Sustainability of rattan harvesting in North Sulawesi, Indonesia

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Introduction

Rattan has attracted interest as a crop that has much potential as a profitable and sustainable non-timber forest product, that might form the basis of integrated conservation and development programmes (Siebert 1993). It is the most important of the minor forest products harvested in Indonesia (MacKinnon et al., 1996) and its extraction from buffer-zone areas can be a source of income to local communities around protected areas. Indonesia's forests, where its rattan species grow, are disappearing at an alarming rate of 1.5 million hectares per year (Walton and Holmes, 2000). Despite this, there is a lack of basic biological information on the taxonomy of rattans and their ecology, particularly under natural conditions. In this chapter, we describe an ongoing project, funded by the Darwin Initiative, to assess the sustainability of rattan harvesting in North Sulawesi, Indonesia. As this project is ongoing, we do not present full results, but instead concentrate on discussing the data collection phase; the types of data collected, the reasons for collecting these data, and some of the issues involved in data collection. We present some preliminary results, and discuss the directions in which the work is continuing.

We aim to assess the sustainability of harvesting in a broad sense. On the ecological side, this includes assessing whether harvesting is causing rattan populations to decline to local extinction or whether the populations can continue to survive and provide harvestable canes into the future. But it also includes the effects of rattan harvesting on the forest ecosystem; for example, does it have adverse effects on species that rely on rattan fruits for food, and does it lead to a change in understorey community structure that might cause a loss of biodiversity? On the economic side, we aim to assess whether current levels of rattan harvesting are likely to continue to provide a source of employment and revenues to all those involved in rattan supply, from collectors through to exporters, and whether there are any policies that could be instituted to improve the industry's prospects, whether they be controls on levels of wild harvesting or subsidies and loans to improve infrastructure. These objectives are particularly pertinent to Article 8 of the Convention on Biological Diversity, concerning the management of biological resources important for the conservation of biological diversity within and outside protected areas, and to Article 10, concerning measures relating to the use of biological resources to minimise impacts on biological diversity.

The rattan industry in North Sulawesi grew rapidly in the mid-1980s to reach a level of around 15,000 tonnes a year, according to government figures (Central Statistical Board of North Sulawesi, 1998). There was a dramatic drop in the amount of rattan produced in 1988-9 compared to the previous year. The Indonesian government banned the export of unfinished rattan from January 1989 in order to stimulate development of Indonesian rattan-based industries (Manokaran, 1990). MacKinnon et al. (1996) note that this led initially to falling prices for Indonesian collectors and cultivators, and suggest that the explanation of the large increase in production followed by a drop was that traders were selling large amounts in anticipation of the ban, following which production was cut back. Since then, rattan production in North Sulawesi province has remained high but variable. It is an important industry, employing an estimated 4000 people in the province, and is the largest and most developed of the non-timber industries based in the province's forests (the others being the wild meat trade, Clayton & Milner-Gulland in press, and gold panning)**.** As a potentially sustainable and lucrative forest-based industry, it could have an important role to play in any management plans for forest conservation, either on a large scale, or in extractive zones around reserves. This is particularly true because rattans require standing forest for support.

Rattans are spiny climbing Old World members of the family Palmae. They belong to a large subfamily of the palms known as the Calamoideae (Uhl & Dranfield, 1987), all of which share a unique characteristic - the presence of overlapping reflexed scales on the fruit (Dransfield, 1992a). Some rattan species are single-stemmed, harvest resulting in the death of the plant, while others are clumped and can be harvested continually. In clumped species, suckers are produced at the base of the original stem which develop into new stems; some species also produce stolons up to 3 metres in length (Dransfield 1992b). Stems are covered by spine-bearing leaf sheaths which detach when the stem is mature, leaving the stem bare. In most rattans aerial stems do not branch. Two whip-like organs are associated with climbing; the cirrus, an extension of the leaf apex, bears reflexed thorns and is present in many rattan species. Other species bear a flagellum, originating from the top of the leaf sheath opposite the leaf base. Grapnel-like spines anchor these whips to potential support trees. There are two main methods of flowering among rattans. In some genera inflorescences are borne terminally, following a long period of vegetative growth; stems die after flowering although the clump continues to live (hapaxanthic flowering). In most genera however, after a juvenile period of vegetative growth maturity is reached; inflorescences are produced continually thereafter and flowering does not result in the death of the stem (pleonanthic flowering) (Dransfield, 1992b). Rattan stems do not increase in diameter with age as do dicotyledonous tree stems; rather there is a gradual increase in the diameter of the stem before it starts significantly to grow upwards; once the stem diameter has reached a maximum the stem then begins significant aerial growth (Dransfield, 1992b).

Data collection

Assessment of sustainable practice requires consideration of a number of disciplines, notably ecology and economics. However, it is rare for a single study to collect all these data types with the aim of integrating them into an overall assessment of sustainability. This paper focuses on a pilot study in the Paguyaman watershed, which is a major rattan-collecting area in North Sulawesi and where contacts with rattan collectors are already well established (Fig 1). This area is also of particular interest as part of the Paguyaman watershed was formally gazetted as a nature reserve (31,000 hectares) by the Indonesian government in July 1999, hence offering the potential for future buffer-zone rattan projects. Techniques for assessment of sustainable practice can be established based on the pilot study here and then extended to other watershed areas.

Rattan identification

A key issue in the project was identification of the rattan species under investigation. The taxonomy of Sulawesi's rattans is very poorly known yet a sound taxonomic base is essential for a scientifically repeatable study, with uncritical use of local names causing considerable confusion. In this study we used local collectors' names are a first step to distinguishing species, but made extensive herbarium collections of each type including fruiting and flowering material for future taxonomic identification, following the methods of Dransfield (1986). An advantage of continuing to use local names alongside true species identifications is that the interactions between collectors and rattans are based on the types that they identify. If a type contains species that are significantly different in their biology, then similar harvesting pressure may vary significantly in its effects on the species' population dynamics.

Harvest rates in the Paguyaman watershed

Data were collected by observing the number of rafts passing a particular location on the Nantu river (the north-west branch of the Paguyaman river). Each raft is composed of bundles of harvested rattan, tied to a few wooden floats on which the collector stands. The data were collected every day by field assistants resident at the Adudu base camp on the Nantu river. This camp is located on the river bank; all rafts from upstream must pass this point and are clearly visible from the camp, making recording of numbers of passing rafts straightforward. A sample of rafts were stopped near the base camp and examined to give information on the type and quality of the rattans being collected, as well as on the average number of canes per raft. Collectors were asked where they had been collecting, how long they had been in the forest for, and how many people were in their group. Each cane was examined and its diameter measured using a collector's ruler. A problem with this method is that rafts are composed of bare canes and these can only be readily identified to local names.

The number of rafts observed each day over the study period was combined with the information from the sampled rafts on the number and type of canes per raft to give an estimate of the offtake rate. This enables us to estimate the total amount of rattan of each type being harvested from the forest of the Paguyaman watershed upstream of the sampling location during the study period. The information on the location of the harvest was collected to allow us to investigate spatial differences in harvest pressure, in the types of rattan growing in each area and in collector selectivity, when combined with ecological surveys of the same areas. Data on the time spent in the forest by each group of collectors were recorded in order to estimate the costs of rattan collection.

Industry structure and profitability

Data collected covered the costs and prices for rattan collectors, in order to calculate their profits. The supply structure in the rattan trade, from collector to rattan company, was also investigated, including prices at every stage, to show how profits are distributed and how possible efficiency improvements, such as through capital provision, might be achieved.

Information was gathered during informal interviews and discussions with experienced collectors acquainted with the authors for almost ten years. Companies in Gorontalo, the main rattan processing town in North Sulawesi, were contacted to investigate amounts of rattan handled there and to gain a wider perspective on the province's rattan trade. Company owners were interviewed and asked about the problems they perceive their industry to be facing and the reasons for these. Data on volume of rattan traded were obtained from one of these companies, as well as from official government statistics (Central Statistical Board of North Sulawesi, 1998). Data on general economic indicators, such as inflation rates, were also provided by the Central Statistical Board of North Sulawesi.

