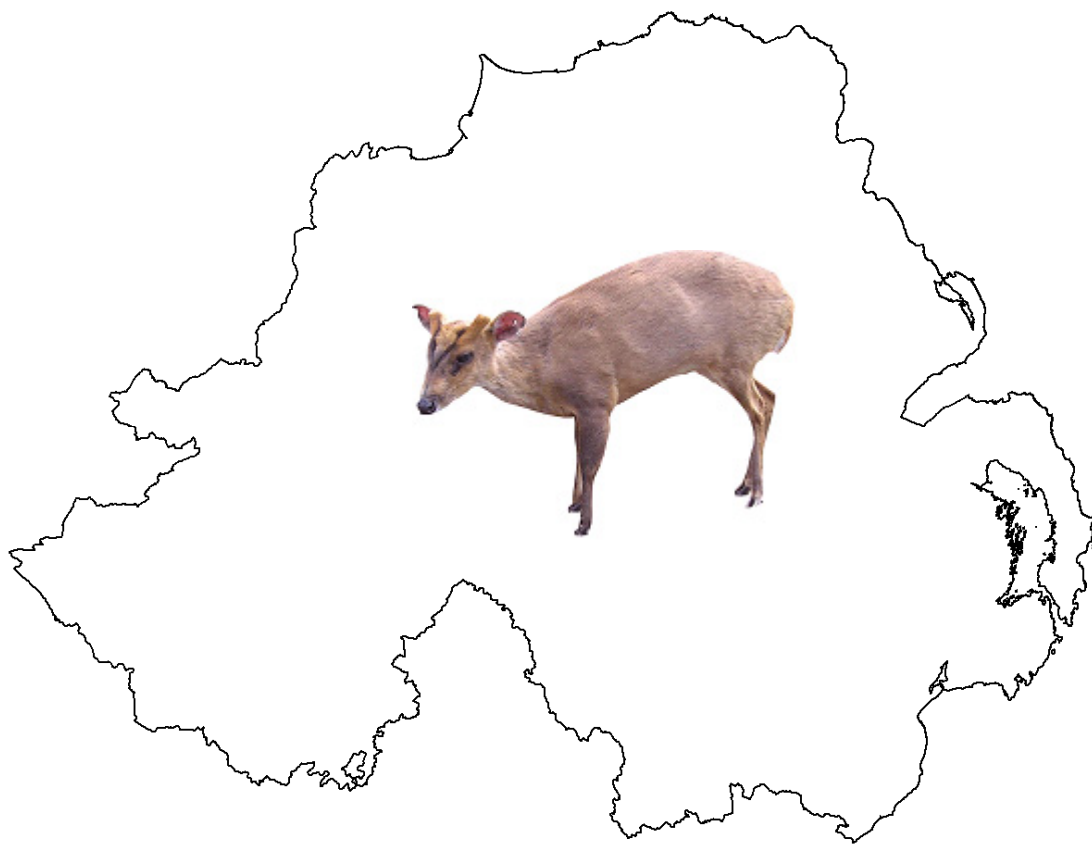


Natural Heritage Research Partnership

# Muntjac Knowledge Transfer: Ecology of introduced muntjac deer and appraisal of control procedures

*Quercus* Project QU08-11



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by  
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## Executive Summary

1. One of the greatest problems facing conservation in the British Isles is the spread and establishment of introduced species. Chinese or Reeves' muntjac deer (*Muntiacus reevesi*) is a highly invasive species which causes extensive ecological and economic damage to forestry, crops, biodiversity, species of conservation concern and humans directly.
2. Muntjac have been confirmed as present in the Republic of Ireland and anecdotal reports of their presence in Northern Ireland have been increasing in frequency. The species can be legally held in captivity and the risk of its establishment appears high. Consideration should be given to outlawing muntjac imports and registering captive animals under licence.
3. It is, therefore, timely to transfer knowledge on effective, safe and efficacious control of muntjac deer to Northern Ireland in logical preparation for their colonisation.
4. Muntjac invasion ecology and ecological and economic impacts have been reviewed and the efficacies of three methods of control assessed: 1) classical stalking by foot, 2) stationary use of a buttolo call and 3) stationary elevated high seat shooting.
5. A reference collection of muntjac specimens has been collected to facilitate species identification training and detection in Northern Ireland, including a full-body mount, full and partial skins, skulls including uppers canines, lower jaws and teeth, faecal pellets and plaster casts of footprint slots and pads.
6. Molecular markers have also been developed to facilitate species identification from tissue or possibly faecal samples using a 675 base-pair fragment of the mitochondrial cytochrome b (CYTB) gene.
7. During 2009, 10 x 1 hour species detection and identification training seminars will be held to increase awareness of muntjac deer to the Northern Ireland Environment Agency (NIEA), British Deer Society (BDS), National Trust (NT), Queen's University Belfast (QUB) staff and other interested parties.

8. We list five options for action; each is scored on its cost and the risk it represents in allowing muntjac to become naturalised in Northern Ireland:

*i. Reactive legislative response*

No further action is taken until muntjac presence is confirmed after which the species is placed on a year-round open season to facilitate control.

