NINA Report 457

Sefydliad Norwyeg i Waith Ymchwil ym Myd Natur
Norwegian Institute for Nature Research

Ail-gyflwyniad yr afanc Ewropeaidd *Castor fiber* i Gymru. Astudiaeth dichonoldeb ecolegol

The reintroduction of the Eurasian beaver *Castor fiber* to Wales: An ecological feasibility study

D.J. Halley
Adrian Lloyd Jones
Sarah Chesworth
Chris Hall
Derek Gow
Robert Jones-Parry
Jane Walsh



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Halley, D.J.; Jones, A.C.L.; Chesworth, S.; Hall, C.; Gow, D.; Jones-Parry, R.; & Walsh, J. 2009. The reintroduction of the Eurasian beaver *Castor fiber* to Wales: an ecological feasibility study / Ail-gyflwyniad yr afanc Ewropeaidd *Castor fiber* i Gymru. Astudiaeth dichonoldeb ecolegol. - NINA Report 457. 66 pp.

Trondheim, March 2009

ISSN: 1504-3312
ISBN: 978-82-426-2026-2

AVAILABILITY
[Open]

PUBLICATION TYPE
Digital document (pdf)

EDITION
1

QUALITY CONTROLLED BY
Kjetil Bevanger

SIGNATURE OF RESPONSIBLE PERSON
Inga Bruteig, research director

CLIENT(S)
Ymddiriedolaethau Natur Cymru / Wildlife Trusts Wales

CLIENTS' CONTACT PERSON(S)
Adrian C.L. Jones

COVER PICTURE
D.J. Halley; Ian Sargent ; S. Halley

KEY WORDS

Beaver Castor fiber Wales reintroduction feasibility

NØKKELORD

Bever Castor fiber gjeninnføring Wales gjennomførlighet

Abstract

Halley, D.J.; Jones, A.C.L; Chesworth, S.; Hall, C.; Gow, D.; Jones-Parry, R.; & Walsh, J. 2009. The reintroduction of the Eurasian beaver *Castor fiber* to Wales: an ecological feasibility study / Ail-gyflwyniad yr afanc Ewropeaidd *Castor fiber* i Gymru. Astudiaeth dichonoldeb ecolegol. - NINA Report 457. 66 pp.

This report discusses the biological feasibility of the reintroduction of the Eurasian beaver *Castor fiber* to Wales. Beavers are one of the most extensively reintroduced species of the European fauna, and a great deal of information is available on the methods, progress, and effects of reintroductions.

In most of Europe beavers live mainly in human-dominated 'cultural' landscapes, and are managed as an element of that landscape. This assessment considers feasibility primarily in this light, that is, of the reintroduction of a formerly present element to the Welsh cultural landscape. However, while touching on matters of desirability and management where appropriate in such a context, it is not primarily concerned with those topics but, rather, is intended to provide part of the basis on which further consideration of those issues can proceed.

A survey of the extensive beaver reintroduction ecology literature shows that beaver populations spread rapidly through watersheds but only slowly (and with appropriate management containably), between them. This implies that reintroductions, and management, should be considered at a whole watershed scale. Accordingly, following training and experience in beaver ecology on the ground, fieldworkers closely familiar with Welsh rivers conducted an appraisal of the country and identified six river systems for more detailed analysis: the Glaslyn, Dee, Rheidol, Teifi, Eastern Cleddau, and Western Cleddau.

Investigation of these river systems indicates that all, with the possible exception of the Glaslyn, could support viable populations of beaver of varying size. Potential populations on each river, their distribution, and ecological factors such as the likely degree of dam-building activity, which is closely related to stream flow characteristics, are discussed.

Beaver reintroduction to Wales is biologically feasible and would be technically unproblematic to achieve. In landscapes dominated by human activities, European experience indicates that the human element is by far the most influential in determining the practical feasibility of a programme. The biology of beaver reintroduction is very well known; the course of population development on a river system and its ecological effects can be predicted with reasonable confidence. It is the (human) social aspects of reintroductions that typically require the most attention, care, and forethought.

Crynodeb

Halley, D.J.; Jones, A.C.L.; Chesworth, S.; Hall, C.; Gow, D.; Jones-Parry, R.; & Walsh, J. 2009. Ail-gyflwyniad yr afanc Ewropeaidd *Castor fiber* i Gymru. Astudiaeth dichonoldeb ecolegol / The reintroduction of the Eurasian beaver *Castor fiber* to Wales: an ecological feasibility study - NINA Report 457. 66 pp.

Mae'r adroddiad hwn yn trafod ymarferoldeb biolegol ailgyflwyno'r afanc Ewrasiaidd, *Castor fiber*, yng Nghymru. Yr afanc yw'r rhywogaeth sydd wedi'i ailgyflwyno fwyaf bron o blith anifeiliaid Ewrop ac mae llawer iawn o wybodaeth ar gael am ddulliau, cynnydd ac effeithiau'r ailgyflwyno.

Yn bennaf, mae afancod Ewrop yn byw mewn tirluniau 'diwylliannol' a reolir gan ddyn yn bennaf. Mae'r asesiad hwn yn ystyried yr ymarferoldeb yng ngoleuni hyn, yn bennaf, hynny yw, ailgyflwyno elfen o dirlun diwylliannol Cymru a arferai fod yn bresennol yma o'r blaen. Fodd bynnag, tra'n rhoi sylw i faterion fel dymunoldeb a rheolaeth lle bo hynny'n berthnasol i'r drafodaeth ar ymarferoldeb mewn cyd-destun o'r fath, nid yw'n ymwneud yn bennaf â'r pynciau hynny ond, yn hytrach, y diben yw darparu rhan o'r sail ar gyfer bwrw ymlaen ag ystyriaeth bellach o'r materion hynny.

Mae arolwg ar y llenyddiaeth eang sydd ar gael ar ecoleg ailgyflwyno'r afanc yn dangos bod poblogaeth yr afanc yn ymledu'n gyflym iawn drwy wahanfeydd dŵr ond dim ond yn araf iawn (a chyda rheolaeth briodol a chynhwysol) rhyngddynt. Mae hyn yn awgrymu y dylid ystyried ailgyflwyno, a'r dull o reoli hynny, ar raddfa gwahanfa ddŵr gyflawn. Yn unol â hynny, wedi hyfforddiant a phrofiad o ecoleg yr afanc ar y tir, cynhaliodd gweithwyr maes oedd yn gyfarwydd iawn ag afonydd Cymru werthusiad o'r wlad gan nodi chwe system afon ar gyfer dadansoddiad manylach: y Glaslyn, y Ddyfrdwy, Rheidol, Teifi, Dwyrain y Cleddau a Gorllewin y Cleddau.

Mae ymchwiliad i'r systemau afon hyn yn dynodi y gallai pob un, ac eithrio'r Glaslyn o bosibl, gefnogi poblogaethau hyfyw o'r afanc o faint amrywiol. Trafodir y boblogaeth bosibl ar gyfer pob afon, eu dosbarthiad a ffactorau ecolegol fel graddfa debygol eu gweithgarwch codi argaeau, sydd â chysylltiad agos â nodweddion llif nentydd.

