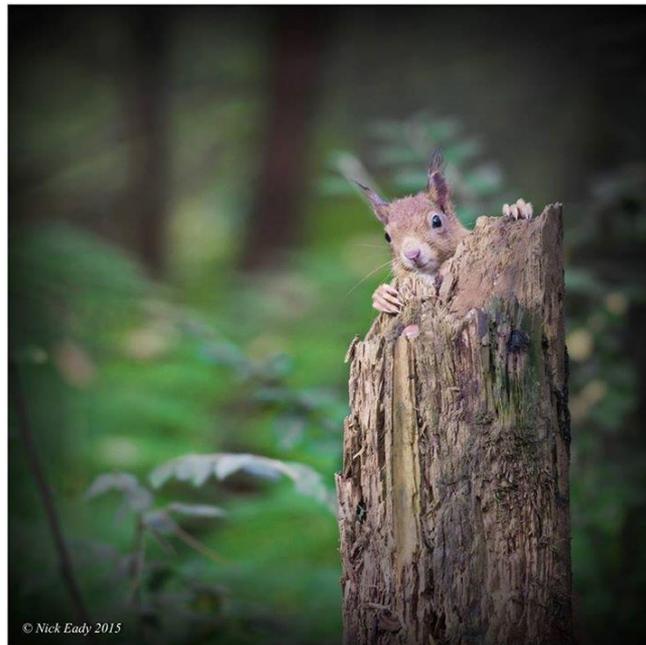


Red Squirrel (*Sciurus vulgaris*) Conservation Plan for Anglesey & Gwynedd



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Executive Summary

This Action Plan provides detailed conservation prescriptions and guidance to secure the long term sustainability of the single red squirrel (*Sciurus vulgaris*) population distributed across Anglesey and adjacent northern Gwynedd woodland landscapes. We present aims and associated objectives in relation to grey squirrel control, epizootic infections, habitat management and squirrel population monitoring. A legislative review is included to inform local woodland managers and to assist with policy making decisions. Community and regional stakeholder involvement have been integrated into delivery of conservation outputs. The probability, likely scale of impact and measures necessary to mitigate or prevent, risks to successful red squirrel conservation are presented. The Action Plan also highlights areas of scientific uncertainty where future detailed research would guide in situ red squirrel conservation.

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¹ Reproduced from the Red Squirrels United project

1a) Introduction & Background

Red squirrel (*Sciurus vulgaris*) populations have declined across the United Kingdom (UK) as the result of competition from, and epizootic infections (e.g. squirrelpox virus) spread by, the introduced eastern grey squirrel (*Sciurus carolinensis*)¹. Grey squirrels reached the mainland county of Caernarfonshire in the late 1950s, and after colonising the adjacent island of Anglesey in the mid 1960s, a typical pattern of regional red squirrel extinction was observed, with populations being lost first from broadleaved and mixed woodland habitats. The species was latterly confined to spruce dominated stands within the commercial Mynydd Llwydiarth plantation by the late 1990s. These animals were sympatric with grey squirrels that had colonised the forest.

In 1998, grey squirrel control efforts were implemented to restore red squirrels to their historical range on Anglesey². Parallel, and phased, red squirrel reintroductions complemented the natural increase in remnant wild population numbers³. The successful eradication of grey squirrels and restoration of red squirrel island range was documented⁴. Natural dispersal into mainland woodlands was first recorded in 2009 when two male red squirrels were discovered. Subsequently a small mainland red squirrel population established and occasional dispersal was recorded up to 15km inland.

The Menai Strait is a natural feature within the current red squirrel range. Studies have shown that both red and grey squirrels can cross the sea-channel (most likely by swimming or using one or both of the bridges spanning the strait), and thus it does not represent an impermeable boundary to dispersal⁵. Modelling has subsequently shown that without intervention, natural reinvasion of the island by mainland grey squirrels would occur⁷. There is also a risk that intra-specific infection could occur as red squirrels disperse between the island and mainland populations.

¹ Gurnell et al. (2015) Years of interactions and conflict in Europe: competition between Eurasian red squirrels and North American grey squirrels pp19-38 In: Shuttleworth, Lurz & Hayward (Eds.) Red Squirrels: Ecology, Conservation & Management in Europe. ESI, England.

² Shuttleworth CM (2003) A tough nut to crack: red squirrel conservation in Wales. *Biologist* 50, 231–235.

³ Shuttleworth, C.M., Kenward, R.E. & Jackson, N.J. (2016) Developing red squirrel re-introduction techniques for use during regional grey squirrel eradication programmes in Europe. In: 2015 Global Reintroduction Perspectives. Ed. Soorae P. IUCN/SSC Re-introduction Specialist Group.

⁴ Shuttleworth, C.M., Schuchert, P., Everest, D.J., McInnes, C.J., Rushton, S.P., Jackson, N.L. & Kenward, R.E. (2015) Developing integrated and applied red squirrel conservation programmes: What lessons can Europe learn from a regional grey squirrel eradication programme in North Wales? pp. 233-250. In: Red squirrels: Ecology, Conservation & Management in Europe. Eds. Shuttleworth C.M., Lurz, P.W.W. & Hayward M.W. ESI.

⁵ Signorile & Shuttleworth (in press) Genetic evidence of the effectiveness of grey squirrel control operations: lessons from the Isle of Anglesey In: Shuttleworth, Lurz & Gurnell (Eds) *The Grey Squirrel: Ecology & Management of an Invasive Species in Europe*,

⁶ Shuttleworth, Lurz & Gurnell (in press) *The grey squirrel: Ecology and management of an invasive species in Europe*. ESI, Suffolk, England.

⁷ Jones et al. (in press) Mathematical models of grey squirrel invasion: a case study on Anglesey. In: Shuttleworth, Lurz & Gurnell (Eds) *The Grey Squirrel: Ecology & Management of an Invasive Species in Europe*,

The Anglesey red squirrel population is one of three identified 'focal populations' prioritised within the Wales red squirrel conservation plan (Wales Squirrel Forum 2009)⁸. It is currently the largest and most genetically diverse⁹ in Wales. Animals are resident within a wide range of different woodland habitat types and uniquely this is the only focal population where individuals occupy broadleaved woodland and where they are common in garden habitats¹⁰.

The area occupied by red squirrels is currently (2016-2019) encompassed within an EU Life 14/HLF funded programme, Red Squirrels United. Project objectives include establishing early warning and removal protocols to prevent island re-colonisation by grey squirrels, raising public awareness of invasive mammalian species and funding to eradicate grey squirrels from a 165km² area of northwest Gwynedd.

Securing the Anglesey red squirrel population requires the continued absence of grey squirrels and the provision of sufficient areas of well managed and connected habitat to support red squirrels. The activities required to achieve this are dependent upon engagement with a range of stakeholders and the wider public. This Action Plan provides detailed conservation prescriptions and guidance to secure the long term sustainability of the red squirrel population resident on Anglesey and within adjacent northern Gwynedd woodland landscapes.

1b) Characteristics of the Anglesey and Gwynedd focal area

Anglesey contains 2,500 hectares of woodland and additional wooded garden and hedgerow habitats. The largest two habitat blocks are the commercial plantations of Newborough forest (700 hectares of pine dominated stands) and Mynydd Llwydiarth (230 hectares of mixed spruce and pine stands). Woodland cover is low at approximately 4% of the land area (720km²). Red squirrels are widely distributed despite the fragmented nature of the woodland resource. In small and isolated woodlands however it is likely that occupancy is sporadic. Many individuals have local gardens within their home range areas and these animals benefit from supplemental foods often placed out by householders, including items presented to deliberately attract squirrels onto the property. The red squirrel population on Anglesey is estimated to contain in the region of 700 adults in a typical year¹¹.

The last grey squirrel removed during the island eradication programme was recorded in 2013, however in the autumn of 2015 a number of re-incursion events were reported:

⁸ Wales Squirrel Forum (2009) Conservation plan for red squirrels in Wales. Forestry Commission, Welsh Assembly Government, Countryside Council for Wales, Bangor, UK.

⁹ Ogden & McEwing (2011) Revisiting the Anglesey red squirrels: a comparative survey of population genetic diversity. Report to RSST.

¹⁰ Halliwell, E.C., Shuttleworth, C.M., Wilberforce, E.M., Denman, H., Lloyd, I. & Cartmel, S. (2015) Striving for success: an evaluation of local action to conserve red squirrels (*Sciurus vulgaris*) in Wales. pp. 175-192. In: Red squirrels: Ecology, Conservation & Management in Europe. Eds. Shuttleworth C.M., Lurz, P.W.W. & Hayward M.W. ESI.

¹¹ Halliwell, E.C., Shuttleworth, C.M., Wilberforce, E.M., Denman, H., Lloyd, I. & Cartmel, S. (2015) Striving for success: an evaluation of local action to conserve red squirrels (*Sciurus vulgaris*) in Wales. pp. 175-192. In: Red squirrels: Ecology, Conservation & Management in Europe. Eds. Shuttleworth C.M., Lurz, P.W.W. & Hayward M.W. ESI.

sightings which eventually led to three female grey squirrels being trapped in that year¹², and a male subsequently in early 2016.

The mainland red squirrel population is unlikely to contain more than 50 adults¹³. Relatively little is known about productivity, distribution and to what extent persistence is maintained by immigration from Anglesey. Trapping data indicates that a population is well established within Faenol estate and Treborth Botanic Gardens woodland, two locations along the mainland side of the Menai Strait that have been subjected to a degree of annual grey squirrel control since 2009. Trapping and wildlife camera trap data have revealed red squirrels 5-15km inland but such records are infrequent. The mainland red squirrel population is sympatric with a large and ubiquitous grey squirrel population. Adenovirus infection is found in a high percentage of these animals whilst tests indicate widespread exposure to squirrelpox virus^{14 15}; two findings that highlight the inter-specific disease threat posed to local red squirrels. Should inter-specific squirrelpox infection occur, and an infected mainland red squirrel cross to Anglesey, then there is a risk of disease in the conspecifics (i.e. other red squirrels).

Anglesey contains c. 69,700 people, with population centres in Llangefni, Holyhead and Llanfairpwll/Menai Bridge, whilst the City of Bangor has a resident population of 18,800 boosted by 10,000 students during the University term.

1c) Legislative review

As a species listed under schedule 5 of the Wildlife and Countryside Act (1981 as amended), red squirrels are protected from intentional injury, killing or capture. It is also an offence to intentionally or recklessly damage or destroy a structure or place a red squirrel uses as shelter or protection. Most usually this would be a squirrel drey, tree cavity or nest box. Red squirrels are also protected from disturbance whilst occupying a drey or other structure used for shelter or protection.

It is possible to apply to Natural Resources Wales for licence to undertake activities which may cause an offence under the Wildlife and Countryside Act. This would include trapping for monitoring purposes or habitat management for conservation purposes. Offences arising from development or forestry related activities cannot be licensed. However, it may be possible to rely on the defence that *'a person would not be guilty of an offence if the act was the incidental result of a lawful operation and*

¹² Shuttleworth et al (in press) Identifying incursion pathways, early detection responses and management actions to prevent grey squirrel range expansion: An island case study in Wales.

