FINAL PUBLISHABLE SUMMARY REPORT (APODYNA, 220322, AF Malo)

The work carried out to achieve the project's objectives included the selection and set up of a study site in a 1.7 ha mixed deciduous woodland area located at Silwood campus (Imperial College London), Ascot (OS grid ref.: SU 9430 6920). A grid (fitted with flags) containing 170 10x10m quadrants (Fig.3) was set up and a wood mouse population monitored weekly. Individual-, population-state and environmental variables were recorded at different spatial and time scales.

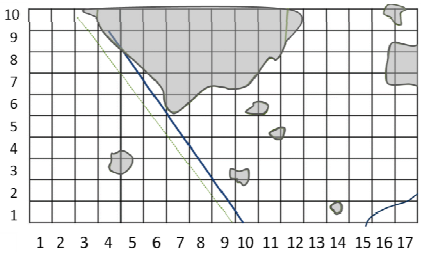

Fig.1 Study site at Silwood Park. Grey patches, blue lines and squares depict rhododendron areas, water streams and 10x10m quadrants, respectively.

Weekly trapping sessions (n=98; 50-170 Sherman live-traps/trapping session; Total trapping effort>7000traps/night; Trapping events>1100; Mice caught=270) were conducted during the total time of the study to collect **individual state variables** (phenotypic and behavioural). Trapping success and individual trap location (quadrant and microhabitat characteristics) was recorded. Upon first capture mice are individually marked, sexed and aged and the following phenotypic data collected: *Anogenital distance* (recorded to indirectly estimate exposure to testosterone levels at gestation), *foot length, tail length*, *body weight* (as an indicator of body condition). *Ecto-parasite* intensity was recorded due to its associations breeding success and survival (larvae, nymphs and adults of *Ixodes ricinus* and *I. Trianguliceps* and the parasitic beetle *Leptinus testaceus*). Implanted PIT-tags and fur clippings allowed for individual identification of adults and juveniles respectively. *Behavioural traits* include behavioural scores at handling and space use. *Space use* was recorded from trapping data and from a new tracking method set up by the fellow consisting in a weather proof rugged box (fig 2) containing two side pipe made entrances leading to a wood chamber fitted with an antenna connected to an ID data loggers (Francis Scientific Instruments; see prototype in Fig.3). Ten ID readers have being rotated randomly around the plot on a daily basis to continuously monitor (24 hours, 7 days a week; third of a second time resolution) mouse presence. Batteries were replaced every10 days. Home range and quality will be estimated from the detailed space use data using a generalised linear mixed modelling framework that corrects for spatial and temporal autocorrelation. The reader units in the plot will also render individual activity rhythm data and social interaction data that will be analysed within the frame of social networks to analyse the interactions between mice in time and space. **Population state variables** included: *sex ratio*, *age structure* and density. **Environmental data collection** included abiotic and biotic factors (which have been recorded at different scales for the last 2 years). Weather data (temperature, humidity and rainfall) has been recorded daily at a regional and local scale. Moon light intensity, which has an effect on habitat use and perceived predation risk, has been recorded daily to test for moon cycle-driven temporal biases in mice density estimates. Microhabitat structure and plant species composition per quadrant (10x10m) has been mapped to include in the models as potential predictors of space use by mice. More specifically, *number, diameter and length of logs, tree stumps, piles of woody debris, shrub cover* (by season), *proportion of ground cover of different species, tree composition, diversity, number* (n=2994) and *size* were recorded. The last 4 variables also allowed calculating seed crop per quadrant as an estimator of food availability in autumn and winter. Tick surveys and invertebrate pit fall trappings have been conducted in spring and summer per habitat type (8 categories) to characterize exposure to *ectoparasites* and *invertebrate food abundance*. *Canopy cover* per quadrant has also been recorded as a contributing factor to predation risk in spring and summer.

