3rd International Conference on Rodent Biology and Management

Hanoi, Vietnam September 2006

3rd International Conference on Rodent Biology and Management

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28 August 2006

Prof. Nguyen Van Tuat
National Institute of Plant Protection
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VIETNAM

Dear Conference Participants

On behalf of the Conference Organising Committee, I have great pleasure in welcoming you to *3rd International Conference on Rodent Biology and Management* (3rd ICRBM) here at the Thang Loi Hotel, Hanoi, Vietnam.

Following the success of both the 1st and 2nd Conferences held in Beijing in 1998 and Canberra in 2003, the objective of the 3rd Conference is to once again to bring together scientists and practitioners who are interested in all aspects of rodent biology and their management. Currently we are expecting up to 150 rodent biologists from around the globe to gather for 5 days to exchange research and ideas.

The Committee trusts that you will make the most of this excellent opportunity to meet others working on many different aspects of rodent biology and management. We hope that many new friendships, learnings and collaborations will develop during the next few days.

We look forward to meeting you during the Conference and welcome your contribution and participation.

Please enjoy the hospitality and culture of Hanoi and Vietnam.

Yours sincerely

Prof. Nguyen Van Tuat
On behalf of the *3rd ICRBM* Conference Organising Committee

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SOCIO-ECONOMIC TOOLS FOR RODENT MANAGEMENT RESEARCH: RECENT EXPERIENCE FROM AFRICA AND ASIA

Steven R. Belmain and many colleagues

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The scientific development of anti-coagulant rodenticides led to a complete transformation of rodent pest control services throughout the world. Suddenly it became economically practical to eradicate localised rodent populations in agricultural or urban environments. The success of chronic poisons became doctrine among rodent experts. However, understanding how rodent behaviour was exploited by chronic poisons, the differences between chronic and acute poisons, and the way poisons need to be delivered, continue to be poorly understood by the general public and people attempting to manage their own rodent pest problems. The success of chronic rodenticides has its limitations prescribed by human knowledge, socio-cultural context and, of course, by the nature of the rodent pest problem experienced. In short, our best rodent management tools can and do fail when individuals and experts do not understand the circumstances and tools with which they are attempting to carry out rodent management.

Recently completed research to develop ecologically-based rodent management (EBRM) strategies for rural agricultural communities in Bangladesh and South Africa has shown that it is vitally important to understand the knowledge, attitudes and practices (KAP) of people experiencing rodent pest problems. Tools for evaluating ethno-ecology and human behaviour were developed and implemented as part of these EBRM research projects. Community focus groups were used to understand the decision making process and the risks and benefits of rodents and management actions. Resource maps, cropping calendars and decision analysis matrices helped describe the opportunities and constraints experienced by community members; while changes in human behaviour in response to rodent management interventions were monitored through the use of individual KAP survey questionnaires and farmer diaries.

By using these socio-economic tools, it was possible to quantify the impact of rodent pests on people's livelihoods as well as the cost-benefits of new rodent management strategies. Data from these studies showed that communities could cost-beneficially reduce rodent impacts. Participatory approaches of research were adopted which allowed rodent ecology research to be carried out that would not have otherwise been feasible, while at the same time improving knowledge among community members about rodents and appropriate management strategies. The prospects of positive long-term changes in human behaviour were enhanced through using these socio-economic tools.

Anthropological and economic studies are essential when trying to understand the impact of rodents on people's lives. Research in the RatZooMan project studying the role of rodents in the transmission of zoonotic diseases in southern Africa showed that human behaviour and actions are often responsible for the persistence and spread of zoonosis in the environment as well as affecting the individual risk of exposure to disease. Socio-economics also affect people's health care seeking behaviour, causing delay or inappropriate treatment choices. Witchcraft, curses, superstitions and religion can influence the fundamental knowledge within a community about human disease and can even affect the way in which rodent pest problems are perceived and managed. Scientists who desire to be praised (and not cursed) for their research on rodent pest management would ignore the socio-economic aspects of rodent management at their peril.

FERTILITY CONTROL OF RODENT PESTS – THE FUTURE OUTLOOK

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The management of rodent pests in agriculture, for biodiversity conservation and for disease prevention is a time-consuming and difficult task. Many of the current tools used in agricultural production require intensive effort mainly by the landowner and the householder, but also by extension officers and other members of the community. The application of poisons, use of traditional methods, fumigation, burrow destruction, establishment and monitoring of trap systems require labour and resources. These current tools are increasingly being used in developing countries to manage rodent pests using an ecologically-based management approach. However, additional tools continue to be required to counter the many impacts of rodents. New tools could include improved poisons, but in this plenary talk I will focus on the potential for the development and application of fertility control and its role in overall strategies for the management of rodents in our production systems and natural landscapes.

More than 20 years ago it was recognised that developing methods for fertility control rather than for lethal control may reduce population increases before they reach levels that lead to damage in crops, storage or households. Fertility control was seen as potentially more species specific, safer in the environment, as well as being cost effective. In the last two decades, various agents such as gonadal steroids, pituitary and/or hypothalamic hormones and chemicals which disrupt follicular development, implantation or cause abortion have been assessed. Their effects were generally neither species specific or permanent.

The first approaches examined the effects of steroids such as oestrogens, progestagens and androgens on male and female fertility. While major effects on the uterus, ovulation and spermatogenesis could be demonstrated, side-effects were often apparent in individuals. The use of these steroids also required continuous exposure and this was difficult to achieve in bait-delivered forms as many were unpalatable at the concentrations required for efficacy. Nevertheless in recent times colleagues in China have been trialling the use of oestrogens and progestagens for rodent pest control in the grasslands. For some species it appears to be effective because the animals cache their foods and continue to eat the bait over several weeks to months. When this occurs during the breeding season there is reduced recruitment (see Zhang et al., Wan et al., this conference).

In the last decade in Australia a major research effort has attempted to develop viral-vectored fertility control for introduced mammal pests (rabbits, foxes and mice). Recently, the work in the rabbit and fox has ceased due to technical challenges with the vectors that were selected for engineering, plus the ecologically-defined targets for the level of fertility control required to reduce the wild populations were extremely high. For the house mouse, a specific virus, mouse cytomegalovirus, has been engineered to carry a mouse reproductive gene, mZP3 (recMCMV-mZP3), which when it infects mice makes them infertile for a period equivalent to the duration of the breeding season. However, our understanding of the transmission characteristics of our chosen vector is insufficient at this stage to ensure that a recMCMV-mZP3 might be effective in the field. Even if we could demonstrate transmission of the recMCMV and induction of infertility in the contact mice there are major hurdles to meet regarding legislative requirements for release in the field in Australia.

More recently in larger mammals, there has been a move towards the development of oral delivery systems for fertility control agents which will directly disrupt follicular and oocyte development in the ovary. Early trials in mice, cats and dogs indicate that some chemicals are highly effective if given intramuscularly in slow release formulations. Adapting this so that delivery can be successful via oral baits is the next challenge. Making it species-specific will also be critical to their application and success in the field.

ANIMAL BEHAVIOUR IN SMALL MAMMAL MANAGEMENT

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Some small mammal populations require intentional human interference to conserve rare or threatened species or to minimise adverse effects in plant production. Without thorough understanding about how small rodents behave in their environment and consideration of how they react to management efforts, management will not be optimal. Social behaviour, spatial and temporal activity patterns, predator avoidance and other behavioural responses can affect management actions taken to minimise unwanted effects of rodents in plant production. Some of these behavioural patterns and their causes are very well studied. However, their impact on pest rodent management, especially for novel management approaches, is not always clear.

This talk is based on data from field studies conducted on several pest rodent species. I limit the scope of the talk to behavioural aspects that are relevant for the management of pest rodents based on habitat manipulation in agro-ecosystems.

Habitat manipulation occurs necessarily as part of land use (e.g. when harvesting) and is linked to seasonal migration of rodents from refuge to crop habitats. As a management technique (removal of refuge, field sanitation) habitat manipulation is usually conducted to reduce shelter and food availability and to increase predation pressure on rodents. In this regard habitat manipulation is thought to reduce the abundance of pest rodents and represents one of the recommended management techniques within the framework of ecologically-based rodent management.

The results of the studies presented show that rodents consistently respond to decreased vegetation height with reduced movements and increased risk sensitivity in their feeding behaviour. This seems to be mainly due to elevated perceived predation risk. The behavioural responses may lessen the efficacy of the management because the desired effects of predators might be mediated. However, it remains largely unknown to what extent behavioural responses compensate at the population level for the expected consequences of habitat manipulation.

The findings highlight that it is advantageous to understand how the target species react to habitat manipulation in order to maximise the management effects by an appropriate combination of techniques, optimal timing and adequate spatial scale.

RODENTS AND PLAGUE: NEW ATTENTION FOR AN OLD FOE.

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Plague (*Yersinia pestis* infection) has in the past had devastating effects on human populations and has become an epithet for outbreaks of infectious disease. Many consider it to be a disease of the medieval times but it remains endemic in natural populations of rodents, and a medical threat with numerous human cases per year throughout Asia, parts of Africa, the United States and South America. During the past years, the infection has received renewed attention due to the alarmingly increasing numbers of cases, predominantly in Africa, the discovery of new or re-emerging foci, the detection of resistance to antibiotics in some strains and the fear for bioterrorism.

Besides being relevant for public health, plague is also a complex ecological system with three components: “host-vector-bacteria”. This makes it an interesting model system for the study of infections within and between species. Recent work has attempted to develop such models, based on statistical analysis of historical time series, or on the mathematical modelling of existing ideas about the transmission of plague. New, or rediscovered, insights however, show that the classical ”rodent-flea-human” transmission cycle, typical for the Third plague pandemic that started in the 19th century, is not universal, and in fact may not even be representative for most of the areas where plague occurs.

There is indeed a large variety of natural plague foci and they seem to be extending at three different spatial levels: (1) the number of countries that recently experienced plague is increasing; (2) new foci are appearing in countries with known plague occurrence; (3) some, although certainly not all, existing foci seem to be expanding slowly. On the other hand, plague has historically shown the capacity to spread very fast over large distances, but most extant foci are highly focalised geographically. The reasons for this enigmatic difference are likely to be found in the interactions between the environment, the pathogen, different potential host and vector species as well as human behaviour. Observations and modelling studies suggest that climate is likely to exert a strong influence on plague ecology and different scenarios for climate change suggest improved conditions for plague persistence or spreading. Historical changes in climate can also be linked to historical plague outbreaks.

In this paper I will present and review data from Vietnam, Central Asia, Africa and North America to illustrate the above and demonstrate that the renewed interest in plague is indeed justified.

ECOLOGICAL ECONOMICS OF RODENT CONTROL

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The lecture will, using a particular case study system (the *Mastomys natalensis* system of Tanzania), summarize the ecological and economic modeling of rodent pests – their impact and control. Both a detail-rich model and a simplified model will be reported and the advantage of different types of models will be discussed. The discussion of the *Mastomys* system will then be put into the broader context of the modeling of rodent pests in agricultural systems.

MANAGING RODENT ZOONOSES IN AN AFRICAN CITY: DOES THE BOSTON MODEL WORK?

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The "Boston model" describes a successful rodent management plan which succeeded in a first world city. Many third world cities are under-resourced and comprise a mix of first world infrastructure and burgeoning informal shack settlements, and it is debatable whether the Boston model would apply. Such a city is Durban, a major harbour on the east coast of South Africa and home to three million people. As a study site in the international "RatZooMan" (Rodent Zoonosis Management: www.nri.org/ratzooman/) project, an opportunity was presented to investigate the sanitary risks due to rodents in both formal (harbour, business district and formal suburbs) and informal (shacks) sectors, and to evaluate the relative merits of different management interventions suggested by the Boston model. Blood and tissue samples of approximately 250 rodents of four species (*Rattus norvegicus*, *R. tanezumi*, *R. rattus*, *Mus domesticus*, *Mastomys natalensis*), from the greater Durban region were tested for antibodies or DNA for plague, leptospirosis and toxoplasmosis. Samples came predominantly from the harbour and commercial districts of Durban and the Cato Crest informal shack settlement. To determine environmental and socioeconomic disease risk factors in Cato Crest, rodent trapping was accompanied by parallel studies of soil pH and socioeconomic factors. No rodents were positive for plague, but five Norway rats, *R. norvegicus* (2.5% of sample tested) were positive for toxoplasmosis, and 19 (10.3% of sample tested) were positive for leptospirosis. Infections were concentrated in two major foci: a localised area of Cato Crest and the CBD of Durban. The results guided precise and effective action by municipal vector control staff (e.g. multi-feed rodenticide baiting) to prevent serious disease outbreaks. Recent serology tests of humans living in Cato Crest (n = 219) showed 0% exposure to plague, 23% to leptospirosis and 35% to toxoplasmosis. Compared to shack-dwellers, residents of brick houses showed slightly lower exposure to both diseases. Based on RatZooMan's results, a grass-roots, politically-motivated beautification campaign has been launched in the Cato Crest shack settlement. The initiative owes much of its current success to implementation of principles inherent in the Boston model.

ECOLOGICALLY BASED MANAGEMENT OF RODENTS IN VIETNAM

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The damage to lowland irrigated rice has been steadily increasing in the major rice growing areas of Vietnam over the last 20 years to > 500,000 ha damaged as new high yielding varieties and double or triple cropping has being implemented. Farmers have been responding to this increase in damage through application of rodenticides and by erecting plastic fences to exclude rats from their fields. These rodenticides and plastic fences are expensive, yet significant damage still occurs. In an effort to reduce rodenticide use and the use of plastic fences, large-scale replicated field experiments were designed to test a range of ecologically based rodent management strategies, based on the breeding dynamics and changes in the population abundance of the key rodent pest species (ricefield rat, *Rattus argentiventer*; lesser ricefield rat, *R. losea*). These practices were developed with farmers, extension personnel and researchers.

A 4-year field experiment was conducted in Me Linh District, Vinh Phuc province to examine the effectiveness of ecologically-based rodent management strategies (Brown *et al*. in press). This study was supplemented by another study at Kim Dong District, Hung Yen, where farmers grew corn and soybeans without lowland irrigated rice. This was a valuable test of the robustness of the recommended rodent management strategies to see if they could be used in a different farming system. In each case we monitored changes in population abundance of rats, damage to crops, and monitored what practices the farmers conducted and performed a partial benefit:cost analysis.

In Vinh Phuc province, there was no difference in the population abundance of rats and no difference in the level of rat damage to crops between the treated and untreated sites. There was a 75% reduction in use of rodenticides and plastic fences on treated sites compared to untreated sites. This translated into a 18:1 benefit:cost ratio on treated sites compared to 3:1 on untreated sites, mainly through the significant reduction in money required for rodenticides and purchasing plastic fences (Brown *et al*. in press, Singleton *et al*. 2004).

In Hung Yen province, damage by rats was ~40% prior to the commencement of this project. Linear trap barrier systems (TBS) were used to intercept movements of rats from source to sink habitats. There was a significant reduction in the use of rodenticides (from 100% to 10%). Yields significantly increased from 3.2 t/ha to 5.4 t/ha (40% increase).

These projects demonstrated the usefulness and broad scale applicability of ecologically-based rodent management systems for a variety of lowland cropping systems in Vietnam.

The major recommendations from this work are:

1. Community TBS
   - 1 TBS per 10 ha
   - Set in summer rice crop only
2. Work together to control rats
   - Control rats together over large area – stop re-invasion
3. Hunt rats and destroy burrows before maximum tillering stage of rice
   - Kill rats before they start breeding.

- Killing one rat in tillering stage is the same as killing 150 rats at harvest.

4. Synchronise planting and harvesting
   - Keep rat breeding season short
5. Keep fields clean of weeds (sanitation)
   - No food or shelter for rats
6. Keep bund size small (<30 x 30 cm)
   - Stop rats from building burrows in fields

A large-scale project is now underway to implement these findings across the Mekong and Red River deltas of Vietnam.

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THE SOCIAL BIOLOGY OF RODENTS

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The social biology of rodents is diverse and results from a series of interactive and complex selective forces for optimal foraging, maximizing reproduction, avoiding predation, survival, and life history traits (Wolff and Sherman, 2007). In this plenary talk, I provide an overview of the basic components of rodent social biology including spacing patterns, mating, dispersal, communication, and associated behaviors that typify this fascinating group of mammals.

The spacing patterns of females are a function of reproduction, relatedness, and protection of offspring, whereas male mating tactics depend on female defensibility. Females typically are intrasexually territorial defending exclusive space with respect to unrelated females. The vulnerability of young to infanticide appears to be the selective force that shapes female spacing and mating behavior. Food does not appear to be a defensible resource for rodents, except for those species that larder hoard nonperishable items such as seeds. Males exhibit four mating tactics depending on access and defensibility of females. Males defend individual females (monogamy), exhibit female- or resource-defense polygyny, occupy large home ranges that overlap two or more females and those of other males (promiscuity), or live communally with several males and females.

Dispersal is male biased and involves emigration of subadults from the maternal site to avoid female relatives and to seek unrelated mates. Young females typically are philopatric and form kin groups resulting in genetic sub-structuring of the population, which in turn affects effective population size and genetic diversity. At high densities when the habitat is saturated, emigration from the natal site is inhibited by a social fence of territorial neighbors resulting in communal nesting and population buildup locally.

Olfactory signals are the primary form of communication and include chemosensory cues for individual recognition, establishing dominance, and reproductive stimulation. Scent marking is a major form of communication and is used in reproductive competition and to assess prospective mates, but it is detected by predators. Avian and terrestrial predators eavesdrop on visual and olfactory cues of rodent urine and scent marks to locate prey. This vulnerability to predation risk, however, does not appear to deter scent marking or inhibit reproduction in rodents.

Females do not appear to alter the sex ratio of litters in response to maternal condition but some arvicoline rodents produce more daughters in spring and sons in autumn. Rodents are relatively monomorphic, however females tend to be larger than males in the smallest species and smaller in the larger species. Aquatic rodents are typically larger than their terrestrial counterparts. Predation by fish might select against small body size in aquatic environments, whereas larger rodents are more vulnerable in terrestrial habitats. Rodents are most vulnerable while foraging and thus predation risk has direct effects on foraging time, place, and activity budgets and indirect effects on life history traits such as group formation, sociality, alarm signaling, and reproductive effort. Knowledge of the social biology of rodents can ultimately affect management decisions.

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Symposium: Building bridges: life histories, behaviour and management

Chairs: Hannu Ylönen and Jerry Wolff

Oral Presentations

TO DISPERSE OR BREED AND DIE - THE RELATIVE SIGNIFICANCE OF VARIOUS DEMOGRAPHIC COMPONENTS FOR THE PERFORMANCE OF POPULATIONS

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In the last few decades several population biologists have focused on the effects of dispersal on the dynamics of populations. This has partly been due to the expansion of landscape ecological theory in general and to metapopulation biology in particular. Furthermore, several population biologists have focused on the significance of dispersal as a factor stabilising populations and an agent for synchronisation of populations in space. However, few studies have tried to compare the relative contribution of various demographic components (i.e. immigration and emigration as two phases of dispersal, death and emigration) in shaping the dynamics of populations.

Here, I will present results from experimental model systems using 28 enclosed populations of root voles, *Microtus oeconomus,* as the experimental unit. The populations have inhabited experimentally manipulated patchy landscapes, and we have monitored the dynamics of all demographic components through time.

Our results show that independent of landscape characteristics dispersal is strongly negatively density dependent. The impact of dispersal in shaping the dynamics of patchy root vole populations is thus limited to situations and patches with low population densities. In particular we show that birth is the most significant component in populations with increasing growth rate, death is the most significant component in populations with decreasing growth rate while all demographics seem to have relatively similar significance in shaping populations with a rather stable population size. However, at low population density emigration is a more important factor than mortality in causing patches to go extinct.

Birth and death events may therefore seem to be more important components in the dynamics of patchy small rodent populations. However, dispersal is essential in the processes of colonisation, in maintaining genetic diversity and in explaining extinctions of particular habitat patches. Furthermore, dispersal may be a factor explaining death events in voles as we can show that it is a risky type of behaviour.

SURVIVAL IN WILD HOUSE MICE (*MUS MUSCULUS*)

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A critical issue for the study of wild rodents as agricultural pests is survivorship and factors affecting survival. Throughout the world, house mice are a serious pest where grain is grown and stored. While abundant data exist on the lifespan and survival of house mice under laboratory conditions, there is a paucity of data regarding questions pertaining to survival for mice living in nature. My study tested the following: (1) What is the survival rate from birth to recruitment? (2) Is there a sex difference in survival to recruitment? (3) Are there any seasonal effects on the survival of young mice to the age/weight of recruitment? (4) What are the survival patterns for mice that attain recruitment age as they mature? (5) Does maternal experience influence survival of progeny to the age of recruitment? (6) What factors are related to survival?

Eight 1-ha outdoor enclosures (25 m x 40 m) located 15 km southeast of Carbondale, Illinois (USA) were used. Wild-caught house mice, trapped in the fall, were bred to produce mice that were placed into the outdoor enclosures in March of each year. Populations were removed in late fall. Thirty-eight populations were followed over a 5-year span (1989-1993). Each enclosure included 4 locations with food and water, 12 in-ground nest sites, and a 5 m trapping grid (N = 54 traps/enclosure). Traps were set on two non-consecutive nights/week and checked/closed the following morning. All mice were marked, beginning at first capture. Food and water were replenished weekly. Mouse tail tips were used to obtain DNA, which was extracted and run on gels using microsatellites (12 loci with 2-5 alleles/locus). This enabled DNA-based parental assignment of progeny for some of the enclosures in each of three different years.

Litters (n=32) directly observed in the enclosures were used to obtain an estimate of 5.65 pups born/litter. Parental assignment data were used to assess survival to ~35 days of age (7-8 gm) at which time the mice are independent. Only 22.5% of all mice born survived to recruitment. Of 353 litters, 181 had at least 1 pup survive to recruitment, but for the rest none survived. There is a significant bias toward higher male than female survival to recruitment. There was a general pattern with higher survival rates in spring and summer than in the fall season. Since density and season were highly correlated in most enclosures, it also can be said that survival declined with increased density. Adult survival, beyond the age of recruitment exhibited similar patterns for males and females, though females died at a slightly higher rate at each 3-week interval through the summer months. By mid-summer 35% of the original cohort of females and 45% of the original cohort of males remained.

I used females that had 3 or more litters to determine whether maternal experience might result in better survival of progeny. Second and third litters showed higher survival to the age of recruitment than first litters, but this effect was not present for females that had 4th or 5th litters. Multiple regression was used to test for possible effects of density at conception, adult body mass, time of conception, time of recruitment, sex, and the influence of the founding mice. There were no sex differences, and most factors did not influence survival. Two exceptions were that adult body mass was positively correlated with survival, and as noted earlier, mice conceived later in the summer had lower survival rates.

I used DNA-based parental assignment data to test for a possible relationship(s) between parental and progeny survival. The coefficient for females was not significant, but for males there was a weak positive relationship between parent and offspring survival.

My data reveal that from birth to recruitment 78% of the mice are lost. Males tend to have slightly higher survival during this interval, and season and maternal experience also influence survival to recruitment. Another 25% of the mice die prior to the age of puberty, a pattern that is typical for many mammals. No sex differences were noted with respect to survival during the time of puberty and dispersal. Selection pressures on mice are maximal during the first 10-12 weeks of life.

DETERMINANTS OF OVERWINTERING SUCCESS IN BOREAL VOLES: IMPLICATIONS FOR POPULATION DYNAMICS AND MANAGEMENT

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In the holarctic region, seasonality is strong: the year is divided into a short intensive breeding season and a long non-breeding season. Boreal rodents are iteroparous, but a major proportion of females breed in one summer only. Thus the large pool of next season's breeders has to survive winter and then breed successfully the following spring. Winter survival and determinants of the variability in the onset of reproduction are major factors shaping life histories in boreal rodents. During the long, harsh, non-breeding season, the unpredictability of the quantity, quality and availability of food, social factors and predation pressure are major constraints determining the onset of reproduction.

Over the last 20 years we have been studying the overwintering success and onset of reproduction in boreal rodents, especially of the bank vole, *Clethrionomys glareolus*. During winter, bank voles nest communally. The studies on social overwintering yield results on communal nesting. The studies on food supplementation demonstrate the importance of food in determining the onset of breeding. However, strong predation pressure, especially by the least weasel, might counter-compensate the food effect and cause delay in the onset of reproduction. Although the bank vole diet is mainly granivorous, it seems that the timing of the onsetof spring reproduction may depend on the availability of animal protein under the snow. This protein may be in the form of insects, pupae and possibly carcasses of mammals and birds.

In terms of population ecology and management, the timing of the onset of reproduction may affect the number of cohorts produced during the breeding season. Besides food and predation constraints, the onset of reproduction may be strongly density-dependent. Under favourable conditions and release of predation, early onset of breeding helps to create high summer densities, which are followed by high winter densities, but poor overwintering success. Common boreal voles are pests in forests and horticulture. Therefore winters with high densities are problematic regarding reforestation and other pest problems.

THE IMPACT OF BLACK RATS ON THE SURVIVAL OF GALÁPAGOS RICE RATS: MANIPULATIONS, MODELLING AND MANAGEMENT

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The recent rediscovery of the Santiago rice rat *Nesoryzomys swarthi* in sympatry with the introduced black rat *Rattus rattus* was a revelation as the latter is commonly implicated as a major factor in the demise of the endemic Galápagos rodent fauna (just 4 of an original 12 species remain). The north-central coast of Santiago is now the only location in the Archipelago known to be occupied by both endemic and exotic rodent species. This system therefore provided the perfect opportunity to explore competition and coexistence between the ubiquitous alien *R. rattus* and the vulnerable endemic *N. swarthi* and to apply this knowledge to the development of conservation strategies for the management of introduced rodents and the protection of the remaining endemic rodents. I shall present an overview of some key aspects of my research on Santiago spanning 2002 to 2004.

I conducted a replicated *R. rattus* removal experiment for 10 months in 2003. The aim was to test for a significant competitive impact of *R. rattus* on *N. swarthi*. The response of the introduced house mouse *Mus musculus* was also monitored to test for indirect effects of *R. rattus* removal. In 2004, a replicated resource supplementation experiment with variable food dispersions was conducted to distinguish between alternative hypotheses to explain the mechanism of competition between *R. rattus* and *N. swarthi*. I also observed the nature and outcome of interspecific encounters at artificial food patches in the field and staged encounters in an arena. Finally, autecological data on *N. swarthi*, *R. rattus* impact data (from the field experiments), and local climate information were used to parameterise a Population Viability Analysis (PVA) to compare the effects of *R. rattus* eradication and climate change on the future probability of survival of *N. swarthi*.

My behavioural research on Santiago revealed that *R. rattus* is aggressively dominant to *N. swarthi*. This appears to have implications at the population level as the rate of the seasonal population decline of *N. swarthi* was significantly slowed by the removal of *R. rattus*. This effect was particularly evident for female relative to male *N. swarthi*. The response of *M. musculus* to *R. rattus* removal has implications for *R. rattus* control or eradication campaigns as it responded with a significant increase in abundance, driven by adult immigration. The PVA indicated that eradication of *R. rattus* would substantially improve the probability of population survival for *N. swarthi*. The consequences of climate change are less certain. Further research is needed to quantify the impact of *R. rattus* on *N. swarthi* under El Niño conditions as black rats exhibited a rapid and dramatic response to resource supplementation with increased adult immigration and juvenile recruitment causing significant increases in black rat density. An increase in the proportion of breeding females indicated a reversal of the usual seasonal hiatus in breeding. In contrast, although significant body mass gain indicated access to the extra food by both sexes of *N. swarthi*, abundance remained unaffected and immigration and residency of females was repressed relative to that of male *N. swarthi* on all supplemented sites. Together the experimental results support a hypothesis of sex-mediated encounter interference competition.

In contrast to its relative eruption with supplementary resources, *R. rattus* crashes during dry periods while a desert rodent life history strategy and exclusive access to endemic *Opuntia* cactus resources ensures that *N. swarthi* maintains a stable population level throughout the year. Coexistence may therefore be facilitated via a trade off in abilities along an axis of seasonal and inter-annual climatic variation. This competitive coexistence/exclusion balance may be tipped by climate change, introduced herbivore removal and/or cactus mortality leaving local control or island-wide eradication of *R. rattus* as perhaps the only options to ensure long term survival of the small, localised population of *N.*

swarthi. Recommendations for conservation management should consider the nature of the competitive interaction between *R. rattus* and *N. swarthi*, the population dynamics of *R. rattus*, the ecological requirements of *N. swarthi*, and indirect effects of *R. rattus* removal as observed during this study.

LIFE HISTORY TACTICS OF PLATEAU PIKA (*OCHOTONA CURZONIAE*) IN THE ALPINE MEADOW ECOSYSTEM

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By tracing the life history of natural populations of plateau pika and recording reproductive data of a captive colony, we tested the following three specific hypotheses about life history tactics of plateau pika in the alpine meadow ecosystem of Qinghai-Tibet Plateau: (1) plateau pika adopts a quick grow strategy, and average mortality of males is higher than that of females; (2) the fitness of plateau pika populations is relatively low compared with those of other mammal species; (3) the general life history features of plateau pika are concordant with the classification standard of Charnov (2002); $E/\alpha \approx 1.35$, $C \cdot E \approx 1.7$, $I/m \approx 0.3$, in which E = average adult life span; α = age at first reproduction, or age of maturity, C = reproductive effort; I = size of offspring at independence; and m = average adult body mass.

From early April 1979 to late October 1981, 1249 individual plateau pika were mark-recaptured by live traps during 19 trapping sessions in an alpine meadow ecosystem of Qinghai-Tibet Plateau. The following phenotypic life-history traits were recorded or calculated: average number and size of offspring, weight growth pattern, life expectancy, age-specific reproductive value, survival curve or mortality pattern and seasonal population density dynamics.

The general mortality pattern of plateau pika was similar to those of other mammal species. Average mortality varied with season. Age-specific mortality pattern was similar to that of boreal pika (*Ochotona princes)* in Alberta, U.S.A., however, juvenile mortality and adult mortality were higher than those of boreal pikas. There were 3 mortality peaks in plateau pika populations. The first was in the neonate period, in which only 50% juveniles survived, which implies that this juvenile period was influenced strongly by natural selection; the second peak was during the period of highest fecundity, which reflected the cost of reproduction; the third mortality was in old-age, the significant loss during this period, implied senescence of plateau pika and the effect of natural selection. The average longevity of all individuals was 16.33 months (≈ 490 days). The average longevity of females was longer than that of males. One female set the maximum life span record of 931 days.

The survival rate of females was significantly higher than that of males, which might reflect the cost of reproduction or other social costs of males. The sex ratio of neonates was 1:1, however, the sex ratio of adults was female: male = 1.31:1, which indicated a higher mortality of males in their life history.

Plateau pikas had 2 litters every year. The average gestation period of females was 18-20 days. The average litter size of adult female plateau pika did not vary with age and was 4.57 individuals. The average weight of neonates was 9.28 g. The breeding season was between April and June. The reproductive value and fertility of 15-18 month old females was highest.

Juveniles grew quickly before 30-days of age, exhibiting a J-form growth curve, and then grew more slowly between 30-65 days age, reaching weight equilibrium at about 65-days old, and implying that 65-day was their age of maturity.

There was no sexuual dimorphism in plateau pikas. The configurations of females and males were similar; the average weight of males was a little heavier than that of females, but the difference was not significant ($F = 1.0854$, $df = 154$, $P > 0.3058$). The weight growth model of juveniles was: $dm/dt = 6.5266 \cdot m^{0.75} - 12.1787 \cdot m$, in which m = body weight and t = time.

The density of plateau pika population in three years was calculated with a computer program compiled in Turbo C language according to Jolly-Seber method. The dynamics of

plateau pika population was stable, which was coincident with the low intrinsic population growth rate (r=0.1125).

Tables of life history features and life history strategies of 65 mammal species across 9 Orders have been compiled according to their life table data, among which the fitness indexes of 46 species have been calculated. The fitness index of plateau pika was ranked at the 43rd position, only higher than those of bank vole (*Clethrionmys glareolus*), chimpanzee (*Pan troglodytes*) and African elephant (*Loxodonta africana*). The fitness index of plateau pika (r=0.1125) was lower than that of boreal pika (*O. princeps*) (r=2.172). The survival rate is the main factor influencing fitness of plateau pika.

MATING SYSTEM OF THE MULTIMAMMATE MOUSE *MASTOMYS NATALENSIS*

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The multimammate mouse, *Mastomys natalensis,* occurs in grasslands throughout sub-Sahara Africa and is a known agriculture and health pest. In Tanzania, the species exhibits irregular outbreaks leading to heavy crop damage. Much of the species' ecology is well known from field and laboratory studies but the mating system in the field remains unknown due to its cryptic behaviour. We conducted two microsatellite studies on the mating system of *M. natalensis* in fallow fields in Morogoro, Tanzania. The first study involved monthly Capture-Mark-Recapture (CMR) in two fenced areas of 0.5 ha each. During the CMR study, all animals were marked by toe clipping and toe clippings were kept for molecular analysis. Pregnant females were taken to the laboratory and after giving birth, their young were marked as well and the mother and the litter were released back into the field. The second study involved a one-week removal trapping in two open populations. Here, all animals were sacrificed and pregnant females were dissected to take embryo samples.

We used ten microsatellite loci. Inbreeding coefficients were calculated using GENETIX. Paternity analyses were performed using a modified procedure based on Marshall *et al.* (1998). We also checked for multiple paternity using GERUD and a manual counting method. Capture history data from one CMR population were used to illustrate spatial distribution.

In total, 359 young in 36 litters from an equal number of females were genotyped. Mean inbreeding coefficients per population were significantly negative for one closed and one open study population. Paternal assignment rate was high in the closed grids (> 77%) but much lower in the open grids (61 and 33%). Male reproductive success was highly variable with a high number of males without (sampled) offspring (> 65%). Polygyny occurred in 30% of all litters in all grids except the open grid with the lowest assignment rate. Multiple paternity also occurred in three out of four grids. Our specific multiple paternity methods however confirm the presence of multiple paternity in all grids in at least 39 % of all litters. No clear spatial structure exists in the CMR population, with mated males and females living far apart.

Our results show that a promiscuous mating system is present in *M. natalensis* with a relatively high level of multiple paternity. *M. natalensis*' mating system resembles a scramble-competition polygyny. Male-male aggression is very uncommon, even in laboratory bred *M. natalensis* populations. Inbreeding avoidance mechanisms could exist in the population (significantly negative inbreeding coefficients). *M. natalensis* also shows a striking sex ratio bias in favour of females during the breeding season. The search for receptive mates could explain part of the observed high male die-off described and explain the lower paternal assignment rate in the open grids. Males will lose energy, have less time to look for food and shelter and be more exposed to possible predators. However, other factors still need to be researched upon (e.g. parasite burden, space and territory use).

Reference

Marshall TC, Slate J, Kruuk LEB, Pemberton JM (1998) Statistical confidence for likelihood-based paternity inference in natural populations. *Molecular Ecology,* 7, 639-655.

PROXIMATE FACTORS AFFECTING COMPOSITION AND ATTRACTIVENESS OF HOUSE MOUSE PHEROMONES

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We conducted a series of experiments to determine the proximate mechanisms that affect pheromone production and response in house mice. Adrenalectomy did not alter the production of dominance-related pheromones (E,E-α-farnesene and E-β-farnesene), nor did it synergistically alter dehydro-exo-brevicomin and 2-(sec-butyl)-dihydrothiazole, and accordingly did not affect their attractiveness to female mice. Further tests revealed that adrenalectomy did not abolish the social rank establishment of male mice. Urine collected one week after social rank was established in dominant, adrenalectomized and sham-adrenalectomized males was more attractive to females than urine from subordinates, and had more abundant E, E-α-farnesene and E-β-farnesene. Additionally, dehydro-exo-brevicomin and 2-(sec-butyl)-dihydrothiazole in the dominant sham-operated males were elevated synergistically. Urine coolected one day after social rank was established from adrenalectomized dominants was more attractive to females and had a higher concentration of E-β-farnesene than that from adrenalectomised subordinates. Urine from the sham-operated males was not more attractive to females and pheromone composition was similar between dominant and subordinate males. These results suggest that adrenalectomy shortens the process of social-rank establishment due to differences in pheromone composition.

We found significant differences in as many as 6 to 21 urinary volatile compounds between two subspecies of mice. Differences in pheromone compounds also occurred between strains within a subspecies. Thus, the chemical composition of urinary pheromones appears to vary with genetic differences between populations within a species.

Mice exposed to cat urine for 8 weeks did not habituate to the odour. Urine produced by mice that had been exposed to urine of a cat predator or rabbit control was more attractive to females than urine from mice exposed to water. These results suggest that mice exposed to urine from cats or rabbits elevate the concentration of volatiles in their urine. Surprisingly, short-photoperiod (SP) females and short- and long-photoperiod (LP) males preferred the odour of urine from SP members of the opposite sex. Thirteen constituents in urine from SP females and 11 in SP males contained significantly higher concentrations than those of LP conspecifics. These varying concentrations might account for the differences in sexual attractiveness of SP and LP mouse's urine. Some of these compounds have been previously identified definitively or putatively as sex pheromones.

Our results suggest that urinary pheromones might be affected by proximate factors including internal genes and physiological states, and external seasonality, social condition and environmental influences. Over the lifetime of house mice, population and social group interactions, variation in the environment and seasons might, in part, influence their pheromone components and attractiveness. It may be useful to collect the urine of house mice which are more attractive to the opposite sex to enhance the attractiveness of baits.

LINKING BEHAVIOUR, LIFE HISTORIES, AND DEMOGRAPHY OF WHITE-FOOTED MICE (*PEROMYSCUS LEUCOPUS*): 33 YEARS IN THE WOODS

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The white-footed mouse is one of the best-studied rodents in North America. It has a vast range across eastern North America and is a reservoir for several human diseases, including Hanta virus and Lyme disease. Based on long-term datasets and new techniques, we are better poised to understand factors governing its populations. This presentation reviews behaviour, life history, and demographic attributes as revealed in a long-term study.

The study site is a 2-ha second-growth forest remnant in northwest Ohio; its principal masting trees are hickory (*Carya spp*.). From 1973 on, the site has been live-trapped during the breeding season (April-October) on 2 successive days once or twice each month. Nest boxes are used to assess density in winter and to obtain data on litters. Mice are ear-tagged or toe-clipped. In some years DNA samples are taken, and a subset of adults is fitted with radio transmitters. In 1986 we began sampling mast each autumn. The only manipulation was the addition of supplemental food during 1983-84.

Behaviour: Females maintain non-overlapping home ranges; males have ranges about twice as big, typically overlapping those of several females. Male home-range sizes compress linearly with density, while those of females do not. Aggression increases during the breeding season; both sexes show a "home field" advantage in arena tests. The mating system is polygynous, but monogamy may occur at low densities. Although adult males are absent from nests with newborn pups, they are often seen with weanlings and in some cases are known to be their fathers. Females sometimes nurse pups of two litters, in some cases one being a sister's litter. During winter months the mice nest communally. Thus this species shows a high degree of behavioural plasticity, especially when results from other sites are included, in terms of use of space and of social and reproductive behaviour.

Life History: Mortality rates are as high as 90%, but show a strong seasonal influence, with much higher survival of spring-born litters; those from primiparous females have the highest survival rate. Cohorts of mice born in nestboxes display a Type 2 survivorship curve after weaning, implying constant mortality at all life stages. At maturity males disperse twice as far as females. There is no longevity difference between sexes, with less than 3% surviving more than a year. Given their short life span and the success of first-born litters in spring, there is little indication of delayed reproductive effort in this species.

Demography: Numbers typically are lowest in late winter and reach a peak in late summer, sometimes exceeding 100 mice/ha. Usually numbers decline rapidly through autumn; this decline occurs even in years of abundant mast and was not stopped by supplemental food. Increased predation and emigration are likely causes but have not been quantified. There is no indication of multi-annual cycles. With the exception of a few major droughts, weather impacts are short-term, acting over 1-2 months. Mast abundance in autumn predicts over-winter survival but not peak densities in late summer. Density-dependent factors also affect population growth rates over the short term, likely because of competition for resources; reproductive maturity is delayed among spring-born females in summer months when density is increasing rapidly.

Synthesis: Behavioural plasticity allows this species to adjust quickly to changing environments. Maximal reproductive effort early in life enables a rapid population response. The importance of short-term weather events makes it difficult to predict future population size more than several months ahead. The effects of weather and food on population growth are in part mediated through competition, including defense of space and suppression of reproduction. The inelasticity of female home ranges likely sets an upper limit to population density.

COMPARATIVE POPULATION DYNAMICS OF *PEROMYSCUS LEUCOPUS* IN NORTH AMERICA: A SPATIAL GRADIENT OF CLIMATE, ACORN PRODUCTION, AND DENSITY DEPENDENCE

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Temporal variation in population size is regulated by density dependent feedbacks and exogenous forces. Accumulating evidence has emerged that temporal and spatial variation in climate and resources can modify the strength of density dependence in animal populations. We analyzed eight long-term time series estimates of *Peromyscus leucopus* abundance from Kansas, Ohio, Pennsylvania, Virginia, Vermont, and Maine, USA, using the Kalman filter and spectral analysis. Model-averaged estimates of the strength of direct density dependence increased from south to north; and the strength of delayed density dependence increased from west to east and from south to north. Longer, colder winter and more variable climate in northerly latitudes might result in stronger density dependence in mouse populations. White-footed mice (*Peromyscus leucopus*) populations show more pronounced cyclicity from west to east, and the spatial gradient of cyclicity parallels the increased presence and dominance of red oaks (*Quercus rubra*) among the eight study sites. Furthermore, variable coefficient models link acorn production to the strength of delayed density dependence in *P. leucopus* populations of Maine: increased acorn crops reduce the strength of direct and delayed density dependence. An acorn failure occurring after peak densities of mice might intensify delayed density dependence and result in a mouse population crash after about a 2-year delay. Our results suggest that in seed-eating *Peromyscus*, cyclicity is regulated from the bottom up.

DO YOU NEED TO KNOW ANY ECOLOGY TO MANAGE RODENT PESTS?

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The management of rodent pests can be carried out with or without any knowledge of their population and community dynamics. The general belief that accumulating ecological knowledge will help us to manage rodent pests more economically and more sustainably can be tested with case studies which contrast rodent control using rodenticides with those using habitat management combined with ecological knowledge of rodent life histories, social organization, and movement patterns.

Using the studies carried out by the CSIRO Rodent Ecology Group, I will illustrate these principles with the house mouse (*Mus domesticus*) in southeastern Australia and the ricefield rat (*Rattus argentiventer*) in Southeast Asia. Obtaining ecological understanding of rodents is useful in the short term for optimal pest control and in the long term for anticipating and reacting to new problems that may arise from climate change and landscape alterations.

Symposium: Hanta-viruses, arenaviruses and emerging rodent-borne viruses

Chairs: Jean-Pierre Hugot and Heikki Henttonen

Oral Presentations

ROBOVIRUSES IN EUROPE AND CENTRAL ASIA - WHAT TO LOOK FOR IN EURASIA IN FUTURE?

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RoBo viruses (rodent-borne zoonotic viruses, cf arboviruses) include (at least) hantaviruses, arenaviruses and rodent-borne orthopoxviruses, and also Bornavirus is often included here.

In Eurasia the research so far has concentrated primarily on hantaviruses. A number of arvicoline and murine carried hantaviruses are known from Eurasia, and supposedly new ones will be described in near future, especially from SE Asia, where the murine diversity is high. Hantaviruses and their rodent hosts show striking co-evolution at the host family and subfamily level. However, at host species and genus level, host switches have taken place. The phylogeny and phylogeography of murine carried hantaviruses in E and SE Asia will continue to be a challenge, and the existing knowledge will be reviewed in several talks in the hanta session. The taxonomy of arvicoline, especially *Microtus*-carried hantavirsues in Europe and Central Asia is complicated, probably reflecting the recent rapid radiation of this group. The hantaviral human epidemics in Europe follow (supposedly) predator driven cycles in the north and mast driven fluctuations in the temperate zone.

Among arenaviruses, only lymphocytic choriomeningitis virus (LCMV) has been described in Eurasia. LCMV has traditionally been connected to *Mus musculus/domesticus* although pet hamsters also have been the source of human infection. However, the most recent data suggest that LCMV in Europe and Central Asia at least might be a complex of more or less host specific virus strains/species. It is not known if the strains from different host species differ in their virulence to humans.

When smallpox was eradicated and vaccination was discontinued, cowpox, a closely related orthopoxvirus, has appeared as an emerging zoonosis. Presently it is known from many rodents species from Europe to Central Asia.

Bornavirus causes a fatal encephalitis (e.g. in horses) and is suspected to cause psychotic depression in humans. Recently seropositive voles and viral RNA in shrews have been in found in Europe.

Some speculations will be made about the future directions of RoBo research in Eurasia.

PREVALENCE OF HANTAVIRUS ANTIBODIES IN HUMANS AND RODENTS IN SOUTHEAST ASIA

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Hemorrhagic fever with renal syndrome is a rodent-borne viral zoonosis caused by viruses belonging to the genus *Hantavirus*, family *Bunyaviridae*. Five distinct hantaviruses are known in Asia: Hantaan virus, Seoul virus (SEOV), Thailand virus (THAIV), Puumala virus, and Thottapalayam virus (TPMV). TPMV was isolated from an insectivore. To determine the infectivity and pathogenicity of Asian hantaviruses, we carried out sero-epidemiological studies in Thailand, Indonesia, India, and Vietnam.

We previously reported THAIV infecting a human and rodents (*Bandicota indica* and *B. savilei*) in Thailand. In this study, we confirmed that two serum samples from one patient were positive for TPMV out of 194 samples from 158 patients with febrile illness of unknown origin in Thailand. However, IgM antibody was not detected in these samples. In Indonesia, one patient had low-level IgG antibody against SEOV out of 84 serum samples from five regions. Nevertheless, we found many positive rats (urban and black rats) in the Thousand Islands, near Jakarta. In addition, 2 of 11 suncus were positive for TPMV. In India, we found four anti-hantavirus IgG antibody-positive samples from patients in the acute phase within 5-7 days of a febrile illness (13 cases) or with renal disorders (106 cases). Using a serotyping ELISA system, two sera showed the THAIV infection pattern. In Vietnam, we screened about 2,500 human serum samples from healthy individuals, those with febrile illnesses, and port workers. We found 12 positive cases from three areas (Haiphong: 6/150 healthy port workers, Thang Hoa province: 3/146 patients, Ha Nam province: 2/158 patients and 1/58 healthy individuals). We also screened 255 rodent serum samples from three provinces and found eight positive cases (Thang Hoa 0/146, Ha Nam 7/48, Tay Nguyen 1/61). In addition, 14 of 120 rats captured in the port of Haiphong were positive. We examined viral RNA and mitochondrial Cytochrome B sequences for species identification. Phylogenetic analysis showed that the Norway rats in the port of Haiphong carried SEOV that was closely related to the SEOV found in Indonesia and Osaka, Japan. We failed to obtain viral genome fragments from black rats, which were identified as *R. rattus tanezumi*. These results indicate that various hantaviruses occur in both humans and rodents in Southeast Asia.

HANTAVIRUSES AND THEIR RODENT HOSTS: CO-EVOLUTION WITH OR WITHOUT CO-PHYLOGENY?

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Many authors have suggested that the phylogenetic relationships of highly host specific parasites would provide valuable information about the evolutionary history of their hosts. This is particularly interesting when co-evolution is occurring between pairs of species from each group: this deals with the hypothesis of co-phylogeny. Irrespective of the outcome, phylogenetic analyses of the different groups are necessary as a first step.

In the following we try to test the hypothesis of co-phylogeny between the hantaviruses and their rodent hosts. The phylogeny of the viruses is based on the Bayesian analysis of the coding part of the short gene. The phylogeny of the rodents summarizes recent works on this topic, using different kinds of data sets. The cladograms are compared using an event-based parsimony method. This allows an evaluation of the congruence of two trees, node by node. However, a high congruence between two cladograms is not necessarily the result of the direct influence of one group on the speciation events of the other. Thus, a component of the work in this kind of study is to distinguish which part in the result of the comparison of a host versus parasite phylogenies may be considered due to transmission by descent and which part may be attributed to other mechanisms. This also deals with the concept of host specificity.

DISTRIBUTION OF THAILAND VIRUS AND ITS POTENTIAL FOR CAUSING HUMAN DISEASE

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Previous serological investigations on *Hantaan*-like viruses from rodents in Thailand identified the giant bandicoot rat (*Bandicota indica*), the Norway rat (*Rattus norvegicus*), the roof rat (*R. rattus*), the lesser rice field rat (*R. losea*), and the Polynesian rat (*R. exulans*) as potential reservoirs of hantaviruses. Subsequent phylogenetic studies on viral genetic material isolated from *Bandicota indica* (M segment) revealed a new virus, i.e. *Thailand virus* (THAIV), that was closely related to *Seoul virus* and grouped with other Murinae-associated viruses (Xiao *et al*. 1994).

In the present study, we focused on immunological analysis of serum samples from rodents and humans in Thailand to detect anti-hantavirus antibodies and, in particular, to identify the viruses involved. Phylogenetic re-examination of THAIV from *B. indica* was performed to differentiate THAIV from hantavirus isolates from *Rattus* species.

