7

Techniques to Estimate Abundance and Monitoring Rodent Pests in Urban Environments

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1. Introduction

Different techniques have been developed in order to study the ecology of animals. The application of each technique depends on the studied animal species, on the type of habitats where they live and the objectives of the study. Most of the ecological studies focus on a unique population, which is defined as a group of organisms of the same species that coexist at the same time and in the same area (Krebs, 1978); or on a community, which is defined as a group of populations that exist at the same time and in the same area (Begon et al., 1987). One of the most important characteristics of a population is its size or abundance. This is determined by the number of individuals born, the number of individuals that dead and the number of individuals going into or out of the area that the population occupies per unit of time (Begon, 1979; Krebs, 1978). On the other hand, some of the characteristics of the animal community are the species composition, its absolute abundances and relative abundances, the richness, dominance, diversity, equitability, trophic structure and the niche structure (Krebs, 1978). Except for the trophic and niche structure, the other characteristics mentioned above are inferred from the abundances of the individual species that make up the community.

Studying the factors which control the species' abundance is one of the main topics of ecology. This topic has been explained by studying the natural variations in abundance according to space and time, or due to experimental manipulation (Aplin et al., 2003). In relation to pest species, knowing the factors which limit the populations' growth allows to take decisions to control them.

In the population studies the sampling method used by the researcher must be the most appropriate to study the particular species and to allow answering the question that has been posed. Regarding the community studies, for practical purposes, it is necessary to limit the community studied to a group of populations that share a determined characteristic and are adequately sampled according to the selected method. In general, this subgroup inside a community is related phylogenetically (e.g. community of insects, birds, rodents, etc) or they are exploiting the same resources in the same way. According to Magurran (1988) the diversity is more informative and easy to understand when it is applied to a limited and well-defined taxonomic group.

The presence or absence at the same time and site is the minimum information that we can have of the populations in a community. The complete list of all the individuals or census is the maximum information that we can have of the size of the population and the diversity of a community (Aplin et al., 2003; Krebs, 1978; Magurran, 1988; Southwood, 1978). A census is rarely conducted in natural ecosystems due to limitations of time, money, personal and/or the difficulty to reach all the individuals in the study area. On the other hand, a census can cause interferences and destroy populations or cause damage or destruction of their habitats; therefore, sampling is generally used instead of a census (Magurran, 1988; Rabinovich, 1980; Southwood, 1978).

According to the study objectives, the absolute or relative sizes of the populations can be estimated (Krebs, 1989). The absolute size estimate allows assessing the density, i.e. the number of individuals present in a determined area or volume (Krebs, 1978). Different methods have been developed to estimate the absolute size of populations, which can be used when certain requirements are met (Brownie et al., 1986; Hayne, 1949; Krebs, 1966, 1989). It is possible to estimate the density with the population size and the size of the studied area. Although it is sometimes easy to calculate the size of the studied area; it is difficult in samplings with traps or another system which depends on the attraction of animals. The studied area would depends on several factors, such as the influence area of the trap, its bait (what distance is necessary for a baited trap to attract an animal) and the animals' mobility. At the same time, the individuals' mobility may depend on species, season, habitat conditions, age, sex and the reproductive condition of the individuals, among other factors.

Sometimes it is not necessary to know the absolute size, but it is wanted to know the spatial and/or temporal variations of abundance; thus, trend indicators or relative abundance indices can be used. The relative abundance is defined as an abundance measurement that is relative to the sampling effort, showing the number of individuals with regard to a measurement different from the surface or volume (Seber, 1973). For example, the number of individuals trapped is used with regard to the number of traps or set nets; the number of animals observed during a period of time, etc. The use of relative abundance estimators allows the comparison of the abundance between sites or of the same site at different times, even if the absolute abundance values are unknown. Two of the relative abundance estimators frequently used are the trap success (Seber, 1973) and the relative density index (Begon, et al., 1987), both of them are calculated as the number of different animals captured / number of active trapping elements * the time that the elements have been active. The trapping elements can be traps, nets, etc.

Another way to estimate relative abundances is with the record of animals signs or related elements that can infer the presence or absence of an animal species in the studied area, and they can also estimate the size of the population calibrating the signs quantity with the abundance (Krebs, 1978; Rabinovich, 1980; Southwood, 1978). The main advantage that these methods or "population indices" present (sensu Southwood, 1978) is that they require in general less effort and expenditure than other methods. For a lot of species it is possible to count footprints, nests, burrows or other habitat alterations, while for birds it is possible to use the record of their songs or calls as signs of their presence (Aplin et al., 2003; Krebs, 1978; Rabinovich, 1980; Southwood, 1978). Finally, it is possible to estimate the relative abundance of an animal by means of surveys or questionnaires (Krebs, 1978). This methodology uses the experience of other people to determine the presence or absence of a species, or to estimate the relative abundance (Filion, 1987).

The most common techniques to estimate the rodents abundance are those based on the use of capture traps or on the record of signs, due to the fact that most of them have crepuscular habits and its direct count can only be used in special cases (Aplin et al., 2003). There is a wide variety of designs for kill or live capture traps, been their designs creative and/or old, some of them were described by Chani (1980) and Hawthorne (1987). Among the relative abundance estimators for rodents, Aplin et al. (2003) pointed out three methods that involve the use of signs that are widely employed: the use of footprint traps, the record of food consumption and the count of burrows. Yo et al. (1987) proposed particularly for *Rattus norvegicus* the count of gnawed wood pegs as a method to estimate abundance and the use of space. Since these mammals gnaw different materials in order to limit the length of their incisors, the record of the marks left on the pegs are good to estimate abundance, independently from the food availability in the environment.

Maybe urban environments are the least studied in relation to the ecology of rodents, probably due to the methodology problems they present: 1) some trap designs could be dangerous for people. For example, snap traps can hurt a person or pet if they activate it accidentally, 2) the difficulty of reaching some sites such as inside houses, shops or industries and 3) there is a big risk of losing the material used to sample, especially the traps which are valuable elements. Another difficulty to study rodents in urban ecosystems is its environmental heterogeneity; so if it is necessary to compare the results of the different environments, the method used to estimate the abundance should be the same. The selected sampling technique should be able to sample for example: inside a house, a shop, an industry, and also open areas such as gardens, parks, lawns, public spaces, etc.