¹³ Halliwell, E.C., Shuttleworth, C.M., Wilberforce, E.M., Denman, H., Lloyd, I. & Cartmel, S. (2015) Striving for success: an evaluation of local action to conserve red squirrels (*Sciurus vulgaris*) in Wales. pp. 175-192. In: Red squirrels: Ecology, Conservation & Management in Europe. Eds. Shuttleworth C.M., Lurz, P.W.W. & Hayward M.W. ESI.

¹⁴ Everest, D.J., Shuttleworth, C.M., Stidworthy, M.F., Grierson, S.S., Duff, P.J., Kenward, R.E. (2014) Adenovirus infection: An emerging factor in red squirrel conservation programmes. Mammal Review DOI: 10.1111/mam.12025

¹⁵ Shuttleworth, C.M., Everest, J.D., McInnes, C.J., Greenwood, A., Jackson, N.L., Rushton, S., Kenward, R.E. (2014) Inter-specific viral infections: Can the management of captive red squirrel collections help inform scientific research? *Hystrix*, Italian Journal of Mammalogy doi:10.4404/hystrix-25.1-10126

could not reasonably have been avoided' but only if adequate safeguards are implemented.

Grey squirrels are listed on schedule 9 of the Wildlife and Countryside Act making it an offence to release, or to allow to escape, a grey squirrel into the wild. It is important to note that this includes any individual that has been caught in the wild even if it were to be released immediately after it was caught.

The red squirrel is included on the NERC Act (2006) Section 42 list of habitats and species of principal importance in Wales. The list is a key reference for the 'biodiversity duty' in the NERC Act whereby decision-makers such as public bodies, including local and regional authorities, are required "to have regard" to the conservation of biodiversity in all their activities.

The Environment (Wales) Act (2016) introduces a new, enhanced 'Biodiversity and Resilience of Ecosystem Duty' on public bodies to ensure that biodiversity is an integral part of decision making. The Duty will replace the existing Natural Environment and Rural Communities (NERC) Act 2006 Duty and the section 42 list will be replaced by a new section 7 list.

1d) Stakeholders

Community support, participation and learning, and wider partnership working are important elements in the delivery of the Action Plan.

We define:

Primary Stakeholders as individuals or groups who are directly involved in the delivery of the action plan or are impacted by the project, e.g. those who live within or visit the area encompassed by the Action Plan.

Wider Stakeholders as individuals or groups with an interest in red squirrel conservation and the Anglesey/Gwynedd focal population but who, while not directly involved or impacted, have a legitimate interest in, or connection to, the Action Plan.

1e) Implementation of the plan

NRW is a Welsh Government sponsored advisory and regulatory body with responsibilities that include the conservation of threatened species such as the red squirrel. Website: <https://naturalresources.wales>

RSTW is a non profit making Company Limited by Guarantee which conserves red squirrels in North Wales. Website: www.redsquirrels.info

Natural Resources Wales (NRW) and Red Squirrels Trust Wales (RSTW) have a Memorandum of Understanding (MoU) to support the delivery of the Red Squirrels United project in Anglesey and Gwynedd including red squirrel monitoring and targeted grey squirrel control (2016-2019). This will form an important mechanism to deliver key elements of this Action Plan.

RSTW will lead on the remaining elements on the Action Plan with local, regional and international partners.

This Action Plan will run from 2016 to 2021

2) Action Plan Aims

This Action Plan provides a framework to maintain or enhance a resilient red squirrel population within the Anglesey/Gwynedd focal population area for the period 2016-2021. The Action Plan has 6 main aims, each underpinned by defined and measurable objectives.

The Action Plan Aims are:

1. To limit the probability of grey squirrel re-incursion on Anglesey, quickly detect incursion events, efficiently remove dispersing animals and thus prevent island re-colonisation.
2. To detect and minimise the frequency of disease spread (e.g. squirrelpox virus, adenovirus) between grey and red squirrels, and within the red squirrel population.
3. To facilitate a resilient red squirrel population through sympathetic habitat management practices.
4. To assess the distribution and relative population abundance of red and grey squirrels.
5. To enhance opportunities for community participation and learning within red squirrel conservation and grey squirrel control actions.
6. To integrate red squirrel ecological requirements within regional recreational and developmental planning and within wider species/habitat conservation initiatives.

The following Action plan sections identify broad areas of work.

3) Recommended approaches for grey squirrel control for red squirrel conservation

Aim 1 - To limit the probability of grey squirrel re-incursion on Anglesey, quickly detect incursion events, efficiently remove dispersing animals and thus prevent island re-colonisation.

Aim 2 - To detect and minimise the frequency of disease spread (eg squirrelpox virus, adenovirus) between grey and red squirrels, and within the red squirrel population

Aim 5 - To enhance opportunities for community participation and learning within red squirrel conservation and grey squirrel control actions.

Objective 1 - To deliver best practice for the control and humane dispatch of grey squirrels.

Objective 2 – To integrate existing *ad hoc* grey squirrel control being carried out by *primary stakeholders* into a wider systematic control programme and offer training for volunteers.

Objective 3 – To highlight, and reduce, infection risks associated with control methods.

Grey squirrels can be controlled in Wales using one or more legal methods. Animals can be (1) dispatched after being caught within live capture traps, (2) killed within spring traps listed within the Spring Trap Approval Order¹⁶, (3) shot with an appropriate firearm or air-weapon and (4) in the case of pre-weaned juveniles, they may opportunistically be removed from dreys and dispatched. Operators must adhere to the legislation covering the positioning, setting and operation of traps (in the context of trapping) and also animal welfare legislation (during all types of control) which make it an offence to intentionally inflict unnecessary suffering. In Appendix A, we present firm guidance on the grey squirrel control methods which should be used within the counties of Anglesey & Gwynedd.

Action 1 – Produce guidance best practice for the control of grey squirrels and make available to all relevant stakeholders.

Action 2 - Ensure that details (location, date) of red squirrels caught or sighted during grey squirrel control are provided and integrated into a wider project database of red squirrel records. (Objective 1) (see section 6).

Action 3 - Maintain, and distribute an accurate and up to date red squirrel distribution map for Gwynedd so that project contractors, volunteers and wider *primary stakeholders* are kept informed. (Objective 1)

¹⁶ http://www.legislation.gov.uk/ukxi/2012/13/pdfs/ukxi_20120013_en.pdf (Accessed 10/6/2016)

- Action 4 - Keep up to date with novel trap designs and new approaches to grey squirrel control, through the scientific literature and other regional grey squirrel control initiatives. (Objective 1 & 3)
- Action 5 - Work with primary stakeholders to undertake comprehensive grey squirrel control training workshops in order to ensure best practice. (Objective 1 & 2).
- Action 6 - Maintain a secure database (within the terms of Data Protection legislation) of project volunteers, and other primary stakeholders undertaking grey squirrel control. (Objective 2).

4) Grey squirrel control to prevent reinvasion of Anglesey and to conserve mainland red squirrels

Aim 1 - To limit the probability of grey squirrel re-incursion on Anglesey, quickly detect incursion events, efficiently remove dispersing animals and thus prevent island re-colonisation.

Objective 1 - To create a flexible grey squirrel control framework with associated resource requirements.

Objective 2 – To create and implement procedures to rapidly detect grey squirrel incursion onto Anglesey and efficiently remove the animals.

Grey squirrels spread into Caernarfonshire in the late 1950s and were first observed on Anglesey in 1966¹⁷. They were eradicated from Anglesey in the summer of 2013¹⁸ and it is now known that during the culling, dispersal from the adjacent mainland population was occurring¹⁹. In the autumn of 2015, grey squirrel island incursion was recorded and the capture of three individuals was documented²⁰. Successful dispersal across the Menai Strait occurred despite control of mainland grey squirrel populations in proximity to the two bridges linking Gwynedd to Anglesey.

Blood tests indicated that one of the three grey squirrels caught on the island in 2015 was revealed to have anti-bodies to squirrelpox virus, which indicates historical exposure to the virus and potentially a current infection.

An intensive mainland grey squirrel control programme (Summer 2016-Summer 2019) will take place as part of the EU LIFE14 NAT/UK/000467 invasive species project. Grey squirrels will be removed from a 165km² which encompasses the mainland coastal plain adjacent to the island and valley landscapes further inland. The project aims to eradicate an established grey squirrel population of approximately 10,000 adults in order to:

- Prevent dispersal onto Anglesey.
- Release the mainland red squirrel population from competitive and disease threats posed by sympatric grey squirrels.
- Empower local people with the knowledge and skills necessary for them to conduct grey squirrel control.

¹⁷ Walker TG (1968) The mammals on Anglesey. In: Jones WE (ed) Studies in Anglesey History, Vol 2. - Natural history of Anglesey, 204-224. The Anglesey Antiquarian Society, Llangefni, Anglesey.

¹⁸ Shuttleworth, C.M., Schuchert, P., Everest, D.J., McInnes, C.J., Rushton, S.P., Jackson, N.L. & Kenward, R.E. (2015) Developing integrated and applied red squirrel conservation programmes: What lessons can Europe learn from a regional grey squirrel eradication programme in North Wales? pp. 233-250. In: Red squirrels: Ecology, Conservation & Management in Europe. Eds. Shuttleworth C.M., Lurz, P.W.W. & Hayward M.W. ESI.

¹⁹ Signorile & Shuttleworth (in press) Genetic evidence of the effectiveness of grey squirrel control operations: lessons from the Isle of Anglesey In: Shuttleworth, Lurz & Gurnell (Eds) The Grey Squirrel: Ecology & Management of an Invasive Species in Europe

²⁰ Shuttleworth, Halliwell & Robertson (in press) Identifying incursion pathways, early detection responses and management actions to prevent grey squirrel range expansion: An island case study in Wales. In: Shuttleworth, Lurz & Gurnell (Eds) The Grey Squirrel: Ecology & Management of an Invasive Species in Europe

Data obtained from the eradication programme will be used to calibrate the resource necessary to successfully exclude grey squirrels from the mainland eradication area. Current provisional modelling has indicated that annually a trapper would need to invest a minimum of six months control within mainland woodlands near the two bridges in order to limit the probability of successful dispersal onto Anglesey, and three months on the island to respond to reports of grey squirrels²¹.

Detecting and removing grey squirrels on Anglesey

In 2008, a number of measures to detect grey squirrel incursion were recommended²²:

- Island surveillance program: Efforts should focus on high-risk sites near natural entry points from the mainland such as woodlands close to the two Menai bridges. .
- Targeted surveillance: Regular and sustained surveillance of areas vulnerable to invasion should be carried out using supplemental feed hoppers to draw animals to a point where they might be observed.
- Community participation: Raising the media profile of the importance of the local community reporting sightings of grey squirrels. This incorporated the promotion of established squirrel project telephone numbers and email accounts which the public could use.

The experience gained and lessons learned from the 2015 grey squirrel incursion²³ are invaluable in developing contingency plans and the response to future grey squirrel dispersal on Anglesey:

- Managers should rank reports of grey squirrels, prioritising those with corroborating photographic evidence, then those with multiple reports from the same approximate area but no photograph, and then those where the observer has demonstrated a knowledge of the key difference between red and grey squirrels beyond colour patterns.
- Reports where an observer is uncertain should be followed up immediately if resources allow, but would be secondary to parallel and higher ranked reports.
- Coat colouration can confound accurate identification of squirrel species because red squirrels can be grey or brown and grey squirrel can have red pelage.
- Grey squirrels have the ability to spread widely within the landscape and in the 2015 case study, the three individuals were found 10km apart.

