1 Purpose of this Document

In the seven years that have passed since the publication of the Fen Management Strategy, considerable steps have been taken to restore areas of fen and to implement follow-up management. Much has been learned during this time, particularly concerning the use of new techniques such as the fen harvester and extensive grazing.

These new experiences gained over the past few years lay behind the purpose of producing the first part of this document, the Supplement. This provides a timely update and re-appraisal of fen restoration and management methods.

The information gathered through the use of the fen harvester and grazing animals also presented the opportunity to explore their potential for use on a wider selection of sites. The recognition of this opportunity led to the production of the second part of this document, the Fen Audit

Having re-appraised the fen management methods open to us and undertaken a realistic assessment of what techniques can be used where, there is clearly the need for a further step. Following the publication of this document, and linked to favourable condition and Public Service Agreements (PSA's), the ecological management requirements of each site need to be assessed. Together this ecological assessment and the practical findings of the fen audit can then be combined to make decisions about the best way forwards in order to ensure sites can be restored and maintained in favourable condition into the future.

Favourable Condition

The Fen Audit process began in February 2002. Since that time, English Nature has developed guidelines for favourable condition, to determine whether a site is achieving its conservation objectives. Public Service Agreement (PSA) targets have now been set and provide organisations with the goal of restoring 95% of nationally important wildlife sites to favourable condition by the year 2010. By providing information on the practical options for managing each fen site, the fen audit will prove a valuable aid when discussing how best to achieve and maintain such favourable condition status.

The Biodiversity Action Plan process

Fen habitats are recognised as priority habitats for restoration and improved management in the Biodiversity Action Plan (BAP) process. National, and Norfolk and Suffolk Habitat Action Plans (HAP's) draw together current information about the status of and threats to fen habitats and set out a framework of actions for their recovery. The information contained within the Fen Supplement and recommendations in the Fen Audit, including practical methods of managing fens, information and skills exchange, and research and monitoring of fen sites, will contribute to achieving the Fen HAP.

2 Introduction

The Broadland fens have been subject to changing fortunes over the last few centuries, and have seen particular change within the last hundred years. The management history of the fens is well known - an environment that was intensively managed for its natural produce, in the space of a few decades became abandoned and neglected. It is this abandonment of fen management which conservation organisations have been trying to tackle since the late 1960s, with the introduction of relatively small-scale conservation management designed to maintain the fens in an open and herbaceous condition.

The Fen Management Strategy was produced in 1997, providing site owners and managers with an agreed strategy for managing the fens. The Strategy consisted of two main elements: the production of descriptive chapters concerning various fen management methods, and the interpretation of the ecological data gathered during the Fen Resource Survey (Parmenter, 1995). In combination, these two elements enabled suggestions to be made as to the types of management most suitable for each site.

The Fen Management Strategy and the workshop that preceded it brought together an agreed approach to the management of fens, and for the first time, placed the emphasis upon the need for large-scale management solutions to address the effects of decades of neglect. In particular, the Strategy formally introduced two potentially large-scale management techniques that were being developed – conservation mowing using a specialised machine, and extensive grazing using large herbivores. Both of these techniques were identified as being potentially suitable for managing large areas of fen although both were largely untested within the Broads at the time the Strategy was written. In addition, the Strategy recommended the large-scale restoration of lost and deteriorating fen through the mechanised removal of scrub in order to restore open fen conditions.

These recommendations have been implemented over the last seven years with considerable effort and resources from many organisations and individuals going into the restoration of fen from scrub and woodland, and also the development and trialling of grazing and fen harvesting. Much has been learned during this time, prompting the need for a re-appraisal of fen restoration and management.

In November 2001 and September 2002, fen workshops were held involving conservation organisations and other wetland specialists. The purpose of these workshops was to discuss past progress, to debate the future direction of fen management and to agree the way forward. There were two main outcomes from the first workshop. Firstly, it was agreed that the Fen Management Strategy should be reviewed and updated to take into account the changes that had occurred over the last seven years. Secondly, it was suggested that a 'Fen Audit' be undertaken to determine which management options were practicable at each site.

This document combines the results of the review of the Fen Management Strategy, and the audit. It is split into two main sections - the Supplement and the Fen Audit.

The Supplement

The Supplement provides an update and assessment of the usefulness, limitations and requirements of old and new restoration and management techniques, incorporating the discussions and outcomes from both fen workshops. Included are sections relating to scrub clearance, lowering of the fen surface, fen harvesting, grazing and the commercial reed and sedge industry. The final section of the Supplement also contains a list of recommendations and actions that emerged from the fen workshops and through the compilation of the Supplement.

This document should be considered as a 'supplement' to the original Strategy, and in no way intends to replace or duplicate the wealth of ecological information, nor the wide-ranging expertise and effort that went into its production.

The Fen Audit

A second and integral part to this document contains the results of the Fen Audit undertaken during 2002-2003, to assess the practical suitability of fen sites for fen harvesting and extensive grazing. It also identifies the areas of reed and sedge currently harvested and those sites with commerc0ial potential for the future. The Audit consists of figures, discussion and maps. Together these display where particular management techniques can be applied and explain some of the constraints and issues limiting the use of certain methods on individual sites.

3 Fen Restoration and Management Methods

The following sections provide an update for each of the fen restoration and management techniques.

Scrub Clearance

In the absence of management, fen vegetation rapidly becomes invaded by scrub. When conservation organisations first began addressing the restoration and management needs of the fens, scrub was removed through hand felling, piling and burning on site. On some sites this method is still employed, particularly where sites are small or difficult to access, however, hand clearance remains very labour intensive.

As the scale of the fen restoration challenge was realised in the Broads, the focus turned to large-scale mechanised methods in order to make headway into decades of scrub invasion. The Fen Management Strategy identified 1130ha of scrub requiring clearance from the peat resource of the fens. This was based upon scrub and woodland that had colonised the fens since 1946. Since the publication of the Strategy, scrub removal operations have followed this broad target and have been driven by additional information such as the Broads candidate Special Area of Conservation (cSAC) woodland survey, which identified woodland and scrub communities for retention owing to their importance. In addition, site-by-site decisions are made regarding the likely return of good quality fen.

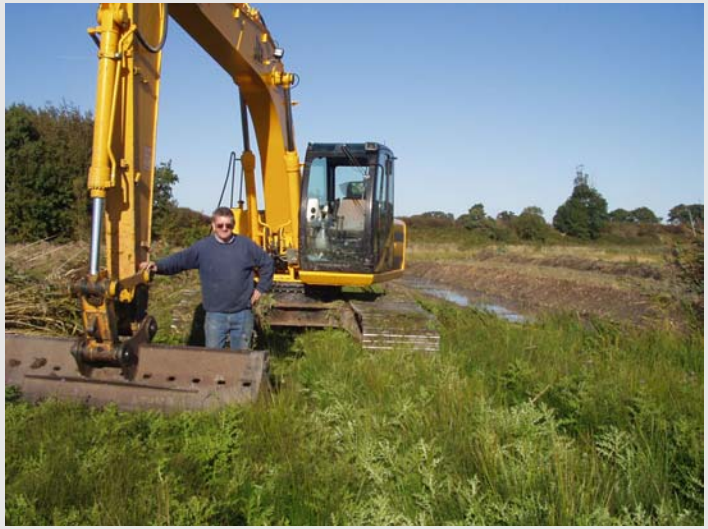
While scrub clearance is seen as a fen restoration technique, it can also be used as a way of providing long-term management. In some cases, long rotation scrub clearance alone may be the most practical or desirable management option, particularly where follow-up management of the open fen may be problematic. While this form of management does not manage the sward, it does maintain 'open' fen habitat.

Methods of Scrub Clearance
The following three pages provide an update and description of scrub management/control methods currently used in the Broads.

JCB Excavator

Tracked machine weighing 18t with a ground pressure of 4.5psi. Tracks around sites on existing banks, the fen itself if dry or mats if the surface is too wet. The mats weigh 1t each and reduce the ground pressure of the machine to 1.09psi.

Extraction & Disposal Methods
Excavator removes the entire tree from the fen including the root system by pulling/pushing and digging around the tree. Woody material is buried under spoil banks if the operation is combined with dyke restoration; material may otherwise be processed through a chipping machine and transported off site using a monorail system (see hand clearance section for description of monorail).


The Broads Authority/English Nature JCB and driver (Rob Andrews)

Advantages
- One machine can restore dykes and remove scrub in the same operation maximising efficiency and cost-effectiveness.
- If scrub is buried, there is no need for additional machinery on site.
- If chipping is utilised, the material is completely removed from site.
- Extraction method means that no stumps remain following restoration, eliminating re-growth potential.
- Large scrub can be tackled owing to ability to dig around the roots and push the tree over.

Disadvantages
- Weight of machinery – damage caused by compaction and repeated passes when tracking directly on the fen surface.
- Extraction method may limit follow-up management – by pulling the entire tree from the ground, holes are left within the peat and the surrounding surface becomes destabilised. This creates problems for both livestock and mowing machines and the surface may remain unstable for a number of years. Large-scale restoration of this kind may temporarily limit the application of large-scale fen management.
- Disposal of material – trees can be buried if the operation is combined with dyke clearance, otherwise there can be a huge amount of woody material to dispose of.