As a brief summary we will mention some of the experiences carried out in cities and the sampling techniques employed. In the 50s. a study was conducted in Baltimore City laying the foundations for the biology of *R. norvegicus* in urban environments (Davis, 1951a, 1951b, 1951c). In that study, trap sampling was conducted using live capture traps, which is the technique also used in various more recent studies (Battersby et al., 2002; Castillo et al., 2003; Cavia et al., 2009; Ceruti et al., 2002; Glass et al., 1988; Traweger & Slotta-Bachmayr, 2005). There is a growing number of studies that estimate abundance with the record of signs. For example, bait stations were used in drains to estimate the population abundance of *R. norvegicus* in Enfield City, England (Channon et al., 2000) and the record of rat bites in patients in the hospitals of New York were used to determine areas with different outbreak risk (Childs et al., 1998). In another study the possible causes of rats and mice infestation in dwellings (Langton et al., 2001) were determined by recording the signs of rodent activity obtained during an inspection of 17100 dwellings in different regions of England. Among the studies conducted to estimate the rodents abundance using surveys, it can be pointed out one conducted to householders in Manchester, the United Kingdom, which determined that 44% of dwellings were infested with *Mus musculus* and 49% with *Rattus* spp. When these results were compared with samplings using footprint traps in dwellings, they were consistent for *M. musculus*, while the abundance for *Rattus* spp. was apparently overestimated (Marshall & Murphy, 2003).

In this chapter different methods to estimate rodent abundance in urban environments are evaluated. For this purpose samples were carried out in a coastal area, in a cars warehouse, in an urban reserve, in a shantytown and in a residential neighborhood. The different methods to estimate abundance that were tested are: record of activity of rodent burrows, visual record of animals, glue traps, wood pegs, bait stations, bait stations with hair-hunting traps, Sherman live traps and cage traps, and the use of surveys.

2. Evaluation of methods to estimate rodents abundance, preliminary survey

Study area

The samplings described in this section were conducted in a coastal area in the city of Buenos Aires where waste materials and soil were deposited in order to gain land from the river and subsequently covered by spontaneous vegetation, figures 1 and 2. The objective of these preliminary surveys were to prove the methods to estimate the rodent relative abundance by counting burrow entrances, active individuals, kill capture with glue traps, live capture with cage traps and by recording consumption in bait stations.

2.1 Materials and methods

Count of burrow entrances

After detecting a colony of *R. norvegicus*, an inspection of the place was carried out in order to find burrow entrances. The number of entrances was recorded in an area of 60 by 30 m, table 1.

Glue traps

Glue traps consisted of pieces of cardboard of 30 by 30 cm covered with a thin layer of commercial glue (Pega-Rat) and baited with peanut butter, figure 3. The glue was placed according to the manufacturer's instructions. Twelve glue traps were placed at burrow entrances in the afternoon and checked in the morning of the following day during four consecutive days, table 1.

Count of active rodents

Observations were performed during four days beginning on 19 June 2001, at three different times: in the morning from 11:00 to 12:00hs, at midday from 13:30 to 15:00hs and in the afternoon from 16:00 to 17:00hs, table 1. In each period three records of five minutes were registered, separated by breaks of five minutes. Two observers stood in the middle of the studied area (60 by 30 meters). The total surface was divided and each observer registered the records in a quadrant of 30 by 30 meters. The quadrant limits were marked with paint over the waste materials. At each interval of five minutes each observer recorded the number of individuals of *R. norvegicus* observed in their area. The average number of individuals observed in five minutes was calculated for the three different periods of time.

Fig. 1. Aerial view showing the coastal area where the samplings were conducted (Source: ©2006 Google Earth, imagery date, April 21, 2000).

Fig. 2. View of a section of the coastal area where some of the samplings described in this chapter were conducted. The de la Plata river can be seen on the right side of the image.

Fig. 3. Photograph of a glue trap placed at a *R. norvegicus* burrow entrance.

Live traps

A capture-mark-recapture sampling was conducted using cage traps, figure 4. Between 14 and 24 August 2001 eight cage traps were set in six opportunities, working one hour between 11:00 and 13:00hs, and they were checked every 15 minutes, table 1. The captured animals were marked with synthetic paint on the back. A different color was used for each day. This way of marking animals was used to prove if it was possible to identify them in subsequent counts. The trap success (TS) was assessed to estimate the relative abundance:

$$TS = I / (T * t - 1/2 * ST) \quad (1),$$

where I is the number of captured individuals, T is the number of set traps, t is the number of intervals of time in hours, nights, etc. that the traps were set active and ST is the number of traps that were sprung without captures during an interval t. Half of the sprung traps without captures is subtracted from $T*t$ since it is not possible to know if the traps were inactive from the beginning, during or at the end of the considered interval. Thus, it is assumed that an average of these traps were inactive half of the interval.

Use of nontoxic bait stations

Twelve bait stations were placed 10m apart of each other on a transect. The bait stations consisted of transparent two liters plastic bottles, containing two grams of a mixture of fat, peanut butter and paraffin. The bait stations were set for three nights, after this period of time it was recorded whether the bait had been consumed, table 1. The proportion of bait stations with rodent activity was calculated (PropABS) to estimate the relative abundance:

$$\text{PropABS} = ABS / (TBS - MBS) \quad (2),$$

where ABS is the number of bait stations with rodent activity, TBS is the total number of bait stations and MBS is the number of missing bait stations. A bait station was considered with rodent activity when bait consumption was recorded.

2.2 Results

A total of 41 active burrow entrances were recorded (figure 5) in 1800 m^2. Only two animals were captured using glue traps. The remains that were found did not allow the identification of the sex nor the size class, because they were eaten by other animals. Up to 17 different individuals were observed at a five-minute interval by direct observations. The number of observed individuals per period of time was (mean ± standard deviation): 6.75 ± 4.33 individuals in the morning, 5 ± 3.30 individuals at midday and 7.91 ± 3.14 individuals in the afternoon. Twelve *R. norvegicus* were captured using cage traps and none individual was recaptured. The trap success was 0.25 individuals/trap per hour, and the highest trapping frequency (5/12) was recorded during the first 15 minutes of the sampling. The bait was completely consumed after three nights in 100% of the set bait stations (PropABS=1).

Fig. 4. Photograph showing a styrofoam bait station of 250 cm^3 prepared with sticky tape on the front (on the left), a cage trap (in the centre) and a Sherman trap (on the right). Observe a one Argentinean peso coin on the bottom left corner to determine the size of the elements.

