Dissertation

Title

"A review of the methodologies used for restoring active blanket bog in the West of Ireland"

(Figure 1 the carnivorous sundew (*Drosera rotundifolia)* supplements its diet by catching insects on sticky hairs of its leaves, is just one example of the type of specialised flora which can be found on active blanket bog sites in Europe).

Course

BSc (Honours) Forestry Management (Distance Learning 2004 to 2006)
University of Central Lancashire, Cumbria Campus.

Module

FY3201 Dissertation

Student

John Le Gear

Module Tutor

Chris Starr

Dissertation Supervisor

Mike Jones

1.0 Introduction

As the agricultural and the Industrial revolution changed land practices, peatlands came to be viewed as wasteland (Smout, 1996). Today this view is changing as people begin to appreciate the natural and cultural heritage of peatlands. It is understood that the term “peatlands” is inclusive of terms “bogland” and “mires”. On a global scale blanket bog is a very limited resource. With an estimated total World resource of about 1.3 million ha (Lindsay, et al, 1988), the predominance of blanket bog over large areas of Britain and Ireland is unique. Britain and Ireland are considered to be classic region for blanket bog development. International experts have acknowledged the peatlands of Britain and Ireland as unique and of global importance, equivalent to Brazil’s tropical rainforest or the African Serengeti (Wilkie, 2003).

Blanket bogs are formed of deep peat soils, which have built up very slowly over hundreds and thousands of years, in areas where the climate is cool and wet. Blanket bog habitat develops in areas that have a minimum annual rainfall of 1,000mm, a minimum of 160 wet days and a cool climate, with an average temperature of less then 15 degrees Celsius (Lindsay et al, 1988). Blanket bogs have more important functions, besides the traditional one of a peat fuel source. They play a vital role in helping to regulate climate on a global scale, because blanket bogs act as carbon stores and carbon accumulating ecosystems. Blanket bogs also contain a diversity of characteristic species and support a large range and diversity of plants and animals which thrive in these wetland bog habitats, such as *Sphagnum* moss, sundews *(Drosera rotundifoila)* (Figure 1), lichens, mosses, dragonflies, spiders, Merlin, red grouse and many more. The blanket bogs of Ireland and Britain are among the richest in Europe in terms of their plant and animal life.

Arguably the finest area of blanket bog in Britain occurs in the great Flow Country in the north of Scotland. In the 1980’s large areas of the Flow Country were afforested and thus the area was at the centre of a debate between conservationists and foresters. In the West of Ireland extensive areas of active blanket bog, which are a natural or semi-natural habitat, are located mainly in the western counties of Galway, Mayo, Donegal and Kerry. They are internationally among the most important intact areas of active blanket bog found in Europe. During 1997, under the Habitats Directive, an estimated 135,139 ha of active blanket bog was proposed as candidate Special Areas of Conservation (pSAC). Like the Flow Country in Scotland during the 1960’s, substantial areas of Ireland's blanket bogs were afforested by the state up to the 1980's. Forestry, then, was seen as a possible land use that would boost the local economy by providing employment in remote areas where large areas of blanket bog occurred. These forests were planted at a time when social, economic and environmental issues were very different from those of today (Pfeifer, 2003)

Prior to the planting of large areas of peatland, extensive drainage and fertilisation was required before the trees could be established. These operations resulted in the degradation and drying out of the habitat and a reduction in the natural biodiversity associated with blanket bogs. Coillte (The Irish Forestry Board), which has a commercial mandate, is responsible for the management of extensive areas of these afforested Western peatlands. Many of these plantations had developed into forest stands of very poor to medium productivity, due to poor drainage, poor fertility and exposure. In today's market the revenue generated is often insufficient to pay for the clearfelling of the sites. Emlaghdauroe sample site C, for example returned a negative stumpage of €9 m^3. In fact the Forest Service (Irish Government body) would refuse grant aid on such sites today because of the inability to produce a commercial crop of trees and the environmentally sensitive nature of the sites. However it is recognised that forests in the west, if restructured appropriately, can contribute to the considerable environmental value of these areas at a wider landscape level (Pfeifer, 2003) and at a nature conservation level by restoring open bog habitat and redesigning plantations to enhance and improve their habitat value for birds and mammals.

1.1 Background to the Irish Blanket Bog Restoration Project

Coillte, consistent with the principles of sustainable forest management, is in a position to make a meaningful contribution to the 2000 National Biodiversity Action Plan through the designation of 15% of its estate for nature conservation. Coillte is currently involved in a EU LIFE-Nature project entitled Restoring Active Blanket Bog in Ireland. The project aims are to restore active blanket bog habitat at 14, unplanted, partly or wholly afforested sites, the general location of the project sites is shown in Figure 2, all the sites are designated as SAC's by the National Parks and Wildlife Service (NPWS). This project, has demonstrated that restoration of suitable active blanket bog sites as one of the management options for afforested peatlands. Appendix 1 presents a decision checklist, which was developed during this report, to help forest managers when they are selecting suitable project sites. The total project area is just over 1200 ha which is all Coillte owned lands. The project began in the year 2001 and its objective was to reverse the degradation of blanket bog habitat, which was caused by afforestation and uncontrolled grazing of open bog areas. The project is not a research project, it had clear targets to restore blanket peat habitat, and there is regular monitoring of vegetation and water levels. Hence this paper is a timely one and welcomed by the project team.

The main restoration targets for the project were,

a) Deforestation of 493 ha to enlarge adjoining open blanket bog areas
b) Fencing to gain control of 718 ha of open bog areas
c) Drain blocking to restore the integrity of the bog hydrological systems
d) Removal of naturally regenerated trees from the open bogs
e) Comply with FSC Criterion 10.5 which concerns restoration of valuable habitats

This Dissertation will review the methodologies used for restoring the 493 ha of afforested area within the project area.

1.2 Aims and objectives

Overall Aim

To evaluate and assess the different techniques and costs used to restore 493 ha of Coillte-owned blanket bog habitat, which were either planted or drained for afforestation in the past. All these sites are part of the EU funded LIFE-Nature, blanket bog restoration project. The conifers on each of the sites were felled and removed (if possible) in order to enlarge the adjoining open blanket bog areas. The aim is to compare these techniques with other techniques, which have been used on other bog restoration projects in the UK.

Specific Objectives

- Identify best practice for the restoration of blanket bog habitat, which was afforested in the past.

- Identify the most cost effective means of restoring afforested active blanket bog back to open blanket bog habitat.

- Produce information to formulate guidelines for forest managers to assist them in the selection and restoration of important active blanket bog habitat, which was previously afforested (Appendix 1)

2.0 Literature Review

2.1 A Background to the Peatland habitat

It was the conquest of the wetland forests of the Tigris and Euphrates, which enabled the beginnings of irrigated agriculture and the birth of the first civilisations of the world, some 9,000 years ago. Since then, humankind has waged a continuous war of attrition against the wetlands of the world (Bellamy et, al. 1997). Catastrophic flooding and the erosion of many catchments have been the results of this war. Civil engineers have alleviated these problems, however the measures are costly and often cause more problems then they solve. The destruction and the drainage of the world's wetlands continue today unfortunately. However, countries as diverse as Thailand, the Netherlands, Spain, UK and Ireland have begun to recognise the value of wetlands as reservoirs for Biodiversity, as natural filters of pollution and as carbon stores. Europe's wetland heritage is second to none and in particular Europe's bog lands.

2.2 Active blanket bog

Active blanket bog is a globally rare habitat for which the UK and Ireland hold an international responsibility. The term "active" blanket bog denotes a living bog that is accumulating peat; this is indicated by the presence of characteristic bog vegetation, especially certain species of *Sphagnum* moss, bog cottons and purple moor grass. Active blanket bog is recognised as a priority habitat for nature conservation action under EU law (EC Habitats Directive) and a number of worldwide environmental conventions (Bern Convention, Ramsar Convention).