Ecological transects

Three transects were set up in the Paguyaman watershed, two in exploited areas (Adudu and Marisa) and one in an unharvested area (Masina, see Figure 1). The aim was to collect data on the number and type of rattans in each area, their density, number of stems per clump and stem maturity, in particular the number of harvestable canes that could be cut from each stem. Data were also collected on environmental variables that might affect rattan populations, including physical factors such as altitude, aspect, soil type, slope, as well as biological factors such as forest cover (which affects both the availability of supports and light levels). This information was used to analyse:

- Factors affecting the distribution of rattans, both physical and biological. This allows us to extrapolate rattan distributions from the sample to the whole watershed, and gives insight into the ecological requirements of different rattans. This would be useful for any future rattan cultivation projects, as well as for increasing understanding of the dynamics of the forest ecosystem.

• Demographic data on survival, growth and reproduction of different rattans, which allows us to construct a model of rattan population ecology. The model can be used to predict optimal harvest rates, and demonstrate how the sustainability of harvesting and potential yields depend on rattan growth form and ecology. In a multi-species harvesting system such as this, it is particularly important to have this information for all harvested species, as some may be much more vulnerable than others, and may be harvested unsustainably as a component of the overall offtake.

• Types of rattan found in each area, previous harvesting levels (estimated crudely from the number of cut stems) and current availability of harvestable canes. This allows the calculation of the relative profitability of a given area, and at what point after collectors have cleared an area it becomes worthwhile to start harvesting there again.

The key type of ecological data that is currently missing, and which cannot easily be obtained from a short study such as this, is the growth rate of individual stems, so that age, length and stem maturity can be related. This is crucial for modelling the rate at which commercial yield can be produced by a rattan population, and so the sustainable offtake rate. However, it can only be obtained through experiments on individual rattans, marking them as seedlings and seeing how quickly they grow, ideally in natural conditions as well as in plantation trials. This point illustrates the weakness of the short-term data collected so far. A small sample of rattans was marked and measured in this way at the Adudu base camp and is continuing to be monitored. Data from two species of cultivated rattans (*Calamus trachycoleus* and *C. caesius*) in Kalimantan suggest that canes may be ready for harvesting approximately 10 years after planting (Menon, 1980; Godoy and Tan, 1989) so clearly such trials are both urgent and in need of a long-term approach.

Ecological data collection methods

Three transects were established using a sighting compass and measuring tape, running north from the main river. Each transect was 10 m wide and of variable length. The transect was divided into ten-m long sections. Flagging tape was used to mark and number each ten-m length of the transect, as well as the transect boundaries. Every rattan plant along the transect was examined and described. Two teams carried out this work, one team of four people cutting, measuring and marking the transect and the second team (two people) examining and describing each rattan plant. Both transect establishment and rattan recording were time-consuming work and were hampered by the mountainous terrain: 300-500 metres of transect could be established in one day (depending on weather and terrain), while every rattan along 150-200 metres of transect could be described per day. Progress was considerably quicker (400-500 m/day) if only plants with mature stems were described, as against every rattan plant. However, while the recording of only mature stems provides a quick estimate of harvest potential it is inadequate for demographic studies. Altitude, slope, light availability and aspect were recorded at every ten-m point along the transects (using altimeter, clinometer, light-meter and compass) and a soil sample was collected for analysis from each transect location.

Costs of Fieldwork

Data from the ecological transects were costly to collect, in terms of time and physical effort. For example, three-hundred and eighty four person hours were necessary to establish and collect all data from the 1650 m long Masina transect (eight days work by a team of six persons, each working an eight-hour day, 7 am to 3 pm). A further seven days were necessary for this team to travel to and from Masina from the nearest village, by longboat and on foot. All supplies and equipment were transported on foot to Masina from the Adudu base camp. Location of an unexploited rattan area was also difficult, since few areas of the Paguyaman watershed remain which have not yet been accessed by collectors. This required a further three weeks ground surveys plus three days of discussions with local collectors.

Counts of rafts required the continuous presence of field assistants at the Adudu base camp between August 1997 and July 1999. Examination of raft content required approximately twenty minutes per raft. Field equipment used in data collection was relatively simple and did not involve large costs.

Results

Ecological data

We present here a few of the preliminary results, to give a flavour of the data collected. Many more transects are needed to cover the Paguyaman watershed more fully, especially as our initial surveys suggest that rattan communities are highly diverse from location to location. The main feature of the rattan communities found on the ecological transects was this diversity, both within and between transects (Table 1). We concentrate here on comparing the results from Adudu, a lowland exploited area which has higher light levels due to some timber removal in the area, and Masina, a remote, more mountainous and unexploited area with totally undisturbed forest cover. The two areas also had different soil types: Masina is a gold-rich area while Adudu is not. The differences in composition of the rattan community between the sites are likely to be due primarily to topographic differences. This is unfortunate in terms of parameterising a harvesting model, because data on rattan population structure and dynamics for model parameterisation can only be obtained from unharvested sites where population dynamics have not been altered to an unquantifiable degree by harvesting. However, in most areas of North Sulawesi only the most remote and inaccessible (hence more mountainous) forests are unexploited - if this means that the communities are very different, parameterisation of any harvesting models will be very difficult. Further transects in unexploited parts of the Paguyaman watershed should provide additional information on this subject.

Comparing the two parts of the transects where all plants were counted, which were of the same length (350 m) in each location, Masina had 18 types of rattan with a density of 47.8 plants/100m^2, while Adudu had 13 types with a density of 57.1 plants/100m^2. Each site had one dominant rattan type, one or two common types, and several less common rattans, although the tail of uncommon rattans was longer at Masina (Fig. 2). The dominant types were different in each case. At Masina Buku tinggi was the dominant type, comprising 49% of plants in the transect; the next most dominant type was Topalo (22%) followed by Susu, Beluo and Batang merah (each comprising 6%), with smaller percentages of other species. At Adudu Batang biasa was the dominant type, comprising 44% of plants in the transect; Susu and Tohiti each made up 24% of plants here, with smaller percentages of other species. Both Buku tinggi and Batang biasa are commercially valuable, but Batang makes up the vast majority of rattan rafted from the watershed - see below). Of those types that were found in significant numbers at both sites (Tohiti, Susu, Beluo), the clump sizes were similar at both sites, as might be expected (Table 2).

The data give useful information on the growth forms of the different rattan types. This is important to analyse because it is a step towards modelling the growth of rattans. Models can be an important tool in understanding rattan population dynamics and in predicting the effect of different harvest rates on a population, and hence sustainable yields. Important parameters to be incorporated into a model of rattan harvesting are dependent on the precise nature of the model but would include cane growth rates, germination, survival and maturation rates. Figure 3 shows the distributions of numbers of stems per plant (3 a) and maturity classes (3 b) for several different rattan types in the unexploited transect, Masina. Those types whose distributions of clump size and maturity class were found not to be significantly different from each other (using a χ^2 test) were aggregated into the “Others” distribution. In figure 3 a types Batang merah, Susu, Tarumpun and Tarumpun daun gros were aggregated. For figure 3 b Susu, Tarumpun, Tarumpun daun gros, Tohiti and Topalo were aggregated together. Such aggregation can be useful for obtaining a crude overall estimate of sustainable yields for the whole watershed, as it avoids the need for modelling each rattan type individually. There were clear differences between the types: Beluo (*Korthalsia celebica* - the only member of its genus occurring in Sulawesi) in particular stands out as having a very different growth form than the others, with more stems, and more mature stems, per plant. This may be explained by the fact that, in contrast to most other rattans, this species exhibits hapaxanthic flowering behaviour (individual stems flowering only once before dying and being replaced by sucker shoots from the base). This species is of no commercial value, mature stems being fine and spindly (3-5 mm diameter). The solitary rattans (Tohiti, Topalo) resemble the majority of rattan types in their maturity distribution, with many juvenile stems and few mature stems (Figure 3 a, b). Although Buku tinggi is similar to the majority of rattan types in the number of stems it produces and their maturity, it is singled out because unlike them, it produces a significant proportion of its new plants through stolons (trailing stems above ground, capable of producing roots and shoots at their nodes). The stolons observed were up to two metres in length. The plants that had produced stolons are significantly larger and more mature than those had not done so (Fig 4).

Spatial distributions

A preliminary examination of the spatial distributions of rattan types along the two transects revealed some interesting patterns, which we are now investigating further using spatial models. In Masina, all plants including seedlings were counted along a short section of the transect (the same length as the Adudu transect), and then mature plants were counted along a much longer transect on either end of the detailed transect. This allows us to compare spatial distributions of mature and immature plants, and to investigate the distribution of plants on both larger and smaller scales.