A total of 402 rodent sera from 19 provinces in Thailand were screened by enzyme-linked-immunosorbent-assay (ELISA) for virus-specific IgG using yeast-expressed His-tagged *Seoul virus* recombinant N protein, a commercial agglutination test based on Hantaan antigen (Hantadia®, Korea Green Cross Corp.), and indirect immunofluorescence using *Hantaan virus*-infected Vero E6 cells. Furthermore, 519 sera from patients (Surin province, Thailand) initially suspected of having contracted leptospirosis were screened and serotyped for anti-hantavirus IgG by ELISA using recombinant entire and truncated N protein antigens of *Hantaan*, *Seoul*, and *Puumala* viruses expressed from baculovirus vectors. The screening for virus-specific IgM was performed with a µ-capture ELISA. To detect virus-neutralising capacity of antibodies and type hantaviruses, all sera, which previously tested positive, were subjected to a focus-reduction-neutralization-test (FRNT) against *Hantaan virus*, *Seoul virus*, and THAIV.

For phylogenetic analysis, total RNA was isolated from THAIV-infected Vero E6 cells and hantavirus-specific cDNA synthesized. The partial M genome segment that corresponds to nucleotides 2000-2300 and the entire S genome segment were amplified by PCR, cloned (S segment) and sequenced. Sequences were aligned using CLUSTALW. Phylogenetic trees were calculated using maximum likelihood and neighbour-joining methodologies.

Serological testing of rodent sera showed that out of 402 rodents, which included *R. norvegicus*, *R. rattus*, *R. argentiventer*, *R. losea*, *R. exulans*, *R. tiomanicus* and bandicoot rats, five *B. indica* and one *B. savilei* from four provinces in the central plains and

northeastern part of Thailand were FRNT antibody-positive for THAIV (3.3% of 152 bandicoot rats). A single *R. rattus* from Petchabun was also hantavirus-seroreactive, but characterization by FRNT was not possible.

Phylogenetic analysis of the coding sequence of the S genome segment of THAIV revealed that THAIV from *B. indica* and Cambodian hantavirus isolates from *R. rattus* were closely related forming a novel cluster besides the various strains of *Seoul virus*, *Hantaan virus*, and *Dobrava-Belgrade virus*. Classification of THAIV as a distinct hantavirus species was supported. Interestingly, *R. rattus* from Cambodia and China were hosts of genetically different hantaviruses.

One patient from Surin province showed symptoms compatible with hemorrhagic fever with renal syndrome (HFRS). The patient's serum contained high titres of IgG and IgM antibodies against a hantavirus. Similar to the sera from bandicoot rats, this serum possessed significant virus-neutralizing capacity against THAIV as detected by FRNT, suggesting that THAIV was the causative agent of disease in this human case.

The results of the present study extend observations of previous investigations in that they pinpoint THAIV to be one of the most prevalent hantaviruses in rodents in Thailand. Previously, giant bandicoot rats generally showed a higher prevalence of hantavirus infection than *Rattus* species. It appears that THAIV is mainly distributed in the central plains and northeastern Thailand, although this requires confirmation by additional serological data from bandicoot rats in southern Thailand and neighboring countries. Interestingly, phylogenetic analysis identified a close relative of THAIV in a *Rattus* species from Cambodia, which lends itself to speculation about how hantaviruses co-evolved with their rodent hosts.

Although a recent human HFRS case in Thailand was attributed to hantavirus infection, the virus was not further characterized. Here, we provide first evidence that THAIV may be the causative agent of HFRS in humans. However, no viral material from the patient was available to confirm this. The observation that the main distribution of THAIV and the human case of HFRS overlap (Khorat plateau) could indicate an epidemiological relationship. This has to be further elaborated by characterization of new viral isolates from rodents and humans.

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HANTAVIRUS INFECTION IN BELGIUM: POPULATION AND TRANSMISSION DYNAMICS IN LOCAL BANK VOLE POPULATIONS.

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Hantaviruses (family *Bunyaviridae*) are causative agents of human zoonoses and each Hantavirus is predominantly associated with one rodent host or insectivore species. Puumala virus (PUUV), primarily carried by the red bank vole (*Clethrionomys glareolus*) in Western and Northern Europe, causes a form of pathology in humans, named Nephropathia epidemica (NE). A focal distribution of PUUV-infected bank vole populations and NE cases has been observed in Western Europe while in Fennoscandia infected rodent populations are present over vast areas and human cases are widespread. We seek to determine the factors and underlying mechanisms that generate this spatial heterogeneity in occurrence of PUUV in Western Europe, but also within smaller regions that show specific infection patterns. We address this goal in the specific case of Belgium; this small country shows a well-defined heterogeneous distribution in both bank vole PUUV infection and NE incidence. Describing underlying mechanisms, at the level of the reservoir hosts, environmental conditions and human activities should enable us to understand spatial PUUV infection patterns in Belgium and extrapolation of these results can explain observed heterogeneity in larger areas. This paper focuses on the level of local bank vole populations. We hypothesize that landscape features (habitat), host behaviour (dispersal, contact rate) and host population dynamics (densities, demography) are important factors that explain geographical differences in virus occurrence (also risk of human infection).

Based on a 10-year dataset of human NE incidence in Belgium, nine study sites were selected in communities with different NE incidence patterns. Sites reflect preferred bank vole biotope in public forests. During the past two years, CMR (Capture-Mark-Recapture) studies were carried out three times a year, enabling monitoring of vole numbers and individual blood sampling (serum IgG detection) in all nine study sites. Data on bank vole presence, movement, condition and PUUV infection patterns, as well as environmental features (spatial imagery studies), soil parameters and species inventories were collected.

General results suggest that sex ratio and age distribution have a big influence on the number of infected animals in a local population and presence of PUUV infection. Significant differences in PUUV prevalence was found among sexes and age classes with varying sexual condition. Density is positively related with the number of infected animals, but no direct relationship or delayed density dependence with prevalence was found. Differences in occurrence of infection were clear in 2004, where only five sites of nine showed PUUV IgG positive bank voles, enabling us to compare among sites. Yet, in spring 2005 eight out of nine sites presented PUUV infection. A general increase in prevalence and number of infected animals was found from 2004 to spring-summer 2005, these results were reflected in the number of reported NE human cases that reached an historical maximum (365) in Belgium that year (Inst. Public Health, Belgium). After the peak in 2005, all populations crashed over winter and during spring 2006 in four of nine study sites no animals were found, in the other sites numbers did not exceed 11 MNA/ha and 48% of the trapped animals represented bank voles from the previous fall. This situation enables us to locate the foci where PUUV persists during very low density periods, sites with better regulatory capacities. Preliminary analyses of environmental features indicate the importance of habitat features for ensuring better survival of the bank vole populations and small scale physical conditions. Our results confirm the presence of foci where PUUV persists and from where infected animals

disperse during periods when bank voles are more abundant. Future study will show us how populations are regulated after the epidemic and how PUUV (re-)enters the populations.

AN ARENAVIRUS ISOLATED FROM *MASTOMYS NATALENSIS* IN TANZANIA: A MODEL FOR LASSA ECOLOGY RESEARCH?

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African arenaviruses include Lassa virus, Mopeia virus and Mobala virus. The first two of these share the same natural host, *Mastomys natalensis,* multimammate mice, but have a separate distribution. Lassa virus is a class 4 pathogen that occurs in West Africa from Guinée to Nigeria and which causes Lassa hemorrhagic fever in humans, with between 100,000 and 500,000 cases per year. Mopeia virus was isolated from multimammate mice in Mozambique but no human disease is associated with it. During routine ecological studies in Morogoro, Tanzania, about 20 years ago, antibodies against Lassa virus were observed in *M.natalensis* in an immunofluorescent assay, but more specific tests were not carried out. Recently, we collected fresh lung tissue from the same population and isolated an arenavirus. At first it was believed to be a new representative of the arenaviruses, but full sequencing now suggests that the virus is conspecific with Mopeia virus.

The identification of this virus, non-pathogenic to humans, in a very well studied population of *Mastomys natalensis* in Tanzania, allows for intensive ecological studies on the transmission and ecology of this arenavirus in its natural host. Such work has been possible with Lassa virus only to a very limited extent because of biosafety precautions.

Preliminary work showed a high seroprevalence of 44% positive individuals (tested n=96) in the population of *M.natalensis*. Using PCR, virus material could be detected in 12 out of 303 individuals. Further analyses are underway to describe basic ecological characteristics of the infection in the natural host population in Morogoro and these will be presented at the conference.

ROLE OF MHC CLASS II GENES IN THE SUSCEPTIBILITY TO HANTAVIRUS INFECTION IN ARVICOLINAE

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Immunogenetics focuses on the study of immune defence genes and on the variability of outcomes generated by genotype-genotype interactions between and within host and pathogen species. It provides essential information to disentangle the effects of genetic variation and environmental factors on the differences observed in the impact of parasites on individual hosts or populations. It thus gives key insight into epidemiology and transmission ecology. One of the leading goals of immunogenetics has been to understand the associations of genetics to immune related diseases. In this context, the Major Histocompatibility Complex (MHC) has been extensively studied. It is a central component of the vertebrate immune system. Certain of these genes are among the most polymorphic coding regions of the genomes.

We studied the genetic diversity of the two most polymorphic MHC class II gene (DRB and DQA) in three species of voles found in the East of France (Bryja *et al*. 2005), an endemic area of Hemorrhagic Fever with Renal Syndrome, disease caused by Hantaviruses. The bank vole (*Clethrionomys glareolus)* is the reservoir of Puumala, the common vole (*Microtus arvalis)* is the reservoir of Tula and the water vole *(Arvicola terrestris)* has not yet been described as a reservoir of an identified Hantavirus. Voles were serologically checked for antibodies to hantavirus. Phylogenetic studies were conducted on the MHC haplotypes detected in 100 individuals of the three species. Associations between genetic parameters (haplotypes or heterozygosity) and infection status were explored using multivariate analyses and logistic regressions.

The phylogeny based on MHC genes revealed a pattern of trans-species polymorphism (Bryja *et al*. 2006). This indicates that a balancing selection acts on these genes, probably through parasite mediated-selection. We detected significant associations between one MHC-haplotype and the susceptibility to Hantavirus infection in *A. terrestris* – the results concerning *M. arvalis* and *C. glareolus* will be confirmed shortly. This result highlights the possibilities of (i) a specific Hantavirus carried by *A. terrestris*, and (ii) a negative impact of Hantavirus infection on Arvicoline fitness.

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HEALTH STATUS, INFECTION AND RODENT POPULATION DYNAMICS: THE USE AND ASSESSMENT OF HAEMATOLOGY

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Our research focuses on the use of haematology as a proxy of general health condition and immunocompetence in wild rodent populations, and its usefulness in assessing susceptibility and response to infection. The haemogram is the cornerstone of laboratory clinical analyses and yields useful information about organismal well-being and disease by evaluating the number and health of the cellular constituents of blood. However, it has very seldom been used to assess health status in ecological studies of natural populations.

Our goal was to describe the relationship between haematological parameters, rodent demographics and population dynamics. Subsequently, these parameters were evaluated in relation to infection with selected pathogens to investigate host susceptibility and response. The haematological parameters evaluated were divided into those that indicate health condition and those that show immunological response to parasitism. Health condition was evaluated as erythrocyte numbers (RBC) in blood, reflecting mainly oxygen uptake efficiency and nutritional status, and lymphocyte counts in blood, reflecting general immuno-competence. The response to parasitism was assessed by total white blood cell (WBC) counts and numbers of neutrophils, monocytes, and eosinophils in blood.

A longitudinal study was conducted sampling four field vole populations from Kielder Forest (Northumberland, UK). Samples were taken every 4 weeks from March 2005 to March 2006 (except in December and February). Every field vole was uniquely identified with a subcutaneous transponder, weighed, sexed, and a blood sample was taken from the tail tip. Haemograms were produced with haemocytometers and blood smears. Infection with various pathogens/parasites (namely, Cowpox virus, *Bartonella* spp., *Anaplasma phagocytophilum*, *Babesia microti*, *Trypanosoma microti*, and gastroenteric coccidians and helminths) was assessed by serology, PCR or examination of microscopic preparations.

Blood cells varied with sex and age in a similar manner to what has been described for laboratory rodents. Red blood cells increased with age and their counts were slightly higher in males than in females. Lymphocytes were the predominant WBC type, and their numbers decreased with age. Neutrophils and monocytes, conversely, tended to increase with age. A marked seasonality was observed in most cell types. RBC counts decreased from the onset of the breeding season (April) until late July, with a much more pronounced decline in females. Later in the breeding season (August), the RBC numbers began a quick recovery, and then declined again for both males and females in wintertime. Total WBC counts followed an inverse pattern. They peaked at the beginning of the breeding season, followed by a consistent decline until January. WBC numbers were higher for males while they were not breeding, but the levels were similar for both sexes during the reproductive season. Lymphocytes were highest during the second half of the breeding season, after which lymphocytes abruptly dropped and reached the lowest counts in early spring. Neutrophil numbers were highest at the onset of the breeding season, but then they declined consistently until November. They began increasing again after January. Monocytes followed a similar pattern, but they peaked later (July). The relationships between haematological parameters and current and previous density are presented, as well as relationships with infection dynamics.

The onset of breeding appeared to have a major impact on the voles' condition, as evidenced by the decline in RBC and increment of WBC as a result of neutrophil production (indicative of infection). Haematology proved to be a useful tool in assessing condition in natural populations of field voles and it might help construct a more sound understanding of the distribution and dynamics of disease in wildlife populations.

SURVEILLANCE OF PLAGUE IN CAPTURED RODENTS IN TWO HISTORICALLY PLAGUE ENDEMIC VILLAGES IN VIETNAM

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Plague is a complex of diseases caused by the bacillus, *Yersinia pestis*. Patients acquire disease from the bites of the infected flea, *Xenopsylla cheopis*, the primary vector of plague, normally found on many species of rodents. Plague foci appeared to be limited to areas in and adjacent to human settlements. In coastal Vietnam, endemic plague has been reported since the early 1900's. Beginning in 1962 through the late 1970's, epidemic plague occurred in provinces throughout most of Southern Vietnam. Plague transmission increases and is dispersed to the rural areas just outside villages during the dry season. During the rainy season, transmission is primarily restricted to within village or town boundaries and case reports drop significantly in these areas. This pattern of seasonal plague dispersal is correlated with the presence and density of *X. cheopis* on rodents during the dry and wet season as well as flea populations indoor and outdoor.

The objectives of the present study were to use the global positioning system (GPS), geographical information systems (GIS) and remote sensing data to analyze rodent and flea distributions and to identify environmental variables that contribute to suitable ecological conditions for those species suggestive of the presence of plague in a historically plague endemic area in South Vietnam. Houses were furnished with 3 medium live-traps. Traps were set up for 3-4 consecutive nights. Captured rodents and fleas were identified. Blood and animal tissue samples were dissected from trapped animals.

Data on rodent and human samples collected from Lam Ha district, Lam Dong Province, have been recorded sporadically during the past 10 years. The latest human case was reported in 1997. From April 2003 to February 2005, the Vietnamese Preventive Medicine team routinely trapped rodents and found 11 and 15 plague-positives in rodent samples in Thon Ba (Village 3) and Thon Bon (Village 4), Lam Ha District. Several plague positive samples were related to the types/styles of housing in the village. Our current monthly trapping activity in over 300 houses in these 2 villages started in October 2005, and over 4,800 traps have been set up. More than 412 rodents were collected with the majority of specimens belonged to *Rattus exulans*. Other species were *Suncus murinus*, *Rattus rattus* and *Rattus nitidus*. Most of the nearly 500 flea specimens collected from captured rodents were *Xenopsylla cheopis*, the primary vector of plague. Results of these collections have been loaded into a GIS data set for analysis. Animal tissue samples are being tested and analyzed for the presence of *Yersinia pestis* by the molecular methods of qPCR techniques.

Symposium: Host-disease interactions

Chairs: Grant Singleton and Jing-Hui Li

Oral Presentations

A COMMENSAL RODENT PLAGUE SURVEILLANCE AND CONTROL MODEL FOR CHINA - PRIOR STUDIES AND RECENT FINDINGS

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Plague is one of the two class-A communicable diseases in China. It is ranked No. 1 of 37 legal communicable diseases in the country and poses a great threat to people's life and health and national economic development. At present plague is re-emerging and remains active on a global scale. In China the foci of plague show a tendency to expand and spread.

The majority of plague patients contract the disease from commensal rodents. The commensal rodents provide the greatest threat to mankind because of their close contact with humans. For example, of the 254 plague cases in China in 2000, 252 were reported as linked to commensal rodents. From this alone we can see the status and magnitude of commensal rodent foci in strategies to control plague in China. Therefore, with the aim to reduce the severe plague situation in China, the current study examined foci of commensal rodent plague.

Since the 1950's our approach to, and understanding of, plague control has seen a great change. Decades ago people thought plague could be eliminated, and some people believed that plague no longer occurred in their country; recent plague cases in a number of countries have dispelled this belief. Today people recognize that as a natural focus disease, plague cannot be eradicated, and so far attempts to develop an effective plague vaccine for plague prevention through inoculation, has met with little success.

To prevent human plague we need to concentrate on the route of transmission in the three key parameters that influence the rate of transmission (the infectious source, the route of transmission and population susceptibility). We have identified two activities that can be done to reduce exposure of humans to commensal rodent plague. One is to conduct regular surveillance of rodent density with control actions triggered when densities go above a pre-determined density threshold. The second is the central reporting of dead rodents; a key indicator of possible plague foci.

The current project comprehensively covers the basic requirements for rodent density surveillance and control as part of a surveillance program for rodent-borne disease. We apply epidemiologically valid and statistical rigorous methods to monitor commensal rodent plague. The key parameters are appropriate sample size, determination of rodent control index based on density estimates, and the number and distribution of monitoring points. These surveillance programs also are tailored to meet the specific conditions of target areas and the availability of labour. The project pays particular attention to the socio-economic context of China's current systems in the common cities and counties. The surveillance and control measures are designed to match the local financial capacities and the network of technical expertise in a region. For example, plague control professionals are trained to be alert to, and report effectively, the occurrence of foci of dead rodents. These people are linked in a formal network with village doctors and villagers in general. The network is established to ensure efficiency so that the involvement of both professional and local villagers does not entail a high work load. The combination of two indicators of plague risk (host density and host death) also enhances surveillance efficiency. The level of our commensal rodent plague surveillance and control program has no parallels in other countries.

The current project and a previous study were conducted in Yunnan Province, the biggest commensal rodent plague focus in China.

The main result of the previous study is that the number of case occurrences of plague decreased from 101 in 2000 to zero in 2001 in the three counties where trial surveillance programs were implemented. Whereas in eight matched counties without such surveillance the number of plague cases increased from 21 in 2000 to 29 in 2001.

The main result of the current project is that the failure rates (= No. of human plague foci / (No. of human plague foci + No. of rodent plague foci)) are 0% for 2004, 33.3% for 2005, 0% for 2006 respectively. Our pre-set goals for the failure rates to the nation were ≤50% for 2004, ≤45% for 2005 and ≤40% for 2006. The results show that all these commitments were clearly met.

Other important outputs from the study include the calculation of a formula for the epidemic intensity of commensal rodent plague in rodents (The epidemic intensity $I_a = -\sum \frac{n_i}{N} \ln(\frac{n_i}{N})$. n_i: No. of focus for a single area; N: No. of focus for all the areas under surveillance, $N = \sum n_i$), and the development of statistically valid rodent control indexes.

All of the results above indicate that the commensal rodent plague surveillance and control model that has been tested and promoted in Yunnan Province is suitable for China. We propose that the system that we have developed would be useful for other countries where commensal rodent plague poses threat to them. Through such a surveillance and control system we are confident that the commensal rodent plague problem will be substantially reduced in both China and other countries in the near future.

SURVEILLANCE SURVEYS ON RODENT-BORNE DISEASES IN THAILAND WITH FOCUS ON SCRUB TYPHUS DISEASE ASSESSMENT USING GEOGRAPHICAL INFORMATION SYSTEM (GIS) TECHNOLOGY

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The epidemiology of many rodent-borne diseases in Southeast-Asia is not well defined. Scrub typhus and leptospirosis are common and medically significant, while other zoonotic diseases such as the Spotted Fever group, Rickettsiae, have been identified, but their overall medical significance is unknown.

Our main objective is to define reservoirs and vectors involved in rodent-borne diseases in Thailand. Rodent surveillance was conducted from June 2002 to July 2004 in 18 provinces. Traps were set up for 1-3 nights. Captured rodents were euthanized. Blood and serum samples were collected and animal tissue samples (liver, spleen, kidney and urinary bladder) were dissected out. Chigger-mites, ticks and fleas were removed from captured rodents. Using both commercial diagnostic kits and in-house molecular assays, animal tissues were examined and screened for zoonotic diseases.

Over the 2 years, 4,536 wild-caught animals were captured. They belonged to 27 species. *Rattus rattus* was the dominant species, followed by *Rattus exulans* and *Bandicota indica*. More than 30,000 ectoparasites were removed from captured animals and about 50% of them were chigger-mites of the genus *Leptotrombidium* (scrub typhus vector). Other species included *Schoengastia* and *Blakarrtia.* Minimal numbers of tick and flea specimens were found (both <1%). Among 5 species of ticks collected, *Haemaphysalis bandicota* was the predominant species, followed by *Ixodes glanulatus*, other *Haemaphysalis spp*., *Rhipicephalus spp*., and *Dermacentor spp*. Only 2 species of fleas were collected with *Xenopsylla cheopis* (rat flea) being predominant.

Six zoonotic diseases were detected: Scrub typhus, Murine Typhus, Bartonella, Leptospirosis, Babesiosis, and Trypanosoma. Most samples were positive for scrub typhus. Other zoonotic diseases still being evaluated are *Borrelia*, *Ehrlichia*, Plague, and other Rickettsial diseases.

The Geographic Information System (GIS), Global Positioning System (GPS) and remote sensing technologies were used to assess the relative risk of scrub typhus in different biotopes within highly endemic areas. Four land cover types (rice fields, forest edge, forest habitats and residential areas) were classified using high resolution Quickbird satellite imagery. Data on rodent hosts and chigger-vectors were entered into ArcGIS to define and analyze the spatial relationships between rodents, vegetation, chiggers and *Orientia* species. Areas showing the presence of chiggers, along with areas of positive scrub typhus, were mapped to provide insights into the nature of these distributions and possible environmental relationships.

PREVENTION OF SANITARY RISKS LINKED TO RODENTS AT THE RURAL/PERI-URBAN INTERFACE IN SOUTHEASTERN AFRICA: OVERVIEW AND OUTCOMES OF THE RATZOOMAN PROJECT

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The close proximity of commensal rodents to human habitation means that rodents can spread and transmit diseases which affect people. The ability of rodents to carry and vector diseases is encouraged by their habits of utilising our waste and sewage, their mobility and the similar physiologies that humans and rodents share. Rodents are able to vector more than 60 diseases, and the list grows as more research on zoonosis continues. Plague is perhaps the most well-known rodent-vectored disease, due to the historical impact it has had on human populations during several global pandemics. Although plague still exists and kills people in many parts of the world, other rodent transmitted diseases such as Lassa Fever and Leptospirosis are perhaps more serious in the numbers of people infected and killed. There is growing concern from many experts around the world that zoonotic diseases are emerging and re-emerging, particularly in developing countries that lack the resources to investigate, manage and treat a number of diseases and the underlying reasons for their spread and persistence.

It has been argued that many factors may be influencing the increased risk of zoonosis transmission between rodents and humans. The RatZooMan project is a large multidisciplinary research project with the overall objective of trying to understand which factors may be important in zoonosis transmission. Climate change, urbanisation, agricultural intensification and anthropogenic changes to the environment (e.g. deforestation) are influencing rural ecology, rodent population dynamics and how rodents may interact with people. Increased transport networks, poor hygiene and sanitation and growing urban rodent populations signify that zoonoses can potentially spread and persist in cities.

The disease prevalence and livelihood constraints were measured for three major diseases, plague, leptospirosis and toxoplasmosis, chosen for the different roles rodents play in their transmission. Ecological and anthropogenic factors responsible for their spread and transmission were identified and evaluated. Project activities were divided into 13 workpackages, each focussing on a set of parameters which are considered important to rodent zoonosis (e.g. human behaviour, socio-economics, rodent species, habitat utilisation, disease susceptibility and prevalence among rodents and people). A geographic information database (GIS) was developed to integrate the data sets linked to GPS coordinates and mapping information to assist in the interpretation of the data. Data were collected from four African countries (South Africa, Zimbabwe, Tanzania and Mozambique) from different focal areas, ensuring a mixture of rural, peri-urban and urban settings were surveyed.

More than 5000 rodent specimens were captured, from which tissue and blood samples were collected for disease analysis. Specimens were taxonomically identified (see Leirs et al. this conference) showing marked differences in diversity depending on the locality where rodents were trapped. Disease prevalence among rodents sampled also showed that rodent species and locality were important factors. Overall, leptospirosis seropositivity was between 5 - 20% for the different localities surveyed. Some rodents (e.g. *Mastomys* sp.) and shrews (*Crocidura* sp.) were found to have much higher leptospirosis prevalence, with serovar Icterohaemorrhagiae being the most prevalent (see Machang'u et al., this conference). In some cases, leptospirosis prevalence in rodents appeared to be linked to localities such as valleys, rivers and broken pipes where there was standing water (see Taylor et al., this conference). Leptospirosis seropositivity ranged from 10 - 20% among the human samples collected, and the potential risk factors continue to be analysed. Toxoplasmosis prevalence ranged from 4–20 % among rodents and 10-30 % among humans. Plague-positive rodents were not detected throughout the project, however, human seropositive cases of plague (3.7%) were found in the Tete-Zambezia focal area of Mozambique. Continued study and analysis of data in the GIS database will be required to understand the linkages between the multiple factors influencing the spread and transmission of rodent-borne diseases.

RODENT ECOLOGY ACROSS RURAL, PERI-URBAN AND URBAN HABITATS: RESULTS FROM THE RATZOOMAN PROJECT IN SOUTH-EASTERN AFRICA

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The RatZooMan project (2003-2006) studied rodents and their significance as carriers of disease at the interface of urban, peri-urban and rural environments in several cities in Tanzania, Mozambique, Zimbabwe and South Africa. A considerable effort was spent on describing the basic ecological characteristics of the rodent fauna in these habitats (species composition, habitat distribution, demography and seasonality). Data were collected by trapping small mammals in a number of habitats in different seasons; the animals were measured, their breeding condition was recorded, and tissue samples were taken for microbiological studies (results reported elsewhere). The carcasses were kept for later taxonomical and ecological study.

In total, approximately 5700 specimens were collected in the removal trapping. These belonged to at least 22 genera but further species identification is still underway. Species diversity differs between countries, and between sites in countries, but the most common species were *Mastomys natalensis* and *Rattus rattus.* In Mozambique, however, more than half of the animals belonged to genus *Mus*. Surprisingly, shrews constituted 12% of all trapped specimens in Tanzania, while they were only rarely trapped in the other countries. Within the extensively sampled city of Morogoro, Tanzania, *M.natalensis* was very common (>75%) in open habitats (swamps, fields, fallow land), but occurred also in considerable amounts in and around markets, houses and other buildings. This species provides a definite route through which infections from rural areas could arrive in the urban environment.

Population dynamics data on *M. natalensis*, were obtained from capture-recapture studies in agricultural and fallow field in or around 4 cities and compared with the information from well-studied populations in a rural area in Tanzania. In this rural area, *M.natalensis* has a strict breeding season and considerable seasonal fluctuations in abundance (factor 20 or more). In the urban areas of Morogoro, breeding is equally seasonal, but the resulting population dynamics show a much flatter and less regular abundance curve. In NE South Africa, the same species also show clear seasonal fluctuations in numbers, but there is some reproduction throughout the year. The abundance peak is reached in the early wet season in Tanzania, but it occurs in the middle of the dry season in South Africa.

The differences between these abundance patterns are now being analysed in more detail and will be presented at the conference.

WHERE RODENT PESTS AND RESERVOIRS MEET: A GEOGRAPHICAL ANALYSIS OF AGRICULTURAL RISK AREAS FOR TRANSMISSION OF CHAGAS DISEASE IN MEXICO

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Rodents constitute agricultural pests as well as reservoirs for many diseases affecting humans worldwide. In Mexico, rodent pest species such as the cotton rat, *Sigmodon hispidus*, and the rice rat, *Oryzomys couesi*, reach high densities imposing severe damage to widely distributed and economically important crops such as sugarcane, rice and sorghum. Both rodents also are known to be reservoirs of *Trypanosoma cruzi*, the parasitic protozoan responsible for Chagas disease, transmitted by blood-feeding insects of the *Triatoma* species group. It is estimated that Chagas disease affects two million people in Mexico.

We modeled the ecological niche of the species and then developed potential geographical distributions, using a computer genetic algorithm (Garp, *Genetic algorithm for rule-set prediction*; Stockwell and Peters, 1999) of both rodent pests (reservoirs), and six species of the tratomine *phyllosoma* group (vectors), recognized as important vectors for transmitting Chagas disease. Garp uses species' point localities and environmental variables as input data to generate the distributional predictions.

We overlaid rodent and triatomine distributions to map agricultural areas for potential transmission of Chagas disease. Rural communities living in these regions are likely to suffer from both crop losses and high infection risk for Chagas disease.

Our approach can serve to:

(i) identify potential host relationships for stratifying Chagas disease risk areas, and
(ii) assist with planning of the operational aspects of an integrated pest management program that will include a vector control program.

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LEPTOSPIROSIS: A NEGLECTED RODENT BORNE ZOONOSIS IN TANZANIA

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Leptospirosis is a zoonotic infection which occurs worldwide. The causal agent, *Leptospira interrogans,* was first described by Inada et al. (1916). Human clinical leptospirosis, commonly known as Wiel's disease (Weil, 1886), is characterized by pyrexia of unknown origin (PUO), general malaise, jaundice and hemoglobinuria. Mortality due to leptospirosis is relatively low (4%), however the debilitating effect of this insinuating disease can lead to severe economic losses due to loss of productivity. Leptospirosis is essentially a water-borne infection, whose reservoirs cum vectors are commensal rodents and shrews, which discharge the infectious spirochete through their urine into water bodies. Humans and domestic animals get infected upon contact with the contaminated water, and may assume a reservoir status over a lengthy period of time. Leptospirosis is, therefore, an occupational condition, which affects persons active in swampy or wet environments, particularly in tropical subtropical climates. Leptospirosis was first reported in Tanzania in 1974. However, serological studies that followed have demonstrated a broad prevalence of this infection in rodents, domestic animals and humans.

A study was carried out in the eastern Tanzanian district of Morogoro, which involved determination of seroprevalence of leptospirosis and isolation of the infectious agent from the kidney tissues and urine of rodents and from urine and blood of humans. Fletcher's and Ellinghausen McCullough-Johnson (EMJH) media was used for primary and secondary isolations respectively. The isolates obtained were subsequently characterized into serogroups and serovariants (serovars) by the microagglutination technique (MAT) and PCR.

From among 35 isolates, 8 serogroups and their respective serovars, were identified. This included a "new" serovar "Sokoine", which appeared to be endemic in this region. Serovars Ballum and Icrerohaemorraghiae, however, appear to be the most prevalent. The most common reservoirs were *Mastomys natalensis* and *Cricetomys gambianus,* rats, and shrews (*Crocidura Spp*.). This is the first comprehensive study in Tanzania to demonstrate the prevalence of leptospirosis and the potential role of rodents and insectivores as reservoirs of this zoonotic agent. Broader studies covering other regions of Tanzania are recommended in future to enable a better understanding of the infection and disease patterns, and of other sanitary risks associated with rodents, factors which for a long time have been overlooked or simply neglected.

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OCCURRENCE OF THE RAT LUNGWORM, *ANGIOSTRONGYLUS CANTONENSIS*, IN POPULATIONS OF THE INTRODUCED *RATTUS RATTUS* INHABITING COASTAL FORESTS OF SOUTH-EASTERN AUSTRALIA

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The rat lungworm, *Angiostrongylus cantonensis*, is a nematode that normally inhabits the pulmonary arteries of black rats (*Rattus rattus*) and brown rats (*Rattus norvegicus*) and was presumably introduced to Australia from Asia with these invasive rodent species. In Australia *A. cantonensis* infection has caused neurological disease (Angiostrongyliasis) and death in humans, birds and a wide range of eutherian and marsupial mammals. Both definitive and non-target hosts become infected by ingesting infective third-stage larvae in intermediate gastropod hosts (snails and slugs). The most common route of human infection in Australia is ingestion of infective larvae in small gastropods or their secretions on unwashed salad vegetables to generally cause mild infection and disease. Native fauna that include snails and slugs in their diet are also at risk of infection, though little is understood of the impacts on wild populations as most reported cases of lethal infection have involved captive animals.

Occurrence and prevalence of *A. cantonensis* in *R. rattus* and native *Rattus fuscipes* was measured seasonally for two years in coastal forests surrounding Jervis Bay in south-eastern Australia. Twelve sites in forests to the north of Jervis Bay (Beecroft Peninsula) and eight sites in forests to the south (Booderee National Park) were sampled. Occurrence of *Angiostrongylus* spp. was measured by extracting first-stage larvae from rodent faeces. However first-stage larvae of *A. cantonensis* are morphologically indistinguishable from larvae of the native *A. mackerrasae*. Infection was confirmed by autopsying rodents and examining pulmonary tissue for adult worms that could be identified to species.

Angiostrongylus cantonensis infected populations of *R. rattus* inhabiting coastal forests to the north of Jervis Bay, but not in the south where the native lungworm, *A. mackerrasae* was present in native rodent populations. The apparent geographical separation of these lungworm species may be a consequence of host specificity and negative associations between *R. rattus* and *R. fuscipes*. In northern forests *A. cantonensis* was sampled from *R. rattus* and their faeces on 8 of 12 study sites. Of 410 *R. rattus* autopsied, 18 (4.4% prevalence) were infected with *A. cantonensis*. Highest prevalence was recorded in summer (11.3%), consistent with when intermediate gastropod hosts are presumably most active in the study area. Seasonal patterns in output of larvae also coincided with peak activity of gastropods in spring and summer.

This study highlights the spread of the introduced *A. cantonensis* 200km south from the city of Sydney and into natural coastal forests where it appears well established. Jervis Bay is now the southern most recording of *A. cantonensis* on the east coast of Australia. Its presence in coastal forests close to campgrounds and rural homes has possible human health implications. For example, lethal infection might occur if an infant places an infected snail in their mouth in the campgrounds where presence of *A. cantonensis* in both rats and snails has been confirmed. Infected gastropods in unwashed salad vegetables from local gardens may also be sources of mild infection and disease. The presence of *A. cantonensis* in *R. rattus* populations also has potential negative implications for native wildlife. Native species of primary concern in the study area include the long-nosed bandicoot and the ringtail possum which despite ongoing fox control remain in low numbers, and the endangered bristle bird which has recently been re-introduced into the area. Risks to humans and native wildlife associated with the presence of *A. cantonensis* warrant management of pest rodents in the study area.

TEN YEARS OF LEPTOSPIROSIS EPIDEMICS IN THAILAND: UNDERSTANDING THE RODENT-TO-HUMAN TRANSMISSION THROUGH SPATIAL ANALYSIS

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With over 50,000 cases and 1200 deaths recorded since 1996, leptospirosis has emerged in Thailand as a major vector-borne zoonosis. Rats previously considered as agricultural pests and occasionally hunted for their meat, have become the target of public health officers in an effort to prevent leptospirosis transmission. I n collaboration with the Thai Ministry of Public Health, a Geographical Information System (GIS) for leptospirosis in Thailand has been developed to set up a surveillance mapping of the epidemics and assess the relations between rodents, socio-environmental patterns and leptospirosis occurrence.

Rodent sampling was conducted in different regions and ecosystems with either low or high leptospirosis human incidence. Rodents were geographically located and identified to species to assess their diversity, describe their niche and observe their proximity with humans. Blood samples and kidneys were collected in field for the identification of *Leptospira* in the laboratory and to determine the main vector species. Monthly cases, reported by the Ministry of Public Health from 2000 to 2004, were geo-referenced at a district level (amphoe), and incidence calculated using population data from the National Census (National Statistical Office). Rainfall and temperature data, provided by the Thai Meteorological Department, were spatially interpolated to assess the close association with the rainy season. Spatial correlations were then refined, for the country, using remotely sensed description of the landscape, derived from Landsat V TM images.

Since the first epidemics, leptospirosis has annually shown both occupational specificity in human exposure, with the highest vulnerability for farmers, and environmental specificity, occurring mainly in Northeast and North regions, in paddy field areas, during or after the rainy season. Rainfall has a complex action by amplifying the hazard and transmission of the leptospire bacteria and, in the long-term, by acting on the dynamics of rodent populations. High risk areas have been identified and these provide an important focus for health campaigns aimed at preventative actions to reduce the risk of leptospirosis infection in humans.

SYNERGISM BETWEEN BIOLOGICAL RODENT CONTROL USING *SARCOCYSTIS SINGAPORENSIS* AND ANTICOAGULANTS

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Biological rodent control using the parasitic protozoan *Sarcocystis singaporensis* has been shown to be effective in various crops and has been commercialized in Southeast Asia (Jäkel et al. 2005). The parasites multiply in endothelial cells of blood vessels of the rat, thereby perforating the vessels once leaving host cells. Based on that knowledge, we anticipated that infection could have some influence on the effect of anticoagulant rodenticides, which generally reduce blood clotting activity. Laboratory experiments with Norway rats from Germany confirmed that combining sublethal infection doses of parasites with sublethal concentrations of coumatetralyl resulted in 100% mortality of rats. These results were the foundation of an international patent issued on the combination of biological and chemical rodent control. Here, we show for the first time that this principle also works well under real world conditions in oil palm plantations, which usually pose a challenge to rodent control due to high rat densities.

Two different field experiments were performed in different crop years (2000 and 2001) inside an oil palm area of about 4000 ha in the southern province of Chumphon in Thailand. In the first experiment, two out of six plots of 4.8 ha in size each (600 palm trees) were randomly assigned either three rounds of lethal treatment with parasites ($2x10^5$ sporocysts per bait-pellet; 1-3 pellets per tree), local growers' practice using flocoumafen (4-gram wax blocs containing 0.005% active ingredient), or three rounds of a sublethal parasite inoculum ($1x10^5$ at 1-2 pellets per tree) followed by sublethal baiting with wheat paste containing 0.0375% coumatetralyl (quantity in the field adjusted to target rats at about 6 mg kg^{-1}). To monitor treatment effects, rat populations, which mainly consisted of *Rattus tiomanicus*, were checked before and after treatments by census baiting and live trapping in a core area of 200 palm trees over a period of six months. Trapped rats were ear-marked and released.

In a second independent experiment, three oil palm plots of 9.6 ha size each were assigned three different treatments: one was treated with three rounds of a lethal parasite inoculum, a second received two rounds of a lethal parasite treatment plus a combination of a sublethal parasite inoculum and sublethal coumatetralyl baiting, and a third plot remained untreated as negative control. Census baiting was performed before the trial and after each treatment, whereas live trapping was conducted before the trial and after the last treatment round. Parasite bait was applied at a density of 1.5 pellets per palm tree in each round complemented by a single round of coumatetralyl wheat paste blocs weighing 5 grams (one per tree).

During the first experiment, live trapping and census baiting indicated a significant rat population decline already after the first application round on the plot receiving the parasite/anticoagulant combination treatment (reduction by 73%-91% in February-March, compared with the population before treatment in January), whereas growers' use of flocoumafen (2%-37%) or a lethal concentration of parasites alone (6%-39%) only showed moderately dampening effects. The situation was similar after further two rounds of treatments, when population reduction by combination treatment was further pronounced to 89%-98% compared with 67%-86% for use of lethal quantities of parasites alone, or 73%-95% in the case of flocoumafen (mid of May). However, results of census baiting in April and June suggested that there was higher pressure on the two latter plots due to rats invading from the neighboring estates. Based on recaptures of marked animals we estimated population densities at the start of the trial at roughly 500 rats ha^{-1}. In the second experiment, a single combination treatment alternated with lethal parasite-baiting showed significantly better results in population reduction over a period of four months (83%-96%)

than lethal parasite baiting alone (38%-52%). On the negative control plot, only a slight decrease of the population was observed.

The present results demonstrate that combination of sublethal quantities of *S. singaporensis* with sublethal quantities of anticoagulant, here the 'first-generation' product coumatetralyl, promises to be a powerful new approach for rodent control in high-density situations. Besides its high effectiveness, the environmental benefits seem promising as potential risks of secondary effects on non-target organisms could be substantially reduced, or even eliminated. Our results are particularly interesting in view of the use of barn owls in rodent control. Barn owls, other birds of prey and domestic animals often fall victim to anticoagulant-poisoned rats, particularly in the case of flocoumafen, which is popular in Southeast Asia. This new approach could also be interesting for areas infested with anticoagulant-resistant rats. The trials also indicated, however, that particularly in oil palm, rodent control can only be successful if orchestrated over large areas and/or integrating a variety of methods, unless one is willing to endure the plight of 'sisyphos'.

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RODENTS AS RESERVOIRS OF PARASITES IN INDIA

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Rodents are involved in the transmission of a variety of parasitic diseases around the world. Many species of rodents serve either as vectors of diseases through the transfer of disease-causing organisms or as reservoirs of diseases which are transmitted by arthropod vectors. The close association that rodents have with man and his livestock plus exposure to blood sucking arthropods, beetles, cockroaches and other invertebrates, enlarges the scope for transmission. Parasitic infections harboured by rodents and conveyed to human or animal populations have not been as thoroughly investigated as microbial infections, especially in India. The parasites of rodents from India are reviewed with special reference to our work related with protozoan, nematode, cestode and acanthocephalan parasites found in different rodent species.

Three different species of wild rodents namely the house rat, *Rattus rattus* (n=42); the lesser bandicoot rat, *Bandicota bengalensis* (n=34) and the Indian gerbil, *Tatera indica* (n=15) were caught using live traps from premises and crop fields. Various organs (liver, stomach, small and large intestine and reproductive tract) were examined. The parasites were collected in normal physiological saline and preserved in 10% formal saline solution for later identification after staining with Borax carmine (cestodes and acanthocephalans) and clearing in lactophenol (nematodes). Tissues were processed for histopathological examinations. Blood and fecal examinations were carried out for any possible protozoan infection.

The three rodent species were found to be naturally infected with one or more species of helminths. The rate of infection was highest in *R. rattus* (40.48%) followed by *B. bengalensis* (35.29%) and *T. indica* (20.00%). Metacestodes of *Cysticercus fasciolaris* (1 to 6) were found in the livers of all the three rodent species. Cats in these areas were seen passing eggs of *Taenia taeniaeformis* in the faeces. In one male *Tatera indica*, numerous robust metacestodes of *Taenia* spp. were found in oval sacs attached to mesentery and the abdominal wall (abnormal site). The cauda epididymal fluid of the same gerbil was also infected with a very rare species of Trichostrongylid nematode. The possibility of sexual transmission of this species along with its effect on the reproductive potential of rodents cannot be ruled out. This appears to be the first report of its kind. In one *B. bengalensis,* the intestine was obstructed with an acathocephalan, *Moniliformes moniliformis* along with concurrent infection of *C. fasciolaris* in the form of multiple cysts in the liver. Although no protozoan infection was reported from field rodents, experimental *T. evansi* infection was established in all the rodent species with high pathogenicity and the possibility of sexual transmission as revealed by the presence of *T. evansi* in cauda epididymal fluid of male rats.

The information presented provides an idea about the parasitic infections which rodents harbour and can transmit to human and animal populations. Further research is, however, needed to understand the role of different species of helminths in regulating rodent population dynamics and on reproduction of different rodent species.

IDENTIFYING ECOLOGICAL FACTORS AFFECTING POPULATIONS OF RESERVOIR HOSTS OF LEPTOSPIROSIS: IMPLICATIONS FOR MANAGEMENT

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The purpose of the study was to identify leptospiral reservoir hosts and ecological factors affecting their populations in the Innisfail and Tully region of Queensland, Australia.

Standardized line trapping was conducted on key habitats on banana farms during the September 2002 dry season and the March 2003 wet season. One farm was located in an agricultural landscape (Farm T) and the other in a mixed rainforest and agricultural landscape (Farm I). Leptospires from kidneys of 330 mammals were cultured and serum samples from 612 were processed by microscopic agglutination test (MAT). The relative abundance of carriers was used as a quantitative measure of the risk of infection of leptospirosis and an analysis of variance was performed using the Mixed Procedure in SAS 8.2. Least square means for each effect were compared using pair-wise t-tests to assess the significance of individual differences.

Rattus fuscipes, *R. sordidus*, *R. leucopus*, *M. domesticus, U. caudimaculatus*, *P. nasuta, H. chrysogaster* and *I. macrourus* were renally infected and/or serologically positive to one or more serovars. *Rattus rattus*, *M. burtoni* and *M. cervinipes* did not demonstrate any sign of infection.

Only sample sizes of *R. fuscipes* and *R. sordidus* carrying *Leptospira interrogans* serovar Australis were large enough for statistical analysis. Both rats exclusively harboured Australis and accounted for 92% of Australis isolations. Mean relative abundance of carriers was significantly (P=0.0196) different between the sites, indicating a higher risk of infection in Farm I (mostly rainforest) than Farm T (mostly sugarcane). Mean relative abundance of carriers differed significantly between habitats (P=0.0353), indicating there was a higher overall risk of infection in the sugarcane than rainforest, grassland and banana habitats. Although these results may suggest that control should be focused in the sugarcane, the banana habitat is where banana workers are exposed to the risk of infection, and control should also take place in the banana habitat. Additionally, the population ecology of each potential carrier highlights site-, season- and habitat-specific times to implement control measures. For both species, control should be implemented when the mean relative abundance is lower in the wet season (P=0.0216 for *R. fuscipes* and P=0.0500 for *R. sordidus*). However, the efforts should be focused in predominantly rainforest landscape (Farm I P=0.0007) and habitat (P= 0.260) for *R. fuscipes*, and in predominantly sugarcane landscape (Farm T P=0.0005) and habitat (P<0.0001) for *R. sordidus*.

Further research is required to critically determine movements of carriers between habitats, the relationship between prevalence and population abundance, and the horizontal and vertical transmission dynamics within and between species. This knowledge will be useful for further developing effective strategies for managing leptospirosis. Manipulative experiments may be used to critically determine if infection will decrease with decreasing numbers of carriers.

EFFECTS OF PARASITISM BY FLEAS ON PHYSIOLOGY AND IMMUNOLOGY OF A MICROTINE.

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By definition, parasites obtain resources from their hosts and have negative effects on host fitness. To respond to the detrimental effect of parasites, hosts have evolved a series of behavioural and immunological defences. However, production and maintenance of defences are costly and investment in these different compartments could change resource allocation in other activities or maintenance. Despite the fact that they should activate immune responses when faced with parasites, parasitized individuals have often been shown to be immuno-depressed. However, a direct link between immuno-depression and depletion by parasites is unclear. Hosts can be immuno-depressed partially because of an injected immuno-suppresor by parasites, but they also can be immuno-depressed because of general exhaustion or a lack in one or several resources. For example, antioxidants (Vitamin C and E, carotenoids, polyunsaturated acids) are important immune activators. Parasites may remove them from the host (selectively or not) and hence be responsible for immuno-depression. In this study we measured body condition, humoral immune responses and antioxidant status of experimentally parasitized common voles (*Microtus arvalis*) after 14 weeks of infection. We studied the effects of parasitism by the flea *Nosopsyllus fasciatus* on 25 captive young vole males, compared to 25 de-parasitized ones. Twenty-one weeks after treatment, we also measured resting metabolic rate (RMR).

We found that parasitized voles were in poorer body condition (*i.e.* low body mass, small gonads and low haematocrit) and had a lower antibody titre than de-parasitized individuals. Moreover, parasitized individuals tended to have higher RMR. In contrast, the antioxidant status was not different between treatments.

Our results suggest that parasitism by fleas induces high metabolic and physiological costs. This pattern of costs is in accordance with previous studies which showed either immuno-depression or increases in daily metabolic rate in gerbils parasitized by fleas. By modifying the host's physiology and by decreasing their ability to mount humoral responses, parasitism by fleas can have strong effects on the reproductive output and population dynamics of voles.

LEPTOSPIROSIS AND TYPHUS IN RICE AGRO-ECOSYSTEMS IN SOUTHEAST ASIA: THE NEED FOR FURTHER RESEARCH

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Rats are becoming the most serious pest of rice in Asia, causing annual pre-harvest losses of about 5 – 10%. In addition, reports of 10% loss of grain post-harvest are not unusual. Rats are also transmitters of important human diseases, such as the plague, arena and hanta viruses, rat typhus, lungworm, leptospirosis and toxoplasmosis. The epidemiology of most of these diseases in Asia is poorly understood. Too little attention has been paid to the whole farming system when developing programmes to manage zoonoses. This paper reviews recent studies on leptospirosis and typhus in rodents and humans in Southeast Asia.

This paper will present data from a leptospirosis epidemic in northeast Thailand, human clinical studies of leptospirosis and typhus in Lao PDR, and a field study of leptospirosis in wild caught rats in the Mekong Delta region of Vietnam.

