# 10. Rodents

## 10.1 Resistance to anticoagulants

### 10.1.1 Resistance in the Norway rat

During 2002, a total of 346 Norway rats (*Rattus norvegicus*) from 37 municipalities were received for anticoagulant resistance testing. Warfarin resistance was found for the first time in the municipalities Augustenborg, Gram, Vojens, Tønder, Vejen, Blaabjerg, Gjern, Hadsten, Midtdjurs, Rougsø, Ry, Silkeborg and Sønderhald; coumatetralyl resistance in Gram, Vojens, Ry and Sønderhald; bromadiolone resistance in Augustenborg, Christiansfeld, Gram, Vojens, Vejen, Blaabjerg, Nørre Djurs, Ry, Skanderborg Sønderhald and Århus; and difenacoum resistance in Gram, Vojens, Vejen, Blaabjerg, Ry, Skanderborg, Århus and Brøndby. Brøndby is a municipality situated in the vicinity of Copenhagen whereas all other municipalities mentioned are situated in Jutland.

J. Lodal

### 10.1.2 Population effects of anticoagulant rodenticide resistance in Norway rats

A Ph.D. study investigating the effects of anticoagulant resistance in populations of Danish Norway rats was finished in May 2002.

Resistance to anticoagulant rodenticides in Norway rats is documented to be associated with pleiotropic effects, notably with an increased dietary vitamin K requirement. The aim of this study was to quantify these effects in populations of Norway rat in Denmark and to see how they manifested themselves by differential selection depending on whether anticoagulants were being used or not. Experimental breeding populations were established under semi-natural conditions with wild rats trapped at two Danish farms, where bromadiolone resistance was prevalent. The individuals caught on each of the two farms were divided into two experimental groups. One group was regularly exposed to bromadiolone (treatment group) whereas the other group was untreated. The two treatment populations were exposed to bromadiolone bait (0.005 %) for one week twice a year. The level of bromadiolone resistance in the four experimental breeding populations was followed for two years.

Resistant rats were found to be favoured in the treatment populations, whereas pleiotropic selection against resistance in the two non-treatment populations was found to be insignificant. We did not find a reduced tolerance to 0.005% bromadiolone when rats, from the non-treatment populations, were tested in a subsequent no-choice feeding test. We concluded that absence of anticoagulant, under the environmental conditions provided, did not lead to a selection favouring sensitive rats. However, selection against presumed homozygous resistant rats under non-anticoagulant conditions was suggested as some animals that died showed clear signs of haemorrhage though they had not been exposed to anticoagulants. Haemorrhagic symptoms are not only observed in sensitive rats that have been exposed to anticoagulants but are also a symptom for severe vitamin K deficiency in resistant rats. This suggests that bromadiolone resistance leads to loss of fitness, albeit the cost is not strong enough to reduce the phenotypic resistance level or counteract the effect of genetic drift.

The Blood Clotting Response (BCR) test was implemented in this study and used for the identification of bromadiolone resistance in two Danish rat populations. In order to evaluate the BCR as a possible substitute or supplement for the no-choice feeding tests in the Danish monitoring programme, 254 rats (progenies of the experimental breeding populations) were tested in bromadiolone BCR and a subsequent 0.005% bromadiolone no-choice feeding test. The BCR test was found to be superior to the feeding test in the identification of bromadiolone resistance and as such recommendable for implementation in the Danish monitoring programme. However, the BCR test could not be used to predict the degree of resistance in the examined

rats. Thus, the test was incapable of differentiating between rats being either a potential control problem or not.

In this study molecular markers were introduced in order to elucidate different population genetic aspects of the Norway rat. Mating and reproductive success are impossible to observe or measure in free-ranging populations of rodents due to their secretive nature. For that purpose molecular markers have shown to be powerful. Five different multiplex polymerase chain reaction (PCR) systems were developed from already known *Rattus norvegicus* specific microsatellite primers.

