at Konni in this year 1993.

Serial No	Date of egg laying	Infested area (ha)
1	Before 18 February	584
2	10-16 March	3673
3	19-21 March	2858
4	25 March- 1 April	9152
5	5-11 April	1543
6	15- 24 April	11900
7	25 April- 3 May	2760
8	11-13 May	2373
9	20-22 May	88
10	1-3 June	373

3.2. Observations on moth aggregation and flight behaviour

During this study, aggregations of moths were observed on several occasions. They were found predominantly on hill tops at Kariem - Muriem. Often, freshly emerged as well as older moths were found in the same group.

Directional flight by groups of moths were observed on a few occasions. Once a steady stream of moths were found flying across a paddy field into a teak plantation.

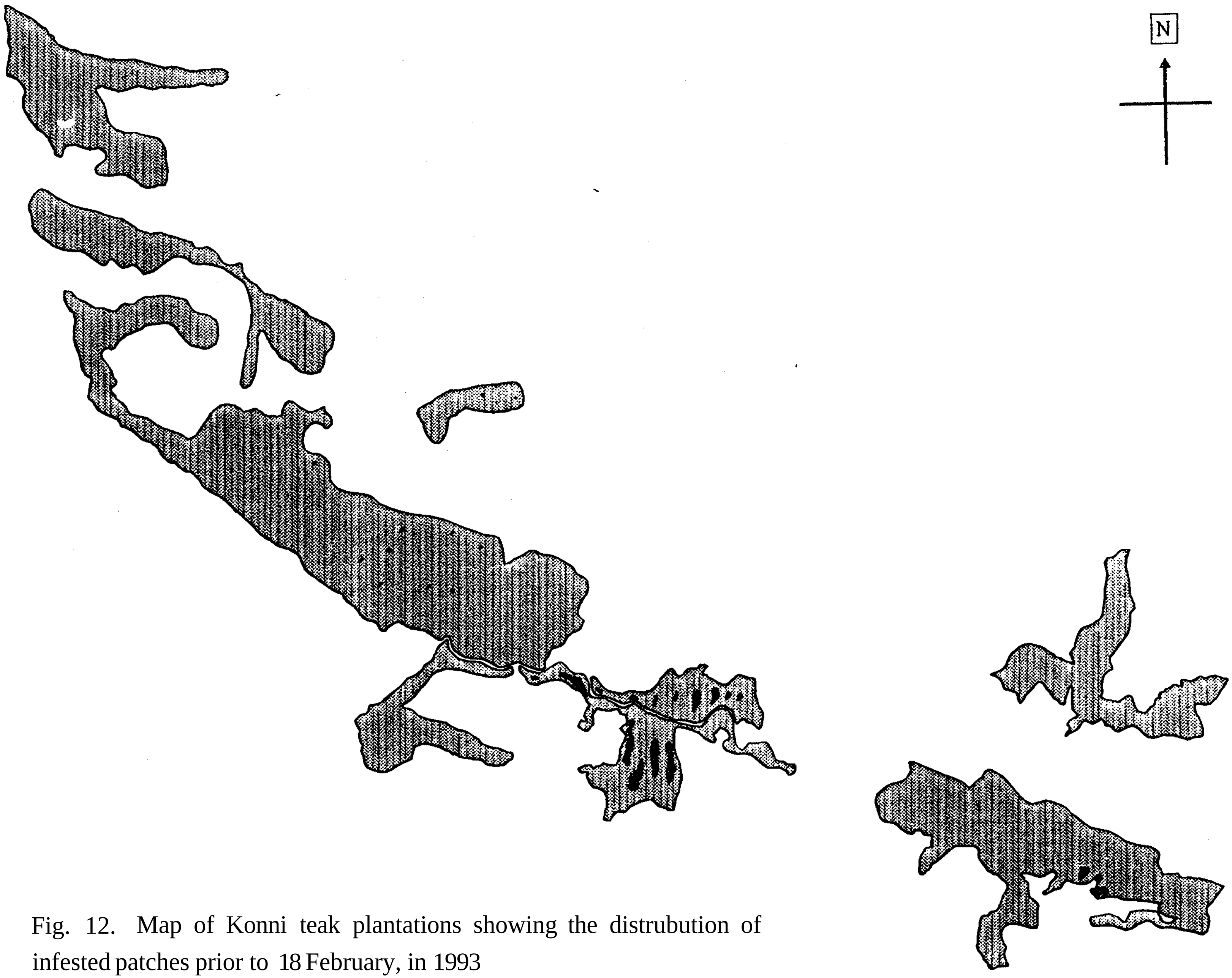

Fig. 12. Map of Konni teak plantations showing the distrubution of infested patches prior to 18 February, in 1993

This movement occurred from 3.45 p.m. to 4.40 p.m., on 5 April 1993. The moths were flying at about 5 m above the ground level of the paddy field. The next day, moths were observed flying in the opposite direction in a 200 m. wide flight path. This flight occurred from 5 p.m. to 7 p.m. Of the 29 moths trapped from this moving group, 28 were females.

Apart from the directional flight mentioned above, moths were also found to undertake short-distance flights during dusk and dawn. At dusk they became active just before sun set at about 6.50 p.m. and were found to fly in all direction singly over short distances at a stretch. As the light faded out, further observations became difficult.