The Masina transect covered two mountains, the first from transect points -500m to 0m with a peak at -370m, the second from transect points 0m to 1150m with a peak at 800m. Inspection of the distribution of rattans along the transect suggests that there is a strong influence of topography on location of rattan types. Thus Umbul (figure 5 a) is found on the slopes of the first mountain, decreasing in abundance as altitude decreases, while Buku tinggi (figure 5 a) is found in large numbers between the mountains, and Susu and Tohiti (figure 5 b) are found mostly on the second mountain. Beluo, on the other hand, is found throughout the transect. There is also evidence of different types clustering together. Paired correlation coefficients calculated for the presence of one type of rattan in a transect location against the presence of each other type indicated that the abundances of Susu, Batang biasa and Tohiti are positively correlated with each other, and negatively correlated (separately) with Buku tinggi and Topalo These correlations could be simply products of similar habitat requirements, or indicate inter-specific interactions between the rattan types. Which is the case will be clearer following detailed analysis of the data.

Within a particular rattan type, the distribution of individuals through the transect may provide an indication of reproductive behaviour (distance of seed dispersal, degree of reliance on vegetative propagation). If plant distribution was entirely random, then the number of individuals recorded at a particular location would be well described by a Poisson distribution.

Deviations from the Poisson distribution might indicate a degree of clumping behaviour by the plants. Indeed, all the types tested (those with at least 20 plants in the sample) showed significant deviation from the Poisson distribution, with more locations having no plants and more having many plants than would be expected if they were distributed at random (Fig. 6). Beluo, however, is an interesting case; all the other types showed significant clumping both at the original $100m^2$ transect location and when locations were aggregated to $500m^2$. However, the distribution of Beluo plants was only significantly different from random in the aggregated data. This suggests that Beluo aggregation is at a different scale to the others, possibly because it has many more stems, or because of its different flowering behaviour or hermaphroditism. This analysis assumes that plants are scattered amongst locations with no effect of neighbouring locations on each other. However in fact the transect is continuous, and there may well be interactions between neighbouring locations. Thus more sophisticated modelling is required fully to understand rattan distributions, particularly of this species.

Economics of the rattan trade

58 rafts were inspected for their contents between 18th and 25th September 1997, belonging to 8 different groups of rattan collectors, each of which had come from a different collection location. The rafts were made up of an average of 155 canes each, and the predominant rattan type was Batang biasa, which comprised 84% of all canes examined. Of the remaining canes tohiti comprised 9%, umbul 5% and ronti 2%. However a note of caution is necessary as it is difficult to assign species or even exact vernacular names to bare rattan canes. Thus the Batang biasa component is known to include a small amount of Batang merah, while the Tohiti component includes some Topalo and possibly some of the Tarumpun types as well. Batang biasa is the type that was discovered to have been most heavily harvested at Adudu, suggesting it is an important type for rattan collectors in the Paguyaman watershed (Table 2). The number

of rattan collectors and rafts passing the Adudu field station showed a steep decline from the start of observations in August 1997, stabilising at a low level from June to September 1998, and rising again thereafter (Fig 7a). This may be connected with the economic crisis in Indonesia: our observations of the people passing the field station suggested that many rattan collectors had turned to gold panning in this period, because of an increase in the value of gold. This suggestion is supported by interviews with collectors passing the camp. Plotting the monthly change in inflation rate over the study period against the number of rattan rafts (Figure 7b) passing the camp suggests that there is a relationship between the state of the general economy and rattan collection; further analysis comparing changes in rattan and gold prices directly is required. However, our data on the offtake of rattan show how strongly linked to the general economy rattan collection is, and will enable us to estimate the profitability of rattan collection and thus predict future offtake levels.

Data obtained from one major rattan company in Gorontalo indicated that 5907 tonnes of rattan left this company between January 1995 and December 1996, for transport to furniture factories in Java. This rattan was obtained from locations throughout North Sulawesi. 1545 tonnes of this (26%) was collected at Paguyaman. A breakdown of this volume by trade names indicates that 50.8% of this volume was Batang, while Umbul comprised 27.5% and Tohiti 1%. Further analysis of company records covering volume traded, described by location and trade names, will give a province-wide picture of rattan purchases by this company.

Concluding remarks

The chapter has given a broad overview of the aims of our study, and of the range of data collected. The major factor that is still missing is taxonomic identification of the herbarium specimens that have been collected, so that local names for rattan types can be related to rattan species. Our study is ongoing, with work now focussing on further field data collection, data analysis and modelling.

Lessons learnt

A key point emerging from this study is the importance of establishing long-term demographic studies of rattan populations, in order to parameterise our models of the sustainability of rattan harvesting. We have also shown the wide range of biological and economic data that is required if sustainability is to be assessed, since sustainability is so multi-facetted (Gatto, 1995).

Recommendations and aims for future action

Future work will include further transects in unexploited parts of the Paguyaman watershed to help parameterize the model, plantation trials in the buffer zone of the newly created Paguyaman reserve, and collection of further data on the rattan trade from companies in Gorontalo. A further key objective is the marking and measuring of a larger sample of individual stems along the transects, in order to monitor how quickly they grow. Collectors are walking further and further into remote parts of the Paguyaman watershed to find rattan. Thus this work is becoming urgent if we are to assist in moving the rattan industry towards sustainability, while preserving the diversity of the forests on which the industry depends.

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Table 1 The rattan types found in each of the transect sites, with possible species attributions and information on growth form (clumped or solitary) and commercial importance. Each row is a separate rattan type as recognised by collectors, with clear morphological differences from the other types. The Sold column shows whether it is commercially important; a star in this column indicates that the type was found during the inspections of rattan collectors' rafts. The abbreviated name (Abbrev) is that used in the figure legends.

Local name	**Latin name**	**Abbrev**	**Adudu**	**Marisa**	**Masina**	**Growth**	**Sold?**
Batang biasa	*Calamus zollingeri?*	BatB	Yes	Yes	Yes	Clumped	Yes*
Batang merah		BatM	No	Yes	Yes	Clumped	Yes
Susu	*Daemonorops robusta?*	Sus	Yes	Yes	Yes	Clumped	No
Tohiti biasa		Toh	Yes	Yes	Yes	Solitary	Yes*
Tohiti bubanger		TohBu	No	No	Yes	Solitary	Yes
Tohiti tunas		TohTu	No?	Yes	Yes	Solitary	Minor
Topalo		Tp	Yes	No	Yes	Solitary	Minor
Topalo tunas		TpTu	-	No	Yes	Solitary?	Minor
Umbul	*Calamus symphysipus?*	Umb	Yes	Yes	Yes	Solitary	Yes*

Umbul tidak coklat		Umbtc	?	No	Yes	Solitary?	?
Beluo	*Korthalsia celebica*	Bel	Yes	Yes	Yes	Clumped	No
Ronti		Ron	Yes	Yes	Yes	Clumped	Minor*
Malie		Ma	Yes	Yes	Yes	Clumped	No
Buku tinggi		BT	Yes	Yes	Yes	Clumped	Yes
Polioto		Po	Yes	No	Yes	Solitary	No
Bukan Susu		BS	Yes	Yes	No	Clumped?	No
Dia lagi		DiaL	No	Yes	No	Clumped?	No
Topeto		Topet	No	Yes	No	?	?*
Tarumpun		Tar	No	No	Yes	Solitary	Minor
Tarumpun daun gros		TDG	No	No	Yes	Clumped	Minor
Tarumpun daun gros bertunas		TarDGTu	No	No	Yes	?	Minor
Tarumpun daun halus/Tohiti halus		TarDH	No	No	Yes	Solitary	Minor
Tarumpun tunggal (=Tohiti topalo?)		TarTung	No	No	Yes	Solitary	Minor
Huwulungo		Huw	No	No	Yes	Solitary	Minor

Table 2 A comparison of the clump size and number of harvestable stems for rattans found at the two transect locations (only showing types for which at least 20 plants were recorded). Mean = mean number of stems in the clump, Median = median number of stems in the clump. Solitary types have both a mean and a median number of stems of one. Plants = number of plants recorded in the transect (all plants, transects were of similar length). Harvestable = the percentage of living stems that are of harvestable length (species of major commercial value are marked with an asterisk, minor commercial value with an asterisk in brackets). Cut = number of stems that had already been cut by collectors. As it is not possible to tell when a stem was cut, this serves only to show which types are targetted. There were no cut stems at Masina.

a) Masina

Type	**Mean**	**Median**	**Plants**	**Harvestable %**
BatM*	2.55	1	38	0
Bel	3.68	3	28	11.7
BT*	3.18	1	262	9.1
Sus	2.19	1	48	0
Tar (*)	1.62	1	39	1.6
TDG (*)	1.69	1	29	0
Toh *	1.00	1	25	0
Tp (*)	1.01	1	385	1.0
Overall	2.11	1.25	854	3

b) Adudu

Type	**Mean**	**Median**	**Plants**	**Harvestable %**	**Cut**
BatB *	3.75	1	231	0.1	45
Sus	2.16	1	223	1.6	1
Toh *	1.00	1	483	2.3	0
Umb *	1.07	1	42	2.0	0
Bel	3.35	3	17	31.6	0
Ron (*)	3.67	4	9	3.0	0
Overall	2.50	1.83	1005	7	46

Figure legends

Figure 1 The location of the Paguyaman watershed, showing the sites of the ecological surveys, the harvest rate survey and the rattan factory.