**Low cost / high risk**

*ii. Limited proactive response*

Transfer detection and identification knowledge to key personnel. Individual parties follow up existing and future anecdotal reports using existing low-tech equipment such as spotlamps and buttolo calls.

**Low cost / Intermediate risk**

*iii. Limited low-tech pre-emptive response*

Employment of a part-time contractor to investigate existing anecdotal reports using low-tech equipment such as spotlamps and buttolo calls.

**Intermediate cost / Intermediate-low risk**

*iv. Limited high-tech pre-emptive response*

Employment of a part-time contractor to investigate existing anecdotal reports using high-tech equipment such as thermography, DNA analysis of tissue and faecal pellets, spotlamps and buttolo calls.

**Intermediate cost / Low risk**

*v. Full scale high-tech pre-emptive response*

Employment of a full-time contractor and a part-time field officer to investigate existing and future anecdotal reports using top-of-the-range image intensifiers, thermography, DNA analysis of tissue and faecal pellets, spotlamps and buttolo calls.

**High cost / Lowest risk**

9. Option *i.* is likely to encourage the deliberate release of muntjac by those keen on year-round stalking; consequently, we recommend that either option *ii.* or option *iii.* Is implemented immediately, whilst consideration is given to the implementation of options *iv.* or *v.* when suitable resources become available.

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## 1.0 Introduction

One of the greatest problems facing conservation in Britain and Ireland is the establishment and spread of introduced species (Harris & Yalden 2004; Stokes et al. 2006). Integrated and co-ordinated species surveillance and monitoring is imperative to document the arrival, establishment, spread and impact of alien species (DEFRA 2003; Harris & Yalden 2004).

Chinese or Reeves' muntjac deer (*Muntiacus reevesi*) are native to China and Taiwan. They are easily held in captivity and habituate to human presence quickly, making them ideal additions to zoological gardens and private collections. The first recorded release of muntjac in Great Britain occurred at Woburn Park, Bedfordshire during 1901. Additional, deliberate releases occurred throughout the south of England during the early 20<sup>th</sup> century (Chapman *et al.* 1994; Smith-Jones, 2004; Ward 2005). Their current distribution now covers most of the south and east of England and extends into Wales and Scotland. The most recent population estimate suggests there may be up to 52,250 muntjac throughout the British Isles, and in some places attain densities of 120 muntjac/km<sup>2</sup> (Harris & Yalden, 2008).

Muntjac cause severe ecological and economic damage in Great Britain, having major impacts on woodland herb layer composition and tree regeneration (Dolman & Wäber, 2008). Denudation of the understorey by muntjac affects overall biodiversity including invertebrates and birds (Pollard & Cooke, 1994; Dolman & Wäber 2008).

The first record of muntjac in Ireland occurred during 2007 when a free-living adult buck was shot near Avoca, Co. Wicklow (Fig. 1; John Griffin, pers. comms.). A second animal was sighted alive and positively identified in the same area, near Trooperstown, shortly thereafter (Wesley Atkinson, Head NPWS Ranger). The Republic of Ireland have launched an aggressive control scheme in an attempt to eradicate any establishing population(s) by placing the species on the Wildlife (Wild Mammals) (Open Seasons) Amendment Order 2008.

Muntjac have yet to be confirmed as present in Northern Ireland, however, there have been numerous anecdotal sightings (Table 1; Fig. 2), with reports increasing in frequency in recent years, raising suspicions that the species may have already established but has thus far gone largely unnoticed.

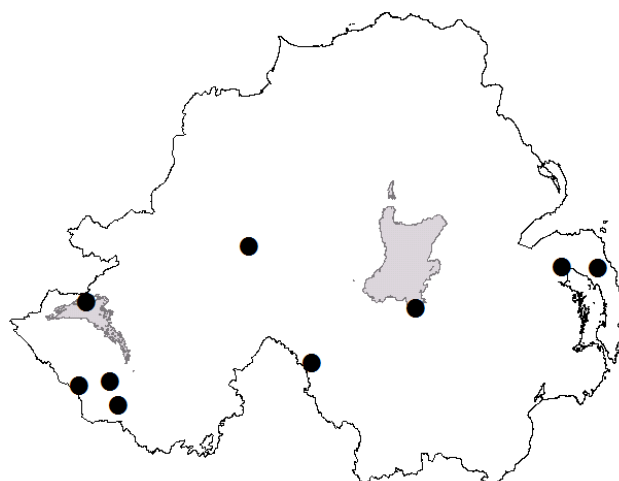


**Fig. 1** Reeves' muntjac deer (*Muntiacus reevesi*) shot near Avoca, Co. Wicklow during 2007.

**Table 1** Recent anecdotal reports of muntjac deer in the north of Ireland.

Situation	Location	County	Source
Enclosures	Carrowdore Castle	Down	Anon
	Mid-Tyrone region	Tyrone	Anon
Free living	Oxford Island	Armagh	Anon
	Scrabo	Down	B. Kelly
	Belcoo	Fermanagh	A. Callander, Co. Down
	Boa Island	Fermanagh	A. Callander, Co. Down
	Florencecourt	Fermanagh	Anon
	Letterbin	Fermanagh	A. Callander, Co. Down