Mae ailgyflwyno'r afanc yng Nghymru'n ymarferol yn fiolegol ac, yn dechnegol, ni fyddai'n broblemus i'w gyflawni. Mewn tirluniau a reolir gan weithgarwch dyn, mae profiad Ewropeaidd yn dynodi mai'r elfen ddynol yw'r un fwyaf dylanwadol o bell ffordd o ran penderfynu ar ymarferoldeb y rhaglen. Mae gwybodaeth dda ar gael am fioleg ailgyflwyno'r afanc; gellir rhagdybio datblygiad poblogaeth ar system afon a'i effeithiau ecolegol yn rhesymol hyderus. Yr agweddau cymdeithasol (dynol) ar ailgyflwyno sydd angen y sylw, y gofal a'r cynllunio mwyaf.

Sammendrag

Halley, D.J.; Jones, A.C.L; Chesworth, S.; Hall, C.; Gow, D.; Jones-Parry, R.; & Walsh, J. 2009. Gjeninnføringen av den Eurasiatisk bever *Castor fiber* til Wales: en økologisk gjennomførliget undersøkelse. - NINA Rapport 457. 66 ss.

Denne rapporten diskuterer den biologiske gjennomførlighet av gjeninnføringen av den Eurasiatiske bever *Castor fiber* til Wales. Arten er en av de mest vidt gjeninnført arter i den Europeiske faunaen, og mye opplysning er tilgjengelig om metodikk, framgang, og effektene av gjeninnføringer.

I det fleste av Europa lever beveren i menneskedominerte kulturlandskaper, og er forvaltet som et element av dette landskapet. Denne vurderingen behandler gjennomførlighet primært i denne lys, det vil si, som gjeninnføringen av en tidligere tilstedsværende element til det walisiske kulturlandskapet. Likevel, mens den berører saker som ønskelighet og forvaltning som hensiktsmessig i konteksten, den dreier seg ikke primært på disse emner men, heller, er tilsiktet som en del av basisen som brukes i videre overveielse av disse emner.

En gjennomgang av den omfattende litteratur på bever gjeninnføringsøkologi viser at beverbestand sperr seg raskt gjennom et vassdrag, men bare sakte (og med tilpasset forvaltning beholdelig) mellom vassdrag. Dette innebærer at gjeninnføringer skal vuderes på et hele vassdrags målestokk. Følgelig, etter opplæring og erfaring i beverøkologi på bakken, feltarbeidere med nær bekjentskap på elvene i Wales gjennomført en vurdering av landet og identifisert seks vassdrag for mer detaljert undersøkelser: Glaslyn, Dee, Rheidol, Teifi, Eastern Cleddau, og Western Cleddau.

Undersøkelse av disse vassdrag indikerer at all, med mulig unntak av Glaslynvassdraget, kan støtte levedyktige bestand av bever av ulike størrelse. Estimerte bestandstørrelser på hver vassdrag, sannsynlig utbredelsen på vassdraget, og økologiske faktorer som den sannsynlig nivå av oppdemningsaktiviteter, som er nær knyttet til strømegenskaper, er diskuterte.

Gjeninnføringen av beveren til Wales er biologisk gjennomførbart og blir teknisk sett uproblematisk å oppnå. I landskapene dominerte av menneskeaktiviteter, erfaringen fra Europa viser at den menneskelige elementet er langt det mest innflytelsesrik i bestemmelse av den praktiske gjennomførlighet av et program. Biologien av bevergjeninnføringer er meget godt forstod og kurset av bestandsutvikling på et vassdrag, og dens økologiske effekter, kan forutsies med rimelig sikkerhet. Det er den (menneskelige) sosiale aspekter av gjeninnføringer som typisk trenger det meste oppmerksomhet, forsiktighet, og omtanke.

Contents

Foreword

The Eurasian beaver is the most widely reintroduced and translocated mammal in the European fauna, excepting species primarily translocated for hunting purposes. At least 203 recorded reintroductions have taken place in Europe, outwith Russia (in which many translocations have also been made). Beavers are now found living wild in every country within their former European range, excepting Great Britain, Portugal, Italy, and the countries of the southern Balkans; a limited trial reintroduction in Scotland will take place in 2009.

This history of reintroductions has yielded a very considerable research literature, which, combined with site studies, allows the prediction of the progress of reintroductions to new sites in fair detail. Reintroduction to Wales is now under consideration, and the first step is to investigate the *biological feasibility* of reintroduction: that is, whether it is possible for beavers to be reintroduced and to form a viable self-reproducing population in the current Welsh landscape.

The purpose of this report is to address this issue. Although it takes into consideration other aspects of reintroduction where pertinent, it does not, and is not intended to, consider the interconnected issues of *desirability* of reintroduction and the *management* of a reintroduced population. If beaver reintroduction is both determined to be feasible and further work on assessing reintroduction considered appropriate, discussion of desirability and management would be appropriate at that stage.

D.J. Halley
Adrian Lloyd Jones
Sarah Chesworth
Chris Hall
Derek Gow
Robert Jones-Parry
Jane Walsh

March 2009

1 Introduction

Article 22a of the European Union Habitats Directive (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1992L0043:20070101:EN:PDF) states:

"In implementing the provisions of this Directive, Member States shall:
(a) study the desirability of re-introducing species in Annex IV that are native to their territory where this might contribute to their conservation, provided that an investigation, also taking into account experience in other Member States or elsewhere, has established that such re-introduction contributes effectively to re-establishing these species at a favourable conservation status and that it takes place only after proper consultation of the public concerned"

In Wales, this responsibility is delegated to the Countryside Council for Wales (CCW). In furtherance of its obligations under Article 22a, CCW, in cooperation with the Environment Agency, People's Trust for Endangered Species, Wildlife Trusts Wales and Wild Europe, has funded a preliminary investigation by Wildlife Trusts Wales in partnership with Wild Europe into the technical feasibility of reintroducing the Eurasian Beaver[1] *Castor fiber* to Wales. Part of the work was subsequently subcontracted to the Norwegian Institute for Nature Research, which is experienced in beaver biology and management issues. This report is the product of a close cooperation between these groups.

2 The Eurasian beaver

2.1 Description, ecology, and taxonomy

Figure 1. Eurasian beaver (Castor fiber).

[1] Hereafter referred to as 'beaver'. The North American beaver *Castor canadensis* will be identified specifically when discussed.

The Eurasian beaver *Castor fiber* is a large semiaquatic rodent. Body length in adults is about 80 to 110 cm, with a tail of 30 to 35 cm, weighing from 13 to 32 kg. There is a slight sexual dimorphism; the average male weighs about 24 kg and is 90 cm long, while the average female weighs 26 kg and is 98 cm long. Beavers have stocky bodies with flattened hairless tails and short legs. They have webbed toes and can use both forelegs like hands. The incisors are large, yellowish in colour, and prominent. They have a thick outer coat of brown, straight hair; the shade varies, and melanism is common in some populations. The underfur is short, very dense, and waterproof. The small eyes have nictitating membranes and the ears and nostrils are valvular. The incisors and mouth musculature are arranged so that the animal can gnaw effectively underwater without allowing water into its mouth.

Figure 2. Beaver swimming. Photo: Ian Sargent

Beavers live on the margins of water bodies in territorial family groups of from 2 to 8 animals, on average 3.2. In Scandinavia, the mean litter size is 1.9 pups; there is one litter a year, born in spring, (Rosell & Pedersen 1999). The family group consists of the breeding adults, and their young of the year and previous year. Young adults usually disperse in the spring of the third calendar year of life (i.e. when about 2 years old), though in unsaturated populations they quite often disperse as yearlings. Females normally breed for the first time at age 3 (Nolet 1997).