In Thailand, a leptospirosis epidemic was first recorded in 4 provinces in 1996 and had spread to 16 provinces in 2001. At the height of the epidemic, >14,200 cases were reported with 362 deaths (Tangkanakul et al. 2005). People who were at high risk of infection included those who spent a lot of time working in flooded rice fields.

In the Philippines, >1,000 people are hospitalized annually with leptospirosis. The fatality rate is high ranging from 11% to 20%. This appears to be in part because people go to hospital only if severe symptoms develop because they cannot afford to pay for long stays in a hospital. Therefore, it is the urban and rural poor who are at greatest risk because of higher rates of exposure to infectious bacteria and little available income for early medical intervention.

In Lao PDR, serological investigation of 427 adults with unexplained fever during 2001-03 indicated acute infection of leptospirosis in 10%, acute murine typhus in 10% and acute scrub typhus in 15%. Field studies of rodent populations in urban, peri-urban and rural areas are planned to determine the likely role of particular rodent species as reservoirs for these diseases.

In Vietnam, rodents were screened from “rat meat” factories in two southern provinces. In Soc Trang, of 65 rats examined approximately 20% were seropositive, whereas in Bac Lieu no rats (n=65) were seropositive. People who process the rats for human consumption take few precautions against contracting rodent zoonoses. A public education program is urgently needed.

More studies are of high priority to determine the main rodent reservoir species, to study the ecology of these species and to improve our understanding of rodent-human interactions in rice-based agricultural ecosystems.

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Poster Presentations

ENDO- AND ECTO-PARASITES OF THE PHILIPPINE RICE FIELD RAT, *RATTUS TANEZUMI* TEMMINCK AT THE PHILRICE FARM*

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The Philippine Rice Field Rat, *Rattus tanezumi* Temminck, is one of the principal pre- and post-harvest pests of rice and other economically important agricultural crops. It also serves as reservoir for infectious diseases that affect humans and domestic animals.

Endo- and ecto-parasites on *R. tanezumi* vector such diseases. At the PhilRice farm, the endo-parasites infecting *R. tanezumi* were as follows: *Taenia taeniaeformis,* (liver cestode), *Rodentolepis* (=*Hymenolepis)* spp. (tapeworm in the duodenum), and *Raillietina garrisoni* (tapeworm in the small intestines), *Angiostrongylus cantonensis* (rat lungworm/nematode in lungs and pulmonary arteries), *Nippostrongylus muris* (intestinal nematode), and *Euparyphium* spp. (trematode in the small intestine). In all samples from *R. tanezumi*, the ecto-parasitic tropical rat mite, *Liponyssus bacoti,* was observed. Some rats had one or both of two species of rat louse (*Polyplax* spp. and *Hoplopleura* spp.).

The majority of the parasites recorded are zoonotic to humans, and as well are known to infect domestic/pet animals. *N. muris* is not a carrier of zoonotic disease. The best prevention to minimize risks of zoonotic infections is to improve environmental sanitation and public hygiene, consume only well cooked rat meat. We strongly recommend the development of a public health education campaign emphasizing these hygienic measures plus early detection and proper treatment. Insect parasite/vector management is equally important to prevent host-parasite transmission cycle(s).

RODENTS, SHREWS, ECTOPARASITES AND DISEASES AT THOUSAND ISLANDS DISTRICT, JAKARTA PROVINCE, INDONESIA

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In July and September 2005, an ecological study was conducted to explore the risk factors to humans of some zoonotic diseases in a group of tiny islands located in the Bay of Jakarta. Part of this study included a survey of rodent diseases. The results are reported here.

Trapping of rodents (rats and mice) and shrews was done using locally made live-traps and a bait of roasted coconut. Trapping was conducted on six tiny islands (Pari, Panggang, Kotok, Untung Jawa, Rambut and Tidung) belonging to the Thousand Island District of Jakarta Province in Java Island, Indonesia.

A total of 191 small mammals were caught in the Islands with capture rates of 15.7%, 29.3%, 3.6%, 19.3%, 1.5% and 30.3% respectively (overall mean 23.8%). The highest trap rate was on the Island of Tidung followed by Panggang, Untung Jawa, Pari, Kotok and Rambut. There were 2 species of rodents (*Rattus norvegicus* and *Rattus rattus* (= *Rattus tanezumi*)) and one species of shrew (*Suncus murinus*). T he trap rates for each of the species were 40.4 %, 51.9 % and 7.7% respectively. All of the trapped rats and shrews were infested by at least one group of ectoparasites (fleas, lice, ticks or mites). The only species of flea was *Xenopsylla cheopis* which is known as a vector of plague. The flea index was 2.8 on *R. norvegicus,* 0.4 on *R. tanezumi* and 0.3 on *S. murinus.* The specific index for *R. norvegicus*, which is known as a reservoir of plague, was relatively high according to previous reports of indices of approximately 1 at plague foci where human cases have been reported in Southeast Asia. Forty three (22.5 %) of rats were antibody positive to hantavirus infection that causes hemorrhagic fever with renal syndrome (HFRS) and Hantavirus pulmonary syndrome (HPS). More than half (12.5 %) of these were from the Island of Panggang and the remainder (10 %) were on the Islands of Untung Jawa and Tidung. Two of 11 (18.1 %) shrews were serologically and genetically positive to Totapalayam virus which has been reported to infect humans in Thailand.

PLAGUE CONTROL AND PREVENTION IN YUNNAN PROVINCE, CHINA

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There are both commensal rodent plague foci and wild rodent plague foci in Yunnan Province, China. Since 1982, when plague reappeared in animals after no reported infections in 26 years, 51 counties and cities have reported 507 human plague cases with 2 deaths. These statistics provide a clear indication of the severity of the epidemic in Yunnan Province.

The current paper introduces the plague situation in Yunnan. We describe the characteristics of the distribution of the disease in humans, the counter measures developed and implemented to reduce the cases of human plague, and the outcomes of these control programs.

Jiangchuang County is the centre of wild rodent plague foci in Yunnan. The main reservoirs are *Apodemus cheverieri* and *Eothemomys miletus*; the main vector is *Neopsylla specialis* specialis. Epidemics of plague may occur every month in Jiangchuang County, peaking in December. Commensal rodent plague foci are distributed in the west, south and south-west Yunnan, covering dozens of counties. The main reservoir is *Rattus flavipectus*; the main vector is *Xenopsylla cheopis*. This plague may also occur every month with higher incidence from July to November. At present, foci of commensal rodent plague are very active and are a serious public health problem in Yunnan.

Since 1982, Yunnan has strengthened its plague surveillance. Initiatives include encouraging the general public to contribute information about plague (especially about dead rats), systematic professional surveillance of rodent carriers and insect vectors, and the addition of mobile medical monitoring units to increase coverage. The surveillance areas have been expanded from 3 districts and 10 cities in 1982 to 14 districts and 101 cities in the present day. Each year the number of surveillance samples accounts for one third of all those taken in China.

PORPHYRIA OBSERVATIONS ON THE CANEFIELD RAT, *RATTUS SORDIDUS*

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Porphyria is a group of diseases caused by defects in heme synthesis. Enzyme deficiencies lead to the accumulation and increased excretion of porphyrins or porphyrin precursors. The conditions are either induced or mainly inherited, and are erythropoietic or hepatic depending whether the enzyme deficiency occurs in the red blood cells or in the liver. Congenital erythropoietic porphyria (CEP) is a rare autosomal recessive condition reported in humans and some animals. Uroporphyrin 1 is deposited in tissues, particularly bones and teeth, resulting in pink coloration and fluorescence of bones, tissues and urine under long wave ultraviolet (UV) light.

In humans, CEP is detrimental and is expressed shortly after birth or early in childhood with a short life expectancy. Patients experience anaemia, splenomegaly and extreme photosensitivity with serious dermal lesions that rupture, become infected, and cause scaring. There have been fewer than 200 reported human cases.

CEP has been detected as a rare pathological condition in cattle, swine, cats, dogs and rodents. But fox squirrels (*Sciurus niger*) have a physiological porphyria that is characteristic to the species and causes no dermal lesions and no detrimental effects to the animal. Among mammals, only in the *Sciuridae* do really red bones appear to occur, though many other rodents have pinkish bones. Other characteristics were that under UV light, the bones shone with a bright red fluorescence and the teeth, although pink at the gum margin, did not fluoresce, nor did the red-brown anterior surfaces of the incisors.

During 2002-2003, a study focusing on animal species in banana fields and their prevalence of leptospirosis in Far North Queensland stumbled onto an interesting observation. Several rodents demonstrated red teeth. As a result from the study, 2 canefield rats (*Rattus sordidus*) were taken to the laboratory and dissected. One skeleton was completely excised and the other specimen was preserved in 95% ethanol. All the bones and teeth were bright red and the cartilaginous tissue was pink. Under the UV light, the skeleton had a bright red fluorescence.

The animals were mature and appeared to be in good health with the clinical manifestations associated with CEP seemingly absent. The two *R. sordidus* collected and the other released rodents (recalled as *R. sordidus*) that showed red teeth were observed in a small isolated patch of sugarcane. Grassland and sugarcane are the preferred habitats of this species. This isolated patch of sugarcane may have allowed for the inbreeding of a small population that would maintain a high incidence of the autosomal recessive genes that causes CEP. The intensity of the red coloration of the bones and the teeth, and the intensity of the fluorescence under UV light have not been reported in any animal, except for the fox squirrel, but even in that species, the coloration and fluorescence is variable.

The implications of this observation suggest *R. sordidus* as an alternative animal model for porphyria research. Until now, the fox squirrel represented the only animal model suitable to determine the genetic basis and physiological conditions of the disease, and an easy and inexpensive laboratory animal for the studies. The capture of affected rats and the establishment of a breeding colony are warranted to determine the condition of CEP in the animals and to determine their suitability as laboratory research animals.

AN AUDIT OF RODENT BORNE DISEASES IN INDONESIA

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Rodent plays an important role in the lives of humans. Their association with humans leads to major impacts through reducing the production of agriculture commodities, through invading homes and grain stores, and as the vector of diseases for humans and their livestock. Of 164 rodent species in Indonesia, eight species (*Bandicota indica, Ratttus norvegicus, R. rattus diardii, R. tiomanicus, R. argentiventer, R. exulans, Mus musculus and M. caroli*) are known to be important agricultural pests and vectors of disease.

This article reviews the published literature and some Government reports on the occurrence and impacts of some rodent borne diseases in Indonesia. The diseases include those caused by viruses, rickettsia, protozoan, fungi and helminthes. Infection in humans generally occurs directly through contact with rodent excrement, through ingesting contaminated food or through rodent bites, and indirectly through bites from ectoparasitic vectors such as fleas, ticks and mites. The diseases we review are plague, leptospirosis, Hantavirus (dengue with renal syndrome), scrub typhus, murine typhus, spotted fever group (SFG) rickettsia, salmonellosis, schistosomiasis, eosinophilic meningitis (angiostrongiliasis) and echinostomiasis. Indonesian Government agencies conduct surveillance programs that collect, analyze, and interpret relevant clinical and epidemiological data on some of these diseases, especially the plague. The primary focuses for this surveillance are antibody titres and disease symptoms in human and rodents.

POTENTIAL OF *SARCOCYSTIS SINGAPORENSIS* AS A BIOLOGICAL RODENT CONTROL AGENT IN VIETNAM

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Rats cause great damage to rice and other crops in Vietnam. Although this problem has decreased in severity over the last few years, rats remain a major issue in agriculture. To control rats, chemical and mechanical methods are usually applied. To implement a new environmentally friendly approach to rodent control, the Vietnam Agricultural Science Institute and German Technical Cooperation tested the usefulness of *Sarcocystis singaporensis* as a biocontrol agent. This cyst-forming coccidian parasite specifically infects rats of the genera *Rattus* and *Bandicota* and is native to Southeast Asia. The technology has been commercialized (Jäkel et al. 2005), including Vietnam, where it is registered as a rodenticide. The present paper presents results of some laboratory and field trials conducted in Vietnam.

To check for pathogenicity of the parasite against the local pest species, *Rattus argentiventer, R. losea, R. rattus ('flavipectus'), R. norvegicus,* and *Bandicota indica* were infected with a lethal dose of infective stages ($2x10^5$ sporocysts) in the laboratory. To test for safety of the bioagent towards indigenous chicken, three young birds were fed rodent bait containing $2x10^5$ sporocysts of *S. singaporensis*. Two animals received plain bait as negative controls. Further growth and general health status of the animals was recorded over a period of two months. Field studies were conducted in two rice fields (two and four ha) of the Hybrid Rice Research Center located in Ankhanh, Hoaiduc, Hatay, and in a vegetable field of about one ha size in the cooperative of Tien Phong, Melinh, Vinh Phuc. One-gram bait pellets consisting of wheat flour and vegetable oil and containing $2x10^5$ sporocysts were distributed in the field in two rounds at a density of about 150 pellets per ha. Rat abundance before and after the experiment was estimated by census baiting using ripening rice and counting 'active' rodent burrows. Rat damage to the crops was also assessed before harvest.

The laboratory studies showed that *S. singaporensis* was highly pathogenic to all rat species tested. Usually the animals succumbed to infection after 12-20 days (mostly 100% mortality), depending on the rat species. Again, as seen in earlier studies, Norway rats were most resistant and bandicoot rats most sensitive to infection. This could reflect differences in the evolutionary relationship between parasite and host. Feeding the parasite to chickens had no negative effects on the animals, confirming that despite its high pathogenicity for rats it is harmless to non-target species. The field experiments showed that rat infestation could be reduced by 85%-87% in rice fields and 88% in the vegetable field. Damage was reduced from 4.6% to 0.8%-1.0% in rice, and from 8.9% to 3.9% in the vegetable field. Economical analysis indicated that application of the bioagent was beneficial to farmers. However, because distribution of the technology in Vietnam is still very limited, the future has to show whether this is an economically attractive alternative to chemical rodent control.

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SURVEILLANCE OF RODENT-BORNE DISEASES IN SINGAPORE

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Singapore comprises old and new residential areas intermingled with food establishments. As this is conducive to thriving populations of rodents, it is essential to determine the zoonotic potential of various rodent-borne pathogens such as hantavirus, *Leptospira*, *Yersinia pestis* and *Rickettsia typhi*. Unfortunately, knowledge of the prevalence of these pathogens is lacking and our study aims to update us on the current baseline level of infection in the rodent population in Singapore.

Metal single-capture live traps were set all over Singapore in various types of premises such as high-rise public housing, low-rise private housing, food establishments, bin centres and construction sites. Live rodents were brought back to the laboratory to be sampled. Blood, ectoparasites and various tissues were collected and processed before storage.

Polymerase chain reaction (PCR) was employed on a segment of the left kidney to detect leptospires. Another segment was cultured in semi-solid EMJH medium (Ellinhausen and McCullough modified by Johnson and Harris). Whole blood was plated on selective BIN agar for *Yersinia pestis.* Enzyme-link immunosorbant assay (ELISA) was performed on serum samples to detect anti-hantavirus IgG using the Seoul hantavirus nucleocapsid antigen. Ectoparasites were sorted and identified by light microscopy.

To date, 354 rodents have been caught. Among the samples tested 30% were seropositive to Seoul virus, 32% were positive for pathogenic leptospires, 37% were found with spiny rat mites, *Laelaps echidnina*, 19% were found with rat fleas, *Xenopsylla cheopis* and 4% of the rodents had both ectoparasites on them.

The seropositivity of rodents towards hantavirus is comparable with the last published data in the late 1980s for Singapore where 26% of commensal rodents were seropositive.

As the project is still at an early stage (our target is 1200 rodents), more serological and genetic testing will be done to develop a more accurate and overall scenario of the prevalence of the pathogens in the rodents in Singapore.

In future, we hope to perform agent isolation and simple genotyping to characterize samples that are positive for virus or bacteria.

Symposium: Rodenticide resistance and other molecular features of rodent populations

Chairs: Hans-Joachim Pelz and Michael H. Kohn

Oral Presentations

DETECTING ADAPTIVE POPULATION GENETIC STRUCTURE IN RODENT POPULATIONS

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The release of the genome sequences of rat and mouse will enable the study of rodent populations with ever-greater ease and power. In addition, new technological genomic platforms and bioinformatics tools enable less costly surveys of the rodent genomes and variations thereof. Both rats and mice play important roles as pest species and carriers of disease. Detecting variation at the level of genes could inform control programs of rodent populations by revealing population structure that is predictive of the spread of disease or via the detection of genetic variants that might mediate resistance to rodenticides.

I will introduce population genetic approaches to map ecologically relevant genetic variants in rodent populations that, with the availability of the mouse and rat genome, are now feasible. Resistance to anticoagulant rodenticides, such as warfarin, in rats (*Rattus norvegicus*) will serve as a case study to illustrate these. Moreover, the case study will underscore the importance of a thorough understanding of population genetic structure over the genome if the goal is to understand adaptation at specific genes. Specifically, non-random association between genetic variants in a genomic region (linkage disequilibrium), loss of genetic variation, and deviations from other equilibrium predictions enable the detection of candidate genes underlying adaptation. However, rat population structure is pronounced and neutral genetic differentiation exceeds differentiation due to selection at some loci. Finally, the problem of inferring the precise location of the warfarin resistance gene is illustrated by presenting data on the wide genomic window (several centimorgan) that is affected indirectly (via genetic hitchhiking) by selection with rodenticides.

The mapping of the warfarin resistance gene is used as an exemplary case of how the new and coming genomic resources might be used to identify genes underlying adaptive population genetic structure in rodents. Inferences regarding the mode and strength of selection are presented. Despite the successful implementation of the approach to map the warfarin resistance gene it is cautioned that the mapping of adaptive genes and inferences regarding the mode of selection at them is adversely affected by strong population genetic structure across the genome in rat populations.

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THE GENETIC BASE OF ANTICOAGUANT RESISTANCE

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Control of Norway rats, *Rattus norvegicus*, is almost exclusively reliant upon the use of anticoagulant rodenticides. Anticoagulants inhibit blood coagulation by repression of the vitamin K reductase reaction (VKOR). Due to their prolonged action these compounds achieve efficient control without causing problems in bait acceptance. Within a few years of the start of their use in the early 1950's a first case of resistance was detected in Scotland. Other cases in several countries worldwide required the development and introduction of more potent anticoagulant compounds in the 1970's, 1980's and 1990's. However, the mechanism of resistance was poorly understood. Great progress was achieved with the identification of the gene VKORC1 encoding for an essential enzyme in the vitamin k cycle (Rost *et al.* 2004).

Recent investigations carried out on resistant brown rats *(Rattus norvegicus)* and house mice *(Mus musculus)* derived from known resistance areas in several European countries revealed that specific point mutations in this gene confer resistance to anticoagulant compounds (Pelz *et al.* 2005). About ten different mutations conferring resistance in the *VKORC1* gene have been identified so far, demonstrating that such mutations developed several times independently. A field study on wild brown rats in Germany showed that the mutation Tyr139Cys is specific for the German resistance area where it was found in 98% of 286 rats classified 'resistant' by the blood clotting response test (BCR), while the mutation was absent from 97% of 142 rats classified susceptible by the BCR-test. Samples from Danish wild rat populations suggest that Denmark and Germany share the mutation Tyr139Cys in resistant rats. While breeding colonies of 'Welsh-' and 'Scottish-'type resistant rats were each characterised by specific point mutations in VKORC1 (Tyr139Ser and Leu128Gln respectively), Hampshire-' and 'Berkshire-'resistant rats shared the mutation Leu120Gln. Resistant rats from Belgium (Flanders) and France (Burgundy and Center) shared the mutation Tyr139Phe.

Results achieved so far suggest that mutations in VKORC1 are the prerequisite for the development of anticoagulant resistance in wild populations of rodents. The mutation indicates resistance to warfarin, usually progressing to more potent anticoagulant compounds (e.g. bromadiolone, difenacoum) within a short time, once the mutation has become established in a population. This may require the involvement of additional genes that are still unknown. Knowledge of the resistance gene sequence allows the design and application of more efficient resistance monitoring methods based on tissue and excrement analysis. Further studies are required to determine and compare the impact of the different mutations on blood clotting activity and control efficacy.

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MIGRATION AND DIFFERENTIATION BETWEEN SURFACE RAT POPULATIONS IN AN URBAN AREA: CONSEQUENCES FOR THE SPREADING OF RESISTANCE AGAINST RODENTICIDES

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Knowledge about delimitations of populations of pest species and assessment of gene flow between neighbouring populations may be very valuable for the planning of future pest control strategies. We examined the genetic structure of brown rats (*Rattus norvegicus*) to identify possible gene flow between different geographic areas and to delimit presumed populations. We investigated variation in 10 polymorphic microsatellite loci in rats collected from 15 localities distributed over six municipalities across Denmark. Genetic similarity in the investigated populations can be due to either a shared origin or an ongoing gene flow. An ongoing gene flow is critical when dealing with rodent control/eradication as this could lead to a control failure due to re-colonization. Furthermore the understanding of migratory patterns is crucial in understanding the spread of unwanted genes/biological traits, such as the anticoagulant resistance.

We found a significant correlation between genetic and geographical distance with a high level of differentiation even within short distances among the examined populations. However, we found that differentiation between neighbouring areas was higher than between distantly located areas suggesting higher differentiation within municipalities than among them. Though migration seemed to occur, primarily, over short distances, even short distances or simple landscape barriers had a considerable negative effect on migration.

We also found that earlier rodent control at the examined localities did not cause any bottleneck effects in any of the investigated populations, indicating little effect of eradication programs or intense immigration from neighbouring areas.

SPREAD OF RESISTANCE TO ANTICOAGULANT RODENTICIDES IN *RATTUS NORVEGICUS* IN FRANCE AND IN GERMANY

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Investigations into resistant Norway rat populations from several European countries have revealed that region-specific point mutations in this gene confer resistance to anticoagulant compounds (Pelz *et al.* 2005). For France, information on the occurrence of resistance is still very poor. Catalytic studies in Vitamin K epoxide reductase subunit 1 (VKORC1) showed that the mutation Y139F, prevailing in France and in Belgium, confers a strong degree of resistance to warfarin in rats (Lasseur *et al*. 2005). It was found in the centre of the country (departments Eure et Loir, Loir et Cher, Loiret and Yonne). The mutation Y139C, prevailing in Germany and in Denmark, confers a moderate degree of resistance. Anticoagulant resistance in Norway rats in Germany is restricted to an area in the Northwest of the country. Compounds affected are warfarin, coumatetralyl, bromadiolone and, to a lower proportion, difenacoum.

Based on the identification of the resistance gene VKORC1 (Rost *et al*. 2004), tissue or excrement samples can be analyzed for resistance-mediating mutations with molecular genetic methods. Using such methods we analysed Norway rat tissue and faecal samples from outside the known resistance areas in France and in Germany.

In France, we analysed 500 rat tails from 39 different localities, initially suspected for resistance. The mutation Y139F (heterozygous and homozygous) was identified in additional locations (e. g. departments Eure et Loir, Loiret, and Rhone). Moreover, for the first time in France we identified resistant rat populations with the VKORC1 mutation L120Q in the department Charentes (France middle-West).

In Germany the investigations revealed that the resistance area is reaching considerably further east. The easternmost populations containing resistant individuals with the mutation Y139C have now been detected in the city of Hannover, which is about 100 km east of the known resistance area. Assuming a mobility rate of 5 to 8 km per year, this spread is still in line with the normal extension of the species. On the southern edge our results suggest that the extension of resistance towards the highly urbanized Ruhr Basin takes place at a slower rate. The Ruhr Basin is still mostly unaffected. Resistance to anticoagulant rodenticides in *Rattus norvegicus* in Germany is now estimated to cover an area of roughly 26,000 km^2. Our results suggest that resistance in both countries is more widespread and diverse than hitherto suspected, with propagation in the countryside being probably faster than in urbanized areas. They emphasize the need for thorough resistance monitoring as a basis for adequate control measures and prevention of the use of ineffective pesticides. Further studies are required to evaluate the significance of the different mutations in VKORC1 and their impact on the mechanism of resistance.

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NOVEL SEQUENCE VARIANTS OF THE VKORC1 GENE IN RODENTS FROM POTENTIAL WARFARIN-RESISTANCE AREAS IN EUROPE, EAST-ASIA AND BOTH AMERICAS.

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Cumarin derivatives, e.g. warfarin, are in world-wide use for rodent pest control since they effectively repress blood coagulation. However, rodent populations have developed resistance soon after the introduction of such compounds. Today, in many countries, effective rodent pest control is hampered by the rapid spreading of warfarin-resistant populations.

Recently, the target enzyme of cumarin poisons has been identified: VKORC1, a key component of the vitamin K redox cycle, is capable of reducing vitamin K epoxide and is inhibited by warfarin. Mutations in VKORC1 have been shown to confer resistance (*in vivo* and *in vitro*) to anticoagulant rodenticides in laboratory strains and wild catches of *R. norvegicus* and *M. m. domesticus* from various countries. Apparently, independent mutations have arisen in different resistance areas which affect different amino acid positions of the VKORC1 protein.

Table 1: *VKORC1 mutations and polymorphisms found in rats and mice from different geographic, anticoagulant-exposed areas.*

Geographic area	Amino acid substitutions	No. of specimens	Neutral mutations (SNPs)
Rattus norvegicus			
England, Cambridge / Essex	Phe63Cys + Ala26Thr Phe63Cys + Tyr39Asn Phe63Cys	1 1 15	Ile82Ile Ile82Ile Ile82Ile
Hungary	Tyr139Cys	4 2	Ile82Ile Ile82Ile
Korea	Tyr139Phe	1	
Indonesia		1 1 1	Ile90Leu + Ser103Ser + Ile107Ile + Thr137Thr + Ala143Val; Ile90Leu + Ile107Ile + Thr137Thr; Ile82Ile
Japan	Glu67Lys	6	
USA, Santa Cruz		3	Arg12Arg + Ile90Leu + Leu94Leu + Ile107Ile + Thr137Thr + Ala143Ala
Argentina, Buenos Aires	Trp59Arg	7 8	Arg12Arg + Ile90Leu + Leu94Leu + Ile107Ile + Thr137Thr + Ala143Ala; Ile82Ile
Mus musculus/domesticus			
Germany, Berlin	Glu37Gly	12	
Germany, Münsterland	Arg58Gly Arg12Trp + Ala26Ser + Ala48Thr + Arg58Gly+ Arg61Leu	13 7	

Here, we report on the analysis of the VKORC1 gene in more than 100 additional samples of rats and mice from potential resistance areas in Europe, East-Asia, North- and South-America (Table 1). A total of 16 novel variants have been found demonstrating a high degree of sequence divergence in both species. Some variants do not alter the amino acid sequence of the protein and are shared by animals from distant populations. Thus, they are likely to represent neutral polymorphisms. Other variants, however, are predicted to alter the protein's composition and should, therefore, lead to functional impairment of VKORC1 activity and/or warfarin sensitivity. Enzyme measurements are required to further study the effect of these presumed mutations.

We thank in-country colleagues for providing samples.

SPATIAL GENETIC STRUCTURE OF THE GRAY-SIDED VOLE, *CLETHRIONOMYS RUFOCANUS*, IN HOKKAIDO, JAPAN

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The gray-sided vole, *Clethrionomys rufocanus*, is one of the most common rodents in Hokkaido. Its distribution is restricted to this northernmost island in Japan. The population dynamics of this species has been extensively studied for forest management. In this study we analyzed the spatial genetic structure of the mainland and island populations.

We compared the mitochondrial DNA variation of the gray-sided vole from 15 mainland populations and three island populations (Rebun, Daikoku and Kunashiri). Direct sequencing of the partial mitochondrial DNA (mtDNA) control region (745 bp) in 213 voles from the 18 populations revealed 94 haplotypes. Among the haplotypes, nucleotide substitutions were observed at 79 variable sites. Most substitutions (61) were transitions. There were shared haplotypes among the mainland populations that did not form any apparent geographic partitioning. Rebun Island shared two haplotypes with two mainland populations. The Daikoku Island population had one unique haplotype while the Kunashiri Island population had several unique haplotypes. The median-joining network showed that several haplotypes from mainland populations and median vectors (extinct or unsampled haplotypes) formed the main framework suggesting possible ancestry of the other haplotypes. Haplotypes from the island populations, on the other hand, were found at the periphery of the network, suggesting that these populations are younger.

The absence of an apparent geographic pattern for the mtDNA haplotypes suggests that the gray-sided vole population, which has diverged haplotypes, migrated from continental Asia to Hokkaido via Sakhalin relatively recently.

PHYLOGEOGRAPHY AND MOLECULAR ADAPTATION OF PHEROMONE RECEPTORS (V1r) IN SYMPATRIC AND ALLOPATRIC POPULATIONS OF NATIVE AUSTRALIAN *RATTUS*: A PROSPECTUS

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One of the great promises of the post-genomic era is the ability to identify genes of adaptive significance within and among species and populations. While to date, genomic analyses of genetic adaptation have been limited to model organisms, primarily in a laboratory setting, the application of these tools to natural populations will be essential to integrating the ecology, biogeography and population biology of species with the evolutionary processes of diversification and adaptation. We will use molecular tools available from the *Rattus norvegicus* genome to investigate the adaptive divergence and demographic history of natural populations of two closely related Australian *Rattus* species, the bush rat (*R. fuscipes*) and the Cape York rat (*R. leucopus*). We will sequence the complete vomeronasal 1 receptor (V1r) gene family for sympatric and allopatric populations of each species. In addition, we will use information from multiple genetic markers to set the adaptive differences among *Rattus* populations in the context of their demographic histories. We present a review of vomeronasal receptor adaptation and function and an overview of our prospective research on detecting signatures of selection in natural populations of Australian *Rattus*.

The vomeronasal organ (VNO) is a chemoreceptor organ separate from the olfactory epithelium and composed of two types of receptors (V1r and V2r) that are distinct from the larger family of olfactory receptors (OR). Vomeronasal receptors are active in a wide diversity of vertebrates including teleost fish, squamates, and most mammals, with a notably dramatic reduction in humans. The VNO is implicated in the recognition of pheromones that provide information about social and sexual status. Physiological studies indicate that VNr are essential for social recognition of conspecifics and are involved in expression of sexual behavior. Pheromonal and urinary scent cues have been demonstrated to induce copulatory behavior, puberty acceleration, termination of pregnancy and to influence mate selection, estrus synchronization, and estrus suppression. Furthermore, vomeronasal receptors (VNr) are highly polymorphic and comparisons of the genomes of humans, mice and rats indicated elevated signatures of radiation and adaptation of VNr in rats and mice. Thus, VNr are involved in sexual and social behavior and exhibit macroevolutionary patterns of adaptive divergence.

The most significant result of adaptive divergence is the formation of two populations of organisms that no longer interbreed and thus become true biological species. Identifying the genes that are associated with speciation and the barriers to reproduction among species is central to understanding the evolutionary processes generating biological diversity. The physiological and reproductive importance of VNr and their strong signatures of selection, when compared among species, indicate that they may play an important role in the reproductive isolation of species.

Native Australian *Rattus* are an ideal system to evaluate the importance of pheromonal cues and receptors in the reproductive isolation of species. The seven species of *Rattus* native to the Australian continent colonized the region within the last 1-2 my. Despite this young history, five species are endemic, have expanded throughout Australia, and have adapted to a variety of habitats. Despite broad overlap among closely related species, such as *R. fuscipes* and *R. leucopus*, they are not known to interbreed in the wild and hybrids formed in the laboratory exhibit extreme or complete loss of fertility. How Australian *Rattus* avoid hybridizing in the wild is not clear, but pheromone cues represent the most likely candidates and provide an exemplary system for testing the importance of genetic variation in VNr in the reproductive isolation of vertebrates.

We will sequence the complete complex of V1r genes (~100 genes in *R. norvegicus*) for two species of Australian *Rattus, R. fuscipes* and *R. leucopus.* Both species are present in rainforests of the southern Cape York peninsula. The range of *R. fuscipes* extends south along the eastern and southern coasts of Australia and as far west as Perth, while the range of *R. leucopus* extends north and into New Guinea. Where they are sympatric, they breed at the same time and are often found in the same forest patches. Thus, mating between the two species is likely to be restricted by behavioral isolation. These species therefore provide an ideal starting point to evaluate the importance of VNr in adaptive divergence and reproductive isolation in natural vertebrate populations.

We will compare sequences of V1r genes for both species from sympatric and allopatric populations using a comparative phylogenetic approach. The expression of all gene products will be confirmed with rtPCR. If V1r are important in the reproductive isolation of *R. fuscipes* and *R. leucopus* then they should exhibit elevated levels of divergence in sympatric populations consistent with a history of reinforcement selection (i.e. hybrid avoidance). A candidate set of genes that exhibit elevated divergence among sympatric populations also will be sequenced for population level analyses. Comparison of rates of synonymous and non-synonymous substitutions within populations, among sympatric and allopatric populations of the same species, and among species will be used to identify loci that exhibit elevated levels of positive selection due to sympatry of *R. fuscipes* and *R. leucopus*. These patterns would indicate the importance of these loci in the maintenance of reproductive isolation.

Finally, the adaptive divergence among species and populations will be set in the context of their demographic histories. Mitochondrial DNA and ~5 nuclear introns will be sequenced for samples from throughout the range of the two species. An additional 10-15 introns will be sequenced for the focal sympatric and allopatric populations. Demographic parameters will be estimated from these sequences 1) to estimate divergence time among populations and among species, 2) to estimate the time of sympatry, 3) to evaluate effective population size fluctuations and 4) to evaluate isolation and gene flow among sympatric and allopatric populations.

Poster Presentations

A SEWAGE RAT PROJECT FOCUSING ON POPULATION DYNAMICS, CONTROL AND RESISTANCE.

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The knowledge we have on the biology and behaviour of sewer rats (*Rattus norvegicus*) is limited. Thus management strategies and general use of anticoagulants in the sewers to control rats are based on the assumptions that the biology of sewer rats and surface rats are identical. A detailed knowledge and understanding of the biology and behaviour of sewer rats will give us a valuable tool for targeted and efficient rodent control.

Sewer rodent control is carried out in 81% of the municipalities (total = 275) in Denmark. Large amounts of anticoagulants are used by the municipalities in the sewers alone (approx. 100,000 sewer blocks = ~20,000 Kg). The effect on population densities has never been documented, and facts on when to control and how much rodenticide is needed and if anticoagulant resistance is present are issues which have hardly been addressed.

A three year project has been initiated in Denmark in order to elucidate some of the unknown biological and rodent control aspects of the sewer rat. In this project we will investigate if intensive rat control compared to no rat control in the sewers has substantial effects on the population densities. Besides investigating the efficiency of rodent control, some of the other questions that we want to address relate to the general population dynamics such as densities, survival and sex ratios and whether these parameters vary according to season. Do rats within the sewers constitute one large population unit or are there several genetically defined populations? What factors may cause a possible population differentiation? By tracking rats within the sewers and looking at differences at the genetic level we hope to answer these crucial questions.

Symposium: Rodenticide usage

Chairs: Penny Fisher and Brian Hopkins

Oral Presentations

THE EFFICACY OF ZINC PHOSPHIDE BAIT TO CONTROL RODENT POPULATIONS IN TEAK AND HOOP PINE PLANTATIONS

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Two species of Australian native rat cause serious damage to timber plantations in Queensland. The canefield rat (*Rattus sordidus)* is responsible for major economic losses to teak plantations, while the pale field rat (*R. tunneyi culmorum)* can devastate young hoop pines. Both species can cause severe tree damage by burrowing in root systems to consume the soft, starchy outer-root tissues. The present studies aimed to determine if RATTOFF® Zinc Phosphide Bait Sachets (developed for rodent control in sugarcane crops) reduced the populations of these rats at the Mount Ray teak plantation (north of Cooktown, Qld, Australia) and in hoop pine plantations at Yarraman (south-east Qld, Australia).

In the *R. sordidus* teak plantation efficacy trial, trapping on standardized grids was conducted in October 2005 in paired treatment-control sites on two blocks. Trapping was conducted at all sites for four consecutive days pre-treatment, then RATTOFF® was applied at 1 kg/ha (100 sachets/ha) to the two treatment sites and left undisturbed for seven days. This was followed by three consecutive days of post-treatment trapping at all sites. A total of 137 *R. sordidus* were captured over 1,015 trap nights at the four sites. The pre- and post-baiting population size of *R. sordidus* on each trap grid was estimated using the closed-capture population analysis in program MARK. The Model M_0, which assumes no variation in capture probability, was selected by the model selection procedure for 5 of the 8 populations, therefore all populations were analysed using the M_0 model. After baiting there was a significant reduction in the population size at the two treatment sites (Z test, both $p<0.01$) and a significant increase at the two control sites (Z test, both $p<0.01$). There was also a significant reduction in the survivorship of rats at the two treatment sites (Z test, both $p<0.01$) but there was no change at the two control sites (Z test, $p>0.01$). Zinc phosphide baiting reduced the two estimated *R. sordidus* populations by 82 and 85%.

In the hoop pine plantations, break-back traps were placed along census lines, in control (n=1) and treatment (n=2) blocks in accordance with the Queensland Department of Primary Industries forestry management guidelines, during March 2002. Trapping for *R. tunneyi culmorum* was conducted at all sites for two consecutive days pre-treatment, then RATTOFF® was applied at 1 kg/ha to the two treatment sites and left undisturbed for five days. This was followed by two consecutive days of post-treatment trapping at all sites. Rodent density indices (RDIs) were calculated from the outcome of the census line trapping. There was a significant reduction in the RDIs (Chi-square, $p<0.01$) between treatment and control sites after the application of RATTOFF®. Zinc phosphide application reduced the RDIs of *R. tunneyi culmorum* by 74 and 100%.

In both trials, extensive non-target observations and carcass searches revealed no impacts on either bird or mammal populations. The results of the two trials indicate that the application of RATTOFF® achieved substantial control of rodents in both plantation situations. RATTOFF® may therefore provide an efficacious control for these two rodent species in teak and hoop pine plantations.

IMPROVEMENTS IN THE TARGETING, EFFECTIVENESS AND USE OF RODENTICIDES: 1996 – 2006

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Rodenticides for broad scale field control came under scrutiny in the 1980's and 1990's. Considerable research has been undertaken to update the toxicology databases of older compounds, such as diphacinone, and non-anticoagulant poisons, such as cholecalciferol and 1080, to meet current international standards. In parallel, we focussed on identifying "use patterns" and formulations that are effective at killing pests but also less hazardous to other wildlife. The risks to non-target animals that accompany the use of rodenticides are determined by intrinsic susceptibility, the toxicokinetics of the compound used, and the degree and frequency of exposure. In this regard, improved bait quality and reduced sowing rates for aerially applied rodenticides has reduced non-target risk in New Zealand. These developments were coupled with the identification of improved baits for ground-based control of rodents. Finally, *in vivo* metabolism and persistence studies, coupled with field surveys have provided us with an improved understanding of the toxicokinetics and non-target effects of different anticoagulants. This enabled us to improve our choice of rodent control tools for island versus mainland use. The risks associated with "one –off" applications of baits containing second generation anticoagulants (SGARs) for rodent eradication on islands are considered to be very substantially outweighed by the potential benefits of rodent eradication to their ecosystems. On the mainland, contamination of wildlife and game species and risk of secondary poisoning have been substantially reduced by switching from SGARs to first generation anticoagulants, notably the indandiones, integrated with alternatives to anticoagulants such as cholecalciferol and trapping. These represent significant achievements resulting in more effective control with reduced side effects. Nevertheless, safer use patterns and formulations, and new rodenticides are still required and this will be a major challenge for the 21st century.

RODENTICIDES USAGE IN TANZANIA, A NEED FOR ALTERNATIVE MANAGEMENT STRATEGIES

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Rodents are serious pests in agricultural fields and human dwellings in Tanzania. Populations of the multimammate rat (*Mastomys natalensis)* can erupt irregularly, reaching densities of 1400 rats ha^{-1} as was recorded in Lindi region in 1998, causing severe crop losses. In the 1997/1998 farming season, losses of 48%, 60% and 75% in ripening maize was reported in Morogoro, Bagamoyo (Pwani) and Tanga regions respectively. A 100% loss in maize seedlings was observed in Lindi in the same season. The main rodent species responsible for this damage was *M. natalensis.* Individual farmers often control rodents with rodenticides provided by the Tanzanian government. During rodent outbreaks, zinc phosphide is the rodenticide of choice in campaigns organized by the government, while bromadiolone is used indoors and for plague rodent foci. However these campaigns are very costly. For example, in the 2005/2006 farming season, the government spent US$54,666 on rodent control in Tanzania.

Data on rodenticide usage from 1983 to February 2006 were collected from seven regions (Mtwara, Morogoro, Lindi, Tanga, Arusha, Pwani and Mbeya) that have experienced frequent rodent outbreaks. Records held by the Rodent Control Centre, the Ministry of Agriculture, Food Security and Cooperatives included the year and months of each outbreak, the rodent species involved, estimates of rodent density for each species, the geographical extent of outbreaks within a district and the number of hectares treated with rodenticides. The amount of zinc phosphide used varied between regions and between years. Mtwara region experienced few rodent outbreaks between 1983–2005, but for the three farming seasons of 1990, 1998 and 2005 when widespread rodent outbreaks were experienced, large quantities of zinc phosphide were used (725 kg of concentrate; approximately 43,500 kg of bait). In comparison, in the Morogoro Region regular outbreaks occurred over the same period and 650 kg of zinc phosphide concentrate (approximately 39,000 kg bait) was used. Lindi region also experienced regular, severe rodent outbreaks between 1983-2005, and on average used more zinc phosphide than any other region in Tanzania (>1410 kg zinc phosphide concentrate; approximately 84,600 kg bait).

For small-scale farmers in Tanzania, rodenticides are the best option for rodent management in their small fields. However, the reliance on rodenticides has several major constraints: zinc phosphide and other rodenticides are expensive and they are not always distributed in time to arrest the outbreaks. There are also concerns about the environmental effects of rodenticide use. Therefore, reliance on rodenticides as the main strategy for rodent management in Tanzania cannot be a sustainable approach and we suggest that management of rodent pests should preferably focus on the use of integrated methods and approaches instead of poisons alone. In addition, multi-sectoral collaboration is expected to enhance the development of control methods that are socially and culturally acceptable to local communities, as well as being economically feasible and locally appropriate.

BAIT PREFERENCE TEST OF LESSER BANDICOOT RAT (*BANDICOTA BENGALENSIS*) AND THE EFFECTIVENESS OF RODENTICIDE

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The lesser bandicoot rat (*Bandicota bengalensis* Gray & Hardwicke) is the main urban pest of cities in Asia, including Indonesia. It causes structural damage to buildings (houses, offices, warehouses, and factories), and consumes stored food products in houses and warehouses. However, contamination of the food and feed with hair, faeces and urine is always greater than the quantity of food consumed. Furthermore, *B. bengalensis* plays an important role in transmitting diseases to humans, pets and other animals. Mechanical and chemical control methods are commonly used in controlling *B. bengalensis*. People use single or multiple capture live-traps for mechanical control and poison baits (either acute or chronic) for chemical control. Both methods require a highly palatable bait to attract this species. The objective of this research was to determine the most palatable bait for the lesser bandicoot rat, based on human foods and livestock feeds. The overall goal was to develop the most effective food bait in combination with a rodenticide to control the lesser bandicoot rat in urban areas.

We conducted a series of no-choice and multiple-choice tests of several kinds of baits. Bait types included rice, unhulled rice, corn, wheat, fish feed, fried egg, tuna fish, chicken meat, sweet corn and coconut. Rats were held individually in a cage. Each bait was provided *ad libitum* in a separate steel container. The quantity of each bait consumed each day either for 20 days (no-choice test) or for 3 days (choice test) was determined. For the rodenticide test, two of the most preferred food baits were individually mixed with zinc phosphide (1% active ingredient) and compared with a ready-to-use anticoagulant rodenticide baits (warfarin, coumatetralyl, flocoumafen and brodifacoum), and rice with or without zinc phosphide was used as a control. All rodenticides were offered simultaneously to individual rats. The quantity of each rodenticide consumed in 1 day was determined.

In the no-choice tests, the lesser bandicoot rat preferred sweet corn more than fried egg, chicken meat, and other baits. In multiple-choice tests, sweet corn was again the most preferred food, followed by fried egg and coconut. Corn, wheat, unhulled rice, and tuna fish were less palatable in all trials. In the tests with rodenticides we found that sweet corn mixed with zinc phosphide was the most preferred poison bait, followed by coconut mixed with zinc phosphide and rice without poison. Brodifacoum (block form) was the least preferred poison bait. All of the test animals died in less than 12 hours, due to the effects of zinc phosphide.

We conclude that sweet corn baits containing zinc phosphide could be used for control of the lesser bandicoot rat in urban areas. However, precautions would need to be taken to prevent non-target uptake and impacts.

SENTINELS ON RODENT-FREE ISLANDS: PALATABILITY AND EFFICACY OF FRESH AND AGED TOXIC BAITS TO HOUSE MICE, NORWAY RATS AND SHIP RATS

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Current surveillance programmes to detect rodent (re)invasion of rodent-free islands in New Zealand often involve the placement of toxic baits in bait stations. To investigate whether the choice of 'sentinel' bait types could be optimised to target different invading rodent species, we measured the relative palatability and efficacy of six currently available toxic bait formulations against house mice (*Mus musculus*), Norway rats (*Rattus norvegicus*) and ship rats (*R. rattus*). Many rodent-free islands upon which sentinel systems are required are remote and infrequently visited, so that regular bait replacement is often impractical. To gauge the effective field life of "long-life" bait types, we also measured the effect of bait weathering on the relative palatability and efficacy of two bait types against the same three rodent species.

Wild-caught rodents were acclimatised to individual housing in captivity. In the first trial, six bait types were assessed: Pestoff® 20R cereal pellets (20 ppm brodifacoum), Pestoff Rodent Block (20 ppm brodifacoum), Syngenta Talon® Wax Block (50 ppm brodifacoum), Contrac All-Weather Blox (50 ppm bromadiolone), Rentokil Ridrat Super wax (50 ppm bromadiolone) and Kiwicare possum gel (50 ppm brodifacoum). For each rodent species, treatment groups of 20 were offered a two-choice test between a toxic bait type and non-toxic feed pellets over 10 consecutive nights. Baits were weighed daily and replaced, and the rodents were monitored for 21 days after the removal of bait, to determine mortality or survival. In the second trial, Pestoff® Rodent Block and Contrac All-Weather Blox were weathered under natural conditions for 1, 3, 5, 8 and 12 months. At each time point, the palatability and efficacy of the two bait types were tested on each rodent species (n = 10 of each) in a standard choice-test (30 g of one type of toxic bait and 30 g of non-toxic RS5 bait) for up to 10 nights, with bait intake and mortality monitored as before.

Pestoff® 20R cereal pellets caused 100% mortality of ship rats and Norway rats, and 95% of mice. However, this bait type was recognized as having a relatively short field-life. The overall best-performing "long-life" bait formulation was Pestoff® Rodent Block, which caused 95% mortality of Norway rats, 85% mortality of ship rats, and 100% mortality of mice. In the bait weathering trial, mould on baits was observed at about 2 months, and covered 50–100% of the bait surfaces after 8 months. Both Pestoff® Rodent Block and Contrac All-Weather Blox were more palatable to mice than to either species of rat, and more palatable to ship rats than to Norway rats, and the Pestoff® caused higher mortality than Contrac to all three species. At the time of writing, the 12-month weathering assessment is yet to be completed, but no decline in palatability or efficacy of either bait type to any of the three rodent species appears to have occurred over 8 months of weathering. Complete results including the 12-month time point assessment will be presented.

BAIT STATION PREFERENCES OF INTRODUCED RODENTS IN NEW ZEALAND

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New Zealand's Department of Conservation (DOC) has an active and successful programme of eradicating introduced rodents, including ship rats (*Rattus rattus*), Norway rats (*R. norvegicus*), Polynesian rats (kiore, *R. exulans*), and house mice (*Mus musculus*) from offshore islands. Surveillance to detect rodent reinvasion of these islands currently involves observation of interference with toxic baits in bait stations. This study was initiated to determine whether the different rodent species have preferences for different types of bait station. A separate study is investigating rodent preferences for different types of bait.

To date, we have monitored the behavioural responses of Norway rats to four different types of bait station (wooden "motel", yellow plastic Novacoil pipe, white plastic bottle and black plastic box-shaped Protecta® bait station), and the responses of ship rats to two of the same types of bait station (wooden "motel" and yellow plastic Novacoil pipe) and two different types (wooden tunnel and white plastic Philproof rodent bait station). Each trial was undertaken using 24 wild-caught rats acclimatised to captivity. Each rat was transferred from its indoor cage to an outdoor pen for 1 night at a time, and presented with a different bait station type each night, in random order for 4 nights, at about 2-weekly intervals, in a crossover design. All bait stations contained the same bait type, which was non-toxic Pestoff® Rodent Bait Block (normally containing 20 ppm brodifacoum), similar to the type of toxic bait used in surveillance programmes. The responses of the rats were recorded using a time-lapse video recorder under low white light, and the tapes analysed to determine time to first approach, time to first entry, duration of first entry, and frequency and duration of subsequent entries. We also calculated the amount of bait eaten.