The bird populations on blanket bog are of particular conservation importance and several are 'Red List' species. Hen harriers, merlins, short eared owls, golden plovers, dunlins and greenshanks breed on the hummocks vegetation while red and black-throated divers, greylag geese, wigenos and common scoters nest around the lochs which are an important feature of blanket bog in parts of its range (Wilkie, et al.1988). Open habitat of 270 ha is the minimum conservation area required to maintain the natural bird populations of blanket bogs. Clearly, most of the sites in the Irish LIFE Nature project do not reach that area threshold but add significantly to the open habitat of adjoining SAC areas. However, the sites have been nominated as SAC's not just for their fauna, but because they retain good bog vegetation which must be protected in an area where most of the upland bog habitat has been extensively planted with conifers.

Despite the undoubted number of birds supported on some bogs, the invertebrate populations are not considered particularly unique. Nonetheless, a number of important moths, butterflies (large heath), dragonflies (azure hawker), tipulids and beetles (*Oreodytes alpinus)* do occur.

2.3 Distribution

Peatlands cover over 4 million Km^2, which equals 3% of land and freshwater surface of our planet and represent almost 70% of global wetlands (Clarke et, al.2002). Peatlands are the most widespread of all wetland types in the world. In these ecosystems 10% of global freshwater resources and one third of the world's soil carbon (Joosten et, al. 2002) are found. Peatlands occur on all continents, from the tropical to boreal, artic zones and from sea level to high alpine conditions, Figure 3 presents a World distribution map of peatlands. Peatlands throughout the world form a significant part of global biodiversity. These ecosystems are characterized by the ability to accumulate and store dead organic matter from *Sphagnum* mosses and many other non-moss species, under conditions of almost permanent water saturation. The key to the maintenance of peatland habitats is water hydrology i.e. the controlling and sustaining of water levels. If high water levels are not maintained peat- forming vegetation such as *Sphagnum* mosses and cotton grass do not thrive.

The peatland flora and fauna are adapted to the extreme conditions of high water levels, low oxygen content and low availability of plant nutrients. Their water chemistry varies from alkaline to acidic. It is these remarkable conditions combined which create a specialised flora and associated fauna. The carnivorous plants serve as a good example e.g. the sundew *(Drosera spp.)* (Figure 1), found mostly on peatlands in European countries.

2.4 Importance of Peatlands

Peatlands are important ecosystems for a wide range of reasons including biological diversity, carbon storage/sequestration, hydrological integrity /freshwater quality, and geochemical /palaeo archives. In addition to the occurrence of specialised species bogs are host to a large array of species, which are also found in other habitats. Golden plover and dunlin for example, which can be found feeding on the mud-flats of eastern England, may have spent their summer breeding on the boglands of northern Scotland. The lowland bogs can form a wildlife oasis in an increasingly sterile (for wildlife) agricultural landscape (Brooks et, al. 1997).

Peatlands are natural systems performing local, regional and global functions, however they mean different things to different people. They can be considered as land, wetland, water body, geological deposit, forest stand or natural habitat. In fact they are all these things at one time (Clarke et, al. 2002). They are unbalanced ecosystems. The rate of dead organic matter accumulation exceeds that lost by decay. As a result, layers and layers of organic matter and water develop to form mires. Effectively, mires sequester carbon dioxide from the atmosphere and preserve the carbon as peat in the developing mire (Stoneman et, al. 1997). Their total carbon pool exceeds that of the world's forests and equals that of the atmosphere. It is estimated that peatlands hold between 330 and 530 billion tonnes of carbon (Clarke et, al.2002), which is up to 3 times the carbon of tropical rainforests, and about a fifth of all soil carbon, and would have sequestered about 100 million tonnes of carbon per year (Immiriz et al, 1992). However due to exploitation for agriculture, forestry and peat extraction it is estimated that as much as 600 million tonnes of carbon dioxide are released into the atmosphere every year. This is turning the world's peatlands from a sink to a source of carbon.

2.5 Protection of Peatlands

Protection of peatlands, including the mitigation of damage is essential to ensure that sufficient areas of peatland remain on this planet to carry out their vital functions. Over the past two centuries the global area of peatlands has been reduced by between 10 to 20% (Clarke et, al. 2002). This reduction has been caused as a result of human activities, in particular by drainage for agriculture and forestry. Both continue to be the most important factors affecting change in peatlands, both locally and globally, particularly in the Tropics.

The United Kingdom and Ireland are among the last outposts of peatlands in Western Europe (The Heritage Council, 1992). Peatlands in Europe and globally have disappeared at an alarming rate. In Germany, Poland and the Netherlands, virtually all-natural peatlands have been lost. In the United Kingdom 90% of blanket bogs have been lost. In Ireland, where it was assumed that peatland once covered one sixth of the country, 86% of blanket bogs have been damaged or destroyed. It is now estimated that around 112,000 ha of blanket bog survive relatively intact in Ireland today (The Heritage Council, 1992).

2.6 Peatlands, a vital resource

Peatlands satisfy many essential human needs for freshwater, food, warmth, shelter and employment. Many stakeholders locally, regionally and globally are using peatlands for fuel, agriculture, forestry, recreation and tourism, nature conservation and scientific research. There are indeed many other uses of peat and peatlands which include, environmental improvement and purification systems, medicine, alcoholic drinks, building and insulation systems, textiles and animal stable litter (Joosten et, al. 2002). All these peatland uses, not only generate billions of dollars each year but more importantly underpin downstream businesses, which support the livelihoods of many thousands of people.

Human pressures on peatlands are both direct through drainage, land conversion and exaction and indirectly, as a result of air pollution, contraction as a result of drainage, water contamination and infrastructure development. With the increased human demand for the resources, services and diverse functions provided by peatlands and the growing understanding of their ecological importance to our planet, conflicting uses of peatlands arise (Clarke et, al. 2002). Outlined below are some examples of the diverse, conflicting and important concerns, demands and needs of these ecosystems and their natural resources.

2.7 Concerns

The potential threat from climate change could over-ride many of the following factors. However, it is precisely because of the unknown effects climate change could have that it is important as much of the resource as possible, representing its full bio geographical extent, is brought into, or maintained at, favourable conditions. Pollution, from sulphate and nitrate deposition, may also be significant in certain areas, such as the Southern Pennines.

2.7.1. Peat fuel

Peat is extracted and burned for its high-energy value, in several countries, because it provides an important local and national source of heat and power. It is estimated that 21 million tonnes (Clarke et, al 2002) of peat generate about five to six million tonnes of oil equivalent per year. Around 2000 Km^2 of peatland are used for energy generation and the production of plant growing media. Once the peat is extracted, the bare peat fields are inhospitable to vegetation establishment although, with careful management, wetlands can be created. Without management, peat fields slowly succumb to scrub.

2.7.2. Horticultural uses

Peat forms the basis of growing media required for horticultural plant production. It is an ideal substrate because it is high performing, cost effective, easily processed, uniform and readily available. Almost 40 million m^3 of peat was used around the world in 1999 (Joosten et, al 2002). It is estimated that this business is worth around $300 million per year. This use has had dramatic effects on Europe's lowland peat bogs in the last thirty years. The Government in the UK have recognised this threat, and have set a target that 40% of peat uses should be met by peat alternatives by 2005 and 90% by 2010. Many companies are producing peat alternative products. Scott's company, which is a major peat extractor, has spent more then stg£1 million on research into this area since 1990. The overall goal is to halt all commercialised peat extraction and safeguard the remaining peat bogs in England.

2.7.3 Agriculture

In Europe peatland has had a vital agricultural value for several centuries, and has been the principal sector use of peatland, occupying an estimated 125,000 km^2 (Clarke et, al. 2002). Well-drained peatland soils are among the most productive agricultural lands available, and produce essential food crops. There is a long tradition, which continues to this day, of burning and drainage to dry out the peatland, in an effort to improve grazing. These activities, plus fertilising and seeding, gradually diminish any peatland character. However, many of the peatland areas that have been 'improved' for grazing are classed as marginal agriculture only. The regime of burning and drainage tends to produce vegetation dominated by heather to the detriment of other typical bog species, *Sphagnum* moss for example.

However new drains continue to be dug and old drains cleaned in some areas. Even without maintenance most drains continue to lower the adjacent water table and some initiate erosion. Heavy grazing (by sheep, red deer, cattle and horses) - especially if accompanied by supplementary feeding, burning, fencing and drainage, has a significant impact on vegetation. This is a particular concern on common land.