*NB: These reports remain to be confirmed.*



**Fig. 2** Map of recent anecdotal reports of muntjac deer in Northern Ireland listed in Table 1.

This project aimed to transfer knowledge of muntjac detection, invasion ecology and control procedures to Northern Ireland [principally to the Northern Ireland Environment Agency (NIEA), British Deer Society (BDS), National Trust (NT) and Queen's University Belfast (QUB)]. The specific objectives of this project were to provide:

1. *A brief review of muntjac invasion ecology, ecological and economic damage and effectiveness of eradication and control techniques*
2. *A mounted specimen for training and identification*
3. *Skins as reference material for hair identification*
4. *Skulls, including upper canines, lower jaw and teeth, as reference material*
5. *Faecal pellets as reference material for training purposes*
6. *Plaster casts of footprint 'slots' or 'pads' for training purposes*
7. *Tissue samples for testing the efficacy of identification using DNA analysis*
8. *A programme of training seminars/displays for interested parties*

We list five options ranging from low to high cost and low to high risk in terms of muntjac becoming naturalised in Northern Ireland.



## 2.0 Methods

### 2.1 Training in behaviour and invasion ecology

To transfer knowledge on effective, safe and efficacious control of muntjac deer to Northern Ireland, Dr. Jaimie Dick, Reader in Behaviour, Ecology & Environmental Biology, Queen's University Belfast, was trained to stalk muntjac by Trevor Banham, Chief Wildlife Ranger, East Anglia Forest District, Forestry Commission England.

Forestry Commission staff demonstrated the use of lamps, image intensifiers and thermal imaging equipment for detection and study of muntjac. Interviews were conducted with regards to muntjac behaviour, ecology, effects on local flora and fauna and human impacts (e.g. damage to gardens, buildings, road traffic accidents). Individual Forestry Commission Rangers were interviewed as well as Norma Chapman (Bury St. Edmunds, Suffolk), a leading expert on muntjac in Great Britain, and Kristin Wäber, a PhD student at the University of East Anglia under the supervision of Dr Paul Dolman. Photographs were taken of muntjac damage to woodlands and data were collated on culling efforts within the East Anglia Region from 1997 to 2008. Muntjac were also observed in captivity.

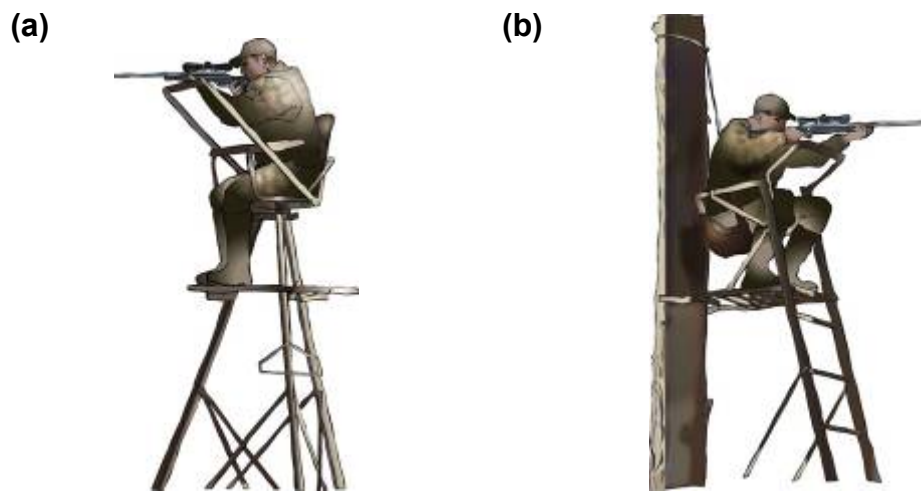
### 2.2 Efficacy of control methods

The efficacies of three methods of muntjac control were assessed first hand: 1) classical stalking by foot, 2) stationary use of a 'buttolo' call and 3) stationary elevated 'high' seat shooting (Fig. 3). The buttolo call is a rubber squeaker which mimics the calls of female roe deer (*Capreolus capreolus*) to attract bucks during the rut (Fig. 4). The same device can be used to attract muntjac of both sexes (T. Banham pers. comm.; J. Dick pers. obs.). Strategic use of such calls can elicit responses from nearby muntjac or draw individuals out of cover to aid detection and stalking.

Muntjac were stalked during 8 x 3 hour crepuscular trips near Thetford, Norfolk from Nov 30<sup>th</sup> - Dec 6<sup>th</sup> 2008. Stalking was conducted under permit after a compulsory shooting competency and accuracy test followed by a briefing on safety and deer

culling issues. A .308 calibre 'Sako' rifle with a 'reflex' sound moderator and 150 grain soft-pointed ammunition was used.

Culling was restricted to pre-determined cull areas and overseen by Forestry Commission Rangers. Prior to a shot being taken, the cull target was confirmed by an accompanying Forestry Commission Ranger. Each method for culling muntjac was evaluated by direct trails and interviewing Forestry Commission Rangers.



**Fig. 3** Elevated high seats can be (a) free-standing or (b) secured to trees or poles approximately 4m above ground level.