'Bird-eye' and Incineration

This technique uses a tracked excavator (working on mats), fitted with a special cutting head known as a 'Bird-eye' (pictured right) – the excavator has a ground pressure of 1.5psi. This cutting technique has been combined with a large portable incinerator to dispose of the woody material. The incinerator itself can be moved around the site using the excavators, although a new system of locomotion is being investigated for use in the Broads using an experimental air platform, i.e. similar to a hover craft. The incinerator has a ground pressure of 0.8psi with floats, and 1.3psi without floats.

Extraction and disposal
The bird-eye cutting head consists of one spinning disc, which fells the trees, and grind stumps. Once the trees are felled, they are placed within the large portable incinerator where they are reduced to ash. The grinding process kills many stumps, especially if they are flooded at the time or shortly afterwards. Some stump re-growth may need treating. Initial trials suggest that 1 hectare of scrub can be cut within 4-6 days, with an incineration rate of a further 4-6 days.

From top left (clockwise) Kori excavator, 'bird-eye' cutting head, incinerator without floats, incinerator with floats. (Tim Hanks).

Advantages
- Large trees can be felled (maximum 2'6" to date at Dec 2003)
- Cutting and stump grinding can be achieved using the same machine.
- Wide reach and low number of passes result in little damage to fen peat surface (e.g. oxidation caused by break-up of peat, leading to production of soft sediments and vegetation changes). This allows rapid recovery of "instant fen".
- Incineration system ensures complete burn of material enabling huge amounts of material to be reduced to manageable proportions.
- The cutting machine and incinerator carry large reserves of fuel, negating the need for repeated passes across the fen for refuelling. One refuelling trip per hectare is anticipated.

Disadvantages
- Incineration method will result in greenhouse gas emissions

Hand clearance

Often undertaken by volunteer teams using manual saws or by contractors with chainsaws.

Extraction and disposal
Scrub is cut at the base of the trunk. The material is then either burned on site at a designated bonfire site or loaded into a chipping machine. If the scrub is chipped, a monorail system can be used to transport the material to the edge of the site for removal. The monorail consists of a 4" wide single rail that rests upon a simple 'H' frame. The legs of the frame can rest directly on the fen, or on wet sites, can be placed upon an inflated rubber tyre to prevent damage to the surface. A skip-like container is towed along the rail by a small diesel engine. The chipper blows directly into this skip, which when full, is towed back to the beginning of the monorail where it is tipped out. Whether cut manually or by chainsaw, all stumps are treated to prevent re-growth.


The Monorail (Rob Andrews)

Advantages
- If material (before chipping) is burned on site, no heavy machinery is needed thus limiting damage to fen surface (see disadvantages)
- No requirements for large vehicular access to sites – useful for isolated sites
- If chainsaws and chipping are used, the speed of operation increases

Disadvantages
- Labour intensive and hard physical work
- Small-medium scale only
- Hand clearance of scrub is often undertaken by groups of people, e.g. volunteers. This repeated walking by numerous people on wet peat sites can cause more damage to a site than low ground pressure machinery
- Monorail requires additional equipment or manual labour to move pile of chips from tipping point
- Finding an outlet for chipped material

Protocol for Scrub Management

Coppicing as a form of woodland management (Rob Andrews)

In recent fen management workshops (November 2001 & September 2002), the opportunity has been taken to review all fen management activities. Experience with scrub removal over the last seven years has led to reinforcement of certain principles, and in some cases, refinements to future working practices have been suggested. The following list summarises the main recommendations and working practices for scrub clearance as discussed and agreed at the 2001 and 2002 fen workshops:

Fen restoration should work in closer harmony with follow-up management
Large-scale scrub removal techniques that generate holes and leave the surface unstable may require some years before the site is safe for machinery and livestock. In comparison, techniques that leave stumps insitu will only be suitable for hand mowing, grazing or will require stump grinding.

Also, if grazing is to be used as the follow up management, planning needs to be undertaken at the restoration stage to ensure scrub is left in high dry places in order to provide a network of shelter and resting places for livestock.

Scrub removal should be prioritised to link habitats
The clearance of 1130ha of scrub as suggested within the Strategy should not be seen as a goal in itself. Continued scrub clearance should be directed towards the linking up of existing open fen habitat to provide corridors for species dispersal across the catchment. Clearance should also avoid important scrub and woodland communities and continue to be targeted to those areas that are likely to produce good quality fen following restoration.

Cyclical scrub removal can be used as a form of fen management
On many sites, periodic removal of scrub is utilised as a method of fen management. This approach concentrates solely on keeping the fen open through the cyclical removal of scrub rather than managing the herbaceous sward through mowing and/or grazing. For those sites where management following scrub removal is problematic, this may be a viable option whereby the woody element of the fen can be controlled. However, this would not be appropriate at all fen sites as many open fen specialists and rarities require regular management of the sward to ensure their survival.

The distribution of scrub on the ground should be considered when deciding the proportions of scrub to open fen
When restoring or managing sites, up to 10% of the open fen area may remain as scrub. This is the figure used within the Environmentally Sensitive Area (ESA) scheme's Fen Tier to quantify the area of scrub/woodland allowed within an area of fen that is receiving payment. However, the way in which scrub is distributed within an area may determine what is a suitable amount on the ground.

For example, whilst 10% mainly in clumps still allows relatively easy management of the remaining 90% of fen, if organised as scattered trees, fen management may become more difficult. Scrub itself is an integral element of open fen and its specific importance for invertebrates and birds as well as a landscape feature needs to be recognised and promoted. Therefore, if only a small percentage of scrub is to be left on fens, a mixture of scattered bushes and small clumps is advisable when considering both ecological value and the practicalities of fen management.

The impacts of large-scale scrub removal upon the peat substrate should be considered
The fens are soft, fragile systems, which are vulnerable to the weight and passage of large machinery, people and livestock. While developmental measures are being taken to design machines suitable for working in such conditions, some damage to the fen is likely to occur as machines track over the surface. Disruption to the peat also occurs through the actual process of pulling trees out of the substrate. What is less clear is the long-term impact of such damage to the structure and hydrological functioning of the peat. This underlines the need for targeted scrub removal that considers site fragility against expected restoration gains.

Small-scale scrub removal techniques should be used where appropriate
Small-scale techniques should still be encouraged and used where appropriate, particularly on small sites, or areas with difficult access or those that are especially sensitive to damage.

Stumps should be treated following clearance
Appropriate herbicides should be used or stump grinding should be undertaken to ensure that there is limited re-growth of scrub and to facilitate follow-up management. Combining herbicide treatment and stump grinding should ensure that most trees are killed. Different methods are used across the Broads with herbicide used before stump grinding in some cases, and in others, stump grinding is followed by selective herbicide treatment as required.

Scrub removal operations should be monitored
Monitoring should be undertaken to determine the effectiveness and impacts of each clearance method, e.g. response of scrub seed banks, the effectiveness of stump treatment, damage to and recovery of the substrate.

Bonfire sites should be placed in non-sensitive locations
If scrub is to be disposed of through the use of on-site bonfires, care should be taken to locate these in the least sensitive areas, e.g. on a raised dyke bank. Alternatively, bonfires can be contained on tin sheets so that the resulting ash can be removed from the site. However, it is appreciated that both of these suggestions may be impractical, particularly when considering the health and safety requirements associated with ash disposal (legislation requires operator to wear full safety equipment). In addition, more damage may be caused to a site by repeated passes to remove ash, than the resulting nutrient enrichment from a bonfire.

A scrub and tree management guide for riverside locations is being developed as part of the Broadland Flood Alleviation Programme. This is likely to impact upon how scrub on ronds is managed. (Document in press).

Lowering the Fen Surface

Large-scale peat removal at East Ruston (Rob Andrews)

Arresting natural succession within a wetland system can be achieved through scrub clearance as described in the previous section. However, further work can be undertaken to achieve an even earlier phase of successional development, whereby bare peat or open water is reintroduced to the fen environment. This can be achieved through the removal of peat, either in defined excavations, or across a wider area; both methods are described below.

Methods of peat removal

Two techniques have been employed within fen restoration that involve surface peat removal; these are turf ponding and scraping. Whilst both these methods involve peat extraction, a clear distinction needs to be drawn between these two techniques:

Turf ponds:	Scraping:
○ removal of peat, usually to a varied depth across the excavation ○ purpose can be varied – part of scrub removal operation, to reinstate open water as part of the fen environment or to reintroduce an early successional phase ○ a turf pond is a feature within a compartment	○ removal of surface peat, usually to a shallow and equal depth sometimes resulting in a short period of open water ○ purpose is to rejuvenate a fen which has either become too dry or nutrient enriched ○ scraping often occurs across a whole compartment

An experimental programme of turf pond creation began in the late 1980s, which was coupled with a monitoring programme to assess fen recovery following excavation (Kennison, 1986-97). Conclusions from that programme were presented within the original Strategy and suggested that more time was needed to monitor existing ponds to determine the long-term results of such work. Discussions at recent workshops have shown continued support for turf pond creation, particularly where scrub is being removed. The need for a variety of designs and the use of sites where a range of environmental variables can be studied were also suggested, followed by additional monitoring of the colonising vegetation.

Scraping is a technique that has been used on a few sites with the specific intention of lowering the surface of the fen to 'wet-up' the site, or to remove layers of nutrient enriched peat to encourage re-colonisation by earlier successional swamp communities. Concerns have been raised over the regularity of use of this technique, which has possibly been seen as a way of managing fens on a long rotation.