2.7.4. Forestry

In the tropics and continental climates, hot and dry summer weather allows trees to establish on peatlands and to become part of the sites natural flora. However in Britain and Ireland due to the exposed oceanic climate, trees are very rarely a natural component of peatland vegetation. In the last fifty years extensive commercial forestry operations have been established on peatlands as technology has allowed foresters to exploit peatland areas. Lodgepole pine and Sitka spruce, both non-native species, can be established on deep peat sites, following extensive drainage and fertiliser application. As the trees mature and the tree canopy closes, the rainwater is intercepted by as much as 30% (Stoneman et, al .1997), which maintains sufficiently dry conditions for tree growth. The once open peatland is transformed into a monotonous monoculture of non-native conifers overlaying a bare, shaded ground surface covered with dead pine needles.

On unplanted areas and open rides, (Figure 4) for example shows an unplanted area at Pollagoona sample site A, some of the character of the former bog remains, which suggests that rehabilitation, may be possible. It is estimated that nearly 150,000 km^2 of the world's peatlands have been drained for commercial forestry (Joosten et, al 2002). Current forestry policy in Ireland recognises the ecological importance of peatlands by no longer grant aiding afforestation on peatlands designated as National Heritage Areas (NHA) or Special Areas of Conservation (SAC) and with agreement will remove the legal obligation to replant areas, which have been clearfelled on such sites. In the UK, new guidelines published by the Forestry Commission (Forest and Peat Guidelines) will serve to further protect areas of blanket bog from afforestation.

2.7.5. Burning

Agricultural and sporting management both involve the use of fire to modify moorland vegetation for the benefit of livestock, grouse and deer in particular. Poorly managed and/or accidental fires can be particularly damaging to blanket bog (Clarke et, al.2002).

2.8 The justification for removing conifer crops from active blanket bog

The impact of conifer afforestations on active blanket bog ecosystems is well known. The biggest issue is the impact of tree evapo-transpiration on the wetness of the bog. This effect along with the extensive drainage required to establish a crop of trees, can dry out the peatland and lead to a loss of the characteristic flora and fauna. The impacts of shade from tree canopy closure and needle-fall are also considerable.

Managers, who are faced with the difficult task of deciding what actions to take when trees have to be removed from peatland restoration sites, do have choices. The first choice could be to wait until the ends of the crops rotation, allowing the trees to reach harvestable age, then harvest the trees and restore the site. Conservation agencies may disagree, stating that the last opportunity to restore afforested peatlands with optimal chance of success is before the forest canopy closes and finally shades out what remains of the peatland vegetation community. The alternative is to remove the trees before this stage and forego the profit of the timber crop.

Malcolm Newson and Amenda White (1998) from Newcastle University were commissioned by the Border Mires active blanket bog rehabilitation project Committee, to carry out a number of reports on this issue. Their findings can be summarised below.

- A conifer crop damages a peatland site. Removal of the trees was a priority on the Border-Mires project because an estimated 80% of the damage came from evapotranspiration and about 10% from drains.

- Conifer crops on blanket bog can be split into 4 types and action on when to remove them depends on this classification (Table 1).

(Table 1, Four types of conifer crops outlining action on when to remove conifer crops, source Newson and White, (1998) Newcastle University, reports commissioned by the Border Mires active blanket bog rehabilitation project Committee)

Types	**Descriptions**	**Actions**
Type 1	Trees on Mire. Small, stunted and	Remove urgently.

	the canopy not yet closed.	
Type 2	Trees on Mire. Over 3 meters, closing canopy. Restoration potential unknown.	May need to wait until harvestable age.
Type 3	Trees on soligineous bog margin.	Remove at harvesting age and leave unplanted thereafter.
Type 4	Trees on input slopes not on original mire.	These areas can remain planted and be re-planted as long as the drainage is considered and impact on bog margins reduces.

These results gave the Border Mires project team, a clear priority to remove smaller and stunted plantations as a matter of urgency and allowed more time to investigate the restoration potential of larger crops.

2.9 Examples of Peatland Restoration Projects

Many restoration projects have already been started in a number of countries. However, these have mostly been on drained or cutover bog. Few have been on afforested bogs; therefore published reports of vegetation change following bog restoration are difficult to interpret because the projects reported on are generally too recent for the direction of succession to be clear.

2.9.1 Thorne and Hatfield moors, South Yorkshire, and Wedholme Flow in Cumbria, England.

One of the biggest restoration agreements, which English Nature has negotiated, has been the early handover of the UK's largest areas of peatland from the Scotts Company, a major peat extractor. The £17 stg million deal, which began in 1992 following an agreement with one of Scotts predecessors, Fisons, secured 1,526ha of Thorne and Hatfield moors in South Yorkshire, and Wedholme Flow in Cumbria. The agreement sends out a powerful message that the future of horticulture lies in the use of peat alternatives, not peat-based products. Under the agreement, which the Department of Environment, Food and Rural Affairs has funded, Scotts agreed to cease work on the Thorne and Wedholme moors immediately, but continued to harvest parts of Hatfield Moor for a further two to three years. This work had to be done in strict accordance with management guidelines set down by English Nature. The work also helped maintain the local workforce at Scotts Hatfield processing factory as alternative products to peat are developed. As part of the agreement English Nature enlisted Scotts knowledge, workforce and hardware to help with the four-year restoration programme.

The agreement has meant that the largest peat bog SSSI's will no longer be affected by peat extraction. Wedholme Flow and the two adjacent SSSI bogs are three of the most important bogs in the UK, containing some of the best and most extensive areas of original, intact, uncut mire. There is only an estimated 450ha of such bog surface left in England and about 100ha of this is on Wedholme Flow.

Restoration work started on Wedholme bog and on the parts of Hatfield where extraction had ceased. Firstly the physical condition of the peat had to be examined, from the sluices and the dams that controlled the water levels. English Nature has been restoring bogs since 1985 and has pioneered a range of restoration techniques. They have been imaginative in their methods and techniques and many have followed their example. They consulted widely and studied restoration techniques used in the

Netherlands, Germany and Canada. Following the assessment of the landforms and the conditions of the site, blocking of the drainage ditches commenced and dams were installed in agreed areas of the bog. The maintenance of the correct water level is crucial, too much water and nothing will grow, not enough, and then bracken and birch will generate on the bog surface. One of the problems faced by English Nature was the complete absence of plants crucial to peat restoration on some parts of the bog. Some parts of the bog had been completely stripped down to bare brown peat with no donor or 'refugia' plants left at all. Therefore restoration work included translocation of plants from other parts of the bog and collecting seeds from plants, which were then broadcast in the bare areas.

To qualify for selection under the Species and Habitats Directive, an area of cut-away bog should be able to re-establish peat forming vegetation over a 30-year period. Restoring Wedholme Flow, Thorne and Hatfield moors to something of their former glory is more then just an exercise in environmental restoration. As an endangered and rare habitat, lowland blanket bog harbours many species, which cannot or rarely exist elsewhere. Preserving the Peatland will help safeguard rare species such as the European nightjar, large heath butterfly and bog bush cricket, mire pill beetle, the bog rosemary and sundew for example (English Nature, 1995). "It is great to have the handover of land and the restoration to follow, but we must ensure we're not left with a huge, fenced off area that people can't visit" (Jeff Lunn, English Nature).

2.9.2. The Border-Mires Active Blanket Bog Rehabilitation Project 1998 to 2003

The Border Mires, located in the North of England, are designated cSAC active blanket mires, because of the quality and extent of their bog vegetation. Outside of the Flow Country found in Scotland they are one of the best areas of mires landscape in the British Isles. Between the 1940's and up to the 1960's large-scale afforestation resulted in extensive areas of these mires being disturbed following drainage and planting of trees. However, since the mid 1980's six agencies (The Forest Enterprise, Newcastle University, English Nature, Northumberland Wildlife Trust, Northumberland National Park Authority and The Royal Air Force (RAF) at Spadeadam) have been working together to manage the conservation of this important group of mires. The overall aim of this group has been to restore the previously afforested areas by removing the trees and restoring the hydrology of the mires by blocking drains.

The main problems that needed to be addressed were,

- The area of blanket bog had been reduced due to afforestation.
- Natural water levels on the open bog had been lowered as a result of forestry and agricultural drainage.
- Natural regeneration of conifer trees on the open bog.