**Fig. 4** A 'buttolo' call emits a sharp 'fliep' or squeak which attracts both buck and doe muntjac.

### **2.3 Reference material collection**

To facilitate muntjac identification training based in Northern Ireland, a reference collection of material useful for species ID was assembled:

- 1) *A culled muntjac buck was full-body mounted*
- 2) *One full skin and two partial skins were prepared for hair identification*
- 3) *Two buck and two doe skull mounts were prepared including upper canines, lower jaws and teeth*
- 4) *Faecal pellets were collected and have been stored for identification training*
- 5) *Plaster casts of footprint 'slots' and 'pads' were taken*
- 6) *Muscle tissue and faecal pellets have been stored and the efficacy of DNA identification trialled*

All taxidermy was conducted by Chris and Jim Penny, Banbridge, Co. Down.

### **2.4 Efficacy of molecular identification using DNA**

Primers were designed from existing sequences available on GenBank to allow polymerase chain reaction (PCR) amplification of a 675bp fragment of the mitochondrial cytochrome b (CYTB) gene. Samples were amplified and sequenced and compared with published cervid CYTB sequences to ascertain the distinctiveness of muntjac and the ability to differentiate future tissue samples from other species.

### **2.5 Knowledge transfer**

Reference collection material will be used during 10 x 1 hour training sessions throughout 2009 given by Dr. Jaimie Dick to any interested parties including the Northern Ireland Environment Agency (NIEA), British Deer Society (BDS), National Trust (NT) and Queen's University Belfast (QUB). Species identification training will be accompanied by seminar presentations on the invasion ecology, behaviour and control of muntjac.

## **3.0 Results & Discussion**

### **3.1 Muntjac identification**

Muntjac are small reddish-brown deer with a conspicuous white underside to the tail, held vertically and very prominent when alarmed. Males have short simple antlers with or without small brow tines. Upper canine teeth protrude below the lip in males and are vestigial in females. Facial markings are unlike any other deer in the British Isles, with black frontal stripes on a ginger face. Sometimes animals stand with their back arched and commonly hold their head down such that the rump appears higher than the withers. Skulls can be distinguished from other deer species at any age by the presence of a pair of sub-orbital pits which are almost as large as the ocular orbits. In males, the pedicles, from which the antlers grow, arise from an elongation of the ridge on the frontal skull bone. Footprints are smaller than other ungulates at 3 x 2cm. When walking, hind feet pads match forefeet pads with prints usually about 30cm apart. Faecal pellets are black, shiny, striated and may vary in shape from spherical to cylindrical (0.1-0.2g and 6-12 x 5-11mm) and deposited in heaps between 20-120 pellets. Animals frequently use the same latrine regularly (Smith-Jones 2004; Harris & Walden, 2008).

### **3.2 Detection**

Detecting and estimating the density of muntjac deer is notoriously difficult (Cooke, 2006). Detection by pellet surveys is reliant on species specific identification which is difficult in multi-species assemblages. Furthermore, density estimates from pellet-group-based counts are subject to error and uncertainty in estimating defecation and decay rates in addition to sampling variance (Hemami *et al.* 2007). In comparison, nocturnal image intensification and infrared thermography have proved highly useful in detecting large mammals (McCafferty, 2007), including muntjac (Hemami *et al.* 2007).

In Northern Ireland, where recently introduced animals are likely to occur at extremely low densities, thermography or DNA identification of tissue or faecal pellets are almost certainly the only practical and cost effective means of detection.