Disadvantages of peat removal
Whilst it is recognised that the purpose behind turf ponding and scraping is quite different, both techniques have the potential to cause damage to the fen:

- Removal of peat and surface vegetation is destructive to invertebrates that inhabit the litter layer and/or surface layers of peat.
- Excavation machinery can cause significant damage to the site.
- Creating a new water feature, i.e. a turf pond, may impact upon the existing water flow within a site.
- Both techniques result in considerable quantities of spoil which require either on-site or off-site disposal. If used on-site to create bunds, these can disrupt water flow. Lack of disposal sites often prevents peat removal.
- Disturbance and exposure of bare peat results in nutrient enrichment, which encourages colonisation by weeds and rank vegetation.

Protocol for peat removal
The above concerns suggest that both techniques should be considered carefully, particularly scraping, as this technique could be seen as a relatively 'easy' method of managing fens on a long rotation.

Scraping may be acceptable where:

- a site is suffering from desiccation which cannot be ameliorated by changes in water level alone and where non-intervention would result in loss of fen value greater than the potential damage caused by lowering the fen surface;
- a site is suffering from past nutrient enrichment which is preventing the colonisation of valuable plant species, or
- to rejuvenate a commercial reedbed.

Turf ponding may be acceptable where:

- a distinct open water feature is desirable, or
- a key objective is to create an early successional stage of fen development.
  (See Kennison, 1995 for turf pond creation guidelines)

It should be noted that in all of these cases, an individual site assessment should be made of the benefits of undertaking such work as opposed to doing nothing.

A number of years have passed since the original programme of turf pond creation was completed, with the last monitoring report produced in 1997. During the summer of 2003, some of the deeper excavations were surveyed for their aquatic plant interest (Harris, in press). It is suggested that the full suite of original turf ponds should be re-visited to determine the changes that have occurred over the last seven years. These findings should be presented and used to inform any future turf pond creation programmes.

Burning

Standing burn of fen vegetation (Broads Authority)

Burning is a management method that periodically returns to the discussion table for consideration and has more recently been revisited at the fen workshop in September 2002. In reality, little has changed since the production of the Fen Management Strategy, with the same reservations being held by some ecologists over the potential damage of burning large areas to invertebrates. In addition, regular burning of large areas has its own set of practical issues such as the release of greenhouse gases and the danger of fire to near-by thatched properties. However, the technological and resource difficulties associated with other management methods do encourage the examination of all alternatives.

Through the Broads Research Advisory Panel and signed up to by English Nature and the Broads Authority, a policy was established which considered burning acceptable in the following circumstances:

- Sites that have been managed traditionally through burning for a long period of time to maintain them in an open condition.
- Small-scale restoration burns to restore mixed fen or to rejuvenate commercial reedbeds and sedge beds.
- Where an area has been cleared of scrub and is destined to be turf ponded.
- Mown material may be piled and burnt on recognised fire sites in all but the most sensitive areas.

It should be noted that on SSSI's, individual site discussion is required with English Nature.

This policy may need reviewing should new scientific information come to light, e.g. if alternative forms of management are found to be more deleterious to the fen interest. Some sites may require specific discussions to ascertain the best management option.

Mowing


An area of fen managed by mowing (Richard Starling)

Mowing is a generally accepted method of maintaining open fen communities owing to its long history of use in the Broads. Previous research (e.g. by Kennison, 1991) has enabled recommendations to be drawn as to the best mowing regime for particular species assemblages or specialists.

More recently, concerns have emerged in conjunction with the introduction of large-scale mowing such as that achievable by the fen harvester. Outstanding questions remain regarding the possible damage to substrate and vegetation owing to the size and weight of the machine.

Non-commercial hand mowing

Much of the fen habitat in the Broads is unsuitable for commercial harvest of reed or sedge owing to species composition and quality. For many years, conservation organisations have managed such areas of mixed open fen of high wildlife value through non-commercial hand mowing. This is often undertaken using reciprocating pedestrian mowers, similar to those now used by the reed and sedge cutters, or through the use of brushcutters. As the fen material is not intended as a commercial product, the condition of the cut crop is not important. In most cases, the cut material is raked into piles and left, or burned on site in bonfires.

Advantages

- A flexible management technique that can be targeted to site requirements.
- Small size of machinery means that access to small isolated sites is often possible.
- The prime purpose of this method is to maintain areas of open fen for conservation, many of which have been managed in such a way for years. As such, the cost of hand mowing is accepted.
- Not constrained by commercial requirements and thus means that varying mowing regimes can be applied without needing to consider other constraints, e.g. annual, biennial, longer rotations for the benefit of species like Milk parsley or to maintain open fen.

Disadvantages

- No outlet exists for the cut material resulting in the need for disposal on site, often through burning or the accumulation of 'habitat piles'.
- Labour intensive and expensive form of management – productivity is limited to the size of the cutting machine and the efforts of the operator.
- Compaction – pedestrian mowers and the people that drive them exert certain pressure on the surface and substrate of the fen; owing to the difficulties of measurement, the long-term impacts of this are currently unknown (see compaction section on page 33).
- Greenhouse gases will be released through the use of bonfires.
- All mowing techniques can cause damage to tussock-rich sites as the vegetation is cut at one height, thus cutting through tussocks. This can only be avoided by cutting with a brush-cutter thus enabling the operator to change the height of the cut and avoid the tussocks.
- The inability to cut at a variety of heights leads to a loss of surface variability within the vegetation.

Commercial Reed and Sedge Cutting

Commercial reed stacked and ready for transport (Broads Authority)

For many decades, crops of reed and sedge were harvested from the fens as part of a productive rural economy. This industry declined significantly following the Second World War, which in turn resulted in a rapidly dwindling number of marshmen working the fens. Today, only some fifteen commercial cutters work across the length and breadth of the Broads, several of whom are beyond or approaching retirement age; between them they harvest less than 200ha of fen. These numbers remain threatened with further losses owing to a variety of factors that are undermining the viability of the industry, so that Norfolk reed and sedge could potentially become a product of the past (see 'rejuvenating the industry' on page 16). The repercussions for the conservation interest of the fens of such a loss would be considerable, with the cessation of management on many sites, which have been maintained through commercial harvesting for decades.

Marsh hay is another traditional crop that has been harvested from the fens. This practice has also declined in recent years owing to the costs of baling and transporting the crop from the fen and the competition from farmers producing grass-based hay away from the floodplain. There are a number of fen sites that could be returned to annual marsh hay production if there was an interest and market for the product.

Modern-day reed and sedge cutters largely use pedestrian-driven reciprocating mowers to harvest their crop. Bundles of material are then tied and removed from site (often by boat) ready for sale to local thatchers.

Typically, commercial reed *(Phragmites australis)* is taken from areas where it is the dominant, if not the sole plant. For reed to be considered of commercial quality it must reach certain levels of strength, shape and height. Areas are cut on either an annual cycle (single wale) or biennially (double wale); longer rotations result in a build up of too much litter and in many cases bog myrtle, which makes the stand unsuitable for commercial harvest. In conservation terms, a double wale cut is very much preferred within blocks of fen as this gives other associated species a longer period of habitat cover.

Commercial sedge (*Cladium mariscus*) is cut on average every four years. This gives the sedge the time required to regenerate to a harvestable condition, and also meets conservation objectives for maintaining the sedge community interest. Leaving the stands for much longer generally results in the accumulation of litter, which becomes un-commercial and also shades out some of the smaller and interesting associated plant species.

Although commercial cutting can remove large blocks of vegetation, many sites are cut in small patches, often avoiding very wet or unstable areas. This ensures that some tall vegetation is left standing as habitat for associated plants, insects, birds and mammals.

Advantages

- An outlet exists for the product resulting in removal of material from site making it a more cost-effective form of fen management, and avoiding the need for burning or piling on site.
- Areas are often managed by one or two people resulting in low amounts of people-pressure on the fen and a low level of disturbance.
- Small size of machinery means that access to small isolated sites is often possible.
- The same people manage the same areas and so over time develop detailed site knowledge and sensitivity.

Disadvantages

- Short rotations for reed cutting are not always ideal for enhancing the conservation interest of site.
- Compaction – pedestrian mowers and the people that drive them exert certain pressure on the surface and substrate of the fen; the impacts of this are unknown (see compaction section on page 33).
- All mowing techniques can cause damage to tussock-rich sites as the vegetation is cut at one height, thus cutting through tussocks.

Rejuvenating the industry

Following the fen workshop in November 2001, work began on an initiative to rejuvenate the commercial reed and sedge harvesting industry. Risk and Policy Analysts were commissioned by the Broads Authority to investigate the factors that have contributed to the decline of the industry and to consider the feasibility of its recovery (RPA, 2002). The study determined a number of factors that have contributed to the decline of the commercial reed and sedge industry:

- Insufficient income
- Old machinery which is expensive to replace
- Access difficulties onto fen sites
- Lack of space and expertise to offload harvested material for road transport
- Imported reed depressing the market
- Fen tier payments not passed on to cutters & royalties imposed on cutters by landowners
- Difficulties associated with attracting new and young people to the industry

The study also identified a number of options that could be followed to rejuvenate the industry. Since then, significant action has been taken to attempt this:

- Reed and sedge cutters have formed an Association and have successfully applied for grant aid from the Sustainable Development Fund and The Broads and Rivers Leader Plus Project.
- These grants have allowed new machines to be purchased for those most in need of replacement.
- An initial meeting has been held between cutters and conservation organisations to investigate methods of working together more effectively - this has involved discussions on how cutters may be able to undertake contract work for conservation organisations outside of the cutting season.
- Meetings have been held between cutters and individual site managers to resolve issues, e.g. access difficulties caused by large dykes and concerns over the impact of grazing on commercial sedge.