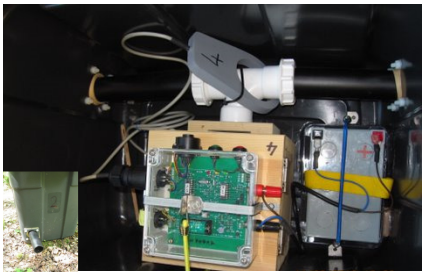
Fig.2 Individual data logger fitted in a weather proof box.

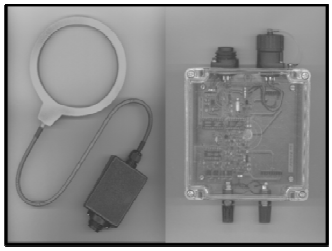
Fig.3 Antenna and data logger unit designed and manufactured by Mike Francis.

Results

What specifically has the Apodyna project shown up to date?

First, we have shown that an invasive species with pervasive effects in native woodland dynamics can, at the same time, have a positive effect on native fauna. **The invasive *Rhododendron ponticum* shrub has a positive effect on the wood mice** (*Apodemus sylvaticus*), sustaining 2-5 fold larger densities than surrounding their native open deciduous woodlands. This has been shown by analyses of the weekly trapping data generated during the past 2 years in the study site set up by the researcher at Silwood Park (results presented at the ESA 2010 Meeting in Pittsburgh; *Malo et al. in prep for J. Anim Ecol*). Further results (see below) suggest different selective pressures operating in the two contrasting habitat types.

Second, we have also shown that the native fauna can have positive effects on invasive plant species. A seed removal field experiment showed that **mice transported native tree seeds from the open and edge woodland areas into rhododendron patches and not the opposite, indirectly increasing seed mortality of native species** (hazel, oak, beech, birch...) which are unable to germinate under the dense *Rhododendron* cover. These results suggest an association between mice and *Rhododendron* by which 1) **mice derive anti-predatory benefits from preferentially using Rhododendron areas** (predictably increasing survival and reproduction) and 2) the **rhododendron outcompetes native woodland species by "using" mice to decrease native seed survival**. This effect occurs more strongly on the *Rhododendron* edge -where the competition for light between the invasive and the native plant species is stronger- where mice literally wipe out the seeds of competitor native tree species tipping the balance towards the invasive *Rhododendron* (results to be presented at the ISBE 2010 Meeting in Perth; *Malo, Taylor, Coulson in prep. For Biology Letters*).

Third, **mice recapture rates are significantly affect by rhododendron cover, year, season, temperature, rain, moonlight and microhabitat structure, as well as by some of the interactions** (as shown by live-trapping data). This suggests that recapture

rates and survival estimates (which are calculated from recapture rates in mark-recapture analyses) can be biased if trapping protocols do not control of data analyses do not account for these sources of variation. The seasonal interactions are notable and highlight the shift in the selective pressures *Apodemus* suffers in temperate latitudes from autumn-winter (non reproductive) to spring-summer (reproductive season). During autumn and winter maximizing survival seems to shape mice behaviour through a minimization of predation risk factors (including , whilst during spring and summer those factors such as moon, rain and temperature the importance of survival seems to decrease and mice tend to maximize reproduction opportunities (*Malo et al. in prep*). More complex analyses characterising the phenotypic contributions to demographic rates such as reproduction and survival, and hence to population growth rate, are underway and should be submitted to a high impact journal in the following months.

Complementary to the trapping data base generated (including all the phenotypic records from the mice), the data loggers rotating in the study site have generated a data base comprising more than 60.000 mouse records that will allow us to ascertain the importance of temporal and spatial use patterns on reproduction and survival. The likelihood of these results being published in a high impact factor journal is high.

Other more specific results with lower general impact in the field but equally publishable in more specialised journals (parasitology and behaviour) include the lower tick presence in *Rhododendron* areas as compared to open woodlands that lead to lower ectoparasite intensities in those mice which preferentially use the *Rhododendron* (*Grange and Malo in prep*) or the results showing the difference differences between non-reproductive and reproductive individuals in their stress levels as inferred from the behavioural scores.

