Insect drift over the northern Arabian sea in early summer

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Air borne insects, mostly carried by wind currents, were trapped over the northern Arabian sea (16° to 20° N; 68° to 72° E), in the course of cruise No. 111, ORV *SAGAR KANYA* (March 14 to April 7, 1996). A total of 2,301 insects belonging to 8 different orders, 47 families and 173 species were trapped. Of these, Hymenoptera was represented by the largest number (1082), which was followed by Hemiptera (586), Diptera (552), Coleoptera (51), Neuroptera (10), Trichoptera (03), Lepidoptera (03) and Orthoptera (01). The trapped insects were mostly between 0·6 mm to over 11 mm long. The data was examined for α-diversity as well as for possible correlations between various parameters like the diversity index, size and number of insects trapped on one hand and the distance of the nearest land mass in wind direction, on the other.

1. Introduction

Except for a small number of species of a single genus *Halobates* (Heteroptera: Gerridae: Halobatinae) which live on the water surface of open oceans and are known as sea skaters, all insects are essentially terrestrial, although some of these have secondarily adapted to fresh water. However, the atmosphere over the oceans is not devoid of insects at any time. A large variety and number of insects, mostly small, are carried passively or atleast partly passively, over the oceans by wind currents emanating from land masses (Cheng 1976). Eventually these insects fall into sea waters and contribute to the oceanic biomass. They are either consumed by surface feeders or disintegrate within a period of approximately 48 h (Cheng and Birch 1977). However a miniscule number of these insects do happen to land on islands or reach distant continents and depending upon factors like the availability of food and presence or absence of predators, may become established in their new habitats (Holzapfel and Harrell 1968). Dispersal of insects over and across the oceans is thus a vital aspect of their zoogeography which in turn, plays a major role in their evolutionary trends.

Numerous studies of air borne insects have been made over the Pacific (Gressitt and Nakata 1958; Yoshimoto and Gressitt 1959, 1960, 1961; Harrell and Yoshimoto 1964; Harrell and Holzapfel 1966), Antarctic (Gressitt *et al* 1960; Yoshimoto *et al* 1962a; Yoshimoto and Gressitt 1963), Atlantic (Clagg 1966), North sea and English Channel (Hardy and Milne 1937, 1938a, b; Hardy and Cheng 1986). No data is available from the Indian ocean, except for what has been reported by Yoshimoto *et al* (1962b) who reported the trapping of insects along the eastern coastline of India in the Bay of Bengal, in the course of the Danish "Galathea" expedition of 1950–1952, and Pathak and Parulekar (1988) from the Arabian sea. Results of an investigation in the northern part of the Arabian sea in early summer (= premonsoon) are presented here.

2. Materials and methods

2.1 *Area of investigation*

Air borne insects were collected between 16° to 20° N and 68° to 72° E, covering an area of approximately

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[§]Deceased.

75,000 km^2, aboard ORV *SAGAR KANYA*, in the course of cruise No. 111 (figure 1) from March 14 to April 7, 1996. Overall aerial density of insects over the study area was $7{\cdot}6 \times 10^4$/km^3 and the total number of air borne insects/ insect parts trapped was 2,301. Of these, 13 were broken parts of insects and remained unidentified. One insect, an orthopteran, was trapped in the interior of the vessel and may have been living on the ship. This insect has been excluded from the data for analysis.

2.2 *Trapping of air borne insects*

Air borne insects were trapped with the help of a specially designed trapping net system (patent applied for), consisting of conical nylon nets (three nets mounted on nylon rope on each side of the bridge). The nets could be hoisted up, covering a height of 18 to 22 meters above sea surface and could rotate freely so that the mouths of the nets (dia 75 cm each) were always facing the wind. Each net was lowered and examined for any insects trapped, twice every day, at 0730 h and 1800 h (locations referred as sampling stations). Insects collected were sorted out and immediately transferred to glass/plastic vials containing 80% alcohol. Identifications (mostly up to families, but in some cases up to genera and species) were carried out later, in the laboratory. Although identifications were not carried out up to species in all cases, it was confirmed that there were 173 'recognisable taxonomic units'.