The project objectives were to expand the area of high quality blanket bog by,

- Deforestation of an estimated 200ha to enlarge the blanket bog area.
- Ditch blocking to reinstate the integrity of the hydrological systems.
- Removal of naturally regenerated trees from the open bog area.
- Creation of small pools to improve the breeding habitat of wading birds.

2.9.2.1 Overview

During the four years of the Border Mires LIFE funded work, the project team has designed and delivered a programme of bog restoration. In order to achieve bog restoration, the project team have been through a learning process, which included the definition of restorable bogs, the costs and likely problems of the range of conifer removal techniques and their relative strengths and weaknesses. The project team that completed the restoration work on the Border Mires have built up considerable expertise due to the wide range of techniques trailed, the experience of where they are appropriate and the associated costs. The attendance and feedback at seminars and the numerous enquiries and visits for example visits from groups of Irish Foresters confirms the team’s viewpoint. The planning and costs of the Coillte project were based on the Border Mires project, Tom Kavanagh and Philip Murphy from the Coillte project team visited the UK to investigate the Border Mires project in 2001 while putting together their application for LIFE funding for the Irish project. The team were surprised at the scale of interest from the professional conservation sector.

2.9.2.2 Conifer clearance from the Border Mires Project

The techniques that were used for the removal of conifers from the Border mires project were not well understood at the outset due to limited knowledge and little experience of this type of operation. Therefore the techniques had to be developed which were most appropriate for the removal of different sized conifer crops. Working with a wide range of tree sizes and species with a fixed budget led to experimentation with a number of different techniques. The project team have stated that this has been an extremely valuable exercise; because it has enabled them to learn which techniques were most appropriate in the different conifer crops and how the choice of technique is influenced by budget constraints. Methods of conifer clearance and the cost per ha used in the Border Mires Project 1998 to 2003 are presented in Table 2.

The project received funding from Life-Nature, which helped to raise the profile of the project and enabled the rehabilitation work over a larger area and within a shorter time scale. The following work was completed in the first four years of the project, felling of 240ha's of conifer plantation, clearance of 90ha's of Sitka spruce regeneration, the construction of almost 3,500 dams and the creation of 130 pools to improve breeding conditions for wading birds. About 25% of the rehabilitation work is now completed, which has seen 500ha of mire restored to favourable conditions with 250ha of cleared mire steadily improving in quality. It has been the bog restoration techniques used on afforested peatland pioneered on this project and links with other LIFE funded projects with an emphasis on tree clearance, which have been applied and developed on the Irish blanket bog restoration project.

2.9.2.3 Blocking the Drains

A high water table is the key to restoring bogs and actions such as blocking the drains to raise the water table are likely to be necessary. Drains may need to be blocked by damming to reduce their effect on water levels in the peat. Blocking drains on peat sites is an accepted and common means of locally raising water tables. Dams can also help prevent or reduce erosion in ditches, particularly where they are large and/or deep, and also creates areas of open water for colonisation by vegetation and invertebrates. Blocking drains has a marked effect on water levels within and immediately adjacent to the ditch. Circumstantial evidence also points to improvements in the overall wetness of a bog over a large area once major and minor drains are blocked.

3.0 Methodology

During the study the effects and results of 3 different conifer clearance techniques (outlined below) were assessed. All the sites lie within or adjoin candidate Special Area of Conservation (SAC) active blanket bog areas.

The sites range from areas of unplanted blanket bog to areas of blanket bog, which were afforested and containing tall, closed canopy conifer trees. As a result of the different degrees of tree cover and age, the restoration of each of the project sites involved the implementation of a range of different conservation techniques and measures. In general terms the main restoration measures completed were the removal of the conifer trees and the blocking of any existing active drains. It should be noted that many of the sites contained a mixture of open and planted areas and thus required more than one of these restoration techniques.

The effects, advantages, disadvantages and results of each of the different techniques listed below are compared. The effects of each of the techniques used will be recorded as part of the field visits and the results will be compared:

a) Technique No 1, Manually block drains with plastic sheeting and fell all trees to waste manually (using a chainsaw). (Sample site A, Pollagoona project site no 4 Co Clare).

b) Technique No 2, Fell all trees to waste manually (using a chainsaw) and windrow the site with excavator and block the drains with peat and plastic sheeting. (Sample site B, Shanvolahan project site no 11 Co Mayo).

c) Technique No 3, Harvest all trees mechanically and extract timber from the site and block drains with plastic sheeting and with peat (Sample site C, Emlaghdauroe project site no 5 Co Galway).

3.1 Site Monitoring

A standardised recording form (Figure 5) has been created and these were used during field visits to each of the selected sample sites. Site monitoring of the selected sample sites included the following:

- A visual assessment of water levels on the site after tree felling and drain blocking.
- An inspection of the effects of the different techniques used to harvest or fell to waste the trees from each of the sampled sites, highlighting the advantages and disadvantages experienced on each site.
- An inspection of natural site features such as rare plant communities.
- Collect measurements from dipwells (Walrags) to directly access the effect of drain blocking and hydrology of the sites (Figure 6 and 7).
- Vegetation description will be carried out in selected plots and percentage cover recorded on target species e.g. Purple moor Grass and *sphagnum moss* to assess the recovery of the bog vegetation (Figure 7a).
- Record any other observations.

3.2 Water Monitoring

Bog restoration requires a thorough understanding of the hydrology of a site. Conservation management of bogs is undertaken to change vegetation composition and structure; this is achieved by direct methods of vegetation management or indirectly by modifying hydrology (Stoneman el al, 1997). In order to facilitate bog growth the water table has to be kept within 10cm of the ground surface for at least 90% of the year (Conaghan, 2006).

Hydrology monitoring of the selected sample sites to assess the effectiveness of the restoration techniques, was completed on one of the sample sites. Emlaghdauroe was the site selected because it was the only sample site which had a complete set of results since restoration work commenced in 2003. Measurements of the water levels were carried out using instruments, which measure the actual ground water level such as dipwells. WaLRaGs (Water Level Range Gauge)(Figure 8) are dipwells, which show the current depth to water table (DWT) and also shows the highest and lowest DWT since previous reading. Walrags have been in place on some of the 14 sites since the project began in 2001, earlier data collected on the sample sites, was updated with measurements recorded from field days carried out as part of this dissertation. Lower extremes are particularly useful to know because this is a limiting factor for many typical bog species (Brooks et al, 1997). Fixed point photograph monitoring was also used, as it is a valuable way of monitoring the visual history of change from the same view at different times.

The field visits for this dissertation will concentrate on and compile data from a selection of sample sites, which have been restored since the project began in 2001. It was not possible to visit all 14 sites during this dissertation due to time restrictions; therefore 3 sites were selected which featured the three techniques being studied. The recovery of the bog vegetation and effectiveness of each of the techniques used were monitored and the data collected compared to the results of the baseline surveys of the sites conducted before any trees were removed in late August and early September 2001 by Dr John Conaghan, Enviroscope Environmental Consultancy. The species composition of sample plots gives an indicator of site wetness. This methodology is still in an experimental stage but initial results suggest that this is an effective tool for monitoring the recovery of the bog ecosystems.

3.3 Vegetation monitoring

During the site visits vegetation monitoring was carried out on each of the sample sites on representative parts of the bog, which had been afforested in the past and are now felled. The presence and cover of target species such as Purple moor Grass and *sphagnum moss* was recorded using the survey card. Plant species were used to monitor vegetation change on the sample sites where conifer removal had been undertaken using the different techniques. Plant species composition was used to monitor vegetation change in the dammed areas and in areas cleared of conifer plantation on the project sample sites. Plots of 8m by 8m were positioned on the sites and their location recorded with GPS. The most important vascular plants and bryophyte species were identified in each plot, with the percent cover of each species being estimated visually. The number of plots taken and on each sample site within each technique used is presented in Table 3.