We recommend that feeding hoppers with wildlife cameras (passive infra-red beam triggered) are deployed as part of squirrel monitoring (see Section 6).

In response to sightings and evidence of grey squirrels RSTW will:

²¹ Jones, White & Lurz unpublished data

²² Shuttleworth CM & Jackson N (2008) Red squirrel reintroduction contingency and quarantine plan. Unpublished report to the National Trust, Plas Newydd, Anglesey.

²³ Shuttleworth, Halliwell & Robertson (in press) Identifying incursion pathways, early detection responses and management actions to prevent grey squirrel range expansion: An island case study in Wales. In: Shuttleworth, Lurz & Gurnell (Eds) *The Grey Squirrel: Ecology & Management of an Invasive Species in Europe*

- Gain access permissions from landowners.
- Trap all woodland within 1km of the sighting following best practice (see Section 3) and for 5-10 days following 3-5 day trap pre-operation baiting (to draw animals to locations).
- In locations or circumstances where trapping is prohibited or capture rates depressed, shooting should be considered.
- Collect data on non-target species capture rates (including red squirrels).
- Record trapping effort (trap days) per woodland and both biometric and reproductive data from captured grey squirrels.
- Collect blood, spleen, gut and hair samples from grey squirrels caught (Section 7, Appendix B)²⁴.
- Have histological tests carried out on the sample.
- Ensure that press, social media and local landowners are informed and provided with regular progress reports.

Action 1 - Undertake EU LIFE14 NAT/UK/000467 invasive species project (2016-2019): collecting trapping effort, grey squirrel biometric and reproductive data, harvesting tissues and undertaking histological tests, and training volunteers to control grey squirrels. (Objective 1),

Action 2 – Develop predictive models on the spatial intensity and pattern of culling necessary to prevent grey squirrel incursion onto Anglesey and limit threats posed by the invasive species to native red squirrels. (Objective 1).

Action 3 - Implement an island wide squirrel monitoring programme (see Section 6) to detect grey squirrel incursion (Objective 2).

Action 4 - Provide online and printed materials to help educate local people on squirrel species identification, signs of disease in squirrels and on who to contact if a grey squirrels is seen (Objective 2).

Action 5 - Evolve current strategy for the detection and efficient removal of grey squirrels on the island. (Objective 2).

²⁴ Shuttleworth, Shirley, Mill & Rushton (2015) Understanding how grey squirrel infections impact upon native wildlife and domestic animals. Report to Royal Society of Wildlife Trusts.

5) Community participation in red squirrel conservation and grey squirrel control

- Aim 1 - *To limit the probability of grey squirrel re-incursion on Anglesey, quickly detect incursion events, efficiently remove dispersing animals and thus prevent island re-colonisation.*
- Aim 2 - *To detect and minimise the frequency of disease spread (eg squirrelpox virus, adenovirus) between grey and red squirrels, and within the red squirrel population*
- Aim 3 - *To facilitate a resilient red squirrel population through sympathetic habitat management practices.*
- Aim 5 - *To enhance opportunities for community participation and learning within red squirrel conservation and grey squirrel control actions.*

Objective 1 - To empower *primary stakeholders* with the knowledge and skills to differentiate between squirrel species, report squirrel sightings and signs of epizootic disease in red squirrels through workshops, information leaflets and electronic media.

Objective 2 – To encourage *primary stakeholders* to control grey squirrels by providing training workshops.

Objective 3 - To encourage sympathetic management of woodland habitat to maintain or enhance local red squirrel populations.

Objective 4 - To encourage landowners to maintain and create more dedicated sites where the public can watch wild red squirrels.

Feeding red squirrels

Following grey squirrel eradication and red squirrel recovery, many local people are regularly seeing, and some feeding, red squirrels in their gardens²⁵. There are also several locations on the island where the public can visit and are able to watch wild red squirrels at dedicated viewing areas. These include Plas Newydd (National Trust), Henllys Hall (HPB Ltd), Llyn Parc Mawr (NRW), Coed Cynol (Menai Bridge Town Council) and the Llangefni Dingle (Anglesey County Council).

- Where animals have access to supplemental foods it is important that signs of disease amongst the population are reported and that feeding stations/bird tables are regularly disinfected to lower the risk of them becoming a source of infection.
- The visibility of animals at feeding stations can provide an early warning of epizootic disease and also to the presence of grey squirrels. For example, during the recorded grey squirrel incursion onto Anglesey in the autumn of 2015, two

²⁵ Shuttleworth, C.M., Schuchert, P., Everest, D.J., McInnes, C.J., Rushton, S.P., Jackson, N.L. & Kenward, R.E. (2015) Developing integrated and applied red squirrel conservation programmes: What lessons can Europe learn from a regional grey squirrel eradication programme in North Wales? pp. 233-250. In: Red squirrels: Ecology, Conservation & Management in Europe. Eds. Shuttleworth C.M., Lurz, P.W.W. & Hayward M.W. ESI.

of the three animals caught after being reported had been initially observed whilst at garden bird feeders.

- The ‘monitoring’ value of feeders forms a key element in strategic planning to maintain Anglesey as a red squirrel refuge.
- Supplemental feeding may buffer populations from the effects of harsh weather (which reduce foraging efficiency) and may help for short periods when natural food is scarce.
- The ability of local people and island visitors, to be able to watch wild red squirrels is a fundamental catalyst for learning and experience. Ensuring accessibility for those with disability is of paramount importance to ensure opportunities are all inclusive.

Woodland management

Both woodland owners and the wider public often have an interest in enhancing woodland habitats in order to attract red squirrels or increase their numbers. With grey squirrels absent from the island, any new woodland planted is at a much lower risk from bark stripping damage, the threat of which historically may have been a disincentive to tree planting. Woodland management and creation which is sympathetic to, or geared towards, the conservation of red squirrels offers opportunities to benefit a wide spectrum of native flora and fauna. It is recommended that:

- The selection of tree species in new plantings will seek to benefit red squirrels²⁶ whilst improving stand species diversity and ecological resilience (in the face of climatic change, known and emerging forest pests)²⁷.
- Primary stakeholders are provided with information on the ecological requirements of red squirrels and the relative importance of different tree and shrub species as food sources (seed, flowers, shoots and buds).
- Whilst recognising that woodland habitat needs to be managed to keep it in good condition, management should seek to be sympathetic to red squirrel requirements; be carried out in a way that minimises the disturbance of legally protected places used as shelter by the red squirrel; and should avoid habitat fragmentation.
- Landowners will be encouraged to take advantage of Glastir woodland creation and management grants.

²⁶ Lurz, Shuttleworth & Gurnell (2016) Which trees help red squirrels? Westmorland Red Squirrels Newsletter. Spring 2016: 6-8.

²⁷ Shuttleworth, C., Lurz, P., Geddes, N. & Browne, J. (2012). Integrating red squirrel (*Sciurus vulgaris*) habitat requirements with the management of pathogenic tree disease in commercial forests in the UK. *Forest Ecology and Management* 279: 167-175.

Participation and learning in red squirrel conservation

RSTW will offer the following opportunities for direct community participation in and learning from red squirrel conservation activities on Anglesey and in Gwynedd:

- Stalls and information displays on squirrel ecology and conservation
- Printed guidance notes on squirrel management
- Trapping workshops and trap loan schemes
- Illustrated slideshows and guided walks
- Squirrel population monitoring workshops
- Tree planting and habitat management workdays and events
- Nest box and feeder construction workshops
- Online platforms to share experience of squirrel management

Patterns of forest ownership

Both landscape scale red squirrel conservation, and grey squirrel control, are based upon mapping exercises to identify woodland cover, connectivity and spatial distribution of forest. Project managers must also understand the pattern of land ownership in order to seek and obtain the land access necessary to:

- Respond rapidly to epizootic outbreaks
- Control resident and colonising grey squirrels
- Undertake grey squirrel control training workshops
- Arrange for volunteer trapping to take place
- Survey and monitor red squirrel populations
- Organise red squirrel themed woodland events

Land within the focal area is a mixture of private, organisational and state ownership. RSTW will work with primary stakeholders to ensure that comprehensive access is obtained to the woodland resource.

Action 1 - Regular grey squirrel control training workshops will enable local volunteers to efficiently trap and dispatch grey squirrels whilst minimising disease risk posed to red squirrels by such operations. (Objective 1 & 2) (see Section 3)

Action 2 - Dedicated mobile App and online website and social media platforms will be in place to allow reporting of red and grey sightings. (Objective 1) (see Section 6)

Action 3 – Protocols will be in place to act in the event of epizootic disease outbreaks amongst red squirrel populations. These will include proactive surveillance and reporting of grey squirrels on Anglesey and of sick or dead red squirrels. (Objective 1)

Action 4 – RSTW & NRW will work with officials administrating Glastir agri-env scheme to maximise outputs that enhance red squirrel abundance, and will directly provide landowners with advice about management for red squirrels (Objective 3).

Action 5 - Provide information to *primary stakeholders* on red squirrel supplemental feeding, locations where they can see the species in the wild, techniques to monitor populations and sympathetic woodland management practice. (Objective 3 & 4) (see Section 6)

6) Squirrel population monitoring techniques and protocols

Aim 1 – To limit the probability of grey squirrel re-incursion on Anglesey, quickly detect incursion events, efficiently remove dispersing animals and thus prevent island re-colonisation.

Aim 2 – To detect and minimise the frequency of disease spread (eg squirrelpox virus, adenovirus) between grey and red squirrels, and within the red squirrel population

Aim 3 –To facilitate a resilient red squirrel population through sympathetic habitat management practices..

Aim 4 –To assess the distribution and relative population abundance of red and grey squirrels.

Aim 5 – To enhance opportunities for community participation and learning within red squirrel conservation and grey squirrel control actions.

Aim 6 – To integrate red squirrel ecological requirements within regional recreational and developmental planning and within wider species/habitat conservation initiatives.

Objective 1 – To develop an effective monitoring protocol for red squirrels capable of detecting changes in red squirrel distribution and abundance

Objective 2 – To implement the monitoring protocol, recruiting volunteers to take part.

Objective 3 – Interpret and publish the collected data.

Objective 4 – To maintain a red squirrel sightings database (established in 2001).

The actions in this plan are designed to ensure the conservation of the red squirrel populations in the Anglesey/Gwynedd focal site. Understanding the success of these actions will be dependent on an understanding of the status of the red squirrel population, both in terms of distribution and population size. Monitoring and distribution data will support other objectives such as disease surveillance, understanding the success of habitat management and planning decisions.

However, the red squirrel is a difficult species to monitor for a number of reasons:

- Field signs for reds and greys cannot be distinguished
- Red squirrels are hard to detect (low encounter rate)
- Red squirrel populations undergo natural fluctuations in size related to seed availability
- A high sampling effort is needed to detect population change

Information is currently gathered from trapping results and the collation of sightings but there is no systematic monitoring of the red squirrel populations across the area.

The pros and cons of different red squirrel monitoring techniques were reviewed by Gurnell et al (2009)²⁸. Only hair tubes and visual surveys (apart from live trapping) are able to differentiate between the presence of red and grey squirrels. Visual surveys have a low detection rate, and whilst baited transects increase the chances of observing red squirrels they are not suitable for low density red squirrel populations. Hair tubes have been used with some success, but are fairly resource intensive due to the need to regularly rebait.