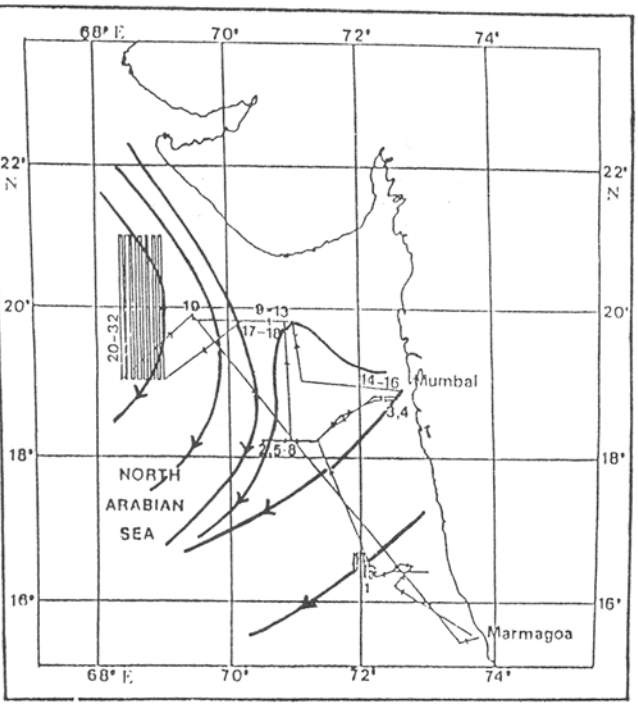

Figure 1. Track of cruise No. 111, ORV *SAGAR KANYA* in the northern Arabian sea during March–April 1996. Numbers along the track indicate sampling stations for air borne insects. Superimposed on the track is the generalized wind flow pattern during the period.

2.3 *Meteorological data*

Wind direction was noted with the help of wind vanes mounted on the bridge, at 0730, 1400 and 1800 h. The readings were then corrected in relation to the direction of the ship movement with the help of standard tables (Marine Observer's Handbook 1992). The wind speed was noted with the help of portable anemometers (OGAWA SEIKI, Japan) and corrected for the ship speed and direction of movement using standard tables. Generalized wind flow patterns were then drawn using these readings and the records of wind direction on the western coast line, provided by the National Data Centre for Indian Ocean, Goa (figure 1). While calculating the distance of the nearest land mass in wind direction, due credence was given to the generalized wind current flow over the sampling stations.

2.4 *Calculations of the aerial density of insects*

Aerial density of insects over the ocean was calculated by dividing the number of insects trapped by the product of the distance travelled, height (i.e., between 18 and 22 meters) and width (i.e., the mouth of the nets) and expressed as number of insects/km^3 at a height of 18 to 22 meters above sea surface.

2.5 *Analysis of data*

The insects were trapped unevenly in five clusters of 4–5 sampling stations. The data generated was subjected to the following analysis:

(i) Frequency distribution was studied by plotting the number of species against the number of individuals per species, after Warwick and Buchanan (1970). The frequency was plotted on arithmetic scale, the vertical lines indicating the observed distribution and the crosses joined by a broken line showing the theoretical log series distribution.

(ii) Index of diversity was calculated after Williams (1964). Fisher *et al* (1943) had suggested that the frequency distribution of species in a random population, represented by 1, 2, 3, etc., individuals may conform to the logarithmic series, which is an integer series with a finite form