Figure 2 The number of plants found in $100m^2$ of rattan transect, ranked from the commonest to the least common type, for the two sites, Masina and Adudu.

Figure 3 Distributions of growth form of plants in the Masina transect, using data from the area in which all plants were counted. a) The number of stems per plant. The rattan types with large enough sample sizes and distributions that were not significantly different from each other were aggregated into the “Others” distribution; these were Batang merah, Susu, Tarumpun and Tarumpun daun gros. b) The maturity class of the stems. These were divided into seedlings (S), juvenile stems (J), mature stems which are hard but not yet long enough to provide a commercially harvestable cane (M0), and mature stems that could provide from 1 to more than 6 commercially harvestable canes (M1-M6+). The rattan types with large enough sample sizes and distributions that were not significantly different from each other were aggregated into the “Others” distribution; these were Susu, Tarumpun, Tarumpun daun gros, Tohiti and Topalo.

Figure 4 Differences between Buku tinggi plants that have formed stolons (Stolons), those that are still visibly stolons from a parent plant (New) and those that have not formed stolons (Lone), in terms of a) the distribution of maturity classes of their stems and b) the number of stems per plant. In both cases all three distributions are significantly different (χ^2 test, $P <$ 0.001).

Figure 5 Distribution of rattan plants along the Masina transect (only those plants with at least one mature stem are counted). The data are aggregated so that each location represents the number of plants recorded over the previous 500m^2 section of the transect (thus -460m is the number recorded from -500 to -460 inclusive). The transect covered two mountains; the first from -500m to 0m with a peak at -370m, the second from 0m to 1150m with a peak at 800m. a) Umbul and Buku tinggi, b) Tohiti and Susu.

Figure 6 Frequency distribution of the total number of rattan plants (of all types) found in a particular 100m^2 location on the Masina transect (Observed) compared to the expected frequency distribution if the plants were randomly distributed amongst transect locations (Expected). The two distributions are significantly different (χ^2 test, $P<0.001$), with the observed distribution having more locations that have either very few or many plants in them than would be expected.

Figure 7 a) The number of rattan rafts and rattan collectors passing the Adudu field station each month from August 1997 to September 1998. b) The number of rattan collectors passing the field station plotted against the change in inflation rate in Manado, capital of North Sulawesi, in the current month compared to the previous month.

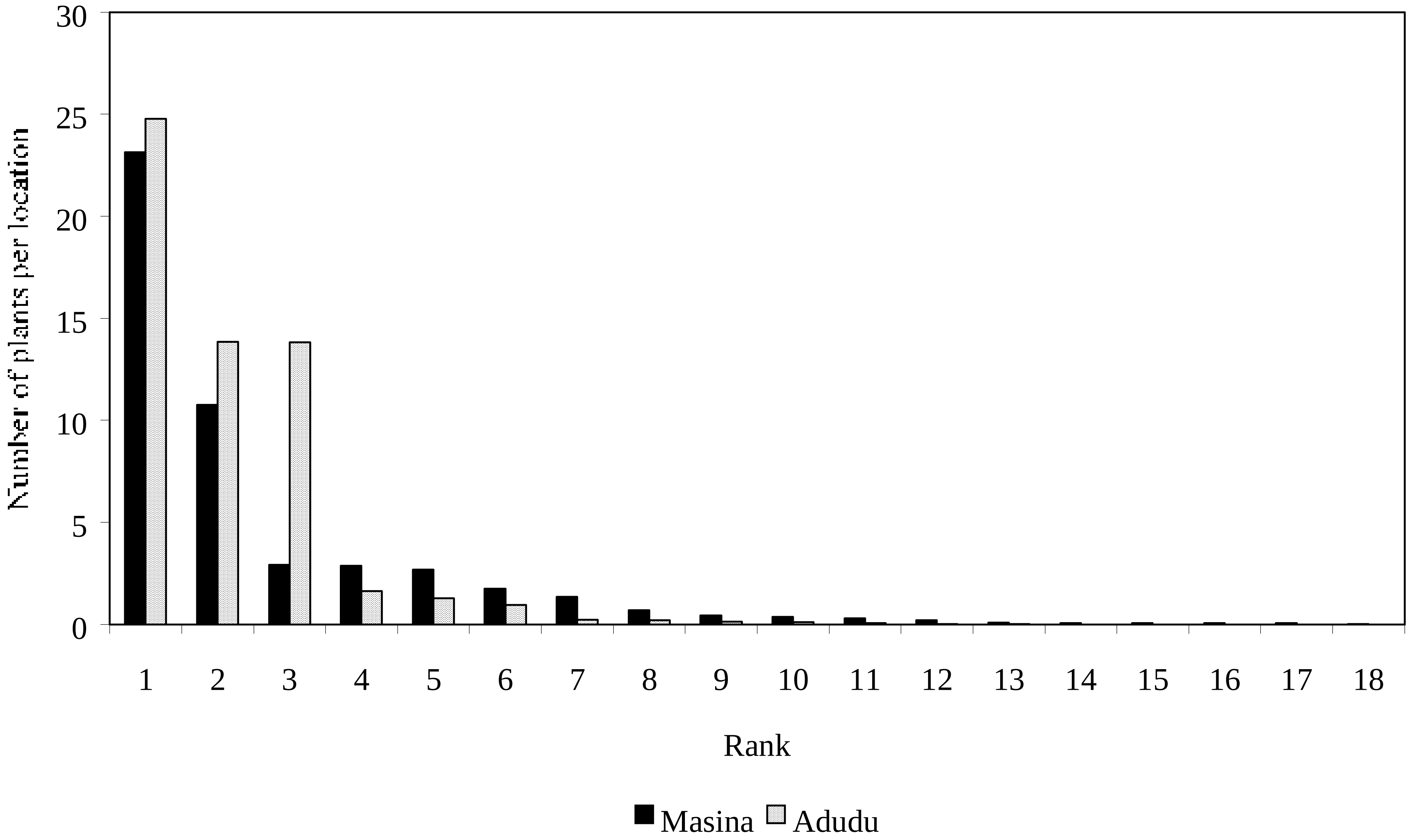

Number of plants per location
0
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Rank
Masina
Adudu