The rejuvenation of the commercial reed and sedge industry is an ongoing process, but one that has the support of the cutters themselves, the Broads Authority, English Nature, local conservation organisations and the wider public. Through a process of initial grant investment, and initiatives to identify more options for income, it is hoped that the industry will recover and continue to make a significant and valued contribution to fen management. If all goals are achieved, the current association hopes to raise the area of fen currently managed to around 400ha, that is, 24% of the existing open fen resource (figures taken from the results of the Fen Audit – see page 42).

Large-scale conservation mowing – The Fen Harvester

The fen harvester at work (Rob Andrews)

When the Fen Management Strategy was published seven years ago, the design and manufacture of a large-scale mowing machine suitable for the fens was still in its inception. The Strategy had recognised that in order to maintain the current 2000ha of open fen and to restore a further 1000ha, a range of management techniques were required. In total, the Strategy suggested that approximately 1000ha of mixed tall herb fen could be managed through mowing, which on a suitable rotation would equate to approximately 250ha mown per year. At the time of the Strategy, conventional mowing machines would only have been able to mow and remove fen vegetation from a fraction of this amount.

In addition, much of this open fen would not be of suitable composition for commercial harvest, even if it could be accommodated within the industry. The need for new harvesting techniques was clear.

In April 1997, a three-year EU LIFE funded project sponsored by a number of organisations began which involved the development and testing of innovative harvesting machinery, suitable for working on fen habitat. The 'New Wetland Harvests' project developed and demonstrated the use of a highly specialised mechanical harvester with very low ground pressure, designed to cope with wet, soft and uneven terrain of high environmental sensitivity. This 'fen harvesting' machine, in a single pass, cuts the material with double reciprocating blades. The same machine is then able to collect this cut material using an augur, which feeds it via rollers into a forage harvester which chops the material into c.20mm long strands and throws it up a chute into a $8m^3$ bin. The harvester can then either tip and pile the material or tip the load into the bin of the blower machine.

In many ways, the blower machine has been a revolutionary development in terms of fen management. Previously, the limiting factors in managing the fens were not connected to cutting, but to gathering and removing the cut material from sites. The development of a Blower machine has meant that material can be blown offsite using a pipeline. The blower feeds the cut material with air into a pipeline, where it can either be blown into a pile or directly into a bulk trailer thus avoiding the repeated use of terrestrial vehicles and the damage they would cause to the fen surface. A subsidiary objective of the project was to find useful outlets for the arisings so that the disposal costs may be offset with the sale of the fen produce, e.g. animal feed, animal bedding, composting, biofuel.



The fen harvester tipping into the blower & the blower pipeline (Rob Andrews)

This three-year project resulted in the manufacture of a machine and associated components that could potentially cut, gather and remove fen vegetation from large areas with minimal environmental damage. Since the completion of the initial EU project, the harvester continues to work in the Broads, supported by English Nature and other local partners and managed and operated by the Broads Authority. These last seven years of fen harvester operation have provided evidence of what the fen harvester can achieve for fen management and some of the problems associated with its use.

Positive Achievements

Development of low ground pressure machinery
The fen harvester provides the technological ability to cut, gather and remove vegetation from large areas of fen using environmentally friendly low ground pressure machinery (1.5psi).

Cut material can be picked up and removed from site
The use of the fen blower allows cut fen material to be transported off-site without the damage caused by repeated tracking of a terrestrial machine over the fen surface, or additional labour.

Significant areas of fen are under harvester management
Between December 1997 and March 2003, 85ha of fen (5% of the fen resource) was cut by the harvester with an additional 80ha of fen meadow/rush pasture also managed by this technique.

Portable dyke crossing ability has been developed
Lightweight and portable bridging systems have been developed to enable the harvester to cross dykes and access most fen compartments. Modular Jet Floats are now used, which consist of 0.5m x 1m plastic blocks that can be joined together in various lengths, or doubled-up to carry extra weight.

Restoration potential for commercial crops
Monitoring undertaken during the first three years of the project suggested that the harvester may be suitable for undertaking restoration cuts to rejuvenate commercial sedge beds. Whilst there appeared to be a decrease in sedge within the trackways of the harvester, the amount of sedge increased in the cut areas. The harvester also appeared to cut the stems more cleanly than hand mowers (Andrews, 2000). Recent investigations suggest that such restoration should only be undertaken in very dry conditions to avoid damage to the sedge (following observations at Sutton Fen, summer 2003).

Disposal outlets are being developed for fen produce
Research has been undertaken into the possible uses of the cut fen material once off-site, including animal feed, bedding, compost and use as a biofuel. The latter two options appear most promising and the feasibility of building a local biofuel station is currently being investigated, with the final phase of grant application underway. One landowner is using the cut fen material as part of compost spread on land used to grow organic crops. The material is mixed with animal manures, put into long rows, turned regularly with a tractor bucket, and spread on the land after 12 - 18 months. This particular landowner has a number of compost sites, so the material can be taken to the one closest to the fen site being cut (these are all located within the Northern Broads).

Refinements can be made to the cutting operation
Use of the harvester by trained operators has resulted in amendments to cutting regimes to maximise environmental benefit. Cutting regimes have been developed with experience and knowledge to reduce the drastic effects of large-scale cutting on invertebrate numbers and diversity. Only up to 60% of a compartment is cut in any operation, leaving untidy corners and uncut strips throughout. Cutting is on a long rotation of 4 - 8 years and it is envisaged that the second cut would be at right angles to the first, again leaving strips that remain uncut for several years. This ensures that some structural diversity remains within and around the cut area, providing refuges for less mobile invertebrates.

Encouraging results for fen plant communities
The overall picture of regeneration and diversity maintenance has been encouraging. Based on the results to date, no particular species or community has been adversely affected, nor has any expanded greatly from fen harvesting. In addition, species diversity has increased significantly following a harvester cut on sites that had previously been classified as species poor (Andrews, 2000).

Problems associated with the fen harvester

High running costs
Owing to the developmental nature of the machinery, significant adjustments have been made to the equipment in order to enable the machine to cope with on-site conditions. Some of this developmental cost will decrease over time as the machine becomes more suited to the role, although the specialist nature of the machinery will always command higher maintenance costs than conventional machinery. In addition to developmental costs, repair & maintenance costs have been increased by a number of unexpected hydraulic pump failures.

The machinery running costs and the costs associated with removing the cut material from site (via blowing) do not result in a cheap method of managing the fens. Cutting fen with the harvester costs in the region of £2000-£3000 per hectare (revenue costs only), which while considerably higher than grazing, is still lower than hand mowing (assuming the costs of removing the cut vegetation are included for both methods – see Appendix 1 for an explanation of the costs of managing fen by different methods). There is potential for some of the cost to be offset through receipt of fen tier payments and if a market can be found for the cut product. However, it is likely that there will remain a significant net cost associated with fen harvesting.

Limitations of the blower and pipe technology
The design of the pipeline allows for cut fen vegetation to be blown over distances of more than 1000m. However, in practice, blowing performance tends to decrease after 700m owing to a reduction of air pressure leading to blockages in the pipe. This varies from site to site depending upon the amount of woody material and the moisture content of the cut vegetation. Both of these factors affect the blowing efficiency and thus restrict the distance from upland access that the harvester can work. When blockages or holes occur within the pipe, they have to be cleared and repaired manually before the operation can continue. This involves the operator walking the length of the pipe – often crossing numerous dykes – to find and then mend the problem. This can occur many times within one cutting operation drastically reducing efficiency and may cause compaction damage along the pipeline as the operator walks back and forth repairing the pipe.

Difficulties associated with disposing of cut material
There are a number of sites where either the blower cannot get onto site, or where the size of the site prevents the use of the pipeline. i.e. too long distance. There are two possible ways to overcome this – the harvester to track back across and to the edge of the fen to tip each load of cut material into the blower (this has implications in terms of repeated passes of machinery over the delicate peat substrate), or to pile the cut material on site. However, owing to the ecological sensitivity of wetland sites and the uncertainties surrounding the release of chemicals from large piles of decomposing material, a position has been taken in the fen audit, whereby piling on site will not be considered as a disposal option. However, the results of the fen audit show that this position limits the application of the harvester quite significantly and thus requires further discussion between the statutory and voluntary organisations, including the Environment Agency, English Nature, the Broads Authority and the wildlife trusts.

Location of disposal outlets limit the geographic range of the harvester
The current composting outlet covers the Ant, Thurne, Muckfleet and the north side of the Bure Valley upstream to Wroxham. The proposed biofuel station will be located in the northern Broads and so will have a similar catchment area. Without more outlets for the cut material in the southern part of the region, it becomes impractical to harvest sites that are too far from existing disposal facilities owing to the financial and environmental costs of transporting the cut material. At the present time, the harvester operation is solely dependent upon one composting outlet – if that becomes unavailable, material cannot be disposed of and sites cannot be cut.

Impractical for use on small sites
Moving the machine and setting up on new sites is time consuming and expensive. This makes small sites less suitable for fen harvesting.

Damaging to tussocks and lack of surface variability
All mowing techniques can cause damage to tussock-rich sites as the vegetation is cut at one height, thus cutting through tussocks. Despite the low ground pressure, the large tracks of the harvester would also cause some damage. Similarly, the harvester like other mowing methods cuts at set heights and so reduces surface variability within the vegetation.