$$n_1,\ n_1x/2,\ n_1x^2/3,\ n_1x^3/4\ \ldots\ n_1x^{n-1}/n,$$

for the number of groups with 1, 2, 3 etc., units per group,

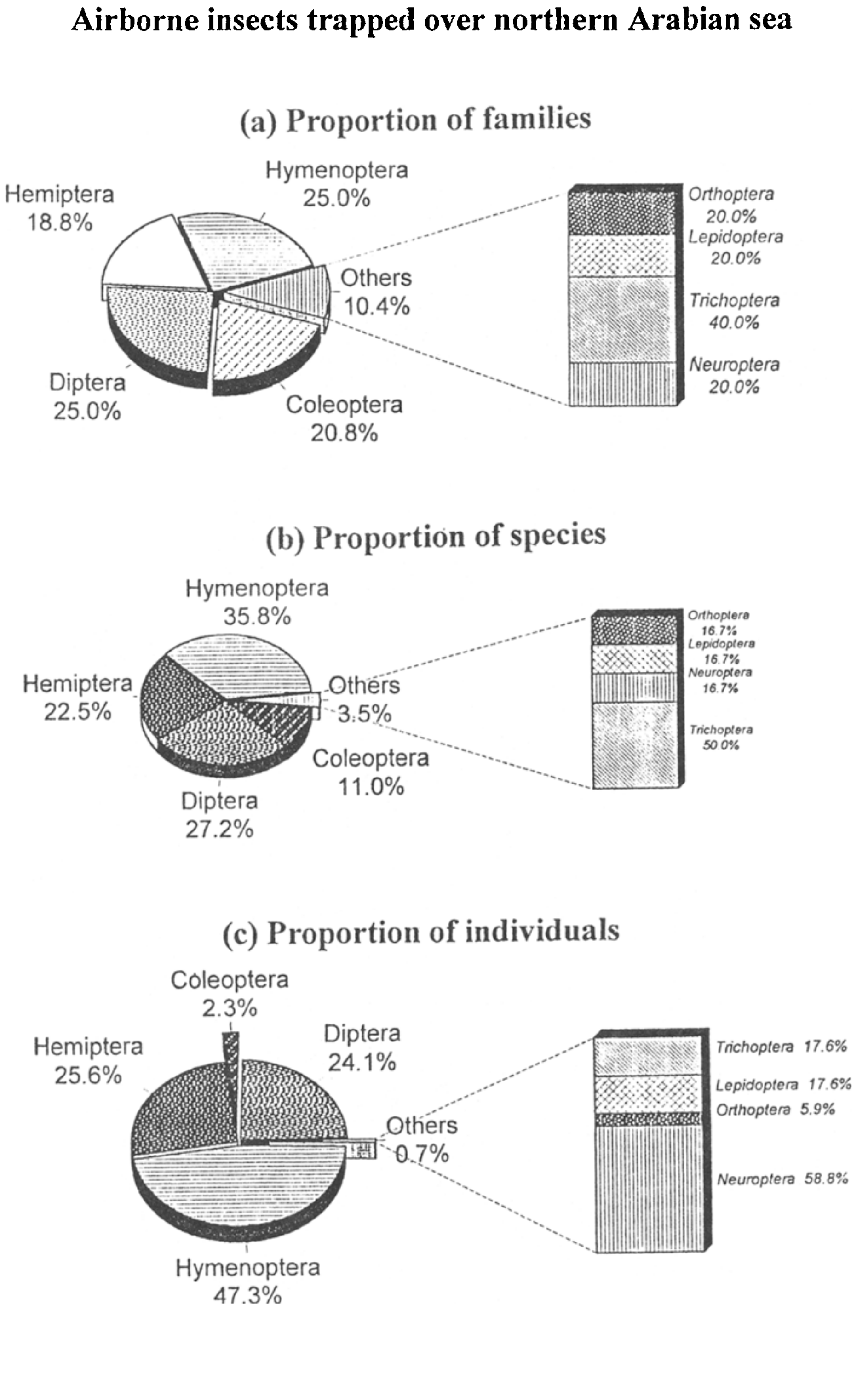

Figure 2. Pie chart showing the proportion of (**a**) families, (**b**) species and (**c**) individuals belonging to various insect orders in the trappings of air borne insects over the northern Arabian sea.

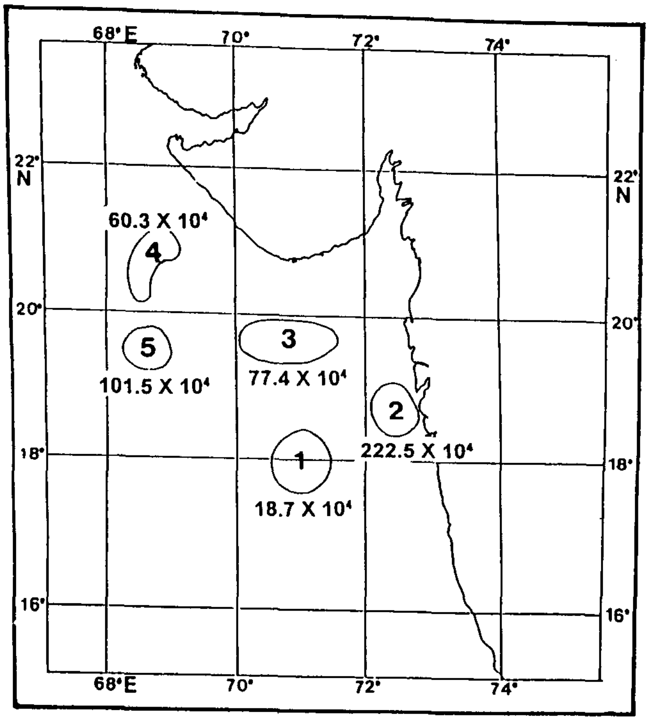

Figure 3. Aerial density (per km^3) of insects in different clusters of the study area in Arabian sea.