Figure 2

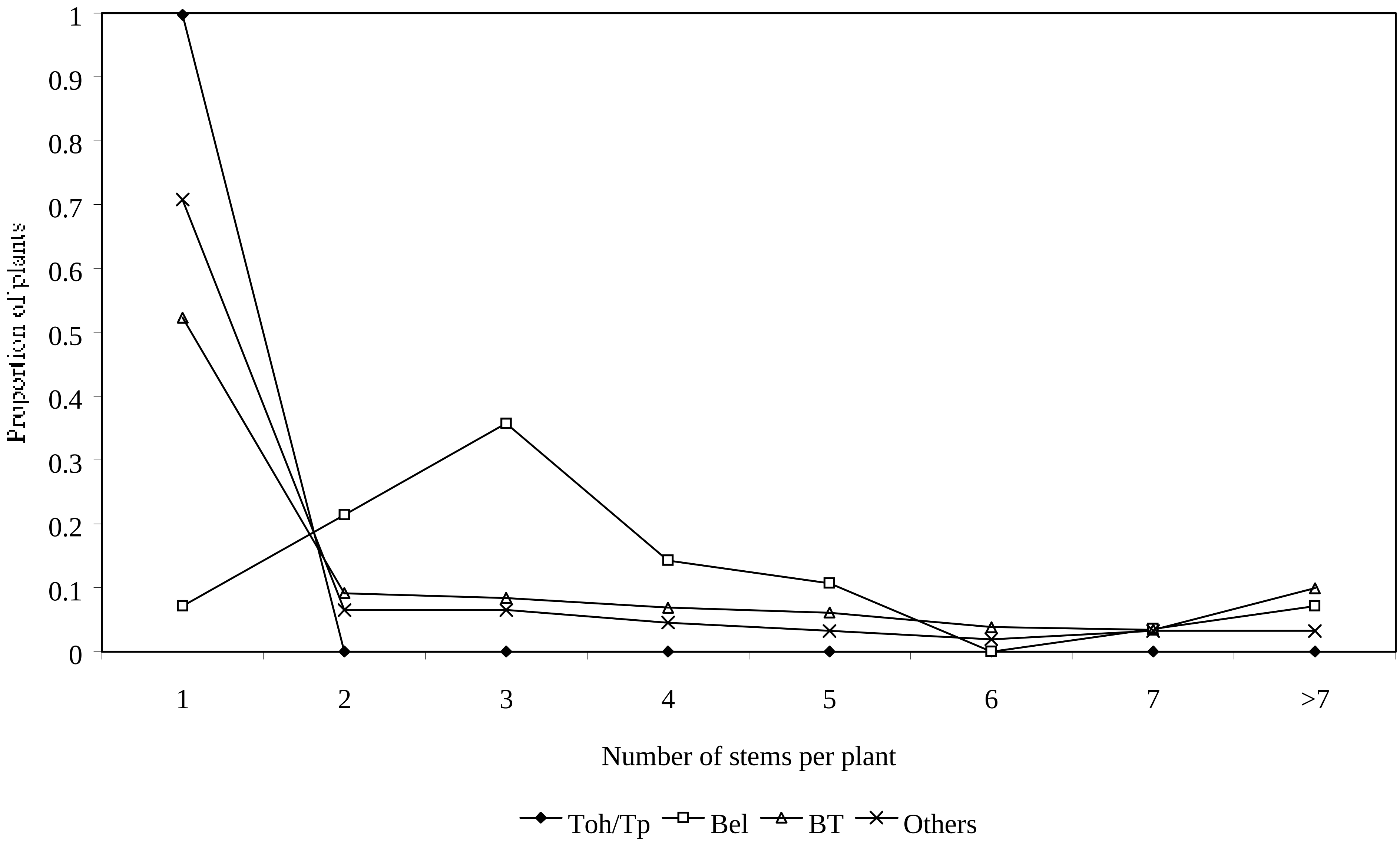
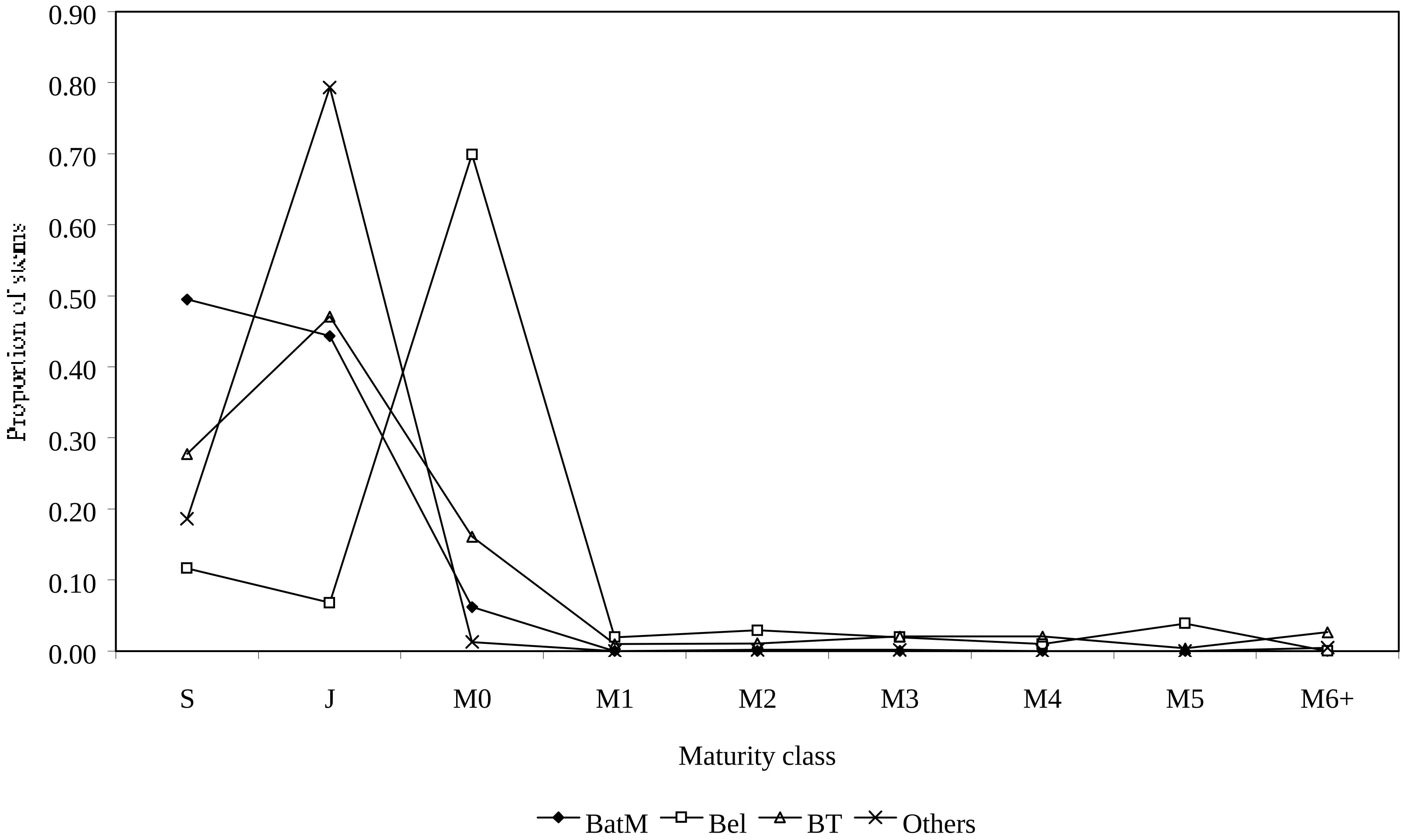

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Proportion of plants
1
2
3
4
5
6
7
>7
Number of stems per plant
Toh/Tp
Bel
BT
Others

Figure 3a



Proportion of swarms
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
S
J
M0
M1
M2
M3
M4
M5
M6+
Maturity class
BatM
Bel
BT
Others