(Table 3, Number of plots located on 3 sample sites within three conifer clearance techniques)

Site	**Fell to Waste**	**Fell to waste & wind-row**	**Fell & Extract harvestable material**
Site A, Pollagoona	**0**		

	(Site extremely difficult to access visual inspection carried out during site visits)		
Site B, Shanvolahan		**2**	
Site C, Emlaghdauroe			**3**

3.4 Sample Site Descriptions

The general location of active bog restoration project sites in Ireland is shown in Figure 2, the map highlights the location of each of the sample sites selected.

3.4.1. Sample site A, Pollagoona Bog, Co Clare, Project site No 4

Pollagoona Bog is a small blanket bog, situated at an altitude of 150m above sea level, in a shallow saddle on gently sloping terrain within the Slieve Aughty uplands in County Clare, Ireland. The site lies about 20 kilometres southeast of the town of Gort, Co. Galway). Lough Atorick lies just to the northwest of the site. Coillte-owned conifer plantation, much of which is more than 15 years old, surrounds the bog. The intact bog core has been designated an SAC, and in addition some of the surrounding planted bog has been included. The bog displays some features transitional between blanket and raised bog. A map of the site is shown in (Figure 9) and an aerial photograph of the site before restoration work commenced is shown in (Figure 10).

In general, the bog is of high ecological value, being soft, wet and quaking over most of its surface. Along the intact bog margins, where the peat is relatively shallow the vegetation is dominated by purple moor-grass (*Molinia caerulea*). The central areas of the bog are wetter and in these central areas plant species such as bog asphodel (*Narthecium ossifragum*) and cross-leaved heath (*Erica tetralix*) dominate along with *Cladonia portentosa* and *Sphagnum capillifolium*. *Sphagnum* cover was high, with some well-developed hummocks and lawns, with white-beaked sedge (*Rhynchospora alba*) present. An unusual feature of the bog vegetation here is the presence of bog rosemary (*Andromeda polifolia*), and cranberry species that are more typical of raised bogs.

During 2004/2005 the conifer plantation, which was a poor low-yielding crop, has been removed using Technique No 1 (Manually block the drains and fell trees to waste with a chainsaw). Before the trees were removed the margins of the bog were noticeably drier than the centre, however with the removal of the trees and the blocking of the drains the drying out has been reduced to some extent. In parts of the area of the plantation where the trees were poorly developed, there has been good regeneration of blanket bog species, most notably *Molinia caerulea.*

3.4.2. Sample site B, Shanvolahan bog,Co Mayo, Project site No 11

The Shanvolahan site lies within the extensive Bellacorick bog complex, which is one of the finest examples of a relatively intact lowland blanket bog landscape in Ireland. An SAC protects the whole area, which is notable for the widespread occurrence of flush and fen vegetation. These flushes contain mineral-rich and calcareous groundwater seepage areas, which support a number of rare plant species, for example cranberry(*Vaccinium oxycoccus), Homalothecium nitens* and the legally protected species slender cotton grass(*Eriophorum gracile).*A map of the site is shown (Figure11).

The majority of the site had been planted with conifer trees of varying ages and size. There were also small areas of open blanket bog, which were not planted due to their very wet, pool-studded nature, which have a high ecological value. It was crucial that these were protected from damage during the restoration works, which included the felling of the trees and the blocking of drains. In an effort to understand the hydrology of the area a detailed ecohydrological survey was carried out. There are a number of permanent sample plots located within different parts of the site, in order to monitor the future vegetation recovery.

Approximately 20% of the site contained young, low-yielding conifers, which were removed during 2003/2004, using Technique No 2 (fell trees by chainsaw and windrow). Approximately 36% of the site contained mature conifer trees, which were removed in 2005,using Technique No 3 (Harvest all trees and extract timber from the site). Figure 12 shows a harvester felling mature pine trees at Shanvolahan sample site B and Figure 12a shows forwarder extracting timber from the harvester to the roadside at Shanvolahan sample site B.

3.4.3. Sample site C, Emlaghdauroe, site 5, Co. Galway

The Emlaghdauroe site is located in Connemara Co Galway, and lies on the southwestern slopes of Ben Gleninsky, which is on the southern edge of the Twelve Bens mountain range. The area surrounding the site is all zoned SAC and once the restoration work completed on the site has been shown to be successful, the site will be subsumed into the SAC. This site had 64 ha of mature conifer trees, which contained very little bog vegetation on the ground due to the advanced age of the plantation. A map of the site is shown in (Figure 13).

Most of the area was commercially felled in 2003 with a small area to the west of the road felled in 2004. The trees generally grew well and effectively killed off much of the bog vegetation. Approximately 85% of the conifer crop has been removed here using, Technique No 3 (Harvest all trees and extract timber from the site). There was a small area of the site were the trees were poor, so they were felled to waste and chipped. The remaining 15% of the plantation was removed using, Technique No 1 (Fell trees to waste with a chainsaw) because the area was too steep and dangerous to operate the harvesting machines.

4. Results and Analysis

Details for all plots taken are shown on completed site survey sheets in (Appendix 2).

4.1.1. Sample site A - Pollagoona Bog

The manual blocking of drains and felling trees to waste using a chainsaw technique was used on this site, therefore the tangle of fallen trees and debris made it extremely difficult to gain access. As a result no plot was laid down. From a visual inspection, during a number of site visits the following results are a fair reprehension of the site.

Overall assessment of bog vegetation recovery – The recovery at this site has been good where the trees were small, due to the fact that there was a high percentage of vegetation present before the trees were felled. There is a strong re-growth of purple-moor grass, which is the main re-colonising species in Irish lowland blanket bogs (Figure 14 shows Pollagoona before trees were felled and figure 14a shows after the trees were felled). However in other areas it will take another couple of years before the felled trees degrade sufficiently to allow bog development.

4.1.2. Sample site B - Shanvolahan bog

The younger felled conifers were windrowed and now there is a strong re-growth of purple-moor grass. (The windrowed site is shown in Figure 15). The area that was recently cleared of the larger conifer crop (Figure 16) is dominated by brash and pine needle litter at present. However blanket bog species such as purple moor-grass and various *Sphagnum* species are already starting to colonise the wetter, flatter areas of the site where drainage is impeded.

Overall assessment of bog vegetation recovery – Very good recovery in areas were there were younger trees, which were felled to waste and windrowed. Bog vegetation recovery in the areas, which have only recently been cleared of larger conifers, will take a much longer time, however initial observations are promising.

4.1.3. Sample site C - Emlaghdauroe

Since felling, the recovery of bog vegetation has been slow. Fixed-point photographs, viewed from the public road before and after the trees were felled are shown in Figure 17 and 18. Over much of the site there has been re-growth of purple moor-grass, however this has been quite patchy. In sloping areas in the southern half of the site, where tree growth was best, the regenerating vegetation is dominated by soft rush (*Juncus effusus*) (Figure19). This growth of soft rush is probably due to a combination of the drying out of the peat soil by the trees and flushing effects caused by flowing surface water after the tree canopy was removed and the disturbance of the machinery. It is thought that the cover of soft rush in this area will decline over time, as the peat is re-wetted and the nutrient level of the peat declines.

Overall assessment of bog vegetation recovery – The recovery of bog vegetation at this site has been generally slow due mainly to the well-developed conifer crop, which previously dominated the site. Where there were poor areas of trees the bog vegetation recovery is much faster, due to the presence of bog vegetation pre clearfelling. There are also very flush areas with a high percentage of purple moor grass, which were not planted i.e. old ride-lines (Figure 20).

The different techniques of conifer clearance and the cost per ha used on Coillte LIFE project sites in the west of Ireland are present in Table 4. A summary of the advantages and disadvantages of conifer clearance techniques is presented in Table 5, which was used on the Coillte Blanket bog restoration sites. The positive and negative factors affecting the feasibility and cost effectiveness of the restoration of active blanket bog habitat are presented in Table 6.

(Table 5, Summary of advantages and disadvantages of conifer clearance techniques used on the Coillte, Blanket bog restoration sites).