3. Comparison between the active rodents count and the use of bait stations to detect changes in abundance

A sampling was conducted in the same coastal area as in the previous sampling with the objective of assessing if, when modifying experimentally the size of the population the changes were detected by the methods for estimating the abundance by counting active animals and the use of bait stations.

Fig. 5. Photograph showing a *R. norvegicus* burrow entrance.

3.1 Materials and methods

Rodent abundance was modified using rodenticides in a part of the coastal area. Two or three blocks of five grams of a commercial rodenticide were placed into the burrow entrances found on 1 October 2001, table 1. This area covered a coastline of approximately 150m long, which is called the treated area. The rest of the place is the control area (not treated).

In the treated area the activity of *R. norvegicus* was recorded by means of the active individuals count in the same way as it had been performed in the preliminary sampling. Two samplings were conducted: one before the use of the rodenticide between 27/08 and 10/09/01, and another after its use between 10 and 18/10/01, table 1. The daily mean animals observed at five-minute intervals between the samplings before and after the use of rodenticide were compared by means of the Mann Whitney test (Daniel, 1978).

The relative abundance was also recorded, before and after the use of rodenticide, by means of bait stations with nontoxic bait, which were placed on transects 100m apart: one in the control area and the other one in the treated area on 28/9 and 12/10/2001, respectively (table 1.). Each transect consisted of 12 bait stations placed every 10m. The bait stations were set active during the same time and had the same characteristics as the pilot sampling, but in this opportunity they had 18-20g of bait, since in the pilot sampling it had been consumed after three days. The proportions of bait stations with rodent activity before and after the use of rodenticide were compared statistically by means of a proportions test (Zar, 1996).

	Date	Activities
Preliminary survey	28/05/01	Burrow entrances survey
	28/05 – 01/06/01	Glue traps sampling
	19 - 22/06/01	Direct observations of individuals at three different times
	14 - 24/08/01	Live capture and marking of rodents
	14 - 15/09/01	Sampling with bait stations
Comparison of bait stations and direct observations	27/08 – 10/09/01	Direct observations of rodents at three different times
	29/09 - 2/10/01	Sampling with bait stations (control and treated)
	01/10/01	Use of rodenticide in burrow entrances
	10 – 18/10/01	Direct observations of rodents at three different times
	12 – 15/10/01	Sampling with bait stations (control and treated)

Table 1. Schedule of activities performed with the objective of testing different rodent sampling techniques.

3.2 Results

In the treated area, up to 11 different individuals were detected at a five-minute interval in the previous sampling and two in the sampling after the use of rodenticide. The mean number of individuals seen at a five-minute interval decreased from 1.32 to 0.45 between both samplings, these differences were marginally significant ($U=3.5$; $p=0.1$), figure 6.a.

The proportion of bait stations with rodent activity decreased significantly after the use of rodenticide in relation to the previous moment in the treated area ($p=0.039$). In the control area, changes in the proportion of bait stations with rodent activity were not observed between the moments before and after the use of rodenticide ($p=1.000$), figure 6.b.

4. Comparison of use of pegs and bait stations

With the objective of comparing the use of wood pegs and nontoxic bait stations as methods to estimate the rodent relative abundance, two samplings were performed: one in the coastal area of the de la Plata river and the other one in a judicial cars warehouse in an urban area in the city of Buenos Aires.

4.1 Materials and methods

In the coastal area of the de la Plata river three plots of 2000 m^2 (100 by 20 m) were selected. In each plot they were set 32 stations with eight pine pegs, eight pine pegs scented with vanilla essence, eight pine pegs scented with almond essence and eight bait stations consisting of plastic containers of 20 cm depth and 10cm diameter with a mixture of cow fat, paraffin and peanut butter. The pegs were scented putting them into water and edible essences during 72hs. The stations were placed 10m apart, making a grid that occupied all the plot. The different elements were placed in the stations alternately and systematically. Both the pegs and the bait stations were set active for 3 days and checked every day, recording the gnawing evidence on the pegs and the consumption of bait. The bait stations where consumption was detected were replaced for a new one each time they were checked.

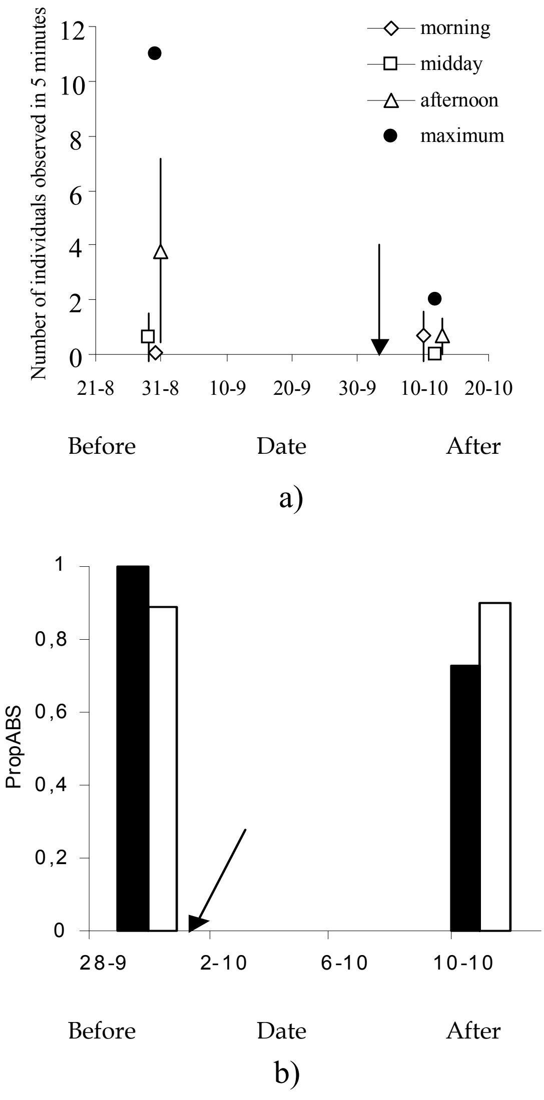

Fig. 6. a) Mean number of animals observed at five-minute intervals at different times: in the morning (11:00-12:00hs), at midday (13:30-15:00hs) and in the afternoon (16:00-17:00hs) and the maximum number of animals seen at five-minute intervals (maximum) before and after the use of rodenticide in the treated area; and b) proportion of bait stations with signs of rodent activity (PropABS) in the control area (white bars) and treated area (black bars) before and after the use of rodenticide. The arrows in both figures indicate the moment at which the rodenticide was set in the treated area (1/10/2001).