Impacts of machinery on the peat substrate
Despite the low ground pressure and specially designed tracks of the harvester it is likely that some compaction of the fen surface is occurring as the harvester moves over the fen. Ground disturbance and minor rutting can also occur when tracking back to the blower, coming off site for fuel or repairs and in turning areas. On a small-scale, this can be beneficial as it creates new habitat and germination/egg-laying opportunities for flying insects. However, ground disturbance at established access points can result in future difficulties when accessing the site. To alleviate some of these problems, the amount of tracking across the fen is kept to a minimum, the blower is parked on firm dry ground and sites with sensitive plant communities and unstable substrate are not worked by the harvester.

Extensive Grazing

Konik ponies grazing wet fen (Sue Stephenson)

The Fen Management Strategy identified 2090ha of grazeable fen communities. Grazeable in the context of fens is defined as fen communities where a significant proportion of the component plants are palatable to grazing animals, and generally include rushes, sedges or grasses.

There are a number of accepted principles associated with extensive grazing and these have been considered in utilising grazing as a fen management technique, e.g. the structural diversity resulting from extensive grazing is of benefit to invertebrates (Kirby, 1992).

Research undertaken by Tolhurst (1997) identified the grazing characteristics of various types and breeds of animal in order to prioritise the use of animals most suited to grazing fen vegetation and coping with the harsh environmental conditions. This research has aided the selection of grazing animals in the Broads.

Since the writing of the Fen Management Strategy and its subsequent publication in 1997, a number of fen grazing trials have been set up within the Broads, both by conservation organisations and private individuals. ESA Fen Tier figures show that 419ha of fen had management agreements for grazing by the end of 2002 (Figures from the Rural Development Service).

Each site that is grazed differs in terms of the site characteristics and the grazing regimes used, however, the experiences gained from a number of fen grazing projects have provided us with some common benefits and issues. These experiences have given flesh to some of the assumptions about fen grazing made in the Fen Management Strategy.

The positive experiences of extensive fen grazing

Promotes structural diversity
Extensive grazing creates good structural diversity within the vegetation, i.e. a heterogeneous mix of vegetation height and density. This is very difficult to achieve with any other management method. The exact grazing densities where this occurs remain difficult to determine and depend upon the type and number of animals and also the species composition of the vegetation.

Diverse areas are managed
In general, and where given sufficient choice and variety, grazing animals tend to favour areas of diverse or species-rich vegetation – this helps to ensure that these important areas receive management.

Creation of ecotones and habitat diversity
In an extensive system grazing animals create ecotones at the transition between scrub and fen. Where woodland and scrub exist within the fen, glades may also be maintained and expanded over time, creating 'walking habitat mosaics'. In year-round grazing systems, animals make seasonal use of the site, moving around and changing grazing areas as their dietary requirements adjust to the changing environment, again promoting habitat diversity across the site.

Non-catastrophic management method
Because grazing animals in an extensive system create these walking habitat mosaics, the management of the vegetation is spatially varied and thus less catastrophic (in terms of vegetation removal) than mowing.

Suitable sites can promote good animal health
A mosaic of habitats that provide a variety of food, shelter and other welfare requirements also provide a healthy system in which the animals can live. The experience of a number of grazing projects has shown how excellent animal health can be maintained with minimal intervention if the site is suitable.

Wet sites can be grazed
The types of grazing animal used to date, have demonstrated an ability to graze hover and very wet peat, including areas flooded with significant surface water (assuming dry areas are also available for animals to retreat to and rest upon).

Presence of dung is beneficial to the ecosystem
Animal dung provides an important habitat and food source for a wide range of invertebrates and in turn, their predators. The presence of rich dung communities on grazed reserves has led many conservation organisations to ban the use of worming drugs such as ivermectins, owing to their toxicity and long residence time in the dung.

In general, these positive achievements have demonstrated that fen grazing can be utilised as a successful form of conservation management. It is important to note however that all of these achievements are dependent upon a number of other factors such as choosing appropriate sites, the most suitable animals, and making adjustments to both along the way!

The limitations of extensive fen grazing

Grazing as a new option for fen management has raised numerous concerns. Unlike mowing, this is a technique that does not have a long history of use on Broadland fens and uncertainties remain over its possible impacts. However, it should be noted that many sites have had and still do experience grazing impacts from deer, so some 'natural' grazing does already occur.

Localised overgrazing and undergrazing may occur
Areas favoured by grazing animals may become overgrazed. Recent observations of grazing on sites where only one or two shelter trees have been left following restoration have shown that localised overgrazing occurs on the fen adjacent to these trees. To avoid this situation, clumps of scrub/trees should be left scattered across the site to provide numerous shelter areas. In comparison, there will be other areas within the site which are not favoured or even avoided and so will see little grazing. Depending on the objectives for the site, localised over and under grazing may or may not be acceptable.

Invasive plant species may not be controlled
Many sites have a network of dry spoil banks that were created during dyke restoration and perform a useful role in providing grazing animals with dry refuge areas and a dry route around a site. However, some of these spoil banks also develop rank and invasive vegetation (nettles, thistles and rush), which may not be managed by grazing animals at low densities.

Extensive grazing will not arrest succession
Different types and breeds of animal appear to consume differing proportions of scrub within their diet. For example, Konik ponies choose to eat scrub as part of their winter diet, whereas Welsh ponies appear to consume little if any woody food. Even so, the Koniks do not remove mature scrub, but rather, they have tended to stunt the expansion of new saplings. Except where animals are grazed on an area of scrub re-growth following clearance, they are unlikely to perform a significant scrub control and removal role but may keep clearings open. Thus there is often a need to mix both grazing and some form of cutting and scrub removal.

Impacts of livestock on the peat substrate
Owing to the small hoof size of a large herbivore in relation to its body weight, animals exert considerable pressure on a surface when they stand and move (c.14psi for a standing 500kg pony). This may have deleterious effects on the substrate through compaction of the peat.

Understanding animal behaviour
Using animals to manage fens provides numerous advantages, one of which being that because they are living creatures, their behaviour and choices can create a natural form of management, i.e. a lack of uniformity, unlike a mowing machine. This intelligence and choice also means that scenarios have to be carefully thought through, e.g. if a site is subject to prolonged flooding, there needs to be safe access routes which can be used to evacuate animals from a site.

Animals' requirements in this way are significantly different to those of machines, as they will often refuse to cross soft flooded ground, which may otherwise provide safe passage. This may result in the need for increased infrastructure.

Site conditions may compromise animal welfare
If site characteristics are not ideal, e.g. poor food variety, lack of dry refuge land, or if a group of animals are put onto site without the experience or knowledge to deal with wetland conditions, their health and welfare can be seriously compromised.

Recommended protocol for extensive fen grazing

When proposing to initiate a new grazing scheme on fens it is essential to take the following into account

Commence a project with low numbers of animals
Many variables influence the choice of an appropriate grazing density. There is clearly a balance to be made between having enough animals to manage a range of vegetation types across the site, and having too many which results in over-grazing of favoured areas or indeed the whole site and the resultant loss of ecotones and structural diversity. Rather than moving towards definitive advice on grazing densities, experiences so far have demonstrated the difficulties associated with deciding upon grazing densities for individual sites.

Factors which need to be considered include: amount of dry land available, amount and availability of food throughout the grazing season, range of habitats including scrub/trees for shelter, ground stability, incidence of flooding, and of course the conservation objectives for the site. Owing to these variables it is very difficult to calculate an exact density. To avoid damage to the site and welfare problems it is thus advisable to commence a project with low numbers and adjust them as necessary as the results of the grazing become apparent.

Primitive breeds tend to be better suited to extensive systems
Domestic breeds of animal are generally not so well equipped to cope with harsh environmental conditions owing to the fact that they have been bred for meat/milk production or the show ring and are used to depending on humans for their needs. Developing a breed for these purposes inevitably prioritises certain characteristics over those needed for survival in more natural conditions. Fen grazing requires animals that have the innate ability to adapt and exploit wet, swampy environments while maintaining good physical and mental condition. Primitive breeds of livestock tend to maintain the characteristics required for this adaptation.

Animals with prior experience of grazing fen habitat are ideal
Experience gained over a number of years has shown the real difference this makes to the ability of animals to graze successfully both in terms of the fen environment, and for their own health. Ideally animals obtained for fen grazing need to have some prior experience of grazing wet habitats. They then know how best to use the site and the dangers to avoid. It is also beneficial to keep the same group of animals on a particular site so that they can learn the site fully and how best to use it. This is particularly beneficial if breeding animals are obtained as youngsters can learn directly from experienced adults.

Match the animal to the management system
Year-round and seasonal grazing projects require animals with different behavioural characteristics. On year-round sites, where the animals receive most of their requirements from the site and require little human intervention, they may become largely self-sufficient which in turn encourages more natural or instinctive behaviour and thus a very natural form of management. However, this can result in animals becoming more difficult to handle if livestock movement or veterinary attention is required.

Experience has shown that matching the site and chosen management system to the most suitable animal is crucial, e.g. if animals need to be moved regularly between sites or compartments, obtaining individuals that recognise feed and are used to human contact is advisable.

Animal welfare requirements
Whatever grazing regime and animal is chosen, it is essential that the welfare requirements of the animals are thought through and provided. Following the risk assessment approach as developed by the Grazing Animals Project is particularly helpful (see Appendix 2). Some dry areas and indeed shelter within the grazing unit are important when considering animal welfare needs and will encourage exploration of the site. Similarly, if grazing is to be year round, access to adjacent dry grassland is essential for the animals' welfare.