Territories are generally linear, size varying with stage of population development and habitat quality; and perhaps also with the historical pattern of settlement, which can ‘freeze’ large, early-established territories in place (Campbell et al 2005). In average quality habitat at carrying capacity, a rule of thumb is that each territory requires c. 3km of shoreline (c.1.5km of river/stream course) (Rosell & Pedersen 1999). However, this is very variable, from as low as 0.25km shoreline in very favourable habitat to, exceptionally, as much as 21km in poor habitat (Rosell & Pedersen 1999). In Wales, with its mild climate and long growing season compared to most beaver-inhabited areas of Europe, territory sizes needed to sustain a family group will probably tend towards the lower end of this spectrum, all else being equal. While preferring stable water conditions, beavers cope well with considerable water fluctuations, including both seasonal and irregular flooding of marshlands, and even the temporary drying up of watercourses in droughts (Kurstjens & Bekhuis 2003). The watercourse must be flat or not too steep: a gradient of more than 2m in 100m (2%) is generally unsuitable (Howard & Larson 1985; Webb et al. 1997, though in a few places dams have been built on streams of up to 2.5% gradient, rendering the water surface gradient 0% very locally - Schulte 1989 and see below). They can be very tolerant of human activity, such as golfing, jogging, dog-walking, and swimming (figure 10), adjacent road traffic, and street lighting illuminating the main lodge (figure 13). Such beavers are often habituated to humans and ignore them to distances down to c.10m (figure 3); and even swim on the surface under the lines of bankside anglers (*pers. obs.*).

Figure 3. Habituated beaver in a city edge park. Beaver usually emerge c.20:00 in the evening regardless of the light conditions and latitude. This has provided the basis for a number of wildlife tourism operations.

Diet is entirely herbivorous; the species has been described as a 'choosy generalist' (Jenkins 1975; Haarberg & Rosell 2006), able to eat a very wide variety of plants, but selecting for high quality forage when available. The diet most famously includes deciduous tree bark, largely a food outside the growing season (e.g. Elmeros et al 2003), though in some cases aquatic plants have been used as a substitute for bark (Simonsen 1973). Conifers are rarely or never taken (Haarberg & Rosell 2006; Parker et al 2001). Deciduous tree bark alone is not a sufficient diet for survival and reproduction, and at other times of year, grasses, forbs, tubers, and aquatic plants typically dominate; in Sweden beaver densities are positively correlated with the abundance of grasses and forbs (in an environment always wooded to a significant degree) (Hartman 1996). While trees of up to 1m in diameter can be felled, beavers prefer small tree stems with diameters of less than 10cm (Wilsson 1971); in a Norwegian study, 95% of stems cut were less than 5cm in diameter (Haarberg & Rosell 2006). Larger trees are most often felled in autumn when preparing winter food stores (Nolet 1997). This suggests that tree felling may be relatively less common in Wales, given the mild winter conditions. It is possible that in places with abundant herbaceous and/or aquatic vegetation and no need for lodge or dam construction, beavers could live in places with very limited tree/bush availability in Wales. However, we have erred on the side of caution and assume a requirement for deciduous tree/bush availability as in the modified Allan model (see Methods, below)

Foraging generally takes place close to the bank; in Denmark, for example, 95% of beaver cut stems were within 5m of water (Elmeros et al 2003); in Russia, 90% of cut stems were within 13m of water and 99% within 20m (Baskin & Sjöberg 2003). Beavers can, however, exceptionally forage up to 150m from water, typically to obtain aspen or poplars (*Populus* sp.), highly preferred forage species, when not available near shore (pers. obs.). Beaver regularly occur on watercourses with only a narrow fringe of riparian vegetation. The main advice on habitat restoration (and conflict avoidance) for beaver recommended to the Council of Europe was the establishment of a 20m wide riparian strip adjacent to watercourses (Nolet 1997).

Figure 4. Beaver coppice, willow on left and birch on right. Beavers normally fell deciduous trees only; the dead spruce sapling behind the birch was felled by humans as part of forestry thinning operations. Beaver stumps are 'pencil stub' shaped while human cuts are straight.

Figure 5. A typical example of 'beaver coppice' or 'beaver pasture'. This is the patch nearest to the inlet stream of the small lake territory shown in Fig. 10, and is a mature example after 33 years of continuous occupation of the site. There has been little observable change in extent or structure for at least 15 years. The main impact has been to convert a patch of woodland, c. 50x20m, of mainly birch, willow, and alder, to coppice growth with a rich ground layer of grasses and forbs. This area and one other similar-sized patch (Fig 10) are the main foraging areas of this beaver family, regularly cropped, mainly for grasses and forbs in the growing season. Coppicing activity is most active in autumn, in preparation for winter iceover..

Beavers are capable of modifying their habitat through the construction of dams and canals, though generally prefer habitats where such modification is not necessary when available; most damming therefore occurs at high population levels[2], and later in the process of population development on a watershed (Halley & Rosell 2002; Zurowski & Kasperczyk 1986). Dams are largely confined to smaller, shallower streams; on average 2.5±1.1m wide and 0.36±0.14m deep in a Swedish study (Hartman & Törnlöv 2006). 97% of dams were on waters less than 0.7m deep and all on waters less than 0.85m deep; the extreme maximum stream width dammed was 6m. The average height of dams was also modest, raising the water level 0.46±0.21m on average, maximum 1.0m. Exceptional cases of deeper dams are known from elsewhere, usually of 'plug' type where steep banksides form 'side walls'. The height water was raised was negatively correlated with original depth (i.e. deeper waters were raised less). The overall aim appeared to be to achieve a water depth behind the dam of about 0.7-1.0m.

The steepest gradient on which Eurasian beavers have been found to build dams is a case where the stream had a fall of 2.5m in 100m, or 2.5% (Schulte 1989), though in France dam building ceased at gradients over 1% (Erome 1983, cited in Hartman & Törnlöv 2006), and in Sweden at 2% (Hartman & Törnlöv 2006).

Figure 6. A large beaver dam at low water flow conditions in summer. The former irregularly-flooding forest bog with scattered scrub behind the dam has been modified to a pond and sedge water meadow. Most of the water flow at this site was diverted around the edge of the dam to right of picture.

[2] North American beavers *C. canadensis* differ significantly in dam building behaviour from the Eurasian species. *C. canadensis* builds larger, deeper, and more frequently than *C. fiber*, even where the two species occur together in the same habitat in Russian Karelia (Danilov & Kan'shiev 1983; Danilov 1995). Perhaps as a result it appears that the species can tolerate steeper gradients than *C. fiber*, which rarely dams streams over 2% in gradient, with a maximum recorded of 2.5% (Hartman & Törnlöv 2006; Schulte 1989); *C. canadensis* dams have been recorded, although exceptionally, on streams of up to 4% gradient (McComb et al 1990); however increasing stream gradients are increasingly strongly selected against. The mean stream gradient at *C. canadensis* dammed sites is 0.8%, and in most areas the extreme upper limit for dam construction is c.3% (see review in Curtis & Jensen 2004)

Figure 7. Beaver dams after heavy rain in November (left) and in spring spate (right). Dams typically divert water around them, or shelve water over the top, at normal flows; after heavy rain or in spring spate breaching is usual.