Squirrel feeder boxes are increasingly being used to detect the presence of red or grey squirrels when used in combination with a trail camera and/or sticky pads to collect hair (Seward 2013²⁹, Brassey 2013³⁰). A feeder box has the advantage over techniques such as hair tubes because the bait is not easily accessible to other animals and therefore remains active as a monitoring tool for a longer period without the need for rebaiting. Visits to a feeder box cannot easily be quantified to provide data on population size, but will provide information on the extent of red squirrel activity throughout a woodland or wider area.

Action 1 – Review monitoring options, finalise and agree monitoring protocol (Objective 1 & 2).

Action 2 – Establish and support a network of volunteers to implement the monitoring protocol (Objective 2).

Action 3 – Hold monitoring training events for volunteers (Objective 2).

Action 4 – Encourage reporting of red squirrel sightings through media, and maintain an existing red squirrel sightings database (Objective 4).

Action 5 - Analyse and publish the monitoring results (Objective 3)..

²⁸ Gurnell, J., Lurz, P.W.W., McDonald R., Pepper, H. (2009) *Practical Techniques for Surveying and Monitoring Squirrels*. Forestry Commission Practice Note 11

²⁹ Gurnell, J., Lurz, P.W.W., McDonald R., Pepper, H. (2009) *Practical Techniques for Surveying and Monitoring Squirrels*. Forestry Commission Practice Note 11

³⁰ Brassey R., Heinz, T., Tonkin, M. (2013). *Saving Scotland's Red Squirrels – Results of Spring 2013 Surveys*. www.scottishsquirrels.org.uk/docs/008_042_ssrsspring2013surveys_1380881055.pdf

7) Disease and mortality surveillance

Mainland grey squirrel control and the removal of grey squirrels detected on Anglesey form a cornerstone of red squirrel conservation. Control will reduce the probability of inter-specific disease risk (see Appendix A). Additional supporting actions will also be required to protect native red squirrels.

Aim 2 - To detect and minimise the frequency of disease spread (eg squirrelpox virus, adenovirus) between grey and red squirrels, and within the red squirrel population

Objective 1 - To publicise, maintain, and where possible enhance, the existing telephone/internet reporting system for public reporting of sick or injured red squirrels.

Objective 2 - To maintain centralised freezer storage of recovered carcasses at Bangor University.

Objective 3 - To establish partnerships with veterinary research organisations in order to obtain post mortem and histological screening.

Objective 4 - To put in place a reactive epizootic contingency plan.

Objective 5 - To undertake routine surveillance of viral infections in grey squirrels in order to quantify potential inter-specific risk posed to native red squirrels.

Objective 6 - To disseminate data on causes of mortality, infection risks and risk mitigation best practice to both *primary* and *wider stakeholders*.

Long term investigative studies have revealed a range of causes of mortality amongst red squirrels on Anglesey including road traffic deaths, predation events, enteric disease and a variety of other chronic conditions³¹. There have been no cases of Squirrelpox virus infection (either pathological or asymptomatic). This scientific research has established mechanisms for the public to report sick or dead animals: a dedicated phone line, online guidance (website/facebook) and an associated email address. Carcasses are stored with identifying data (written in pencil on a card) and frozen at -20⁰ within freezers at Bangor University. An associated MS Excel database contains collection date and associated data for each body.

Historically, carcasses were sent to APHA Penrith Veterinary Investigations Laboratory for Post Mortem examination and histological testing, but in 2014 the scheme was restricted. The majority of red squirrel carcasses recovered are now archived in storage and there is a need to establish new collaborative projects with a university veterinary research department in order to get gross examinations undertaken.

³¹ Shuttleworth, C.M., Signorile, A.L., Everest, D.J., Duff, J.P. & Lurz, P.W.W (2015) Assessing causes and significance of red squirrel (*Sciurus vulgaris*) mortality during regional population restoration: An applied conservation perspective. *Hystrix, The Italian Journal of Zoology*.

A four year (2016-2020) programme of histological studies on dead Anglesey red squirrels has been funded by Welsh Government. This will encompass adenovirus, squirrelpox virus, Ljungan and Hantavirus.

Blood and tissue samples were harvested from grey squirrels on Anglesey during the eradication. Studies on this material revealed that adenovirus infection was present and also that as culling occurred levels of exposure to squirrelpox virus declined in the residual population³². Viral surveillance of the mainland populations have shown consistently high (70-80%) proportions of animals with antibodies to squirrelpox. Funding has been secured to annually (2016-2019) undertake 100 ELISA tests for squirrelpox and 200 PCR tests for squirrelpox & adenovirus³³.

Grey squirrel (reinvansion) incursions onto Anglesey from the mainland were recorded in the autumn of 2015³⁴ and although there was no evidence of inter-specific squirrelpox infection from grey squirrels, trapping operations demonstrated the challenges of catching targeted animals (grey squirrels) amongst a widespread resident red squirrel population. A similar logistical challenge would be encountered when trying to remove individual red squirrels infected by pathogenic disease during targeted trapping operations within any disease contingency plan.

The management of pathogenic disease contains three elements (1) surveillance, (2) routine/best practice measures to prevent or retard disease spread, and (3) reactive contingency procedures to tackle the emergence of epizootics. A provisional disease contingency protocol is presented in Appendix B.

In relation to the Aim (2) and the six associated Objectives, there are four Actions:

Action 1 - Regularly review with *primary stakeholders* existing processes for reporting, collection and storage of red squirrel carcasses. (Objective 1 & 2).

Action 2 - Seek partnership with veterinary pathology groups to undertake gross post mortem examinations. Funding has been secured to undertake histological tests on red squirrel carcasses (2016-2020) and also on culled mainland grey squirrels. (Objectives 3 & 5).

Action 3 - Publish disease/infection/mortality research findings in peer reviewed journals such as *Veterinary Record*. Post updates on disease surveillance online via dedicated project website, Twitter™ and Facebook™. Issue press releases to local and regional media and circulate updates via the Wales

³² Schuchert P, Shuttleworth CM, McInnes CJ, Everest DJ, Rushton SP (2014) Landscape scale impacts of culling upon a European grey squirrel population: can trapping reduce population size and decrease the threat of squirrel pox virus infection for the native red squirrel? *Biological Invasions* DOI 10.1007/s10530-014-0671-8

³³ Shuttleworth, Shirley, Mill & Rushton (2015) Understanding how grey squirrel infections impact upon native wildlife and domestic animals. Report to Royal Society of Wildlife Trusts.

³⁴ Shuttleworth, Halliwell & Robertson (in press) Identifying incursion pathways, early detection responses and management actions to prevent grey squirrel range expansion: An island case study in Wales. In: Shuttleworth, Lurz & Gurnell (Eds) *The Grey Squirrel: Ecology & Management of an Invasive Species in Europe*

Squirrel Forum and Squirrel Accord in order to inform *primary* and *wider stakeholders*. (Objective 4).

Action 4 - Work with *primary* and *wider stakeholders* to implement proactive measures to limit infection/disease (mainland grey squirrel culling, Welsh Government funded red squirrel disease surveillance and developing a community invasive species early warning network etc) and to establish reactive contingency plans in the face of epizootic infections amongst the red squirrel population. (Objective 5, see Appendix B).

8) Woodland management for red squirrel conservation

Woodland managed by Natural Resources Wales are subject to Forest Resource Planning encompassing Coupe Planning systems. Private woodland owners will use a diverse range of planning mechanisms and will require licences to fell large volumes of timber. This Action Plan will inform all ownership sectors.

Aim 3 - To facilitate a resilient red squirrel population through sympathetic habitat management practices..

Aim 6 - To integrate red squirrel ecological requirements within regional recreational and developmental planning and within wider species/habitat conservation initiatives.

Objective 1 – To provide woodland owners and managers with guidance on the ecological requirements of red squirrels (habitat and age structure, connectivity, tree species offering key food resources) and guidance on sympathetic management practices.

Objective 2 – To provide guidance on the use of tree species in future planting to maximise ecological resilience in the face of climatic change and the threat posed by established and emerging invasive pests and pathogens.

Objective 3 – To encourage the use GIS map based assessments of habitat cover to predict how changes in woodland distribution and connectivity will affect red squirrel population dynamics and local persistence.

Objective 4 – To provide land managers with guidance and advice necessary to integrate red squirrel conservation into complimentary or conflicting ecological drivers.

The red squirrel is an arboreal species which benefits from complex vertical and horizontal forest stand structure³⁵. Interlocking branches between neighbouring trees and wider canopy connectivity aid both local foraging activity and wider dispersal or ranging behaviour. Canopy and stand fragmentation are associated with declines in population density³⁶. In extensive areas, where tree crowns have become isolated from each other, studies have shown that resident populations decline³⁷. Individual squirrels may continue to venture in to exploit tree seed crops within these open habitats, but the presence of these animals is maintained by the proximity of adjacent dense forest patches within which they are resident.

³⁵ Lurz, P.W.W, Gurnell, J., Rushton, S.P., 2004. Managing Forests for Red Squirrels, in: Quine, C., Shore, R., Trout, R., (Eds.), Managing woodlands and their Mammals. Forestry Commission, Edinburgh, pp. 25-28.

³⁶ Gurnell, J., Clark, M.J, Feaver, J., 1997. Using geographic information systems for red squirrel conservation management, in: Gurnell, J., Lurz, P.W.W. (Eds.) The Conservation of Red Squirrels *Sciurus vulgaris*. P.T.E.S, London, pp. 153-159.

³⁷ Flaherty, S., Patenaude, G., Close, A., & Lurz, P.W.W. (2012) The impact of forest stand structure on red squirrel habitat use. *Forestry* 85: 437-444.

Red squirrel populations are positively correlated with tree species richness (i.e. the variety of trees within a forest habitat)^{38 39}. In broadleaved dominated habitats, the presence of coniferous trees is particularly beneficial⁴⁰ and conservation approaches seek to retain and/or establish a degree of mixed woodland. Published scientific research contains comprehensive guidance on the relative value of tree species as nest sites and as sources primary food items (seed, flowers and buds)^{41 42 43} It is also important that habitat management recognises the value of fungal fruiting bodies as an autumn and winter food source.

Red squirrel population densities respond positively to an increase in the abundance and availability of specific tree seed crops including many non-native tree species such as Norway spruce, sweet chestnut and European larch, and native species of which Hazel and Scots pine are two good examples (Table 1). The potential benefit of using non-native trees as part of the strategic conservation of red squirrels was summarised by Lurz et al. (2016)⁴⁴:

'Climate change will also impact on [tree] planting choices and future strategy and conservation efforts for red squirrels might need to adapt. At least for red squirrels, one might need to consider conservation efforts in terms of maintaining forest ecosystems (and their services) by using non-native tree species favourable to reds and adapted perhaps to drier, warmer conditions. We already do this when it comes to economics (timber production), but we might have to consider that non-native tree species may become an important component in saving native red squirrels from grey squirrel competition and to maintain forest ecosystem services.'

Forest management is a dynamic process within which future proofing and ecological resilience are increasingly prominent drivers. In this section of the Action Plan we present key elements that woodland managers should consider implementing in order to integrate red squirrel requirements in forest/stand management.

Red squirrel presence

It is an offence to intentionally kill or injure a red squirrel (adult, weaned juvenile or dependent young in a nest) or to damage or destroy places used for refuge or shelter. Legislation also makes it an offence to prevent a red squirrel from accessing their nest

³⁸ Andrén, H., Lemnell, P., 1992. Population fluctuations and habitat selection in the Eurasian red squirrel *Sciurus vulgaris*. *Ecography* 15, 303-307.