Mixed social structure
Experiences with pony grazing have demonstrated the added advantages of obtaining a group of animals that consist of a mixed social structure, i.e. age and sex. The more natural the group composition is, the better they seem to cope as each age, sex and position within the hierarchy has a role to play in the functioning of the herd. This is probably also true for other types of stock.

Combination of management techniques
At extensive grazing densities, animals will not manage all components of the site equally. This is clearly one of the advantages of extensive grazing as it is this very lack of uniformity that promotes habitat and structural diversity. However, it also raises the point that depending on site objectives, alternative forms of management may be needed in combination with grazing to achieve optimum results. The use of targeted mowing can be particularly advantageous as cutting areas that may otherwise not be favoured by the animals can encourage them to utilise and possibly improve the diversity of these areas for the future.

4 General Issues Limiting Fen Management

The previous sections provided updates for each of the restoration and management techniques. This section identifies some of the common issues that can limit or prevent the application of management on certain sites. Some of these can be at least partly addressed with future planning and injection of resources, e.g. access improvements or stump grinding following scrub clearance. Those constraints driven by external factors however, e.g. high water levels, are more difficult to alleviate and are potentially the most restrictive. All of these issues were recorded as constraints to management during the fen audit. As the Audit did not assess the suitability of sites for non-commercial hand mowing, the constraints affecting this technique are not specifically mentioned here. However, many of the issues facing commercial reed and sedge cutting may also apply to conservation cutting.

High Water Levels

Flooded reedbed (Richard Starling)

Winter flooding has been a characteristic of Broadland hydrology for centuries. However, this has been exacerbated in recent decades by changes in the floodplain and catchment management and will be affected again by any future sea level rise. This flooding, which for many sites can be deep and prolonged, often prevents management from taking place during the winter months; this can be an issue for three months or more every year.

Flooding is a problem for grazing in that animals must have ready access to dry land or need to be taken somewhere dry for the winter months. High water levels also prevent machines from working and can result in the fen harvester being unable to work for a significant period of time. Because of the high fixed costs associated with running the harvester, this inability to work renders the harvester uneconomic. Commercial reed harvesting can also be limited by winter flooding resulting in a direct loss of income to the cutter. Failure to harvest one year may also affect the commercial quality of the crop in the following season thus having knock-on impacts over a longer time scale.

Some sites have water control, which enables water levels to be dropped for temporary management. This can be utilised to aid commercial cutting and other forms of mechanical harvesting but would not aid grazing as levels would need to be controlled for the entire winter period, which is not always desirable. The other option to facilitate grazing would be to obtain layback land adjacent to fen sites so that animals can have open access to dry land. However, much of the land adjacent to the fens is in arable production and may be costly to purchase or lease.

The table below summarises the impacts of high water levels on each of the management techniques and also highlights possible solutions.

High water levels continued:

Technique	**Impact of High water levels**	**Solution**
Commercial	Can prevent machines and operators from reed cutting, resulting in a loss of income and a reduction in crop quality the following year	Look into ways of providing temporary winter water control to allow a reed harvesting window (this may not always be compatible with conservation objectives)
Fen Harvester	Machine unable to cut in high water. High fixed costs result in the harvester becoming uneconomic if standing idle	Timetable the harvesting of sites which have water control to the winter and cut flood-prone sites during the summer (if vegetation communities /species allow)
Extensive grazing	Welfare issue – animals require dry land available at all times	Obtain and secure dry land adjacent to the fen for animals to retreat to at times of flood

Bird Breeding Season

Bearded tit (Richard Revels & RSPB-images.com)

Under the Wildlife & Countryside Act (1981), it is an offence to disturb, damage or destroy a bird's nest that is in use. This has implications for fen management work, which may disturb birds during the breeding season. Therefore, the fen harvester largely stops work from mid-April to July and the operators continually monitor worksites throughout the remainder of the summer. (This 'quiet' period has been defined in consultation with the RSPB and English Nature). However, this does mean that the harvester is unable to take advantage of the drier conditions of late spring and early summer, thus reducing the total amount of fen that can be harvested each year. Commercial cutting continues during the bird breeding season as the areas mown are generally small and nest sites can be readily observed and avoided. Low intensity grazing is not deemed to be disturbing to breeding birds.

The table below summarises the impacts of the bird breeding season on each of the management techniques and also highlights possible solutions.

Technique	**Impact of bird breeding season**	**Solution**
Commercial	Cutting continues during this time owing to small areas of disturbance and ability to avoid nests	Cutters and RSPB to draw up a protocol for working during the bird breeding season
Fen Harvester	Ceases work between mid-April and July, reducing the amount of sites that can be harvested in some of the driest months of the year	Unavoidable?
Extensive grazing	Not considered as disturbing to breeding birds	N/A

Outlets for fen produce

Commercial reed and sedge harvesting is the only management method that currently has a market for the cut fen material. Removing material from the fen is a very time consuming and costly exercise unless a ready market exists. Owing to the ecological need to remove piles of cut material from site, the other management methods have attempted to develop ways of achieving this. Non-commercial cutting either burns the material in strips, uses designated bonfire sites, or in some cases leaves the cuttings as habitat piles. Part of the design of the fen harvester was to devise a way of collecting and removing material from the fen without the need for repeated passes across the site – hence the development of the blower and pipe technology. However, there is still the question of how to dispose of the material once off-site. Several options have been investigated with the two most promising being the use of cuttings in farm compost and providing part of the fuel source for a local biofuel station.

Grazing management does not produce an end product as such as the vegetation is consumed and cycled through the animal. Because of this, there will be an overall decrease in nutrient levels with grazing, although some localised enrichment will occur owing to the deposition of dung.

Photo - Potential products resulting from fen harvester cut material (Rob Andrews)

The table below summarises the impacts of material disposal on each of the management techniques and also highlights possible solutions.

Technique	**Impact of material disposal**	**Solution**
Commercial	Majority of cut material removed from sites and used for thatching/reed panels etc	N/A
Fen Harvester	Large quantities of material produced for which there is currently only one outlet (compost), thus geographical operation of harvester is limited by means of disposal owing to transportation costs	Animal feed, bedding, compost and biofuel outlets have all been investigated – the latter two currently appear the most promising. More discussion is needed regarding on-site disposal and additional off-site outlets.
Extensive grazing	Animals do not generate a product although the vegetation is consumed and some of the nutrients are recycled through the passing of dung	N/A

Access

Good access on and off sites is essential for all management techniques although those utilising large machinery may require more infrastructure. Grazing requires vehicular access for a four-wheel drive vehicle and livestock trailer to the edge of the site, or at least to a point where animals can be offloaded and herded safely onto and off the site. Such access must be available and usable throughout the year if a site is to be grazed year-round. Many sites do not currently have such infrastructure in place and are only accessible using soft mud tracks or by passing across cropped fields.

For the fen harvester and blower machine to get to sites, they are transported by road using a tractor and trailer to the nearest track or roadside access. The machines can be driven down tracks to a site carrying the equipment, provided the access is wide enough. To remove material from a site, the closer the road is to the site, the shorter the pipeline length required to blow the cut material from fen to trailer, thus making the operation more efficient and less problematic. For some sites, fen harvesting is not an option owing to the long distance between fen and trailer. Once the material is in the trailer, access routes need to incorporate sufficient parking and turning space. Ideally these need to be laid with hard-standing to avoid rutting which may make the area impassable in wet weather.

In some cases, restoration work undertaken on sites has become a limiting factor for commercial cutters, for example, where dyke excavation results in dykes that are too wide for standard liggers to cross. All restoration and management techniques have the potential to cause access issues through the installation of features that conflict with other users, and/or by causing damage to the substrate at access points. Improved communication and planning could address these issues.

The table below summarises the impacts of access on each of the management techniques and also highlights possible solutions.

Technique	**Impact of access difficulties**	**Solution**
Commercial	Improvements in access for large machinery can often result in problems for commercial cutters through the installation of wide dykes that cannot be crossed with standard liggers. Access onto site is often by boat – many boat dykes are not being maintained and many have bunds installed across them to facilitate large machinery or grazing access, but which disrupt transport via boat	Improved communication between cutters and conservation organisations when planning fen restoration. Cutters to identify dykes for maintenance – liaison with conservation organisations
Fen Harvester	Requires hard standing access tracks to the edge of fen sites along with turning and parking areas for the material trailer. Some sites have no such access if surrounded by crops	Tracks can be upgraded and turning circles created – can be costly. Ideally, vehicular access needs to be as close as possible to avoid using long pipes to blow material off-site
Extensive grazing	Requires dependable vehicle and trailer access at all times to ensure animal welfare needs are met	Tracks can be upgraded – can be costly. Ideally need adjacent dry land located as part of grazing unit to maintain good access in all weather conditions

Condition of sites following restoration

Ground disturbance following restoration (Tim Hanks)

Much effort in recent years has been directed towards the large-scale removal of scrub that has invaded open fen habitat. In many cases, the methods employed to remove scrub involve either pulling trees out of the peat with an excavator, or cutting the trees down with a chainsaw, leaving the stumps behind. Either technique can result in the fen being unsuitable for follow-up management owing to the presence of holes and disturbed peat, or the presence of stumps over which machinery such as the harvester cannot pass. In the case of holes and unstable substrate caused by the removal of the whole tree, many years may be needed for the fen surface to 'heal' before either the harvester or grazing animals can venture onto the site to manage the resulting open fen vegetation. New methods are being investigated whereby large-scale scrub removal is combined with stump grinding to avoid problems such as those noted above (see page 6).