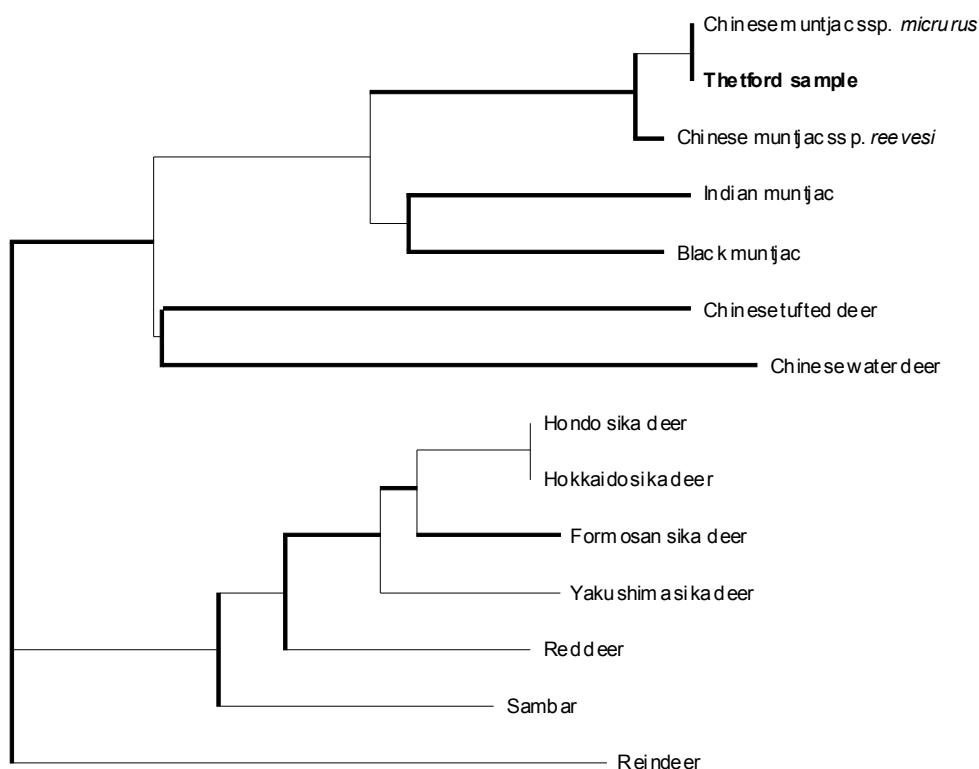
Detection of muntjac using visual light spotlamps and image intensifiers is useful but restricted in thick vegetation, fog and mist or at distance. The 'Archer' night-vision monocular ( $\approx$  £2,000) with a 'Longbow' night-vision rifle 'scope ( $\approx$  £6,000) would be most useful in detecting and facilitating eradication/culling of muntjac in Northern Ireland (T. Banham, pers. comm.). Further, thermography allows the detection of any heat source at several hundred metres through dense vegetation or poor weather conditions. Thermal imaging equipment also prevents disturbance to local residents. Advanced thermal units allow photographs and video of images to be captured enhancing species ID. Civilian thermal imaging equipment supplied by Starlight Night Vision Ltd is recommended ( $\approx$  £20,000). Direct census methods using thermal imaging provides best results at night during winter when temperatures are low ( $-7$  to  $+3^{\circ}\text{C}$ ) and ground vegetation minimal.

Remote detection using infrared game cameras provides a less labour intensive detection method. The Moultrie I60 Game Spy camera ( $\approx$  £200) is used by Central Science Laboratory for monitoring badger movements (Dr. Robbie McDonald, pers. comms.) and is likely to be effective in detecting muntjac if present.

Using tissue samples collected in Thetford, we were successful in confirming the distinctness of Chinese or Reeves' muntjac from other deer species including closely allied muntjac sub-species (Fig. 5). Primers were designed to offer a quick and inexpensive polymerase chain reaction (PCR) based assay to confirm whether unknown samples of tissue, and potentially faecal samples, are from muntjac. Such analysis is rapid (c. a few hours) and can be easily deployed in future to aid detection of the species in Northern Ireland.

### **3.3 Ecological damage**

Deer can cause considerable damage to woodlands and habitats of conservation interest such as heathland, grassland and wetland (Putman & Moore, 1998). Within woodlands, the major problem is in damage to coppice re-growth where sites are managed, but deer also cause concern over the loss of sensitive ground flora and suppression of natural regeneration. Where densities are high, muntjac can cause



**Fig. 5** Phylogenetic tree showing relationships between cervid species including muntjac based on the CYTB sequences. Samples from Theford clustered with Chinese muntjac, confirming the utility of this gene for species identification.

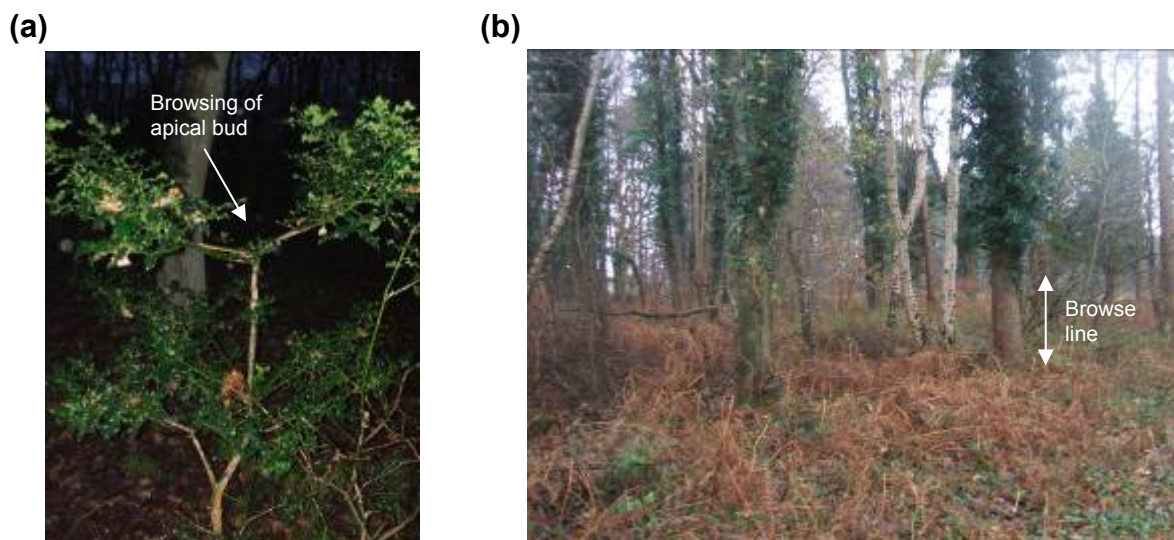
horticultural damage to pasture, cereals, oilseed rape, nurseries and orchard crops (Putman & Moore, 1998).