³⁹ Kenward, R.E., Hodder, K.H., Rose, R.J., Walls, C.A., Parish, T., Holm, J.L., Morris, P.A., Walls, S.S., Doyle, F.I., 1998. Comparative demography of red squirrels (*Sciurus vulgaris*) and grey squirrels (*Sciurus carolinensis*) in deciduous and conifer woodland. *J. Zool.* 244, 7-21.

⁴⁰ Wauters et al. (2001) Does inter-specific competition with introduced grey squirrels affect foraging and food choice of red squirrels. *Animal behaviour* 61: 1079-1091.

⁴¹ Shuttleworth, C., Lurz, P., Geddes, N. & Browne, J. (2012). Integrating red squirrel (*Sciurus vulgaris*) habitat requirements with the management of pathogenic tree disease in commercial forests in the UK. *Forest Ecology and Management* 279: 167-175.

⁴² Lurz, P.W.W., Garson P.J., Ogilvie J.F., 1998. Conifer species mixtures, cone crops and red squirrel conservation. *Forestry* 71, 67-71.

⁴³ Krauze-gryz & Gryz (2015) a review of the diet of the red squirrel in different habitats pp51-65 In: *Red squirrels: Ecology, Conservation & Management in Europe*. Eds. Shuttleworth C.M., Lurz, P.W.W. & Hayward M.W. ESI.

⁴⁴ Lurz, Shuttleworth & Gurnell (2016) Which trees help red squirrels? Westmorland Red Squirrel Group Spring 2016 newsletter.

sites. It is imperative therefore that surveys are carried out to avoid felling trees containing dreys or den sites (tree cavities or hollows) and particularly during the breeding season. On Anglesey, Natural Resources Wales have a moratorium on harvesting operations during the period March to September so as to avoid the peak period when unweaned red squirrel pups are present in dreys. This is a good practice and RSTW will work towards it being adopted by the private sector.

When harvesting operations are proposed it is imperative that (1) woodland owners contact RSTW and their local records centre as a first step to establish whether red squirrels are present or potentially present and (2) use appropriate methods to survey for red squirrels.

If the species is found to be present, then a drey survey must be conducted, and land owners should:

- Best practice is not fell woodland in the period March to September when unweaned young are most likely to be present in nests.
- Ensure that the surveyor contracted to do the work has relevant experience or qualifications.
- Conduct surveys well in advance of any planned work.
- Ensure that the entire area affected by scheduled felling operations is surveyed.
- Determine conclusively whether there are red squirrel dreys present on site and, if so, record where these are. This information should be presented on a map at 1:500 scale.
- Note that it is a best practice to mark a 50m buffer zone around an active drey, an area within which there should be no disturbance⁴⁵.
- Record all attempts to collect evidence of red squirrels and findings.

Sympathetic timber harvesting

In coniferous plantations thinning should focus upon early interventions and use line thinning in preference to selective thinning. Where a selective thinning is to be implemented, for specific silvicultural reasons, felling should seek to retain a well connected canopy branch matrix so that animals can move between areas with ease, and without having to venture to the ground. In broadleaved crops selective thinning is a standard technique and here maintaining canopy matrix should be a high priority.

Where timber crops are affected by, or vulnerable to, pathogenic or pest infections, where heavy thinning or clear-felling are potential interventions, woodland owners should take a balanced view of impacts in terms of likelihood, scale and associated

⁴⁵ <http://www.snh.gov.uk/about-scotlands-nature/wildlife-and-you/red-squirrel/mitigation/>

potential risk. In such circumstances, Natural Resources Wales and RSTW will produce agreed guidance to ensure an evidence led approach which takes into account local circumstances so that red squirrel populations are buffered as much as possible.

Future proofing ecological resilience in red squirrel habitats

The absence of grey squirrels on Anglesey means that woodland owners may plant tree species that would otherwise provide grey squirrels with significant resources. Red squirrel management recommendations for mainland scenarios prescribe the use of birch, alder and willow when managers wish to diversify coniferous habitats containing red squirrels. This is because these tree species do not offer meaningful food sources for squirrels⁴⁶. However, the value of this approach really depends upon local circumstances (relative isolation of forest blocks, proximity of grey squirrel source populations, presence of other woodland species which do not benefit) and in Gwynedd woodland managers would be better to diversify, particularly as we now have the complication presented by non-native introduced tree pests/diseases and climatic change.

To maximise benefits for red squirrel populations, woodland owners should consider:

- Planting a component of European coniferous and broadleaved species e.g. Serbian spruce, Macedonian pine, Holm oak, European Walnut which are suited to warm climates.
- Selecting a range of coniferous tree species to ensure that at least one tree species is producing seed in a forest area (Table 2)
- The types of emerging woodland product markets (e.g. coppice biofuel, nut crops and green leaf animal forage) which diversified woodland may be able to support.
- The trade offs between changing species mixtures to achieve future forest resilience against any conflicting need to maintain forest structure and arboreal connectivity.
- Preferentially removing mature Ash (vulnerable to Ash die back and Emerald Ash borer *Agrilus planipennis*) during thinning operations to retain tree species that are currently not, or less, threatened by pests and pathogens.
- Creating woodland edge and woodland glades that are orientated to be south facing to maximise the amount of light interception.
- Working with RSTW to involve the local community in tree planting projects.
- Entering into Glastir (Agri-env) woodland creation and woodland management schemes.
- Seeking funding support for woodland creation and management.

Habitat connectivity

⁴⁶ Lurz, P.W.W., Garson P.J., Ogilvie J.F., 1998. Conifer species mixtures, cone crops and red squirrel conservation. *Forestry* 71, 67-71.

Recent squirrel dispersal models and genetic studies on both red^{47 48} and grey⁴⁹ squirrels have illuminated the potential for movement of animals across island despite the fragmentary nature of woodland habitats.

Genetic interchange between red squirrel sub-populations should be facilitated by the improvement of links between habitat patches, whilst local stand management should seek to maintain or enhance population size in order to reduce local extinction probabilities. In this context, Newborough forest, the largest discrete woodland area on Anglesey is an important source of dispersing animals which could re-colonise smaller patches where local extinction has occurred (e.g. via Allee effects). We provide management prescriptions for Newborough in Appendix C in a meta-population context and with a view to integrating the ecological requirements of this species with conflicting requirements of other native species and habitats in the local landscape.

It should be noted that the risk of epizootic disease spread could be increased by improving connectivity. This however must be balanced against negative impacts (lower occupancy, genetic inbreeding) of fragmenting squirrel populations.

When seeking to improve habitat connectivity, policy makers and landowners should consider:

- Establishing new connecting woodlands or hedgerows.
- Reducing the frequency of hedgerow trimming or alternating cutting so that each side of the hedge is cut in alternate years. This allows better branching structure to develop and widens the hedge depth.
- Planting hedgerow 'standards' isolated trees that offer vertical structure and may make a hedgerow more attractive to dispersing animals.

Action 1 - Maintain regular contact with woodland owners in order to foster and maintain a dynamic working relationship (Objective 1).

Action 2 - Ensure that woodland managers and council/NRW staff are aware of the legal protection afforded to the red squirrel and places used as shelter or refuge (Objective 4).

Action 3 - Work with Anglesey County Council, Gwynedd County Council and Natural Resources Wales to produce clear operational guidance for woodland management operations, (2) produce guidance on management of activities likely to impact red squirrels e.g. applications for felling licences (Objective 2 & 4)

⁴⁷ Ogden R & McEwing R (2011) Revisiting the Anglesey red squirrels: a comparative survey of population genetic diversity. Wildgenes, Zoological Society of Scotland report to the Red Squirrels Survival Trust. pp17.

⁴⁸ Jones et al. (in press) Mathematical models of grey squirrel invasion: a case study on Anglesey. In: Shuttleworth, Lurz & Gurnell (Eds) The Grey Squirrel: Ecology & Management of an Invasive Species in Europe

⁴⁹ Signorile & Shuttleworth (in press) Genetic evidence of the effectiveness of grey squirrel control operations: lessons from the Isle of Anglesey In: Shuttleworth, Lurz & Gurnell (Eds) The Grey Squirrel: Ecology & Management of an Invasive Species in Europe

Action 4 - Build upon earlier spatial squirrel population modelling⁵⁰ and investigate how changes in forest cover may affect red squirrels (Objective 3).

⁵⁰ Jones et al. (in press) Mathematical models of grey squirrel invasion: a case study on Anglesey. In: Shuttleworth, Lurz & Gurnell (Eds) *The Grey Squirrel: Ecology & Management of an Invasive Species in Europe*.

Table 1. Tree species value as food source for red squirrels. Value is scored on an arbitrary scale of 1 (no significant value) to 5 (high value) and levels of exploitation of seed, flowers and shoots are presented.

Common name	Latin name	Value (0-5)	Degree to which squirrels exploit the resource		
			Seed crop	Flowers	Buds/Shoots
Scots Pine	<i>P. Sylvestris</i>	5	High	High	Medium
Oak	<i>Quercus</i> spp.	3	Low	High	Low
Sweet Chestnut ¹	<i>Castanea sativa</i>	4	High	Low	
Willow	<i>Salix</i> spp.	1	None	Low	None
Birch	<i>Betula</i> spp.	1	None	None	None
Alder	<i>Ulnus</i> spp.	1	None	None	None
Balsam poplar	<i>Populus balsamifera</i>	2	None	Medium	No data
Larch ²	<i>Larix</i>	4	High	Medium	Medium
Hazel	<i>Corylus avellana</i>	4	High	Medium	Medium
Beech	<i>Fagus sylvatica</i>	5	High	Medium	Low
Yew	<i>Taxus baccata</i>	4	High	Low	Low
Common Walnut	<i>Juglans regia</i>	5	High		
Lodgepole pine	<i>Pinus contorta</i>	4	High	Medium	Low
Corsican Pine	<i>Pinus nigra var laricio</i>	5	High	Medium	Medium
Maritime pine	<i>Pinus pinaster</i>	5	High	Medium	

¹ Note the threat posed by the oriental chestnut gall wasp (*Dryocosmus kuriphilus*), a parthenogenic species, affects nut production but not timber quality or incremental tree growth.

² Larch is currently not planted on Natural Resource Wales holdings. It is however still being planted by private landowners on Anglesey.

Table 2. Values used to determine age classes for mature and young (not yet producing a good seed crop) trees for the key conifer tree species used by red squirrels in commercial plantations in UK. Source: Lurz et al. (2003)⁵¹; Hibbard (1991)⁵².

Tree Species	Latin Name	Average interval between good seed crops	Age to first good seed crop
Scots pine	<i>Pinus sylvestris</i>	2-5	15-20
Lodgepole pine	<i>Pinus contorta</i>	1-3	15-20
Sitka spruce	<i>Picea sitchensis</i>	3-5	30-35
Norway spruce	<i>Picea abies</i>	3-11	30-35
Japanese larch	<i>Larix kaempferi</i>	3-5	15-20
European larch	<i>Larix decidua</i>	3-5	25-30
Corsican Pine	<i>Pinus nigra var laricio</i>	3-5	25-30
Douglas Fir	<i>Pseudotsuga menziesii</i>	4-7	30-35

⁵¹ Lurz, P.W.W., Geddes, N., Lloyd, A.J., Shirley, M.D.F., Rushton, S.P., Burlton, B. (2003) Planning a red squirrel conservation area: using a spatially explicit population dynamics model to predict the impact of felling and forest design plans. *Forestry* 76, 95-108.