A total of sixteen microsatellites were used to estimate effective population sizes ($N_e$) in the four experimental breeding populations over the study period of two years. Two different estimates of $N_e$ were used and compared. One estimate was based on a maximum likelihood approach using observed temporal changes in allele frequencies and the other estimate was based on knowledge obtained from parentage assignments of the actual number of reproducing individuals and number of progeny assigned to the individual parent. The two estimates were of comparable sizes and we found both estimates of $N_e$ to give reliable estimates.

The sixteen microsatellite markers were furthermore used for parentage assignment using the software package CERVUS 1.0. The resolution of the used markers proved to be too low to resolve the parentages with high confidence. However, we were able to utilize detailed information on the "life history" of most of the implicated individuals, which proved to be valuable for the evaluation of the individual assignments. Thus, despite the lack of genetic variation we achieved a success rate of 77% to 94% for first parent assignments and 67% to 87% of the offspring was successfully assigned to a second parent.

In addition, multiple paternity was verified in wild Norway rats based on the usage of microsatellite markers. Though the power of paternity assignments in CERVUS is sensitive to relatedness among candidate fathers, the likelihood-based approach was found to be superior to the method based on presence of non-maternal alleles. Furthermore, the CERVUS assignments are considerably more informative on mating strategies in populations of promiscuous individuals than would be obtained from mere observations.

Though the number of litters is too low to draw definitive conclusions, the data do indicate that there is an age-dependent mating strategy. The older females mated with one single older male, whereas younger females tended to mate with multiple mates. It is speculated that mating among older individuals to a higher extent is dominated by pre- and post-copulatory mechanisms than among the younger and inexperienced individuals.

A.-C. Heiberg

### 10.1.3 Vitamin K requirement in Danish anticoagulant-resistant Norway rats

A M.Sc. study investigating vitamin K requirement of Danish bromadiolone resistant Norway rats was finished may 2002.

Today one of the consequences of anticoagulant resistance in Norway rats (*Rattus norvegicus*) that has been acknowledged in British resistant rats is increased requirements of dietary vitamin K. The purpose of this study was to 1) elucidate the level of vitamin K requirement of Danish anticoagulant-resistant Norway rats and 2) to examine if anticoagulant resistant rats from different geographic localities had different requirements of vitamin K. Wild bromadiolone-resistant rats sampled from different localities in Denmark and rats from bromadiolone-resistant and susceptible laboratory strains were fed on a vitamin K deficient diet over a maximum period of 15 days. Development of vitamin K deficiency was found in 43% (N=106) of the Danish resistant rats. The level of vitamin K requirement was found to be moderately increased compared to susceptible rats and resembled that of the Scottish resistance type that has been identified in the UK. We found that development of deficiency was slower for resistant rats that were vitamin K3-supplemented prior to the feeding test, suggesting storage of the vitamin K body pool. We did, however, not find evidence of a

locality-dependent response to the vitamin K deficient feeding that could indicate that more than one type of anticoagulant resistance was present in Denmark.

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## 10.2 Other work on rodents and rodent management

### 10.2.1 Pest problems in organic pig production

Within the framework of the Research Programme for Organic Agriculture (FØJO/DARCOF) a collaborative research project entitled "Management in relation to health and food safety in organic pig production" was started in 2001. Researchers from the Danish Institute of Agricultural Siences and the Royal Veterinary and Agricultural University and DPIL make up the project group. DPIL has a work package "Development of strategies for pest management in selected production systems". A questionnaire survey has been conducted as a first step for identification of pest problems and pest-supporting factors. The results of the survey showed that rats and smaller rodents (mice and voles), foxes and hares were the most frequently occurring mammals in fields with pigs. The farmers considered rats and foxes to be the most important (pest) problems. Occurrence of rats is reported significantly more frequently in organic pig farming than in traditional pig farming in open fields. The answers given by the farmers have been analysed further as to possible relationships between occurrence of / problems with rodents and the practice regarding the pig farming. The results of the analysis indicate certain factors that may be practicable as preventive measures against rodents. The type of feeding and water supply systems, type of hut and the distance to stacks of hay and straw in the fields are examples of factors to be considered by farmers when a production system is to be established. The second step of the project is more direct ecological studies of the rodents at two selected farms with the aim of defining the key factors that may be limiting for the size of the pest populations. The field studies will continue in 2003.