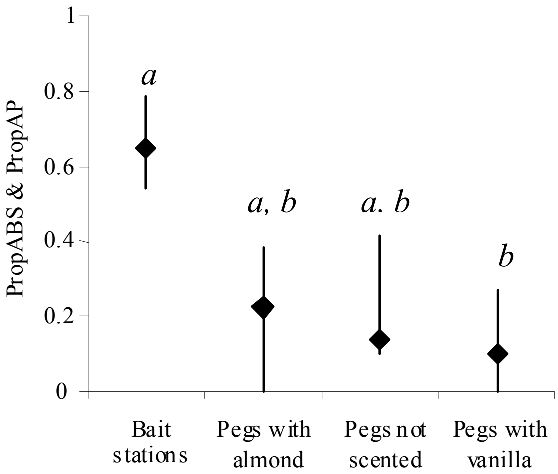

Fig. 7. Median proportion of bait stations (PropABS) and pegs (PropAP) with signs of rodent activity per grid in the coastal area. X^2= 6.517; gl= 3; n= 3; p= 0.089. The proportions that share the indices *a* and *b* do not show differences for the Wilcoxon test per pairs (X^2_c>0.05; p>0.2).

In the judicial cars warehouse, where complaints of rodent infestation have been made, five grids of 1900 m^2 (190 by 10 m) were placed. Each grid consisted of two parallel transects 10m apart, with 20 stations each one 10 m apart. The bait stations and the pegs were placed alternately in each station. In this site only pegs without essence were used. The bait stations and the pegs had the same characteristics as in the sampling performed in the coastal area and they were also set active during three nights.

For both samplings, the proportion of bait stations with rodent activity was calculated as in the previous section. The proportion of pegs with signs of rodent activity (PropAP) was calculated as follows:

$$\text{PropAP} = AP \big/ (TP - MP) \quad (3),$$

where *AP* is the number of pegs with signs of rodent activity, *TP* is the number of set pegs and *MP* is the number of missing pegs. The gnawing evidence on the wood was considered as signs of rodents on pegs. The possible differences in the proportions of pegs and bait stations with rodent activity per plot were assessed using a Friedman test. If differences were detected, comparisons per pairs were performed using a Wilcoxon test (Daniel, 1978). In the sampling performed in the coastal area, the missing pegs and bait stations were assessed.

4.2 Results

The proportion of bait stations with signs of rodent activity was marginally higher than the proportion of pegs (X^2= 6.517; gl= 3; p< 0.089) in the coastal area and significantly higher in the cars warehouse (X^2= 5; gl= 1; p< 0.025), figures 7 and 8. The use of essences did not increase the proportion of pegs with rodent activity (p>0.29). In both environments the bait stations were more sensitive than the pegs to detect the presence of rodents; since in some plots the presence of rodents was detected with bait stations and not with pegs. The loss of sampling elements was one of the problems. There were more missing pegs than bait stations, probably because it was more difficult to find them in the field due to their small size, figure 9.

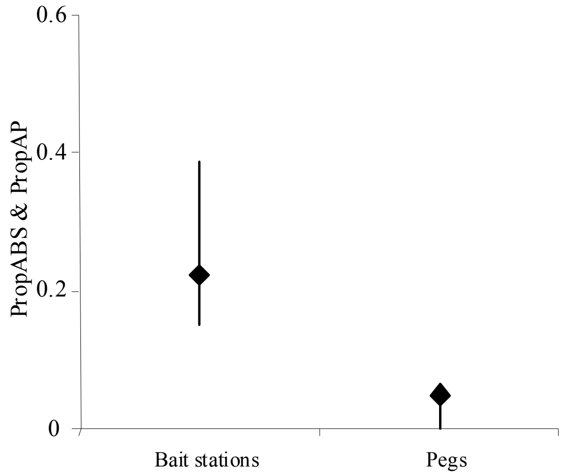

Fig. 8. Median proportion of bait stations (PropABS) and pegs (PropAP) with rodent activity per grid in a judicial cars warehouse X^2= 5; gl= 1; n= 5; p= 0.025.

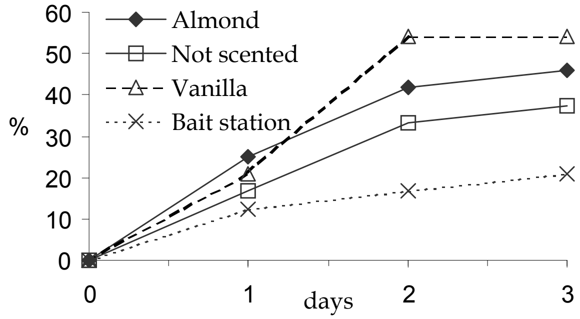

Fig. 9. Missing pegs and bait stations (in %) over the three days of sampling in the coastal area.

5. Evaluation of the use of bait stations to estimate the relative abundance in an urban reserve

According to the previous results, where it was observed that the bait stations could be used to detect the presence of rodents; in an urban reserve it was assessed if there was a good relation between the proportion of bait stations with signs of rodent activity and the relative abundance estimated using traps. For this purpose samplings were performed in an urban reserve which presents various environments with rodents of different species and with different abundances.

5.1 Materials and methods

A total of five samplings were conducted in the urban reserve, one in spring 2002 and four between autumn 2004 and summer 2005.

In spring 2002, 10 transects were placed. Thirty live capture traps, 15 Sherman traps and 15 cages, and 15 bait stations with hair-hunting traps were set on the transects. The arrangement of the traps and bait stations along the transect is shown in the figure 10.a. The traps were active during three consecutive nights and checked every day in the morning. The bait stations with hair-hunting traps consisted of styrofoam containers of $250cm^3$ containing 10g of a mixture of peanut butter, fat and vanilla essence. A strip of sticky tape was placed on the entrance of the container, so hair of the animals that entered stick on this tape. This allows to identify the individuals' species that have visited the bait stations, figure 4 and 11.