The incidence of damming depends on the characteristics of individual watersheds, but except in very flat terrain is not usually a common feature at a watershed scale. As a fairly typical example, the Numedalslaget watershed in SE Norway flows through a narrow valley in broadly similar hilly to mountainous terrain as is typical of Wales. Beavers occur there at capacity populations. There were (2003) 29 beaver territories on the river system, of which 3 (10.3%) had actively maintained dams. There were also two dams no longer maintained, which would have been breached at the next spate (Parker & Rønning 2007); on average there was one dam per 14.3km of tributary stream length suitable as beaver habitat (i.e. excluding the main river, which could not be dammed). On gently rolling terrain in NE Poland, with low gradients and numerous shallow marshlands, Zurowski and Kasperczyk (1986) found damming at 50 of 257 territories, or 19.5%, in a population at or near capacity numbers. Danilov and Kan'shiev, in the flat terrain of the Karelian plateau of NW Russia, found damming at 19, 26, 29 or 53% of territories, depending on the region.

Dams are typically, though not always, relatively short lived structures, lasting a few years to a decade or so before relative or absolute depletion of food sources behind them, and/or siltation, make the energetic costs of maintenance no longer worthwhile. They typically breach in autumn and spring at high water discharges. Size varies, up to about 30m long in *C. fiber* (*C. canadensis* can build larger dams than this), though usually only a few metres or less, and usually less than 1m high. A comprehensive discussion of the ecological effects of beavers and their constructions is provided by Rosell et al. (2005). The effects on fish populations in particular, which are complex and variable at the scale of an individual dam but for which there is little evidence of impact either positively or negatively on a watershed scale, are reviewed in detail by Collen & Gibson (2001), and summarised by the Salmon and Trout Association in a briefing paper at:

http://www.salmon-trout.org/files/issues/Briefing_Papers/Beaver_Reintroduction_Briefting_Paper.pdf.

Figure 8. A beaver meadow created after a beaver dam has gone out of use. The photograph was taken in the late summer of the year following the abandonment of maintenance of the dam (the previous autumn/winter) after c. 6 years of use. Vegetation was formerly predominantly birch scrub. Silt deposition has created rich soil; the regenerating sward is highly attractive to grazing animals.

The possible effects on salmonid migration have to date been the most controversial issue regarding dams in the UK, though not in North America or continental Europe (including Scandinavia), where it is the subject of little research given the general lack of perception of conflict[3]. In this connection, Collen and Gibson's (2001) scientific review of the subject (http://www.springerlink.com/content/v48769740n817601/fulltext.pdf) concludes that the view that dams will routinely be impassable to salmonids is not supported by the evidence, and that both seasonal variations in water discharge, and site specific characteristics, are important in this regard. Dams may also provide positive effects in the form of better habitat for trout parr and refugia for larger fish in low water conditions; there is some evidence from N. America indicating that Atlantic salmon parr grow larger, and more rapidly, in beaver ponds (Sigourney et al. 2006). Parker & Rønning (2007) concluded that even assuming dams were a barrier to, or advantageous for, anadromous salmonids (which they did not check), they were so uncommon and peripheral structures on the Numedalsågen watershed as to be 'insignificant' for anadromous salmonid populations. The Numedalslågen is one of the top ten salmon rivers in Norway, by catch weight.

On most rivers most beaver groups do not build dams, and many families which do are not dependent on them (irreparable dam failures are a common feature of beaver life, e.g. when a structural weakness holes the dam at the base – beavers can only repair rim breaches). In many parts of Europe dams are not protected, or a liberal regime allowing removal at landowner discretion is applied. This has not affected population viability; in practice landowners have usually allowed most dams to remain intact.

Figure 9. Sedge water meadow created by the beaver dam in Figure 6.

[3] The assertion sometimes made in Britain that beavers and salmon do not overlap in distribution in Norway is not true. Five of the top ten salmon rivers, by catch weight, and many smaller salmon rivers, have well established beaver populations. In many of these rivers, such as the Namsen (No.2-4 in catch weights depending on the year, and where beaver are a common game animal), salmon spawning is intensively monitored and common on small tributaries. Beaver are not mentioned in the annual monitoring reports, which discuss in detail factors affecting salmonid populations (e.g. Berggård & Berger 2008).


Beach
(artificial)
Picnic tables
25m
Colonised 1975
Photo summer 2008
Picnic tables
Secondary
lodge
Jogging trail
Golf tee
Golf course
Old lodge
Main lodge
Beaver
coppice
Beaver
coppice
Golf course
Picnic
place
TRONDHEIM
Theisendammen
2km

Figure 10. (previous page). A typical example of beaver impacts in a managed landscape. A beaver family has continuously occupied this site in Norway, a small artificially dammed lake of 7.5ha and 1.6km of shoreline, for 33 years. The growing season locally is c.100 days/year. The two small bushy, coppiced areas on the farther bank at lower left and left centre of picture are a result of beaver activity. The understory within c.15m of the bank elsewhere is cropped to some extent and occasional larger deciduous trees are felled; however, the structure of the woodland is substantially unchanged. Image is a montage of air photographs; perspective varies slightly across the image as a result.

Figure 11. (above). A typical example of beaver impacts in a managed landscape, on a mid sized river in Norway. Beavers have occupied this site continuously for at least 16 years (probably considerably longer). The lodge is on the small islet by the shingle bar in mid photograph. The bankside vegetation is mainly a relatively dense growth of thicket alder interspersed with willow and birch, with an understory of grasses and forbs. Felling of larger trees is unnecessary at this location, and although beaver signs are easily found, the structure of the vegetation is largely unaffected; many local people are unaware of their presence.

Figure 12. (previous page). An example of beaver impacts in a managed landscape, at the higher end of the impact scale. This site is on a small stream, 1-1.5m across, at the limit of stream gradient that beavers can tolerate, in a periurban forest park in Norway. This is poor habitat for beavers, as the stream is steep and the vegetation dominated by conifers (which beavers do not eat). It was occupied only after beaver had been present in the wider stream system for c. 30 years. Damming is needed to create the water conditions beavers require. The lower two dams are of 'plug' type, which deepen a stretch of stream behind them without significantly broadening it. The upper dam is large, though because of the gradient creates only a small pond, just sufficient in size for the lodge and winter food store; a small number of trees behind the dam have been drowned as a result. Considerable felling of deciduous trees (mainly birch) has taken place here, partly for food but mainly for construction material, significantly opening the canopy of an area of c.60x30m above right of the lodge. This site was occupied for c. 5 years and then abandoned, leaving a small number of dead standing trees at the old pond site, and a patch of meadow/open coniferous woodland. The path at upper left is a prepared walking/jogging trail c.1.5m wide.

The family group lives in one or several burrows or lodges (mud and stick constructions with a central nest cavity) constructed on the river or lake bank with direct sub-surface access to the water. Burrows are generally preferred, lodges being built where the bank is too flat or rocky to permit burrowing. Hybrid burrow-lodges may also be constructed, beginning as a burrow but roofed with mud and sticks.

Figure 13.. Three beaver lodges. The lodge top left is of burrow-lodge type; material has been placed over a living chamber beginning as a burrow, after it broke the surface. Most such structures are small, in this case c.1m in diameter and 50cm above surrounding ground level. This is an old site, occupied for over 15 years, and the material has mostly broken down to soil, producing a grassy mound apart from the recently added mud at front. The spruce on top sprouted on the lodge material. Top right a lodge of average dimensions on a river backwater unsuitable for burrowing, built out into the water to achieve an underwater exit. It is about 1.5m in diameter and about 1m high. Lower left an unusually large lodge in a periurban location (note streetlight), about 2.5m high. The size is necessary to place the living chamber above frequent floods at this marshland site; the slope behind is a thin layer of soil over rock, unsuitable for burrowing. Burrows (the majority of beaver dens in most areas) are normally invisible above ground.