Techniques (Methods) And Sample Sites were each method was used	**Advantages**	**Disadvantages**
Technique No 1 (Fell trees to waste with a chainsaw) **(Sample site A) Pollagoona**	• Relatively inexpensive and easier. • No damage to peat surface with machinery. • Best technique for clearing tree crop on isolated and inaccessible sites.	• Enrichment, shade if crop is dense. • Loss of aesthetic appeal, trees left lying on site. • Impossible to carry out follow up work, such as the blocking of drains and

		monitoring for conifer regeneration. • Felled trees, once tried out on elevated ground can be blown off the site.
Technique No 2 (Fell trees by chainsaw and windrow) **(Sample site B) Shanvolahan**	• Relatively inexpensive and easier than fell and chip. • Proven to be the most successful technique for the removal of unproductive crops (developed during the Irish project). • Machinery used to windrow site can be used to block drains with peat, which reduces costs. • No dried out felled trees can be blown off the site if windrowed.	• Size, species and planting density affect felling work. • Slight risk of damage associated with machinery used to windrow the site. • Limited to sites which allow access for machinery.
Technique No 3 (Harvest all trees and extract timber from the site) **(Sample site C) Emlaghdauroe**	• No additional input and therefore no net cost, but this depends on crop value. • Can manage mature tree crops. • Bog recovery rate in non-brash areas is good.	• Bog vegetation killed off by crop. Unknown timescale for full recovery. May take 30 to 40 years. • Site damage from machinery can be considerable.

(Table 6, Highlights the positive and negative factors affecting the feasibility and cost effectiveness of the restoration of active blanket bog habitat).

Positive factors aiding cost-effective restoration of active blanket bog habitat	Negative factors hindering cost-effective restoration of active blanket bog habitat
• Maximum distance to solid road if less then 1 km^2 will allow harvesting of productive timber without the cost of making a new road. • Easy site accessibility and flat ground are important when installing dams to	• Maximum distance to solid road more then 1 km^2 may require a new road, which increases the restoration costs, fragments and damages the site. • Sloping site makes rewetting more difficult and can be difficult to access

aid rewetting of the bog. • If timber is productive, pure Sitka spruce crops provide good quality and quantity of brash, which provides good brash mats to aid extraction and leaves a clearer site to restore. • Unplanted pockets within the forest site provide remnant bog vegetation, which is a source for re-colonisation. • Site adjoins area of unplanted bog habitat, which provides remnant bog vegetation as a source for re-colonisation. • Presence of key drainage exit points, where drain damming can be straightforward and results in the rewetting of large areas of the bog.	with machinery. • Pure lodgepole pine crops are more difficult to harvest due to brash shortages and breakages. Needle litter from pine crops will slow down bog vegetation re-colonisation. • Older productive plantations where the forest canopy is closed, will have very little or no remnant bog vegetation. • No adjacent unplanted bog, resulting in very little or no bog vegetation to act as a re-colonisation source. • Absence of key points in drainage system makes rewetting far more expensive.

4.2 Blocking the drains

Blocking of the drains can be carried out using a variety of materials, however only 2 types of material were used on the Irish project, each of which has its own advantages and disadvantages (Table 7).

(Table 7, Blocking of the drains in peat bogs. Advantages and disadvantages of 2 different materials used on the Irish project)

Materials	Advantages	Disadvantages
Plastic piling	• Easy to use with little training required • Can be made of 100% recycled plastic	• May require additional support on large ditches if holding back more then a head of about 30cm for each dam • It is an expensive material to use

	• Few tools required to install (chainsaw and rubber mallet) • Extra pieces can be added later on, if the dam does not work the first time • Versatile, quick to install and light to transport	and must be imported • If cut off, site sizes need to be assessed accurately first
Peat	• Where machinery access is possible large numbers of peat blocks can be installed quickly • Free material available on all sites • If a site is being windrowed the same machine can be used to block the drains, more cost effective	• Can cause damage to nearby bog if material is not carefully sourced or installed • Only suitable for small dams with low water flow • Can breakdown faster then plastic piling

4.3. Yield Class

The yield classes of the conifer crops, which were removed during the Irish LIFE Bog Restoration project have been summarised in (Table 8). The yield class of the crop is a measure of the mean annual tree increment and is a very good indicator to establish the quality and productive capacity of the crop.

(Table 8, Overview of YC for the 493 ha's felled on the Coillte Life project sites)

Yield Class	Percentage of total ha's of each yield class
YC 16	3% 17ha's has a YC of 16
YC 14	15% 75ha's has a YC of 14
YC 12	28% 135ha's has a YC of 12
YC 10	47% 231ha's has a YC of 10
Undeveloped	7% 35ha's was classed as undeveloped

4.4 Walrag results

(Figure 21) Shows a graph of the results from 3 walrags (W1, W4, W8), which are located on the Emlaghdauroe site. The three walrags were chosen at random and their location was used as the centre point for the vegetation monitoring plots, their locations are highlighted on the site map Figure 13. Measurements were collected during the field visits and these measurements were added to the previous measurements recorded by Dr John Conaghan, the results of the measurements are presented in Appendix 3.

(Figure 21a) Shows a graph of the results from the walrag measurements recorded by Dr John Conaghan from another project site at Owenanirragh, Co Mayo, project site No 9. The reason for including this is in order to show how intact bog, bog with small trees and bog with large trees behave. The results of the measurements are presented in Appendix 3.

5.0 Discussion

There are two main issues to be considered when deciding on the best technique for the removal of conifer trees from a bog restoration site.

Firstly the site needs to be accessed to establish the size, density and quality of the trees to be removed because these factors will dictate which techniques can be used.

- Harvesting and extraction of the marketable timber is the only suitable technique for mature crops, there is considerable experience in the forestry sector and particularly in the West of Ireland of harvesting on wet sites.
- Fell to waste on inaccessible and isolated sites and fell to waste and windrow trees if site is accessible are most suitable for young and small unproductive

crops. Cut and chip has proven unsuitable, due to the high cost, and was too slow and was limited to trees size, during the Irish project.

Secondly cost is a major factor.

- While fell to waste is cheap for smaller crops a lot of bulky material can be left on site, which will take much longer to recover.
- Fell to waste and windrow; costs are more but like harvesting and extraction most of the bog surface is cleared of bulky material allowing the bog to recover much quicker as highlighted by the sample plots.

Project managers must weigh up if they have a large or small area of trees to clear, what budget is available, will the site be suitable for LIFE Natural funding and how quickly they want the site to recover. All these factors will influence whether they will opt for an expensive or cheaper technique. We do have a good idea of the costs involved for the different techniques; the average cost per ha from the Border Mires project was £848stg ha (or €1130 ha) to clear 246 ha based on prices paid from 1998 to 2003 and the average cost from the Irish project was €1108 ha to clear 493 ha based on 2006 planned prices (Table 2 and table 4). However it will be some time before it is clear how quickly and to what quality some of the sites will recover. We now know that fell to waste and windrow will result in rapid recovery of the site. In mature crops the only technique is to fell and extract the timber but recovery time will be much slower, possibly 20 to 30 years. The fell to waste technique is the only option for inaccessible areas, but recovery will be slow, because the material remaining is so dense that it shades the bog surface preventing the growth of bog vegetation. Therefore it will be some time before we have a clear answer.

One problem associated with the project, especially for Technique 3 fell and extract, was the use of heavy machinery working on deep bog. Bogging of machinery causes problems in that recovery is time consuming, requiring more machinery, which increases costs and causes extensive damage to the bog surface and its vegetation. Multiple runs over the same extraction rack, even using a lightweight machine with tracks can cause damage to the surface and slow down bog vegetation recovery. This was a particular problem at Emlaghdaure site, because of bad weather during the summer of 2003, perhaps if the forest road was extend the damage would have been reduced, but this would have increased the costs and the construction of the road would have reduced the area of bog surface and fragment the site.

Brash mats can be very efficient at spreading the weight of machines and are used extensively in forestry operations on peat site. However pine brash is not as effective because it breaks down faster then spruce brash. The trees felled using technique 2, fell to waste and windrow at Shanvolahan sample site B, are also used to form brash mats to reduce the damage to the bog surface and prevent the digger from bogging. Manual felling is suitable for sensitive sites and inaccessible sites like Pollagoona sample site A, where trees are being felled to waste. However, any manual work is expensive, slow and impractical for any large task and impossible where removal of the crops is involved.