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### 10.2.2 Rodents, *Salmonella* and *Campylobacter*

A collaborative research project involving researchers from the Danish Veterinary Institute, Zoological Museum and DPIL entitled "Wildlife as a source of salmonella infection in food-animal production" was initiated in 2000 and is to be finalized in 2003. Due to supplementary funding it has become possible also to include campylobacter in the project. Farms with pig, cattle or poultry or without production animals have been included. As part of the project rats, mice and voles have been trapped or faeces from the rodents have been collected. The data are now being analysed, and the results will be published elsewhere.

J. Lodal

### 10.2.3 STAPLERAT: Protecting staple crops in eastern Africa: integrated approaches for ecologically-based field rodent pest management

STAPLERAT is a collaborative project with different partners in Africa and Europe: DPIL, University of Antwerp, Belgium, University of Rome “La Sapienza”, Italy, University of Oslo, Norway, Sokoine University of Agriculture, Morogoro, Tanzania, Rodent Control Center, Morogoro, Tanzania, Kenyatta University, Nairobi, Kenya, Addis Ababa University, Ethiopia and Mutanda Research Station, Solwezi, Zambia. DPIL co-ordinates the project.

Two years have passed in the STAPLERAT project and all studies are well established with a large amount of data collected already. Although some of the data analyses are still preliminary a number of interesting results can already be listed from the data. Brief summaries of achievements in each work package are listed below.

**Identifying the pest rodents.** Genetic work on the rodents present in staple crop fields in Ethiopia, Kenya, Tanzania and Zambia has identified several species of the genera *Arvicanthis, Tatera, Mastomys, Aethomys, Mus, Lemniscomys* and *Cryptomys*. Often more than one species of a genus occur at the same site, which is important since different species may have different properties with regard to damage or control. Further species identifications will be carried out for rodents belonging to the genus, *Grammomys, Graphiurus, Acomys, Mus, Praomys (Myomys), Dendromus* (?), *Thallomys, Lemniscomys* and *Tachyoryctes*.

The taxonomic collections of rodents have identified the five most important potential pest species from the study sites: *Mastomys sp.* in all study sites, *Arvicanthis sp.* in Ethiopia and Kenya, *Tatera sp.* in Ethiopia and South Tanzania, *Saccostomus* sp. in Zambia and *Mus sp.* in Zambia and Kenya. *Mastomys sp.* is by far the most abundant species at all sites although *Arvicanthis sp.* is also abundant in Ethiopia. The relative density of the rodent species at different growth stages of the maize fields shows very different patterns between countries. Such variations are probably related to the reproductive patterns and will be investigated more intensively by an examination of reproduction patterns in rodents from removal grids.

**Damage characteristics.** Data from the farmer participatory research (FPR) have been analysed for Ethiopia showing that the majority of farmers are small-scale farmers, who cultivate fields of about 1-1½ ha. Most farmers ranked rodents as crop pests higher than insects and reported maize to be the most affected crop. The farmers experienced highest damage during planting of the maize and therefore applied rodent control before planting. This shows that the farmers know when rodent control is most effective. The farmers use several control approaches but field sanitation is prioritized very low. It is therefore doubtful whether the farmers realise the importance of field sanitation in reducing rodent numbers and crop damage.

The damage assessments in Tanzania show that rodents are not the sole source of damage to maize. However, both crop yields and rodent populations were unusually low, probably due to very limited rainfall, and the damage patterns may therefore also be affected.

**Economics and effects of control.** An important preliminary result of this work package is that rodent control must be highly effective in reducing population size in order to give a damage reduction, which is economically interesting. The data, however, are still too scanty for a proper analysis, and more complete results are only expected after the third year.

**Rodent population dynamics.** The capture-recapture studies in maize fields continue in Tanzania and Zambia but were terminated as planned in Kenya.