Scrub removal and dyke restoration can also affect the quality of commercial reed and sedge cutting if spoil banks are positioned in such a way to affect water flow on and off compartments. Because of this, spoil banks can also cause long-term change to fen vegetation communities. In addition to major dykes, there is also a considerable network of open footdrains that were installed to aid the ebb and flow of water onto the fen. These can also be damaged through restoration if they are not bridged and/or repaired.

The table below summarises the impacts of site conditions on each of the management techniques and highlights possible solutions.

Technique	**Impact of site disruption through restoration**	**Solution**
Commercial	Crop quality can be affected by any restoration that affects water flow, e.g. dyke clearance which creates spoil banks and prevents free movement of water resulting in stagnant conditions	Improved communication between conservation organisations and cutters when planning restoration. Amelioration work on affected sites, e.g. installation of additional pipes to connect fen and dykes.
Fen Harvester	Scrub removal can result in unstable substrate and holes, or stumps, depending on the method used. Either can result in sites that are unsuitable for fen harvesting.	Improved link between restoration and follow-up management, i.e. stump grinding in anticipation of harvester use.
Extensive grazing	Unstable substrate and holes present dangerous conditions for animals	Improved link between restoration and follow-up management.

5 Understanding the Impacts of Fen Management

This section considers the impacts of fen management on the fen ecosystem, focusing in particular upon compaction, hydrology and plants and invertebrates.

The importance of the fen habitat in the Broads is well known, supporting as it does numerous rare and scarce species of plant, bird, mammal and invertebrate. In order to maintain open fen conditions, some form of management is needed to remove the biomass and halt the ingression of scrub and woodland. However, owing to the sensitive ecology of the fens and the soft wet nature of the peat substrate underlying them, management of any kind is likely to cause some damage to the fen. This creates something of a dilemma whereby management is needed in order to maintain an internationally important habitat but with the understanding that this management may also be damaging part of that interest.

Studying the impacts of fen management upon the habitat is not a new concern. Monitoring has been undertaken on some sites for many years, and in particular where novel techniques have been applied to restore part of the habitat, e.g. creation of turf ponds and their subsequent development and re-colonisation (Kennison 1986-97). Concerns regarding disturbance to birds and the impact of management on less mobile species such as invertebrates are also well-voiced and efforts have been made to introduce measures within management programmes which alleviate some of these impacts, e.g. rules governing disturbance of birds during the breeding season, and avoiding cutting large stands of fen vegetation which leave little behind for invertebrate re-colonisation.

Old and new concerns have come to the fore more recently with the introduction of new and large-scale management techniques. The fens have a history of intensive yet small-scale management. Looking back to when the fens were harvested by the local populace, a huge area was under management, but the techniques used were largely small-scale and the impacts were owing to the presence of men rather than machines. In recent years, the conservation management of these sites has resulted in the introduction of new and novel techniques, which have the potential to manage large areas, and thus concerns have been raised over their potentially large-scale impacts.

If we accept that some management is required to maintain and enhance the conservation interest of the fens, but that all forms of fen management cause some damage to some elements of the fen habitat, it becomes vitally important to determine the type and degrees of damage and to weigh these up against the benefits of using each management technique.

Compaction

The following section may appear to receive disproportionate attention in comparison with some of the other issues raised in this document. This is owing to the fact that compaction did not feature within the original Fen Management Strategy and thus requires additional background information to fully explain the issue.

An overriding feature of the fens is the wet and soft peat that forms the substrate of many Broadland sites. The saturated and uncohesive nature of these sites makes them vulnerable to the effects of weight bearing machinery, animals and even people. Any compression or compaction of the peat substrate can have a number of deleterious effects on the fen. Vegetation stems and roots can be crushed, tussocks can be flattened, the peat surface can be broken up, resulting in subsequent oxidation and the hydrological properties of the peat itself can be altered.

While we still understand little about exactly how each fen site functions hydrologically, it is thought that some of the Broadland fens have a particularly spongy surface peat layer which is instrumental in facilitating water exchange from dykes to the fen and vice versa. This spongy layer is often associated with infilled turf ponds and broads and can be host to special plants, e.g. mire communities that have a brown moss component. All of these spongy areas are exceptionally vulnerable to compaction damage as any squashing of the peat can affect its ability to transmit water, thus resulting in lower water flow and content. This in turn may to affect the dependent plant communities.

Large and specialised machines such as the fen harvester have been designed with low ground pressure in mind (1.5psi) and owing to the larger contact area, the effects of its locomotion are more spread over the area of its tracks, rather than concentrated in two or four footfalls.

However, there remains a likelihood of peat depression on the trackways and owing to the fact that peat becomes more fluid following mechanical disturbance, the strength of the substrate on which the harvester has passed may also have been compromised. Ground disturbance and minor rutting can also occur in turning areas.

All machinery, including excavators working on mats and small pedestrian mowers will exert weight-bearing pressure on the peat resulting in some level of compression or compaction. (This is noted in earlier sections of this document where each of the restoration and management techniques are discussed). The presence of people likewise results in an exertion of pressure on the fen and to a much higher degree in terms of pounds per square inch (psi) than many machines as the ratio of weight to ground contact area is much greater. This is amplified further with grazing animals, as while they have four feet as opposed to two, they are considerably heavier. People and animals may sink some distance into soft peat; where repeated passes are made over the same area, this can cause significant disturbance, which on some sites may be undesirable.

Accepting that damage may occur with any management, it is the recovery of the peat following compaction that is important. However, measuring this is problematic as the soft peat substrate is inherently variable and the techniques used in engineering circles are designed for testing high load bearing soils rather than the low load bearing substrates of the Broads. The inconsistency of the peat makes it virtually impossible to obtain an average load bearing ability, let alone assess the exact impacts of management upon the substrate. In addition, the impacts of compaction are likely to only be seen over the longer timescale, and any monitoring of this is likely to be complicated by a suite of other processes causing change over the longer-term.

Recommendations:

- On sites that have retained a special spongy peat layer, i.e. Sutton, Broad Fen, Great Fen at Catfield, Mills Marsh at Ranworth and Upton, the precautionary principle should be applied and the use of large scale novel restoration and management techniques should be avoided.

- On some sites there is a need to consider which attribute of the fen is most valued, as this will guide the type of management options available. For example, the invertebrate interest at Sutton Broad Fen precludes the use of burning due to an agreed management policy, and yet this form of management is not known to be detrimental to either the vegetation communities or the special spongy peat. However, individual attributes are not always known and management decisions often need to be taken based upon the best information available at the time.

- Further discussion is required as to the relative importance of factors influencing sites over the longer-term, and whether the causes of long-term change can be separated and effectively monitored.

Hydrology


Fen dyke (Richard Starling)

The hydrological functioning of peat and the possible changes to this through compaction has already been discussed. However, it is clearly impossible to determine the level of change to a feature without first determining how it should function without interference. There is a general lack of information about the hydrological workings of the fen resource and thus we have little knowledge of how the fens may react to changes in hydrology whether caused by management or external influences such as sea level change.

Studies are underway to help address this and gain a better understanding of the hydrological functioning of the Broads in general, e.g. the Environment Agency's Review of Consents and via the models produced as part of the Broadland Flood Alleviation Project. In addition, further research is being carried out into the hydrological requirements of different fen communities (Environment Agency's Wetland Framework and Ecohydrological Guidelines). However, little baseline information has been gathered as to how the water tables of individual fens act and react, the role of dykes in irrigating and draining the fens, and the influence of saline water both on a day-to-day basis and at times of flood.

In principle, a more naturally functioning hydrological system is more robust in times of change. However, owing to past management intervention by man, the hydrological functioning of the fens is no longer natural and a return to those conditions without fully understanding the system could be disastrous. At the same time, if we try to preserve what we have now, this would involve more and more artificial control, which is not sustainable.

Past policies have resulted in the damming of dykes to separate fens from poor river water quality. On some sites, this has led to concerns regarding the lack of base-rich river water and increasing irrigation from more acidic rainwater. It is now hoped that with continuing improvements to water quality, reconnecting floodplain fens to the river may become a possibility, thus enabling a more natural hydrology to function.

In terms of the hydrological management of fens, the following recommendations have emerged from recent workshops:

- Dykes have ecological value in their own right, are a traditional and historical feature, provide access, and have a crucial role in the water management of the fens. However, owing to uncertainties regarding the exact functioning of dykes, individual hydrodynamic site investigations should be carried out prior to any major restoration or changes to water management.

- A better understanding is needed of the role of dykes – irrigating and draining effects, roles for fish, functionality where connected to turf ponds etc.

An initial step has been taken to address some of this uncertainty through the formation of an eco-hydrology workshop made up of hydrology experts and fen managers to raise awareness and discuss management and monitoring options. In addition, some basic monitoring has been proposed for a number of sites. This includes:

- Regular monitoring of conductivity measurements at various key sites around the Broads.

- Recording of conductivity levels along dyke systems at key fen sites in times of flood to establish the level and extent of saline ingression.

- Recording of river and fen water levels at a range of fen sites that have different hydrological characteristics to determine the role of dykes and response times to water level change.

It is hoped that this basic monitoring will go some way to explain how water travels within the fens and so will also inform decisions regarding management.