In autumn, winter and spring 2004 and summer 2005, nine transects were placed: three transects in a riparian thicket on the coast of the de la Plata river, three in an alders forest and three in a grassland dominated by *Cortaderia selloana*. Forty live capture traps (20 Sherman and 20 cage traps), and 20 bait stations with hair-hunting traps were set on the transects. The arrangement of the traps and bait stations along the transect is shown in the figure 10.b. The traps and stations were baited and checked like in spring 2002, and were active for the same period of time.

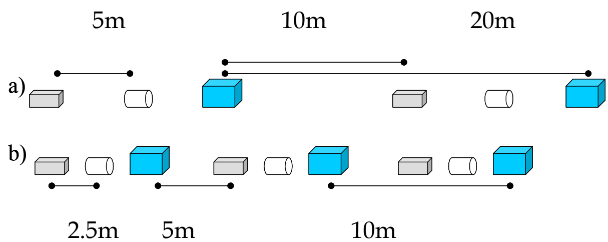

Fig. 10. Display of the different elements on the transects in a) spring 2002 and b) between autumn 2004 and summer 2005. The grey figures represent the Sherman traps, the light blue ones represent the cage traps and the white ones represent the bait stations.

Evidence of rodent activity in the bait stations was recorded third night after the setting. Incisor marks on the bait and/or rodent hair left on the sticky tape were considered as evidence of rodent activity in the bait stations (figure 11).

The trap success was calculated for each transect and this was compared with the proportion of bait stations per transect which showed signs of rodent activity by means of a correlation analysis. For this purpose the trap success was calculated and corrected as follows:

$$TS_c = \frac{(I - 1/6 * I)}{(T * N - 1/2 * ST)}, \quad (4)$$

Where *I* is the number of captured individuals, *T* is the number of set traps, *N* is the number of nights that the traps were active and *ST* is the number of traps that were sprung without captures.

Fig. 11. Photograph where gnawing evidence is observed on the surface of the nontoxic bait on the floor of the bait station as parallel marks, and hair left on the sticky tape.

It was necessary to correct the abundance the bait stations are exposed to, because it had been considered that if an animal is caught in a trap, it can not visit a bait station, so a correction factor of $1/6*I$ was subtracted from the number of captured rodents. It is not possible to know when each individual has been captured, if at dusk, in the middle of the night or at dawn. However, it can be assumed that on average all individuals have been caught in the trap half of the night. It was considered that as each period of sampling consisted of a three-night sampling, i.e. 6 half nights, the factor of correction should be 1/6 per capture.

The association between the proportion of bait stations with signs of rodent activity and the trap success was assessed by means of a simple linear correlation (Sokal & Rohlf, 1995).

5.2 Results

A total of 132 rodents (of six species) and 129 red opossums (*Lutreolina crassicaudata*) were captured, so the association between the percentage of bait stations with rodent activity and the trap success of rodents, of opossums and of both together was analyzed. The proportion of bait stations with rodent activity was correlated with the trap success of rodents (r= 0.4837; p= 0.000) and with the trap success of rodents and opossums together (r= 0.4665; p= 0.001), but it was not correlated with the trap success of opossums (r= 0.1233; p= 0.414), figure 12. These results confirm the observations performed in the field where it was determined that the marks corresponded to rodent incisors and rodent hairs, and not to marks made by opossums, figure 11.

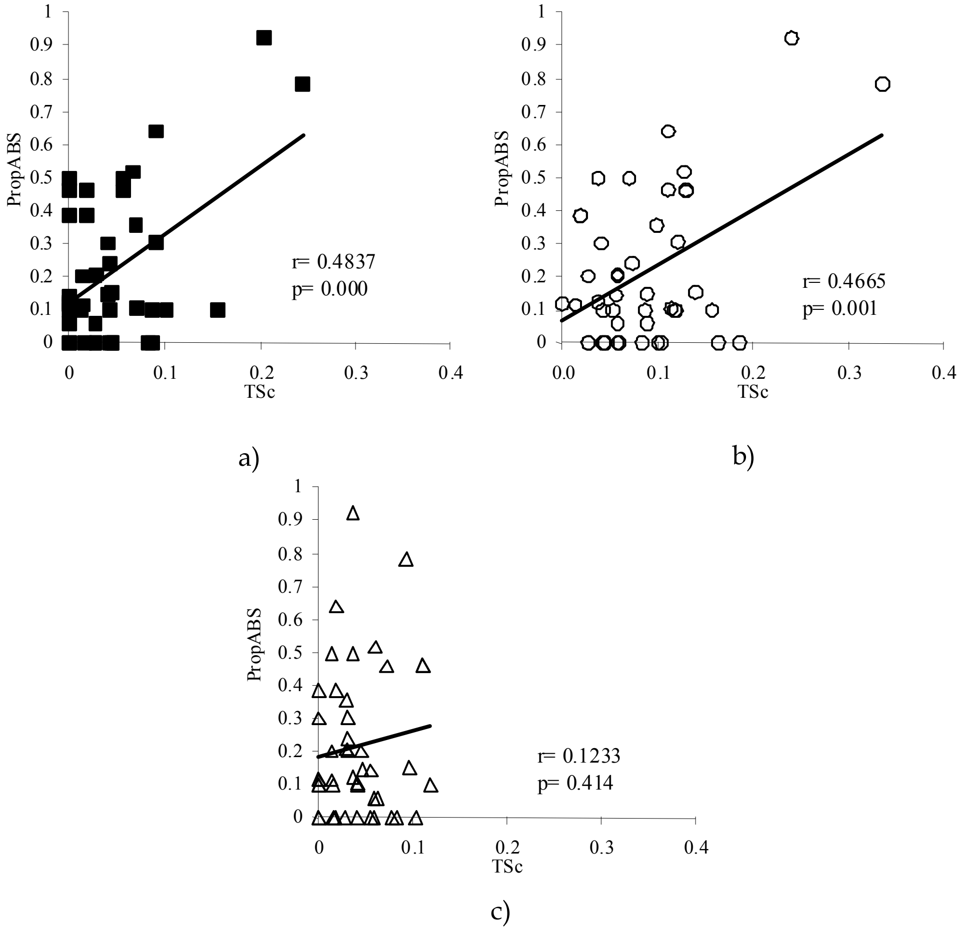

Fig. 12. Relation between the corrected trap success (TSc) and the proportion of bait stations with signs (PropABS). The lines represent the trend of association. a) TSc of rodents, b) TSc of rodents and opossums and c) TSc of opossums.