*Mastomys* is the most important rodent genus in all study sites but *Tatera sp*. is also fairly abundant in the Southwest Tanzanian study site. Seasonal variations in the rodent populations are apparent in the two study populations from central Tanzania. The study populations from Southwest Tanzania and West Kenya on the other hand show no seasonality, although reproduction seems to be restricted to a specific period in Southwest Tanzania. Due to a large data gap in Zambia the population dynamics patterns cannot yet be investigated. Preliminary studies of key factors in one of the central Tanzanian populations show that features favouring survival are particularly important outside the breeding season, whereas features favouring reproduction are of course only particularly important during the breeding season. This would suggest that the most efficient way of affecting population growth is by affecting survival outside the breeding season. The key factor approach will be adapted for all study sites in the coming project year as well as further demographic analyses will be carried out.

**Population models and early warning systems.** Historical outbreak data have still been very difficult to obtain, but the effort continues to locate those data. Historical rainfall data have been obtained from the sites of the WP4 study in Kenya and Zambia as well as from additional areas in Zambia where outbreaks have been recorded previously, but since rainfall data must be matched with the historical outbreak data this task has been postponed again.

Habitat studies show that the demography of *M. natalensis* is basically similar in fallow land, maize fields in monocultures and maize fields in mosaic cultures of field and fallow land. This finding entitles previous models from fallow land to be used in maize field situations with only minor changes to be adapted.

Spatial studies show that 0.5 ha maize fields are recolonized very quickly after control actions during the planting season. The speed at which this happens is not dependent on the success of the control action, thus suggesting that the rodents are very mobile and that control actions have to be synchronized over large areas to be effective.

Due to the delay in the outbreak and rainfall data tasks it has not yet been possible to develop the prediction models. Still, a formal analysis to evaluate the economic benefits of forecasting rodent outbreaks has been carried out. When using forecasts the farmers can minimize the economic impact of rodents.

**Bioeconomics in rodent management.** The originally planned work for this work package was already finished earlier than scheduled during the first year and therefore the opportunity has been taken to take the work further than anticipated. We did this by using a comparative approach, comparing our data on African multimammate rats with the situation with other species on other continents and pointing out the generic nature of the bioeconomic approach.

**Protecting seed with repellents.** Three identified seed dressing compounds (HALT, Thiram and Cinnamamide) were used to treat maize seeds and tested for repellent effects on *M. natalensis* in choice and no-choice laboratory experiments and in outdoor pens. The results show clear potential for Thiram and Cinnamamide to protect seeds from rodent damage whereas HALT in some cases (i.e. the outdoor experiment) causes increased damage to seeds compared to untreated seeds. Further studies will establish the efficacy of Thiram and Cinnamamide as repellent compounds in the field.

**Biological control with predators.** The study has been delayed in Tanzania due to initial reluctance among farmers, but has now been established since April this year. Consequently, few data are still available. The study in Kenya, on the other hand, has been very successful with a high occupancy rate of barn owl nest boxes and a high owl-breeding index already. A large number of avian pellets has been collected and identification of prey species composition in the pellets has started. The appearance of pellets shows high seasonal variation with one peak in a year at one study grid and two peaks in a year at another study grid. These findings suggest that barn owl populations have been limited in nest site availability and that the populations may very well be increased by the application of artificial nest boxes. The owls' potential as biocontrol agents will be evaluated by investigations of the effects on the rodent population.

**Agroforestry as a rodent management tool.** The use of *Tephrosia vogelii* as a repellent agent and a physical barrier to mole rat activity has yielded very promising results in Zambia so far. Its presence in cassava fields, planted as an intercrop or as a fence, reduced the mole rat activity in the fields significantly. The cassava harvest in the coming year will show whether this has a positive effect on the final yield per field.

In contrast, the plant has difficulties establishing at high altitudes of Ethiopia (where enset grows), in spite of many attempts to improve the growth conditions. Consequently mole rat damage is unaltered in the enset farms. Attempts have been made to introduce the plant at a lower altitude and results show that the growth there is faster suggesting that climatic conditions may prevent the use of *T.vogelii* as a mole rat control strategy in enset growing areas.