when 'x' is a constant less than unity. The value of 'x' depends on the size of the sample. Approximate values of 'x' were taken from a conversion chart (Williams 1964, figure 125). More accurate determinations were made by successive approximations using the equation

$$S/N = 1 - x/x\,(-\log_e \overline{1-x}).$$

If we divide n_1 by 'x' and call the result α, we get a simple expression of the series as

$$x,\ \alpha x^2/2,\ \alpha x^3/3,\ \alpha x^4/4 \ldots.$$

This series is convergent and the sum of all groups

$$S = \alpha(-\log_e \overline{1-x}),$$

and the total number of individuals

$$N = \alpha x/(1-x).$$

These being only two parameters (groups and units) and only one possible series for combination of a given number of groups and units, α and 'x' can be found, if the two (N and S) are known. From this, the logarithmic series that fits the data can be calculated. α is a constant and has been found to be a measure of the density of the population, low when the number of groups is low in relation to the number of individuals and high when the number of groups is high. Thus, the structure of the sample indicates the diversity of the population.

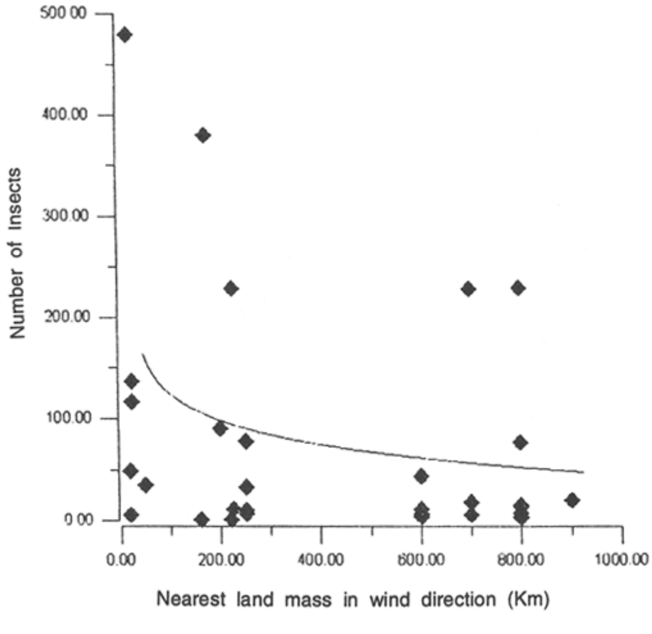

Figure 4. Curve showing the relation between the number of insects trapped in northern Arabian sea and the distance of the nearest landmass along the wind direction. The best fit for the curve was $\log Y = B \log (X) + A$.

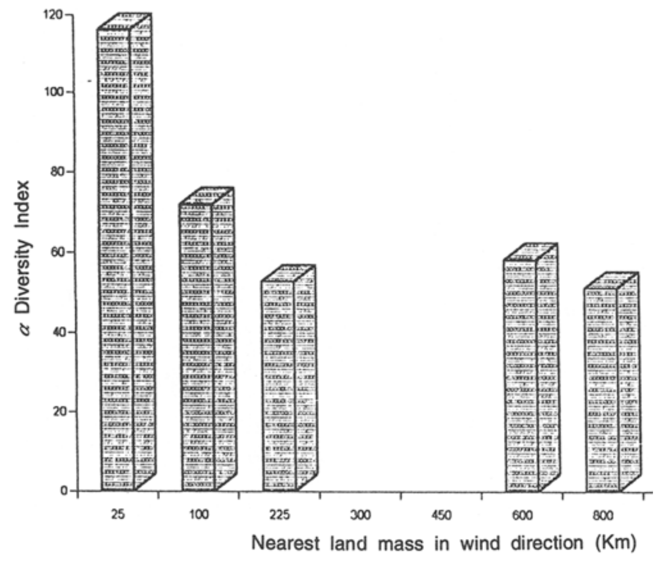

Figure 5. Column chart showing α diversity index of air borne insects trapped in relation to the distance of the nearest land mass in wind direction.