Figrue 3b

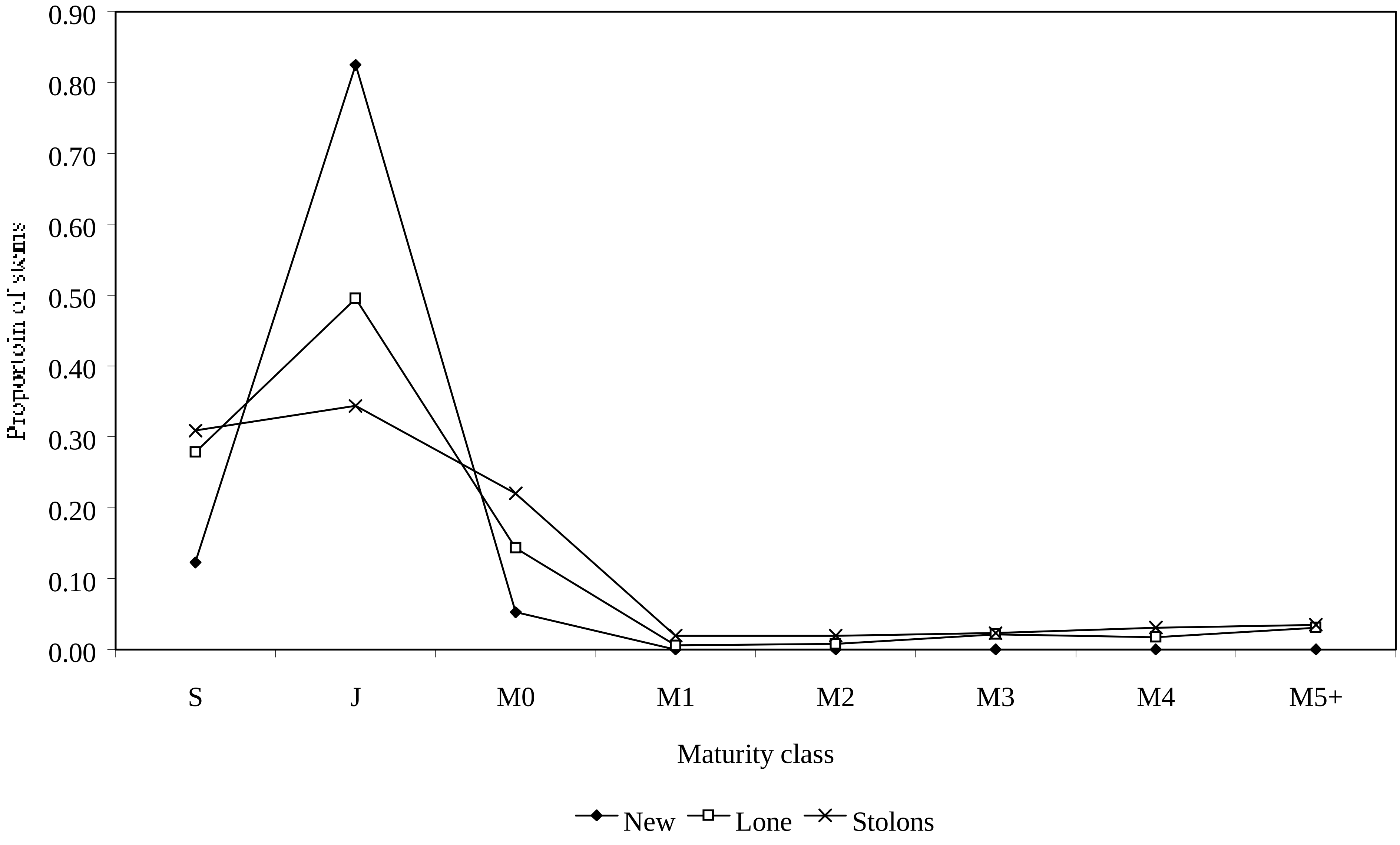

0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Proportion of stems
S
J
M0
M1
M2
M3
M4
M5+
Maturity class
New
Lone
Stolons

Figure 4a

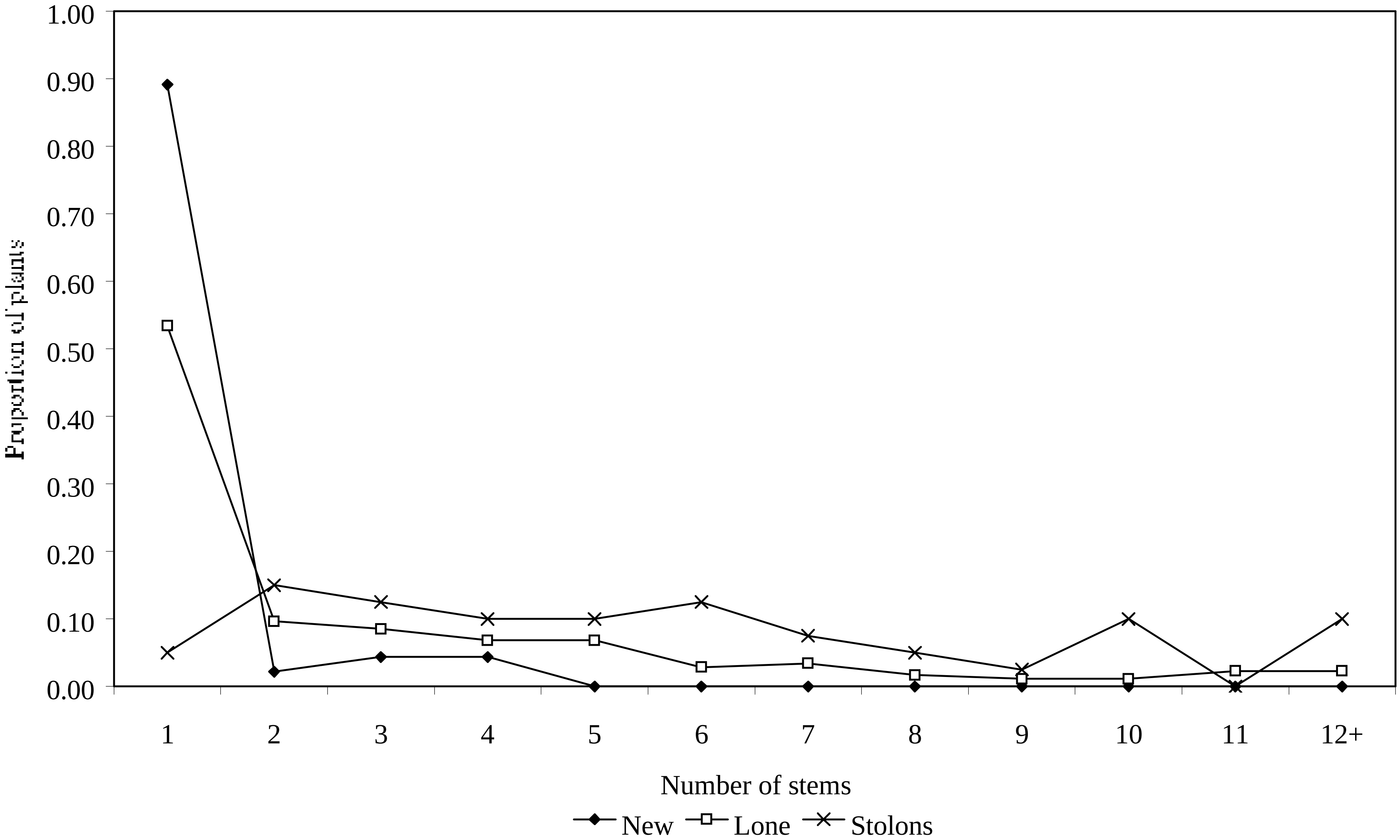

Proportion of plants
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
6
7
8
9
10
11
12+
Number of stems
New
Lone
Stolons

Figure 4b

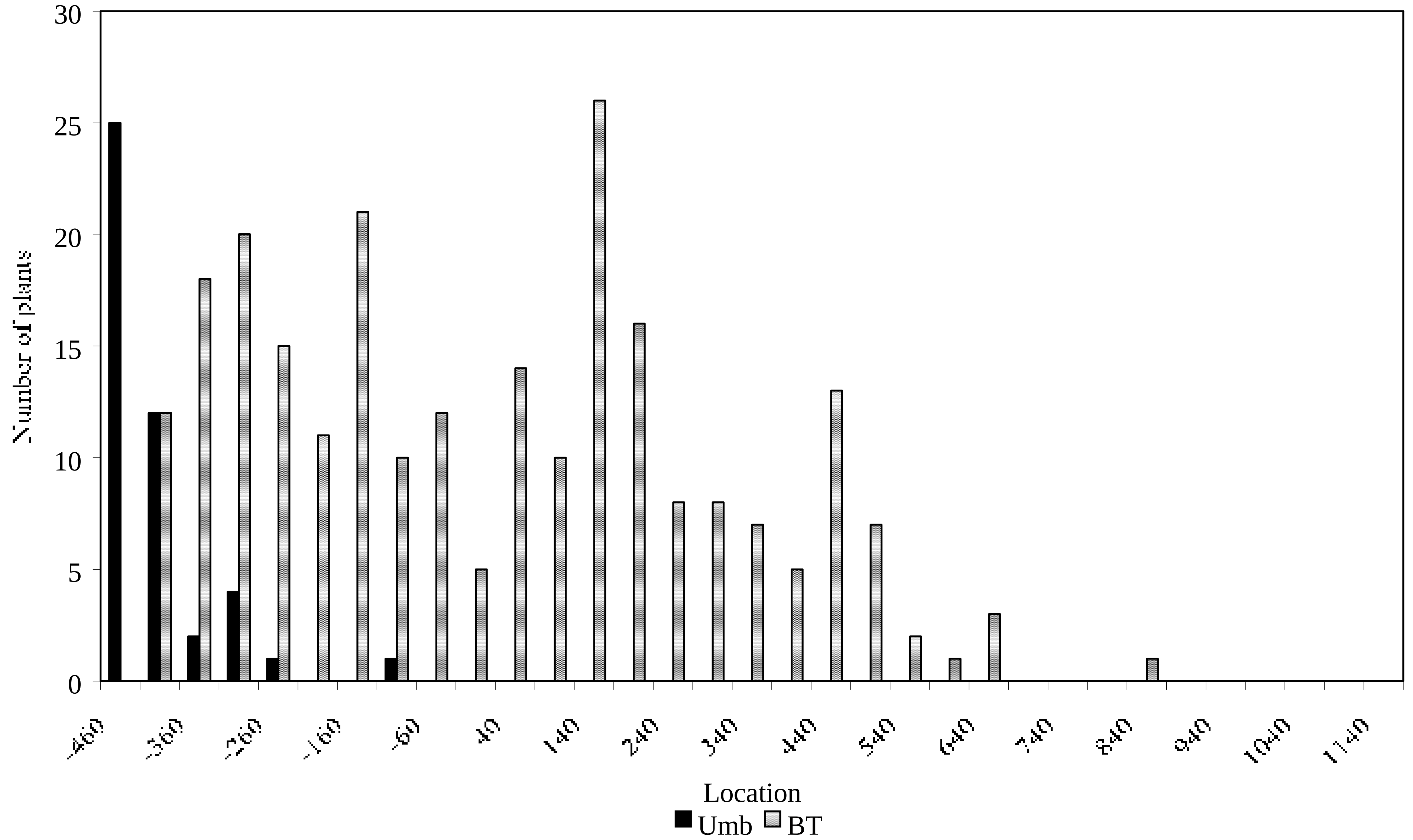

Number of plants
0
5
10
15
20
25
30
-460
-360
-260
-160
-60
40
140
240
340
440
540
640
740
840
940
1040
1140
Location
Umb
BT