In Theford, where muntjac densities are high, there has been substantial reduction in the understorey with the near complete removal of bramble and other palatable species such as bluebells. Tree regeneration has been stunted and a variety of shrubs have been heavily grazed (Fig. 6). Such damage causes a measurable loss of woodland biodiversity, for example, grazing of honeysuckle (*Lonicera periclymenum*), the main larval food plant of the white admiral butterfly (*Ladoga camilla*), has caused the near total loss of the species from Monks Wood National Nature Reserve in Cambridgeshire (Pollard & Cooke, 1994).

### 3.4 Economic damage

In addition to damaging biodiversity, deer cause economic losses due to their involvement in road traffic accidents (RTAs) known as deer vehicle collisions

(DVCs). There are an estimated 74,000 DVCs in Great Britain every year, costing over £30 million in damages ([www.thedeerinitiative.co.uk](http://www.thedeerinitiative.co.uk)). There were a total of 20 human fatalities



**Fig. 6** Deer browsing can (a) stunt the growth of trees and shrubs and (b) alter understorey structure by changing the 'browse line'. [Photographs were taken in Thetford forest during December 2008].

from 2000 to 2005 with 134 serious injuries and 635 slight injuries ([www.thedeerinitiative.co.uk](http://www.thedeerinitiative.co.uk)), however, these are likely to be under-estimates due to under reporting.

The Deer Initiative attribute 25% of deer vehicle collisions (DVCs) to muntjac in England each year ([www.thedeerinitiative.co.uk](http://www.thedeerinitiative.co.uk)). During training, Dr. Jaimie Dick attended a DVC near Thetford involving a fallow deer (*Dama dama*; Fig. 7). The incident resulted in a hospitalisation, with the main road being blocked for more than 40min and two police cars in attendance. The deer was injured and was dispatched by a Forestry Commission Ranger using a hand-gun. Costs of DVCs are further increased as dispatched animals must be transported and incinerated. During 2007, there were a total of 238 DVCs involving 87 muntjac in the Thetford area (defined as <5 miles from the Forestry Commission HQ at Santon Down).

Bovine tuberculosis (bTB) is a serious zoonotic infection, primarily of cattle, however, the infectious agent, *Mycobacterium bovis*, has been detected in free-living muntjac

in Great Britain (Delahey *et al.* 2001). In Northern Ireland, costs of bTB control and compensation to farmers can be as much as £25M per annum (Anon, 2008). A high proportion of muntjac carcasses examined in the Wiltshire, Somerset, Devon, Cornwall, Gloucestershire and Herefordshire exhibited tuberculous lesions suggesting that muntjac should be considered as potential, although probably localised, sources of infection for cattle (Delahey *et al.* 2007).



**Fig. 7** Deer involved in road traffic accidents (RTAs) are frequently injured but not killed raising welfare issues. This fallow deer (*Dama dama*) was injured by a car on a main road in Thetford.

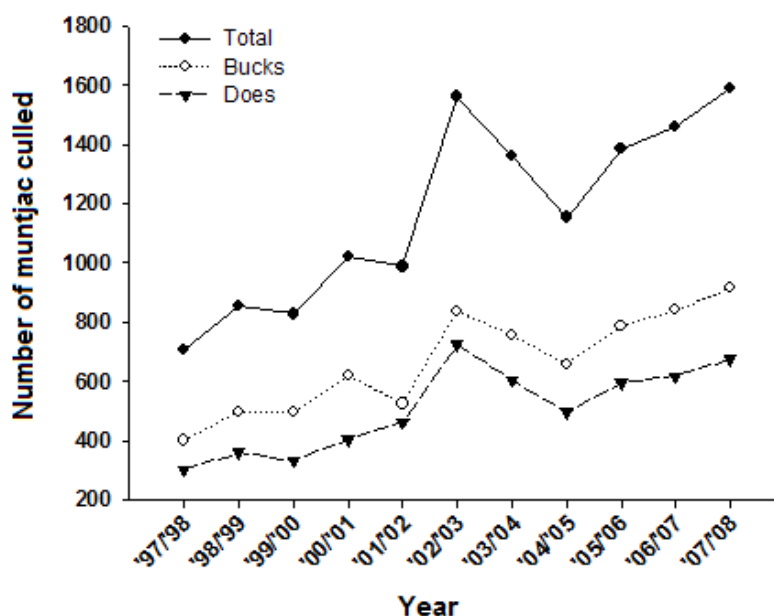
### 3.5 Efficacy of control methods

Muntjac were first recorded in Thetford forest around 1969. During the early years of establishment, Forestry Commission Rangers were discouraged from shooting the deer as they were considered 'harmless and added an exotic touch to the woodland' (T. Banham, pers comm.).