Another problem associated with the restoration of peatlands is leaving material on-site; this mainly is as a result of using technique 1 fell to waste. Apart from the material shading the bog surface and preventing the growth of bog vegetation, it is unsightly (Figure 22) and reduces the aesthetic characteristics of the site. The aesthetic appeal of open extensive peatland sites is considerable and one littered with dead material is perceived as poorly managed and neglected. This is one of the biggest problems with leaving material on site. However after only three years the area felled to waste, at the Emlaghdaure site, which is a high landscape site, is covered by purple moor grass during the summer months and the felled trees are difficult to see. (Figure 23) shows the area from the public road in April 2006 before the growth of the purple moor grass begins.

From the experience gained to date from the projects, what seems evident is that *Sphagnum* growth on cleared areas is much quicker than was thought likely probably because the climate dictates that natural vegetation on these sites should be active blanket bog. Because the project carried out hydrological restoration as well as tree clearance it appears to be leading to a much faster and more extensive recovery of bog vegetation. We can therefore assume from the evidence to date that there will be a strong possibility that a good recovery of these sites will be achieved in the long term.

Initial vegetation growth after tree clearance has been rapid on most of the sites, with large mono-specific stands of *Sphagnum* species growing within two to three years from those plants that were already present, having survived the conifer crop. Other positive indicator species found on the project sites were Bog Bean *Menyanthes trifoliata*, Bog Myrtle, *Myrica gale*, *Hypnum cupressiforme* and *Rhytidiadelphus loreus*.

However restoration results from Scandinavia have been mixed. Koveronneva in Central Finland was one restoration project, which began in 1987. The area was an ombrotrophic blanket bog, within a National park, which had been drained and fertilized in 1970, but the trees had still been poor. There was no visible vegetation response in the restored areas and numerous tree seedlings were growing on the area where the trees had been cleared, perhaps not surprising since the water table had hardly risen (Heikkila. et al, 1995 in Anderson. R., 2001). Thus, early indications were that the restoration of Koveronneva bog was probably unsuccessful. Evidently the use of dams to block drains and furrows is an essential component of all clearance methods. Conifer clearance is only the start in a long process with an uncertain time scale. However, we can be certain that without dams the necessary raising of the peat water will not be as certain and the desired vegetation change to ombrotrophic open active blanket bog will be less then likely.

The main species to re-colonise following conifer clearance is purple moor-grass (*Molinia caerulea*). At most sites the species survived in situ underneath the tree canopy, albeit at a much reduced cover. Following tree felling there is usually a flush of moor-grass growth and it appears that most sites will go through this initial phase of moor-grass dominance. Over time however, as the peat gets progressively more waterlogged, it is anticipated that plant species indicative of wetter bog conditions such as *Sphagnum cuspidatum*, black bog rush (*Schoenus nigricans*), white-beaked sedge (*Rhynchospora alba*) and sundews (*Drosera* spp.) will gradually re-colonise and spread. In areas of older plantation, which have closed canopy, it is evident, even at this stage of the project that the re-colonisation of bog vegetation will take longer than 5 years.

At one of the sites (Emlaghdauroe sample site C) there has been some development of rush-dominated vegetation (Figure 19). Observations of other clearfelled areas in the west of Ireland suggest that areas dominated by soft rush will gradually revert to purple moor-grass over time. The timescale of this changeover will be monitored at this site into the future. It is of interest to note that there has been very little re-sprouting from the cut stumps of conifers. In addition it was anticipated at the beginning of the project that the natural regeneration of pine would be a significant problem however this does not seem to be the case. Small areas of regenerated pine have developed on some sites, but the large pine weevil has joined the restoration team and killed off a lot of the regeneration particularly in Emlaghdauroe sample site C. The project includes a plan and budget to remove any regeneration from the sites; the trees are pulled from the ground or cut with a chainsaw.

There have been several techniques tested for blocking drains, and information on the results shared between different LIFE funded projects (Table 7 and 8) highlight advantages and disadvantages of the methods used on the Irish project. The favoured option is the use of interlocking plastic revetments, because they can be carried onto the site in sections and sawn to the required size. Installation is relatively straightforward; with out requiring ground preparation however the material is expensive, costing up to €30 per drain (Figure 24), compared to €1.50 per drain for peat block (Figure 25). They can be hammered into the ground with a rubber mallet section by section and they can also be extended laterally at a later stage if need be. Spacing between dams is dependent on slope. However, it is not cost effective to do detailed levelling surveys, a general rule of thumb is i.e.

- Fairly level - 1 dam every 20meters
- Obvious slope -1 dam every 10meters
- Steeper slope -up to 1 dam every 3meters (only at the bog edges)

Installing a large number of dams does not always guarantee successful rewetting of the bog. At Horse Hill Moss in Kielder Forest, over 700 dams were used on 1.5 ha of plough furrows but left a confusion of hydraulic pathways, apparently unaffected by the damming (Clothier, 1995). Many of the dams appeared ineffective with only major drains being blocked successfully. A restoration project in southern Finland, which had been drained for 28 years before (Komulainen, et al., 1988), showed a marked rising of the water table when bog restoration treatments were applied.

Rewetting by the removal of trees, blocking of the drains, raised the mean summer water table level from 31-36cm below the surface before to 11-16cm after.

Evidence of successful restoration is limited and little has been published on the costs or results of attempts to restore bogs. This is mainly due to the fact that most projects are only a few years old and it may take 20 or 30 years before the real restoration effects are known. However a lot has been learnt from the Border Mires project and the Irish project. For example, success has been achieved at some of the 14 sites in the West of Ireland, where summer water levels were raised considerably by using a digger, which was on site to windrow the fell trees and to infill the drains with peat from the site. This method was used along with the blocking of all main outlet drains on the boundaries of the sites, using interlocking plastic revetments; this resulted in a huge saving on costs, labour and materials. It was also noted that on some sites, particularly where the site was flat and quite wet, that the requirement to block the drains every 20m was not necessary. On some of the 14 sites where the trees were felled and removed or cut to waste and windrowed, a large amount of lop and top or branches was compacted into the drains, this helped to block the drains and also reduced the need to use interlocking plastic revetments.

Following the blocking of the drains on the project sites, the wetness of the sites is reflected by the rapid spread of *Sphagnum* moss *(Sphagnum capillifolium)* in the drains. However, the resulting deep water-filled drains can be extremely hazardous when walking on a site, and are likely to remain hazardous for many years because of the slow rate of occlusion. Effect of blanket restoration treatments on water levels is summarised in (Table 9).

(Table 9 shows the effect of blanket bog restoration treatments on water levels, source, Andererson.R .1999)

Treatment	**Depth to water table in summer (cm)**	
	Wet month	**Dry month**
Do nothing (control)	16	47
Fell to waste *Or* Fell and remove whole trees from site *Or* Leave trees standing but dam plough furrows	14	38

Fell to waste and dam plough furrows *Or* Fell and remove whole trees and dam furrows	12	31

In general the walrag measurement results (Figure 21 and 21a) show a slow rate of recovery in water levels and it is going to take many years for the water table to return to high values. The period of three years over which the measurements have been read is too short to allow firm conclusions to be drawn.

The results of the assessment of the yield classes from the 493 ha of conifer trees cleared (Table 8) shows that 82% of the sites were yield class 12 or less. However it must be stressed, that for a large number of the sites the inventory data was out of date, some by up to 14 years. If the site were to be resurveyed before the trees were cleared many of the higher yield classes would have been reduced. We can therefore state that the most suitable sites for bog restoration are areas with low yield classes 12 or less and areas of low productivity.

Recreational use of peatlands is a cause of disturbance, due to the soft surface and low growing plants. A study of systematic trampling for 10 minutes, repeated three times a year for three years almost destroyed the cover of *Sphagnum recurvum* and *Sphagnum fuscum*, and had dramatic changes to the soil fauna (Borcard and Matthy 1995). Therefore boardwalks (Figure 26 and 27) have been constructed on the demonstration sites along with information boards (Figure 28) to inform visitors of the aims and objectives of the project.
Other major challenges for the project were the reduction of grazing on overgrazed sites, the inaccessibility of some sites where mechanized felling was carried out and the planning of cost-effective rewetting measures for the afforested sites.

The variety of techniques, which have been used on the active bog restoration project in the West of Ireland, have improved knowledge on the most suitable options for conifer clearance which depends on average tree size, stocking density and availability of funding. Techniques for ditch blocking have also been developed and improved.