More than 80% of the Norway rats entered the wooden "motel", yellow plastic pipe, and black plastic Protecta® bait stations, but fewer than 50% entered the white plastic bottle bait stations. Significantly more Norway rats ate bait from wooden "motel" and yellow plastic pipe bait stations than from the other two types tested. The amount of bait eaten by the rats was not enough for a lethal dose for 50% of the population, had the bait contained 20 ppm brodifacoum, but more than enough had bait contained 50 ppm brodifacoum. At the time of writing this abstract, the ship rat trial was still in progress but will be completed by the time of the conference and the results will be presented there in full. It will be necessary to monitor the responses of kiore and house mice to different bait stations before a final decision can be made on the best bait station type(s) to use in multi-species rodent surveillance programmes on islands.

RICEFIELD RODENTS PREFER RICE: SELECTING BAIT BASE TO INCREASE ZINC PHOSPHIDE AND WARFARIN RODENTICIDE BAIT UPTAKE

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Rodent pests cause major economic losses to rice crops and inflict health risk to people and live-stock in villages in rice fields. Maize based baits were used to control ricefield rodents. This study aimed to determine if replacing maize with rice as bait base would increase uptake of zinc phosphide and warfarin wax block baits in rice crops, fallow fields and villages.

The study site was in lowland ricefields in Samrong, Kampong Cham, Cambodia. Nineteen experimental plots were placed in three habitats, with 3 or 4 plots treated with zinc phosphide and 3 with warfarin per habitat. Each plot consisted of 5 bait points, each with rice and maize-based toxic and non-toxic (placebo) baits.

Mean bait uptake was increased significantly ($F_{1,267}$ = 99.65; P < 0.0001) by 65% through replacing maize with rice as the base. This increase was significantly ($F_{1,267}$ = 6.25; P = 0.0130) greater when warfarin was the active ingredient, rather than zinc phosphide, but both increases were substantial (62% and 51%; Fig. 1). We therefore recommend that rice be the base for delivering both rodenticides. Bait base also significantly ($F_{2,267}$ = 5.69; P = 0.0038) interacted with habitat, with the increased uptake being highest in villages (85%) and rice crops (79%), and lower in fallow fields (49%; Fig. 2). A plausible explanation for this finding was that rodents facing a relatively poor food supply in fallow fields did not have as strong a preference for bait bases as those having a good food supply in rice crops and villages.

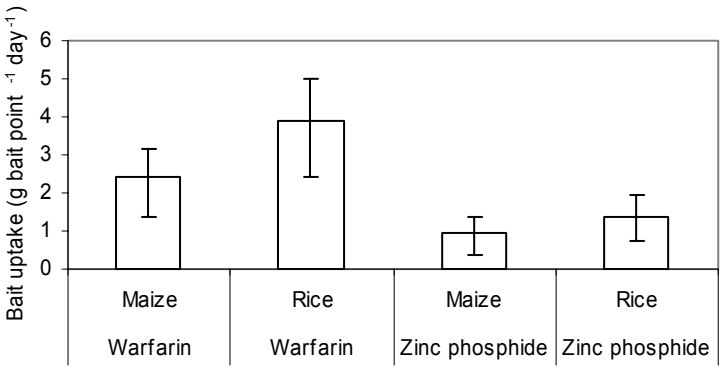

Fig.1. Bait uptake in plots treated with either zinc phosphide or warfarin in lowland ricefields in Cambodia. Both rice and maize bait bases were used at each bait point. The means were adjusted for other fixed effects. The 95% confidence limits are illustrated.

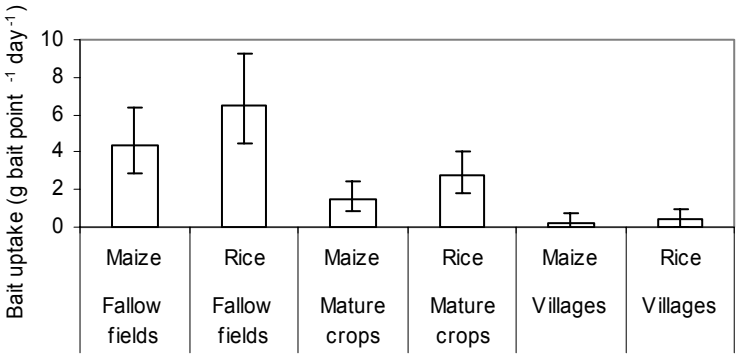

Fig. 2. Bait uptake in plots located in three habitats in lowland ricefields in Cambodia. Both rice and maize bait bases were used at each bait point in all plots. The means were adjusted for the other fixed effects. The 95% confidence limits are illustrated.

Poster Presentations

RESIDUAL BRODIFACOUM CONCENTRATIONS IN LIVER AND MUSCLE AND THE EFFECT OF COOKING.

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Secondary exposure of non-target wildlife to anticoagulant rodenticides occurs in predatory or scavenging species when they feed on poisoned animals or carcasses. Domestic animals or humans may also be exposed to residual anticoagulant concentrations if they eat meat from poisoned animals. The second-generation anticoagulant brodifacoum is among the most acutely toxic and highly persistent (in mammalian liver) of the anticoagulants, so we chose brodifacoum to describe potential 'worst-case' residue concentrations that could occur in liver and muscle of poisoned rats (*Rattus norvegicus*). We also investigated the effects of cooking on the residual concentrations of brodifacoum in liver and muscle of brushtail possums (*Trichosurus vulpecula*).

Groups (*n*=12) of female laboratory *R. norvegicus* were offered cereal pellet bait containing 20 ppm brodifacoum, to simulate three bait uptake scenarios that could occur in field conditions: (1) at death resulting from a "minimum" lethal dose of bait eaten over 4 d (no-choice trial), (2) after one day's feeding *ad libitum* on bait (no-choice trial), and (3) at death resulting from *ad libitum* feeding on bait and non-toxic pellets (two-choice trial). The amounts of bait and brodifacoum consumed by rats in each treatment were measured, and high performance liquid chromatography used to analyse rat liver samples for residual brodifacoum concentrations. In the "cooking" trial, four possums were fed a lethal dose of brodifacoum (an approximate LD_{90} equivalent of 1.19 mg/kg) in 20 ppm cereal pellet bait and euthanased 10 days afterwards. Samples of liver and muscle (~20 g) from each possum were cooked at 180^{o}C for 20 minutes, with uncooked and cooked subsamples analysed for residual brodifacoum concentrations.

There was a reasonable correlation between brodifacoum ingested by rats in bait (mg/kg) and the resultant residual concentration of brodifacoum in liver (µg/g), regardless of whether the rat died of brodifacoum poisoning or was euthanased before this point. In rats that had eaten a minimum effective lethal dose and died as a result, brodifacoum concentrations in liver were approximately 12 times higher than those in the corresponding muscle sample. Rats that had fed freely on bait until they died of poisoning had the highest liver residues, with the maximum individual concentration in liver measured (17 µg/g) approaching the nominal brodifacoum concentration in bait. Hence, the greatest secondary poisoning risk is likely to occur when rats have continuous access to palatable bait and eat well in excess of a minimum effective lethal dose of brodifacoum. Such rats, with a relatively high burden of residual brodifacoum, could either be preyed upon in the later stages of toxicosis (when behavioural signs of poisoning are evident), or their carcasses scavenged. In the "cooking" trial, concentrations (mean $\pm$ SE) of brodifacoum in uncooked possum muscle and liver were 0.06 ± 0.02 µg/g and 0.60 ± 0.12 µg/g respectively, and were not reduced by cooking. The risk of acute secondary brodifacoum toxicity to humans at these liver concentrations is considered very low, and liver tissue is far less likely to comprise a significant proportion of a human diet than meat (muscle tissue). However, because of the lack of information regarding sublethal effects that could be associated with long-term and/or low-level secondary exposures, it is essential to stipulate that meat from animals that might be contaminated should not be eaten, and any perceptions that cooking will eliminate brodifacoum (or other anticoagulant) residues in meat should be countered. Part of this data is from research contracted by the Animal Health Board (Project No R-1450).

TESTING DOSAGE OF BROMADIOLONE AND DIPHACINONE NA-SALT

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This study assessed a range of concentrations of anticoagulant rodenticides for their efficacy in rats and mice held in the laboratory. We used 5 concentrations of Bromadiolone and fed sewer rats (*Rattus norvegicus*)(n=52) captured from the Shunyi district of Beijing in acute no-choice tests over two days. Two concentrations of Diphacinone Na-salt were fed to mice for 5 days.

The results showed that all the concentrations of Bromadiolone caused 100% mortality, there is no relationship between the quantity taken and the concentration of drug-bait, and no notable difference between time of death for rats in each group ($p>0.05$). Each concentration of Diphacinone Na-salt caused 100% mortality of mice. The different concentrations of rodenticide bait made no difference to the time till the onset of symptoms or death ($p=0.20$). The tests revealed that all of the concentrations of Bromadiolone and Diphacinone Na-salt in the range used in the experiments are equally effective for controlling rats and mice respectively. We suggest that the lower concentrations of anticoagulant rodenticides be used to reduce the cost and so that higher doses may be used where resistance to the drugs has developed.

COMPARATIVE ANALYSIS OF ADAPTATION OF NORWAY RATS TO EXTREME CONDITIONS: PERSISTENT RESPONSE TO ANTICOAGULANT RODENTICIDES AND PREDATION RISK

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Under natural environments Norway rats (*Rattus norvegicus*) may have daily contact with anticoagulant rodenticides. Physiological adaptations to persistent exposure to anticoagulant rodenticides are quite well described. At the same time changes in behaviour caused by the presence of anticoagulant rodenticides are less understood. To examine the latter behaviours, we have used two basic genetic models developed in our laboratory: (1) rats selected for avoidance of poisoned food and (2) rats selected for low responsiveness to predator scents. Norway rats which survived multiple applications of warfarin baits were trapped in the Moscow region. These animals became the foundation for a colony of rats for further development of the genetic model. After 5 generations of breeding, we compared in a number of tests, the behaviour of rats which avoided warfarin-containing food with those rats which did not avoid poisoned food. Orienting-investigatory behaviour was recorded in different modifications of the “open field” test, with measurement of the responses of rats placed in an open area under bright light. We also tested different patterns of orienting-investigatory behaviour of rats in enclosures. Passive avoidance behaviour was tested in a shuttle box with negative reinforcement (electrical foot shock). Several tests were used to evaluate neophobia to different types of food. Rats selected for avoidance of warfarin-containing food exhibited significantly ($p<0.001$) higher levels of stress reactivity and passive avoidance behaviour. Investigatory activity in these rats was lower then in control animals ($p<0.05$).

Another genetic model has been developed using rats of a heterogeneous laboratory population. The phenotype of interest is high responsiveness to predator odour. In our earlier studies we examined the influence of predator chemical cues derived from feral cat urine on reproductive output of rats, mice and voles. Animals responded to predator chemical cues with reduced litter size and skewed sex ratio. The reduction in litter size in rodents exposed to predator urine was attributable to suppressed progesterone levels affecting the implantation of embryos. During eight years (1997-2005) we selected rats from the heterogeneous laboratory population for high embryo resorption rate (over 20%, H-line) and accordingly for low resorption rate (less then 10%, L-line) under predator odour exposures. Currently we have 14th generation rats of H-line. Rats of H-line have significantly ($p< 0.001$) higher percent of females with 100% resorption rate of embryos under predator odour exposures relative to rats of L-line and rats of the heterogeneous population. Also there are significant ($p< 0.001$) differences in litter size between animals of H and L line under predator odour exposures. We observed significant differences in stress reactivity between rats of H and L line. Animals of H line exhibited higher level ($p< 0.001$) of stress reactivity (plasma corticosterone levels) and anxiety (performance in an elevated maze) in response to predator odour.

The data indicate that the persistent presence of anticoagulant rodenticides lead to significant increases in percentage of rats in the population with high level of stress reactivity. At the same time rats with high level of stress reactivity have the highest embryo resorption rates under predator odour exposures. They do not develop resistance to feral cat urine. Combined application of anticoagulant rodenticides and active compounds from cat urine may significantly reduce reproductive output of individuals tolerant to anticoagulant rodenticides.

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DOSAGE AND EXPOSURE TIME OF SULFURYL FLUORIDE FOR RAT CONTROL USING A RESPONSE-SURFACE MODEL

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Pests of stored products must be controlled in any commodity storage or processing structure, mill or food handling establishment to protect the integrity of the facility and the commodities produced there. Fumigation is a preferred method of control because the gas can reach the pests in all parts of the storage facility. For many years, methyl bromide was the fumigant of choice, but its use is being phased out under the Montreal Protocol due to concerns about ozone layer depletion. Sulphuryl fluoride is a broad-spectrum, odourless, colourless gas that rapidly vaporizes and is not flammable or explosive. It is non-corrosive and un-reactive to most materials. It quickly distributes throughout the structure, penetrating to wherever the pests are. It also aerates rapidly when ventilation begins, a major advantage since it is highly toxic to humans. Sulphuryl fluoride is already a commonly used fumigant in sanitary treatment, especially in many Chinese ports. Up to now there has been no scientific research about the most effective dosage and exposure time for use in China against the pests of stored products. Correct dosage is important because sulphuryl fluoride not only affects the pest being treated, but may pollute the environment and is harmful to human health if misused. The purpose of this study was to explore the proper dosage and exposure time of this broad-spectrum fumigant for controlling rats and to provide a scientific basis for using this fumigant safely and effectively.

A series of experiments including lab and field studies were designed to determine the exposure time needed to deliver a lethal dose. The goal of the laboratory study was to fit a response surface model to the mortality rate of rats exposed to sulphuryl fluoride as function of exposure time. Rats used in the experiments were provided by the Laboratory Animal Center of Zhejiang Academy of Medical Sciences and were raised according to the Chinese Standards. A warrant for the use of Laboratory Animals was also acquired. Rats were fumigated by Sulphuryl fluoride using the method of static respiratory-tract inhalation. Symptoms of intoxication and death conditions were recorded. The model of lethal dose based on fumigation time was verified in a field study by the fumigation of rats in containers. Negative control groups were established in every experiment.

Clarification of the exposure time needed to deliver a lethal dose offers scientific proof of the correct usage parameters of sulfuryl fluoride. Sulfuryl fluoride may an acceptable alternative to methyl bromide for rat control with proven efficacy under experimental conditions.

Symposium: Impact of agricultural advances on ecology and management

Chairs: Rhodes Makundi and Duncan Sutherland

Oral Presentations

ECOLOGICALLY-BASED MANAGEMENT TO REDUCE RODENT DAMAGE TO LOWLAND RICE CROPS IN INDONESIA

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Integrated management methods based on the ecology of the principal rodent pests have been promoted for developing countries (Singleton *et al*. 1999). There have been few successful studies of integrated management of rodents at a village scale under replicated conditions demonstrating the economic value compared to conventional management based on rodenticides. A 3.5 year study designed to measure the impact of ecologically-based management of the rice field rat, *Rattus argentiventer*, was conducted at a village scale in lowland irrigated rice monocultures in West Java, Indonesia (Jacob et al., 2003), where *R. argentiventer* is the dominant species.

In this farmer-participatory study, the following two key questions for this cropping system were addressed: What is the relationship between tiller damage by rats and yield loss? What is the economic benefit at a village scale of integrated rat management in terms of yields?

The study was conducted near Cilamaya, Subang province, West Java, from 1999 to 2002. The region has a wet and dry season, and the main land use consists of a monoculture of lowland irrigated rice. At four villages, each about 120 ha, rodent densities and damage to crops were monitored at each village for 10 months until October 1999. Then the study was set up as a randomised block design. In two treated villages, farmers adopted the following integrated management: (1) synchrony of planting within two weeks; (2) eight trap-barrier systems (TBS), each 25 x 25 m with a crop planted inside three weeks early; (3) a 2-week rat campaign one week prior to transplanting or within two weeks of crop initiation around source habitats (village gardens and irrigation channels; (Jacob *et al*. 2003); (4) reduction of secondary irrigation banks to less than 30 cm to prevent nesting by rats; and (5) improved field sanitation and general hygiene around villages and gardens. In non-treatment villages traditional rat control was conducted. Damage to rice tillers was assessed at tillering, booting and a week prior to harvest. Rice yield was the amount of unhusked rice per ha. (for more details, see Singleton *et al.* 2005).

Cumulative damage to rice during the dry season was 54% at tillering, 32% at booting, but only 16% at the ripening stage. We found that measured damage at the ripening stage ought to be multiplied by 6.5 to obtain cumulative damage to the rice crop or by 4.2 for an estimate of yield loss.

In treatment villages in West Java, 49% fewer farmers used rodenticides, which was significantly lower than in an untreated village ($\chi^2 = 7.2$, $p < 0.01$, $df = 1$). Also the application of endosulfan plus sump oil fell 28% on treated sites, while during the same three years the activity increased 30% in non-treatment villages ($\chi^2 = 11.2$, $p < 0.001$). This latter cocktail of

chemicals is added to the flooded rice crop and kills most of the animal life, so reducing its use leads to significant environmental benefits.

Integrated rodent management increased rice yields more when rats were common, in both dry and wet season crops. For every 1% increase in tiller damage by rats, there was a decrease of 58 kg/ha in rice yield. Wet season crops benefited more from a trap-barrier-system than dry season crops at the same rat abundance index. The benefit-to-cost ratio for all seasons and years averaged 25:1 but varied considerably from year to year between a low of –2:1 to a high of 63:1. The economic benefit of integrated rodent management was equal to or better than that achieved by conventional management based on synthetic rodenticides, and without the associated environmental risks to non-target species.

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EVALUATION OF RODENT POPULATIONS, DAMAGE, AND MANAGEMENT IN NO-TILL AGRICULTURE IN THE USA

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No-till farming is an important approach to sustainable agriculture because it can conserve soil and water resources. Unfortunately, because the ground is not tilled annually and crop residues are left on the surface, rodent populations (such as voles, *Microtus* spp.) can thrive, resulting in substantial crop damage. Little is known about rodent population dynamics and crop damage levels in no-till agriculture in the USA. Furthermore, methods to reduce damage in this setting have not been investigated.

The objectives of the study were to assess rodent use of various crop fields (barley, corn, pea, wheat), both before and after crop harvest, and surrounding permanent grasslands, using grids of snap traps. Contents of rodent stomachs were examined microscopically to determine food habits. Additionally, GPS locations were recorded for rodents captured with live traps so that capture probabilities could be used to predict rodent distribution with landscape variables such as elevation, slope, cover type, and distance to cover type edge. The amount of damage by rodents to 3 winter pea fields was also determined, using GIS software. Finally, preliminary trials with methods to reduce rodent populations (zinc phosphide rodenticide on grain) and crop damage (metal barrier exclosures from which the rodents had been removed) were conducted.

In September, many more rodents (41.6 per 100 trap-nights) were captured in fields with unharvested crops than in fields containing only plant stubble (6.7), suggesting that rodents leave fields after crop harvest even when adequate cover is available. By April, the population of voles in the area had crashed; this genus is known to follow a 3-5 year cycle. Hence, many fewer rodents were captured. Despite this, capture rates were much higher in surrounding permanent grass areas (9.8 captures per 100 trap-nights) versus the crop fields (4.9), suggesting that these grassy areas serve as refugia for rodents during difficult times. This is further emphasized by the fact that the permanent grass cover type was the landscape variable most associated with rodent capture rates. “Eat-out areas” were assessed in 3 fields of winter peas; about 5-15% of the growing plants had been removed by rodents over winter. Food habit analyses revealed that voles were feeding heavily on grain plants in April, but had a more diversified diet in September (grain plants, forbs, and roots). Deer mice (*Peromyscus* spp.) fed most heavily on grain plants in both April and September and also used insects as food much more so than voles. The crop plants in metal barrier exclosures that had been cleared of rodents in November showed no obvious signs of rodent damage in April. However, when the exclosures were trapped out the following September, rodent capture rates were higher within the exclosures (15.2 captures per 100 trap-nights) than in nearby unprotected areas (2.9). Once the crop height exceeded about 30 cm, the rodents could easily access the interior of the exclosures and perhaps the exclosures provided a better microclimate for the rodents or some protection from predators. While baiting with zinc phosphide on grain normally results in a rapid reduction of rodent populations, areas baited a year earlier had the same capture rates of rodents as nearby areas that had not been baited. This suggests that baiting does not provide a long-term solution to rodent damage in no-till agricultural fields.

REPRODUCTION AND POPULATION DYNAMICS OF *MASTOMYS NATALENSIS* (SMITH 1834), IN AN AGRICULTURAL LANDSCAPE IN THE WESTERN USAMBARA MOUNTAINS, TANZANIA

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The Multimammate Rat, *Mastomys natalensis* (Smith), is an opportunistic species, characteristically conforming to an r-selected strategist, increasing when climatic conditions are favourable. The species occurs in the savannahs of Africa but is largely associated with agricultural land and surrounding fallow fields. It is now hypothesized that population growth of *M. natalensis* is strongly influenced by food availability, which in turn is regulated by rainfall (Leirs *et al*. 1989). However, we still lack an in-depth knowledge of the processes involved in the regulation of populations of *M. natalensis* in different ecosystems in Africa (Makundi *et al*. 1999). In the current study, we investigated reproduction and population dynamics of *M. natalensis* in an area that was recently a natural forest, now transformed for crop cultivation.

The study was carried out at Manolo village, Lushoto District, in the western Usambara Mountains, Tanzania. (040 42' 16"S, 380 12'16'E) at 1826 m above sea level. Rainfall patterns are characterised by a single, but asymmetrical rainy season, extending from October-May and a dry season from July-September. A capture-mark-recapture study was conducted from May 2002 to December 2004 in a 100x100 m grid with 100 trap stations. Trapping of rodents was conducted for three consecutive nights every month. Captured animals were identified, marked by toe clipping, weighed, recorded for breeding condition and released at the point of capture. The density of animals per ha was estimated for each 3-day trapping session using the M(h) Estimator of the Programme CAPTURE for a closed population.

Breeding, abundance and population dynamics of *M. natalensis* in the Usambara Mountains seem to be influenced by two factors:

(i) rainfall indirectly affects the initiation and cessation of reproduction: *M. natalensis* appeared to respond to increased food resources in the aftermath of the rains by rapid breeding and greater recruitment of young. During the dry season from July-September, reproduction of *M. natalensis* ceased or remained very low. The population declined at this time indicating low survival as there was no evidence of increased emigration. Evidence of resource limitations to breeding and growth of the species has been reported in other areas in Tanzania (Leirs 1992)

(ii) deforestation and intensification of agriculture have created savanna-like habitats in the Usambara Mountains, which are similar to the preferred natural habitats at lower altitudes and therefore suitable for colonization by *M. natalensis*. The abundance and quality of food in this habitat increases survival and recruitment of young, leading to increases in population density.

Both the ability of *M natalensis* to rapidly increase in response to rainfall and the changing environment as a result of deforestation and cultivation of crops, favour the invasion by *M. natalensis* into areas which were hitherto unsuitable for habitation. Therefore, the altitudinal range in its distribution will further increase as agricultural activities are intensified in deforested high altitude areas on the Usambara Mountains.

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SUSTAINABLE RODENT CONTROL FOR SUBSISTENCE FARMERS IN SOUTH AFRICA

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Rodent pests affect people's lives by destroying crops, transmitting diseases, contaminating food and water, and damaging buildings and other possessions. Although effective rodent management tools and techniques exist, their poor application and adaptation to particular situations often results in treatment failures, leading to apathy and widespread acceptance of rodent pests in the environment. Using rodent management tools and techniques requires a good understanding of rodent biology and their localised impacts upon people's livelihoods. This knowledge facilitates the development of cost-beneficial strategies where the input costs can be shown to lead to substantially increased food security, financial and health benefits. Rodent pests disproportionately affect the poorest people who are less likely to possess appropriate knowledge, and our research objective was to work with subsistence farmers as a way of developing appropriate rodent control knowledge and tools for these farming communities.

Village volunteers, serving as field staff, were trained in rodent trapping and data collecting skills. Trapping was done in seven rural villages in Limpopo and KwaZulu-Natal (KZN) provinces, South Africa. Baseline population data of rodents in and around 280 houses and from four crop fields were obtained from August 2002. Houses were assigned to treated or untreated (control) groups. In the treated group, households were trapped daily with break-back traps for the duration of the trial while the control group was trapped for three consecutive nights every month. In crop fields an arrangement of three trap lines with 15 trapping stations each was used for three consecutive nights every month. Houses and fields were visited every morning after a trapping night, and captures were recorded and prepared for taxonomic identification. Identification was based on skull morphology, dentition and phylogenetic analysis of DNA from liver tissue samples.

Trapping results, presented in terms of trap success, showed that the effects of intensive trapping in the treated households compared favourably to that of the untreated households. In all villages, trap success declined soon after intensive trapping commenced. Diversity in rodent species was noted, and 14 species of the Order Rodentia were identified in Limpopo, of which *Rattus tanezumi* of the *Rattus rattus* complex was a first record for southern Africa. Species composition also differed between districts, between localities, within houses and between houses and crop fields. The major rodent species in the houses of three arid districts in Limpopo was *R. rattus* while *Mastomys natalensis* prevailed in the more humid Vhembe district. In the three KZN villages the dominant species was *R. tanezumi*. Rodent captures in crop fields were clumped and declined during the census period. Overall trap success was considered to be relatively low due to ongoing drought conditions.

By actively participating in the trapping trial, households developed a better understanding of rodent pest damage levels, and this helped ensure that recommended strategies were socially and financially acceptable. The cost of rodenticides, even though they are used in once-off applications by householders in the survey area, was considered to be high in comparison to the long-term use of break-back traps. User-friendly and effective break-back traps are now being produced locally, and a partnership between research, government and the pest control industry has helped bring improved rodent management training and tools to agricultural extension, environmental health officials and commercial pest control operators.

SOIL TYPE MAY LIMIT POPULATION ABUNDANCE OF RODENTS IN CROP FIELDS: CASE STUDY OF *MASTOMYS NATALENSIS* IN TANZANIA

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Soil type can be an important factor in determining the distribution of animal species and individuals, both directly and indirectly, through vegetation structure and diversity. The soil type will determine the kind of vegetation in an area and the crop that may be cultivated. The fertility of the soil will therefore most likely influence the species abundance in an area. Studies elsewhere have shown that the distribution of mole rats was partially influenced by the nature of soils (Yeboah and Akyeampong 2001). *Mastomys natalensis* is widely distributed in sub-Saharan Africa. In eastern and southern Africa it is a notorious pest which attacks cereal crops, particularly maize. Apart from the biological characteristics of the species, which enable rapid population increases under suitable conditions, environmental factors are responsible for high population densities. Soil characteristics have not yet been given consideration in this framework. We investigated whether different soil types had an effect on rodent population abundance in agricultural fields in Tanzania.

Capture-mark-recapture (CMR) studies were conducted in two agro ecological zones with known soil types. Two grids of 100x100 metres with two different soil types were studied in Chunya district (south west Tanzania) while eight grids of 70x70 metres were studied in Morogoro region (Eastern zone). Trapping with Sherman traps was conducted in each grid for three consecutive nights at intervals of four weeks. Population size was estimated for each 3-day trapping session using the M(h) estimator of the program CAPTURE. Analysis of variance was performed to establish the effect of soil type on rodent population abundance.

In the two study sites, soil type appeared to be one of the factors affecting the abundance and distribution of *M. natalensis* in the fields. Rodent populations differed significantly with soil type in the study area regardless of the type of farming practice. In the Eastern zone, the lowest rodent population was found in the sandy clay soils ($F_{2, 5} = 8.42$; $P = 0.025$), while it didn't differ significantly between sandy clay loam and sandy loam soils ($P \leq 0.05$). In the Southern zone, rodent population abundance differed significantly between sandy loam and the sandy clay loam soils ($F_{1, 2} = 152.3$; $P = 0.007$) with the lowest population in sandy clay loam soils. Interaction effects between soil type and rainfall were also observed ($F_{7, 2} = 29.9$; $P = 0.033$).

The study suggests that *M. natalensis* prefer loam-textured soils. Loam soils have particle sizes and spaces that are intermediate between those of clays and sands. They warm fairly quickly and have good water-holding capacity. Clay soils are often waterlogged and poorly aerated and are likely to be least preferred by *M. natalensis*. Within the sandy clay soils, which become water logged and sticky during heavy rainfall, rodent population abundance seemed to follow a density pattern influenced by the amount of rainfall rather than vegetation type (Massawe 2003). However, from this study, rainfall remained the major factor influencing rodent population dynamics. When there was a high amount of rainfall, population densities within the sandy clay soils decreased rapidly, while in months when it was relatively dry, population densities increased again. Odhiambo (2005) noted that in

south-west Tanzania, sandy loam clay soils had fewer Gerbils (*Tatera leucogaster*) compared to sandy soils. He attributed the differences in abundance to variation in the suitability of the soils for burrowing by this species. Presumably, for *M. natalensis,* abundance in soils of different characteristics is also associated with their suitability for burrowing and probably for nesting places, but further studies are necessary.

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POPULATIONS OF RICE FIELD RAT IN CROPS IN TIEN GIANG PROVINCE, VIETNAM.

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In the Mekong Delta the landscape comprises a mosaic of rice fields, fruit orchards, vegetable and upland crops, un-cultivated and fallow areas. The actual mix of land uses depends on the needs and preferences of farmers who grow specific crops for their food and economic requirements. The changes in agricultural production patterns each year are likely to affect the diversity of natural vegetation in the environment, and could indirectly affect the abundance and activity of rice field rats.

Throughout 2002, populations of rice field rats were monitored at fortnightly intervals using live-capture traps and tracking tiles. The study site was located in Tien Giang province in the Mekong Delta of Southern Vietnam and had two different agricultural land use patterns. These patterns were a rice mono-cropping region (Cai Be district) that suffers a period of flooding during September–October and a mosaic cropping region (Cai Lay district) that has a diversity of crops (rice, fruit orchards and vegetables).

Our trapping results showed that *Rattus argentiventer* and *R. losea* were the dominant species, in both regions, although there were some individuals of *R. koratensis* and *R. flavipectus* in the rice mono-cropping region. The average number (Mean ± SD) of rats captured in the rice mono-cropping and mixed cropping region was 6.4 ± 0.5 and 2.2 ± 0.2 rats per night respectively. The activity of rats (tracking tile success) was also higher in the rice mono-cropping region (74.8 ± 2.7% vs 19.4 ± 1.1%). In the rice mono-cropping region there was a high proportion of female rats (78%) during the initial growth stages of the rice crop in October, a decrease to 17% in November before an increase to 61% in December when the rice plants were at booting and flowering stage. In both regions, the proportion of females which were pregnant was similar, although females were more abundant in rice mono-cropping region. Rat abundance and activity was also assessed in some fruit orchards and was found to be less than 10% of trap success.

Our study indicates that rice-field rats are most abundant in the rice-fields. The planting of rice through out the year can provide a suitable environment with a preferred food source for these rats to feed, survive, and breed. What management should be done? It is necessary to establish a systematic rat control program that starts before planting and through to harvest, and maintain this commune activity year-round. A TBS system is more compatible with synchronized planting in small region when water level decreases gradually.

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THE POPULATION AND BREEDING ECOLOGY OF RODENT COMMUNITIES LIVING IN LOWLAND RICE AGRO-ECOSYSTEMS IN EASTERN BANGLADESH

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Rodents are one of the major pest constraints to increased agricultural production in Bangladesh. Rice is the most important crop in Bangladesh and yield gains in rice enable increased crop diversification into higher value crops. In South Asia, moderately effective strategies for rodent management exist, however they are poorly applied, leading to apathy and widespread acceptance of rodent pests in the environment. Integrated management methods based on the ecology of the principal rodent pests have been promoted for developing countries (Singleton et al., 1999), and they hold promise in the rainfed lowland rice systems in Bangladesh.

Over two years we worked closely with farmers in the Comilla region to develop a better understanding of the ecology and breeding dynamics of the rodent communities living in lowland rice agro-ecosystems. This project was part of a broader DFID-funded study that addressed ecological and socio-economic aspects of rodent management in fields, in houses and in grain stores.

The study was conducted in the Chittagong Division, Comilla District in the villages of Sowara, Jakunipara, Sahapur and Anandapur. The region has a wet (monsoon) and dry season, and the main land use consists of a monoculture of lowland irrigated rice. Twenty traps were set in the following habitats: inside houses, rainfed rice area, irrigated rice area, vegetable/upland area, around ponds and along the road side. Live capture traps were used in all outdoor habitats, while kill traps were used for the household habitat. Traps were set for three consecutive nights in each village once per month over a period of 16 months. Live capture traps were baited with coconut oil and kill traps with fresh coconut each evening. All animals were measured and dissected to obtain taxonomic and reproductive biology information.

Seven species of rodents and one species of shrew were captured. There were no major differences among rodent species in their prevalence in different habitats and the different villages. All rodent species could be found in all places. The village habitat supported large populations of mice (*Mus* spp.) and shrews (*Suncus murinus*) and relatively lower numbers of *Rattus* spp. and *Bandicota benegalensis*. The main rodent species in field crops are *B. benegalensis* and *Rattus rattus*. Species such as *B. benegalensis* appeared more likely to move into village habitats after each rice harvest. Relatively smaller numbers of *Mus* spp. and *B. indica* were found in habitats around field crops, e.g. ponds, river banks, roadsides. Fallow upland habitat had higher numbers of rats and shrews in August and December. Although technically not a rodent, shrews were in high numbers in all habitats, particularly villages. Although shrews may provide benefits via insect predation in field crops, they are considered a pest in households through eating and contaminating household food and potentially spreading disease.

Trap success was much higher in the village habitat than in the outdoor habitats. Most families store their grain inside their houses and rodents generally have easy access to the houses. Village populations of rodents appeared to be a major source for re-colonization of fields after planting.

Rodent breeding occurred year round in village habitats with no clear seasonal trend apparent apart from a mild lull in breeding in February and March. *Bandicota bengalensis* was most common in village houses in Sep-Oct and Feb-April (prior to harvest – and perhaps due to high rainfall in fields). Although there were low numbers of animals caught in the fields, it was clear that the breeding biology is not as strongly cued to the development of the rice crop as occurs with *Rattus argentiventer* elsewhere in Southeast Asia.

The close participation of farmers in this study meant that they too developed a better understanding of the factors that affected the habits of the major rodent pests. The results of the ecology study were used by farmers to develop a community strategy for rodent management – particularly around their village where rodents were a chronic, and often acute, problem.

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MEASUREMENT OF POST-HARVEST LOSSES CAUSED BY RODENTS IN MYANMAR

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Losses caused by rodents post-harvest have been assumed to be similar to the level lost in the fields prior to harvest. However, there are few quantitative data on post-harvest losses. In Myanmar, farmers store their grain in bamboo or wooden structures (bans) that stand alone from other dwellings, but within 20 m of the main house of a family. Rodent losses post harvest have not been studied in Myanmar. To measure such losses is challenging. This presentation reports on a study on post harvest losses conducted in villages in Yangon and Mandalay Divisions in Myanmar. The techniques for assessing losses are based on those developed in Bangladesh (see abstract of Belmain *et al*.). We also assessed the influence of the structure of the grain stores and the level of hygiene around the stores on rodent losses.

In January to October 2004, the study was conducted in two villages in a rural area in the Yangon Division where rice was the main crop. From January to June 2005, the study was conducted in two villages in Mandalay Division. Grain (8kg) was poured into a local woven basket with an open top. There was a gap of 3-5 cm from the top of the grain to the top of the basket. One basket was placed in each of 10 wooden and 10 bamboo grain stores (five of each type of grain store in each village). The weight loss of grain in the baskets was measured every two weeks and then the basket was topped up to 8 kg to maintain the same surface area available to rodents. At the same time interval we: (a) recorded the number of bags of rice, the percent surface area covered by the bags, and the depth and surface coverage of rice that was not stored in bags, (b) set five tracking tiles in and around each grain store to record the presence of rodents and whether they were mice or rats, (c) recorded the hygiene in the vicinity of the grain store on a scale of 1 to 5 (1 = very poor conditions ideal for rodents, with plentiful cover, harbourage, and possibly food and water, and little or no disturbance; 5 = excellent hygiene providing little opportunity for rodent populations to live near to the grain store; very tidy, clean and store is raised above the ground with no material next to store to allow easy rodent access.)

Key assumptions: (a) The amount of grain eaten in the baskets is similar to that eaten by rodents in the rest of the grain store. We checked this assumption by taking 100 grains randomly from within the basket and 100 from outside the basket to measure the amount of rodent damage, rodent faeces and rodent hairs. (b) The grain in the basket does not lose or gain much weight due to climatic conditions. We checked this assumption by having 8 baskets (4 in wood, 4 in bamboo stores) with 8 kg of rice to which rodents were denied access (through having an open metal grill on top of each basket). (c) There is no spillage of grain from or into the baskets. We placed the baskets away from the daily activities of farmers.

The presence of nibbled grain, hairs and faeces in the baskets were similar to that found in the grain store itself, indicating that the baskets were a representative sample of the grain store as a whole. In all sampling periods in each village there were rodent tracks present on the tracking tiles. From an associated trapping study in Yangon, the main species in the villages were *Rattus exulans* (>68% of captures) and *R. rattus* (around 10% of captures). *Mus* species were common in Mandalay study sites. The level of hygiene around a grain

store and the amount of grain in the store seemed to be more important for damage by rats than the quality of construction of the grain store itself.

In Yangon Division, the mean loss from baskets was estimated at 3.4% (range 1-15%) and from each grain store it was estimated to be 14 kg (range 8-20 kg) per crop season.

In the later study in Mandalay Division, the mean grain loss in Tharyarsu village after 3 months was 4.5% (range 1-15%; 20 kg loss per 18 m^2 grain store) and in Pyankapyae village the mean loss was 2.3% (range of 1-3.4%; 8 kg per 17 m^2 grain store). The mean loss over 3 months in Mandalay Division across the two villages was equivalent to grain that could feed 6 people for 3.5 weeks. Grain stores do not get replenished until the next harvest 6 months later. Some grain stores were emptied after 4 months. In those stores that still had grain after 6 months then losses would be expected to be at least doubled – enough to feed 6 people for 7 weeks.

The techniques described here are useful in determining losses by rodents to grain stores in Myanmar. These techniques could be easily modified and adapted to situations in other countries. Research needs to be conducted on developing strategies for reducing these losses and for potential disease transmission to humans and livestock living within the village environments.

MANAGEMENT OF RODENT PESTS IN LOWLAND RAINFED SYSTEMS OF MYANMAR

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Rodents are a significant constraint to farmers in lowland rainfed agricultural systems in Myanmar, in some years significantly affecting food security and rural livelihoods. Losses to rodents are typically 5-40%. Rodents have been identified as the pest that caused most damage to crops and were the most important pest to control. The principal crops grown are paddy rice, corn, oilseeds, sugarcane and pulses. Rice is the staple crop of Myanmar accounting for 97% of total food grain production and provides 75% of total calorie intake. A 3-year farmer-participatory study was conducted to better understand the nature of rodent damage to lowland rainfed crops, the rodent species causing damage, and the efficacy of community-based rodent management strategies developed by farmers, extension staff and researchers.

Workshops were held with farmers, extension staff and researcher to initially develop a suite of community-based rodent management strategies. These were applied at the village level (100 ha) in the 2004 Monsoon rice crop in Yangon (2 treated; 3 untreated) and Mandalay Divisions (2 treated; 2 untreated). Rodent population abundance, rodent management actions conducted by farmers, tiller damage to crops, and yield loss by rodents were monitored. The rodent management strategies were modified and finalised at subsequent workshops through an evaluation of their effectiveness and appropriateness. Surveys of the knowledge, attitudes and practices of farmers were conducted before and after the management strategies were implemented.

Some 19 rodent species were identified in the agro-ecosystems of central and northern Myanmar, with the following species identified as putative pests in field crops: *Rattus rattus* spp (two forms), *Bandicota bengalensis*, *B. indica*, *B. savilei*, *Mus cervicolor*, *M. caroli* and *Mus* sp. (an unnamed relative of *Mus booduga*). Of these, *R. rattus*, *B. bengalensis*, *B. savilei* and *Mus* spp. are likely to cause the greatest impact to cereal crops. The main pests in the villages are *R. exulans* and *R. rattus*.

Pre-harvest rodent damage was generally higher in monsoon crops than in dry season crops (damage was often low, 0-1%, but on occasions was high, particularly at ripening stage, ~ 18%), and damage increased in monsoon crops from booting to panicle development to the ripening stages. In Mandalay Division, community actions increased rice yields significantly in the two treatment villages. In Yangon Division, floods meant results there were difficult to interpret.

Following adoption of community-based rodent management, there was a 47% reduction in the number of farmers using rodenticides and a 97% increase in the number of farmers using trapping to control rodents. There was a 29% reduction in the cost of applying rodent control, but the time spent by farmers conducting control was the same as on the untreated sites (18 hours per season).

The experiments demonstrated that the best times to control rats in the fields are the first and second month of the monsoon crop (April/May); before the main breeding season of rats commenced. In the villages, control needs to be more regular because the species of rats living there bred all year round. In Mandalay Division, there was evidence that the use of a community trap-barrier system (TBS) plus community actions increased yields (up to 34% increase). In Yangon Division, there was no effect of rodent management on yield due to problems with floods.

The main control activities conducted by farmers on treated sites were community campaigns (using a combination of non-chemical rodent control practices) and TBS, which were all conducted early in the cropping season. On untreated sites, significantly more farmers relied on hunting and using rodenticides, and these actions were applied at a later crop stage.

At the completion of the study, farmers and extension staff identified the following recommendations for community-based rodent management: (1) field sanitation during land preparation and booting stages, (2) community rat control campaigns during land preparation, maximum tillering and panicle development stages, (3) keep water high in fields after maximum tillering, (4) use a trap-barrier system (with an early-planted crop) (but there was concern about the high cost), (5) reduce bund size at land preparation, and (6) encourage natural predators and use dogs in the fields and cats in the village. Practices of lower priority were applying rodenticides (at sowing of summer crop or when rodent densities are high), burning rice straw after harvest and traditional fumigation.

ALTERNATIVE RICE VARIETIES FOR THE "TRAP CROP" OF THE COMMUNITY TRAP BARRIER SYSTEM (CTBS) TO CONTROL THE RICEFIELD RAT

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The ricefield rat, *Rattus argentiventer*, is considered a critical factor in reducing rice production in Indonesia. In many regions it is the number one pre-harvest pest of lowland irrigated rice. Ecologically-based rodent management has been developed to manage rodent populations at the village level. The package of community rat control actions includes a simple technology described as the Community Trap Barrier System (CTBS). The CTBS technology relies on an early-planted crop inside a fenced area to attract rats to multiple-capture traps. This is referred to as a "trap crop". The main goal is to establish a trap crop three weeks earlier than the surrounding crop. However, the earlier planting of a trap crop is sometimes very difficult because of the lack of access to water during land preparation. The aim of this study was to identify an early maturing rice variety that is more attractive to rats than the main rice variety and so can be planted synchronously with the surrounding crop.

Three varieties were tested. These were an early maturing variety (Silugonggo), a long lived variety (Cisadane), and an aromatic variety (Sintanur). Ciherang, which is a new high yielded variety, was planted three weeks earlier than the surrounding crop as a control (a standard early "trap crop"). Therefore the research design consisted of three varieties as treatments and one control CTBS. During the Dry Season (2004) and the Wet Season (2004/2005), each of two replications were established within a CTBS (see Singleton *et al*. 2003 for detailed description of CTBS) in Sukamandi village, Subang District, West Java Province, Indonesia.

The results indicated that the three alternative varieties were less effective at attracting the ricefield rat to multiple capture traps than the standard early trap crop. The effectiveness of the alternative varieties were 58% in the Dry Season and 34% in the Wet Season relative to the number of rats caught using the standard early trap crop.

Future research will examine whether using these three varieties during the nursery stage will attract more rats. This would mean adding multiple-capture traps to the standard nurseries that are already surrounded by plastic fencing.

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THE TRAP BARRIER SYSTEM: NEED FOR ASSESSMENT AND DEVELOPMENT IN SOUTH SULAWESI, INDONESIA

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Rats are the most important pests of lowland rice in South Sulawesi, Indonesia. Farmers control rodent pests mostly by applying rodenticides, planting synchronously, and using a variety of traditional methods. Synchronized planting date is no longer practiced by farmers in many areas because of the shortage of irrigation water and also because the price of the grain is low when farmers harvest at the same time. The Trap Barrier System (TBS) uses early crops (trap crops) as a lure for rodents within the main crop, from where they are subsequently controlled. TBS has been shown to be a very effective technique for trapping and controlling rats in some areas of South East Asia.

In the current study, we evaluated the effectiveness of TBS in three districts of South Sulawesi, namely Bone, Wajo and Pinrang. The three districts have different ecosystems. The trials were conducted at one, three and seven locations in Bone, Wajo and Pinrang districts, respectively, in 2004. The TBS were constructed using 25 x 25 m plastic fences in farmers' fields. The trap crop in the TBS was planted at 10–15 days earlier than in the surrounding crop. The development of the TBS in the study locations was monitored until the first cropping season of 2006.

The results of the study showed that the TBS was very effective for trapping rats, but there were three different patterns in the distribution of the captured rats. These patterns were affected by environmental factors and the behaviour of the rats, but not by the seasonal population trends. Although farmers were interested in this new technology, there was no significant increase in the number of TBS adopted in the study areas after two years. Based on these results, further studies should focus on integrating TBS with other rodent control techniques. Studies should also be conducted on factors such as the attitudes, economic conditions and institutional status of farmers, which may influence the adoption of this new rodent control technology.

EXPERIENCE IN APPLYING THE COMMUNITY TRAP BARRIER SYSTEM IN BINH THUAN PROVINCE, VIETNAM

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Bac Binh district is characterized by complex topographical regions – mountainous, mid-land and coastal areas. Rodents have adversely affected rural families in this area for many years. A significant rodent outbreak in Bac Binh in 2001 caused widespread losses of standing rice from 10 to 35% and some paddy fields were severely damaged with 50-100 % loss. This rat outbreak affected six other districts of the province. A local control campaign was launched in Bac Binh using traditional methods (live traps, digging, zinc phosphide and other chemicals). However, none of these methods proved sufficiently effective. The community Trap Barrier System (cTBS), a non-chemical rodent control method, was introduced to Bac Binh under an ACIAR-funded project through World Vision. This project aimed to facilitate the uptake of cTBS to help farmers control rodent outbreaks and prevent further rice losses. Local extension staff and key farmers were trained in the use of cTBS as part of integrated rodent management practices. This presentation describes the successful trial of the cTBS, which has led to replicated trial use of cTBS across the whole province.

A field survey was conducted in March 2001 to identify the rodent species present in the affected region, determine the most destructive species, assess the variation in farming systems, and consider how this was likely to influence the timing and magnitude of pre- and post-harvest damage. It also investigated the current knowledge, attitudes and practices of farmers with regard to rodent pests. Based on the findings, interventions were designed including technical training for key farmers and local extension staff, setting-up of sites for cTBS trials, and on-farm workshops for post-trial evaluation of effectiveness. A total of 14 cTBS trial sites were set up to determine the effect of cTBS during all the cropping seasons of 2001 and 2002. During this period, all material costs for cTBS were covered by the project.

For all sites trialed, a consistent pattern of rat captures was found – rat numbers increased gradually through the crop vegetative growth stage and decreased through the reproductive growth stage to harvest. Observations typically showed that only minor damage could be found in the area around the cTBS. A total of 2890 rats were caught over the two years. Because of the observed effectiveness of cTBS, cTBS trials were requested by the six other districts of the province. Wider cTBS trials over Binh Thuan proved cost-effective (with community contribution), environmentally friendly and safe to aquatic creatures and domestic animals. However, it was found that cTBS operates more effectively in irrigated areas and requires high community participation (Tuan, 2004). Technical staff in the provincial extension network are now trained in integrated rodent management and are ready to train farmers.

Farmers perceive the cTBS as having high cost investment because they tend to calculate costs associated with their own field rather than on a shared, per hectare basis. The method requires labour for establishment, maintenance, and monitoring of the system. It is difficult to convince farmers to pay money to set up a cTBS, even though the money they spend on rodenticides usual exceeds that required for the cTBS. They are unwilling to contribute towards the cost where the level of damage is unforeseeable. Another issue is that lure crops tend to be attacked by insect pests if planted 3-4 weeks ahead of the surrounding field, resulting in low yields in the lure crop.

cTBS may be more successful if it is integrated into an NGO's broader development program. It is particularly suitable with existing high levels of participation of both farmers and agricultural cooperatives, or in situations where cost can subsidized by a donor or the government, thereby reducing farmer contributions. ACIAR's impact assessment survey (Palis *et al*. 2004) also revealed some key factors that contribute to enhanced cTBS

adoption. Those factors are: monoculture farming; good irrigation facilities; presence of a strong cooperative, farmers' association or IPM club; predictable high rodent populations; partial subsidy for small farmers; capacity-building to strengthen the existing cooperative, farmers' association, or IPM club; and large farm size for individual adoption.