Food is stored for the winter in areas liable to iceover, as sticks and branches anchored into bottom mud near the entrance to the lodge. Beavers are crepuscular and nocturnal; where unmolested they typically appear about 20:00 in the evening irrespective of light conditions, including direct sunlight; apparently regardless of latitude (D.Halley, *pers. obs.*).

Beavers have been classified into eight subspecies, one for each of the 19th-20th century refugia where the species never became extinct, based on small morphometric differences in the skull (see Halley & Rosell 2002 for a more complete summary). However, recent DNA work (Ducroz et al 2005; Durka et al 2005) has demonstrated that the species would be more naturally divided into two Evolutionarily Significant Units (ESUs), or subspecies: *C.f.fiber*, including populations descended from the three western refugia (Rhone, Elbe, SE Norway); and *C.f.osteuropaeus*, from refuges in Belarus/Ukraine, Russia, and Mongolia. This east-west split within Europe is characteristic of many mammal species and appears to correspond to earlier Ice Age refugia, in Iberia and southern France, and the Black Sea region, respectively. The majority of reintroduced populations outwith Scandinavia and France are of mixed subspecific origin, by both old and new classifications (Halley & Rosell 2002).

Although it is now clear, from chromosome number differences, anal gland secretion differences, failed crossbreeding attempts, and the lack of observations of hybrids in the wild that *C. fiber* and *C. canadensis* are entirely distinct species (Lavrov & Orlov 1973, Lavrov 1983, Rosell & Sun 1999), this was not appreciated in the early part of the period of reintroductions, and the North American beaver *C. canadensis* formed the source stock for a number of releases. Of these, by far the largest surviving is the population in Finland and Russian Karelia, with small groups on the Amur and in Kamchatka, in eastern Siberia. Where the two species come into contact they competitively exclude one another, such evidence as is available suggesting *C. canadensis* may dominate in boreal climates and *C. fiber* in temperate climates.

The beaver populations surviving in the three western refugia (Telemark, Rhone, Elbe) were reduced to extremely low numbers and are of very low genetic variability (Ellegren *et al*., 1993). Nevertheless, the Scandinavian population has increased from *c*. 100 a century ago to more than 170 000 animals now, suggesting that inbreeding is not a management problem in this species. On the other hand, Elbe beavers are known to commonly suffer from inherited jaw defects, which may be related to inbreeding, and in Russia populations of mixed-refuge origin have larger litters than 'pure' translocated populations, suggesting some inbreeding depression may be occurring (Saveljev & Milishnikov 2002). In the event that a reintroduction to Wales takes place, mixing stock from the three 'western' refugia may be an option to consider, both on animal welfare grounds and in order to provide the maximum genetic variability, within IUCN criteria, from which a restored population can descend.

2.2 Historic and current distribution

C. fiber was formerly one of the most widespread of all Palaearctic species, distributed continuously across Eurasia from Great Britain (not Ireland) to eastern Siberia, throughout the deciduous and coniferous forest zones, and extending in wooded river valleys far into the tundra of the north and the steppes of the south (Zharkov & Solokov 1967; Macdonald & Barrett 1993). The probable former distribution in Europe, excluding European Russia, is shown in Figure 1. Prized for its fur, meat and castoreum (a urine-based fluid from the castor sacs) used in territorial marking by beavers but valued by humans as a medicine and perfume base, overhunting eliminated *C. fiber* throughout most of its range by the middle 19th century (Djoshkin & Safanov 1972). At the beginning of the 20th century about 1200 individuals remained in eight isolated populations (Halley & Rosell 2003; Nolet & Rosell 1998).

Beginning in 1922 with a reintroduction from Norway to Sweden, and combined with natural spread from refugia, the species has made a remarkable comeback in both range and population (discussed in detail in Halley & Rosell 2002). The minimum world population was estimated at 593 000 in 2002 (Halley & Rosell 2002), and is currently estimated at a minimum of 642 000 (unpublished data). The real figure is probably substantially higher. Beaver populations are now found in every modern country of their former world range (excluding microstates like Liechtenstein), except Portugal, Italy, the south Balkans, and the United Kingdom. A trial reintroduction in Knapdale, Scotland, scheduled for 2009, has recently received regulatory approval (see http://www.scottishbeavers.org.uk/).

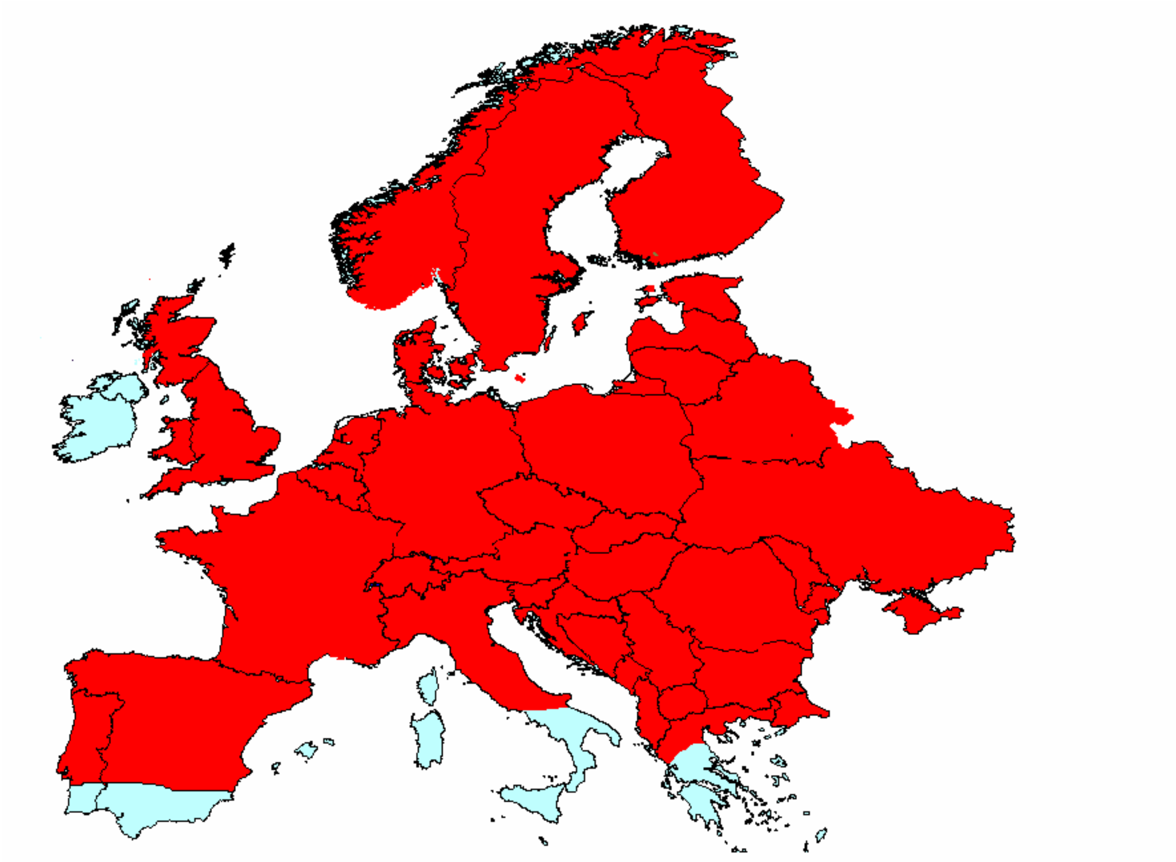


Figure 14.. Probable post-Ice Age distribution of beavers C.fiber in Europe, outwith Russia. Adapted from Halley & Rosell 2002.