⁵² Hibberd, B.G., (1991) *Forestry Practice*. Forestry Commission Handbook No. 6. HMSO, London.

9) Development & planning – recommendations and best practice

Aim 3 - To maintain or enhance red squirrel population distribution and facilitate sympathetic habitat management practices.

Objective 1 - To raise awareness amongst planning authorities and *primary stakeholders* of the legal protection afforded to red squirrels and places of shelter (dens and dreys) and the need to highlight this protected species during pre-planning meetings and within online guidance.

Objective 2 - To foster best practice in red squirrel population surveying conducted as part of planning processes.

Objective 3 - To implement appropriate and sympathetic mitigation in order to minimise the negative impacts of development upon red squirrels.

The red squirrel and structures used by the species as places of shelter or refuge are legally protected under the Wildlife and Countryside Act (see section 1c) with protection including intentional and reckless acts. Red squirrels are now an established feature of suburban, and occasionally urban, wooded habitats, and hence increasingly are affected by planning applications and development. Guidance on survey methodologies, impact assessment and mitigation is available from The Mammal Society⁵³ In Scotland, Scottish Natural Heritage has published online guidance⁵⁴, although it is important to note that there are differences in the legislation in Scotland. In north Wales there has been a lag between red squirrel population recovery and the species being a consideration in planning guidance. This has led to several developments presenting ecological assessments that unintentionally, but regrettably, had omitted to survey/consider the presence of established squirrel populations.

Guidance for developers

During the *initial phase* of development planning, and especially if proposals may result in tree felling, it is recommended that architects or ecological consultants:

- (1) Contact Red Squirrels Trust Wales to request the licensed use of a comprehensive red squirrel record database covering Anglesey or Gwynedd.
<http://www.redsquirrels.info>
- (2) Contact the Cofnod Biological Records Centre to obtain limited county records.
<http://www.cofnod.org.uk>
- (3) Be aware that an absence of recent red squirrel records may reflect a lack of surveillance in a particular geographical area.

⁵³ Cresswell WJ et al (2012) *UK BAP mammals interim guidance for survey methodologies, impact assessment and mitigation*. The Mammal Society.

⁵⁴ <http://www.snh.gov.uk/about-scotlands-nature/wildlife-and-you/red-squirrel/the-impacts-of-development/> [Accessed 4/5/2016].

- (4) Be aware that local Planning Authorities or their Statutory Consultees would require evidence in a planning process to support a statements that red squirrels were not present in an area (e.g. a lack of field signs or dreys during surveys).

During *ecological surveying*, red squirrel site survey methods should be robust and must consider factors that may retard detection of red squirrels (a) habitat characteristics (b) low population density and (c) the presence and effect of local supplemental feeding upon red squirrel foraging patterns.

Developers must:

- Ensure that the surveyor contracted to do the work has relevant experience or qualifications;
- Conduct surveys well in advance of any planned work and at a time of year and time of day which will provide the best opportunity to record the species. Although red squirrels are active all year, late autumn is a prime period when day length is still long but trees are losing their leaves and animals are more likely to be visible through the canopy;
- Ensure that the area covered by survey is representative of the whole site and the adjacent area. Some judgment will be required for each case but 50m is the ideal buffer zone⁵⁵ within which there should be no disturbance to a breeding drey. On that basis, we recommend that survey should extend at least 50m from the edge of any proposed operational site;
- Determine conclusively whether there are red squirrel dreys present on site and, if so, where these are. This information should be presented on a map at 1:500 scale;
- Record all attempts to collect evidence of red squirrels.

During *mitigation planning*, developers should clearly communicate how operations will minimise disturbance to red squirrel nests sites (dreys, dens or summer platforms), and where disturbance occurs, demonstrate that the appropriate legal authority has been granted to undertake what otherwise may represent an unlawful action.

Where a development would have a negative impact upon local red squirrel abundance and or persistence, it is important that mitigation seeks to address this.

Action 1 - Assist local authorities (Isle of Anglesey County Council & Gwynedd County Council) to develop and implement robust pre-submission planning guidance with respect to red squirrels. [Objective 1,2 & 3]

Action 3 - Empower local *primary stakeholders* with knowledge of the legal protection afforded to the red squirrel via online media. [Objective 1]

⁵⁵ <http://www.snh.gov.uk/about-scotlands-nature/wildlife-and-you/red-squirrel/mitigation/>

Action 4 - Notify *primary* and *wider stakeholders* at an early stage of large scale developments that may affect local red squirrel populations in order to get current information relating to red squirrel activity in that area. [Objective 3]

Action 5 - Keep up to date with evolving red squirrel survey techniques and scientific publications relating to squirrel census studies. [Objective 3].

10) Identified delivery risk management

Risk Table

Identified Risk Factor	Likelihood of Occurring	Potential Impact	Prevention/Mitigation
Loss of a central co-ordinating body for disease surveillances & management	Low/Medium	High	Maintain collaborative working with viral research community so that there are partner bodies that could assist in these circumstances.
Resource limitations restrict or prevent grey squirrel control operations	Medium	High	Ensure that a vibrant volunteer base is maintained and empowered with the skills to control grey squirrels. This would provide project resilience in the face of financial restrictions.
Key red squirrel sub-populations are adversely affected by woodland management practices	Low	High	Agreed a collaborative approach to regular population surveillance in state forests. Maintain good working relationship with private woodland owners and ensure that they are provided with guidance on forest management protocols sympathetic with red squirrel conservation. NRW provide guidance in the licensing of forest operations.
Pathogenic tree disease and or insect pest outbreaks in key tree species which provide red squirrel food resources	Medium	Medium/High	RSTW and NRW to be vigilant in the emergence, geographical distribution and potential scale of impacts of, pests and diseases. Encourage a wide diversity of tree species are planted in crop rotation, under planting and establishment of woodlands.

Grey squirrels re establish a population on Anglesey.	Low	High	Maintain a buffer of mainland grey squirrel control to limit dispersal onto Anglesey. Maintain a watching brief for emerging technologies that may assist with preventing squirrel movements across the Menai Strait. Design and implement monitoring and rapid reaction to reports of grey squirrel incursion. RSTW & NRW work with NGOs and squirrel researchers to continually evolve protocols to eradicate incursion before establishment phase.
Negative public opinion develops towards grey squirrel removal.	Low	High	Ensure all volunteers and contractors involved with grey squirrel control work to best practice and maintain high standards of animal welfare. Apply the Red Squirrels United press and media protocols in the light of negative press or protest.
Lack of understanding of adenovirus epidemiology including potential pathogenesis in grey squirrels.	High as it is a current fact.	Uncertain	RSTW will work with partner research bodies to better understand adenovirus and other infections which may threaten red squirrels. It is important that knowledge gaps about the 'ecology' of viral infections are clearly presented to the public. There is uncertainty regarding how squirrelpox and adenovirus are spread from grey to red squirrels (and <i>vice versa</i>) and this fact will be communicated to the public in order to inform decisions such as whether to provide foods to animals and the pattern of feeder disinfection.
Steps to prevent reinvasion of Anglesey by grey squirrels assume that there is a low	High	High	There is little information on the relative frequency with which grey squirrels swim or use bridge links to cross from Gwynedd to Anglesey . This uncertainty will be

probability of individuals swimming the Menai Straits			communicated as there is often scepticism that swimming could ever occur. Increased public awareness of the need to watch for and report grey squirrels crossing the Menai Strait will be encouraged.
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Resource availability 2016-2019

Disease/Infection	£	Duration of funding	Source
Red squirrel histological tests	£1500 pa	4 years	Welsh Government
Grey squirrel histological tests ELISA SQPV	£950 (100 tests) pa	3 years	Red Squirrels United
Grey squirrel histological tests PCR SQPV/ADNO	£7200 (200 tests) pa	3 years	Red Squirrels United
Grey squirrel control contracts (3x fte) and one Red squirrel ranger community post (x1 fte)	£93,000	3 years	Red Squirrels United
Minimum annual grey squirrel control (a resource requirement of 1 fte trapper annually)	£20,000	2019 onwards	To be sourced

fte - full time equivalent; pa - per annum; PCR - polymerase chain reaction; SQPV - Squirrelpox virus; ADV - Adenovirus

Appendices

Appendix A - Grey squirrel control guidance

3a) Operator experience and training

Contractors and project volunteers engaged in grey squirrel control must:

- Be fully aware of relevant wildlife & animal welfare legislation and risks associated with the method(s) of control being undertaken.
- Possess the skills necessary to operate traps and humanely dispatch grey squirrels.
- Possess, or be covered by, Public Liability insurance for grey squirrel control.
- Have a risk assessment and, where appropriate, a lone working procedure in place.
- Have oral or written landowner permission to carry out control within each land holding.
- Have understanding of, and demonstrate due care within, the geographical area where grey squirrels are sympatric with red squirrels.

3b) Grey squirrel control in areas where red squirrels are present

Grey squirrel control practice should be modified where red squirrels are known, or likely to be, present within woodland sites:

- Spring traps should not be used as a means of controlling grey squirrels.
- The daily frequency with which live traps are inspected should be tailored to limit red squirrel confinement to a maximum of 3 hours and to minimise the probability of individuals being confined within traps overnight.
- Live capture traps should be disinfected with Virkon S™ solution following each grey squirrel capture to limit inter-specific infection with bacterial or viral pathogens.
- Grey squirrels should be dispatched 25-30m away from the traps original position in order to minimise blood contamination of trap locations.
- Where shooting takes place using feeding stations to draw animals to a point food source, any resulting grey squirrel blood contamination should be cleaned with disinfectant and operators should take necessary action to prevent red squirrels from coming into contact with blood.
- Grey squirrel carcasses should be removed and not be left on the woodland floor in habitats containing red squirrels.

3c) Methods of grey squirrel control

Live capture traps

Grey squirrel control will be based upon the use of single catch live capture trap designs. The immediate vicinity of trap locations will be baited with whole maize and/or sunflower seed for at least four days before trapping commences. Trap operation will

then follow procedures described within Forest Practice Note 004⁵⁶. Traps will be inspected at least once per day. Trap locations will be recorded in a database along with data on duration of trapping, trap effort (trap day units) and the frequency of captures per species.

Traps will typically be placed at a density of one per woodland hectare in broadleaved habitats and one trap per one to five hectares in coniferous stands dominated by pine and Sitka spruce respectively.

Grey squirrels will be killed using either cranial dispatch or by a shot to the back of the head using an air weapon.

Sex, biometric and reproductive data will be collected along with the date of capture and trap location. Histological samples will be collected in accordance with methodologies defined within specific studies⁵⁷.

The use of spring-traps (kill trap designs)

Project contractors and volunteers controlling grey squirrels to protect the Anglesey & Gwynedd red squirrel population will not use spring-trap designs with the exception of the Magnum 116 trap.

Magnum 116 traps will only be used when set within Fineren boxesTM which have been modified to prevent avian access to the trap housing chamber. Magnum 116 traps will only be deployed in geographical areas outside of the cumulative known and potential red squirrel distribution. Magnum 116 traps will be checked daily in accordance with legislative requirements. Trap spatial distribution will follow that recommended (above) for live capture trap designs.