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RODENT DAMAGE AND CONTROL IN SUGARCANE AND THEIR IMPACT ON SURROUNDING FIELDS

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Sugarcane crops serve as a readily available source of food and protective cover for feeding, burrowing, and breeding activities of rodent pests of agriculture throughout most of the year. The problems of rodent damage and control in sugarcane are particularly severe in tropical and sub-tropical Asia because here small sized fields of different crops are grown simultaneously leading to polyculture cropping. In such situations, sugarcane crops are periodically threatened by waves of rodent immigration from the surrounding fields (often paddy-wheat crops) which are frequently disturbed as a result of rotational agronomic operations. The sugarcane crops suffer extensive damage from rodent activities mainly after September at maturity and pre-harvest stages. Rodents inflict both direct and indirect damages to sugarcane. Direct damages are caused mainly by gnawing through the rind of the lower internodes of canes and by damage to the roots during digging of burrows. Indirect damage is caused via secondary infections of the damaged canes. The aims of the present study are to determine the species of rodents responsible for damage, extent of rodent damage, efficacy of rodenticide application in sugarcane fields and effect of reduction in rodent population in sugarcane on the incidence of rodent damage in surrounding fields.

A survey of rodent damage to sugarcane crops from twelve different villages of three districts of Punjab, India was conducted in January, 2002 (pre-harvest stage). The percentage damage to canes was calculated from three fields in each village by recording damaged and undamaged canes from ten cane bundles selected per field. Rodent species were determined by trapping rodents from sugarcane fields with single-catch and multiple-catch rat traps. Efficacy of rodenticide application was evaluated in five villages of two districts of Punjab, India. Baits of three different rodenticides were applied at different application rates in the months of February and December, 2004; February, 2005 and March, 2006 in different villages (maturity and pre-harvest stages). The rodenticides were 2% zinc phosphide, 0.005% bromadiolone and 0.0375% coumatetralyl. Percentage rodent control success was calculated from pre- and post-baiting censuses from treated and untreated sugarcane fields. Pre-harvest rodent damage in wheat crop fields surrounding treated and untreated sugarcane crops was determined in as percentage of cut tillers and yield loss (g/m^2)

Results revealed $15.6 \pm 4.7\%$ cut canes in survey villages. Higher incidence of cane cutting, up to 50.7%, occurred in fields harbouring a high rodent infestation. Based on rodent trapping, *Bandicota bengalensis* was found to be the predominant rodent species followed by *Golunda ellioti*, *Mus* spp, and *Millardia meltada* in sugarcane crop fields. Results of rodenticide treatments revealed higher acceptance and efficacy of anticoagulant baits (i.e. bromadiolone and coumatetralyl) leading to higher rodent control success (53.2-86.1%) than with zinc phosphide bait (18.3-57.4 %). The percentage of cut tillers found in wheat crop fields surrounding treated sugarcane fields was less (1.1-3.2%) than those surrounding untreated sugarcane fields (6.2-17.5%). The present results suggest greater potential of anticoagulant rodenticides for managing rodents in sugarcane crops at maturity and pre-harvest stages.

METHODS FOR ASSESSING RODENT LOSS, DAMAGE AND CONTAMINATION TO RICE STORED AT THE HOUSEHOLD LEVEL IN BANGLADESH

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What happens to food after it is harvested is a minority concern by agricultural scientists who have traditionally focussed on increasing crop yields. Although increasing concerns over international food safety have kindled a renaissance within the field of post-harvest microbiology, post-harvest science is usually viewed in developed countries as something for engineers as opposed to ecologists. However, what happens to stored food in a developing country raises a number of researchable problems for ecologists interested in the dynamics of crop damage and loss and how to best mitigate against losses in quantity and quality of stored food and protect a farmer's investment when it is at its highest value. Despite rodents being a well-known problem during the storage of grain, there have been few attempts to assess the levels of damage that farmers routinely experience. Designing scientifically objective methods to ascertain grain loss caused by rodents under farm store conditions is technically challenging, and the scientist either needs to build mock grain stores or work with existing farmers' stores. The first option is expensive and may not provide comparable results to what occurs in farmer stores, whereas the second option may result in untrustworthy data because it is virtually impossible to monitor all inputs and outputs from farm stores. Our research addressed these shortcomings, allowing the scientist to maintain control over data collection while still using the environment of the farmer store.

Commonly available baskets made of woven bamboo were purchased from the local market. These baskets could hold 8kg of paddy, bringing the level of grain to within 2-3 cm of the top edge. Farmer consent to place these baskets within their own stores was granted. Farmers promised not to disturb the basket when they removed or added grain to their store, and scientific staff visited fortnightly the baskets of rice to measure loss, damage and contamination by rodents. Starting in December 2002, a series of five trials were implemented over consecutive grain storage seasons. Individual baskets of rice were placed in six to ten household grain stores in each of four different villages. The baskets would be weighed and sub-sampled for the number of rodent droppings, partially rodent-damaged/eaten grains, moisture content and insect damage. The methodology was repeatedly modified to address particular hypotheses, (e.g. effect of parboiling rice) and shown to be a powerful tool for monitoring the effect of rodent management interventions aimed at reducing rodent populations or rodent access to stored food.

The rate of rice lost to rodents was relatively constant among households and villages, independent of farm store size and storage season. Rodent populations were monitored during the same time period (see abstract by Singleton *et al*.), and rodent trapping in village habitats indicated the rodent population remained relatively constant in households over an annual cycle in comparison to fluctuating rodent populations in field areas. The amount of rice lost from each basket was approximately 60 g each day. The rate of loss tended to increase near the end of the storage season as the total amounts of stored grain in the village became scarce through the drawing down of village-wide food stocks before the next rice harvest was brought in. During this time, the experimental baskets would become

relatively more attractive to rodents in search of food in the village. So although the rodent population remained relatively constant (or declined in some cases), the feeding pressure on the experimental baskets increased through diminished food stocks in the village. As this daily loss of rice is related to the surface area of rice in the basket exposed to foraging rodents, a 60 g loss is equivalent to 0.042 g/cm^2/day. This variable can be used to estimate the amount of rice lost in the farmer's own store by combining the rate loss constant with the known surface area of each farmer store. This analysis showed that farmers could expect average losses of 30 kg after 90 days of storage, or about 4% of their entire grain store volume. These losses could be reduced by more than 50% by community trapping programmes (see abstract by Singleton *et al.*). Families in villages that intensively trapped rodents observed that their rice stocks lasted 1-2 months longer than usual.

USING INTEGRATED METHODS FOR CONTROL OF VOLE POPULATIONS THE ALFALFA FIELDS OF THE RIFT VALLEY IN ISRAEL AS A MODEL

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The human-made agro-ecosystem lacks negative feedback control, which may result in rodent population eruption, causing a considerable economic loss, thus increasing the human-wildlife conflict. The traditional solution for eruptions is the extensive use of rodenticides, which have a local and national negative impact on the environment. In the case of the Rift-valley the impact is international, as this is a main route for bird migration from the Euro-Asia to Africa and back. Therefore, the use of rodenticides for vole population control in places like Beit Sheaan valley, Israel, can result in the death of migrating birds, such as storks and herons that prey on the dying voles. Indeed, this was the situation in the autumn of 1997 during the migrating season when thousands of birds on the way to their wintering places died. The implementation of ecological principles into agro-ecosystems should significantly decrease the use of rodenticides.

Recently we have shown that light interference (LI) during short day (SD) acclimation, resulted in the death of social voles *Microtus socialis*, kept in enclosures under natural conditions, in an alfalfa field. Under laboratory conditions such interference caused a decrease in thermoregulatory abilities in the cold which included decrease in heat production, decrease in energy intake and an increase in heat dissipation. Furthermore, LI to SD-acclimated voles increased adrenaline and cortisol secretion pointing out to a stress effect under such conditions. Hence, vole populations were found to be composed of different reproductive types, in relation to their response to photoperiod changes.

Mobile-lines are used for irrigation of alfalfa fields in the Beit-Sheaan valley. When using this devise for irrigating, instead of sprinkling, water can be taken out by a pipe, floating the vole borrows. When they escape to the open diurnal birds as storks and herons, standing on the mobile-lines prey on them. The use of nesting boxes for barn owls and stands for diurnal raptors can decrease vole and other rodent populations. The great advantage in the use of integrated methods is avoidance of adaptations in the pest rodents to one of the methods. Furthermore, treating the alfalfa fields in relation to irrigation, crop yearling and seed production can support vole population control.

Poster Presentations

RAT MANAGEMENT SYSTEM AT THE PHILIPPINE RICE RESEARCH INSTITUTE (PhilRice) FARM

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Management of rats at The Philippine Rice Research Institute (PhilRice) experimental farm mostly relied on the judicious use of both chronic and acute rodenticides. Field assistants and researchers prefer poison baits against rodents to other management strategies because they are easier to apply. For the past 3 years (2002 to 2004) about USD 7,000 was spent by PhilRice for the purchase of poison baits and the costs of application. However, the effectiveness and safety to non-target species were often neglected.

Management strategies such as (1) field sanitation (2) dry ploughing (3) establishing trap barrier system plus trap crops (TBS+TC) (4) night hunting (5) rat hunting and burrow management (6) use of flame thrower (7) water management and (8) use rat traps were either designed or adopted and fitted into the current field situation. These strategies, either individually or in combination with other approaches, are being implemented at PhilRice. All these were executed at the appropriate time based on the previously established rat breeding cycle. This system reduced the use of rodenticides and rodent management costs. It also reduced damage to the rice crop and the active burrows.

KNOWLEDGE, ATTITUDES AND PRACTICES (KAP) OF POOR RURAL FARMERS TO RODENT MANAGEMENT IN THE UPLAND FARMING SYSTEM OF LAO PDR

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Rodents are a serious constraint to poor farmers in the upland farming system of Lao Peoples Democratic Republic (PDR), and have been described as the pest they have least control over. In order to better understand the problems that rodents cause to farmers, a survey was conducted to assess farmers' knowledge, attitudes and practices (KAP). Similar surveys have been conducted in neighbouring Southeast Asian countries, but these studies were conducted with farmers in lowland irrigated rice agro-ecosystems. An understanding of farmer's KAP will enable the development of appropriate management strategies to reduce the impact caused by rodents in a complex upland system.

A structured questionnaire was used to conduct a survey in 12 villages across Louang Namtha, Louang Prabang, and Houaphan provinces in the Lao PDR. Twenty farmers from each village were interviewed (total of 240 farmers). The questionnaire was composed of 50 questions and took approximately 30 minutes to administer per farmer. Data were entered into a Microsoft Access database and summarised for analysis.

Seventy percent (70%) of farmers identified pests as the main impediment limiting production. Ninety eight percent (98%) of respondents indicated that rats were the most important pests. The mean yield loss was estimated at 19% (range 0-100%). Rodents caused most damage to rice (96% of farmers) with minor damage to corn and Jobs' tear (a type of sorghum). Farmers used a range of control techniques for rodents, with trapping being the most common (49%; farmers using both traditional traps and metal traps), followed by rodenticides (37%). Farmers reported that it was important to control rats (72% very important to them), and also that rats could only be controlled if farmers worked together (60% of farmers indicated this to be true always). Only 65% of farmers conducted rodent control by themselves, and 92% of farmers indicated that chemicals (rodenticides) were harmful to the environment.

This survey enabled us to understand the impact of rodents in the upland farming systems, how farmers manage the rodent problems and their knowledge on rodent control. The survey also identified two main constraints, which are the high costs of some control methods and getting farmers to work together as a community. These are the major challenges for developing rodent management strategies for the upland systems in the Lao PDR. A similar survey will be completed at the end of the project to assess changes in knowledge, attitudes and practices of farmers to rodent management after the implementation of community based rodent management strategies.

RODENT DAMAGE AND YIELD LOSS IN AN UPLAND, RAINFED RICE CROPPING SYSTEM, BANAUE, PHILIPPINES.

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Rodents are a major pest in rice crops in the Philippines. In the regions of Luzon and the Visayas, rodents are the number one pest; they reduce rice yield by more than 10%, with localised reports of annual losses of 30-50%. In northern Luzon, upland rice is grown in spectacular terraces in the mountainous regions. Many farmers in this region have low annual incomes and they consider rodents, together with the golden apple snail, as major pests in their rice crops. Little is known about the biology of the main rodent pest, *Rattus tanezumi*, in this region and there have been no previous studies of the damage and yield loss caused by rodents to rice crops.

From May 2004 to March 2005, damage to rice crops caused by rats, and the corresponding yield losses, were measured in upland rainfed rice crops in Banaue. Crop damage was assessed quantitatively at the paddy level and qualitatively at a landscape level in two village environments. Maximum potential yield was measured within rodent exclusion fences, and compared to actual yield in paddies not excluding rodents.

Photographs taken at set photo-points at the booting, flowering, ripening and stubble stages of the rice crop illustrated the extent of rodent damage and the characteristic spatial distribution of damage within a crop ('stadium effect'). These photographs were used to estimate damage at a landscape level. The error associated with these qualitative estimates was determined by visually estimating damage to patches of crop as being low (<10% rat damage), medium (10-25% damage) or high (>25%) and then quantifying the level of damage for a subset of rice fields assigned to each category.

Rodent damage to rice was measured at the booting and ripening stages of crop growth. The actual yield was 43% lower than maximum potential yield measured within rodent exclusion fences. Of the cumulative damage to rice, 73% occurred up to the booting stage and 27% during the ripening stage. Moreover, the total accumulative estimate of tillers damaged over the cropping season was approximately half of the calculated percentage yield loss. Therefore, if damage to cut tillers is only measured at the ripening stage, then it will provide a considerable underestimate of yield loss. We estimated that tiller damage at the ripening stage would need to be multiplied by 7 to obtain an estimate of yield loss.

SAMPLING INTENSITY AND PRECISION FOR ESTIMATING RAT DAMAGE USING SYSTEMATIC ROW SAMPLING TECHNIQUE IN MAIZE FIELDS

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Rodent damage to crops is a serious impediment to agriculture in Tanzania, causing an estimated average loss in maize crops of 15% annually (Makundi *et al*. 1991). It is not unusual for damage to maize to exceed 80% in certain cropping seasons and locations (Mulungu *et al*. 2003). Reliable quantitative assessments of crop losses caused by rodent pests are required in order to evaluate the magnitude of pest problems, model the effects of rodent control strategies and evaluate different management approaches. In Tanzania, a systematic row sampling technique is commonly used to assess rodent damage to seedlings in maize fields (Mwanjabe and Leirs, 1997). In the present study, we investigated the relationship between sampling intensity and accuracy of the estimate for the systematic row sampling technique in maize fields. We did this exercise based on resampling simulations on detailed actual damage figures for a large number of maize fields. The study aimed at providing a sound basis for damage estimations for rodent pest monitoring, surveillance and forecasting and management evaluations.

Field experiments were carried out during the cropping seasons in 1999 and 2000, at Sokoine University of Agriculture, Morogoro, Tanzania. There were fifteen plots (70x70 m each), which were subjected to different treatments. The treatments included: (i) fields planted with maize and surrounded by fallow land, (ii) fields planted with maize and enclosed by iron sheets to prevent escape of rodents within and entry of rodents from outside, (iii) fields planted with maize and enclosed by iron sheets to prevent escape of rodents within and entry of rodents from outside and covered by a net to keep out predatory birds, (iv) open fields planted with maize with perches to attract of predatory birds, (v) fields planted with maize and enclosed by chicken mesh covered by nets, and (vi) fields planted with maize and surrounded by other cultivated maize fields. These treatments provided a range of rodent densities in the fields, ranging from 0 to 140 animals per hectare during the assessment, and consequently also a range of damage levels. Crop damage assessment was carried out at seedling stage, 10 days after planting. We simulated different sampling intensities by resampling from the actual damage data. Different sampling intervals (every 2^{nd}, 3^{rd}, 4^{th}, 5^{th}, ...20^{th} row) were chosen and for each sampling interval, we ran all possible simulations by choosing a different starting line every time.

Results show an increase of estimate variation when the interval between rows becomes larger. For example, the estimate variation was 0 when every row was assessed, whereas a 40% variation was observed when every 20^{th} row was assessed. Thus estimates become less reliable when the interval between rows increases. In some plots the increase of estimate variance at larger row intervals was more dramatic than others, illustrating that damage is not homogenously distributed in all fields.

Our simulation results show that the problems with such heterogeneity can be overcome when the row interval in a systematic row sampling is small enough. Unless resources are unlimited, a compromise must be reached between sample size and reliability. Increasing sample size means that the chances of getting a sample mean nearer the true value of rat damage mean (actual damage) is higher. The average standardized variances of our simulated data show that when a sampling interval of less than 6 rows is used, the variation

of an estimate stays below 10% of the actual damage. The results of this study show that to sample each 5th row in the maize field, as used by Mwanjabe and Leirs (1997), is a reasonable balance with a confidence level of 95%. The present study allows us to quantitatively determine a compromise between the need for accurate estimates and the time or resources available for obtaining the estimate.

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RESEARCH AND DEVELOPMENT OF RODENT MANAGEMENT IN INDONESIA

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Rice is the most important agricultural commodity in Indonesia. More than 200 million people rely on rice for their staple food. However, rice pests are one of the major constraints causing yield loss every planting season in rice-growing ecosystems. Rice field rat (*Rattus argentiventer,* Rob & Kloss) as the major rice pests, have been known to affect rice production significantly with annual damage approximating 20%. A continual effort is needed to minimize rice yield loss caused by rat attack. Ecologically-based rodent pest management which is the major activity of the rodent project in Indonesia has been recognized as an effective approach to control rats. Understanding bio-ecological characteristics of rice field rats such as breeding, diet, habitat and movement is an important part of the project. This basic information will be used as a base to develop rodent control methods such as the improved rat control technique called Trap Barrier System (TBS). An Integrated Ecologically Based Rodent Management (EBRM) approach was designed by integrating all practicable rat control techniques which have previously been developed by considering rat bio-ecological characteristics. This approach has been implemented over a large scale both in farmer's fields and at the research station at IIRR. The results indicate effectiveness and environmental friendliness of such a rat control approach. Therefore, a dissemination of this Integrated Ecologically-Based Rodent Management approach should be accelerated by involving the Assessment Institute for Agricultural Technology (AIAT) to enhance its adoption by rice farmers in Indonesia.

BIO-ECONOMIC MODELING IN PRACTICE: A FIELD EXPERIMENT AND FARMER PARTICIPATORY RESEARCH.

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Bio-economic modelling revealed counterintuitive results in the control of *Mastomys* mice in rural Tanzania. It was observed that control methods based on calendar month would be more beneficial than the traditional methods of applying rodenticides when mice are abundant. In order to verify these results with respect to socio-economic factors, a field experiment and a Farmers Participatory Research were set up.

In a field experiment, 15 plots measuring 70 x 70 m each were used to evaluate two treatments and one control group. On 5 plots, a rodent control operation was carried out in February 2006, before planting time and irrespective of the number of rodents in the field. Another 5 plots were treated with rodenticides when the maize crop was at the cob stage. The other 5 were control plots. The plots received similar, but standard agronomic treatments (early ploughing, application of fertiliser and weeding). Three maize seeds were planted per hole. The planting distance was 60 by 90 cm. Damage assessment was done twice, at seedling stage and harvest. During the first assessment, damage was expressed as the proportion of missing seedlings. In the second assessment damage will be expressed as grain weight loss after adjustment to a common moisture content.

Information on farmers' practices and understanding of rodent problems was evaluated by a structured questionnaire administered to 30 small-scale Tanzanian farmers in three villages. These villages are to be involved in a participatory research to be conducted in October 2006 and February 2007. In village meetings the experimental setup was discussed with the farmers. In each study village, two experimental sites per farmer will be identified. Participants will treat the experimental sites in a similar way. In one experimental site, rodenticides will be applied in October (2006) and February (2007) before planting and irrespective of the number of rodents in the field. The other experimental site will be a control. The harvest from both treatment groups will be compared using a paired t-test.

Both the Farmers Participatory Research and the field experiments are on-going. Preliminary results of the field experiments show a positive correlation between estimated damage at seedling stage and the abundance of rodents in the field. Average estimated damage in the control plots was higher than in plots treated with rodenticides. Eighty percent (80%) of questionnaire respondents experienced rodent problems regularly or at every planting season. Only 46% of them could afford to buy rodenticides. All farmers planted maize during the main rainy season, but only 30% indicated planting during the short rains.

The results of the bio-economic modelling are evaluated under field conditions. The field experiments showed that application of rodenticides protected the seeds from rodent depredation. Through the participation of the farmers, sociological, economic and practical issues of rodent control were revealed. The results of the questionnaire show that some farmers plant twice a year when the short rains in October are abundant. This aspect is not yet included in the bio-economic model. The cost of rodent control operations when rains are abundant is an important consideration. For sustainability, chronic rodenticides are

recommended. However, in the rainy season there is a higher risk of these being washed away because they have to remain in the field for at least two nights before rodents have consumed an effective dose. When a calendar based control operation is planned during the rainy season, the costs will increase. The increased costs as well as the second planting season when rains are abundant would be included in an extended bio-economic model.

MANAGING RICE FIELD RATS USING AN ENVIRONMENTALLY-SAFE PRODUCT: XIGA - SG63q

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The ricefield rat (*Rattus argentiventer*) is considered the most important pre-harvest pest in the Mekong delta region of Vietnam. Some provinces have annual losses of rice production of between 10 and 25 %. Particularly severe damage is commonly recorded in provinces along the border of Vietnam and Cambodia. Efforts to control this rodent pest species often leads to indiscriminate use of non-selective rodenticides, causing high risk to non-target organisms in associated rice habitats.

The Saigon Plant Protection State Limited Company “Mobile Plant Doctor Project” further supports the gains made on integrated ecologically-based rodent management in Vietnamese farmers’ fields. It is testing the use of a new product, XIGA - SG 63q. This is a mixture of potassium nitrate (33%) and sulphur (30%), which on combustion releases sulphur dioxide (SO_2) gas. The concentration of potassium nitrate is such that there is enough to give combustion only, not an explosion. This is the main safety point of this product. In addition, it leaves no chemical residues and thus resistance to it is unlikely to develop. The product is like a smoke/gas generator with a fumigant action inside rat burrows. All rats (adults and juveniles) inside the burrows die within 5 minutes due to suffocation. After several field evaluations to test this product, it received registration approval by the Vietnam Pesticide Registration Agency and is thus allowed to be commercially made available to farmers through the Saigon Plant Protection State Limited Company. The product knowledge, its integration with community-wide rat management options, and its safe use is discussed in this poster. Its use is mainly during short two-week campaigns to collect and destroy rodents (adults and juveniles) at key times: one week prior to transplanting; or within 2 weeks of crop initiation in banks of major and smaller irrigation channels during the non-breeding season when rice is at tillering stage; and rice fields during the breeding season, when rice is at ripening stage.

Symposium: Management of Invasive and Endemic Rodents

Chairs: Garry Witmer and Susan Jojola

Oral Presentations

RODENT RESEARCH PRIORITIES OF THE NEW ZEALAND DEPARTMENT OF CONSERVATION

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The endemic fauna of New Zealand evolved in the absence of mammalian predators and their introduction has been responsible for many extinctions and declines. The amount of predator management being undertaken by the New Zealand Department of Conservation (DOC) is increasing steadily. Our predator control techniques are now not keeping pace with conservation requirements, especially with respect to rodent control over large areas.

There are four species of rodents in New Zealand. The Pacific rat or kiore (*Rattus exulans*) arrived with Polynesian voyagers more than 1000 years ago and although once widespread, is now largely restricted to offshore islands. The Norway rat (*Rattus norvegicus*) arrived with sailing ships in the late 18th century and was initially abundant but has declined both in distribution and numbers. The ship rat (*Rattus rattus*) and house mouse (*Mus musculus*) arrived in the 19th century and are now two of the most common mammals in New Zealand forests.

DOC undertakes rodent control at a number of sites and one of our most pressing problems is how to undertake control over large areas in a sustainable way. To help address this, a workshop was held in March 2006 to prioritise research needs. The three highest were to: Optimise aerial poisoning operations for rats on the mainland; Optimise ground control operations; and Improve mouse eradication techniques.

Large-scale aerial poisoning with 0.15% 1080 (sodium monofluoroacetate) used to control the Australian brushtail possum (*Trichosurus vulpecula*), sometimes, but not always, results in good ship rat kills. Possible influences on the outcome are bait type, toxin concentration and baiting strategy and we are currently investigating these further to see if we can achieve more consistent results.

Most current rodent baits were developed for commercial use and often for dry sites. These baits have been adapted for use by the DOC for use in bait stations to control ship rats on the mainland. The bait stations are laid out in grids generally 100 x 150m apart in areas of up to 3,000 ha. We need to investigate ways to make baits which will remain palatable for long periods and to identify new toxins. Any strategy to control rodents will have to be flexible, and will have to employ toxins with different modes of action.

Currently we have no method of controlling mice over large areas on the mainland. Mice can detect 0.15% 1080, so even if we can optimise aerial 1080 for both possum and rat control, it is unlikely we could control mice unless the 1080 can be masked. Mice are also hard to eradicate on islands and we are not sure why. We are planning to fund studies to look further at some of the possible variables.

New Zealand has a very high proportion of threatened birds, reptiles and amphibians, and rodents are one of the major causes of past extinctions and on-going declines. It is critical for us to improve our control techniques if we want to avoid further extinctions.

EVIDENCE FOR COMPETITIVE EFFECTS OF THE INTRODUCED *RATTUS RATTUS* ON NATIVE *RATTUS FUSCIPES* IN COASTAL FORESTS OF SOUTH-EASTERN AUSTRALIA

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In Australia the black rat, *Rattus rattus*, is a successful invasive species, being commensal with human habitation across extensive coastal environments, but its ecology and impacts in native forests are unclear. It has been suggested that *R. rattus* only colonizes vacant niches often associated with disturbance, which implies little interaction with native species. However, *R. rattus* occurs in intact forests where native rodents are unexpectedly absent or in low densities, suggesting they may compete for space and resources.

We experimentally manipulated populations of *R. rattus* on five 1-ha sites in coastal rainforest of Jervis Bay in south-eastern Australia to test the hypotheses that *R. rattus* negatively impacts populations of the native *Rattus fuscipes* through interference and exploitation competition. *R. rattus* populations on treatment sites were maintained at below 30% of control densities through live trapping and removal of individuals over twelve months. Native species were monitored during this time and for an additional nine months post experimental removal of *R. rattus*, using capture-mark-recapture methods. We compared native populations on removal and control sites for differences in abundance, age and sex class structure, reproduction, body weights and survival.

Populations of *R. fuscipes* rapidly increased in response to *R. rattus* removal, to be more than double the populations on control sites within four weeks of removal. This rapid population response was attributed to immigration and provided evidence for interference competition. Treatment populations continued to increase, reaching densities up to five times greater than control populations in some seasons. These increases were driven by immigration of males in spring with the onset of breeding and high reproductive recruitment in summer. However, reproductive activity and body condition of *R. fuscipes* did not change with long-term removal of *R. rattus,* suggesting that direct interference by *R. rattus* rather than indirect exploitation of resources best explain the low densities and poor juvenile recruitment of *R. fuscipes* in the study area.

The apparent dominance of *R. rattus* may be associated with residency rather than an intrinsic competitive ability. Removal of *R. rattus* facilitated shifts in residency status and competitive dominance from *R. rattus* to *R. fuscipes* so *R. rattus* could not re-establish post removal. Increases in residency times of female *R. fuscipes* with removal of *R. rattus* suggest that females play an important role in establishing resident populations. These findings identify *R. rattus* as a competitive threat to native *R. fuscipes* and highlight the benefits of controlling invasive *R. rattus* populations in native forests where population increases and shifts in residency potentially provide competitive advantage to native populations.

DYNAMICS AND IMPACTS OF INTRODUCED SMALL MAMMALS IN AN ALPINE LANDSCAPE IN NEW ZEALAND

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Every few years, the dominant tussock grasses (*Chionochloa* spp.) in the alpine grasslands of New Zealand produce large numbers of flowers and later set seeds. It is not known whether these periods of plentiful seed availability lead to pulses in the abundance of introduced mammals in alpine habitats, and in turn to increased risks to native biota including birds, lizards and invertebrates. The association between heavy seed production (masting) by southern beech trees (*Nothofagus* spp.) and fluctuations in the abundance of introduced house mice (*Mus musculus*) and of their introduced predators, stoats (*Mustela erminea*), in New Zealand forests is well documented. Alpine mammal populations above treeline may also be directly or indirectly affected by periodic heavy seedfall in the adjacent southern beech forest below treeline.

We assessed the density and diet of house mice and the relative abundance of stoats and brown hares (*Lepus europaeus*) in alpine grasslands and adjacent montane beech forest in the Borland Valley, South Island, between February 2003 and May 2006. At the same time, we measured the flowering intensity of alpine tussock grasses and other alpine plants, and also the production of beech seed.

Mice (based on live-trapping) and hares (based on pellet counts) were consistently more abundant at alpine than at forest sites, but the activity of stoats (based on ink tracking tunnels) were similar in the two habitats. In both habitats, the diet of mice (based on stomach contents) was dominated by invertebrates, especially the large flightless crickets known as ground weta (*Hemiandrus* spp., Orthoptera), spiders (Araneae), caterpillars (Lepidoptera) and grasshoppers (Orthoptera). There was an inverse correlation between capture rates of mice and ground weta in snap traps at alpine sites, suggesting that predation by mice may reduce the abundance of these insects.

Alpine tussock grasses flowered profusely only in the most recent southern summer (December 2005 – March 2006). Although mice were not unusually plentiful in this summer or the following autumn (May 2006), more adult-sized mice were in reproductive condition in autumn 2006 than in autumn 2003, our only previous autumn trapping session. Also, more mice were juvenile-sized in May 2006 than in May 2003. These results suggest the additional food provided by tussock seed may have lengthened the period of summer reproduction into autumn. Whether this extended period of reproduction will lead to a measurable mouse population increase by spring remains to be seen.

Because of the potential threat to native species if outbreaks of introduced rodents and their predators do occur in alpine habitats, it is important to continue to study these relationships. The abundance or predation mortality of alpine species likely to be at risk, such as ground weta and threatened birds such as rock wrens (*Xenicus gilviventris*), should also be assessed in relation to periodic tussock flowering and beech seedfall events. The effectiveness of management interventions to protect these species is likely to depend on their timing and intensity in relation to the population dynamics of introduced mammals.

DEVELOPMENT OF RODENT MANAGEMENT STRATEGIES FOR THE UPLAND FARMING SYSTEM IN LAO PDR

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Rodents cause significant crop losses in the upland farming system of Lao PDR. The upland region is the predominant agricultural system and provides food for the majority of poor rural villages. Rodents have been identified as the most important pest to rice, corn and job's tear with mean yield losses estimated at 19% (range 0-100%). Farmers often apply control after damage has already occurred. In cooperation with farmers, extension staff and researchers, we identified a range of rodent management strategies to test in upland, lowland (in the upland system) and village environments. These rely on applying control before breeding commences for the main rodent pest species (*Rattus rattus*) and through encouraging farmers to work together over a wide area. This paper will report on progress towards testing the recommendations in the field.

Workshops were held with farmers, extension staff and researchers at the commencement of the project. Practices were developed for lowland, upland and village habitat systems. These practices include using traditional and wire traps, pitfall traps, "bait" traps (where rats are encouraged into a small fenced area provided with free food, then traps are set for 2-3 days every week), community campaigns, field sanitation, plastic fences set with traps around grain stores in villages and encouraging the use of cats and dogs in villages. Study sites were established in Luang Prabang (2 treated; 2 untreated sites), Luang Namtha (3 treated and 3 control sites), Oudomxay (1 treated and 1 control site) and Houaphan (1 treated site) provinces. Farmers on treated sites were encouraged to undertake these practices for the wet and dry seasons for 2005. Data were collected on damage to rice crops, yield loss, number of farmers conducting activities, and time and money spent controlling rats to compare the effectiveness of these practices between the treated and untreated sites.

We are still in the early stages of assessing the impact of rodent management in our treatment sites. Damage was low in the wet season in 2005 (< 3%), except at sites in Oudomxay, where damage was approximately 20%. In the field, 41% of farmers were using sanitation and 37% were using local traps. In villages, 43% of farmers used sanitation and 40% used cats. Preliminary data shows there was no difference in activities between treated and untreated sites conducted by farmers. There were significant reductions in the percentages of farmers conducting activities in September and December because farmers were busy with their crops in the field.

Farmers are starting to work together to conduct community campaigns at key times for rodent management. At one village, about 20 farmers worked together to hunt rats in key habitats such as grain stores and around vegetable gardens in the village environment and collected 25 rats in 1.5 hours. The campaign demonstrated the importance of habitat and cover for rats, so now the farmers on treated sites try to reduce areas with long grass, shelter and food for rats.

The farming system in Lao PDR is complex, and rodents utilise and track resources within and between these environments. The results presented here are preliminary, but we are starting to see some benefits of farmers being more aware of applying control early and working together.

THE HABITAT USE OF PEST AND NON-PEST SPECIES OF RODENTS IN THE AGRO-BASED ECOSYSTEMS OF LUZON, PHILIPPINES

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Rodents cause serious damage and yield loss to both upland and lowland rice crops of the Philippines. The island of Luzon has a diverse landscape of forest and agriculture that is inhabited by many rodent species, including non pest species that are endemic to the Philippines. Efforts to control the species of rodent pests often lead to indiscriminate use of chemical rodenticides. However, the risk to non-target native rodents is unclear because little is known about which native species of rodents live in the surrounding habitats. We investigated the diversity and habitat use of rodents in the uplands of the Ifugao Rice Terraces (IRT), Codillera Mountain Range, and the lowlands of the Sierra Madre Biodiversity Corridor (SMBC), with the aim to distinguish between the rodent species causing crop damage and the non-pest rodent species that are present in habitats associated with agriculture.

In the IRT, trapping was carried out in four major habitats that occur around rice fields, using trap lines of 10 or 15 cage-traps. During the months of May and June, 2004, four rounds, each consisting of trapping for 5 consecutive nights, were replicated at two sites. In the SMBC, a more in-depth study began in February, 2006. Trapping was carried out in five major habitats using trapping grids of 20 cage-traps. From February to May, four rounds, each consisting of trapping for 3 consecutive nights, preceded by 3 nights pre-baiting, were replicated at three sites. At both areas, animals were tracked using a spool-and-line method.

A diverse range of rodent fauna was recorded in both the upland and lowland habitats of Luzon. These included the non-native pest species, *Rattus tanezumi* and *Rattus exulans* and the native species, *Rattus everetti*, *Bullimus luzonicus* and *Chrotomys mindorensis*. *R. tanezumi* and *R. exulans* were the most common species found in rice fields, where very few native rodent species were trapped. In forest habitats there was a high abundance of native species and very few non-native species. In the intermediate regrowth habitats of caneland (secondary growth vegetation), hilly areas, and coconut groves, both native and non-native species were trapped. In both the IRT and the SMBC, the trapping and spool-and-line tracking data indicated that the native species do not contribute to rice damage, and *C. mindorensis*, actually may be beneficial in the ricefield ecosystem as primary vermivores that feed on invertebrate pests.

Both pest and non-pest species of rodents are present in major habitats associated with agriculture, thus indiscriminate use of rodenticides presents a risk to the non-pest native species of rodents. A critical balance between rodent control and conservation must be achieved in the species rich agro-based ecosystems of Luzon, Philippines. A better understanding of the breeding ecology, habitat use, and seasonal survival of these rodent species would support the development of an integrated ecologically-based approach to rodent pest management that would provide targeted control of the pest species.

EVALUATION OF ATTRACTANTS FOR NUTRIA MANAGEMENT IN THE USA

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Nutria (*Myocastor coypus*) were introduced from South America to the United States in the 1930s for fur farms and are currently established in 15 states. Nutria are important to the Louisiana fur industry, but cause extensive damage to coastal marsh ecosystems at high densities. The Louisiana Department of Wildlife and Fisheries uses a payment-incentive program to increase nutria harvest efforts by hunters and trappers, which helps control the rapidly growing populations. While this approach is effective, additional management tools are needed to control nutria outside of the trapping season and that, when used with hunting and trapping, would maintain lower nutria densities. Other potential tools for nutria control include toxicants, induced infertility, repellents, and baits and lures. Development of nutria attractants, such as baits and lures, to increase the effectiveness of kill-traps, live-traps, or rodenticide bait stations is a research priority. Effective lures could significantly improve control efforts of nutria.

The objectives of the study were to use wild-caught captive nutria to identify potential olfactory cues in Y-maze trials; assess marsh vegetation and fertilizers as attractants; and assess nutria urine as an attractant. For Y-maze trials, we conducted 2-choice trials with a test material in one arm and distilled water in the other. If after five minutes a nutria did not reach a selection point, a “no choice” was recorded. Test odours consisted of food flavors and fragrances, commercial nutria lures, and synthetic anal gland secretion or fur extract from nutria. *Post hoc* Fisher exact test estimates and one-sample proportion tests were run to detect differences in treatment selections versus non-treatment selections. In marsh vegetation trials, groups of nutria were left overnight in an outdoor enclosure and their activity was video-recorded. We evaluated mean time spent by nutria at treatments of potted plants (*Panicum hemitomon* or *Spartina alterniflora*), soil, and fertilizers (foliar spray or soil-based). In one nutria urine trial, we sprayed a trail of female nutria urine along the ground to determine if individual nutria detected and followed the trail. The percentage of times a nutria passed through an entry marked with urine was determined. In another nutria urine trial, we examined the attractiveness of male urine versus female urine to three (all-male, all-female, and mixed sex) groups of nutria left overnight in a pen. We determined the mean time per event spent by nutria in each urine zone, the number of events with direct contact of the urine, and the frequency of the maximum number of nutria in a urine zone.

In Y-maze trials, the three odour cues selected most were Tom’s Nutria #1 (commercial lure), nutria anal gland secretion B, and female nutria fur extract (both synthetic formulations), however, analyses for each odour indicated no statistically significant difference in treatment versus non-treatment selections. In marsh vegetation trials, nutria did not show a significant preference by plant species or by fertilizer type, but gave significantly more attention to fertilized plants than to non-fertilized plants or to soil treatments. In urine trials, results suggested that nutria did not detect, or choose to follow, the urine trails. In group trials with nutria urine, the mean time per event spent in the male urine zone versus the female urine zone was different only for the mixed sex nutria group. Additionally, the all-male nutria group most actively investigated the source of odours relative to the other two groups. In conclusion, this study identified several nutria attractants that warrant further assessment in the field.

BAIT SELECTIVITY BY NON-TARGET BIRDS AND MICE IN MOUSE BAITING PROGRAMS: NEW USE FOR TRACKBOARDS AND SANDPLOTS

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Increasing numbers of successful eradications of rodent pests on islands have been reported since the turn of the century. These eradications have predominantly been achieved by baiting with second generation anticoagulant poisons such as brodifacoum. Such baiting may have impacts on non-target species. This study aimed to determine if bait consumption by house mice and non-target birds differed between wax block, pellet and grain formulations (non-toxic). Trackboards and sandplots were used to assess bait selectivity and consumption.

The study was conducted on two islands (Heron and Northwest) of the Capricornia Cay National Park in Queensland, Australia during winter, 2006. Three replicate plots (50m x 40m) were assigned to each bait formulation (treatment) per island using a randomized block design and baited at 1kg ha^{-1}. A sample of the applied bait was monitored at each plot by placing each of these baits in the middle of a trackboard (30cm x 30cm), located within a 1m² sandplot. These sample baits were located 10 m apart on a 5 x 6 grid at each plot. Animal tracks found on the sandplots and/or the trackboards were used to determine which animals visited and consumed the bait. Bait consumption by mice and birds was analyzed using a weighed factorial Anova ($\alpha = 0.05$). Results revealed a significant treatment effect for birds ($F_{2,8}=8.17$, $p= 0.012$) with higher mean bait consumption at the grain plots over the waxblock plots (Tukey's pairwise comparison, $p = 0.0094$). The treatment effect for mice, although not statistically significant ($F_{2,8}=4.31$, $p = 0.054$), was very close to $\alpha = 0.05$, implying a possible treatment effect on bait consumption by mice. Comparisons between treatments revealed significantly higher mean bait consumption at the grain plots than the waxblock plots (Tukey's Pairwise Comparison, $p = 0.0481$).

A Selectivity Index (SI) was calculated for each treatment to determine whether mice and birds selected towards a particular bait formulation, given the potential competition between them to consume the available bait:

$$SI = Log_{10}(P_b/P_m)$$

where,

P_b is the amount of bait consumed by birds / bait available
P_m is the amount of bait consumed by mice / bait available

Results revealed a higher selectivity of mice towards waxblocks (SI = -0.6274), similar selectivity between birds and mice for pellets (SI = 0.0891) and a higher selectivity of birds towards grains (SI = +0.6144). Lastly, capture-recapture studies revealed similar mice abundance across the treatment plots, although abundance was higher at Northwest Island than Heron Island.

Overall results from this study highlight the importance of bait formulation selection as part of an integrated mouse management program. Results suggest that the choice of bait formulation potentially impacts, not only the effectiveness of mouse baiting programs, but also the risk to non-target birds. Furthermore, waxblocks appear to be the most suitable formulation for future toxic baiting programs to be conducted at Northwest and Heron islands as they were consumed and selected the least by birds and the most by mice.

A COMPARATIVE STUDY OF RODENT AND SHREW DIVERSITY AND ABUNDANCE IN AND OUTSIDE THE N'WASHITSHUMBE ENCLOSURE SITE IN KRUGER NATIONAL PARK

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Rodents are a very successful group forming the largest Order of mammals, but monitoring trends in populations remains complicated, especially when populations are influenced by changes in vegetation structure, seasonal climate fluctuations and different management practices.

This project aims to determine the biodiversity of rodent populations in the northern plains of the Kruger National Park and to investigate the possible role they may play as bio-indicators for habitat destruction. Movement of rodents from one area to the next is expected to be restricted due to changes in the habitat structure (Johnson, R. *et al.* 2002). This study describes the results of small mammal trapping in, surrounding and outside the N'washitshumbe enclosure site (an area enclosed since 1968 for the protection of endangered antelope species in the northern plains of the Kruger National Park, South Africa), with reference to plant association, seasonal change, management practices (e.g. presence or absence of fire and elephant impact) and community dynamics of rodents.

Three grids each comprising three transect lines of 30 Sherman traps were placed randomly to incorporate top, middle and bottom slopes within, surrounding and inside the N'washitshumbe enclosure site. Markers were placed along each transect line and around each trap to ensure the same site was surveyed each time. Trapping was undertaken 2-3 days each month between June 2003 and April 2005. Traps were baited with rolled oats, peanut butter and cooking oil (Johnson *et al*. 2002) and checked daily. Specimens were identified, sexed, measured and weighed. All specimens were marked by toe clipping (American Society of Mammalogists, 1998) and released.

A total of 2303 specimens were collected between June 2003 and April 2005. All rodents and shrews were sampled in all three habitats in, around and outside the enclosure site. Nine species were collected: *Aethomys chrysophilus; Mastomys natalensis; Steatomys pratensis; Graphiurus murinus; Tatera leucogaster; Mus minutoides; Saccostomys campestris; Myosorex* spp. and *Paraxerus cepapi. M. natalensis* was the dominant species in this area, with a total of 1835 individuals trapped at the 3 grids.

Fluctuations in species diversity occurred monthly, with *M. natalensis* being the dominant species trapped between May and August due to a population explosion. The population grew rapidly in response to late rains in April. *Saccostomys campestris* (n=281 specimens) and *Tatera leucogaster* (n=99) were the next most common species and they were collected more frequently in periods when *M. natalensis* numbers had decreased.

It is argued that progress in estimating rodent diversity to develop our understanding of small mammal community dynamics will be enhanced by building local inventories of fluctuations of species diversity and abundance, and in descriptive and experimental studies of the structure of communities.

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CONSERVATION STATUS OF THE CAPROMYID RODENTS IN CUBA

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The development of legislation for protected areas in Cuba is divided into three historic periods: the colonization period (until 1900), the Republican period (1900-1959) and the Revolution era (after 1959). A number of laws have been promulgated since 1959 to protect Cuban nature and ecosystems. The eleven Cuban terrestrial mammals (Insectivora and Rodentia) are all endemic and some species are particularly threatened due to their restricted distribution. All species, with the exception of one capromyid, *Mysateles garridoi*, are represented in the Protected Area National System, which guarantees their conservation through the enforcement of the legislation, management, and protection actions. The Cuban system for protected areas operates under eight national management categories (matching the IUCN system). The status and threatened of Capromyid rodents in Cuba is presented, 6 species are in the IUCN category of CR, and one is VU. Hunting and invasive species are the principal threats to the terrestrial mammals of Cuba.

REPRODUCTIVE PATTERNS OF THE RODENT PEST SPECIES, *RATTUS TANEZUMI*

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This study was conducted to establish the reproductive patterns of the rodent pest species, *Rattus tanezumi*. Understanding the patterns will serve as basis for the development of various management practices and in determining the most appropriate time for the application of these practices.

Different collection methods, such as trapping, Trap Barrier System + Trap Crop (TBS+TC), burrow excavation/flooding, night hunting, and the use of flame throwers, were employed during the dry (January to June) and wet (July to December) seasons of 2005 at the PhilRice farms.

Using these methods, 5351 rats were collected. Ninety eight percent (98%) of these were *R. tanezumi* and the rest were either *Mus musculus* or *Rattus norvergicus*. Results showed that *R. tanezumi* has a continuous breeding pattern at PhilRice farm. Breeding reaches its peak during the vegetative and maximum tillering stages as indicated by the number of rats at their first trimester stage of pregnancy. The number of juveniles increased as the rice crop entered the booting stage and continued to increase as the crop matured. These results can be used to recommend the best time to apply appropriate management strategies. In addition, this will improve the efficiency and effectiveness of the strategies. Currently, demonstrations of various management strategies and lectures are being undertaken in farmers' fields for evaluation and promotion.

Poster Presentations

INVASIVE RODENTS IN THE WEST INDIES: AN OVERVIEW

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The mammals introduced in the West Indies have a negative impact on the endemic fauna. Rats, mice and other introduced rodents are a danger for the conservation of the Cuban and Hispaniolan solenodons, the capromyid rodents and many species of birds, reptiles, amphibians, and invertebrates. The current state of these invasive mammal species in The Antilles, their impact, available information about introductions, field observations, distribution, etc. is being revisited. The historical collation reports show that a total of 39 species of mammals have been introduced on 121 islands of the West Indies. The black rat, house mouse, and brown rat are the rodent species which are most widely distributed; they are present on 79, 34, 21 islands respectively. The real impact of these species is not known very well in these isolated areas. Management policies for the control of invasive species are very important for the conservation of biodiversity in the West Indies, however they are scarce.

RODENT ECOLOGY IN RURAL AND URBAN SYSTEMS IN THE PAMPEAN REGION OF CENTRAL ARGENTINA

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Rodents have a high reproductive potential that allow them to reach, in many systems, pest level densities which can lead to economic and sanitary damage. This occurs, in particular, in human modified environments, where food and shelter is readily available and/or conditions are favourable, like houses, sheds, cultivated fields, etc. The aim of the Population Ecology Laboratory of the Exact and Natural Science Faculty of the University of Buenos Aires is to study rodents in rural and urban systems in order to contribute to the knowledge of theoretical and applied aspects of their ecology. The studies utilise the capture and recapture of rodents using Sherman (for small rodents) and cage traps (for rats) in cultivated fields and poultry farms in a rural system of Buenos Aires Province, and in Buenos Aires city (Argentina). Sampling in fields started in 1979, on poultry farms in 1997 (this is a relative new industry in Argentina), and in the city in 2001.

Native sylvan and introduced domestic species have been captured in the three systems, but the composition of species is different in each community. In field systems, the sylvan Cricetidae (*Calomys laucha* and *Calomys musculinus),* are numerically dominant in the crops, which are highly disturbed at certain times of the year (e.g. during harvest). The sylvan Cricetidae (*Akodon azarae* and *Oligoryzomys flavescens)*, and the Caviidae (*Cavia aperea)* are more abundant in less disturbed habitats like field borders. The Cricetidae (*Oxymycterus rufus),* is only captured in field borders near water bodies during rainy years. The introduced Muridae (*Mus musculus*, *Rattus rattus* and *Rattus norvegicus),* are rare in both fields and borders, but they are the most abundant species surrounding the breeding sheds on poultry farms, especially *M. musculus* and *R. norvegicus.* Sylvan rodents are also captured in poultry farms, but they are more abundant along the vegetated fences of the farms than surrounding the breeding sheds. Among these species, the most abundant is *A. azarae*, although *C. laucha*, *C. musculinus* and *O. flavescens,* along with the occasional *O. rufus* are also found, in the field system. *C. laucha* is captured in poultry sheds when there are harvest activities in the surrounding cropfields. In the urban system, *R. rattus* is dominant in residential-industrial areas, while *R. norvegicus* and *M. musculus* occurs in parklands (where the sylvan *O. flavescens* and *C. aperea* are also present) and marginal neighbourhoods. The Cricetidae, *Deltamys kempi* and *O. flavescents,* are the dominant species in urban reserves.

Species richness is very similar among the three systems (8 species in fields and poultry farms; 7 in the city), but the composition and/or relative proportion of species differs. The distribution of each species in each community mainly depends on its ability to take advantage of human disturbance and production systems. Thus, the introduced species, *M. musculus* and the *Rattus* species show a growing dominance from the less disturbed system to the most modified by humans (the city). The Cricetidaes, those which are more tolerant to human disturbances (for example, the *Calomys* species), are more abundant in crops (in contrast with the vegetated borders) and can also occupy the sheds in poultry farms. However, *A. azarae*, a less tolerant species, is only abundant in the vegetated borders of fields or farms. *O. flavescens*, *D. kempi* and *O. rufus* are sylvan species associated with water bodies. None of htese is very abundant in any of the studied systems, but in sites which are near rivers (including the urban reserve, which is located next to the River Plate) or in very humid years.