Currently, the Forestry Commissions' muntjac culling programme runs throughout the year and involves a total of 7 full-time Rangers, numerous private stalking clients, the St Hubert's Club, the British Association for Shooting and Conservation (BASC) and several local leasees and tenants. The cost of the Thetford culling operation is around £300,000 per annum, not including infrastructure (T. Banham, pers. comm.). The most recent figures for 2007/08 suggest that 1,500 muntjac were culled over an



area of 271km<sup>2</sup>, averaging  $\geq 7$  muntjac culled/km<sup>2</sup>. In line with the local muntjac population density, cull numbers have increased since records began during 1997/98 (Fig. 8). In addition to muntjac, red (*Cervus elaphus*), roe (*Capreolus capreolus*), and fallow (*Dama dama*) are also culled in the Theftford area.



**Fig. 8** Forestry Commission muntjac cull data for East Anglia Region over the last decade [Data were provide by Trevor Banham]

During training a total of 14 muntjac (9 bucks and 5 does) were culled at a rate of 1.7 muntjac/hr. Typically, sex ratios of shot animals are male biased as females tend to be more cautious and less likely to break cover. A total of 12 muntjac (c. 86%) were shot during classical stalking on foot, 2 (c. 14%) were shot after being attracted by the use of the buttolo call and none (c. 0%) were shot from the elevated high seat. The relative merits of each control method are summarised below:

### 3.5.1 Classical stalking on foot

Muntjac control requires an unusually large calibre of rifle due to the toughness and thickness of the skin, particularly around the neck. Bucks have especially tough hide to protect themselves from antler and tusk damage during fighting. Recommended calibres for muntjac are well above the minimum legal requirement of .22 centrefire (effectively .222 Rem). Theftford Forestry Commission Rangers use .270 and 6.5 x

55 with 110-130 grain soft point ammunition. During cull training, a .308 calibre rifle with 150 grain soft point bullets yielded 13/14 clean kills (i.e. the animal dropped instantly). For a clean, humane kill, bullet placement is critical. In summary, it is recommended that a minimum of .243 calibre with 100 grain soft-point bullets are used for muntjac culling should the need arise in Northern Ireland. For the purposes of eradication, larger calibres of  $\geq .270$  are preferred. Carcasses can be used for sex identification and scientific purposes.

Sound moderators (also known as silencers) are also recommended. Moderation of the very loud report of such rifles often allows a second animal to be shot within a few seconds or minutes. During cull training, two pairs of animals were shot within 20 and 100m of one another respectively. Moderators also alleviate disturbance to other wildlife, domestic animals and local residents.

Shotguns may not be appropriate for muntjac control due to animal welfare implications ([www.bds.org.uk](http://www.bds.org.uk)). Muntjac are known to have survived shotgun wounds with 'bird-shot' due to the thickness of their hides. Legally, shot size of AAA and above is required. In Northern Ireland, the shooting of deer using shotguns is legal under very restricted circumstances. However, current NI legislation refers to red, fallow and sika deer only; further clarification with regards to muntjac control may be required. The Wildlife (Northern Ireland) Order 1985 permits night shooting of deer (and from a vehicle) if it is for scientific or educational purposes. It is recommended that the Planning Environmental Policy Group (PEPG), Department of Environment, should review UK and NI legislation with regards to the legal restrictions on shooting deer at night by spotlight or other devices. In any muntjac eradication scenario, night shooting will be an invaluable technique (lamps, batteries and accessories cost  $\approx$  £200).

Unlike other deer species, muntjac cannot be reliably driven towards waiting guns. Consideration should be given to the efficacy of using dogs, such as hounds, to flush animals to aid detection and for culling/eradication.

### **3.5.2 Stationary use of a buttolo call**

Use of the buttolo call can be very successful in bringing both bucks and does into shooting range, indeed, muntjac were observed running towards the caller and were brought within a few metres. Bucks and does frequently respond by barking and stamping their feet. Buttolos are relatively cheap ( $\approx$  £20 per unit) and may offer a useful technique to detect muntjac at low densities.

### **3.5.3 Stationary elevated 'high' seat shooting**

Whilst no deer were shot using this technique during training, it does provide an effective alternative technique to classic stalking by foot (T. Banham pers. comm.). Muntjac can be attracted to pheasant feeders containing wheat and maize, and also take fruits and other vegetable matter and thus may be baited for the purposes of control. Bait stations may provide a means of attracting muntjac at low densities allowing high seats to be used.

## **3.6 Detection and potential control strategies in Northern Ireland**

Whilst there have been numerous anecdotal reports of muntjac in Northern Ireland, their presence remains to be confirmed. The risk of muntjac establishment seems high given that they are held in captivity in Northern Ireland and have already been found to be free-living in the Republic of Ireland. Consequently, consideration should be given to outlawing muntjac imports and registering captive animals under licence. The following 'options' for further action were assessed in terms of their cost and the potential risk of muntjac naturalising in Northern Ireland:

### **3.6.1 Reactive legislative response**

No action is taken until muntjac presence is confirmed by a carcass (shot, RTA or found). The Department of Environment, Heritage and Local Government in the Republic of Ireland, in common with the UK Government, have placed muntjac on a year-round open season to facilitate control. Whilst there are associated administrative costs, this strategy is relatively inexpensive. However, permitting year-

round shooting may exacerbate deliberate releases by those keen on year-round deer stalking. Consequently, we deem this a risky strategy which may accelerate the establishment of muntjac. As previously discussed, the cost of allowing muntjac to establish in terms of ecological and economic damage including human accidents is considerable. Consequently, we deem a proactive response to be more desirable than a reactive response.