Conclusions, potential impact and use and socio-economic impact of the project

Rhododendron areas have the potential to increase mice population growth rates by reducing predation risk. *Rhododendron* patches have also the potential to increase landscape connectivity between mice populations and hence has implications for disease spread dynamics in rodents. Taking into account the increase disease risk that climate change is now assumed to be promoting, the **scientific community and public health bodies** should see these new results with interest. The starting ERC Advance Grant awarded to Prof Coulson and instigated by the fellow will allow tackling this question further.

Mice might have contributed to the spread of *Rhododendron* throughout the woodland understory of UK islands. The ecological deleterious effects of *Rhododendron* include the disruption of natural woodland regeneration and the modification of successional changes, which lead to a decline in community plant diversity in any community where it becomes established. Economically, the cost of controlling this species has been estimated in as much as £10,000 per hectare. The basic and applied interest of understanding the biological factors influencing establishment and invasion by *R. ponticum* has been stressed in the literature. Hence the results of the project will benefit and attract the attention of the **scientific community and of land managers and policy makers across the UK**. The project has highlighted an important interaction between an invasive species and mice that may well be occurring elsewhere in the globe with different invasive plant and native species, so expectedly the audience interested on these results should be wider. Discussions held recently at the Ecological Society of America meeting with world experts on invasive species suggest this will be the case.

The new rodent tracking device and protocol conceived by the fellow will be of interest to **ecologists and rodent experts worldwide**. A note describing how the method works will be soon submitted to *Journal of Mammalogy*. This method has already generated a heavy data base (>60.000 records) that will allow construction of mice social networks to unravel the way in which different sex, age classes and phenotypes interact in space and time on natural settings. Given the importance of social interactions in disease spread, again this part of the project should be of interest to **public health bodies** and civil society.

The detailed decomposition of the factors contributing to recapture rates (individual phenotype, population state variables, microhabitat and weather variables) should receive the attention of **demographers and ecologists** working on population dynamics in wild populations.

The academic community at Imperial College have benefited from the project. **Imperial College students** (1 Mres, 5 MSc. and one PhD student) have directly benefited from the project by conducting their research under the Marie Curie fellow supervision. First and third year biology undergraduate and master students from Imperial College have been trained in small mammal trapping by the fellow and received lectures on the topic.

Scientific progress in ecology and evolution has been greatly advanced by long term ecological studies such as those conducted on the Red deer (Rum), Soay Sheep (St Kilda) or the Bighorn sheep (Rocky Mountains). This is because their holistic approach to ecological questions and the in-depth analyses they allow to be conducted on the different abiotic or biotic factors and interactions explaining natural phenomena, allow to effectively test simple or complex hypotheses robustly, avoiding the pitfalls of spurious results that might emerge when we rely on assumptions required in more constrained experimental settings. The Marie Curie funded Apodyna project started with the general aim of establishing at Silwood Park a long-term study on rodent population dynamics. The project seems to have achieved this goal. The study site set up, the individual-, population-based and environmental data (weather and microhabitat) collected throughout these two years and the results generated by the Marie Curie fellow and his team (Mres and MSc. students) have generated two impressive data bases, have been considered worth supporting further and having contributed to a 5-year ERC award to Professor Tim Coulson (the Marie Curie fellow supervisor). This project will use a novel wireless sensor network array technology to detect mice that will mainly help address fundamental questions about the relationships between ecological an evolutionary processes, as well as addressing questions related to disease spread dynamics of high applied interest. The continuation of the mouse research at Silwood Park shows the great interest the project has generated as well as its viability. The use in the later ERC project of the data and background results generated from the previous Apodyna project will act synergistically to increase our understanding of the determinants of fitness in wild populations.

A**ddress of the project Website**: http://www.bio-demography.org/aurelio.html

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