6. Evaluation of the use of bait stations and surveys about the presence of rodents to estimate the relative abundance in residential environments

With the objective of evaluate the use of bait stations and surveys about the presence of rodents to estimate the relative abundance, and evaluate their association with the trap success, samplings were conducted in different blocks of a shantytown and of a residential neighborhood in the city of Buenos Aires.

6.1 Materials and methods

A total of four samplings were conducted in the residential neighborhood: in winter, autumn, and spring 2004 and summer 2005; and three samplings were conducted in a shantytown: in summer, autumn and winter 2004. In each opportunity six different blocks in the residential neighborhood and between two and four different blocks in the shantytown were selected.

In each block, cooperation was requested to the people of the dwellings. In a residential neighborhood a dwelling was defined as a house, shop, house-shop or industry built in a lot. In the shantytown a dwelling was defined as a house, shop or house-shop that had a different number provided by the Secretary of Housing. Once "the responsible person" of the dwellings has agreed to cooperate with this study, a survey was conducted to know about the presence of rodents and their signs in their neighborhood and dwelling. The questions were the followings:

1. Have you ever had rats or mice in your house/job or have you seen gnawed objects or droppings?
2. Have you ever seen rats or mice in the neighbourhood?

For both questions if the person answered in an affirmative way, the following question was asked: when was the last time you saw one? in order to separate the recent events from the non-recent ones.

In each of the dwellings where people agreed to cooperate, bait stations with the same characteristics as in the section 5 were placed, figure 4. A fixed number of bait stations were set per dwelling. According to Aplin et al. (2003), in residential environments this way of distributing the rodent sampling elements is more adequate than the display on transects. It was decided that there would be two bait stations per dwelling, but exceptionally this number varied between one and eight when the dwelling was too small or big in size. Evidence of rodent activity was recorded in the bait stations seven days after their setting in the residential neighborhood and three and seven days after their setting in the shantytown. Bait stations were removed on the same day live Sherman and cage traps were set in each dwelling. In the same way as for the bait stations, a fixed number of each type of trap was placed, setting two Sherman and two cage traps in each dwelling. In some exceptional cases, this number varied between one and four Sherman and between one and eight cage traps and they were checked every day in the morning. The species of each captured animal was determined. The animals were sacrificed and collected.

The indices of rodent relative abundance were estimated on the base of the capture data, of the activity in bait stations and of surveys about rodents. In order to analyze the consistency of the associations between the indices, the analysis were performed at three different spatial scales: 1) taking each block as a sampling unit (analysis per block), 2) joining blocks according to their proximity defining different areas, and using these areas as a sampling unit (analysis per areas) and 3) using as different sample units the samplings performed in each period of the year (joining areas) and in each environment separately (shantytown and residential neighborhood; analysis per period).

For each sampling unit (which depended on the analyzed scale) the rodent relative abundance was estimated with the data of the surveys using the following indices: 1) the proportion of people who reported having had rodents in their dwelling during the last year (PropD365); 2) the proportion of people who reported having had rodents in their dwelling during the last semester (PropD180) and 3) the proportion of people who reported having had rodents in their dwelling during the last quarter (PropD90). The same indices were calculated to estimate the proportion of people who reported having seen rodents in their neighborhood at different time scales. The indices were calculated as follows:

$$\text{PropD365} = {PD365}/{P}, \quad (5)$$

$$\text{PropD180} = {PD180}/{P}, \quad (6)$$

$$\text{PropD90} = {PD90}/{P}, \quad (7)$$

$$\text{PropN365} = {PN365}/{P}, \quad (8)$$

$$\text{PropN180} = {PN180}/{P}, \quad (9)$$

$$\text{PropN90} = {PN90}/{P}, \quad (10)$$

where *PD365, PD180* and *PD90* is the number of people who reported having had rodents in their dwelling during the last 365, 180 and 90 days respectively; *PN365, PN180* and *PN90* is the number of people who reported having seen rodents in their neighborhood during the last 365, 180 and 90 days respectively; and *P* is the total number of people surveyed in the sampling unit.

The proportion of bait stations with signs of rodent activity (PropABS, equation 2) and the proportion of dwellings with rodent activity (PropDABS) were estimated using the data of rodent activity detected in the bait stations:

$$\text{PropDABS} = {DABS}/{D} \quad (11)$$

where *DABS* is the number of dwellings with at least one bait station with signs of rodent activity and *D* is the number of sampled dwellings in each sampling unit.

Finally, the rodent relative abundance was estimated with the data of the captures using the trap success (TS, equation 1), and the proportion of dwellings with captured rodents (PropDR) as:

$$\text{PropDR} = {}^{DR}\!/_{D} \quad (12),$$

where *DR* is the number of dwelling with at least one captured rodent and *D* is the number of sampled dwellings in each sampling unit.

Firstly, in order to analyze the association between the different indices of relative abundance, non-parametric Spearman correlations were used due to the low number of sampling unites considered and lack of normality in the distribution of the indices (Daniel, 1978). Then, it was analyzed if there was a functional relationship between the trap success (since it is a relative abundance index widely accepted) and the other indices of relative abundance estimated using simple regression models:

$$y_i = a + b.x_i$$

being for the model y_i the trap success, x_i the other indices, *a* the intercept and *b* the slope of the line. The model was adjusted and the hypothesis of the zero slope was tested with a randomization method (Manly, 1991), 5000 randomizations were performed using the RT program (Manly, 1996).

6.2 Results

In the shantytown and in the residential neighborhood 30.0% of the people surveyed reported having had rodents in their dwellings and 41.0% reported having seen them in the neighborhood during the last 90 days (total of people surveyed = 429). Evidence of rodent activity was detected in 49 out of 805 bait stations set in 382 dwellings. A total of 25 *R. rattus*, 52 *R. norvegicus* and 28 *M. musculus* were captured with a total trapping effort of 1769 cage-nights and 1837 Sherman trap-nights, set in 347 dwellings.

All the indices showed positive associations with the other indices at the three analyzed scales. When each block was considered as a sampling unit, most of the associations were significant with a probability lowered than 0.05 (Table 2). The weaker associations were observed between the trap success and the proportion of people who reported having seen rodents in the neighborhood during the last 90, 180 and 365 days. A weak association was also observed between the proportions of people who reported having seen rodents in their neighborhood during the last 90 days and the proportion of dwellings with captured rodents. The proportion of people who reported having had rodents in their dwellings during the last 90 days showed a higher coefficient of association with trap success than the proportion of people who reported having had rodents during the last 180 or 365 days. Both the proportion of bait stations with signs of rodent activity and the proportion of dwellings with bait stations with signs of rodent activity proved to be associated with the rest of the analyzed indices, being low the coefficient of Spearman association with the trap success and with the proportion of dwellings with rodent capture.