In Britain, subfossil remains of bones and beaver-gnawed sticks, and place name evidence, indicate that the beaver was widespread in prehistoric times, and still to be found in much of the island into the early Middle Ages (Coles 2007). Extinction appears to have occurred around the 12th century in England (MacDonald et al 1995) and 16th Century in Scotland (Gaywood, 2001), though a 16th century English bounty Act lists beavers as one of many species (including otter) on which a bounty was payable, and there is an 18th century bounty payment record from northern England suggesting a few animals may have hung on in wetlands to that late date (Coles 2007).

Hywel Dda, king of most of Wales in the 10th century, specifies in the *Law* that a beaver skin, together with ermine and pine marten, are royal privileges:

> Three beasts to which the king is entitled wherever they are killed: a beaver and a marten, and an ermine - since the ornamentations of the king's clothing are made from their skins.

In evaluating compensation in the *Law*, a beaver's skin is 60 pennies, compared to an ermine at 25 pennies. Set in context of legal compensation, 60 pence was the worth of a 'best horse'- perhaps £5,000 ($12,000), or more, in today's money. This passage indicates that beavers were extant, and strongly suggests that they were scarce and thereby valuable, in the Wales of 950 AD.

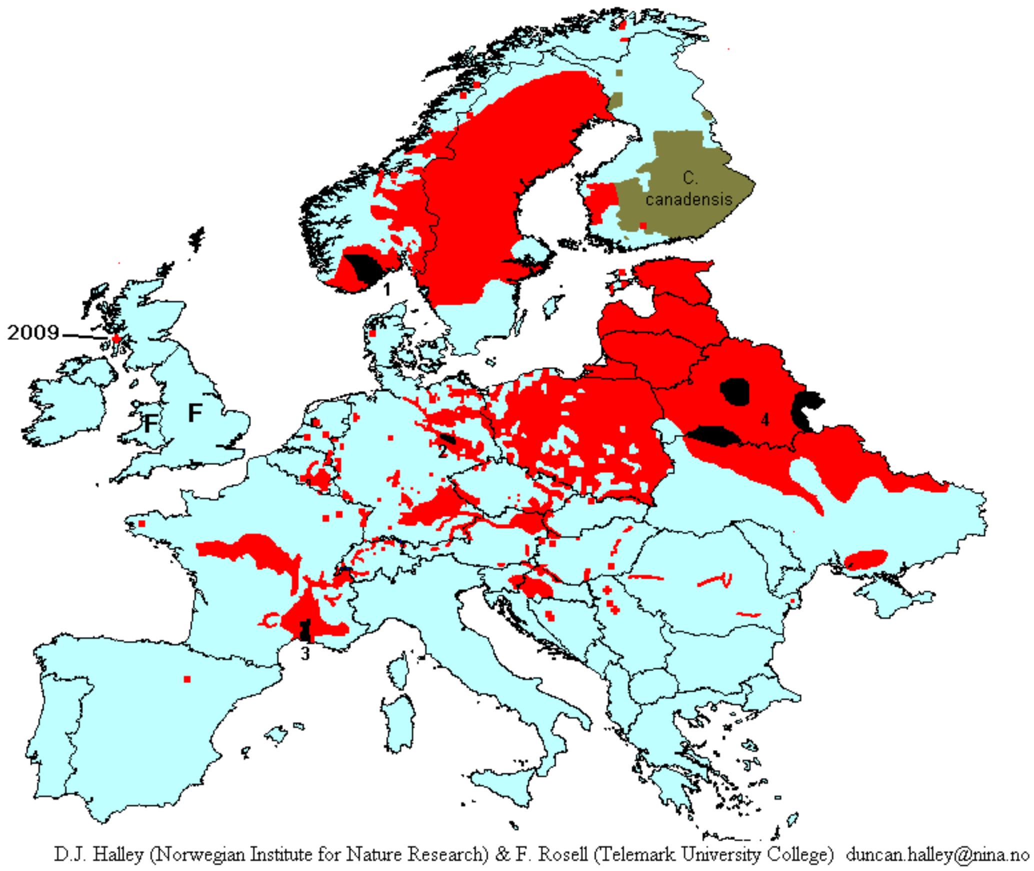


Figure 15.. Current (2008) distribution of beavers C. fiber and N. American beavers C. canadensis in Europe, outwith Russia. Red = C. fiber; green = C. canadensis; black = refugia where beavers did not become extinct; squares reintroduction sites where little spread has so far occurred; crosses planned reintroduction sites, with dates where known; F= feasibility study under way or produced. Updated from Halley & Rosell 2002.

In his journal, *The Journey Through Wales* (1188 AD), the cleric Sylvester Gerald de Barri (Giraldus Cambrensis) observes:

> The Teifi, of all the rivers in Wales and those in England, south of the Humber, is the only river where you can find beavers. In Scotland, or so they tell me, there is again only one stream where beavers live, and even there they are exceedingly rare.

Humphrey Llwyd, the seventeenth century Welsh antiquary, in his *Historie of Cambria,* asserts that there were beavers in Wales in historic times and William Owen Pughe, in his *Myrvyrian Archaeology & Dictionary* (1801) says, that '[yr afanc] has been seen in this valley (Denbighshire) within the memory of man'; however it is unclear whether he means 'living memory', or a living oral tradition; and it is not entirely certain, though probable, that ‘yr afanc’ refers to a beaver.

At Coygan cave, Laugharne, Carmarthenshire, a find (1880) of bones and teeth of Upper Palaeolithic period contained a possible beaver tooth. More recently (1991), at Newton Moor on the Gwent Levels, a survey conducted by Michael Hamilton, of the University of Wales, revealed beaver tooth marks on alder or hazel branches, possibly contemporaneous with a brooch-find of the early Middle Ages.

There is a passing early 14th century reference to beaver by Wales’s pre-eminent poet, Dafydd ap Gwilym, in an untitled poem in which he compares his mistress’s husband to a beaver’s anus. While a comically outrageous insult in a poetic context, this does imply a certain familiarity with the species was still current in Welsh culture at that time – ap Gwilym would expect his audience to know what he meant.

Taken together the evidence indicates that in Wales beaver were scarce, but still common enough to specify laws concerning ownership, in the early Middle Ages; and still extant in the 12th century. Final extinction occurred at some uncertain time thereafter.

3 Reintroduction biology of beavers

Beavers have been very extensively reintroduced throughout their natural range in the period from 1922, and reintroductions continue in a number of parts of Europe (Halley & Rosell 2003). Outwith the former Soviet Union, over 203 separate reintroduction events are on record, and there were in addition massive translocations within the Soviet Union, especially in the 1950s-1970s. Many of these, e.g. the Dutch and Swedish reintroductions (Ellegren et al 1993; Nolet 1994; Nolet & Rosell 1994; Hartmann 1994a, 1994b, 1995, 1996), have been studied in considerable detail. There is a very comprehensive research literature, which enables the likely course of any subsequent reintroduction to be predicted in fair detail (Halley & Rosell 2002 for review). Here we summarise the main features of interest to a prospective Welsh reintroduction, and which have guided our research strategy in conducting this study.