(iii) Relationship between index of diversity and the distance of the nearest land mass in wind direction was probed by plotting one against the other.
(iv) Correlation between insect size and the distance of the nearest land mass in wind direction was studied by creating a scatter plot of insect size and the distance of the nearest land mass in wind direction (figure 7) and running simple correlation between them.

3. Results

3.1 *Insects trapped*

A total of 2,301 insects were trapped at 32 sampling stations. These belonged to 8 orders, 47 families and 173 different species (figure 2). Of the total, almost half (47%) belonged to Hymenoptera, while Hemiptera (mainly sub order homoptera) and Diptera constituted about 25% each. Other orders viz., Coleoptera, Neuroptera, Trichoptera, Lepidoptera and Orthoptera together contributed less than 3% of the total catches. Of these 13 insects/insect parts were damaged to such an extent that these remained unidentified. Out of the 173 species, one insect, belonging to family Gryllidae was captured in the interior of the vessel and may have been endemic on the same. One species and family to which the three microlepidopterans belonged, also remained unidentified. It was noticed that specimens of family Agaontidae were largest in numbers and variety (17 species). However, for the same order, family Eulophidae had as many as 14 species but only 36 specimens. Other important families from this order which were well represented were Hermatidae, Braconidae and Encyrtidae. Amongst Hemiptera, Fulgoridae topped with 7 species and 208 specimens. Jassidae and Chermidae were other homopterans. Coreidae was the major heteropteran family with 15 species and 278 specimens. Amongst the Diptera Chloropidae topped, followed by Cecidomyiidae, Agromyzidae and Chironomidae. Most numerous among these however, were chironomids followed by agromyzids, chloropids, cecidomyiids and drosophilids.

3.2 *Aerial density of insects over the area of study*

A comparison of the number of insects trapped and the area covered, gave us the aerial density of these air borne insects at a height of 18 to 22 meters above sea surface, which came to $7{\cdot}6 \times 10^4/\text{km}^3$. But the density was not uniform all over. While it was high at some points, it was much lower in other areas (figure 3). It is clear that air currents do not carry insects in a uniform manner: their density depending upon their density on land at the time of their getting caught in these wind currents.

3.3 *Correlations between wind speed, distance of the nearest land mass in wind direction, number of insects trapped and their size*

Figure 4 shows a negative correlation between the distance of the nearest landmass in the direction of wind and the number of insects trapped, the latter declining with increase in the former. However, the correlation was statistically not significant (Pearson's $r = 0{\cdot}292$; $P = 0{\cdot}05$). The curve that best fits the data is the log curve. Analysis of the trapping in each of the five sampling clusters showed that the α diversity index varied from as high as 116·1 to as low as 51·3 (figure 5). The diversity was the highest close to the coastline (cluster 2), declining in clusters 1 and 3. It was however higher in cluster 3 which received wind currents from north also (Gujarat coast) in addition to those from the west coast, the distance of the former being distinctly lesser than the latter. But the situation was not so simple as the index was again found to be higher, although slightly, in case of cluster 4, which had an even longer distance over which the winds had travelled. The index was the lowest in cluster 5, with the nearest land mass in wind direction being over 800 km away. Correlation between the α diversity index and the nearest landmass in wind direction was also not statistically significant (Pearson's $r = 0{\cdot}68$; $P = 0{\cdot}05$). Evidently some insects appear to have perished on way to the fifth cluster. Frequency and the log series distribution are shown in figure 6.

Relation between insect size and the distance of the nearest land mass was also investigated by plotting size against distance. For this, the size of all the 171 species (not including three microlepidopterans and the lone gryllid), trapped at various distances, was plotted. The scatter plot (figure 7) however does not show any clear correlation. When the same data was run for the coefficient of correlation, the value came to 0·13, which was again statistically non-significant ($P = 0{\cdot}05$).