S. Vibe-Petersen, H. Leirs and J. Lodal

### 10.2.4 Population ecology of the African multimammate mouse *Mastomys natalensis*

S. Vibe-Petersen finished the data analysing of her Ph.D. project ”Predation pressure and population dynamics in African *Mastomys* rats: possibilities for integrated pest management?” The research project began in November 1997 and evaluates the effects of predation pressure on the population dynamics of the most common rodent pest species in eastern Africa, the multimammate mouse *Mastomys natalensis*. The research was conducted in Tanzania in small (0.5 ha) maize fields where natural rodent populations were subjected to a combination of predation and dispersal treatments. Three levels of predation risk were used: no predation pressure (excluding predators by nets), natural predation pressure (unmanipulated control) and increased predation pressure (attracting predators by nest boxes and perch poles). Because dispersal of the rodents could mask the effects of predation, control and predator exclusion treatments were repeated in enclosures. Monthly rodent data were collected by a capture mark-recapture study.

*M. natalensis* population growth during the increase season was faster in the absence of predators and peak population size increased. Otherwise dynamics patterns were similar for populations where predators had access or were attracted, suggesting that compensatory mechanisms operate when rodents are exposed to high levels of predation risk. Reducing dispersal of rodents removed the negative effect of predation pressure on population growth and peak size, suggesting that predators may be a strong driving-force for emigration in *M. natalensis* populations.

Maize yield was largest in fields where predators were attracted, despite the fact that the population dynamics did not differ from fields where predators had access. This indicates that other factors than direct mortality caused by predators affected the rodent damage to the crop.

The body weight of subadults was highest in populations where predators were attracted in the first population increase season, but highest in populations where predators were absent in the following increase season. Predation pressure may reduce the prey’s foraging activity, whereas the reduction of population size due to predation (“thinning”) may improve conditions for the survivors due to decreased intraspecific competition. We propose that when food is abundant, increased predation risk negatively affects individual body weight of rodents by reducing their foraging activity, while thinning has no compensatory effect. When food becomes depleted, increased predation risk has no effect on individual body weight, but thinning affects it positively.

Modelling survival and capture probability showed that attracting predators increased the survival probability of subadult females in the annual population increase season. For subadult males the survival probability increased both when predators had access and were attracted. Dispersal lowered the survival probability and in subadult males could explain the difference observed between predation treatments whereas in subadult females it could not. In the annual population decrease season the survival probability decreased when predators were attracted, especially for subadult males. Dispersal lowered the survival probability but only for subadult females.

Predation may affect the survival probability of subadult *M. natalensis* both negatively and positively. The findings suggest the existence of a compensatory mechanism when subadult females are exposed to high predation pressure. We propose that during the increase season when food is still available and predation pressure only slowly increases, increased predation pressure selects for the female individuals with the lowest fitness thereby improving the conditions for the remaining female individuals and increasing their survival probability. During the population decrease season when food becomes increasingly sparse and predation pressure high, both subadult females and males trade off energy gain against survival, thereby increasing exposure to predation and decreasing the survival probability.

Excluding predators extended the period of sexual activity in *M. natalensis* females and tended to lower the proportion of breeding females, probably due to an increased density of sexually active but non-breeding females. The sex ratio differed between predation treatments at capture sessions around the population peak and/or at capture sessions during the decrease season; in most cases the proportion of females was lowest in fields where predators had access or were attracted, indicating that predators selectively predate on females.

Despite this, the predatory effect on onset and cessation of actual breeding, on breeding intensity and thereby on reproductive output was insignificant, probably due to a low presence of avian predators during the main breeding season.

The results suggest that the use of avian predators as a single control approach of *M. natalensis* may be ineffective in reducing rodent density, since the avian predation pressure was low during the breeding seasons in our study years and was only built up with a delay of some months to the annual prey population increase seasons. Still, because this pattern of predation pressure depends on the types of avian predator species that inhabit the population, it need not mean that avian predators in general may be ineffective bio-control agents of *M. natalensis*. In years with off-season breeding, the breeding will coincide with the high avian predation pressure. Hence, it is possible that avian predators have an impact on breeding in years with a potential risk for population eruption. Further, although manipulating predation pressure by perch poles and nest boxes may not affect the rodent population dynamics directly, it may still have an indirect beneficial effect on maize yield.

S. Vibe-Petersen