3.1 Patterns of spread

Following reintroduction to a river system, extension in range is usually very much faster than expansion in population. This appears to be due to the fact that beavers will move a long way through unsuitable or less suitable habitat to settle on the richest habitat available within a river system, before occupying less favourable habitats in between. This phenomenon has been noted widely throughout Europe: on the main Danube river system (J. Sieber *pers. comm*; G. Schwab *pers. comm*), and its tributaries such as the Morava (Valachovic 1997), Dyje and Otava (Kostkan 1999); on the Loire (Office Nationale de la Chasse 1999; P. Rouland *pers. comm.*); the Glomma and Orkla in Norway (Bevanger 1995; *pers. obs.*); and has been studied in detail a number river systems in Sweden (Hartman 1994a, b; Hartman 1996; Fig. 3), in each of which the same pattern of rapid range extension followed by rapid population increase was repeated. In the Netherlands, beavers which were sequentially released into a previously unoccupied area settled first in rich habitat, then in poor habitat, and then became floaters (Nolet & Rosell 1994).

The exception to the rule of rapid spread throughout watersheds is that large man-made dams often form quite strong barriers to population spread. This seems to be because beavers are generally very reluctant to venture far from water; 99% of beaver activity on land is within 20m of the bank (Elmeros et al 2003; Baskin & Sjöberg 2003). Beavers are slow and vulnerable on land, and retreat to water is their main predator defence mechanism. French management authorities, concerned to allow spread and prevent population fragmentation, have developed and installed “beaver ladders” on a number of hydroelectric barrages, to permit beaver passage both up and down stream (Office Nationale de la Chasse 1997); for example, hydroelectric barrages on the upper Garonne watershed have limited downstream spread of beavers from the Cévennes, and several barrages on the Rhone have prevented or hindered spread both on the main river and on tributaries (Office Nationale de la Chasse 1997). Similar barrier effects have been noted at the Grabcikovo dam in Slovakia (Pachinger & Hulik 1998) and elsewhere. A 1m high netting barrier running across the stream and c. 100m up both banks, with ‘wings’ to lead animals wandering on to land back to the stream on the inner side of the barrier may be fairly effective at keeping beavers in (or excluding them from) a stream stretch (see Halley & Bevanger 2005 for details).

In the absence of such barriers, the distribution of beavers within a river system cannot, in practice, be limited to a particular area without a heavy, and constant, directed hunting or trapping effort. Wildlife managers need therefore to be clear that reintroducing beavers to a river system is to reintroduce them to the entire river system, and that beavers will not necessarily remain in the vicinity of the reintroduction location if the habitat is less favourable than elsewhere on the river system[4]. In Switzerland, a number of reintroductions failed for this reason, and in other cases beavers moved out of the reintroduction site to more favourable habitat on flatter ground downstream (Macdonald *et al*. 1995; Czech 1997).

Movement between watersheds is much more restricted. Even where good beaver habitat occurs on headwaters on both sides of a watershed, population spread is significantly slowed. This effect was studied in detail by Hartman (1994a,b; 1995) in Varmland, Sweden (Fig. 3), a heavily forested area of low, rolling relief with, typically, short distances between beaver habitat on adjacent headwaters.

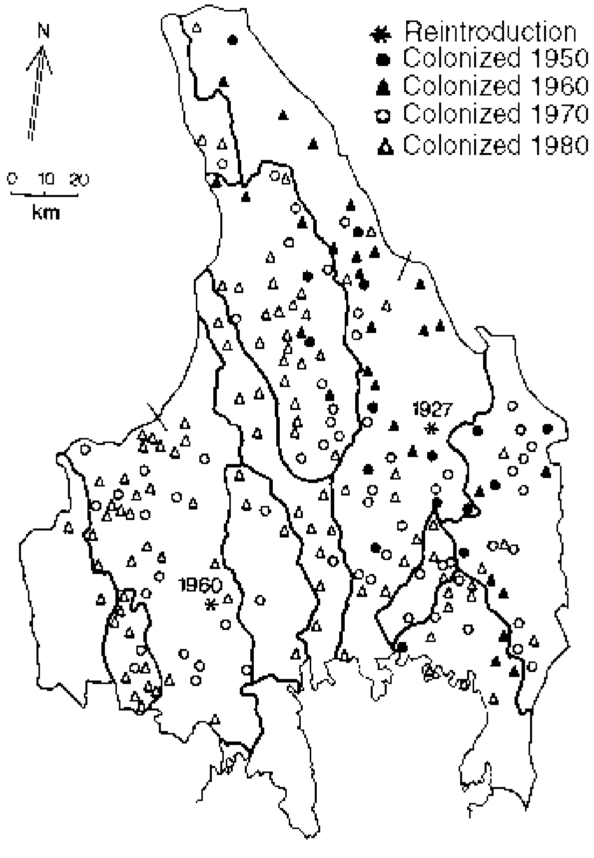


Figure 16. Patterns of spread of beavers recolonizing Varmland province, Sweden. Watershed divides are shown by bold lines. Dates and locations of reintroductions are indicated. Beaver spread very rapidly throughout watersheds after initial recolonization, with infilling thereafter. Watershed divides, however, significantly slowed range expansion. Figure adapted from Hartman (1994).

A small scale example of the same process can be seen in the Trondheim Bymarka, a small peninsula west of the city of Trondheim in Norway (Fig. 4). The Bymarka is hilly (0-600m) and heavily wooded, drained by a number of small stream systems which empty separately into the fjord or the river Nidelva in Trondheim city. Beavers were directly reintroduced to this area in 1975, to the two central stream systems, Lierelva and Ilabekken. The species was soon well established on both streams, including two marginal sites later abandoned. Beaver had also quickly moved down Lierelva, through

[4] Certain ’soft’ release techniques may be effective in reducing the chance that reintroduced individuals will wander from the release site.

several kilometres of suburban housing, to establish several territories on the Nidelva river within Trondheim city. Further expansion on the river has so far been curtailed by a hydroelectric dam immediately upstream, and tidal water downstream. Beaver, probably also from Lierelva, have also colonised two sites on the Ristbekken in the west. In 2005 a site on the Trollabekken was colonised. However, by 2008, with all suitable sites at Theisendammen and Lierelva long occupied, beaver had still not succeeded in crossing the watershed to colonise any of the remaining main stream systems, at least six of which contain sufficient suitable habitat for one or several colonies. This is despite the fact that beaver-navigable streams on each watershed come within a few hundred metres of one another, in easily walked terrain.