4. Discussion

Since dispersal of air borne insects has not been reported over any part of the Indian ocean so far, it is not possible to compare the above data. Also, it is not known whether there is any seasonal variation in the number and variety of the trapped insects. It is logical to expect a seasonal variation which is directly linked to the direction of wind flow in various seasons and the land mass(es) from where these winds, carrying insects, originate. Even the report of insect trapping by the "Galathea" expedition (Yoshimoto *et al* 1962b) is not very relevant as the trappings were carried out in the Bay of Bengal (a long way from the present study area), and that too only along the eastern coastline of India and not in the open ocean. The only report of insect trappings in the Arabian sea is that of

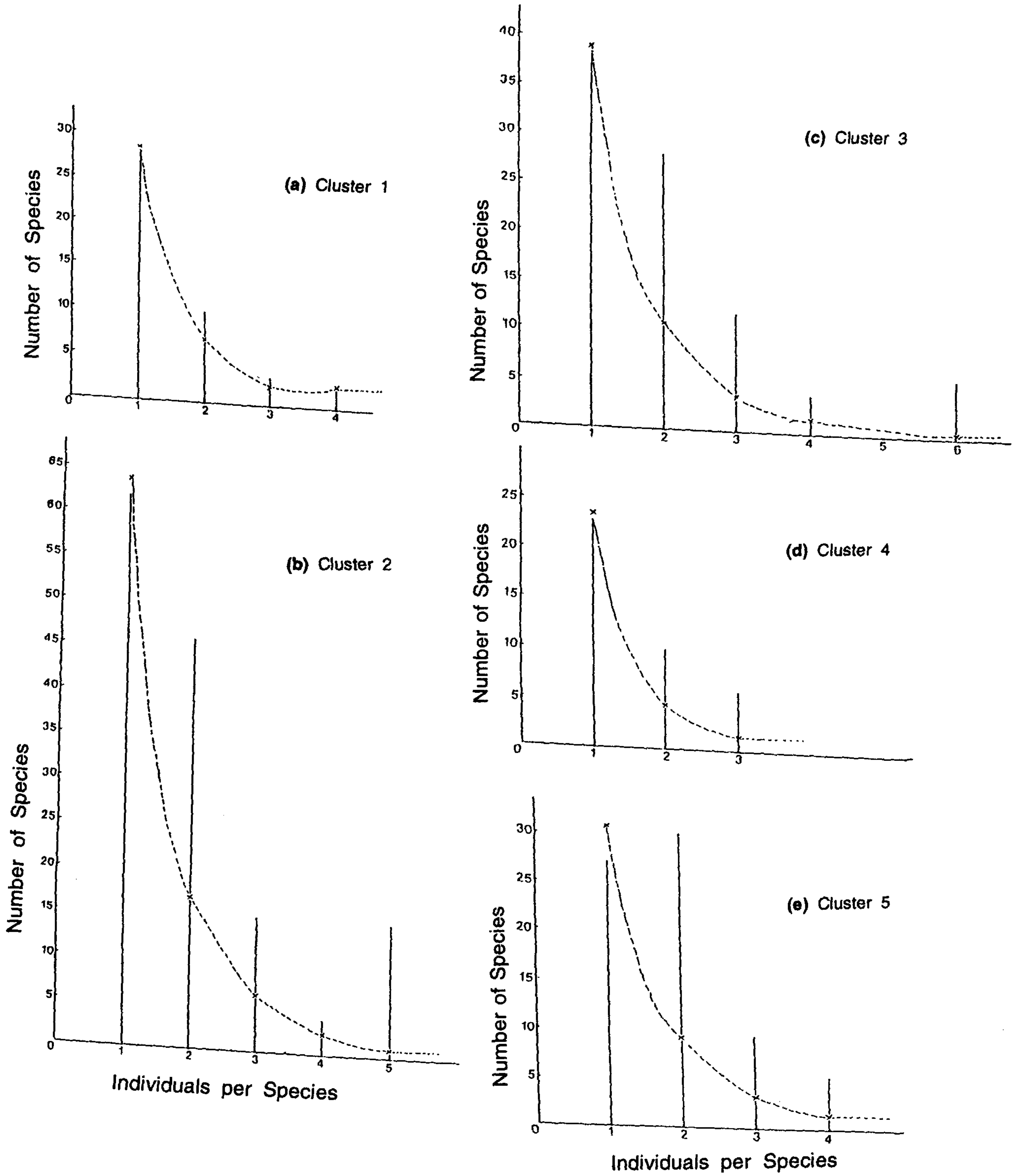

Figure 6. Frequency distribution of the insects in the five clusters. Vertical lines show the number of individuals per species. Crosses joined by broken lines show the log series.