SCATTER-HOARDING BY EDWARD'S LONG-TAILED RATS (*LEOPOLDAMYS EDWARDSI*): A TEST OF OPTIMAL CACHE SPACING MODELS

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Scatter-hoarding has two paradoxically demographic consequences: cache recovery for hoarding animals and cache ignorance for successful seed dispersal. In relation to parent plants as food patches, there are two well-known models - the optimal cache spacing models proposed by Stapanian and Smith (1978) and Clarkson et al. (1986), respectively. The optimal models are used to predict how scatter-hoarding animals store nuts and seeds from a concentrated food source to maximize the number of caches recovered. By tracking the fate of tin-tagged seeds around parent plants with three categories of resource availability, we tested related hypotheses and predictions originating from both models by quantifying scatter-hoarding and seed dispersal by a key scatter-hoarder, Edward's long-tailed rats (*Leopoldamys edwardsi*) in oil tea (*Camellia oleifera*, Theaceae) in a subtropical forest, Southwest China.

The scatter-hoarding patterns changed with distance from parent plants, with smaller caches and longer distances for subsequent caches. This supports the rapid sequestering hypothesis that hoarding animals should rapidly harvest and hide the food to protect it from other competitors when they encounter a rich, ephemeral source. Initial caches were more likely to be established along the direction of the nest of hoarding animals. Secondary caching rearranged the seed shadows of initial caches, with smaller caches and further spacing. Patterns of cache survival and recruitment were either hump-shaped or declining with distance from parent plants for initial caches, but were concave-shaped for secondary caches. High resource availability at a concentrated source had less effect on dispersal distances of initial caches with higher survival of initial caches near parent plants, while lower resource availability significantly increased secondary caching with higher survival of secondary caches far from parent plants. The observed patterns of scatter-hoarding and cache survival in oil tea provide either strong or weak support for or against the predictions from both models, but confirm most of predictions by Clarkson et al. (1986). Using the "real" dispersal and survival data, we found that patterns of cache survival and recruitment in oil tea depend upon the density or frequency of caches around parent plants.

Our study indicates that spatial patterns of caches and their probability of survival are regulated by the shared mechanisms for both hoarding animals and related plants, e.g. rapid sequestering (including secondary caching) and resource availability.

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Symposium: Taxonomy and Systematics

Chairs: Kevin Rowe and Nick Oguge

Oral Presentations

PHYLOGEOGRAPHY OF THE EASTERN AFRICAN *PRAOMYS*

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Although the number of species in genus *Praomys* remains unclear, at least nine are recognized. These soft-furred rats occur widely in Africa within the inter-tropical zone. Four different species groups or complexes have been suggested in this genus: (i) the jacksoni complex (*jacksoni*, *minor*, and *mutoni*); (ii) the tullbergi complex (*missonnei*, *morio*, *rostratus* and *tullbergi*); (iii) the delectorum complex (*delectorum*); and (iv) Hartwig's praomys - *hartwigi*. The *Praomys delectorum* group have been described only on the eastern coast of Africa. This includes *P. delectorum* (Thomas 1910 Mlanji Plateau), *P. taitae* (Heller 1911 Mt Mbololo, Taita Hills), *P. tullbergi melanotus* (GM Allen & Loveridge 1933 Nyamwanga, Poroto Mts), and *P. jacksoni octomastis* (Hatt 1940 Old Mbulo reserve, Arusha). In order to understand the phylogenetic relationship within the delectorum complex, and how this relates to other *Praomys* complexes, we undertook a partial 16S rRNA mitochondrial gene sequences study.

Praomys samples from Democratic Republic of Congo (Kisangani), Kenya (Abadares, Kakamega, Kaptagat, Mt Kasigau, Kyulu Hills, Mt Kenya and Taita Hills), Malawi (Chipita) and Tanzania (Uluguguru (Bondwa), Kidege, Mbizi, Meru, Mweka, Pare, Rungwe, and Udzungwa) were studied. These animals had been variously described as *P. tullbergi, P. melanotus*, *P. taitae* and *P. jacksoni octomastis* We analysed 498 base pairs (bp) long amplified 16S rRNA fragments for a total of 37 *Praomys* and two *Hylomyscus* specimens using *Mus musculus* and *Rattus norvegicus* as outgroups. DNA was isolated from toe-clipped or muscle samples using the standard proteinase K method, purified by phenol-chloroform extraction and ethanol precipitation. The polymerase chain reaction was used to amplify segments of the mitochondrial 16S rRNA mitochondrial gene using standard protocols.

The obtained phylogeny show very low sequence divergence among mtDNA haplotypes within each of *P. delectorum*, *P. tullbergi, P. melanotus*, *P. taitae* and *P. jacksoni octomastis* samples suggesting that each comprises a single species. It also confirms that *Praomys* from Mt Kenya and Abadares are of the jacksoni group. The difference between the delectorum and jacksoni groups showed high bootstrap support suggesting a vicariant event perhaps occasioned by the Great Rift Valley formation. Presence of the jacksoni group in Mt Kenya and the Abadares which are to the east of the Rift Valley may be explained by dispersal from western Kenya, with possible recent common ancestry with the Kaptagat population with which they show low sequence divergence. Although much confusion continues to persist in *Praomys* taxonomy, our study strongly supports those morphometric studies that recognizes only one species in *P. delectorum* taxonomic complex.

TAXONOMY AND DISTRIBUTION OF TWO *MUS* SPECIES IN THE CENTRAL RYUKYUS, JAPAN

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The central Ryukyu Islands are considered to have been geographically isolated from all other landmasses since the Pliocene. Most of the mammals found on these islands are endemic elements; while several murid species are thought to have been introduced by humans. However, the dispersal histories of the introduced species remain obscure, mainly due to insufficient information on their taxonomy and distribution.

During 1993 and 2000, one of us (MM) visited 14 islands in the Central Ryukyus and set a total of 3632 small mammal traps. Traps were set in anthropogenic habitats such as sugar-cane fields, other cultivated fields, grass land, road edges, and so on. Specimens were weighed and measured; and vouchers are deposited in the Kyoto University Museum.

In total, 374 individuals of small mammals were collected, identified as four murid species: *Mus musculus* (n=87), *M. caroli* (n=89), *Rattus rattus* (n=2), *R. norvegicus* (n=5); and two insectivore species: *Crocidura watasei* (n=153) and *Suncus murinus* (n=38). *Mus musculus* and *M. caroli* can be distinguished by differences in coat color, tail ratio, and hind foot length. *Mus caroli* has a bicolored tail with a clear border between the upper and lower surfaces; a longer tail, as long as head and body length, and a longer hind foot. *Mus musculus* was collected from five islands including Okinawajima, while *Mus caroli* was only found on Okinawajima. Trap success for *M. caroli* was much higher in the central and southern part of Okinawajima island, than in the northern part. This species was dominant in sugar cane fields, while *M. musculus* was found mainly in grass land. On the other four islands, *M. musculus* was common not only in grass land but also in sugar-cane fields. Patterns of distribution of the two *Mus* species at island level and at local habitat level thus appear to reflect resource competition between the two species.

Because these two *Mus* species have been confused taxonomically, *M. caroli* is sometimes thought to be widely distributed in the Ryukyus. However, our data confirm that *M. caroli* is restricted to Okinawajima, from whence this species was originally described. Each of us independently examined the holotype of *M. caroli* Bonhote, 1902 in the Natural History Museum, London (BMNH) to check this identification. *M. musculus* in the Ryukyus are sometimes treated as an endemic subspecies, *M. musculus yonakuni* Kuroda, 1924, described from Yonaguni island in the southern Ryukyus. Although the holotype was destroyed, MM located a specimen used in the original description in BMNH. We also examined a further ten specimens from Yonaguni Islands, deposited in the National Science Museum, Tokyo, and compared these with specimens of *M. musculus* from other Ryukyu islands and from elsewhere across its range, and with specimens of other species of *Mus*. Specimens from Yonaguni Island differ strikingly in features of coat color and skull morphology from specimens of *M. musculus* from the central Ryukyu and Taiwan specimens, and show some similarities to examples of *M. terricolor* Blyth, 1851 from the Indian subcontinent. The latter species also occurs in Sumatra, presumably as a result of human introduction, hence its occurrence elsewhere in this region might be anticipated. However, further studies of *M. m. yonakuni* are needed to confirm this tentative identification, including molecular methods. Specimens of *M. musculus* from the central Ryukyu islands closely resemble examples of *M. musculus castaneus* from the Philippines and Taiwan, and specimens of *M. m.* '*molossinus*' from Japan. External measurements (head and body length and hindfoot length) did not distinguish between specimens from the central Ryukyu islands and the Japanese main-islands. However, specimens from Okinawajima and the Japanese main-islands specimens tend to have greater body weights than specimens from

four other islands in the central Ryukyus. This difference in body weight between Okinawajima and the other islands may reflect the presence/absence of *M. caroli* and consequent differences in habitat utilization. Further studies of geographic variation in *M. musculus* in the Ryukyu islands are needed to further explore these interesting taxonomic and ecological observations.

COLONIZATION AND DIVERSIFICATION IN AUSTRALIA AND NEW GUINEA: A MULTILOCUS VIEW OF THE OLD ENDEMIC RODENTS (MUROIDEA:MURINAE)

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The Murinae are the most diverse subfamily of mammals with centres of diversity in Africa, Southeast Asia, and the Sahulean supercontinent (Australia and New Guinea). The rodents of Sahul are comprised of recent (< 2 mya) *Rattus* immigrants from Southeast Asia and a diverse assemblage of old endemics, including nearly 150 species in over 30 genera. These old endemics represent one or more large adaptive radiations including novel morphological adaptations to aquatic, arboreal, hopping, and arid ecologies. The four tribes recognized within the Sahulean old endemics (Hydromini, Conilurini, Anisomyini and Uromyini) reflect distinct biogeographic and ecomorphological hypotheses about diversification within the old endemics.

Here we present the results of a multi-locus phylogeny of the Sahulean old endemics, including 26 of the 34 recognized genera and representing all tribes and divisions. This is nested within a broader phylogeny of the Murinae, including representatives of 24 of the 29 recognized divisions. Phylogenies were estimated from over 2500 nucleotides of mtDNA sequence and over 9500 nucleotides from 6 autosomal nuclear loci including 5 exons and 2 introns. Phylogenies were estimated for individual genes and for the full concatenated dataset using maximum parsimony, maximum likelihood and bayesian criteria.

Our phylogenies strongly supported the monophyly of the Sahulean old endemics with a sister relationship to the Philippine old endemics. The primary diversification of the group is deeply nested within the Murinae and is consistent with a single colonization of the Sahulean continent with subsequent *in situ* diversification. Our results did not support monophyly of the Anisomyini and the Conilurini. Our results supported a monophyletic Uromyini nested within the Conilurini and a monophyletic Hydromyini. The phylogeny identified at least 9 colonization events in the history of the Sahulean old endemics. At least three of these events preceded phylogenetic and morphological diversification within the group (1.the primary Sahulean colonization of New Guinea; 2. either two conilurine colonizations of Australia or one conilurine colonization with a Uromyine colonization of New Guinea). The remaining colonization events did not lead to major diversifications and at least one radiation (Hydromyines) did not result from colonization of a new landmass.

Poster Presentations

SPECIES IDENTIFICATION OF RODENTS AND SHREWS FROM KISANGANI (D.R.CONGO): A DNA BARCODING APPROACH ALLOWS THE TRANSLATION OF SEQUENCES INTO SPECIES NAMES

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Tropical rainforest and associated forest faunas are disappearing fast worldwide and many taxa may disappear before they have been characterized and described as species. A recently started project that intends to study the adaptation ability of small mammal populations (rodents and insectivores) to the changing conditions around Kisangani, D.R. Congo requires that the taxonomic composition of these faunas is adequately characterized. This is not an easy task, because despite the fact that hundreds of African murid taxa are described, their taxonomy remains confused. It is often difficult to identify closely related species, particularly since recent studies indicate that scores of taxa remain to be described. To provide taxonomic support for the ecological project we have developed a molecular tool to facilitate the identification of these murines.

The used approach links mitochondrial DNA sequences from tissue collections to type specimens that are usually not suitable for DNA studies. We use a combined analysis of craniometric and cytochrome b sequence data from freshly collected specimens with measurement taken from all available type specimens. Based on extensive specimen and tissue collections (>5000 specimens, ±1000 sequences) throughout Sub-Saharan Africa, we use this approach to link the operational taxonomical units (OTUs) and corresponding sequences from specimens collected in the area of Kisangani to type specimens, or to attribute them to undescribed taxa. This implementation resembles the DNA barcode identification system that is proposed by CBOL (Consortium for the barcode of Life) and allows the correct translation of DNA sequences into the current taxonomical points of reference (types) for African murids.

The taxonomical work carried out together with the University of Kisangani will allow us to revise the different rodent and insectivore taxa in the north of the D.R. Congo. It will also facilitate the identification of species used in the capture-mark-recapture studies that intend to assess the life-history of these taxa. It is clear that the combined use of craniometric and DNA sequence data will facilitate the description of new species in the course of this project.

Molecular and craniometrical taxonomical work on the already collected rodents and insectivores has started. We argue that this is possibly the only way to develop a DNA barcode identification system that allows the correct translation of DNA sequences into the current taxonomical points of reference (types) for African murids and shrews. Our poster will illustrate our findings using this approach. So far the identified rodents are: *Stochomys longicaudatus*, *Lophuromys rita*, *L. luteogaster*, *L. huttereri*, *L. dudui*, *Hylomyscus stella*, *H.*

parvus, *H. aeta*, *Grammomys rutilans*, *Oenomys hypoxanthus*, two members of the *Praomys jacksoni* species complex, *P. mutoni*, *Malacomys lukolelae*, *Malacomys longipes*, Mus (*Nannomys*) *cf grata*, *Lemniscomys striatus* and an unidentified *Hybomys* species. The identified shrews are so far: *Crocidura cf littotalis* sp1, *C. cf littotalis* sp2-3, *C .olivieri*, *C. cf ludia* complex, *C. dolichura*, *C. grassei*, *Paracrocidura cf maxima*, *Sylvisorex johnstoni*, *S. cf ollula* and *Scutisorex somereni* [cf names refer to a species that is morphologically similar but molecularly different from a known species].

HYBRIDIZATION IN EVOLUTION OF *MUS MUSCULUS* SPECIES GROUP: INTERDEPENDENCE OF COMMENSALISMS

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The process of speciation, the significance of introgressive hybridisation in the evolution and diversification of mammals are important problems of evolutionary theory. The *Mus musculus* species group includes closely related taxa in different stages of divergence: sympatric species (*Mus musculus – M. spicilegus*; *M. domesticus – M. macedonicus; M. domesticus – M. spretus*; parapatric taxa which hybridize in zones of their contact (*M. musculus – M. domesticus – M. castaneus* and allopatric species (*M. spicilegus – M. macedonicus – M. spretus*) As a result the *Mus musculus* s.l. has served as model group in studies of microevolution. The aims of this work are (i) evaluation of the interdependence of commensalism and hybridization in evolution of *Mus musculus* s.l. species group, (ii) revision and discussion of origin of commensal Trans-Caucasian populations of house mice possessing high levels of genetic variability.

There are different kinds of hybridization in commensal taxa of house mice: a narrow 16-50 km wide zone of introgressive hybridization between *M. musculus* and *M. domesticus* in Central Europe, a well-studied "tension zone" zone of secondary contact; large zones of gene introgression in Asia between *M. castaneus*, *M. domesticus* and various subspecies of *M. musculus*; hybrid origin of *M. m. molossinus* of Japanese island (a possible example of stabilized hybrid genome); hybrid origin of population at Lake Casitas, California, intermediate between *M. musculus* and *M. castaneus*; and hybridization of different commensal taxa in large cities.

Allozyme analysis has shown that Trans-Caucasian populations of commensal house mice possess an admixture of *musculus* and *domesticus* genes. This region is either a zone of secondary contact between *musculus* and *domesticus*, with very wide introgression of *domesticus* genes into the genome of *musculus*, or these are relict populations descended from non-differentiated forms with ancestral polymorphism. The main feature of this zone is the unusually large extent of *domesticus* genes, which occur throughout the entire Trans-Caucasus (about 350 000 km^2). Data and observations favour the view suggest that Trans-Caucasian house mouse populations are relicts of an early-differentiated form of *M. musculus*, preserving much of the ancestral gene pool. The second possible hypothesis is that populations of Trans-Caucasus are result of hybridization of ancient not finally differentiated forms of house mice. It is possible that ancient "oriental" lineage and ancient form of *musculus* were colonised the Trans-Caucasus and mixed in this territory. The Adjarian populations would then be a product of contact between these forms and fully differentiated *M. domesticus* from Turkey.

It is possible to predict different ways of evolution in hybrid populations: stabilisation of hybrid genome, formation of premating reproductive isolation arise between parental taxa or "dedifferentiation" of closely related taxa. The analysis of different kinds of hybridization supports the hypothesis of "dedifferentiation" and demonstrates that now this process really exists in commensal populations of house mice.

Analysis of hybrid populations of commensal house mice demonstrates the particular significance of hybridization in the evolution of commensal taxa. This enhanced role in commensals is linked to their unique ability to expand their geographic ranges through human agency and even survive as commensals in areas that are beyond their physiological tolerance.

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GENETIC STRUCTURE OF *MUS MUSCULUS* POPULATION IN A RURAL AREA OF BUENOS AIRES PROVINCE, ARGENTINA.

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It has been demonstrated that many populations of *Mus musculus* are divided into small demes (reproductive units) with limited genetic flow between them. In some rural areas of Argentina *M. musculus* exist in isolated groups with limited interchange of individuals, even among different sheds on the same farm. However, during high population densities, subordinate individuals may emigrate, thus connecting the groups.

The goal of this work was to examine the genetic structure of *M. musculus* from sixteen poultry farms in Exaltación de la Cruz Department (Buenos Aires Province, Argentina), using six microsatellite loci. The rodents were captured between December 2004 and May 2005, using live-capture traps. The data was analyzed with TFPGA y FSTAT programmes.

We found that *M. musculus* from the poultry farms were genetically differentiated (F_{st} = 0.11; $p<0.05$). An isolation by distance pattern was observed between the groups ($r = 0.25$; $p = 0.02$). Genetic differentiation among the studied farms is consistent with the notion that individual movement between the farms is a rare event. Our result probably reflects the fact that population densities of *M. musculus* in the farms typically remain below the level at which individuals are forced to emigrate. The presence of discrete demes, even within each population, probably accounts for a low observed incidence of heterozygote individuals (F_{is} = 0.09; $p<0.05$).

BATS AND RODENTS FROM HUU LIEN NATURE RESERVE, LANG SON PROVINCE, VIETNAM

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Huu Lien Nature Reserve, in the Tower Karst Region of Northeastern Vietnam, lies about 90km due north of Hanoi. In August 1986, it was decreed as a 3,000 ha nature reserve for the conservation of limestone forest and musk deer. A Nature Reserve management board was established in 1989, and in 1990, the area of the Reserve was declared as 10,640 ha with a buffer zone of approximately 10,000ha. Dang *et al*. (2000) recorded 39 large mammals in the Reserve, 21 of which are listed in the Red Data Book of Vietnam (2000) and IUCN Red Listed (2006).

From 1998 until 2000 some surveys for bats and rodents were conducted in Huu Lien Nature Reserve. In 2004, in collaboration with the Institute of Ecology and Biological Resources and American Museum of Natural History a further field survey was conducted and a total of 39 species were recorded, including 22 species of bat and 17 species of rodent, and six species listed as threatened in IUCN Red List (2006) and three listed as rare in Red Data book of Vietnam (2000).

A new genus and species of murine rodent, *Tonkinomys daovantieni,* was also identified from this area (Musser *et al.* 2006). It is represented by 14 adults collected from talus habitats in the forested Tower Karst landscape of Huu Lien Nature Reserve. The new species is distinguished from all other Indomalayan murines by the combination of semispinous, dense, grayish black fur covering upperparts; a dark gray venter; gray ears, a thick, bicolored tail considerably shorter than length of head and body; and large, extremely bulbous footpads. The new species is petricolous, includes insects in its diet, and was found only in talus composed of large limestone blocks. Its distribution in the reserve is probably patchy. Whether this limestone rat is restricted to the extensive karst regions of northeastern Vietnam or also occurs in southern China and elsewhere in the northern landscapes of Indochina, and Vietnam in particular, will be known only after conducting surveys in limestone regions outside of northeastern Vietnam.

Populations of bats and rodents in this area have been seriously effected by habitat loss, guano collecting and hunting activities. Management capacity of the nature reserve and local authorities is currently weak. Therefore conservation efforts for wildlife in general, and for bats and some rodents (e.g. tree squirrels and flying squirrels) in particular, is poor. Improvement of financial support and management capacity are main measures for biodiversity conservation in the present context of Huu Lien Nature Reserve.

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PHYLOGEOGRAPHY OF RAT-LIKE HAMSTER (*TSCHERSKIA TRITON*) IN CHINA MAINLAND INFERRED FROM MITOCHONDRIAL DNA SEQUENCES: RECENT POPULATION EXPANSION

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We investigated the genetic structure of the rat-like hamster, *Tscherskia triton*, a species widely distributed in the farmland of Northeast Asia, to reveal the genetic consequences of quaternary climatic oscillations in temperate Asia. We sequenced 686 base pairs of the mitochondrial DNA D-loop region from 357 individuals collected from 32 locations in China mainland. 135 haplotypes were resolved, belonging to three lineages: Clade I , Clade II and Clade III. The low divergence of these lineages suggested a recent population history. Fu's *Fs*, Tajiam's *D* and mismatch distribution tests demonstrated that Clade II and Clade III underwent recent population expansion. The star-like pattern of the haplotypes network and nested clade analysis also indicated a population expansion history. Using the stepwise expansion model and 2% per Ma molecular clock, we estimated the expansion time of Clade II and Clade III, to be 0.3 Ma and 0.2 Ma, respectively. Our results show that the expansion time of these two Clades is consistent with two distinguishable interglacial periods on the China mainland: Dagu-Lushan interglacial (0.5 Mya-0.3 Mya) and Lushan-Dali interglacial (0.2 Mya-0.1 Mya). From there, the rat-like hamster has expanded more than one time during the quaternary.

Symposium: Reproduction, Metabolism and Pheremones

Chairs: Jiangxu Zhang, Dehua Wang and Lyn Hinds

Oral Presentations

DEVELOPMENT OF IMMUNOCONTRACEPTIVE SYSTEM FOR FERTILITY CONTROL OF BRANDT'S VOLE

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Brandt's vole (*Microtus brandti*) is a major rodent pest in the grasslands of Inner Mongolia. Population explosions of Brandt's vole have contributed to overgrazing of the native grasslands, permanent degradation of the semiarid region and widespread soil erosion. Conventional methods to control Brandt's vole, such as poison baiting or trapping, are ineffective in the long term and also cause environmental problems. It is therefore necessary to develop alternative methods for controlling the populations of Brandt's voles, and immunocontraceptive control has been proposed as a potentially effective method.

The Brandt's voles were obtained from the captive colony maintained at the Institute of Zoology. Full-length cDNA encoding Brandt's vole zona pellucida 3 (vZP3) was isolated using rapid amplification of cDNA ends-polymerase chain reaction (RACE-PCR) (Li *et al*. 2006). According to the cDNA sequence of cloned vZP3, a synthetic vZP3 peptide was conjugated to Keyhole Limpet Hemocyanin (KLH-vZP3) and used to immunize female Brandt's voles by intra-muscular injection, or primary intra-intestinal treatment followed by 3 oral boosts. The serum antibodies against vZP3 were measured by enzyme-linked immunoabsorbent assay (ELISA) and immunohistochemistry, and the fertility of the animals was analyzed 14-21days after the last boost by pairing females with males for a further 5 weeks.

A full-length cDNA encoding vZP3 contains an open reading frame of 1254 nucleotides. The deduced amino acid sequence of vZP3 contains 418 amino acid residues, and is highly homologous with hamster (82.1%), mouse (81.3%) and rat (80.6%) ZP3. The 16-amino acid peptide corresponding to amino acid residues 328-343 ($vZP3^{328-343}$) is highly species-specific and contains B and T cell epitopes associated with infertility. Voles injected intra-muscularly with $vZP3^{328-343}$-KLH peptide produced increasing levels of circulating antibodies to vZP3 after each immunization, whereas those injected with KLH exhibited only background levels of antibodies to vZP3 peptide. Immunohistochemistry revealed intense staining in ovarian zona pellucida of normal voles probed with antisera collected from $vZP3^{328-343}$-KLH-immunized voles. The fertility of the females immunized with $vZP3^{328-343}$-KLH peptide was reduced by 50% compared with controls without evidence of significant ovarian pathology. However, when the females were immunized with primary intra-intestinal injection followed by three oral boost of $vZP3^{328-343}$-KLH peptide, serum antibody against vZP3 could hardly be detected. The fertility of these animals was not affected.

The data indicates that vZP3 peptide has potential for immunocontraceptive control of Brandt's voles; however, there remain many challenges for the development of an oral vaccine.

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AN OVERVIEW OF ADVANCES IN FERTILITY CONTROL OF RODENTS BY USING THE CONTRACEPTIVE COMPOUND EP-1; A COMBINATION OF LEVONORGESTREL AND QUINESTROL

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Refer to posters by Wan *et al.*, Zhao *et al*., Zhang *et al* and Liu *et al.*

SEASONAL REGULATION OF SERUM LEPTIN LEVEL AND UCP1 CONTENT IN BROWN ADIPOSE TISSUE IN ROOT VOLES FROM THE QINGHAI-TIBETAN PLATEAU

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The survival of small mammals in winter requires adjustments in physiology, behaviour and morphology. This study was designed to examine the changes in serum leptin concentration during periods of exposure to cold and the molecular basis of thermogenesis in seasonally acclimatized root voles (*Microtus oeconomus*) from the Qinghai-Tibetan plateau.

Root voles tended to decrease body mass and body fat mass in winter and their capacity for non-shivering thermogenesis was enhanced. Cytochrome c oxidase activity and mitochondrial uncoupling protein-1 (UCP1) contents in brown adipose tissues were consistently increased in winter in the voles. Levels of circulating serum leptin declined significantly in winter and increased in summer. Correlation analysis showed that serum leptin levels were positively related with body mass and body fat mass while negatively correlated with UCP 1 brown adipose tissue contents.

Together, these data provided further evidence for our previous findings that root voles from the Qinghai-Tibetan plateau mainly depend on elevated non-shivering thermogenesis coupled with body mass reduction to enhance winter survival. Further, root voles could increase the mobilization of fat deposits in cold winter. Serum leptin was potentially involved in the regulation of body mass, composition and thermogenesis in root voles. Serum leptin might act as a starvation signal in winter and satiety signal in summer.

ROLE OF THE VOMERONASAL SYSTEM IN RECEPTION OF PREDATOR ODOURS

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The behaviour of prey may be changed radically by the presence of predators. Small mammals tend to avoid predators and chemosensory detection may be an important aspect of their avoidance strategy. In our earlier studies (Voznessenskaya et.al. 2000, 2002) we examined the influence of predator chemical cues derived from feral cat urine on the reproductive output of several rodents: rats, mice and voles. Animals responded to predator chemical cues with reduced litter size and a skewed sex ratio in favour of males. Urine from overcrowded conspecifics produced the very same effect. The reduction in litter size in rodents exposed to predator urine was attributable to suppressed progesterone levels affecting the implantation of embryos. Removal of sulfur containing compounds from the urine completely suppressed the effect.

In the current study, we compared patterns of *c-fos* activation in receptor tissue of vomeronasal organs in mice, *Mus musculus,* in response to stimulation with different predator scents (urine, faeces, saliva from cats) and urine from overcrowded conspecifics. The mouse olfactory system consists of the main olfactory and vomeronasal system. Receptor cells from the main olfactory epithelium send their projections to the main olfactory bulb. Receptor cells from vomeronasal epithelium project to the accessory olfactory bulb. The vomeronasal system is more specialized for pheromone reception though other odorants also can be detected by vomeronasal receptors. Receptor tissues of the rodent vomeronasal organ can be subdivided into two major functional zones: basal and apical. Basal zone sends projections to the caudal part of the accessory olfactory bulb. Receptors belonging to V2 family are expressed only in basal zone. We observed a consistent pattern of *c-fos* activation in the basal zone (V2) of receptor tissue. In addition, we used as stimuli single compounds isolated from predator excretions. Patterns of activation in the vomeronasal receptor tissue, main and accessory olfactory bulb, were analyzed depending on the time course of exposure (0.5-2h) and hormonal status (plasma concentrations of testosterone and corticosterone) of the signal recipient. Our findings indicate the involvement of the vomeronasal system in the reception and detection of predator scents.

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SEX PHEROMONES IN PREPUTIAL GLANDS OF MALE BRANDT'S VOLES: POSSIBLE INFORMATION FOR IDENTIFYING GENDER AND INDIVIDUALS

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The purpose of this study was to investigate putative sex pheromones and the possible coding for individual information of 32 components (corresponding to 29 GC peaks) in preputial gland secretions in Brandt's voles (*Lasiopodomys brandtii*). We analyzed and compared the chemical composition of the preputial glands of ten intact and nine castrated males with a combination of dichloromethane extraction and gas chromatography–mass spectrometry. We found that 10 components (9-decenyl acetate, n-decyl acetate, isomer of n-heptyl hexanoate, n-hexyl octanoate, Z9-dodecen-1-yl acetate and n-dodecyl acetate, n-heptyl octanoate, Z9-E12-tetradecadien-1-yl acetate peak, Z5-tetradecen-1-yl acetate and E,E-farnesyl acetate) of 32 investigated compounds were reduced by castration and thus were regarded as putative sex pheromones. E,E-farnesyl acetate (FA) was the most abundant of these components.

A behavioural assay revealed that solutions containing high concentrations of preputial gland secretions (0.56%) and FA (50 ppm) elicited female aversion, while low concentrations of preputial gland secretions (0.056%) and FA (5 ppm) were attractive to females. These results indicate that attraction of females to these secretions is concentration-dependent.

Extremely high relative standard deviation values of the GC peak areas among individual samples implied that the varying relative concentration of some preputial gland volatiles might code for individual information. The compounds reduced in response to castration might play roles in conveying sex and individual information.

PRELIMINARY OBSERVATIONS ON THE PRODUCTION POTENTIAL OF THE GREATER CANE RAT (*THRYONOMYS SWINDERIANUS T.*) IN BACKYARD MANAGEMENT SYSTEMS IN SOUTHWESTERN NIGERIA.

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This study was part of a large scale study to examine the role of greater cane rat (*Thryonomys swinderianus T*., local name 'grasscutter') production in poverty alleviation and environmental conservation programs. We evaluated the constraints and benefits associated with greater cane rat production, and also quantified annual productivity indices of greater cane rat females under smallholder production systems in Ibadan, an urban setting in Southwestern Nigeria. Information gathered would be used to develop interventions that could increase productivity in greater cane-rat farms. Increased production would have positive effects on family welfare and income as well as soil/environmental conservation through reduction in the usual bush-burning practices used in catching greater cane rats from the wild.

The study was conducted in 15 randomly selected rat farms in Ibadan, Southwestern Nigeria. It involved on-farm visits, with monitoring/recording of management practices and a questionnaire. Survey questions covered socio-economic profile, management practices, rat breeding biology and the benefits and constraints involved with greater cane rat production under a backyard system. Responses in the questionnaires were collated and analysed using SAS software.

Respondents to the survey included both public and private sector employees. Perceived benefits of greater cane rat farming included a means of increasing and diversifying income sources, extra animal protein for the family and as an avenue for meaningful engagement or hobby. Production constraints included high kid mortality (especially during the rainy season), labour requirements for forage harvesting and feeding and initial start-up capital. The source of breeding stocks are mostly friends, other greater cane rat farmers or from a greater cane rat domestication centre in a research institution.

Most rat-farms in the study were very small operations. Colony sizes ranged between 12 to 50 animals, with an average of 34.8 ± 12.7 (mean ± standard deviation). The doe to buck ratio in each rat-farm was approximately 3 to 1. The age of greater cane rat does at first litter was 10.92 ± 0.76 months. Litter sizes at birth and at weaning were 5.4 ± 1.45 and 2.68 ± 1.03 respectively. Pre-weaning mortality was approximately 42%. There was marked variation in the age at which the young were weaned, ranging between 49 and 84 days, with a mean of 56.98 ± 10.22 days. Litter intervals ranged between 196 to 238 days with a mean of 212 ± 9.3 days. Each doe produced an average of 4.64 weaners per year. Potential productivity is 8.02 weaners per doe per annum based on a gestation length of 154 days and a kindling to weaning interval of 28 days; the shortfall is due largely to the long litter interval, high pre-weaning mortality and sub-optimal management.

Based on the annual productivity index of 4.64 observed in the study, a farmer raising 4 greater cane rat does would have about 27.84 kg meat annually or 0.5kg of meat per week based on a mature slaughter weight of 2.50 kg and a dressing percentage of 60%. While this seems low, it makes a significant contribution to family protein intake especially under impoverished conditions. Options for boosting the output of greater cane rat farms through Research & Development programs and policy intervention measures are proposed and the environmental effects of such practices are discussed.

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GROWTH IN CAPTIVITY OF THE DORMOUSE TUFTED-TAILED RAT (ELIURUS MYOXINUS) AND DETERMINATION OF THE AGE CLASSES IN NATURAL HABITAT

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Eliurus myoxinus (Muridae, Nesomyinae) is one of the four species of Malagasy endemic rodents known in the national Park of Ankarafantsika, located in the northwestern part of Madagascar. Its existence in this forest has been known since 1991. This species can be found in several sites of the island, from the north to the south eastern point passing through the north-western and the south to an altitude of approximately 1250 m.

Two methods have been adopted to follow the growth and the determination of the age of onset of breeding of *Eliurus myoxinus* in natural habitat: breeding in captivity and capture-mark-recapture in its natural habitat. Each individual was marked by amputation of the phalanx fingers. The weight and the body measurements were recorded for each individual. To determine the animals' age classes in the natural habitat, the successive maximum method for captured animals based on their size to obtain a middle growth curve, and the Von Bertalanffy method of mathematical representation by using the least squares method to give a straight line, were used.

The data collected on the breeding of *Eliurus myoxinus* in captivity demonstrated that females can give birth to a litter of no more than four pups, with up to four litters per year. *Eliurus myoxinus* are continuous breeders with the potential to breed all-year round. The reproduction of *Eliurus myoxinus* is more likely to be continuous in captivity than in natural habitat; however some young individuals were nearly captured every month from the natural habitat which is evidence that breeding is occuring all year. If parturition fails then post partum mating occurs. Females are polygamous. The sex ratio of pups at birth favours females by approximately 3:1. Pups show a rapid linear growth phase from birth until one month of age. Between 1.5 and 2 months of age, the growth continued to increase but was slowed around the time of weaning which occurs by 3.5 months of age.

The successive maximum method of age determination showed that the young individuals with a body length of 90mm and a weight of 30g were between 1.5 and 2 months age. The greatest variation in the juvenile's measurements occurred at 3.5 months of age. At this time the sub-adults resemble adults but their external genitalia are not fully developed. Individuals were classified as adults if they had reached a body length of 110 mm and body weight of 40g. This occurred at more than 4.5 months of age and they were generally reproductively active. The Von Bertalanffy method indicated that all individuals become adult by 6 to 7 months of age. Males are more precocious and achieve the size and weight stages more rapidly, reaching adulthood by 5.5 months of age whereas for females this does not occur until 6-7 months. The high proportion of female pups at birth and that observed at the time of the monthly capture may be due to a survival strategy of this species that could be an adaptation to ecological conditions. The decrease in growth rate in juveniles corresponds to the period of weaning and to their adaptation to the external environment in natural conditions.

WINTER ENERGY METABOLISM AND THERMOREGULATION OF *APODEMUS AGRARIUS* FROM NORTHEAST CHINA

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Environmental conditions are very important in shaping the ecophysiological features of a species. The deviation in metabolic level and thermoregulation in one species in a given region from the general pattern seen in other mammals can reflect specific adaptation and evolution. Seasonal changes in the ecophysiological characteristics of a species are one of the important factors constraining their distribution. The striped field mouse, *Apodemus agrarius*, has an extensive distribution from north to south China. To understand its adaptive ecophysiological characteristics, we studied the energy metabolism and thermoregulation of adult *Apodemus agrarius*. In October, 2005, 8 adult striped field mouse (4 males, 4 females) were live trapped from farmland at Changtu County (124°07′E, 42°47′N), Liaoning Province. Animals were held at Shenyang Normal University in plastic cages (30×15×20cm^3) under natural photoperiod and temperature in an artificial tent outside the laboratory and were fed laboratory rat chow. The experiments were carried out from November, 2005 to January, 2006. The environmental temperature ranged from -22~6°C. The mean body mass of the mice was 22.7±1.37g (Mean±SE). Metabolic rates were measured at a temperature range from 5 to 34°C using a closed-circuit respirometer, in which temperature was controlled by water bath. Nonshivering thermogenesis (NST) was induced by subcutaneous injection of norepinephrine with a dosage based on equation: dosage (mg/kg) =3.3$M_b^{-0.458}$(g) (Merritt, 1986). The body mass and body temperature of animals were measured before and after each experiment. The energy intakes were estimated in food trials.

The thermal neutral zone (TNZ) of *Apodemus agrarius* in winter was 27 to 30°C, and mean basal metabolic rate (BMR) within the TNZ was 2.17±0.08 (mlO_2/ g·h). Mean body temperature at the temperature range of 5 to 34°C was 35.7±0.2°C. The minimum thermal conductance within the temperature range of 5 to 27°C was 0.27±0.01 (mlO_2/ g·h·°C), and when the temperature reached 34°C, thermal conductance was 0.77±0.40 (mlO_2/ g·h·°C). The maximum NST of *Apodemus agrarius* was 8.11±0.07 (mlO_2/ g·h) in winter. The energy intake, digested energy and metabolizable energy intake were 3.72±0.080 (kJ/ g·d), 3.65±0.079 (kJ/ g·d) and 3.07±0.076 (kJ/ g·d), respectively, while the digestibility and metabolizable energy efficiency was 82.4±0.004% and 80.8±0.004%, respectively.

According to the allometric equations of Hayssen and Lacy (1985) BMR=6.966$M_b^{-0.332}$, the BMR of *Apodemus agrarius* in winter is 82.3% of the predicted value. It is also lower than the BMR measured in this species in summer (128%) from Heilongjiang Province (124°51′E, 48°29′N)(Liu, et al., 2004). The minimum thermal conductance and maximum NST in our results are both higher than the summer results (0.25±0.00 mlO_2/ g·h·°C, 6.13±0.28 mlO_2/ g·h·°C), while mean body temperatures are lower than that in summer(37.5±0.2°C) (Liu, et al., 2004). The energy intake, digested energy, metabolizable energy intake, digestibility and metabolizable energy efficiency are close to other granivorous animals, such as *Meriones unguiculatus*(Li, et al., 2005).

These characteristics suggest that *Apodemus agrarius* might adopt several strategies including increased heat production (NST), energy intake, metabolizable energy efficiency and decreased energy expenditure (lower T_b and BMR) to cope with the high energy requirement under the rigorous cold ambient temperature in winter. These results also show

that the energetic, metabolic and thermoregulatory features in striped field mouse are highly modifiable and may permit their broad distribution from north to south China.

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EFFECT OF URINE ON GROWTH AND SEXUAL MATURATION IN BRANDT'S VOLES (*LASIOPODOMYS BRANDTII*)

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Most small mammals, including Brandt's vole (*Lasiopodomys brandtii*) transfer sexual signals through the urine. In this research we examined the effect of urine on the growth and onset of first oestrus in infant voles, comparing the effects of the urine of oestrous and rutting voles with anoestrous and non-rutting voles.

We found that the urine of non-rutting and anoestrous Brandt's voles had no effect on the growth rate of infant voles or their time to sexual maturity. The urine of oestrous female Brandt's voles increased the growth rate of infant voles and decreased the time to sexual maturity. Infant voles may reach their first oestrus 15-20 days earlier than normal. Also, the weight of infants exposed to the urine of oestrous females was 2-5g higher than those not exposed. The urine of rutting males can also increase the growth rate of female infant voles with sexual maturation 10-15 days earlier than average and bodyweight 2-6g higher than those not exposed. Exposure to the urine of rutting male voles retarded the growth of male infant voles and delayed sexual maturity by 20-27days. The bodyweight of male infant voles was 4-8g lower than male infants not treated with the urine.

The chemical composition of the urine of Brandt's was analyzed by gas chromatography. We found that the urine of rutting male voles has six peak values that are different to that of non-rutting males. The urine of oestrous females also differed from that of anoestrous females in five peak values. These results suggest that the observed differences in effect on the growth and sexual maturation of infant voles depends on the sex and reproductive condition of the animal from whence the urine was obtained and may be due to differences in the chemical composition of the urine.

TRIAMICILONE, A PUTATIVE OESTRUS-SPECIFIC CHEMICAL SIGNAL IN FEMALE RAT (*RATTUS NORVEGICUS*)

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Rodents depend on chemical signals for communication because of their secretive mode of life. Communicating the time of ovulation and co-ordination of sexual behaviour is important to ensure successful fertilization in rats. Female rats indicate the time of ovulation via urinary chemo-signals. This study was designed to identify the volatiles in the urine of female rats during various reproductive stages in order to detect oestrus-specific chemical signals.

Urine was collected from fifteen adult female rats (*Rattus norvegicus*) at various stages in the oestrous cycle (determined by vaginal smear). Urine was extracted with dichloromethane (1:1 ratio v/v) and analyzed by Gas Chromatography linked Mass-Spectrometry (GC-MS). Numerous compounds were identified in the urine. Visual examination of all the chromatograms showed that there was a consistent qualitative and quantitative difference between the profiles for the different stages of the oestrous cycle. Most of the identified compounds were found to be alkanes. Two compounds namely pentacosane and triamicilone, were specific to the period of oestrus. However, the compound pentacosane has also been identified in the urine of males. We suggest that the compound, triamicilone, may be a possible biomarker for the detection of oestrus.

This study provides some evidence that female rats signal their reproductive status by excreting specific urinary chemical compounds during the oestrous cycle, which may help other rats to identify their reproductive status. The use of this information will aid us in developing pheromonal traps for rodent pest management (RPM).

ENERGY METABOLISM, THERMOGENESIS AND BODY MASS REGULATION IN BRANDT'S VOLES (*LASIOPODOMYS BRANDTII*) DURING COLD ACCLIMATION AND REWARMING

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Environmental cues play an important role in the regulation of an animal's physiology and behaviour. The purpose of this study was to test the hypothesis that ambient temperature is a cue to induce adjustments in body mass, energy intake and thermogenic capacity in Brandt's voles (*Lasiopodomys brandtii*). We hypothesise that these adjustments are associated with changes in serum leptin levels.

We found that Brandt's voles increased their energy intake and resting metabolic rate (RMR) while their body mass remained stable when exposed to the cold and showed a significant increase in body mass after they were returned to normal temperatures. The increase in body mass when returned to normal temperature conditions was associated with a higher energy intake compared with control animals. Uncoupling protein 1 (UCP1) content in brown adipose tissue increased while the voles were held in cold temperatures and decreased after rewarming. Serum leptin levels decreased in the cold and increased after rewarming, which is consistent with the changes in energy intake. Further, serum leptin levels were positively correlated with body mass and body fat mass. Together, these data supported our hypothesis that ambient temperature was a cue to induce changes in body mass and metabolism.

We conclude that a decrease in serum leptin levels is a signal to the body to increase energy intake, preventing starvation. As serum leptin increases on the return to warmer conditions, it is a signal to the body of satiety. Thus serum leptin is important in the processes of thermogenesis and body mass regulation in Brandt's voles.

Poster Presentations

STUDY ON THE SOCIAL BEHAVIOUR OF BRANDT'S VOLES (*LASIOPODOMYS BRANDTII*)

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In this study we observed the mating behaviours of Brandt's vole (*Lasiopodomys brandtii*) in relation to their positions in the social hierarchy. The study was conducted on a one hectare site of Wulagai grassland in Inner Mongolia from April to October 2003. An experimental population was established containing 5 social groups of voles, each with one male and a number of females (97 females in total).

There were marked differences between higher and lower-ranking voles in their access to food, nest-building , body-language such as lying down, fighting, territorial displays, courtship behaviours and breeding success. The social order of animals within the group is relatively stable, but changes to the hierarchy can occur through fighting. Both males and females can be towards the top of the hierarchy during non-breeding periods, but in general, the young and the females in the group are dominated by a male during the breeding season.

When a strange vole enters a group, the highest-ranking members of the group may attack it immediately. If the stranger is a male, the attacker will also be male, while an unfamiliar female may be attacked by the highest-ranking female of the group. Female voles are more likely to tolerate the entry of an unfamiliar animal to the group than are males. On encountering an unfamiliar group, 70 percent of males which are high-ranking in their own social group will attack the resident high-ranking male. If the intruder wins the contest they will have access to all the female voles in the group.

The courtship behaviour of male voles differs depending on whether they are approaching a female from their own social group or one from another social group. The male will approach a familiar female, will smell it and mating may occur. When the female is from a different social group, there is little courtship behaviour which may be due to the defensive actions of other male voles. We observed mate-choice by females based on the position of a potential mate in the hierarchy. Female voles are more likely to accept the courtship behaviours of high-ranking males than of middle or lower-ranking males. These low-ranking male voles will rarely have the chance to mate because dominant males will drive them out or even bite them to death if courtship behaviours are displayed towards females. A female vole in oestrus will generally accept the courtship behaviours of the male vole from their own social group and may even try to prevent other females from having access to the male.

The bodyweight of female voles may influence their breeding success. During the course of the experiment, 42% of female voles weighing in excess of 42g produced a litter. This proportion was lower in females weighing 36g to 41g. Of individuals weighing between 26g and 35g, only 19% produced a litter and many low-ranking females refused to mate with males. The breeding success of a female may then influence their social position, with non-breeding females being lower in the hierarchy.

SOCIAL ORGANIZATION AND HOME RANGE BEHAVIOUR IN TWO SYMPATRIC CLOSELY RELATED SPECIES: HOUSE MOUSE (*MUS MUSCULUS*) AND MOUND-BUILDING MOUSE (*MUS SPICILEGUS*).

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Mus musculus and *M. spicilegus* are sympatric closely related species and do not hybridize in nature. *M. musculus* is east-European and Asian commensal species, *M. spicilegus* occurs in some countries of east Europe. Mound-building mice inhabit a variety of agro-ecosystems and, as a rule, are abundant throughout their range. A distinctive characteristic of *M. spicilegus* is grain-hoarding activity. In autumn, groups of 4-14 mice construct special mounds (kurgans) in which to store food and spend the winter. Seeds of 84 species of plants belonging to 29 families have been found within these mounds; 28 of these are major forage plants (Muntyanu, 1990; Sokolov *et al*. 1998). The aims of this work consist of investigation of: 1) social organization of *M.musculus* and *M. spicilegus* in semi-natural conditions; 2) home range size and mobility of *M.spicilegus* in autumn; 3) role of aggressive and amicable interactions in segregation and integration of *M. musculus* and *M. spicilegus*; 4) seasonal differences in aggressive behaviour in *M. spicilegus* and its interrelation with annual life cycle.

In laboratory studies 14 groups each comprising 2 males and 2 females were observed in enclosures (100 x 100 x 30 cm) and 6 groups of different sexual composition (in whole 27 mice) were observed in large enclosures (20 m^2). In large enclosures, 4 groups included unfamiliar individuals and 2 groups consisted of familiar individuals of *M. spicilegus* collected in the same mound. Each group was under study from 18 to 38 days. The duration of behavioural observations was 430 hours. During maximal activity of mice, all mouse interactions were recorded. Seasonal differences in aggressive behaviour of *M. spicilegus* were investigated in pair encounters on neutral territory (85 encounters, 27 males and 33 females). In *M. spicilegus* collected in the same mound (n=6, 53 males, 91 females) the type of nervous system (“strong”, “middle” or “ weak”) was detected by electro-defensive technique described by Kamenov (1973). In the field in autumn the home range of groups of *M. spicilegus* from the same mound was investigated by capture-mark-recapture method.

The social structure of *M. musculus* and *M. spicilegus* was similar in groups consisting of unfamiliar individuals. In these groups, males established an hierarchical order. Females of *M.spicilegus* were more aggressive compared to females of *M. musculus* and they formed an hierarchical order. In groups consisting of unfamiliar individuals, subordinate males and subordinate females were lost between 3-20 days of group formation. *M. spicilegus* did not demonstrate aggressive behavior in groups consisting of familiar individuals captured in the same mound, but all members of the group were aggressive to intruders (males and females). In these groups all individuals exhibited similar behavioural stereotypes. Relationships of *M. spicilegus* in family groups were amicable. In autumn, unfamiliar *M.spicilegus* demonstrated high levels of aggressive behaviour in pair encounters. In summer and spring the level of aggression declined. We propose that the high level of aggressive behaviour of *M. spicilegus* in autumn is related to the defence of stored forage. “Strong”, “middle” and “weak” types of males and females were found in *M. spicilegus*. In the same mound, generally, only one “strong” male and 2-4 “middle”/“weak” males coexisted.