Figure 5a

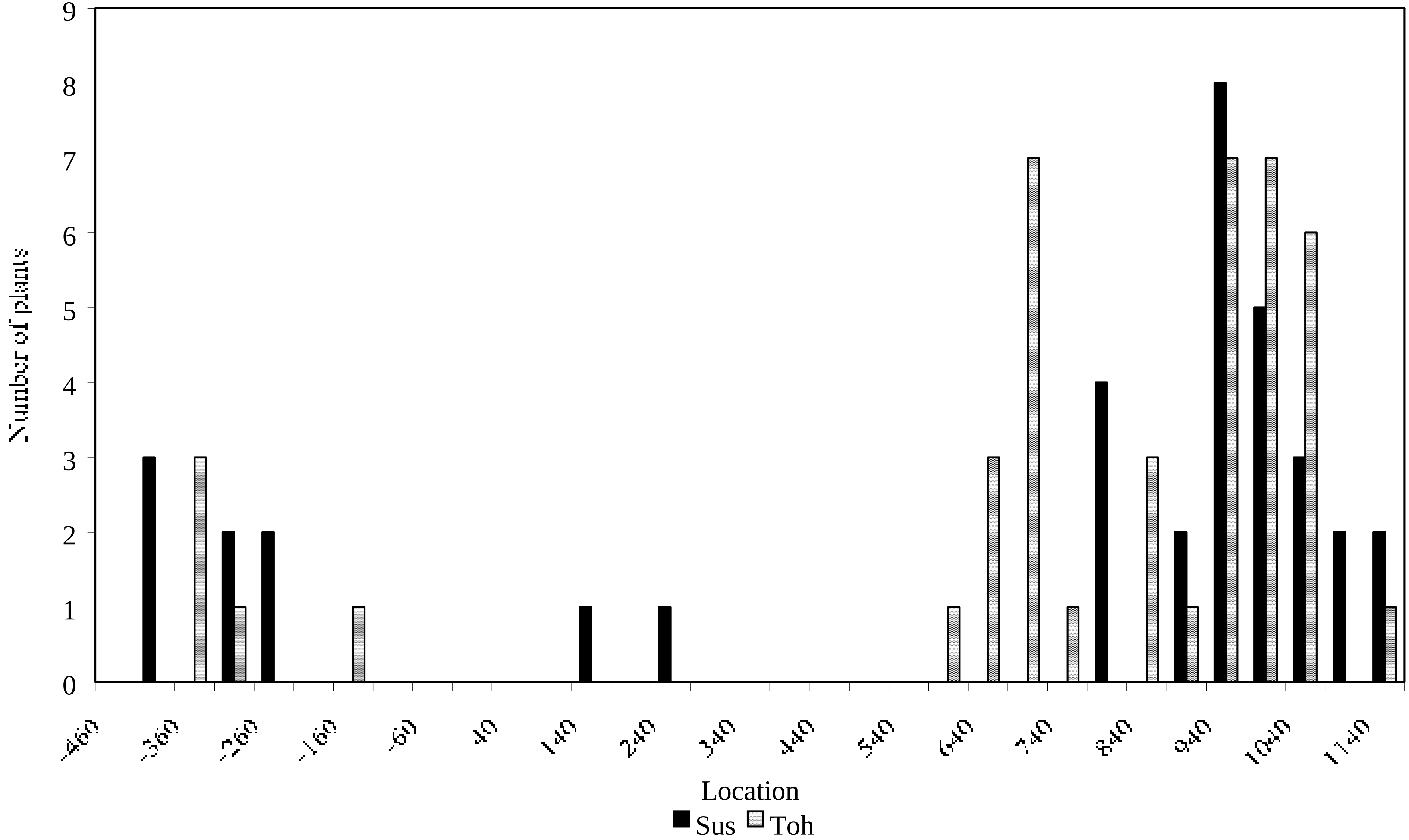

9
8
7
6
5
4
3
2
1
0
Number of plants
-460
-360
-260
-160
-60
40
140
240
340
440
540
640
740
840
940
1040
1140
Location
Sus
Toh

Figure 5b

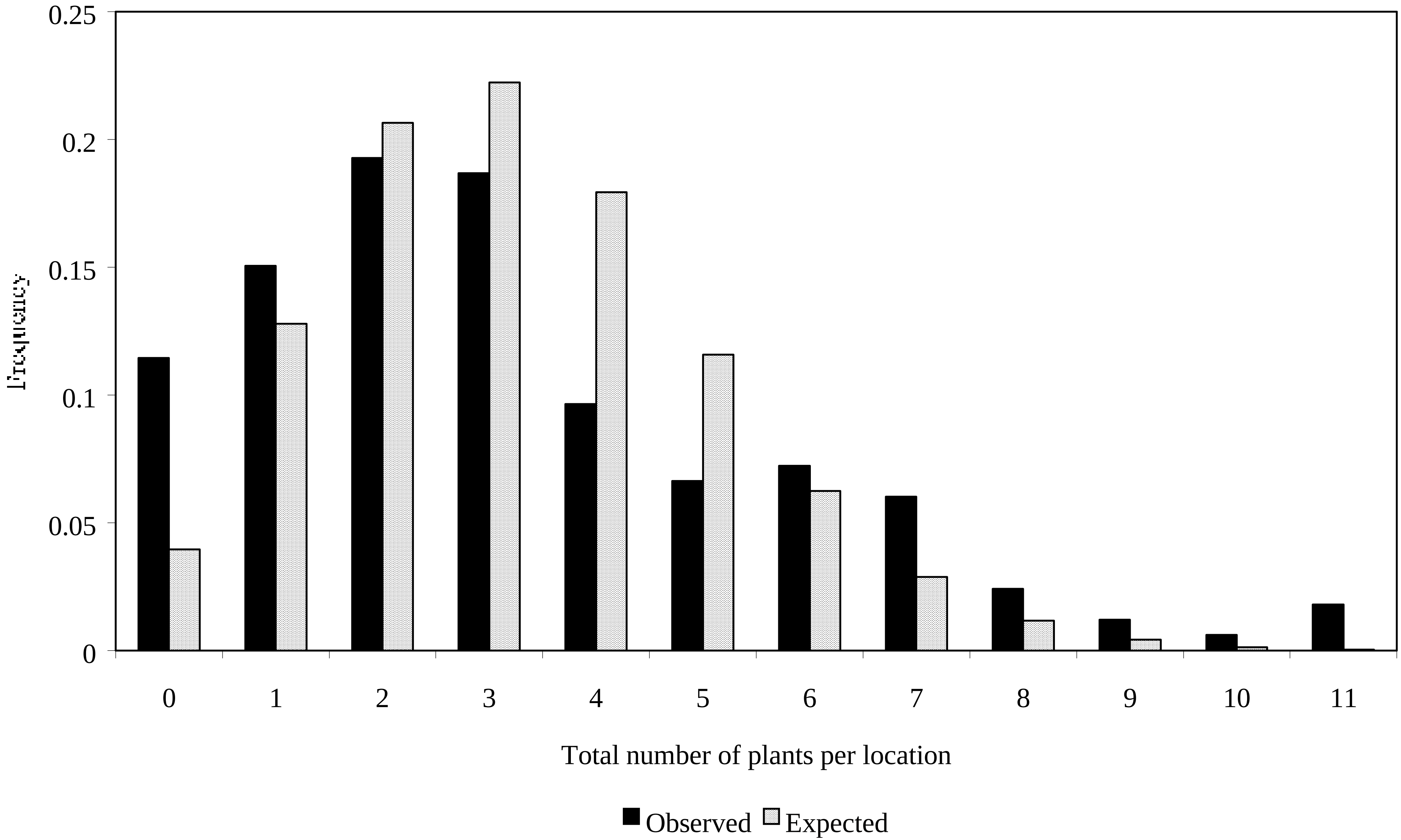

0.25
0.2
0.15
0.1
0.05
0
Frequency
0
1
2
3
4
5
6
7
8
9
10
11
Total number of plants per location
Observed
Expected