6.0 Conclusions

Over the last five years of the Irish LIFE funded active blanket bog project, the team has successfully designed and delivered a programme of bog restoration and are to be complemented on achieving their aims. The team have been through a steep learning curve, because there had been so few examples of how to do this type of work and only a few other restoration projects, which involved the removal of conifer plantations. The project team for the Border Mires project in the UK have been extremely helpful and the sharing of their experiences and their feedback, through numerous seminars and site visits has been invaluable to the Irish project.

However each site is very different and presents new and challenging issues and the use of a wide range of techniques is required. Some of these have been learnt through experience of success and failure, because there are so few examples of how to do this type of work. Therefore the team had to adapt and experiment with a wide variety of techniques. A good example of this has been where the technique of fell and chip which was tried at 2 sites but was not suitable, because of accessibility, huge costs and it's suitability for only small diameter trees. This led to the development of a new technique for younger plantations or poor areas of unproductive trees. By using the cut to waste method manually using a chainsaw and windrow method with a low ground pressure digger with wide tracks, the machine could also be used to block the drains using peat. Both lead to a more cost effective method of restoration. There is no sense in spending €4,480 per ha, when you can spend only €1,100 per ha and deliver comparable results in 3 to 5 years. The different restoration techniques described in this report will deliver bog recovery at different rates for example the cut to waste and windrow sites are expected to recover faster than where the harvesting and extraction of timber took place. However at some point in time the results from the different techniques will merge and will be impossible to differentiate the effects of the different treatments. It is difficult to predict how far away this point of merging will be, it could take 20, 30 or even 50 years. The further away in time this merging occurs the easier it will be to justify expensive treatments.

There are limited early signs of success. These justify doing further research on the definition of restorable bogs, the range of techniques required to restore active blanket bogs, the strengths and weaknesses of the techniques, and the costs and likely problems involved. Careful monitoring is required to provide more information for reviewing bog restoration policy in future.

Costs of rewetting sites using current techniques are highly variable and depend on site-specific factors, such as ground slope and the degree to which water levels are controlled by discrete blockage drains. There is scope for developing cheaper methods of rewetting bogs. A number of gaps in the knowledge we have on peat restoration exist, because all the post-forestry projects so far undertaken are too recent. The main issues are:

- The potential for increasing cost effectiveness of bog restoration techniques.
- The feasibility of recreating high quality bog habitat on afforested active bogs.
- The thresholds, in terms of the water level regime, for successful bog restoration.

Further research is needed to close these gaps. It is vital that the LIFE project teams continue the networking and disseminating of their results and continue with site visits and seminars. There is considerable interest within the professional conservation sector in all the project results.

To state in the words of the Conservation Agencies, we have moved the bogs from an ‘unfavourable declining’ condition into an ‘unfavourable recovering’ status. The vegetation will take 30 to 50 years to fully recover, before it is undamaged active blanket bog again. However the obstacles to that recovery have now been removed, so we must be patient and let the vegetation recover.

The following are the key lessons that have been learned from the restoration projects,

- The resources required for completing the task of restoring afforested bog, back to active blanket bog habitat.
- Recovery of the bog will be surprisingly quick if you get the hydrology of the site correct.
- The advantages and disadvantages of the different techniques and their unit costs Table 2 and 4.
- Landscape scale active blanket bog restoration is possible.

The benefits for the stakeholder of the blanket bog restoration project are very long term. The bogs in question are the most important remaining in Europe and are probably the most extensive of their type in the world. The disappearance of Irish bogs would have serious international consequences. For various plant and animal species the last remaining european refuge would be destroyed and several species of birds would lose important winter-feeding grounds.

The main conclusions from this dissertation are as follows,

1) It is preferable to fell the tree crop and block the drains before the tree canopy has closed. This ensures that the bog vegetation has not been killed off, which will result in a more rapid recovery of the peatland ecosystem.

2) Felling to waste and windrowing of the conifer trees appears to be the best method of restoring blanket bog. This technique ensures that larger areas of the bog surface are cleared which facilitates more rapid recovery of bog vegetation and enables subsequent restoration operations e.g. drain blocking and removal of any natural regeneration of conifers to be carried out.

3) The restoration of blanket bog after a commercial tree crop has been removed is much more difficult and long term. Much of the blanket bog vegetation has to re-colonise from surrounding areas of intact blanket bog. The main problems following the removal of a commercial tree crop are the invasion of soft rush (Figure 19) and the re-colonisation of conifer trees.

Literature cited

Action Plan for blanket bog, Online, last accessed 14.04.2006 @ URL: http://www.ukbap.org.uk/UKPlans.aspx?ID=21

Anderson, R. (2001). A review of deforesting and restoring peat bogs. Forestry Commission Technical Paper 32. First published 2001

Cobbaert, D., (2003) A Biophysical Inventory of the Lulu Island Bog. Danielle Cobbaert, M.Sc., Ph. D.

Coillte. (2004) Background to the Red Areas Project (Low production forests). Paper compiled by Coillte Teoranta 20th February 2004.

Conaghan, J. (2003) The restoration of blanket bogs in Ireland. Irish Timber and forestry Vol.12 No.5.

Conaghan, J., (2001) Baseline ecological studies of planted and unplanted areas within proposed candidate special areas of conservation with a view to their rehabilitation and conservation. Coillte internal report, September 2001.

Department of Agriculture for Northern Ireland Forest Service (1993). Afforestation-The DANI statement on environmental policy. Department of Agriculture (NI),Belfast.

English Nature. Saving our peatlands for the future. Habitat Restoration.

European Commission. (1996). Interpretation Manual of European Union Habitats. European Commission, Brussels.

Gorham, E. and Rocheford, L. (2003) Peatland restoration: A brief assessment with special reference to *Sphagnum* bogs. Wetlands Ecology and Management 11: 109-119, 2003.Kluwer Academic Publishers. Printed in the Netherlands.

Hickey, D., (2004) Wetlands' riches are worth protecting. Irish Examiner. Monday, June 7, 2004.

Irish Peatlands Conservation Council.1992. Irish Peatland Conservation Council Policy Statement and action Plan 1992- 1997. IPCC, Dublin.

Joosten, H., and Clarke, D., (2002), Wise use of Mires and Peatlands. Background and principles including a Framework for Decision-Making. Printed November 2002, Saarijarven Offset Oy, Saarijarvi, Finland.

Kavanagh, B., (2002) What Future For Cutaway Bogs? Living Heritage.

Kavanagh, T., (2001) Kilder Forest – LIFE Nature Project. The border Mires Active blanket bog active rehabilitation project. Completed by Tom Kavanagh for Coillte following a site visit to the project.

Kennedy, N. (2004) The West Awake- Part 1. Teagasc. SIF Study tour.

Lindsay R.A. and Immirzi, C.P.1996. An inventory of lowland bogs in Great Britain. Scottish Natural Heritage, Battleby.

Pfeifer, A., (2003) Regeneration Options for Forests on Western Peatlands. Forest Research Programme 2000 – 2006.

Restoring Active Blanket Bog of European Importance in North Scotland. Project Ref: LIFE00NAT/UK/7075. Interim Report 1st March 2001- 31st March 2003.

Stoneman, R., and Brooks, S., (1997), Conserving Bogs. The Management Handbook. First published 1997. The stationery office limited, South Gyle Crescent, Edinburgh EH12 9EB.

The Border-Mires Active Blanket Bog Rehabilitation Project. Final Report 2003. Northumberland Wildlife Trust. The Garden House, St Nicholas Park, Gosforth, Newcastle upon Tyne, NE3 3XT.

The Lifeline peatland project newsletter (2001-2005). Issue No 2. September 2003.

Tiernan, D., (2003). Long term forest planning in sensitive areas. Coillte, November 2003.

Walker, C and Gunn, J (1998) 45 Ecological and hydrological interactions on blanket bog, Cuilcagh Mountain, County Fermanagh, Ireland. Hydrology in a changing environment. Volume 1. (1998) British Hydrological soeiety.

Wilkie, N.M. Thompson, P.S., and Bain, C., (1988).A brighter future for blanket bogs. RSPB Conservation Review 12:37-44.