4. DISCUSSION AND CONCLUSIONS

The annual population trend of *H .puera* is characterised by two distinct phases (1) a low density phase during which the population remains sparse and almost undetectable (generally September - October to March-April) and (2) a high density outbreak phase during which starting from concentrated outbreaks is small patches, the outbreaks spread over large areas engulfing most of the plantations and then slowly return to the low density phase (Nair *et.al.,* 1994). The rationale for undertaking the present study was the hypothesis that during the outbreak phase, the insect population is built up step by step, starting from some epicentres whcrc favourable conditions exist for population build up. Detection of outbreaks in very small patches of plantations about two months in advance of major outbreaks (Nair and Mohanadas, 1996) gave support to this hypothesis. It was suspected that these centres may be areas where, due to environmental or other reasons, tender leaves niay appear earlier than in other areas *(H. puree* lays eggs only on tender leaves), providing favourable conditions for population build-up, so that over subsequent generations a large population could be built up. It was argued that if such epicentres existed , large scale outbreaks could be prevented by applying control measures in the small epicentres. A strong correlation between the early outbreaks and occurrence of pre-monsoon showers also suggested that sudden influx of a group of moths, brought in through the wind from far off places, may also create an epicentre.

In order to interpret the results of this study in relation to the epicentre hypothesis, it is useful to examine the generally accepted concept of an epicentre. The epicentre concept arose in the context of insect populations which occasionally erupt and spread over large areas (Berryman,1986). Such eruptive outbreaks are believed to start in local environments which are very favourable for the reproduction and survival of the pest. Such local environments have been termed ‘epicentres’ . After multiplication in such epicentres, the population moves to less Favourable environments, where through the advantage of numbers, the pest makes the environment favourable to it, by overcoming the resistance of the host by mass attack or by satiating the parasite and/or predator populations. Thus the high population density has a positive feed back effect, causing further increase of the population, leading to population eruption. An epicentre and subsequent outbreak can also be initiated by immigration of insects. Among forest insects, the mountain pine beetle, *Dendroctonus punderosae* and the spruce budworm, *Choristoneura* *fumiferana* have been cited as examples of initiation of outbreaks from epicentres (Berryman, 1986). A typical example, from India, is the sal borer *(Hoplocerambyx spinicornis)* outbreak.

The data gathered in this study has clearly shown that at Nilambur the outbreak phase of *H.puera* begins with typical small-patch infestations. Similar observations have been reported earlier based on observations over a limited area (Nair and Mohanadas, 1996).

As indicated earlier, except for a few of the initial and later infestations, the major infestations were attributable to the progeny of these early populations. Therefore, the early infestation patches can be considered as epicentres where population build up occurs. However, the sudden appearance of the infestation patches, their incidence one after the other within a short period (Table 1.) and their erratic distribution with respect to flushing status of teak trees suggest that these sites do not represent particularly favourable local environments for pest build-up as the classical definition of epicentre suggests.

In spite of this fact, these early infestation patches are centres where population build-up occurs. For that reason they must be recognised as epicentres. These centres can be conceived as sites where immigrant moths or moths concentrated by wind patterns (from dispersed endemic populations) assemble and lay eggs. Due to adequate availability of food (tender leaves) and ability to withstand pressure from parasites and predators (because of the large size of the population), they are able to survive and reproduce.

Thus the data prove the existence of epicentres where population build-up occurs. But these epicentres are not the typical highly suitable local environments. They are not constant sites where we expect the early outbreaks to occur year after year, but fortuitous sites determined by as yet unknown, apparently weather-relaled phenomena. This imposes restriction on their timely detection for application of control measures. Also, we do not know how many of the later infestations are caused by immigrant or presumably wind-concentrated groups of moths. Although most of the later infestations could be attributed, in theory, to the progeny of the epicentre populations, we cannot prove it. This is because immigration or wind-concentration of moths during these times cannot be ruled out. Perhaps a combination of both occur during the peak infestation period. The best way to shed further light on the origin of the outbreaks is to experimentally control the early patch infestations in a place like Nilambur and then observe the progress of infestations.

On a larger spatial scale, Kariem-Muriem and the Sankarangode-Nedungayam-Kanjirakadavu areas (Fig.10.) can be considered as epicentres where most of the population build-up occurs. The interrelations between orographic features and the high incidence of outbreaks in these areas needs further analysis. If the interrelations are understood we may be able to identify high-risk areas and apply control measures in such areas. Control of the insect in these major epicentres at Nilambur may lead to prevention of outbreaks in other areas, to which these populations may migrate/disperse.

In summary, the conclusions derived from this study are the following.

1. In a large teak plantation area such as Nilambur, *H.puera* outbreaks begin in comparatively small epicentres less than 12 ha in area. Earlier studies indicate that such epicentres can be as small as 0.6 ha. The data from Konni also suggest this, but the data were insufficient for reliable interpretation.
2. These epicentres are not constant over the years as indicated by the results of earlier studies (see Nair and Mohanadas, 1996) and do not represent highly favourable local environments. It is hypothesised that epicentres are sites where a group of immigrating or wind-concentrated moths assemble and lay eggs.
3. Extensive outbreaks which occur subsequently can be attributed to the pest population built up in these epicentres. Therefore it appears that large scale outbreaks can be prevented by controlling the small epicentre populations. However, the recurrence of epicentres cannot be ruled out. An experimental study involving control of epicentre populations is recommended to examine the effectiveness of this approach to teak defoliator management, and to shed further light on the dynamics of outbreaks.
4. An unexpected, but highly useful results of this study is the finding that teak plantations in all areas are not prone to defoliator attack. Incidence of outbreak appears to be related to orographic features. More detailed analysis of the data using GIS techniques and additional data for at least one more year are necessary to elucidate these relationship.

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