**Cost: Low (one off admin cost)**  
**Risk assessment: High**

### **3.6.2 Limited proactive response**

Knowledge transfer to key personnel of Northern Ireland Environment Agency (NIEA), British Deer Society (BDS), National Trust (NT) and Queen's University Belfast (QUB) as an output of the current project (£0). Subsequently, individual bodies follow up existing and future anecdotal reports of muntjac presence. Low-tech equipment such as binoculars, cameras, buttolo calls and lamps are required. If the species is confirmed as present, then low effort culling should be implemented using local land-owners, gamekeepers, shooting syndicates, local rangers and other qualified personnel. This strategy relies on the availability of limited funding and self-imposed co-operation of relevant bodies.

**Cost: Low (£1,500-2,000 per annum)**  
**Risk assessment: Intermediate**

### **3.6.3 Limited low-tech pre-emptive response**

Employment of a part-time contractor to investigate existing anecdotal reports using spotlamps, buttolo calls, and private firearms. Includes part-time salary (for example, 4 days per month), travel, expenses and limited capital costs. Reviewed after 6 and 12 months.

**Cost: Intermediate (£15,000-17,000 per annum)**  
**Risk assessment: Intermediate-low**

### **3.6.4 Limited high-tech pre-emptive response**

Employment of a part-time contractor to investigate existing anecdotal reports using thermography, DNA analysis of tissue and faecal pellets, spotlamps, buttolo calls, and private firearms. Includes part-time salary (for example, 4 days per month), travel, expenses and reasonable capital costs. Reviewed after 6 and 12 months.

**Cost: Intermediate (£18,000-50,000 per annum)**  
**Risk assessment: Low**

### **3.6.5 Full scale high-tech pre-emptive response**

Employment of a full-time contractor and a part-time field officer to investigate existing and future anecdotal reports using top-of-the-range image intensifiers, thermography, DNA analysis of tissue and faecal pellets, spotlamps, buttolo calls and high-spec firearms. Includes full-time and part-time salaries, travel, expenses and high capital costs. Reviewed after 12 and 24 months. Full integration and organisation of key parties.

**Cost: High (£60,000-120,000 per annum)**  
**Risk assessment: Lowest**

### **3.6.6 Added-value**

The options presented here should not be considered in isolation with regards to muntjac. Surveillance of large ungulate communities in Northern Ireland will aid the detection of other potentially invasive species including roe deer, Chinese water deer (*Hydropotes inermis*) and wild boar (*Sus scrofa*). There have been anecdotal reports each of these species being held in private collections or being imported for sporting purposes (John Griffin pers. comm.).

Furthermore, better estimates of existing populations of red, fallow and sika deer are needed for Northern Ireland and deployment of the various options above will permit the full integration of ungulate population monitoring throughout Northern Ireland. A PhD focusing on deer populations in Northern Ireland, funded by the Programme for

Government, commenced in the School of Biological Sciences, Queen's University Belfast during autumn 2008. Integration of the detection and control measures listed above with current studies would bring further collaborative benefits.

Thermography equipment would also be useful for other NIEA funded projects including annual Northern Ireland Irish hare surveys.

## 4.0 Recommendations

Consideration should be given to outlawing muntjac imports and registering captive animals under licence.

Under further actions, option *i.* (the reactive legislative response) may be attractive in terms of economy, but it represents a high risk strategy that may exacerbate muntjac imports and attempted releases by those keen on year-round stalking. With the best interests of Northern Irish biodiversity in mind, we strongly advise a proactive rather than reactive response.

In the first instance, to ensure some level of proactive surveillance, we recommend that either option *ii.* or option *iii.* is implemented immediately. Options *iv.* and *v.* are likely to be prohibitively expensive in the short term and thus may not be suitable for immediate deployment. Nevertheless, they offer the lowest risk strategy in terms of the likelihood of muntjac naturalizing and we, therefore, recommend that consideration be given to their implementation as and when suitable resources become available. Greatest value will be in integrating options *iv.* and *v.* with the existing and future need for large ungulate monitoring in Northern Ireland including estimates for deer species density and their potential impact on designated sites such as Areas of Special Scientific Interest (ASSIs).

## 5.0 Conclusion

The UK and Ireland have international obligations under the Convention on Biological Diversity (1992), the Bern Convention (1979) and the European Habitats Directive (EEC 43/92) to address invasive species issues. By 1932, muskrats (*Ondatra zibethica*) had successfully established in fourteen counties in Great Britain (Fairley, 2001). However, this species was successfully eradicated by 1936 after almost 4,500 individuals had been killed (Warwick 1940). Similar efforts successfully eradicated both muskrats and roe deer (*Capreolus capreolus*) from Ireland during the early twentieth century (Fairley, 2001; Fairley *et al.* 2002), demonstrating the attainability of total extermination if a population is targeted early in its establishment phase. Immediate action is often the only opportunity for cost-effective eradication (Stokes *et al.* 2006).

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