Figure 6

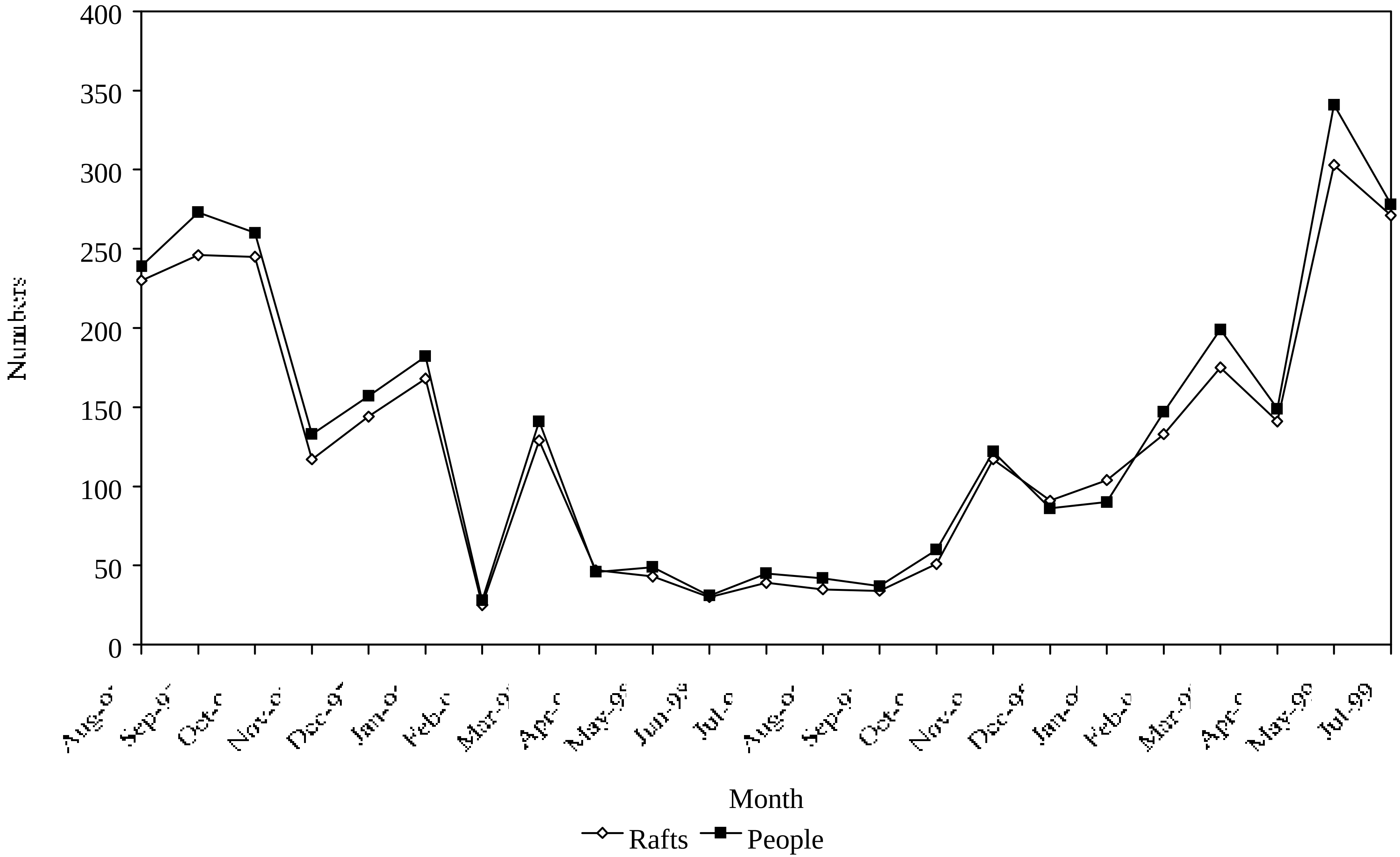

400
350
300
250
200
150
100
50
0
Numbers
Jul-99
Month
Rafts
People

Figure 7a

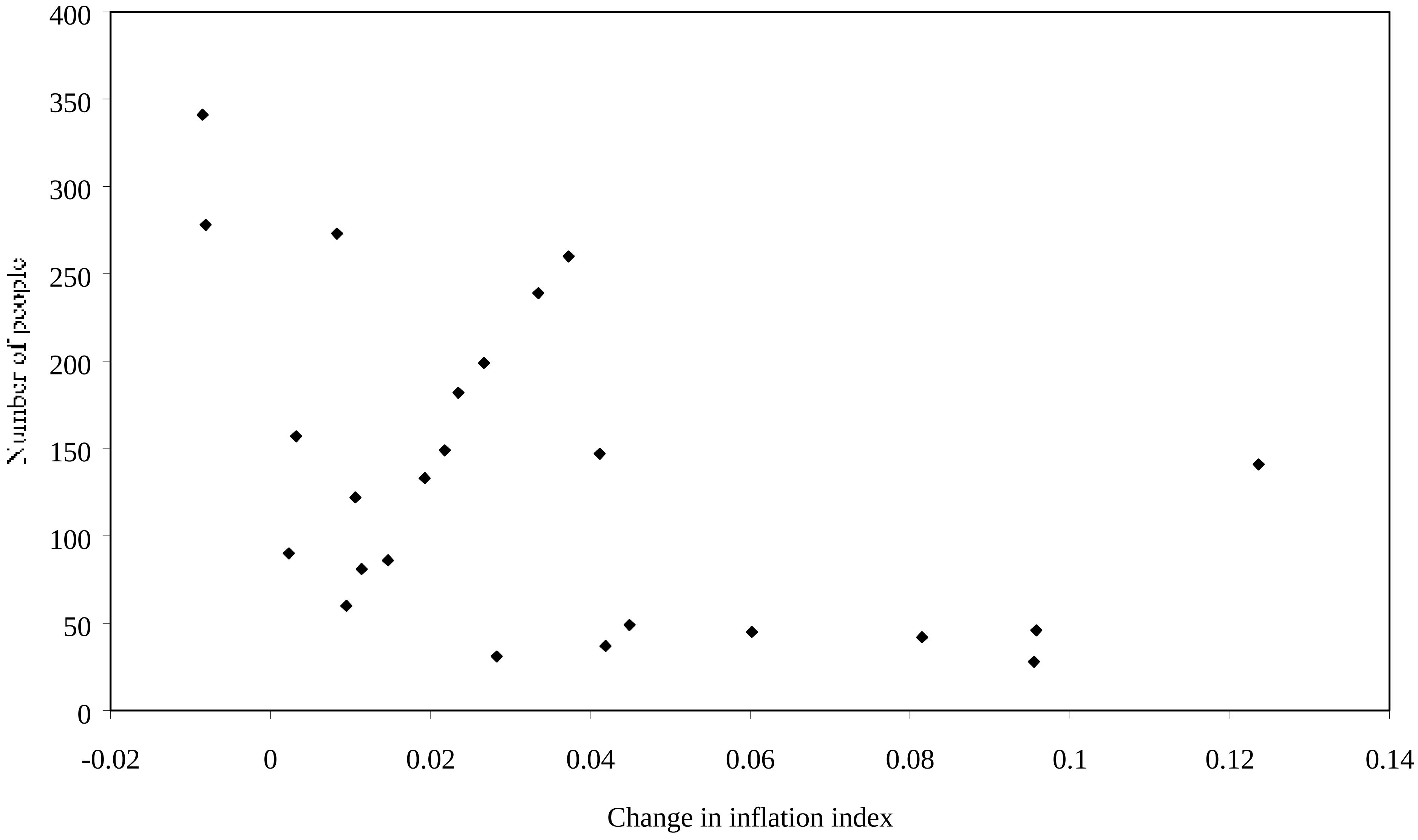

400
350
300
250
200
150
100
50
0
Number of people
-0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
Change in inflation index

Figure 7b