Shooting

Shooting is a popular recreational pastime and is also a common method used in the control of grey squirrels within woodland occupied by red squirrels. The efficacy of shooting based control remains unclear, and is perhaps unfairly associated with the failure of cartridge schemes to prevent expansion in grey squirrel distribution in the 1950s. With the development of cheap telescopic sights, modern air-weapon designs and heat-sensitive cameras, there is some evidence that local grey squirrel populations can be depressed significantly via strategic shooting alone. However, the relative efficiency of shooting and trap based control has yet to be quantified,

Shooting at feeding stations which have been baited to draw in grey squirrels should seek to minimise the risk of inter-specific infection risk posed by body fluids, in particular aerosol blood particulates that result from animals being shot. Operators should take every effort to disinfect feeding stations and the ground beneath if grey squirrels are sympatric with red squirrels.

⁵⁶ Mayle et al. (2007) Controlling grey squirrel damage to woodlands. Forestry Commission Practice Note 4. HMSO.

⁵⁷ Grey Squirrel Tissue Sampling Protocol LIFE14 NAT/UK/000467 Sciuiriosity - Evolving IAS Grey Squirrel Management Techniques in the UK

3d Strategic approach to control

Trapping will follow best practice described in Mayle et al. (2007)⁵⁸ and Gurnell & pepper (in press)⁵⁹. Red Squirrels Trust Wales will coordinate volunteer and contractor effort to ensure that grey squirrels are controlled efficiently at a landscape scale.

Volunteers involved with grey squirrel control will be trained and insured to conduct trapping. Grey squirrel trapping will occur across the seasons, but will be focussed upon the January to August period, the time when natural food is scarce and hence the animals are drawn more to traps:

- Traps will be set at the base of large trees and preferentially those with little surrounding ground vegetation. Where livestock, deer, badgers (*Meles meles*) or other wildlife likely to interfere with traps are present, then traps will be placed on boards fixed horizontally to the trunk at 1.5m height.
- Traps will be spaced at a density of one per hectare in hardwood stands and one per two or three hectares in coniferous habitats.
- However, although idealised prescriptions for trap spacing and management will be followed where practical, trapping is influenced by many factors that often necessitate sub-optimal trap placement, Information on how to adapt a trapping programme in the light of public access to woodlands, conflicting land use activities and logistical challenges will be produced as a priority.

⁵⁸ Mayle et al. (2007) Controlling grey squirrel damage to woodlands. Forestry Commission Practice Note 4. HMSO.

⁵⁹ Gurnell & Pepper (in press) The control and management of grey squirrel populations in Britain In: Shuttleworth, Lurz & Gurnell (Eds) The Grey Squirrel: Ecology & Management of an Invasive Species in Europe,

Appendix B) Disease management and contingency planning

Background

An established protocol is in place for public reporting, recovery and the subsequent storage of dead red squirrels. The date, location, sex and life stage of each animal is entered into a database along with a unique identification number. The carcass is then stored in a freezer zip-bag along with details written on a cardboard sheet in pencil.

Resources are secured until 2019 to pay for histological tests on both red and grey squirrel carcasses (currently focussed upon squirrelpox and adenovirus infections).

These two elements form part of an important retrospective surveillance of causes of mortality. There is a parallel need to design and implement a best practice protocol triggered by the discovery of epizootic disease; in particular squirrelpox virus.

Introduction

Squirrelpox is a highly infectious disease which is passed between red squirrels through intra-specific infection. Infection pathways include direct contact and via exposure to viral particles in the environment (potentially within dreys or at scent marking points). The virus is, with the exception of a single recorded pathological case, asymptomatic in grey squirrels and cycles through populations. The presence of pustular lesions (sores) around the lips, eyes, nose and on digits are characteristic of this infection in native red squirrels, but symptoms can be confused with severe dermatitis associated with *Staphylococcus aureus*.

Following infection, there is a period of a week or so when the animals show no, or few, outward symptoms, by the three week stage the lesions are typically extensive and the animal is shedding significant viral loads. Death typically results in the following days. This timeline means that infectious animals have the opportunity to interact with con-specifics, to visit supplemental feeding stations and to use one or more nest sites, but is a short enough duration that the virus may not spread to an entire population.

Squirrelpox has occurred in red squirrels during a reintroduction project in Conwy during the 1990s, and although it has to date not been recorded in wild populations in Wales, this may reflect a lack of surveillance in the 1970-1980s when rapid red squirrel declines were taking place.

It is strongly recommended that animals suspected as being infected with squirrelpox virus are removed quickly. This means that *primary stakeholders* should be provided with the information and skills necessary to identify the signs of a potential pox case so that they can alert authorities about suspected cases.

The presence of squirrelpox on Anglesey could originate from grey squirrel incursion (inter-specific infection), or may be an via intra-specific transmission of the infection following dispersal or movement of an infected mainland red squirrel onto the island.

Primary actions in the event of suspected squirrelpox case

- Directly confirm (via email or telephone) with person reporting the case that the symptoms are potentially squirrelpox.
- If carcass has been reported then make arrangements for the body to be moved away from scavaging animals and collect as soon as possible.
- Record details of the location including proximity to sources of supplemental foods such as bird tables, red squirrel feeding stations or other obvious point food locations that may facilitate infection spread.
- Stress the importance of cleaning feeders and bird tables (using proprietary disinfectant or anti-viral wash) and monitoring other animals for signs of infection.
- **Where intensive surveillance and monitoring of animals is possible, and disinfection is taking place, then continuing to provide supplemental foods is an option.**
- Where a carcass has been recovered, a section of lesion should be collected with a surgical scalpel and placed within a 2ml sample tube. The material should then be posted to APHA for Transmission electron microscopy (TEM) testing to confirm the presence of pox particles.
- In circumstances where there has been a report of a live animal with potential pox symptoms, live trapping should be undertaken in order to catch, collect lesion samples, assess what veterinary treatment and/or quarantine is required.
- Where quarantine is required, animals should be transported to Q-yard at the Welsh Mountain Zoo.

Secondary actions

- A press release and associated email should be issued to make primary stakeholders aware of the confirmed presence of squirrelpox infection in red squirrels. A media release should be considered where there is a strong suspicion of infection but animals have yet to be captured in order to confirm pox (and differentiate symptoms that feature in other dermatological conditions).
- Current information should be shared and updated on Facebook, Twitter and other online social media platforms.
- Woodland owners within 2km of the location should be contacted and informed.
- A decision to undertake intensive trapping to monitor population health will be dependent on a range of factors: ability to monitor animals visually (determined by habitat and level of supplemental feeding), woodland extent and degree of isolation. Live trapping requires due diligence to trap disinfection following each red squirrel capture.

Assessing the potential impact of epizootic infections?

Management of squirrelpox (and other infectious pathological infections) requires an understanding of the logistical limitations of potential interventions, and needs to balance these against the likely extent and population impact of the epizootic.

Preliminary modelling work⁶⁰ has predicted that:

(1) while localised pox outbreaks would cause red squirrel mortality on Anglesey, provided grey squirrels are prevented from establishing on the island the red squirrel population will return to pre-infection densities following disease fade-out.

(2) squirrelepox was not predicted to spread extensively across Anglesey as it failed to spread throughout the predominantly low density landscape that connected fragments and blocks of better quality habitat.

In the light of these findings, and with due respect to the model caveats, even if squirrelepox infection were to be initiated by mainland red squirrel dispersal onto the island, complete population extinction is unlikely. Localised % population loss could be significant, cumulative outbreak events could lead to loss of genetic diversity and would have a major impact upon local people's ability to watch foraging animals.

Intervention should focus upon maximising early detection of pox infection and preventing wider spread (by removing infected animals and implementing disinfection of point food sources). Once an outbreak has spread across several square kilometres of landscape, the logistics and resources required for intensive intervention are prohibitive and project managers would have to focus resources based on circumstances at the time.

⁶⁰ Jones et al. (in press) Mathematical models of grey squirrel invasion: a case study on Anglesey

Appendix C - Meta-population management: Newborough forest red squirrel conservation.

This Appendix delivers upon NRW commitments under the existing Forest Management Plan: *AP 6.1.9: Contribute to the development of a viable red squirrel population on Anglesey in line with relevant strategies. NLP Recommendation No. D.1(iv). FCW will liaise with the Anglesey Red Squirrel Project to produce a project plan for red squirrels in Newborough that links in with the Squirrel Conservation Plan launched by Jane Davidson and Elin Jones in February 2010. This project plan will include the requirement for forest management measures (adequate connectivity in the forest and food sources) and adequate control measures (of grey squirrels, with this work being funded and controlled through the Anglesey Red Squirrel Project).*⁶¹

Aim 3 - To facilitate a resilient red squirrel population through sympathetic habitat management practices..

Aim 5 - To enhance opportunities for community participation and learning within red squirrel conservation and grey squirrel control actions.

Aim 6 - To integrate red squirrel ecological requirements within regional recreational and developmental planning and within wider species/habitat conservation initiatives.

Objective 1 - To provide forest management prescriptions to maintain red squirrel distribution and enhance habitat carrying capacity for the species.

Objective 2 - Provide recommendations to buffer red squirrel populations from, and integrate their conservation into, parallel forest management operations which will benefit other species.

Objective 3 - To maximise opportunities for people to see red squirrels in the forest.

Background

Recent population modelling has indicated that the red squirrel population in Newborough is an important element in the island meta-population system^{62 63}. This is because:

- The population is geographically buffered from any epizootic squirrel-pox outbreaks in woodlands nearer to the mainland and bridges
- The forest extent could support a red squirrel population of a size that would limit allee effects (the reduction in individual genetic health and fitness due to low population densities) and thus ensure that Newborough is a source of dispersing red squirrels to re-colonise other parts of the island should local populations decline or be lost in forest fragments.

At just over 700 hectares in area, the coastal Newborough pine forest is the largest block of woodland on Anglesey and is situated in the south west of the island. The Corsican

⁶¹ Newborough Forest Management Plan – FINAL v1.0

⁶² Jones unpublished PhD Research.

⁶³ Jones et al. (in press) Mathematical models of grey squirrel invasion: a case study on Anglesey. In: Shuttleworth, Lurz & Gurnell (Eds) *The Grey Squirrel: Ecology & Management of an Invasive Species in Europe*,

pine (*Pinus nigra*) dominated commercial conifer plantation was historically occupied by red squirrels until their extinction during the late 1990s.

Following an assessment against IUCN translocation guidelines, red squirrels were successfully reintroduced to the forest via a series of releases from 2004 to 2008⁶⁴ ⁶⁵. During the translocation process, red band needle blight infection was found to be extensive within the Corsican pine stands and in 2010 a forest management plan was produced which contained strategic plans to limit the adverse impact of the fungal infection upon tree growth whilst minimising the impact of thinning upon red squirrels⁶⁶.

The IUCN guidelines place a firm obligation upon any translocation to implement long-term population monitoring and maintain sympathetic habitat management in order to prevent future population extinction. In that context, we headline the impact and legacy of recent stand management and make recommendations for future red squirrel conservation at this site. We also highlight opportunities and a framework to reconcile conflicting biodiversity and conservation targets within the forest.