Plants and invertebrates

Swallowtail butterfly on Ragged Robin (Rob Andrews)

As stated earlier in this document, the impacts of mowing on fen vegetation have been monitored and the results of these studies have been used to devise a range of cutting regimes to manage and benefit different types of plant community. These mowing regimes are accepted and applied through various land management schemes across the fens.

However, these regimes were devised at a time when pedestrian mowers were the only option available to fen managers. Thus, when the fen harvester began trial cutting in the Broads, the effects and impacts of its use were also monitored to ensure that this 'new' method of mowing would not be detrimental to the plant communities. This monitoring was undertaken as part of the three-year New Wetland Harvests LIFE project. However, many of the conclusions were preliminary and may warrant further and longer-term consideration.

The impacts of fen management upon invertebrates have also been considered and through various studies on different habitats, a number of principles have been established. For example, owing to the diversity of invertebrate groups and species and their individual life cycle requirements, management that produces a range of habitats, ecotones and structural variation is likely to be of benefit to a wider range of invertebrates than a single homogenous form of management. (Kirby, 1992) In addition, a workshop was held in the early 1990's between eminent entomologists and the key conservation organisations in the Broads. This group concluded that the sheer heterogeneity of fen vegetation and the huge diversity of invertebrate populations and their requirements prevent the establishment of comprehensive and replicable studies.

Uncertainties remain over the use of grazing animals and the effects they may have upon the fens and their associated species. Concerns raised at recent workshops include possible changes to plant community composition through selective grazing, inability to control scrub invasion and confirmation that extensive grazing is indeed of benefit to invertebrates. All these questions point to the need for rigorous monitoring, however, the inherent variability within and between fen sites, and the random nature of grazing animals, makes the design and replication of useful monitoring problematic.

In many cases the problems of monitoring and an inability to reach an agreed approach towards it have resulted in observations of grazing rather than a robust scientific project. One of the main problems with monitoring extensive grazing over large sites comes down to the very nature of grazing animals. On a large site, it becomes difficult to predict where a herd of animals may concentrate their grazing effort – this will be greatly influenced by the rate the animals explore the site and according to the distribution of habitats across the site; the animals will also change their use of a site over time.

This results in difficulties when planning monitoring on the ground, particularly as any monitoring of change should be preceded by an assessment of the site before management is initiated. As such, fixed monitoring areas or transects may be located in areas which are not grazed, at least not initially. In addition, different types, breeds and indeed groups of animals may all use a site in different ways.

Because of these difficulties and lack of consensus, the approach taken by some has been to trial different methods to try and obtain some data about grazing and observe and document the difficulties experienced. Is this better than doing nothing at all? Are we answering the real questions? Can the real questions be answered?

The two grazing monitoring programmes that have been set up by the RSPB and NWT have been designed for very different purposes. The RSPB example was designed specifically to look at the impacts of grazing primarily upon molluscs owing to the importance of a particular site for mollusc fauna, although wider impacts of grazing in terms of the use of the site and observable habitat change were also studied. The NWT example in comparison, will study general habitat changes in a system where grazing is just one of a number of different management options. If grazing is to expand, further work clearly needs to be done to establish some baseline monitoring methodology, which goes some way to answering specific grazing questions.

One of the main problems with monitoring any 'new' and particularly large-scale technique is the fact that any changes imposed by those techniques are likely to be long term and only detected by long term monitoring programmes. Unfortunately, monitoring can be very expensive and is generally not successful at attracting significant funding. However, the strength of concern expressed at recent workshops regarding grazing, fen harvesting and also the need to monitor some of the more established methods suggests that efforts need to be made to answer some of the questions regarding the benefits and impacts of fen management techniques. To try and address these, the following course of action is recommended:

Recommendation

- *Organisation of a monitoring workshop*
  This workshop should include representatives from all the local conservation organisations, consultants and interested landowners. Experts should also be invited who will be able to provide advice regarding the monitoring of specific subjects. The objective of this workshop will be to discuss the monitoring needs of all restoration and management methods, to identify specific areas to be monitored and to devise some standards, which should enable specific questions to be answered.

6 Recommendations and Actions

As stated at the beginning of this document, the Supplement is intended to act as an addition to the Fen Management Strategy (1997). As such, ideas and principles stated within that Strategy have been taken forward and indeed evolved within the Supplement. The points listed below, summarise the actions and recommendations that have emerged from this Supplement and a number of these relate directly to recommendations made within the original Strategy (see Appendix 3a).

Summary Recommendations from the Supplement

1) Effective communication is needed between all parties throughout the fen restoration and management process. In particular, continued formal and informal meetings are required between conservation organisations and commercial reed and sedge cutters to ensure that compatible working practices are employed. A formal meeting once or twice per year is recommended to update and plan future work, with further informal site visits organised as required. Individual site meetings are needed to discuss amelioration work needed on sites that have already been restored resulting in follow-up management difficulties, e.g. Sutton Fen.

2) Review the amount of woodland to be cleared on the basis of the fen audit results which highlight: the practical ability to manage restored fen, the need to clear scrub to link areas of open fen, more accurate area measurements of open fen areas.

3) All scrub clearance should be followed by stump treatment or grinding – method used should be tied into planned follow-up management, e.g. grinding is more suitable for mowing.

4) Ensure scrub is retained on fens as an integral component of the habitat. Plan to leave clumps of trees/bushes, as well as odd scattered trees and bushes. Continue to implement Broads-edge scrub clearance works and other protocols, e.g. maintaining scrub strips adjacent to woodland margins to provide transitional habitat and retaining mature carr and valley margin wood.

5) Expand hand mowing onto areas of high priority that are identified within the fen audit as unsuitable for other forms of management.

6) Maintain hand mowing on fragile or sensitive sites to ensure the interest and species are retained.

7) Further develop machinery to enable remote, non-commercial areas to be cut, and vegetation removed in a cost-effective way, but which does not damage the fragile habitat.

8) Continue to retain areas of uncut tall herb vegetation for mammal and invertebrate refuge as part of standard mowing procedure.

9) Further discussion is required regarding the disposal of fen harvester cut vegetation, both on-site and through the use of new outlets e.g. trials with farmers to use cuttings on arable land, provisions of outlets in the Southern Broads.

10) Utilise the results of the fen audit to timetable sites for fen harvester management, e.g., cutting sites during the summer that have high winter water levels.

11) Support commercial reed and sedge as an environmental and economic means of managing the fens. Provide opportunities to cutters for other appropriate fen work, including predator control, scrub clearance, routine dyke maintenance, bird survey etc.

12) Explore opportunities identified within the fen audit to expand the area of fen managed by extensive grazing, but avoid the sites that retain a special spongy peat layer (Upton, etc).

13) Utilise the results of the fen audit to identify sites that require the purchase/lease of adjacent land to enable grazing management. A pro-active study is required to identify the best opportunities for valley-side restoration - this links to points 21 and 23 below.

14) Ideally graze fens as an integral part of a much larger system that incorporates a mixture of habitats, including woodland, heath and grass.

15) Where possible use family (if not breeding) groups of animals in order to fulfil psychological welfare requirements of self-reliant grazing livestock.

16) Continue to explore the use of different large herbivores and assess associated benefits and constraints.

17) Explore opportunities identified within the fen audit to further expand summer grazing opportunities, either with conservation stock or through utilising an appropriate commercial grazier.

18) Site meetings are required to discuss how high water levels can be alleviated to facilitate management *where appropriate*, e.g. temporary water control, identifying strategic dry land for purchase to support grazing projects.

19) Protocol to be drawn up between RSPB and commercial cutters and agreed with English Nature, to provide formal guidance on working practices during the breeding season. General guidance for other work practices are also needed, e.g. scrub clearance.

20) Consider the impacts of restoration and management techniques on delicate peat substrates when planning activities on site.

21) Actively seek opportunities to allow rare and transitional fen communities to develop through valley side restoration projects (assessing the need for scrub clearance on a site-by-site basis).

22) Continue to seek opportunities through BFAP and other initiatives (including the Higher Level Stewardship Scheme) to create/expand reedbeds and fen habitat and manage water levels.

23) Investigate potential benefits and opportunities for semi-natural habitat on valley margins

24) Seek opportunities for fen restoration and creation.

25) Seek opportunities for fen meadow restoration, including M22 & M24 communities.

26) Survey peat resource to establish depth of peat.

27) Seek opportunities to restore/create fen on peat areas that do not currently support fen vegetation.

28) Review action on turf pond creation

29) Install greater numbers of pipes in bunds to ensure connectivity between dykes and fens is not impeded.

30) Review the need on a site-by-site basis, as to whether dykes and fens would benefit from greater connectivity with the rivers. Further eco-hydrological monitoring may aid this assessment.

31) Consider methods of dyke restoration which do not disadvantage reed and sedge cutters; this particularly relates to very wide dykes, and installation of bunds which disrupt boat transport. Increased communication between all management groups is recommended.

32) Many of the above actions involve expanding areas of semi-natural habitat, and in effect are promoting the formation of 'large areas' whereby habitats have the ability to move and evolve. It is suggested that an action plan for implementing large areas in the Broads is set in motion, linking the actions noted here with the aspirations of the Norfolk Large Areas BAP Topic Group.

33) Organise a monitoring workshop involving local conservation organisations, consultants and interested landowners. Experts should also be invited who will be able to provide advice regarding the monitoring of specific subjects. The objective of this workshop will be to identify areas to be monitored and to devise some standards, which will enable specific questions to be answered. All restoration and management techniques should be considered.