In the analysis per area, the general patterns of associations observed at block scale were maintained; except for the proportion of people who reported having seen rodents in their neighborhood during the last 90 days, which was significantly related to the trap success ($p<0.05$) and the associations between the trap success and the proportion of bait stations with signs of rodent activity and of dwellings with signs of rodent activity, which were marginally significant ($p<0.10$), table 4.

At a larger spatial scale (per period) several associations lose their statistical significance; however, the associations between the trap success and the proportion of people who reported having had rodents in their dwellings during the last 90, 180 and 365 days continue to be significant, table 5. The proportion of bait stations with signs of rodent activity and the proportion of dwellings with signs of rodent activity showed the same association pattern with the other indices of relative abundance that had been observed at the "per area" scale. The decline of significance in the correlations could be due to the lower number of sample units, and not necessarily due to the absence of association between the indices. This is because at higher scale there are less sampling unites as a consequence of pooling the sampling units of the lower scale; and, although the correlation coefficients increased, some were not significant because the degrees of freedom decreased, tables 2, 3 and 4.

The regression analyses were performed at block scale due to the fact that: 1) there are more sampling unites, 2) it demands less sampling effort per replica making this analysis scale the most feasible to use in future works, and 3) the highest number of significant associations was observed at this scale. The regression analysis was not performed for the proportion of people who reported having seen rodents in their neighborhood during the last 180 and 365 days due to the fact that the associations were marginally significant. The proportions of people who reported having had rodents in their dwellings during the last 180 and 365 days were not analyzed either, because the information provided by these indices is redundant in relation to the proportion of people who reported having had rodents in their dwellings during the last 90 days, being this index the one which presents a higher association with the trap success.

	PropD180	PropD90	PropN365	PropN180	PropN90	TS	PropDR	PropABS	PropDABS
PropD365	0.932*	0.904*	0.588*	0.509*	0.550*	0.561*	0.540*	0.547*	0.533*
PropD180		0.964*	0.581*	0.586*	0.628*	0.573*	0.567*	0.620*	0.611*
PropD90			0.582*	0.656*	0.695*	0.579*	0.580*	0.590*	0.581*
PropN365				0.675*	0.688*	0.284+	0.338*	0.391*	0.419*
PropN180					0.953*	0.257+	0.313*	0.479*	0.479*
PropN90						0.248+	0.294+	0.492*	0.494*
TS							0.972*	0.326*	0.314*
PropDR								0.389*	0.380*
PropABS									0.993*

Table 2. Coefficient r of Spearman correlations test between the indices of relative abundance considering each block as the sampling unit (N=34). PropD365, PropD180 and PropD90: proportion of people who reported having had rodents in their dwellings during the last 365, 180 and 90 days, respectively; PropN365, PropN180 and PropN90: proportion of people who reported having seen rodents in their neighborhood during the last 365, 180 and 90 days, respectively; TS: trap success; PropDR: proportion of dwellings with rodent capture; PropABS: proportion of bait stations with signs of rodent activity; and PropDABS: proportion of dwellings with bait stations with signs of rodent activity. * $p<0.05$ y $+p<0.10$.

	PropD180	PropD90	PropN365	PropN180	PropN90	TS	PropDR	PropABS	PropDABS
PropD365	0.963*	0.945*	0.665*	0.583*	0.671*	0.668*	0.573*	0.688*	0.716*
PropD180		0.963*	0.664*	0.636*	0.722*	0.679*	0.595*	0.779*	0.798*
PropD90			0.631*	0.718*	0.778*	0.716*	0.672*	0.706*	0.731*
PropN365				0.700*	0.731*	0.359+	0.335*	0.584*	0.650*
PropN180					0.964*	0.359+	0.484*	0.729*	0.753*
PropN90						0.362+	0.431*	0.768*	0.793*
TS							0.934*	0.368+	0.381+
PropDR								0.370+	0.379+
PropABS									0.993*

Table 3. Coefficient r of Spearman correlations test between the indices of relative abundance joining blocks according to their proximity, considering these new areas as sampling units (N=17). Symbols and abbreviations idem table 2.

	PropD180	PropD90	PropN365	PropN180	PropN90	TS	PropDR	PropABS	PropDABS
PropD365	1.000*	0.929*	0.500	0.714*	0.893*	0.750*	0.679+	0.886*	0.886*
PropD180		0.929*	0.500	0.714*	0.893*	0.750*	0.679+	0.886*	0.886*
PropD90			0.464	0.679+	0.821*	0.929*	0.857*	0.829*	0.829*
PropN365				0.571+	0.679+	0.357	0.607+	0.886*	0.886*
PropN180					0.893*	0.429	0.536+	0.829*	0.829*
PropN90						0.607+	0.679+	0.886*	0.886*
TS							0.893*	0.600+	0.600+
PropDR								0.600+	0.600+
PropABS									1.000*

Table 4. Coefficient r of Spearman correlations test between the indices of relative abundance per period of the year, maintaining the residential neighborhood and shantytown samplings separately (N=7). Symbols and abbreviations idem table 2.

The four models of regression presented intercept close to zero and positive slopes. For the proportion of people who reported having had rodents in their dwelling during the last 90 days and the proportion of dwellings with rodent capture, the slopes were significantly different from zero, while the proportion of bait stations with signs of rodent activity and the proportion of dwellings with bait stations with signs of rodent activity were only marginally significant, table 5.

Regressor	Model	*t*	*p*
PropD90	*a:* -0.002		
	b: 0.076	3.99	0.0004
PropDR	*a:* 0.001		
	b: 0.145	7.65	0.0002
PropABS	*a:* 0.016		
	b: 0.082	1.75	0.0828
PropDABS	*a:* 0.017		
	b: 0.042	1.49	0.0880

Table 5. Simple linear regression models $y_i = a + b\, x_i$, where y_i is the trap success, x_i are the other indices of relative abundance, *a* is the intercept and *b* is the slope of the line or regression coefficient. $t_i = b_i / SE(b_i)$, i = 1 until n, and *p* = exact probability of the value t_i for the regression coefficient estimated with a randomization method. Symbols and abbreviations idem table 2.