In autumn in the field, food resources (corn, sun flower and sorgo) were abundant. The home range of group of *M. spicilegus* was approximately 45-50 m^2. In virgin land with restricted food resources, mound-building mice collected seeds from as far as 120-140 m^2.

The role of aggressive and amicable interactions in segregation and integration of individuals in *M.musculus* and *M. spicilegus* has been demonstrated. Our data supports earlier literature in terms of the level of aggression in different populations of *M. musculus,* and the high seasonal variability of level of aggression in *M. spicilegus*. We conclude that aggression is not a species-specific trait. Social organization and the level of aggression in commensal species is related to the living conditions of the populations and geographical variation is common.

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EFFECT OF COLD STRESS ON IMMUNE RESPONSE IN THE GREY-SIDED VOLES, *CLETHRIONOMYS RUFOCANUS*

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We investigated the effects of cold stress on energy demand and immune response in the grey-sided vole, *Clethrionomys rufocanus*. We divided the laboratory-born voles and the field-caught voles into two groups maintained at 5°C (low temperature group) and at 23°C (room temperature) respectively, with 12L: 12D cycle (lights on at 0700) for 16 days. All voles were allowed free access to food (ZC-2 pellets) and water throughout the experiment. On the 10th day of the experiment, all voles were injected with a standard dose of a non-pathogenic antigen (sterile SRBC) into the peritoneal cavity. On the 6th day after immunization, blood was collected from the heart and then the plasma was extracted. Antibody (IgM) titres against SRBC were assessed by haemagglutination.

Grey-sided voles exposed to cold stress showed a weaker immune response to the challenge antigen (mean IgM titre ± SE; 1.6 ± 0.37 for wild; 1.1 ± 0.50 for lab) than control voles (mean IgM titre ± SE; 3.5 ± 0.58 for wild; 3.1 ± 0.47 for lab). Food intake of the voles under cold stress increased in comparison with control groups under room temperature, and there was a reduction of fat reserves in the cold-stressed voles during the experimental period (16 days). Furthermore, the heart and small intestine of cold-stressed voles were hypertrophied by approximately 20% compared with the controls.

Voles exposed to cold stress will need to increase food intake with the hypertrophy of metabolic organs for thermoregulation. Exhaustion of fat reserves and unutilized digestive capacity of the gut (i.e. digestive safety margin) triggers hypertrophy of the gut, in anticipation of prolonged energy stress (Cichoń et al. 2002). Thus, our results verify that a trade-off exists between thermoregulation and immunity in the grey-sided voles, as it has been observed among other physiological functions. These physiological reactions caused by cold stress may cause higher mortality of the grey-sided voles during winter in the field.

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ANTIFERTILITY ACTIVITY OF BEIAO ANTI-PROCREATE FOR THE CLAWED GERBIL (*MERIONES UNGUICULATUS*)

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In this study we tested the activity time and efficacy of Beiao, a novel male anti-fertility agent of plant origin (*Tripterygium wilfordii*) for the clawed gerbil (*Meriones unguiculatus*). We compared the effects of dose and frequency of administration on several indicators of male fertility and on their ability to reproduce.

Four groups of animals were established; two groups were given Beiao at an oral dose of 40mg/kg daily for four weeks, one group was administered a single dose of 100 mg/kg and the fourth group was a control. The testis and epididymis organ coefficients (organ weight/bodyweight × 100%), the density and activity of sperm and the outcome of test matings with females were used to assess fertility.

The organ coefficients of the testis and epididymis of animals in the 40mg/kg daily group were significantly smaller than the control group. Marked decreases were observed in the density and activity of sperm, the percentage of live sperm and the actual fertility rate (assessed via test mating) in comparison with the control group. There was a greater proportion of misshapen sperm among males in this group compared with the control group. Where a single dose of 100 mg/kg was administered, the epididymis organ coefficients were significantly decreased and the misshapen sperm rate was markedly increased compared with the control. However there were no observed differences in sperm motility, percent live sperm and sperm density.

A lower dose (40 mg/kg) of Beiao administered daily was more effective in reducing male fertility in clawed gerbils than the administration of a single high dose (100mg/kg). Indicators of fertility and actual fertility (based on test mating with females) declined markedly in treated animals after four weeks of daily treatment.

EFFECT OF THE CONTRACEPTIVE COMPOUND (EP-1) ON REPRODUCTION OF THE STRIPED HAIRY-FOOTED HAMSTER IN THE TYPICAL STEPPE

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In this study we have assessed the effect of the EP-1 contraceptive compound (quinestrol, 33.3% and levonorgestrel 66.7%) on recruitment in a field population of the striped hairy-footed hamster. We applied the EP-1 compound in a wheat bait at a ratio of 1:10000, in a 800ha pasture in Abagaqi for the month of May 2004. An adjacent pasture (1100ha) was used as the control site. Wheat bait was delivered by 1.25kg per hectare. A trapping census (250 traps per site) was conducted over 72 hours each month from before baiting commenced in May through to September, to assess the reproductive status of the population of striped hairy-footed hamsters.

In May, the density of hamsters was similar in both the baited and control areas. From May to August, 237 and 145 adults hamster were captured from the baited and the control sites respectively. Over this period 122 and 98 juveniles hamster were captured from the baited and the control sites respectively. The proportion of adults to juveniles was higher in the control sites. There was also some evidence of movement of animals from the control site to the treated site.

Our analyses show that EP-1 affects the reproductive success of the female hamsters. In the baited area, the EP-1 affected the uterus of 80% of mature females. The uterus was enlarged and remained oedematous for more than 3 months. Compared to the control area, in the baited area, the pregnancy rate and the litter size of females was reduced to 20% and 66% respectively. EP-1 had no effect on the proportion of males in the population with scrotal testes.

Our study has shown that EP-1 affects the fertility of female hamsters for more than 4 months following a single application of the compound in the field in spring. This prolonged effect may be related to the food-caching behaviour of the striped hairy-footed hamster. We conclude that EP-1 has the potential to control recruitment for the duration of the breeding season of the hamster.

BASAL METABOLIC RATE AND ORGAN SIZE IN BRANDT'S VOLES *(LASIOPODOMYS BRANDTII)*: EFFECTS OF PHOTOPERIOD, TEMPERATURE AND DIET QUALITY

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This study examined the effects of photoperiod (long day, 16 light:8 dark and short day, 8 light:16 dark), temperature (cold 5^{o}C and warm 23^{o}C), and diet quality (high-fibre diet containing 36 % neutral-detergent fibre, or low-fibre diet containing 23 % neutral-detergent fibre) on basal metabolic rate (BMR), digestible energy intake, and organ size in the Brandt's vole (*Lasiopodomys brandtii*).

Voles housed at the colder temperatures showed significantly increased BMR and a significant interaction between temperature and diet quality was observed. Voles subject to a short photoperiod and colder temperatures increased their intake of food and thus digestible energy. Voles on a high-fibre diet increased their food intake but the digestible energy intake was stable. Voles housed in the cold had heavier liver, kidneys and gastrointestinal segments but a lighter carcass overall. Segments of the gastrointestinal tract tended to be heavier when voles were fed the high-fibre diet. Voles subject to shorter photoperiod (with increased food intake) tended to have a lighter heart and kidneys but heavier gut segments. After removing the effect of body mass, BMR was significantly related to the dry mass of heart, liver, kidneys and caecum. Digestible energy intake was significantly related to the dry mass of kidneys and stomach. These significant relationships between BMR and organ dry weights remained after accounting for the effects of body mass, temperature, photoperiod and diet quality. There was also a significant correlation between BMR and digestible energy intake.

Our results suggest that variations in BMR reflect the evolution of metabolic machinery that induces higher energy intakes. The data also support the assimilation capacity model of endothermy.

EFFECTS OF PHOTOPERIOD HISTORY ON ENERGY METABOLISM AND BODY MASS REGULATION IN BRANDT'S VOLES (*LASIOPODOMYS BRANDTII*)

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Many small mammals respond to seasonal changes in photoperiod via alterations in morphology, physiology and behaviour. In this study, we tested the hypothesis that pre-weaning photoperiod experience can affect the subsequent development in thermogenesis and body mass. Brandt's voles (*Lasiopodomys brandtii*) were gestated and reared to weaning under either a short photoperiod (8 hours light, 16 hours dark) or a long photoperiod (16hours light, 8 hours dark). At weaning, male juveniles were either maintained in their primary photoperiod or transferred to the alternative photoperiod.

Eight weeks after photoperiod transfer, voles housed under a short photoperiod post-weaning had lower body mass, lower body fat mass and lower serum leptin concentrations than voles housed under a long photoperiod. These variables are associated with higher thermogenic capacity. In addition, voles exposed to short photoperiod during pre-weaning followed by a long photoperiod post-weaning showed a higher body mass, energy intake, cytochrome c oxidase activity, and uncoupling protein 1 (UCP1) concentration than voles exposed to a long photoperiod both pre- and post-weaning. Serum leptin concentrations were positively correlated with body and body fat mass, but negatively correlated with gross energy intake and UCP1 content of brown adipose cells.

Our results suggest that post-weaning development was predominantly influenced by post-weaning photoperiod, while pre-weaning photoperiod experience may modify the development of thermogenesis and body mass. Further, serum leptin acted as an adipostatic signal and may be involved in the regulation of both energy intake and energy expenditure. However, serum leptin levels were unlikely to serve as the driving force in photoperiod-induced body mass dynamics in Brandt's voles.

REGULATION OF THERMOGENESIS, FOOD INTAKE AND SERUM LEPTIN IN COLD EXPOSED LACTATING BRANDT'S VOLES (*LASIOPODOMYS BRANDTII*)

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Lactation is the most energetically expensive period for mammals and is associated with increased metabolism and energy intake and decreased thermogenic capacity. Small mammals increase food intake and thermogenesis in the cold. The purpose of this study was to explore the combined effects of lactation and cold on thermogenesis, body mass, energy intake and serum leptin concentrations in Brandt's vole (*Lasiopodomys brandtii*). Changes in serum leptin concentrations as energy intake and thermogenesis increases or decreases are also explored.

The voles were placed into one of two temperature treatments, either warm (23±1°C) or cold (5±1°C). Each temperature treatment was further divided into two groups by the reproductive status of the animals (either virgin females or lactating females at the peak of their first lactation with natural litters of 6 pups).

In animals housed under cold conditions, increased uncoupling protein 1 (UCP1) levels were observed in lactating females compared with non-reproductive females. Gross energy intake in the cold-exposed lactating females at peak lactation was increased, however the digestibility of the food was decreased when it was cold suggesting that the sustained energy intake may be limited. Serum leptin levels (which were positively correlated with body mass and body fat mass and negatively correlated with gross energy intake) decreased significantly during lactation. In addition, serum leptin levels were positively correlated with UCP1 levels, but only when the animals were housed under warm conditions.

These findings indicate that lactating voles can increase their thermogenic capacity and energy intake to enable them to meet the extraordinary energetic costs of simultaneous lactation and cold exposure. Further, serum leptin levels were associated with the energy intake regulation, but may be not directly involved in thermogenesis during cold exposure.

METABOLISM AND THERMOREGULATION IN THE WILD HOUSE MOUSE (*MUS MUSCULUS*) FROM NORTHEAST CHINA

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Thermogenic and thermoregulatory abilities are critical to the survival and distribution of mammals (Karosov, 1986). House mice (*Mus musculus*) are a widespread species which can be easily found from the warm south to the cold northeast of China. In order to understand the characteristics of their metabolism and thermoregulation, we measured resting metabolic rates (RMR), body temperatures and thermal conductance across a temperature range of 5-34^{o}C.

Ten house mice (5 males and 5 females), freshly captured from farmland near a rural village in Changtu (124°13'E, 42°8'N), Liaoning province China, November 2005, were used. The body weight was 13.9 ± 1.7g (mean ± SD). Before each RMR testing, animals were fasted 4 hours and the recordings were made after an adaptation period of 30 minutes. RMR were measured by using a closed circuit respirometer with circulating water bath to maintain constant temperature in the chamber (size 3.6L). Nonshivering thermogenesis (NST) was also determined at 29^{o}C. This was induced by scapular subcutaneous injection of norepinephrine with a dosage based on the equation: dosage (mg/kg)=6.6$M_b^{-0.458}$(g) (Heldmaier, 1971). A digital thermometer was used to measure their body temperatures by inserting the sensor into the rectum.

Our study indicates that the mice had either no distinct thermal neutral zone (TNZ) or only a narrow TNZ range of less than 2.5^{o}C. At an ambient temperature of 30^{o}C, animals showed minimal mean RMR of 2.13 ± 0.55mlO_2/g.h (Standard Temperature and Pressure condition). This can be considered their basal metabolic rate (BMR), which is 120% and 102% of predicted values based on body mass by Kleiber (1961) (for Mammalia: BMR(mlO_2/g.h) = 3.42$W^{-0.25}$(g)) and Hayssens and Lacy (1985) (for Rodentia, BMR(mlO_2/g.h)=4.98$W^{-0.33}$(g)), respectively. Within the temperature range of 5-27.5^{o}C, mice could maintain a fairly constant body temperature at an average of 34.9±0.7^{o}C. Thermal conductance within the temperature range of 5-15^{o}C remained at the lowest level of 0.30±0.03 mlO_2/g.h.^{o}C, which was 123% predicted value by Bradley and Deavers (1980) (C(mlO_2/g.h.^{o}C)=0.76$M_b^{-0.426}$ (g)). NST was 7.40±1.05 mlO_2/g.h in house mice and the ratio of NST/BMR is about 3.5. Small body size may be responsible for some of their thermal biological characters such as no distinct TNZ, high NST/BMR ratio and NST level. Furthermore, high NST level and lower body temperatures are adaptive properties to cold climate of Northeast China.

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PREPUTIAL GLANDS OF BRANDT'S VOLES (*LASIOPODOMYS BRANDTII*) CONTAIN MANY COMPOUNDS ANALOGOUS TO INSECT PHEROMONES

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With a combination of dichloromethane extraction and gas chromatography–mass spectrometry, we found 34 compounds in preputial glands of male Brandt's voles (*Lasiopodonmys* (*Microtus*) *brandtii*). Thirty three components were esters. E-β-Farnesene and n-Tetradecyl acetate were confirmed by a parallel analysis of preputial glands of house mice (*Mus domesticus*). Farnesyl acetate was confirmed by matching with an authentic analog. Of all the components, 27 have been previously described in the pheromone blends of insect species. Some major components such as Z9-E12-Tetradecadien-1-yl acetate, Z5-Tetradecen-1-yl acetate, Z9–Tetradecen-1-yl acetate and n-Tetradecyl acetate have been described as part of the pheromone blend in many moth species, and others such as farnesyl acetate, farnesyl butyrate and farnesyl hexanoate in many bee species. In addition, n-Hexadecyl acetate, a pheromone in 59 moth species, was found to be a major constituent of the preputial gland secretions of house mice. We did not find any relationship between the chemical composition of preputial gland secretions and the phylogenetic relationship among the rodents. This is the first time so many compounds analogous to insect pheromones have been found in the scent glands of one species of mammal.

DIFFERENT RESPONSES OF MICE TO URINE ODOUR OF FEMALE AND MALE FERRETS AND ITS MAJOR VOLATILE CONSTITUTES

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In a previous investigation we showed that the concentration of urinary volatiles in male ferrets (*Mustela furo*) was much higher than that in the urine of females. In this study, we aimed to clarify how ferret (predator) urine and its major components influence behavioural responses of a prey species, the house mouse (*Mus musculus*).

Male mice displayed no differences between their behavioural responses to raw male and female ferret urine odour. Male mice responded less to female mouse urine that had been mixed with ferret urine than to pure female mouse urine. Male mice responded least to female mouse urine that had been mixed with male ferret urine (rather than with female ferret urine). Our results suggest that male mice might be more likely to continue their normal mate choice behaviours in the presence of female predators than in the presence of male predators.

In an additional experiment, we added one or all of the three major sexual volatiles (quinoline, 2,5-dimethylpyrazine and 4-hepatanone) found in male ferret urine to female mouse urine or female ferret urine to mimic male ferret urine. Either quinoline alone or all three volatiles together were almost as effective as raw male ferret urine in changing the behavioural responses of male mice. These results indicate that the three major constitutes in ferret urine may attenuate the responses of male mice. In house mice, 2,5-dimethylpyrazine is specific to female urine and 4-heptanone is positively correlated with lactation in female mouse urine. Although these two chemical are in both female mouse urine and in ferret urine, the avoidance response of male mice to ferret urine is not lessened.

SEASONAL CHANGES IN CHRONIC SOCIAL INTERACTIONS AND PHYSIOLOGICAL STATES IN FEMALE RAT-LIKE HAMSTERS (*TSCHESKIA TRITON*)

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We examined the behavioural characteristics and physiological states related to solitary lifestyle and dominant-subordinate relationships in female rat-like hamsters, *Tscheskia triton*. Wild adult hamsters were captured and caged singly in the laboratory during the non-breeding and breeding seasons. The experimental hamsters, two unfamiliar and weight-matched females, were subjected to 5 minute staged encounters every day for 28 consecutive days, in a neutral arena. Aggressive behaviour, defence and flank marking were quantified everyday within the first week and once each week during the last three weeks. Animals were then autopsied and their physiological and reproductive state assessed.

Our results suggested that dominant-subordinate relationships could be established especially in non-breeding conditions, where the dominant displayed more aggression and flank marking, and less defence than its opponent. Breeding females followed this pattern except there was no difference in aggressive behaviour between the two animals. Repeated encounters did not appear to reduce aggression or lead to bonding. At the end of the experiment, breeding females had higher levels of serum oestradiol, progesterone and corticosterone than non-breeding females. Both dominant and subordinate females in non-breeding condition had atrophied ovaries and uteri, whereas both dominant and subordinate females in breeding condition had hypertrophied ovaries and uteri. Non-breeding females had heavier and thicker flank glands than breeding females. Dominant females displayed longer or thicker flank glands than subordinates.

The behavioural traits observed in our experiment support the idea that the lifestyle of adult female rat-like hamsters is solitary and that physiological states show some differences between social ranks and seasons.

EFFECTS OF A CONTRACEPTIVE COMPOUND (EP-1) ON REPRODUCTIVE ORGANS OF MALE GREATER LONG-TAILED HAMSTERS.

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In previous studies, the compound levonorgestrel and quinestrol has been shown to be effective in reducing the fertility of some female wild rodents. If the compound is used in the field, males will also be affected. However, the effect of the compound on males is largely unknown. This study determined the effect of the compound EP-1 (a mixture of levonorgestrel and quinestrol at a ratio of 6:3) on male greater long-tailed hamsters (*Tscherskia triton*).

Hamsters in the treatment group (n = 10) were provided with wheat baits with 0.001% EP-1 for six consecutive days, while hamsters in the control group (n = 7) were provided with plain wheat. One week and three weeks later, reproductive organs of hamsters of both groups were measured, respectively.

We found the size and weight of testes, seminal vesicles and epididymes of the treatment group were significantly reduced compared to the control group, and this reduction was further accelerated by the third week.

The results indicate that EP-1 has the potential to reduce the fertility of both male and female hamsters.

EFFECT OF A CONTRACEPTIVE COMPOUND (EP-1) ON FERTILITY OF MALE AND FEMALE BRANDT'S VOLES

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This study reports the effects of the compound EP-1 (a mixture of levonorgestrel and quinestrol at a ratio of 6:3), levonorgestrel (P) and quinestrol (E) on the fertility of male and female Brandt's voles.

Male Brandt's voles (n=4-6, per group) were treated with either EP-1 (1mg/kg body weight), P (0.66mg/kg body weight), or E (0.34mg/kg body weight) for 5 and 14 days. Autopsies of males were conducted at 30, 60 and 90 days after the end of treatment; weight of testis and epididymis was recorded, and histology was done at 60 days; matings were conducted at 90 days after the end of treatment.

Female Brandt's voles (n=3-4 per group) were treated with either EP-1 (1mg/kg body weight), P (0.66mg/kg body weight), or E (0.34mg/kg body weight) for 3 days and another 3 days following a 7 days interval. Females were autopsied at 15, 30 and 75 days after the end of treatment (weight of uterus, ovary were recorded, and histology undertaken at 75 days). The fertility of females was assessed by mating at 30 and 75 days after the end of treatment.

We found quinestrol alone affected male fertility, testis and epididymis structure. Females mated with quinestrol-treated males had reduced litter sizes and pup weights. Treatment with levonorgestrel alone or with the combination of levonorgestrel and quinestrol did not induce similar effects. For females, there was no change in uterine or ovarian weight in response to treatment, and neither levonorgestrel nor quinestrol alone or in combination affected the fertility of female voles. The results indicate that quinestrol may have more potential to affect and reduce fertility of male than female Brandt's voles.

EFFECT OF THE CONTRACEPTIVE COMPOUND EP-1 ON THE FERTILITY OF THE MALE ALBINO RAT

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Although the effects of EP-1 (a compound composed of levonorgestrel and quinestrol) on reproduction in some female rodents has been demonstrated, its effect and mechanism of action on male rodents is largely unknown. Understanding this process will help evaluate the significance of EP-1 in fertility control of both sexes.

In this study, we examined the effect of EP-1 on the fertility of the male albino rat. Rats (n = 10 per group) were fed with wheat bait containing either 0.005% of levonorgestrel (P) only , 0.005% of quinestrol (E) only, 0.005% of a mixture compound of E and P (EP), or plain wheat (Control) for 7 consecutive days. After end of the treatment, all animals were raised normally for another week. After this, 5 rats in each group were autopsied at day 14. A week later (at day 21), the remaining animals were paired with female rats for one week, and all were autopsied at day 28. The serum hormone levels and the reproductive organs were measured at autopsy.

The results indicate that in male rats treated with E only, the weight of the testis, epididymis and seminal vesicle were significantly reduced; seminiferous tubules and sperm morphology were also obviously affected. The concentrations of oestradiol, progesterone and follicle-stimulating hormone in serum increased significantly. However, treatment with the compound had no effect on the fertility of the males: there was no effect on litter size and pregnancy rate of female rats mated with treated males at 3 weeks after the end of treatment. The results indicate that a longer interval between treatment and mating may be required to demonstrate the effects on the fertility of the males. At 3 weeks post treatment it is likely that there were still sperm in the epididymis which were present before the treatment started (the spermatogenic cycle in rats is about 6 weeks).

Symposium: Rodents as indicators of habitat integrity

Chairs: Nico Avenant and Simon Mbugua

Oral Presentations

CORRELATING RODENT COMMUNITY STRUCTURE WITH ECOLOGICAL INTEGRITY IN TUSSEN-DIE-RIVIERE NATURE RESERVE, FREE STATE PROVINCE, SOUTH AFRICA

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Rodents form a vital component of Free State ecosystems. They are not only important in nutrient cycling, habitat modification, as consumers of plants, dispersers of seed, and predators of invertebrates, but also constitute the primary link between primary producers and secondary consumers. However, the mechanisms of these relationships are extremely complex (see Avenant 2000a). In general, changes in rodent habitats are associated with changes in rodent diversity and community structure. Accordingly, Avenant (2000a,b, 2005) reasoned that the monitoring of rodents may be a relatively quick and inexpensive method of indicating healthy or unhealthy ecosystem functioning, and should, therefore, be included in assessments (e.g. as part of Environmental Impact Assessments).

Our present study program aims to quantify rodent community structure in Free State grassveld habitats, reports on the seasonal abundance, species richness, Shannon diversity, and evenness of rodents present in these habitats, and inspects the most successful sampling method for these habitats. In this contribution we report on results found in the Tussen-die-Riviere Nature Reserve, where small mammal community variables were correlated with an Ecological Index (≈ EI value of veld), the leading method used to interpret habitat integrity in Free State nature reserves, and a useful tool driving management decisions.

Rodents were surveyed over four successive seasons using snap traps. Four homogenous (see Avenant 2000b) grassland sites (≈ habitats) were used in total. The substrate (loamy, well drained soil) and other geographical features of three of these sites (Sites 2, 3 & 4) were considered to be identical, and the sites were, therefore, assumed to be "similar", but in different stages of succession. Site 1 (clay/loamy soil, with a higher water-holding capacity) was considered to be the possible "outlier". Two hundred traps, spaced 5 m, were set on four trap-lines (spaced 10 m apart) in each site. Trap-lines were moved every season in such a way that they were never closer than 150 m to any previous lines in the same habitat. Traps were left open for *c.* 240 hours (10 days), and checked and rebaited at sunrise and just before sunset. In autumn the contribution of individual plant species were recorded within a 2.5 m radius around each of the 200 small mammal traps in each of the four habitats. These species were divided into ecological groups according to their ecological or grazing value. The EI value of each site was determined using the sum of these values, divided by two (in order to yield a maximum EI value of 1000 for the specific site).

EI values increased from Site 1 (EI = 277) to Site 4 (EI = 593) ($F_{3, 796} = 156.72$, $p<0.001$), with significant differences observed between all sites (Tukey HSD test). Percentage crown cover followed the opposite pattern, ranging from a low 66% (Sites 1 and 2) to 74% (Site 4). The relatively low percentage of Increaser I grass species further confirmed our notion that the vegetation at all four sites was in a pre-climax state. Our hypothesis was, therefore, that rodent numbers (i.e. trap success), species richness and diversity at the three "similar" sites would increase with EI value, following Tilman's hump-shaped curve model (see Avenant 2005). These were compared with the rodent community variables at the fourth, "outlier", grassland site (Site 1).

During all seasons the total number of rodent species (mean = 7 ± 0.8) were reached between 48 and 96 hours (mean = 3 ± 0.8 days), while immigration started to have a significant effect from the sixth day of trapping (as deduced from trapping pattern over the ten day period). It was, therefore, decided to only use data accrued during the first four days and nights. Both species richness and Shannon diversity increased significantly from Site 2 to Site 4, following EI value. At Site 1 these variables were intermediary, statistically similar to that of Site 3 (Kruskal-Wallis, $p<0.05$). No difference in trap success could, however, be found between sites ($p>0.1$). The indicator species *Mastomys coucha* occurred at all sites. It contributed the largest proportion of the total captures (*c.* 80%) at the site with lowest EI value (Site 1). This result, therefore, agrees with Avenant (2000a,b, 2005) who stated that *M. coucha* numbers dominate the small mammal component in more disturbed grassland areas. Other results important for small mammal monitoring and collecting are that trap success and species richness was highest in autumn, the preferred period for small mammal sampling in Free State grasslands (also Avenant 2000a,b). As was found at Korannaberg (Avenant 2000b), this study also showed that four days and nights' continuous trapping is essential for the effective studying of rodent communities. In conclusion, therefore, our results partially support expectations that the number of specialist species increases with succession, *M. coucha* dominance acts as an indicator of habitat disturbance, rodents conform to Tilman's hump-shaped curve model, and adds to a baseline of diversity indices in a variety of grassland habitats (see Avenant 2000a, 2005).

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TOWARDS A PROCESS OF DEFINING NEW PROTECTED AREAS USING RODENTS

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Madagascar, an island continent of megadiversity with a high level of endemism, is incomparable to any other tropical country in the world. It has been identified as one of the world's 34 "biodiversity hotspots". It has six endemic families of vascular plants, five endemic families of birds and five endemic families of primates. At least 24 species of rodents are endemic to Madagascar, grouped in one family and nine genera. Speciation is very well represented on Madagascar; the genus *Eliurus* consists of ten species, while *Macrotarsomys* and *Nesomys* each consists of three species. New species are still being described.

In order to ensure the protection of Malagasy biodiversity, Key Biodiversity Areas (KBA) are being identified as a tool for supporting the proclamation of the new protected areas system, as well as to support the management of the existing protected areas. During the World Park Congress in Durban 2003 the President of the Republic of Madagascar committed himself to increasing the surface of the protected areas by three times - from 1.7 million ha to 6 million ha by 2008. Criteria for KBA sites are the presence of globally threatened species, restricted range species and high species diversity.

To date, 164 KBAs have been identified, of which 10 were selected due to the presence of key rodents or their diversity. From the newly (2005) designated protected areas, *Eliurus antsingy* and *Eliurus petteri* are known from Daraina forest (70,837 ha) and Zahamena Mantadia corridor (425,000 ha), respectively. On the wave of designing the system of protected areas in Madagascar (SAPM), *Macrotarsomys petteri* is the indicator species for Mikea forest (310,000ha), *Hypogeomys antimena* for Menabe forest (125,000 ha), *Macrotarsomys ingens* for Bongolava forest (60,589 ha) and *Brachytarsomus villosa* for Anjanaharibe Sud-Marojejy future SAPM (134,405 ha).

THE INFLUENCE OF LAND USE PATTERNS ON DIVERSITY AND ABUNDANCE OF RODENTS IN GACHOKA DIVISION OF MBEERE DISTRICT, KENYA

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The aim of this study was to establish how patterns of land use influence the diversity, distribution and abundance of rodents in Kiritiri, Gachoka division of Mbeere district, Kenya. Data on the abundance of rodents was collected through captures on square grids of 64 live traps, set out over an area of 70m x 70m in each of four land use types: cultivated, grazing, fallow (land previously under cultivation but abandoned for at least three consecutive years thus re-vegetating naturally) and bushy sites. The number and composition of woody plant species, and the number of rodent burrows and mounds were estimated in a habitat survey which was conducted along belt transects in each land use category. Grass species composition, percentage cover and soil depth were measured in 1m x 1m quadrants placed at 10 metre intervals along the transects. The area sampled for habitat parameters corresponded with trapping points of rodents.

A total of 213 specimens comprising of five species of Murids were recorded. Three species, *Lemniscomys barbarus, Otomys thomasi* and *Acomys percivalis* were the most abundant with percentage abundance values of 35.6%, 35.2% and 16.4% of total captures. The abundance of rodent species was correlated with vegetation cover but no such relationship existed for burrows. The diversity and distribution of species of rodents were both correlated with microhabitat parameters occurring in sites with different land use. Bushy grassland and fallow sites had greater diversity of plant and small mammal species than cultivated and grazed lands. The abundance of *Lemniscomys* and *Acomys* was found to be greatest in uncultivated (bushy and fallow) sites, while *Otomys* was dominant in cultivated and grazing sites. Fallow land had the highest diversity of both plants and small mammal species. This site hosted varying proportions of the five species of captured rodents. The findings of this study demonstrate that land use practices influence the diversity and abundance of rodents with diversity being lowest in cultivated land.

This research was funded by UNEP-GEF Land Use Impacts and Dynamics (LUCID) Project

PREDATION ON SNAILS AND OTHER FOOD SOURCES DURING NON-RICE GROWING PERIODS BY THE PHILIPPINE RICEFIELD RAT, *RATTUS TANEZUMI* TEMMINCK

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Predation preference by the principal rodent pest species, the Philippine ricefield rat, *Rattus tanezumi* Temminck (formerly known as *Rattus rattus mindanensis*), for the invasive alien freshwater snail, the golden apple snail, *Pomacea canaliculata*; native non-pest freshwater snail, *Radix quadrasi*; and other alternative food resources was studied at the experimental lowland rice fields at PhilRice, Maligaya, Science City of Muñoz, Nueva Ecija during the rice fallow months.

Based on the free-choice field tests, *R. tanezumi* fed mostly on small snails, and preferred *P. canaliculata* over *R. quadrasi*. In contrast, the large-sized *P. canaliculata* were carried more often by *R. tanezumi* into their burrows and consumed. Irrespective of the snail species, predation was highest at lower elevations (closer to water source) and almost always at night. It was difficult to establish field preference(s) for milled rice grains either with or without rodenticide, due to the interference by fire ants, *Solenopsis geminata* and house sparrows, *Ploceus philippinus*.

EXPANSION OF THE GREATER CANE RAT, *THRYONOMYS SWINDERIANUS*, INTO THE DRIER PARTS OF SOUTHERN AFRICA

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At more than 4.5 kg, Greater canerats, *Thryonomys swinderianus*, are the second largest rodents in Africa. They are "specialised in their habitat requirements and are found in reedbeds or in areas of dense, tall grass types with thick reed or cane-like stems", never far from water (Skinner and Smithers 1990). However, they adapt well to cleared areas where food and industrial crops are grown, and to secondary savannahs formed as a result of forest destruction. Canerats are often a nuisance in gardens and culprits in farmland. They are known to raid croplands of groundnuts, pumpkins, sweet potatoes, potatoes, pineapples, maize, millet, sorghum, wheat, cassava, eggplant and sugar cane, often causing serious damage throughout their range. In South Africa they are widespread in the eastern parts of the North-West Province, the north-western parts of Gauteng, Limpopo Province and Mpumalanga, and their distribution extends southwards through Swaziland into KwaZulu-Natal and narrowly into the Eastern Cape as far as Grahamstown. The first canerat in the Free State Province was reported in the mid-1980s. However, the scientific community is still unaware of this species' presence and increase in range in this province over the last two decades. The purpose of this study therefore, was to report on the expansion of the distribution range of the Greater canerat into the Free State and to highlight its potential danger as a pest species in agricultural areas.

Distribution records of the Greater canerat in the Free State Province were obtained from museum records, as well as through communication with the public. Since 1995 meticulous records were kept of all phone calls reporting the presence of Greater canerats in the Free State Province. Callers were asked specific questions in order to verify the correctness of identification. Where there was uncertainty about the identification of the canerat, records were ignored and only "positive" phone calls are discussed further. In an attempt to confirm the distribution boundaries of Greater canerat in the Free State Province, as well as to form an idea of its historical presence/absence in the specific areas, phone calls were made to veterinarians, Chairpersons of Agricultural Associations, Nature Conservation Officials, previous Oranjejag problem control officials, Agricultural Extension Officers and professional hunters/hunting farms in districts just inside and just outside the occupied area, and the public's contribution towards this project considered in relation to actual specimens present in the National Museum, Bloemfontein collection.

At present museum records are available for more than 15 localities in the Free State, with the most westerly record at 28°13'S, 26°02'E in the Bultfontein district. This implies a westward movement of *c*. 400 km in 20 years. The public's contribution shows that this movement may have been a gradual invasion - a notion supported by museum records. Our data also indicates that the number of localities reported by the public has increased since the mid-1980s, and how the number of "positive" phone calls to NLA has increased dramatically since 1999. All localities, except two, were close to (500 m at most) a major river or its tributaries, indicating that the canerat is already present in all the major north and northwest flowing river systems in the Free State Province. The two exceptions mentioned above (28°13'S, 26°02'E and 27°43'S, 26°27'E) are both next to a series of seasonal pans that connect to the Vet River and Sandspruit. Greater canerats probably already occur along the Vaal River down to the confluence with the Vals River (confirmed at 27°20'S, 26°27'E by honorary game ranger K. van Zyl), but there are no signs of this species in Sandveld Nature Reserve at the confluence of the Vaal and Vet rivers (A. v.d. Westhuizen pers. comm., NLA pers. obs.) or at Hoopstad, further east along the Vet River (K. Pretorius pers. comm.).

The southernmost point is at Erfenis Dam on the Vet River. Alarming, however, is the 2003 report from the Leeu River valley (J. Oberholzer pers. comm.), a tributary of the Caledon River in the eastern Free State and the only "record" in a south-flowing basin – suggesting that the Greater canerat is moving towards the Orange River. No records or traces of Greater canerat could be found further south along the Caledon River at the Caledon Nature Reserve or beyond.

The large percentage of first time records of canerats from specific districts (74% of callers), as well as indications that canerats have adapted permanently to the "new" areas (see below), strengthens the assumption that this species' density and distribution range is increasing in the Free State Province.

All correspondents contacted telephonically towards the end of the study reacted favourably, with most of them calling back after making further enquiries. Only two new localities could be added: Sasolburg (c. 26°45'S, 27°47'E) and Wesselsbron (27°43'S, 26°27'E). Contact with veterinarians proved most rewarding: in all districts where canerats were found to be present, local veterinarians already knew about them.

Little variation was found in the habitats in which canerats occurred. Most records came from long grass or reedbeds on the banks of perennial rivers, water canals, irrigation dams, mine dams and swampy areas. Five reports were, however, of canerats killed or sighted in lucerne and maize fields. These habitats, therefore, agree with those mentioned by Skinner and Smithers (1990) for other parts of southern Africa. "Water areas", such as rivers and streams, are also expected to be the corridors along which canerats move through the Free State. A combination of museum records and comments from the public may best indicate how this spread has taken place. (1) The current theory is that canerats disperse along rivers and tributaries, but also cross from upper ends of tributaries over watersheds to adjacent tributaries / watersheds. (2) Accidental import from KwaZulu-Natal by train (e.g. canerats that were initially trapped with sugar cane, transported and left behind when train carriages were emptied in KwaZulu-Natal before journeying further, into the Free State – H. le Roux pers. comm.), (3) import and/or local movement by people as a source of meat (e.g. miners from Mozambique – A. Schlemmer pers. comm.), and (4) import and local movement as pets (not common, but *T. swinderianus* does tame easily – J. Knoessen pers. comm., NLA pers. obs.).

But have canerats adapted to the natural Free State environment? Not only have both adult and juvenile specimens been recorded, and "positive" reports received throughout the year, but *T. swinderianus* is also still present in all river catchments where it was located previously – indicating that this species survives and breeds under local conditions. This survival and spread should benefit from the presumed change in predator community structure (≈ absence or lower densities of predator species such as leopard and baboons) over the last 200 years, and the damming of rivers that has created suitable habitat with water, reed and riverine bush throughout the year. The present state of health of all the catchments in the Free State in which Greater canerats occur is considered *poor* to *fair* (River Health Programme 2003). Canerats may well exacerbate the poor state of these ecosystems, thereby degrading habitat integrity even further. Furthermore, although not much is known about their diet in the Free State, it is almost certain that canerats will become pests in lucerne, wheat and maize fields as their numbers increase. Studies elsewhere have indicated that a family of canerats can cause severe damage to such crops, stressing the importance and urgency of further studies for economic reasons. From a conservation point of view, it is uncertain how canerats will affect the natural ecosystems and, therefore, their importance as an invader species in the Free State is also unclear.

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SMALL MAMMAL DIVERSITY AND HABITAT REQUIREMENTS OF RODENTS IN THE ALBERTINE RIFT, EASTERN DR CONGO

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This report presents the results of an ongoing study on small mammals in the western part of the Albertine Rift, in the eastern Democratic Republic of Congo. The work aimed to provide a more complete list of species recorded to date as well as their habitat requirements.

Two kinds of break-back traps, Sherman live traps and Pitfall bucket traps were used to capture rodent species in four habitat types (primary forest, secondary forest, swamps, open habitats near cultivations or cultivated areas) in the montane sector of Kahuzi-Biega National Park and surrounding areas to the west of Lake Kivu, as well as on Idjwi Island.

A total of 47 species were recorded of which 10 are endemic to the Albertine Rift. One squirrel species, *Funisciurus carruthersi* is considered vulnerable, while two species, *Lophuromys medicaudatus* and *L. rahmi* are red-listed as lower risk, and *Hybomys lunaris* near endemic. The smallest number of species (n=5) was recorded in cultivated areas and surrounding open habitats, with an almost similar species composition in these two habitats. The forested areas housed more forest dependent species (n=20), most of which are less tolerant or completely intolerant of disturbance.

This study has recorded more species than any other study in this area, and some of the species have never been recorded before. These differences can be attributed to the differences in trapping methods used, as well as the areas sampled. More research is needed to sample the small mammal community structure and species present in the different habitats of this area; for example, the swamps in mountain areas and in deep forests have never been sampled.

RODENTS FROM PRIMARY RAINFOREST AND DEGRADED HABITATS AROUND KISANGANI (D.R.CONGO): LIFE HISTORY AND MOLECULAR ECOLOGY

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Tropical rainforest is disappearing fast worldwide. Anthropogenic habitat (farmland or secondary grasslands) replaces the forest habitat. The original rainforest species come under considerable pressure and many disappear. Some small mammal species however, appear to have a better adaptation ability and persist in the anthropogenic habitats or even become a pest for local agriculture. We want to investigate which life history characteristics allow those species to adapt. Here we present a project that has started just recently, in which we want to study the adaptation ability of small mammal populations (rodents and insectivores) to the changing conditions around Kisangani, D.R. Congo.

Kisangani is uniquely located at the bank of the Congo river and in between several major tributaries. These large rivers form known zoogeographic barriers to rodents and this allows us to conduct the study simultaneously at three independent sampling localities. First, the composition of the fauna in the original rainforest habitat and the anthropogenic habitats will be studied with craniometrical and molecular techniques, based on capture-removal studies using different trap types and baits. Furthermore we will investigate the ecological effects of habitat change and study the genetic effects of habitat fragmentation during a two-year capture-mark-recapture (CMR) study at three independent sampling localities in the vicinity of Kisangani. At each locality, a similar CMR grid in primary rainforest and in secondary habitat (old or young growth fallow fields) will be used.

The taxonomical work carried out together with the University of Kisangani will allow us to conduct a revision of the different rodent and insectivore (shrew) taxa around Kisangani. An assessment of the effects of the different rivers on species composition and speciation will also be made.

The capture-mark-recapture study will allow us to assess the life history (reproduction, age structure, growth, recruitment, survival and spatial patterns) differences and changes between the same and/or congeneric species in primary rainforest and secondary habitat. In this part of the study, mainly the most abundant species will be studied.

Tissue samples taken in the CMR study will serve as a base for molecular ecological research (and if needed for molecular species confirmation). We want to study possible founder effects, genetic variation and genetic drift, inbreeding, inbreeding avoidance mechanisms and genetic exchange between populations in primary and secondary habitat.

Field work for the taxonomic part of the research is almost completed. Molecular and craniometrical taxonomical work on the collected rodents and insectivores has started.

The capture-mark-recapture study will be set up in Kisangani at three already designated localities starting from November 2006.

THE EFFECT OF FOOD SUPPLEMENTATION ON THE HABITAT USE OF *RATTUS FUSCIPES* IN COASTAL FOREST OF SOUTH-EASTERN AUSTRALIA

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Food is a critical variable affecting population dynamics and social behaviour in mammals, and the experimental provisioning of food has been a key manipulation. Changing the pattern of food distribution, as occurs during a food supplementation experiment, is likely to change an animals foraging behaviour by focusing activity around the food addition sites. Few studies, however, have examined the behavioural response of animals to food supplementation.

We investigated habitat use of the bush rat (*Rattus fuscipes*) in response to food supplementation in Booderee National Park, on the shores of Jervis Bay, approximately 200 km south of Sydney, Australia. Eight study sites, each 1-hectare in size, were located in open sclerophyll forest that had been burnt by a large bushfire in December 2003, 10 months prior to this study. All sites were within 200 metres of a watercourse or gully, where vegetation cover was denser than on trapping sites. Supplementary food was provided in four stations on each treatment site, while stations were left empty on control sites. An automated event recording system was used to monitor visits to stations by individual *R. fuscipes*. Radio-telemetry was used to assess habitat use.

The food stations were a successful method for delivering supplementary food to *R. fuscipes*. Approximately 60 % of tagged *R. fuscipes* visited food stations within four nights of food being added compared to only 23 % of tagged animals that visited empty food stations. There was no clear evidence from this study that *R. fuscipes* aggregated at food stations. Individuals generally visited stations only once or twice a night. Radio-tracking supported these results with no significant difference found in the habitat use of *R. fuscipes* between food supplemented and non-food supplemented sites, with the exception of brief forays to the food-supplemented stations. However, *R. fuscipes* was found to spend more time around watercourses and gullies than if they had used them in proportion to their availability. A large proportion of burrows (65 %) also were located near watercourses or gullies. This was irrespective of whether the sites were food supplemented or not. This suggests that vegetation cover is a key determining factor in the habitat selection of *R. fuscipes*. Even with the addition of food, individuals may still need to select the densest habitat to minimize predation risk.

Poster Presentations

A REPORT ON THE COMMUNITY OF RODENTS OCCURRING IN THE ITOMBWE MASSIF, EASTERN DEMOCRATIC REPUBLIC OF CONGO

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This report presents the results of a study of the rodent community in a non-protected forest block of the Albertine Rift. Itombwe massif is known as an important, high diversity bird area that also supports important large mammal populations (it is also supposed to be rich in plant, frogs and small mammals). All previous work here has focused on birds, large mammals and plants, while the small mammals have never been studied. The area is of conservation concern as it encompasses large blocks of continuous forest, extending from lowland to montane areas. The threat to the habitats and their biodiversity is high as the local people rely on the forest for food and various other needs. Three habitat types (swamps, primary and secondary forest) were surveyed with museum specials, Pitfalls and Sherman live traps, as well as being caught by hand. Some specimens were bought from locals.

In total, 26 rodent species have been recorded in the area. *Praomys jacksoni* was the most abundant and widespread (present in all habitats), followed by *Lophuromys flavopuctatus (*absent in one of the three habitats). *Oenomys hypoxanthus* and *Mus triton* were found only near human settlements and seemed most tolerant to disturbance. *Rattus rattus*, on the other hand, was only trapped in human habitations (houses). Most of the species collected are forest dependent species, but some were also found in undisturbed or less disturbed areas (e.g. squirrels and *Lophuromys woosnami*, *Mus bufo*, *Hylomyscus sp.*, and *Hybomys univitatus)*. The rodent species-list for the entire area is considered far from complete as most areas in the lowland were not assessed and only three localities were sampled in this big block of forest. To expand on the species list further sampling needs to be done. Other aspects, like the ecology and ethology of some of these rodent species, also remain unstudied.

THE POTENTIAL IMPORTANCE OF RODENTS IN MANAGING TWO PROBLEM CARNIVORES, AND SUBSEQUENTLY IN PROMOTING ECOSYSTEM CONSERVATION AND SUSTAINABLE SMALL STOCK FARMING PRACTICES IN SOUTHERN AFRICA

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In southern Africa caracal *Caracal caracal* and black-backed jackal *Canis mesomelas* have been impacting small stock farming for many decades. This impact is on the increase. Today, losses due to these two predators are reported to be "excessive", with "no permanent solution" and this has become a major threat to the small stock farming industry. Desperation has led to uncontrolled blanket-control and poisoning practices in some areas, with many of these methods being unselective. Those methods that are considered to be "fairly" species-specific are mostly non-selective for the culprits and ignore the effect that social structure has on territorial and breeding behaviour and therefore also on its effect on population increase, prey species diversity and numbers, and ecosystem health and stability. Due to current management practises, biodiversity in most ecosystems in small stock farming areas in South Africa is under constant threat, while small stock losses continue to escalate. Researchers from the National Museum, Bloemfontein, and the African Large Predator Research Unit have recently launched the Canis-Caracal Programme (CCP) with the aim to (1) improve methods and procedures to manage caracal and black-backed jackal, (2) reduce the financial impact on the livestock industry, and (3) address the issue of biodiversity/ecosystem conservation in livestock areas. This first comprehensive programme is based on the premise that we do not have adequate information upon which to formulate a proper, workable control policy, and that there is a the lack of information in a variety of habitats on predator densities, damage due to predators, and the value of predators to both the ecosystem and the farmer. A well-managed series of studies (ranging from the collection and collation of basic information and literature, to economical, social, management and ecological studies on each of the individual species and/or the interaction between them, in a wide variety of habitats) are essential if we want to address this problem effectively.

This contribution focuses on the importance of rodents in formulating hypotheses that will be tested in a variety of areas and under different management practises during the ecological part of the CCP, as well as the role that rodents can play as indicators of habitat integrity, and therefore their role in evaluating predator control and small stock farming practises.

Not much ecological research has been done on caracal and black-backed jackal. For example in only one study has caracal home range use been correlated with its diet and prey abundance in specific plant communities and on various contours and slopes (in the West Coast National Park (WCNP) (Avenant and Nel, 1998, 2002). Rodents (especially *Rhabdomys pumilio* and *Otomys unisulcatus*) were the most important prey, with a relative percentage occurrence of >70% and highest importance value of 13.42. The WCNP study added to our understanding of the role of this top predator in this specific ecosystem (*inter alia* in keeping prey densities low and ensuring strong, healthy prey populations and greater species diversity). It also indicated the role that the social behaviour of caracal can play in prohibiting caracal population explosions, the protection of natural prey populations and diversity, and limiting the predation on unnatural, "easy" small stock by non-territorial cats. Amongst others, territorial caracal spent a significant amount of time (when active) in the areas with highest rodent density. They also moved directly from one "hot spot" to another, presumably to maximize energy intake and to minimize energy expenditure. This

strengthens the idea that territorial caracals know their territories and where the areas with the highest prey densities are, patrol these territories in a way that ensures sustainable utilization of prey inside their home ranges, and limit the time that non-territorial animals spend inside their home range areas. The non-territorial caracal were found to scavenge, strengthening the belief that these individuals experience the highest energy stress as they constantly have to evade the territorial cats, do not know where the areas of highest prey densities are, and are the individuals most likely to prey on “unnatural”, easy prey. This study also showed that female caracal were found to switch to larger prey items (smaller antelopes) when they had young, indicating that the loss of small stock farming could be minimized by changing management practices throughout the year. The observed impact of rodent diversity and density on caracal social and ranging behaviour, thus, laid the foundation for the CCP; i.e. the management of caracal (and black-backed jackal) to “limit” stock loss, as apposed to hunting them in order to “stop” stock loss, thereby working towards 'co-existence' with wildlife, rather than conflict.