Forest management impacts

Although generic guidance on forest pest and pathogen management are often available, forest managers typically lack prescriptive guidance in circumstances where they have to balance or integrate forest hygiene operations (prescriptive felling) against the impact upon rare and in many cases, legally protected, species. Thinning regimes described in the Newborough management plan were an attempt to address this⁶⁷, and basically prescribed small scale felling interventions that would produce discrete forest openings within which tree regeneration (either natural or via planting) would take place. The surrounding matrix would have a light thinning, and this would maintain arboreal connectivity for red squirrels whilst increasing air flow through the canopy to lower red band needle blight speculation rates.

Thinning has created forest gaps but unfortunately natural regeneration rates have been poor and tree planting has been limited. This has meant that neither the tree species or stand structural diversity of the forest have been measurably improved. In addition, in many localities bramble and fireweed have colonised to produce dense ground layer which will act to retard tree regeneration.

⁶⁴ Shuttleworth, C. M., Kenward, R. E. & Jackson, N. (2008) Re-introduction of the red squirrel into Newborough forest on the island of Anglesey, UK. pp 163–166. In: Global Re-Introduction Perspectives: Re-Introduction Case-Studies from Around the Globe. Ed, Soorae, P.S. IUCN/SSC Re-introduction Specialist Group.

⁶⁵ Shuttleworth, C.M., Kenward, R.E. & Jackson, N.J. (2016) Developing red squirrel re-introduction techniques for use during regional grey squirrel eradication programmes in Europe. In: 2015 Global Reintroduction Perspectives. Ed. Soorae P. IUCN/SSC Re-introduction Specialist Group.

⁶⁶ Shuttleworth, C., Lurz, P., Geddes, N. & Browne, J. (2012). Integrating red squirrel (*Sciurus vulgaris*) habitat requirements with the management of pathogenic tree disease in commercial forests in the UK. *Forest Ecology and Management* 279: 167-175.

⁶⁷ Shuttleworth, C., Lurz, P., Geddes, N. & Browne, J. (2012). Integrating red squirrel (*Sciurus vulgaris*) habitat requirements with the management of pathogenic tree disease in commercial forests in the UK. *Forest Ecology and Management* 279: 167-175.

Thinning of the wider forest matrix has, particularly in recent interventions, excessively removed trees in the forest adjacent to the gaps created. Scalping back of forest edge adjacent to roads, ditches and existing forest rides has further fragmented the woodland. The loss of edge trees which typically have a deeper canopy and higher seed crops than those within a stand is an additional negative impact on red squirrels. A five year moratorium on pine thinning has subsequently been implemented by NRW⁶⁸ in order to monitor the response of forest canopy to earlier thinning interventions.

Natural regeneration is generally limited and patchy in the western part of the forest. Inland, where the soils are better, birch has dominated. Under-planting has been limited, and where it has taken place, a large proportion of the trees have died as a result of exposure (winter waterlogging) and intense competition with ground/field layer flora. This has meant that tree species diversity has not been significantly enhanced, vertical structure remains poor, and red squirrels have experienced canopy fragmentation and an associated loss of high quality tree seed with secondary forest growth generally dominated by tree species (willow and birch) that do not provide food sources⁶⁹.

In the light of this assessment, and against the back ground of reconciling conflicting management drivers (see later), we make the following broad recommendations:

- Red squirrel population size should be assessed using random 1x1m quadrats to calculate the volume of stripped cones per hectare - this can provide a density of animals per hectare⁷⁰ and will be a future Bangor University MSc project.
 - The assessments would help predict the likely impact of further thinning operations upon the red squirrel population.
 - The assessments would inform recommendations regarding the future spatial pattern of stand intervention (thinning operations) and whether there is a need to extend the pine thinning moratorium beyond 2020
- Management of birch dominated woodland should seek to diversify stand species richness by preferentially felling birch to release oak, beech and conifer tree species from competition/shading.
- Extensive annual tree planting, both to under-plant matrix canopy, and to establish/reinforce saplings in forest gaps should be a priority with monitoring of survival rates and 'beating up' (replacing dead young trees) scheduled.
- Tree species should be selected in the light of relative risk to pests/pathogens, of growth in relation to climatic change, value as a food source for red squirrels (see Tables 1 & 2) and benefits to other wildlife.
- Managers should have regard to the scientific recommendations in Shuttleworth et al. (2012) in relation to tree species selection, in particular Scots pine and hazel which produce early seed crops and which are positively correlated with red squirrel population sizes.
- Re-establishment of arboreal links e.g. every 50-100m, between forest areas disconnected by the removal of edge trees and woodland linkages would assist red squirrel movement between adjacent stands by replanting.

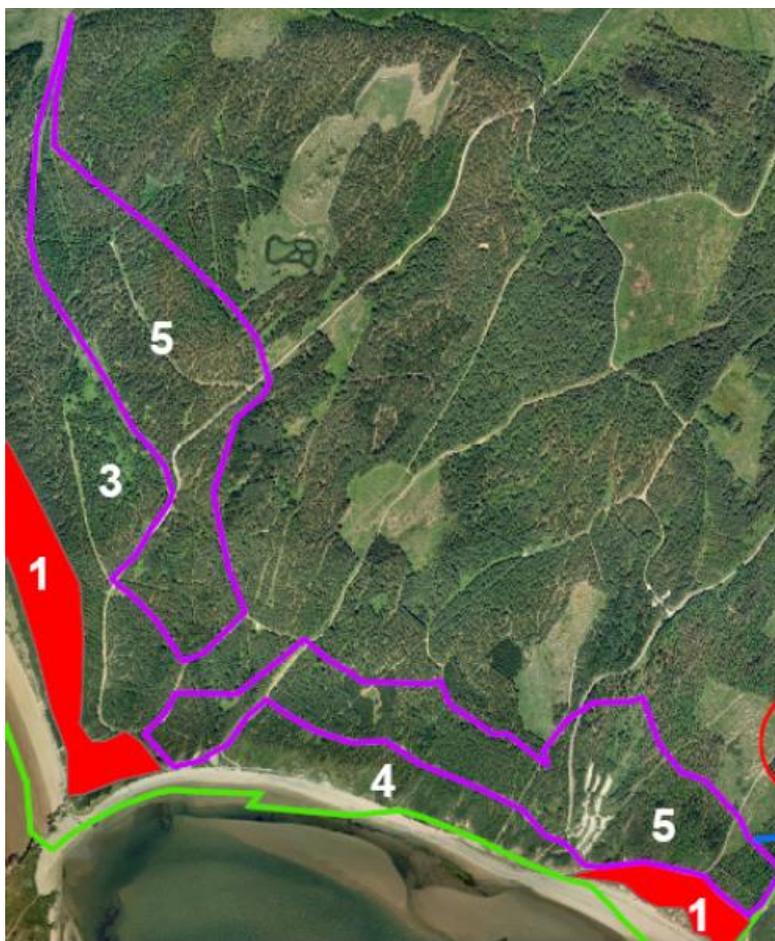
⁶⁸ Kim Burnham personal communication

⁶⁹ Lurz personal communication

⁷⁰ Lurz, P., Bertolino, S., Koprowski, J., Willis, P., Tonkin, M., & Gurnell, J. (2015) Squirrel monitoring: snapshots of population presence and trends to inform management. In C. Shuttleworth, P. Lurz & M. Hayward (Eds) Red Squirrels: Ecology, Conservation & Management in Europe, 279-297. European Squirrel Initiative.

- Remedial measures to tackle bramble and fireweed growth should seek to facilitate establishment/survival of tree regeneration (under-planting and natural regeneration) e.g. planting young trees behind brush pile lines in order to shelter them from salt-laden winds and using cell/pot grown trees.
- The establishment of salt tolerant under-planting of forest stands behind 'Area 1' and in particular Area 5 as defined in the 2010 forest management plan⁷¹ is an urgent action as this would provide shelter to more salt/exposure sensitive species planted behind. The plan also has 90% of the forest under LISS management which includes associated underplanting in all woodland inland from Area 1 (Figure 2).

Figure 2. Forest Zones defined in the 2010-2015 Newborough forest plan. The forest is managed under LISS except for Zones 1 & 4. Prescriptive forest regeneration within LISS are given in the plan and include intensive under-planting in Zone 5.



Reconciling conflicting biodiversity targets

There are opportunities at the Resource Plan planning stage to (1) explore the plasticity of species in relation to habitat characteristics (structure, species richness, species type) and (2) investigate novel and co-opting ways in which otherwise conflicting habitat requirements can be integrated.

⁷¹ Newborough forest management plan (2010) Forestry Commission Wales.

The extent and intensity of new planting should be defined to avoid undue misconceptions or concerns of mono-culture planting as was the case when Sweet Chestnut was proposed as useful cavity and food resource for red squirrels⁷².

NRWs strategic plan has a focus on mitigating for, and future proofing ecosystems in the light of, climatic change. The use of European tree species climatically adapted to predicted weather regimes, and species which, in the absence of Anthropocene change that retard their geographical spread may well naturally have colonised Wales in the future, are clear considerations. Newborough remains a multi-use forest and thus future proofing biodiversity, economic and cultural values at the site will be important - a process that should seek to integrate red squirrel conservation at each stage.

Red squirrel population monitoring

Llyn Parc Mawr (on the eastern edge of the forest) is one of the premier places on Anglesey where people can view red squirrels, and is particularly useful because vehicles can be parked within 20m of the established wooden squirrel feeders. This resource provides viewing access to individuals who, for what ever reason, are unable to walk into the woodland. The maintenance of this inclusive visitor experience is important to ensure that participation and learning opportunities remain comprehensive.

The presence of focal supplemental feeding locations is an important element in achieving Action Plan aims with respect to detecting and managing epizootic disease on the island (see Section 7). It is recommended that additional locations in Newborough forest are established as a disease/infection monitoring tool.

Bi-annual red population census should be implemented. Given that the forest broadleaved component currently offers limited food sources, red squirrel population size should be based upon quantified conifer cone consumption rates using 1x1m² quadrats and randomly stratified sampling. Studies should investigate:

- Spatial distribution and intensity of foraging.
- Stand structure (canopy connectivity scores) in relation to rates of cone exploitation (% stripped vs unstripped cones).
- Data could also be compared with 2002/3 and 2003/4 patterns of cone abundance and exploitation by grey squirrels in the forest (a period before recent intensive forest thinning and edge removal).

The results of surveys should be considered in the light of recent predictive modelling work.

Action 1 – The NRW Resource Plan for Newborough forest and the wider landscape (NNR/SAC) should define the number of young trees for each tree species to be planted annually in the forest, prescriptions to enhance sapling establishment and survival (in areas of extreme exposure and areas of heavy ground/field layer growth) and forest thinning protocols.

⁷² Loxton 2013 unpublished broadleaved woodland report to CCW.

Action 2 - An adaptive forest planning approach should seamlessly integrate conservation targets into wider forest management through the use of an adaptive 'opportunistic biodiversity' approach which (1) identifies novel and co-opting ecological interventions the benefits of which are shared by species, and (2) exploring the relative plasticity (adaptability) of species in relation to other native and introduced habitat elements, management interventions and non-interventions.

Action 3 - Establish supplemental feeding of red squirrels at Llyn Parc Mawr and feeding stations elsewhere in the forest.

Action 4 - Conduct biannual population census of red squirrels using feeding signs in a random stratified habitat survey.

Action 5 - Review and amend forest practice in the light of field survey data.