7. Discussion

The different evaluated methods detected evidence of rodent activity; however, the count of burrow entrances and animals only allowed to detect the presence of *R. norvegicus*. The differences in body size between *R. norvegicus* and the other smaller native species, in their behavioral habits or simply because they were not present in the area could be the cause for not detecting them with these techniques. The methods of kill trapping of animals are only accepted in particular cases and the methods producing a quick death and without suffering for the captured animals are advisable (Beaver et al., 2001). Taking into account this recommendation, the glue traps should not be used under any circumstance, because the animals captured could die due to stress or simply because of tiredness when trying to get released (Kravetz, *personal comments*). In addition, they present other disadvantages such as its use is limited to closed environments, with low humidity and without environmental dust since the external environmental conditions limit the glue adherence. Another problem of the glue as a method of kill trapping is the risk of capturing and killing unwanted species. This type of trapping is frequently used by pest controllers because it is economical and allow the capture of several animals per trap, while other killing traps (e.g. snap trap) are more expensive and become inactive after the first capture. When rodenticides are used to control rodents, the animals die at the site and many times in places that are difficult to reach; thus the pest controllers prefer to use glue traps at sites where it is risky to use toxic substances and it is also necessary to remove the animals from the site, such as food warehouses, food industries, supermarkets, etc.

The use of footprint traps was not considered as it is possible to be used in closed spaces, but with some limitations in open areas, and they can be disturbed by other animals, wind, etc.

In relation to the detection of differences in the abundance, the bait stations were more sensitive than the direct observation; probably because of the low number of days the counts were performed, and because of the large variation per interval of time and between the different times of the day in the number of active animals. A correct estimate of the abundance using this last method requires a lot of intervals of observation. The count of burrow entrances can also be used to estimate the abundance, but its use would be limited by the visibility conditions of the entrances in relation to its size and by the visibility of the habitat. This technique may not be appropriate under high cover conditions or where the rodent density may not be as high as the one observed in this sampling, since even 17 individuals were recorded in 1800 m^2 in a period of five minutes (in a time of the day where *R. norvegicus* has low activity, Macdonald et al., 1999) and an average of two individuals were captured with eight traps in an hour.

The bait stations were useful to detect the presence of rodents in the coastal area; they detected changes in the abundance due to the use of rodenticide, and showed an association with the trap success both in natural environments as the urban reserve, and in residential environments as the studied neighborhoods.

The proportion of bait stations with signs of rodents seem to be an adequate variable to estimate the abundance of small mammals (Blackwell et al., 2002; Brown et al., 1996; Gurnell et al., 2001; Gurnell et al., 2004), while the quantity of consumed bait would be affected by competition, microhabitats preferences and the risk of predation (Brown, 1988; Kotler, 1997). The use of bait stations allows performing monitoring programs of pest species in big areas due to its low cost (Battersby & Greenwood, 2004). Disposable containers could be used as bait stations and then discarded after the sampling, which simplifies the post sampling activities, since they do not need to be disinfected and washed like in the case of traps. In addition, due to its low cost, they do not represent an expensive element for people, being low the risk of loss due to theft. This allows its use in a wide variety of public spaces such as lawns, parks and in the streets. On the other hand, the bait stations are easy to be prepared and set, and in relation to the wood pegs they are easier to locate and are more effective to detect rodents. However, in the same way as it happens with the methods that involve animal trapping, there are a number of factors that will affect this index of relative abundance; thus, the indices can only be comparable under similar conditions and during short intervals of time.

The use of bait stations as a method of rodent sampling has the disadvantage of not providing any information regarding the individuals; such as species, body size, sex, reproductive condition, etc. The addition of sticky tape to the bait station where samples of animal hair were left could allow the identification of rodent species that visited it, due to the fact that the hair has specific characteristics (Busch, 1986; Cavia et al., 2008; Day, 1966). Nevertheless, for this purpose it is necessary to have an identification key according to the morphological characteristics of the hairs of the species likely to be present in the study area.

The use of surveys is a methodology widely employed in the field of sociology (Galtung, 1978; Kerlinger, 1988) and there is a significant number of works where they are used to assess the condition of the population of wild species with some risk of preservation or with an economic relevance (Filion, 1978). Sometimes hunters, park rangers, naturalists, etc. are surveyed because they are considered well-qualified. In the present study non-qualified people were surveyed. Surveyed people remembered quite accurately the moment and the place where they were in contact with rodents, probably because of being afraid of them. The surveys can only be used in inhabited places (residential and/or work) where people stay most of the time. The question asked to people about whether they had rodents in their dwelling seems to be more adequate than the question about whether they had rodents in their neighborhood, since the responses of the first question were associated to the other indices of relative abundance at the three analyzed scales, while the responses to the second question showed associations only with some indices and at some scales. Besides, the proportion of people who reported having had rodents in their dwelling during the last 90 days presented a linear relation with the trap success, indicating that both indices vary proportionally.

It would be useful to compare the indices used with absolute values of rodent abundance, but for this purpose some assumptions need to be met, and they are sometimes difficult to guarantee. In order to estimate the abundance with capture-mark-recapture samplings like the ones performed in the reserve; it is necessary to have recapture rates higher than 20%, which were not reached in this environment and with the sampling design made. In the case of removal samplings such as the ones performed in the neighborhoods, in order to apply the pattern of capture per effort unit (Hayne, 1949), there should be a decrease in the number of animals captured in the following days and this did not occur in these samplings. Due to the impossibility of calculating absolute abundances with the data obtained, the indices were contrasted, and the trap success was considered as the most reliable way to estimate the relative abundance because it is associated with the absolute abundance (Bronner & Meester, 1987) and it is widely used to estimate the rodent abundance.

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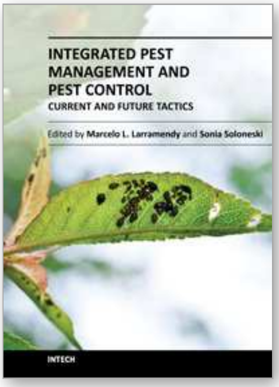

Integrated Pest Management and Pest Control - Current and Future Tactics

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Integrated Pest Management is an effective and environmentally sensitive approach that relies on a combination of common-sense practices. Its programs use current and comprehensive information on the life cycles of pests and their interactions with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means and with the least possible hazard to people, property, and the environment.