To investigate the influence of various predator control and farming practises in different areas, rodents will also be sampled as part of the monitoring program that will assess habitat change. Avenant (2003) regarded the study of rodent community structure as an effective and relatively easy and inexpensive method of indicating ecosystem integrity. The monitoring of rodent populations will, therefore, not only be important for studying caracal and black-backed jackal diet, social and ranging behaviour, but will also contribute towards evaluating ecosystem integrity and, ultimately, best small stock farming and problem animal control practises.

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THE IMPORTANCE OF INCLUDING RODENTS IN VELD CONDITION ASSESSMENTS: A CASE STUDY

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Over the last 100 years in southern Africa, humans have increasingly altered ecosystems, their processes and consequently ecosystem health (≈ ecosystem integrity). The need to manage and improve ecosystem integrity has thus become imperative. However, in order to manage ecosystem integrity, we need to increase our understanding of ecosystem processes and establish efficient strategies for the monitoring of ecosystem integrity. In South Africa, the Grassland Biome is currently one of the most extensively transformed, and a monitoring strategy for grassland ecosystems is, therefore, long overdue. Given that the components of ecological integrity in grassland ecosystems are so diverse and that it is time consuming and difficult to measure all the factors of these components, it is necessary to develop grassland indicators that are efficient and rapid in their assessment of grassland ecosystem integrity.

The present study is the first in southern Africa to investigate the relationship between changes in veld (vegetation) condition and insect and rodent community structure. These changes were proposed to conform to Tilman's hump-shaped curve model (see Wang *et al*., 1999). The study was conducted in the De Brug Military Training Grounds, Free State Province, South Africa, during April 2004. A total of four "pure" grassland sites in different stages of succession (i.e. burnt < one year, two years, four years, and > eight years prior to this study) were selected; each with vegetation of apparently different ecological status and grazing value. The nearest plant survey wheel-point method was used to determine the plant species composition of the different sites. Plant species were identified and classified into ecological groups according to their ecological status. Veld condition was quantified in terms of Ecological Index (EI) values, number of individuals per species, mean percentage of occurrence, mean diversity and basal cover. Insects were sampled by standard sweep netting. They were assigned to functional feeding groups (FFGs) following Seaman and Louw (1999). A weighting or 'quality' score between 1 and 5 was given to each FFG. Subsequently, the sum of these values gave a SAGraSS score for each site. The insect community structure was quantified in terms of SAGraSS scores, relative order and family richness, and Shannon indices. Bray-Curtis index values were used to compare the similarity of the insect faunas in the four sites. Other alternatives for rapid assessments, using the order Coleoptera, were also investigated. Rodents were sampled using the standardised method suggested by Avenant (2000). The presence/absence of indicator species, the trap success, species richness, Shannon diversity and evenness (E_{var}) were used to describe and measure the structure of the various rodent communities.

EI values, basal cover, and the contribution of Decreaser and Increaser II group species were considered to be good indicators of veld condition. These variables all indicated that the veld condition increased from Site 1 to Site 4. Similar trends (≈ significant correlations with EI values) were found for SAGraSS and $SAGraSS_{col}$ scores, average score per FFG, the number of Coleoptera families, the number of Coleoptera individuals, and the Total Intolerance Score. However, no distinct trend could be observed for any of the rodent variables studied. No correlations were found between any plant and rodent community characteristics or between any insect and rodent community characteristics. A combination of rodent variables (e.g. low diversity, species richness and evenness), together with the absence of specific indictor species suggested that the habitat integrity of the four grassland sites was not as high as indicated by the veld condition and that a factor, or a combination of

factors, is affecting ecosystem functioning negatively. This was not detected by either the vegetation survey or the insect survey. Results from this study, therefore, showed that the EI value may be a good indication of grazing capacity and soil binding processes, but not necessarily of habitat integrity. It furthermore stressed the importance of including more than one group or taxa in future studies of habitat integrity. The inclusion of rodents, in particular, proved to be valuable to this study. At high diversities and densities of up to 200 individuals/ha, rodents are not only a key prey species for a wide spectrum predators, including carnivores, raptors, and reptiles, but they are also important predators (mostly of vegetation and invertebrates). They are also important dispersers of seed, soil fertilisers, and can, through their burrowing actions, be considered as ecosystem engineers contributing to healthy ecosystem functioning and diversity. Avenant (2000) therefore regards rodents as good indicators of ecological integrity, as well as a convenient means to sample for it in a relatively quick, easy and inexpensive manner.

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STRUCTURE OF COMMUNITIES OF RODENTS (RODENTIA: SCIURIDAE, MURIDAE) IN TROPICAL FOREST OF SOUTH VIETNAM

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Rodents (Rodentia) comprise 25% of the mammal fauna of Vietnam and consequently should play a leading role in the function of its tropical ecosystems. There are few studies on the organization of the communities of ground- and especially canopy-dwelling rodents of tropical forests of Vietnam. Our research has investigated this problem.

Basic studies were done on the main transect-line *"Afzelia"* (1500 m long) in primary unlogged tropical forest in Cat Tien National Park (South Vietnam). This site is dominated by the forest species *Afzelia xylocarpa* and characterized by a dense canopy structure as well by many lianas. The transect-line was installed in two strata: traps were placed on the ground (n=60) and in the canopy (2–12 m above the ground, n=60). Capture-marking-recapture (CMR) techniques were used.

Four hundred and thirty eight rodents (173 squirrels, 252 rats, 13 mice) of 12 different species (Scuridae 1 sp.; Muridae 11 sp) were marked (979 recaptures) on the transect-line *"Afzelia"* from January 2005 to January 2006. Two species were predominant: rats *Maxomys surifer* and squirrels *Callosciurus flavimanus*. The average number of *M. surifer* for the period from January-June 2005 remained constant at 2.7±0.35 individuals per 100 trap days, but at the end of a wet season (at the end of December 2005 – January 2006), the abundance of *M. surifer* increased to 4.3 individuals per 100 trap days. Similar relative changes in abundance were recorded for other species of rats (*Niviventer fulvescens*, *Niviventer bukit*, *Leopoldamys sabanus*, *Leopoldamys edwardsi)*, except for *Rattus sp.* whose numbers sharply increased in April, and which locally replaced *M. surifer* at this time. The high activity of *Rattus* sp. in April is related to the forest conditions: the quantity of leaves of the semi-deciduous tropical forest is decreased and the forest becomes clearer. *Rattus* prefers the less dense canopy structure and more disturbed tropical forest habitat. Squirrels *C. flavimanus* showed two peaks of abundance: in April and December, 2005 (7.0 and 5.3 individuals on 100 trap days respectively). More than 95% of *C. flavimanus* were caught in the canopy (2 -8 m above the ground), and particularly in the traps located 3-4 m above ground. This may be due to the density of the canopy, where squirrels can easily move on dead branches, lianas or small trunks and they are more protected from predators such as birds of prey. In January 2005, of the total captures of squirrels 19% were at ground level, while in June this was only 2%. This result contrasts with another tropical forest in Binh Chau region, South Vietnam where in February 2005 50% of *C. flavimanus* were captured on the ground.

We also obtained data on the proportion of resident and migrant squirrels and rats on the transect-line *"Afzelia"*. Most of the squirrels (60%), but less than 10% of rats, were resident in the same habitat for one year. Thus, the population of squirrels *C. flavimanus* appears to be more permanent residents than the population of rats *M. surifer.*

The transect-line, *"Afzelia"*, is located in slightly disturbed tropical forest, and we observed no quantifiable difference in the distribution of rodents between arboreal and ground strata. For example, the number of captures on the ground versus in the arboreal strata was 15.4 and 13.2 individuals per 100 trap days respectively. On the transect-line *"Lagerstroemia"*, located on a site of strongly disturbed tropical forest in Cat Tien, this equivalent balance was not observed (23.4 and 2.6 individuals per 100 trap days respectively). This study shows that the abundance of rodents in the arboreal strata and at ground level depends on the degree of disturbance of the tropical forest.

The new quantitative data on communities of rodents are important for an estimation of conditions of stability of modern tropical ecosystems which are being subject to the various impacts of human activities.

Symposium: Impact of agricultural advances on ecology and management - Attitudes

Chairs: Rhodes Makundi and Duncan Sutherland

Oral Presentations

THE SOCIAL AND CULTURAL DIMENSIONS OF RODENT PEST MANAGEMENT

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Rodents are historically mankind's oldest competitor in acquiring and storing food. They are generally perceived to be consistently outsmarting humans, and considered as one of the major constraints in agricultural production. In irrigated rice crops, rodents are the number one pre-harvest pest in Indonesia and amongst the top three pests in Vietnam. Hence, ecologically-based rodent control technologies were developed to manage rodents in rice-based farming systems in Asia such as integrated rodent management at the village level (IRM-V), including the community trap-barrier system (CTBS) (Singleton et al., 2004). These cost-effective and environmentally benign rodent control technologies are currently being disseminated to rice farmers in Vietnam, Laos, Myanmar and Indonesia. The adoption of these technologies, however, requires community participation and is largely influenced by farmers' perceptions on their technical effectiveness and feasibility in terms of economic profitability, social acceptability and cultural suitability. Hence, it is important to understand farmer knowledge about rodents, and rodent control practices, farmers' beliefs regarding rodents, and the social and cultural mechanisms involved in maintaining community participation to further understand the conditions under which CTBS and IRM-V work, and do not work.

This paper aims to show the results of the assessment of ACIAR-funded projects on the delivery of these technologies in Vietnam, and associated projects funded by AusAID, and in collaboration with World Vision (Palis et al., 2004). To our knowledge, this is the first published independent assessment of the impact of ecologically-based management of rodent pests. The assessment addressed issues relating to current adoption level and sustainability of adoption and the change in farmers' net income as a result of adopting the technology. The key question that remains unanswered is: Will farmers continue to apply integrated village-level rodent management strategies, including CTBS, if these strategies are no longer subsidized by governments or through donor funding? Information used for the assessment was through key informant interviews and focus-group discussions among people involved in the projects, and among farmers representing the treatment and control areas in five provinces of Vietnam: Vinh Phuc (North), Binh Thuan (South-Central), and Bac Lieu, Soc Trang and Tien Giang (South).

Results of the assessment showed that IRM-V, which was introduced in the north, has been adopted. Farmers also have used CTBS, but adoption has been relatively slow. However, this technology has positive impacts for the government at both the national and provincial level. The results of the ACIAR project in the north became the basis for government policy pronouncements about the use of IRM-V. These results were also the basis for an information campaign about rat control, which was aired on television and radio. In addition, at the provincial level, a budget has been allocated for further CTBS demonstrations and implementation of IRM-V.

Farmers believe that CTBS is effective, but they are constrained by the costs associated with it. Conditions for CTBS adoption include: (1) monoculture farming; (2) good irrigation facilities; (3) presence of a strong cooperative, farmers' association or integrated pest management (IPM) club; (4) high rodent population; (5) partial subsidy for small farmers,

cooperatives, farmers' association or IPM clubs; (6) capacity building to strengthen existing cooperatives, farmers' association or IPM clubs; and (7) large farm size for individual adoption.

Some positive indicators point out a wider and sustained adoption of IRM-V, including CTBS. These are as follows: (1) a policy pronouncement from the prime minister directing the use of integrated rodent control; (2) existing infrastructure, for example, cooperatives for sustained implementation; (3) budgetary allocation from the government; (4) culture of community cooperation; (5) individual adoption by small farmers in areas with a high rodent population; (6) individual adoption by farmers with relatively bigger farms; and (7) strong support by provincial governments in the south (e.g., Bac Lieu) and north (e.g., Hai Phong) that were not involved in the studies.

The quantitative benefits that farmers derive from the use of CTBS and practice of IRM-V are:

I. increased yield resulting from reduced yield losses from rats,
II. a lower rodent population in project areas,
III. reduced use of toxic rodenticide due to the shift to ecologically based rodent control methods,
IV. decreased use of plastic fence to protect the whole area, and
V. decreased rodent control cost.

The assessment also showed a positive impact on farmers' welfare in terms of financial benefits since in all five provinces, the net present values (NPVs) are positive and the benefit-cost ratios (BCRs) are greater than one.

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GAMING AS A PARTICIPATORY RESEARCH TOOL FOR RISK MANAGEMENT ASSOCIATED WITH RODENT DAMAGE IN RICE CROPS

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Rodent damage to rice crops can be catastrophic for poor farmers living at subsistence level, especially where they are dependent upon a single rice crop each year. This is certainly the case in Cambodia, where rodents are commonly identified as a major pest of rice crops. Trap Barrier Systems (TBS) have been proposed as a means of controlling rodent damage in a cost-effective and environmentally friendly manner. It is thought that rodent mobility and possibilities for the build up of large numbers of rodents, mean that TBS will be most effective if implemented broadly over the landscape. This requires social coordination on the part of farming communities such that village and commune wide coordination is desirable in Cambodia.

This paper describes an investigation into farmer attitudes towards risk in Cambodia in the context of rodent control measures at individual and group levels. The paper reports on the use of gaming as a tool for participatory research into risk management.

A gaming activity was introduced to farmers in Samrong Commune in Kampong Cham, Cambodia as an information gathering and learning exercise. At that time, many farmers were experienced in the group organisation and operation of TBS. Rice production was very important for the commune and rats were difficult to control. Farmers stated that as far as they knew, the TBS were good for them and they wanted to continue working with TBS. However they did point out that some farmers were not interested and these farmers needed further explanation of the technique, so that they would be willing to contribute funds for trap construction. Further activities were needed to achieve a broader understanding of the technique and the necessity for group cooperation. Gaming activities were included in field days which brought together a large number of farmers from the 11 villages making up the commune.

Some 40% of farmers who participated in the gaming were found to be strongly risk preferring in their gaming behaviour. The women participants particularly appeared to be risk preferring, but this may have been due to inexperience with gambling. Farmer leaders and extension staff involved in the gaming enjoyed the exercise and suggested modifications to the game to improve the efficiency of play and the realism of the gaming scenarios. This was a good indication of both their interest and understanding.

These results helped researchers and participants to understand the decisions farmers were making about participation in groups for the construction of the TBS and their individual decision making processes. In the long term however, most farmers reverted to alternative rodent control measures, including baiting, hunting, trapping and lethal electric fencing.

COMMUNITY-BASED EVALUATION OF A RODENT MANAGEMENT TECHNOLOGY: BEYOND FARMER PARTICIPATION

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In recognition of the need for more contemporary participatory approaches to research and extension and the need to explore the appropriateness of a rodent management technology known as the Trap Barrier System (TBS), a project called FARMERS (Farmer-based Adaptive Rodent Management, Extension and Research System), has been underway since July 2001. FARMERS is a collaborative project between farmers of Samrong Village, the Office of Agricultural Extension (OAE), the Cambodian Agricultural Research and Development Institute (CARDI), the Provincial Department of Agriculture, Forestry and Fishery (PDAFF), and The University of Queensland (UQ); and is funded by the Australian Centre for International Agricultural Research (ACIAR). The project is based in Kampong Cham Province, Cambodia, and the research has taken place in Samrong village. One of the central problematic issues at the beginning of this project (an issue that remains problematic), was whether or not the TBS is actually a feasible option for a farming community in Cambodia. That is, the TBS technology in Cambodia and elsewhere has yet to be defendable as an appropriate rodent management technology. While much has been learned of the *ecological* properties of the TBS, the *economic and social aspects* of this technology are poorly understood. However, what is clear is that the use of the TBS will be less than socially optimal if managed by individual decision-makers acting in isolation, and that the management of this technology as a common property resource is necessary.

FARMERS is based on an Adaptive Management (AM) methodology. The definition of AM within the FARMERS project is based on an action research model and is an integrated, problem-solving approach, with community participation in all phases of the planning, implementing, monitoring, interpretation and evaluation of the research. After 3 years of research, it was time to evaluate the appropriateness and usefulness of the TBS technology in Samrong. To do this, a 2-day training workshop was conducted with staff from CARDI, OAE, PDAFF and the Community Health Education Program (CHE), to develop, implement and evaluate a community process for assessing the TBS technology. Drawing on their experience from previous participatory methods training and examples of different participatory evaluation processes (eg. Citizens Jury, participatory monitoring and evaluation tools), trainees developed a community-based evaluation process suitable for the Cambodian context - calling it the Cambodian Community Committee to Judge (CCC-J). Trainees then facilitated this 1-day CCC-J process in Samrong with 26 farmers (men and women), 16 visiting farmers from two other villages, and 14 visiting researchers and extension staff. This paper highlights the findings from this community-based evaluation of the TBS and also reports on the trainees' reflections on the use of the CCC-J as a community-based evaluation tool. This, in itself, was a novel process – as the evaluation of technology and technology 'adoption' has often been undertaken by so-called 'experts' (eg. project scientists, funding body representatives), rather than farmers themselves.

MODELLING THE EFFICACY OF RODENT CONTROL METHODS IN CAMBODIA WITH BAYESIAN BELIEF NETWORKS

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Trap-Barrier Systems (TBS), rodenticides, electric fencing, hunting and netting are the most common rodent management methods used by farmers in Samrong Commune, Prey Chhor District, Kampong Cham Province, Cambodia. These five rodent control techniques were evaluated using a system modelling approach employing Bayesian Belief Networks (BBN) to capture and integrate farmers' knowledge of the critical factors influencing the efficacy of each technique.

BBN models were constructed in a series of workshops with expert farmers of the Commune using a Participatory Systems Analysis process. The resulting models were used as decision support tools to compare the efficacy of different rodent control techniques under specific scenarios and also to identify those factors believed to most influence the efficacy of individual rodent control techniques. The model developed to assess the efficacy of the Trap Barrier System (TBS) is shown in Figure 1 below:

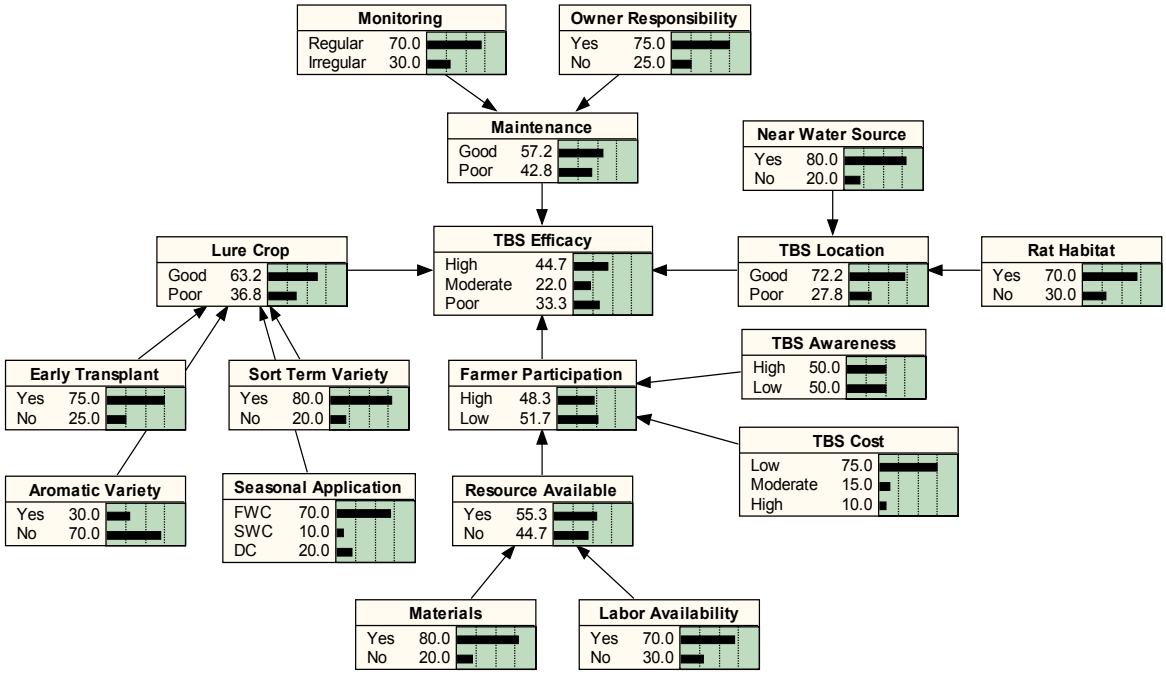

Figure 1: Efficacy model for TBS

We conclude that although there has been a growing awareness of TBS among farmers as a rodent control technique and several years accumulated experience in the commune, farmers still found other techniques to be highly effective in comparison to TBS due to cost and availability of labour and materials.

Symposium: Population dynamics and regulation/predator-prey

Chairs: Jens Jacob and Zhibin Zhang

Oral Presentations

SPATIAL POPULATION DYNAMICS OF INTRODUCED SHIP RATS (*RATTUS RATTUS*) IN NEW ZEALAND PODOCARP-BROADLEAVED FORESTS

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The population density, rates of increase and rates of re-colonisation of ship rats (*Rattus rattus*) in New Zealand broadleaved-podocarp forests are likely to depend on (a) local habitat attributes, (b) habitat attributes of adjacent areas, (c) variability in food resources between seasons and years, and (d) population densities of directly interacting species (competitors such as brushtail possums [*Trichosurus vulpecula*] and predators such as stoats [*Mustela erminea*]). The aim of this project is to improve our efficiency in controlling ship rats, thereby increasing conservation benefits to native flora and fauna, by understanding their spatial dynamics. In theory this could allow managers to focus control programs on 'hotspots' in the landscape where rats occur at high density, and which are a potential source of animals invading adjacent habitats.

Our initial approach to tackling this problem has been to collate information on the population dynamics of ship rats in New Zealand forests and, based on these data, to develop conceptual models (hypotheses) about the spatial dynamics of rats that can be tested experimentally. The hypotheses are (1) ship rats have an *unpredictable, patchy distribution*, where there are no identifiable environmental attributes that characterize the locations of high and low density populations; (2) ship rats have a *variable, resource-driven distribution*, where the rate of increase of localized rat populations simply reflects the spatial and temporal variability of food supplied by fruiting tree species; (3) ship rats have *source-sink populations*, where high density populations (or populations with high rates of increase) occur in high-quality patches with fixed locations and low density populations, persisting only with sufficient immigration, reside in the surrounding poor-quality areas; or (4) ship rats occur in *metapopulations*, where high density populations (or populations with high rates of increase) occur in high-quality patches with fixed locations and only dispersing rats occur in the poor-quality, inter-patch matrix.

Models of the spatial population dynamics of ship rats will be constructed to compare the outcomes of applying control programmes in areas of high population density compared to low population density. In terms of population reduction, control success is likely to depend on the relative productivity of high- and low-density areas, the rate at which ship rats move between these areas, and the rate at which animals are removed. The models will be used to examine the environmental and economic trade-offs between pre-emptive management of ship rats when they are concentrated in 'hotspots' and not causing immediate serious damage compared to reactive control programmes imposed when ship rats are widespread (e.g. following mast years for fruiting trees) and causing significant damage.

Development of initial hypotheses and conceptual models has allowed us to identify critical gaps in our understanding of the spatial population dynamics of ship rats in New Zealand forests, and the habitat factors that drive these dynamics. The next step is to develop and refine quantitative models using data from experimental manipulations of the spatial population dynamics of ship rats. The ultimate aim is to predict (and map) critical areas that should be targeted during control programmes. The output is not expected to be a static map but rather a process for updating maps based on the spatial dynamics of fruiting forest tree species.

IMPACT OF SELF-REGULATION, PREDATION AND EL NINO / SOUTHERN OSCILLATION (ENSO) ON THE CLASSIC HARE-LYNX DYNAMICS

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The 10-year hare-lynx cycles in boreal forest of North America have been well known for more than 100 years, but the underlying mechanism is still a mystery. Prey-predator interactions are generally thought to be the major causative factor for the cycle. The effect of climate on the hare-lynx cycle has been largely ignored. By using cross partial correlation principal component regression and autoregressive integrated moving average (ARIMA) models, we re-analyzed Hudson Bay's well-known hare-lynx time series (1845-1935) to evaluate the effects of intrinsic self-regulation, prey-predator interactions and El Nino/Southern Oscillation (ENSO) on the hare-lynx dynamics.

Our results indicated that the abundance of hare and lynx populations was strongly regulated by their own past abundances. Effects of prey-predation interaction and ENSO were also detected, but the results varied somehow with the study periods and the methods. Cross-spectral analysis revealed that hare and lynx abundances were significantly correlated with southern oscillation index (SOI) at the period of 10-yrs. Our study suggested that the classic hare-lynx cycle widely cited in ecological textbooks was mostly determined by self-regulated intrinsic factors instead of by prey-predator interactions as popularly thought. SOI affected the hare-lynx cycles probably through ENSO-linked precipitation.

HOW DO SOCIAL INTERACTIONS DRIVE MOUSE PLAGUES?

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The dynamics of feral mouse populations in grain growing regions of south-eastern Australia have puzzled ecologists and managers since the first recorded eruption or "plague" a century ago. To date, almost all hypotheses proposed to explain mouse plagues have focused on extrinsic drivers such as rainfall, weather patterns or predation. Rainfall is an important bottom-up process that drives food availability, but the timing of rainfall events alone cannot explain the instances in which plagues fail to occur despite favourable environmental conditions. It is therefore likely that secondary, top-down processes must also operate in mouse populations to regulate responses to food supply. These may comprise extrinsic processes such as predation and disease; however, intrinsic regulation through social interactions also has the potential to limit mouse density by affecting dispersal, reproductive output and mortality.

The activity of mice was monitored via intensive mark–recapture trapping and an automated event recording system that detected the activity of marked individuals at burrow entrances. Tissue samples were also collected for genetic analysis. Observed changes in demography, social structure, age structure, social interaction rates and kin structure during the course of a mouse outbreak were compared to predictions derived from published hypotheses of self-regulation in other rodent populations (Charnov and Finerty 1980; Krebs *et al.* 1995; Lambin and Krebs 1991).

None of the published models fully explain observed changes in feral mouse populations during an outbreak. I have developed a conceptual model for population fluctuations specific to house mice in Australia that incorporates the well-recognised extrinsic drivers but introduces intrinsic drivers as well. The findings do support a model whereby mice switch from an almost asocial structure at low densities to a territorial system as abundance increases. Adult females appear more likely than males or juveniles to make the significant social shift. I propose that plagues arise from increased juvenile survival afforded by the maintenance of female kin groups through the preceding winter.

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PREDICTIVE THRESHOLDS FOR CONTROLLING MICE IN SORGHUM CROPS

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Vertebrate pests cause major economic losses in agriculture. The extent of pest damage is theoretically related to the pest density. This leads to the concept of threshold pest density (D_T), above which the economic benefits of control exceed the economic costs of control. This study aimed to prove this concept for managing a vertebrate pest. Mice (*Mus musculus domesticus*) were used for the study because mouse plagues and smaller scale outbreaks of mice cause major economic losses in cereal crops in many parts of the world.

D_T was determined through estimating the relationship between density of mice introduced to sorghum crops at physiological maturity and yield loss (*YL*) due to damage caused by mice. The crops were enclosed by rodent- and predator-proofed pens.

The estimated relationship was asymptotic exponential: *YL* increased linearly with mouse density until interference between mice occurred at densities ≥ ~500 mice ha^{-1}; and interference limited further increases in *YL* at densities ≥ ~3,000 mice ha^{1}. D_T varies depending on the effectiveness of control in reducing mouse density and cost of control as a percentage of the farm gate value of sorghum (Figure 1).

Baiting is the main method for controlling rodent pests. D_T is 100 mice ha^{-1} for triggering aerial zinc phosphide baiting if this method is effective in reducing mouse density by 88%.

We recommend that mouse densities be monitored well before crop maturation so that the density a week before crop maturation can be forecast by the trend of monitored densities. If the forecast mouse density exceeds D_T, control will be applied a week before crop maturation (we allow a week for baiting to take effect). However, if the forecast mouse density is much higher than D_T so that even after control the reduced density would still be higher than D_T, then additional control may be applied earlier so that the control measure applied a week before crop maturation would reduce the density below D_T.

D_T can be used immediately to minimise *YL*. Our results will promote more informed use of bait to minimise its environmental impacts.

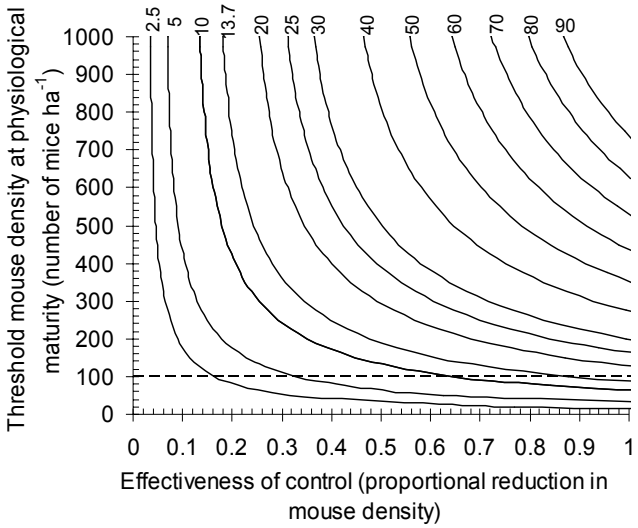

Figure 1. Threshold mouse densities for triggering control methods with varying effectiveness in reducing mouse density. The cost of control, as a percentage of the farm gate value of sorghum, is indicated on the top of each curve. This was 13.74% for aerial application of zinc phosphide bait in Australia.

A LARGE-SCALE EXPERIMENT DESIGNED TO UNDERSTAND THE INTERACTIONS AMONG MULTIPLE PEST SPECIES IN NEW ZEALAND FORESTS.

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Introduced mammal pests pose the major immediate threat to biodiversity conservation in New Zealand. Progress in 'halting the decline' of iconic fauna is critically limited by incomplete knowledge of interactions among suites of mammal pests. A greater ecosystem-level understanding of the consequences of pest control is required by managers. We will develop such an understanding for key interactions among multiple pests threatening fauna and provide a system that supports the application of this knowledge to conservation management.

To identify the mechanisms that drive interactions among mammal pests, we will impose several large-scale pest removal experiments. The pests we are primarily interested in are rodents (rats and mice) and their predators (stoats) and competitors (possums). We will (1) measure the effect of food resource availability on pest abundance (termed 'bottom-up' effects); (2) determine the ability of top-order predators to limit lower trophic level pests ('top-down' effects); (3) quantify the use of resources by pests (through numerical and functional responses); and (4) identify mechanisms that drive direct or indirect competition for resources among pest species. We will use these ecological relationships to develop models that predict: (1) temporal variation in rodent abundance, (2) responses of secondary pests (stoats) to removals of primary pests (rodents), and (3) the relative benefits of alternative pest control strategies to protect conservation assets.

RODENT OUTBREAKS IN TANZANIA: MATRIX BASED SIMULATION FOR TESTING DIFFERENT HYPOTHESES.

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Mastomys natalensis populations exhibit irregular population outbreaks. During such outbreaks severe damage to crops is experienced. Researchers have used cumulative December-January rainfall to explain observed outbreaks from 1947 to 1977 and have suggested that extra seasonal breeding is the main mechanism behind population outbreaks of these mice (Leirs *et al*. 1996). This logistic model shows that abundant cumulative rainfall at the end of a year is likely to precede an outbreak. However not all high rainfall years lead to outbreaks and vice versa. Inter-annual variation in demographic parameters remains unclear. A survival analysis of ten years of capture-recapture data was carried out. Results of this analysis are incorporated into a population dynamics matrix model. Two mechanisms, although not mutually exclusive, that might generate these outbreaks were examined through simulation: (i) extra-seasonal reproduction, (ii) increased reproduction and/or survival after long dry periods. Here we will present preliminary results of this analysis.

Survival and maturation probabilities were estimated by multi-state capture-recapture modelling based on ten years of monthly capture data at a 3 hectare mosaic grid. To ensure the most general model fits the data, all first individual capture histories were suppressed. Thus we carried out an analysis on the resident *Mastomys* mice on the grid. Covariates such as density and rainfall were included in a logit linear way. Model selection was based on AICc values. Point estimates for both adult and subadult mice survival and maturation probabilities, with their respective variation, were calculated using software package M-Surge. The estimates with their respective variation were used to build a three-stage matrix model, including juveniles, subadults and adults. The procedure IML of the statistical software package SAS was used to carry out the demographic simulations. Simulations are ongoing and the results will be presented at the conference.

Initial goodness of fit tests showed major deviations in both the assumption for trap dependence and transients. After suppressing the first capture history of each individual the most general model fitted the data sufficiently well. The model with the lowest AICc value has different covariates explaining variation in survival and maturation probabilities. In this model, cumulative rainfall over the past rainy season and peak density of mice during the previous year were used to explain variation in survival probabilities. For maturation the density the previous month and cumulative rainfall over the past three months were used as covariates. A positive effect for the covariates including rainfall was found in explaining both maturation and survival probabilities, while a negative effect was estimated for the covariates including densities.

In suppressing all first capture histories, the results of the survival analysis apply to the resident population only. The support for a model with a one year time lag of peak density suggests a trophic interaction in the population dynamics of *Mastomys natalensis*. A likely explanation for this mechamism of population regulation would be avian predation. Both Barn Owl (*Tyto alba*) and Black-shouldered kites (*Elanus caeruleus*) prey on *Mastomys*. Collections of Barn Owl pellets over a 4-year period showed both seasonal and inter-annual

variation in amount of mouse skeletons. Peak abundance of pellets occurs on average one month after mice peak densities. Cumulative rainfall during the wet season can be seen as a proxy for the amount of food available in the forthcoming dry season. As for the maturation rate, it has been suggested that sprouting grasses trigger the reproduction of *M. natalensis* (Firquet *et al*. 1996). Since the cumulative rainfall over the previous three months can be seen again as a trigger for growing green material, a positive relation was expected.

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DETERMINING THE FACTORS WHICH REGULATE THE DURATION OF THE BREEDING SEASON OF THE BRANDT'S VOLE (*LASIOPODOMYS BRANDTII*) IN TYPICAL STEPPE

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The duration of the breeding season is one of key parameters which defines the population dynamic of small mammals. We examined the factors which trigger the onset and end of the breeding season of a field population of Brandt's voles (*Lasiopodomys brandtii*) in the grassland of Inner Mongolia. We analysed the status of the vegetation in the grassland and the changes in population density to determine if they influenced the duration of the breeding season of the voles from 2003 to 2005.

The results indicate that the growth and biomass of grassland vegetation plays an important role in the onset of the breeding season in spring. The earlier the grass starts to grow, the earlier the voles start breeding. Moreover, the litter size is also highly associated with the vegetation biomass: a high biomass of fresh vegetation results in higher average litter sizes. However, the density of the vole population at the beginning of spring does not seem to have an influence on the onset of breeding or the litter size.

The effect of food supplementation on breeding in the vole population has also been assessed. In 2003 and 2004, we added special food (wheat) to over-wintering colonies in November and check the food effects in the following spring. In spring, monitoring of the voles showed that the breeding commenced about 20 days earlier in those colonies receiving supplemented food compared to voles in control colonies. Therefore food availability (quality and quantity) appears to be a key factor in triggering the onset of breeding in the field population. Moreover, the food supplement also highly improved the over-wintering survival rate of the Brandt's vole.

We also analysed various factors which may be important in the cessation of breeding in Brandt's voles. We conducted this experiment in 11 field sites in Abagaqi in August 2005. Our results indicate that the time voles stop breeding is significantly correlated with the vole density of each sample plot: higher densities result in earlier cessation of breeding. However, none of the vegetation factors (i.e. height, biomass, coverage, composition) of each plot appeared to influence the time breeding ceased. Further, the time that voles ceased breeding was not correlated with the timing of the start of the breeding season in that spring.

We concluded that the food and the population density were two key factors to determine the duration of the breeding season of the Brandt's vole. In spring, the food availability was the main factor to trigger the onset of the breeding. However, population density determined the cessation of breeding in Autumn.

LONG-TERM POPULATION DYNAMICS OF SMALL MAMMALS IN QINGHAI-TIBET PLATEAU

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Understanding the population dynamics of small mammals has played a key role in protecting local biodiversity and alleviating the degradation of grassland in Tibetan plateau. We analyzed the changing abundance of four small mammal species associated with the variation in climate, vegetation, and poison campaigns in Qinghai Province, People's Republic of China from 1978 to 2000.

Heavy snow occurring in winter or early spring could dramatically reduces the population density of plateau pikas (*Ochotona curzoniae*) which employ non-shivering thermogenesis to survive during the period of food shortage and severely low air temperature, but has less effect on root voles (*Microtus oeconomus*) which store food in winter. The population densities of plateau pikas and root voles decreased by >90% and 52.5% respectively while the population densities of plateau zokors (*Eospalax fontanierii*), the only subterranean rodent in the region, increased by 18.7% during the winter and early spring.

The population densities of root voles and Gansu pikas (*Ochotona Cansus*) showed a significant positive correlation with the height and cover of vegetation. Both species are found in greater abundance in those years when the rainfall and above-ground biomass of plant are relatively high. The population density of Plateau zokors was relatively stable during different years and was not strongly affected by climate factors such as precipitation, plant biomass and ambient temperature. The population densities of plateau pikas were always high during dry years when the biomass and cover of vegetation was reduced in the region.

After the commencement of a poisoning campaign conducted by local officers and farmers, plateau pikas and plateau zokors have declined progressively in abundance since 1989. However, these activities have not caused the eruption of root voles and Gansu pikas even though more space and food became available.

PREDATION ON TWO PREY TYPES: EXPERIMENTS WITH VOLES AND WEASELS

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Dissimilar vulnerabilities of different prey types and preferences of predators are factors likely to contribute to community dynamics. One way for this to happen is via predator-mediated apparent competition, in which the increase of one prey type has a negative effect on the other prey type indirectly via a shared predator. From the prey's point of view, species and sex-specific characters and environmental conditions are more or less fixed. However, changes in prey behaviour should increase its survival prospects. Examples in the evolutionary arms race between predator and prey should be seen in changes in space use and activity to avoid predation.

We have studied space use and activity of the prey and predation rate and preferences of the predator in the model systems consisting two sympatric vole species, either the field vole (*Microtus agrestis*) and the bank vole (*Clethrionomys glareolus*) or the grey-sided vole (*C. rufocanus*) and the bank vole and their common specialist predator, the least weasel (*Mustela nivalis nivalis*), in experiments in large outdoor enclosures. The two vole species represent different vole types that are thought to have different vulnerabilities, so that larger and clumsier species, the grey-sided vole and the field vole, are more vulnerable to weasel predation than the more agile bank vole, which may also use trees as a refuge. The first experiment, with field voles and bank voles, was conducted using constant vole densities but with varying relative abundance of the two species. In the second experiment with grey-sided voles and bank voles, the relative abundance changed during the experiment according to the weasel's hunting success. In this latter experiment also the habitat type was manipulated to provide different escape possibilities for voles.

In the first experiment, we found that weasels showed higher predation rates on bank voles, and that male weasels had higher predation rate than females. Weasels killed disproportionately more of the more abundant prey species, but they preferred bank voles over field voles when both were equally available. In the second experiment only a weak preference of the weasel on the grey-sided voles was found, and it was stronger in open habitats. A stronger preference was observed on male grey-sided voles than on females. There was no difference for bank voles. Grey-sided voles tended to enlarge their home range in the weasel presence and include more forest in their home ranges. Generally, voles increased their movements after weasel introduction, but especially immediately after introduction. Later, they matched their activity during the times of weasel inactivity. Fates of the voles depended on their mobility and sex. Females that moved more were killed by the weasel while males that increased their movements survived better than less mobile males.

Results suggest that the least weasel hunts according to prey availability and suitability of the hunting habitat. Results also suggest that the first reaction of voles to predation risk is to increase their movements, move away from risky areas and seek refuge. Later, if predation risk is ubiquitous, individuals restrict their movements towards times of lowered risk. Furthermore, the same anti-predatory strategies may contribute differently to the survival of different sexes. The conclusion is that even if the least weasel is a specialised predator of small rodents it acts like a generalist predator within the small rodent guild and may facilitate the co-existence of the prey species via predator switching. This may lead to often observed

inter-specific synchrony between prey populations. In terms of rodent management, the apparent competition might have potential applications. Let us assume that the more important pest species in a rodent community is also more vulnerable to predation than the other non-pest prey type, then it might be possible to control for pest density by combined predator and competition impacts. This may be possible by providing good conditions for the population growth of the non-pest type, which thus support relatively large predator population which is able to control the pest species.

HOW NOT TO GENERATE A MOUSE PLAGUE: MANIPULATIONS OF FOOD, WATER AND COVER FOR FERAL HOUSE MICE

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At irregular times in grain growing regions of Australia mouse populations increase rapidly leading to significant damage. We tested the factors that may cause this by manipulating food, water and cover for mouse populations living in a semi-arid agricultural cropping system in southeastern Australia.

On experimental treatment areas, *ad-libitum* food was provided in small plastic containers, freely available water was provided in drums, and cover was provided by laying out wire netting over the ground. The treatments were set out in a factorial design along 250 m sections of fenceline between crop and pasture fields.

There were few treatment affects on the population rate of increase throughout the experiment, although there were some marginal water by cover interactions. Natural cover provided by grasses and weeds growing along the field margins was more important than artificial wire netting cover. The results for survival and reproduction are still being analysed.

We conclude that we could not generate a mouse plague and that other factors, such as social organisation of related females, in combination with food, water and cover could be important in generating mouse plagues.

EVALUATION OF RAPTOR USE OF ARTIFICIAL PERCHES AND IMPACTS TO PRAIRIE DOG RODENT POPULATIONS IN THE USA

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Black-tailed prairie dogs (*Cynomys* ludovicianus) are burrowing rodents that once were very common across the plains of North America. Populations have been greatly reduced over the decades because of the damage they cause to agricultural crops, rangeland and property. They also pose a plague threat to people, livestock, and companion animals. Current efforts, however, are aimed at protecting some populations of prairie dogs while reducing conflicts with humans. Some populations are protected on public property, but methods are needed to reduce or prevent the expansion of those populations on to private lands where conflicts occur. We investigated the use of artificial perches, placed in prairie dog colonies, by raptors (hawks and owls). It was hoped that the perches would result in more predation by raptors on the rodents, and hence, prevent or slow prairie dog colony expansion.

The objectives of the study were to assess raptor use of artificial perches placed in 3 prairie dog colonies in Fort Collins, Colorado. Perches were observed from a distance in mornings and afternoons of the fall and spring. All observations of raptors, both flying and perched, were recorded. We also collected raptor casts (regurgitated pellets containing indigestible parts of animals consumed) from below the artificial perches so that we could determine the food habits of the raptors using those perches.

There were 75 observation periods for a combined total of 128 hours of observation of the artificial perches during the fall of 1999 and the spring of 2000. Raptors were observed during 63% of the 75 observations periods. Five species of raptors were observed. Raptors were seen flying during 51% of those periods and perching during 62% of those periods. A food habits analysis of 78 regurgitated pellets found beneath the artificial perches demonstrated a broad prey base, but one dominated by voles (*Microtus* spp.) and prairie dogs. It appears that artificial perches may increase raptor predation on prairie dogs and, thus reduce prairie dog colony expansion in urban-suburban settings.

HOME RANGES OF TWO SPECIES OF AFRICAN RODENTS

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The home ranges and movement patterns of African rodents are poorly known, but have been determined for *Mastomys* and *Lemniscomys* in various habitats in East Africa. Similar work, however, has not been conducted in southern Africa.

Field work was conducted in natural subtropical grassland in Swaziland, southern Africa. Rodents were trapped monthly on a 100 m x 100 m grid over a one year period. One hundred Elliot and Sherman live-traps were set 10 m apart on three consecutive nights per month. Each rodent was uniquely toe-clipped, sexed and weighed. Home ranges were calculated for two species *Mastomys natalensis* and *Lemniscomys rosalia* using the minimum convex polygon method. Only mice that were captured four or more times were included in the analysis, totaling 46 *M. natalensis* and 20 *L. rosalia*.

The home range for *M. natalensis* was 682 m^2 for males and 686 m^2 for females, the difference not being statistically significant. Similarly, there was no statistically significant difference in the home range of adults and subadults. *L. rosalia* ranged over a significantly larger area (1209 m^2) than *M. natalensis*. However, there were no differences between sexes and age in *L. rosalia*. In both species there was significant overlap in the ranges of both males and females, suggesting that territories were not being defended.

The home ranges determined from trapping on a grid as presented here are approximately half that of those from radio-tracking, suggesting that trapping significantly under-estimates the movement of rodents. Home ranges tended to be smaller on fallow agricultural fields where food is more abundant and rodent populations are higher.

The mean mass of *L. rosalia* is approximately 20% greater than that of *M. natalensis*, partly explaining the larger home range in the former species. In addition, *L. rosalia* is predominantly herbivorous, while *M. natalensis* is mostly granivorous.

EFFECT OF MASTING AND RODENT ABUNDANCE ON SEED PREDATION AND DISPERSAL BY SMALL RODENTS

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Mast seeding is a very common phenomenon in plants that are dispersed by seed scatter-hoarding animals. This reproductive strategy has been explained as an adaptation to satiate predators, and predator abundance affects the seed availability and the extent of satiation. However, most studies of mast seeding have focused on predator satiation. Few studies on seed predation have documented how seed dispersal changes with seed crop size, although seed dispersal dynamics are central to evaluating the hypothesized role of seed-dispersal mutualists in the evolution of masting. Besides seed abundance, the rodent population fluctuations also have an important impact on seed predation and seed dispersal, since both prey abundance (seeds) and predator density (seed-eating vertebrates and insects) are key factors determining the relative food availability. Hence, we need to assess the seed abundance and the predator population, as well as their dynamic interactions.

We studied how seed masting and rodent abundance influenced seed dispersal and predation by rodents in *Prunus armeniaca* (Rosaceae) in Dongling mountains of Beijing, China. We tracked the individual seeds marked with coded tin tags. The effects of seed abundance and rodent density were examined in a mast year and a non-mast year, and in three seasons (May, August and October) when rodent densities were different.

Most seeds were removed by the Korean field mouse (*Apodemus peninsulae*) and subsequently were taken into their burrows or buried in scattered, single-seeded caches within a distance of 35 m. Seeds that were not removed failed to establish seedlings. The seed removal was slower in the seed rich year. However, the scatter hoarding was greater, larder hoarding was lower, and seed dispersal was further in the mast year than in the non-mast year, suggesting better dispersal under high seed crop. In the mast year, in autumn, seeds were deployed and buried at greater distances, and had a higher probability of seedling establishment. The cache microhabitat did not strongly differ between the mast year and the non-mast year in this study. This result supports the opinion that masting does not influence cache site selection. All seedlings emerged at the edge of shrub cover. The seasonal trend was similar for two years with the seed removal rate decreasing in the following order: summer > fall > spring. The seed removal rates were positively correlated with the rodent abundance in different seasons.

Overall, the seed predation and dispersal of *Prunus armeniaca* are influenced by both mast seeding and rodent abundance. The scatter-hoarding rodents can select for large seed crop. For large-seeded *Prunus armeniaca* that are dispersed by scatter-hoarding rodents, mast seeding may be an evolutionary response to selection towards large synchronous crops resulting from seed predation. Changes in rodent abundance may facilitate the predator satiation, which may reinforce mast seeding.

Poster Presentations

DIFFERENT RESPONSES TO ACORN MASTING BY DIFFERENT SPECIES OF FOREST DWELLING RODENTS IN HOKKAIDO, JAPAN

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We analyzed the relationship between rodent population dynamics and acorn (*Quercus crispula*) masting using time series data (1992-2005) on three rodent species, *Apodemus speciosus, Apodemus argenteus,* and *Clethrionomys rufocanus*. The data were obtained at the Hokkaido University Forest in northern Hokkaido by live trapping for rodents and direct count of acorns on the ground. We examined the effects of rodent density and acorn masting to explain rodent dynamics.

Acorn abundance in the previous year significantly contributed to the abundance of *A. speciosus* in the current year. However, such effects were not detected for the other two species. Differences in effects of acorn masting among the three species may be caused by differences in their food habits and in their physiological tolerance of the tannins in acorns. Acorns of *Q. crispula* contain approximately 10% tannins, which are potentially toxic to rodents (Shimada and Saitoh 2003). Shimada *et al*. (2006), however, demonstrated that *A. speciosus* can detoxify the toxic effects by tannin-binding salivary proteins and tannase-producing bacteria. Thus, the *A. speciosus* population may positively respond to the acorn abundance. *A. argenteus* and *C. rufocanus* may not have such counter-active mechanisms against tannins and/or may not use *Q. crispula* acorns. Though *A. argenteus* is granivorous, they prefer smaller seeds to *Q. crispula* acorns. The feeding habit of *C. rufocanus* is intermediate between granivory and herbivory.

Further analyses demonstrated that the best model predicting *A. speciosus* abundance is as follows: $X_t = (1 + a_1)X_{t-1} + a_2A_{t-1} + a_3X_{t-1}A_{t-1}$,
where X_t is logarithmic abundance of *A. speciosus,* A_t is logarithmic abundance of acorns, and *a* are coefficients. The interaction term can be included in the density dependence term as follows: $X_t = (1 + a_1 + a_3A_{t-1})X_{t-1} + a_2A_{t-1}$.

Our modelling indicates that acorns may relax intra-specific competition between *A. speciosus* and the other two rodent species because *A. speciosus* uses *Q. crispula* acorns as a food resource.

References

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