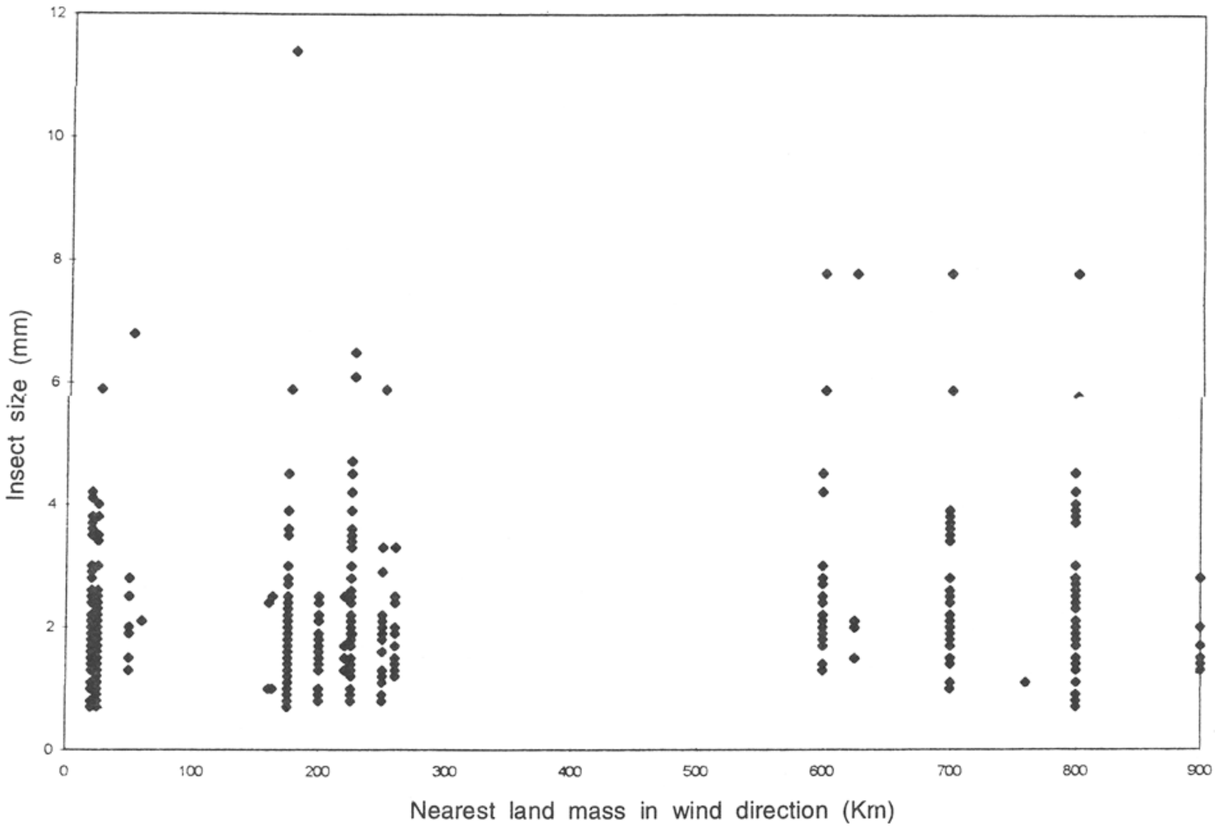

Figure 7. Scatter plot showing the relation of insect size and the distance of the nearest land mass in wind direction.

Pathak and Parulekar (1988) in the month of May, in which only a small number of insects were trapped, about 200 km west of Mumbai, without using any specific trapping system.

It is notable that small insects (0·6 to 3 mm in length) predominate the present collection. Most of these insects are weak fliers and their dispersal appears to be almost entirely passive in nature. Wind patterns have helped workers to determine the possible land of origin of the insects trapped at sea (Holzapfel and Harrell 1968). In the present investigations, the wind flow pattern gives a general idea of the possible land of origin of the trapped insects, but no definite suggestion has been made here because information like the aerial density of specific insect species over various land masses in the region is not available. This is very relevant as these are the insects likely to be caught in the convection currents and then moving seawards with the winds.

A negative correlation does exist between the distance of the nearest land mass in wind direction and the number of insects trapped, α-index of diversity of the air borne insects over the ocean apparently decreasing with increasing distance. A negative correlation between insect size and distance of the nearest land mass in wind direction was expected but a positive value, even though marginal, is intriguing. It appears that the weight of the insects trapped in this investigation is less than what can be carried by even slow wind currents. Perhaps there is a threshold weight beyond which air borne material tends to descend with increasing distance. Absence of larger insects, at distances exceeding 100 km from the nearest land mass in wind direction, also appears to support this suggestion.

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