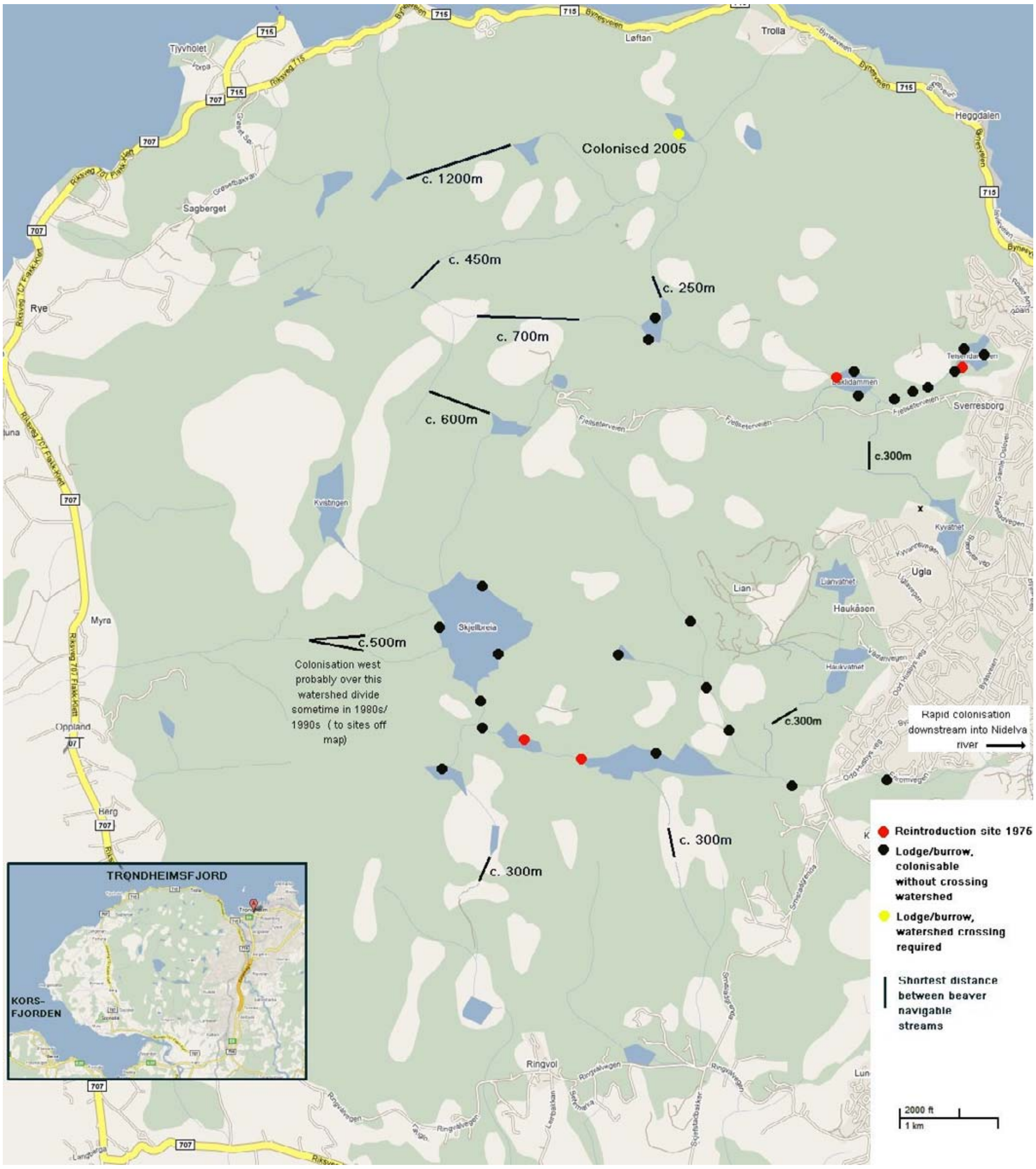


Figure 17. Distribution of beaver lodges and burrows in Trondheim Byneset, Norway, in 2008 (NB some beaver territories have multiple lodges/burrows). Beaver were reintroduced to the Ilabekken and Leiraelva stream systems in 1975. Two colonisations of stream systems involving crossing land have since occurred. At least six other stream systems contain sufficient habitat for beaver colonies, but as yet remain unoccupied. Minimum crossing distances between occupied and unoccupied streams are shown.

Where beaver habitat is separated by serious natural or man-made barriers, the isolating effect appears to be very strong. A remnant beaver population survived in Telemark in southeastern Norway, and has expanded only slowly in range (though greatly increased in numbers) since the turn of the century. This appears to be due to the mountainous terrain (especially in the west) and lack of unifying river systems locally. Meanwhile, c. 80 beavers originating from this population were introduced to the flat ground and large river systems of Sweden from 1927, of which a maximum of 47, at 11 sites, bred successfully (Ellegren *et al*. 1993). All of the beavers of Sweden and almost all in the contiguous range in Norway (>125 000 animals) are derived from these individuals, mainly through natural spread.

In much of western Europe suitable beaver habitat is fragmented, and isolated by large stretches of man-made unsuitable habitat. Where the region is also one of small, isolated river systems, this can prove a strong, although not impermeable, barrier to range expansion. For example, 10 beaver were reintroduced to the Elez river in Brittany (Bretagne) in 1969, and rapidly expanded to a population of c. 40. The population has remained stable at this level ever since. Spread outside the Elez to an adjacent watershed did not occur until 1997 at the earliest (Lafontaine 1990 and *pers. comm*.; Gillie 1996; A. Stevenson *pers. comm.*).

The lesson for nature managers generally, and specifically in Wales, where watersheds are numerous and relatively small and isolating barriers generally strong, is that, if desired, beaver expansion between watersheds can be contained relatively easily. Depending on the desired goal, this may indicate a strategy of many reintroductions to many river systems, or conversely of the rapid removal of any pairs which do manage to establish naturally on watersheds where their presence is considered undesirable, before they have the chance to spread their progeny widely within the river system. However, to reintroduce beavers to a watershed is, with the important caveats noted above, to reintroduce them to the whole of that watershed.

3.2 Population development

The pattern of settlement described above means that dispersing individuals may not find a suitable mate in low density populations with large unoccupied stretches, especially in larger river systems. This appears to be the cause of the characteristic lag phase in population development after initial recolonisation, which may be as long as 20 or 30 years, before a population reaches the phase of rapid population growth (Hartman 1994a,b; 1995).

In most parts of Europe beaver are in either the lag phase or the rapid increase phase of population expansion. However, ”mature” populations are found in Russia, Belarus, parts of the Baltic states, and parts of Scandinavia. In Sweden, it has been possible to follow population development in detail from initial re-establishment on a watershed to population maturity. Results show that beaver populations exhibit a classic S-curve pattern, with a lag phase, followed by rapid population increase at intermediate densities, a slowdown in population increase after the rapid expansion phase, occupation of marginal habitat not capable of sustaining beavers permanently, a consequent modest decline in population as the ”capital” of these marginal areas is depleted, and then rough stability (e.g. Hartman 1994a, b; 1995). The whole course of this transition typically takes from 30-40 years, but will vary considerably depending on the size and characteristics of a given watercourse, and the exact reintroduction strategy (more animals to more places accelerating the process). Reproduction, survival, and dispersal are density-dependent. As population density increases, so do mortality rates, while pregnancy rates and litter size decrease, and sexual maturity and dispersal are delayed (Heidecke & Ibe 1997; Hartman 1994)

3.3 Implications for survey strategy

The above mentioned factors indicate that reintroduction feasibility in Wales should be considered at a watershed scale. A three-stage strategy was accordingly devised: 1) a training and familiarisation course for Welsh researchers familiar with their local river systems in Norway, aimed at developing the ability to recognise suitable beaver habitat and roughly categorise quality; 2) a rapid appraisal by these researchers of all of the watersheds likely to be feasible for beaver reintroductions as regards habitat suitability and extent, and 3) a more detailed appraisal of the 'Top 5' river systems by Dr. Duncan Halley from NINA, an experienced beaver biologist, in conjunction with Welsh researchers.

4 Methods

4.1 Field course in beaver ecology at Songli Research Station, Norway

A field course in beaver ecology was held at Songli Field Station, near Trondheim, Norway from 26th May – 2nd June 2008. The purpose was to familiarise the initial survey team, all of whom are experienced naturalists who know the watersheds under consideration well, with the ecology of beavers, and in a simple classification of habitat quality. Beavers are common in the area, and examples of all of the main types of habitat occupied by beavers are present.

Twenty two beaver territories were visited in the course of the field course, representing beaver territories of all qualities from optimal to marginal, including several sites now abandoned. All the main types of beaver habitat modification were covered, as well as examples of good quality habitat where little modification is required and beaver activities and presence are not evident to the casual eye.

A simple guide to beaver habitat quality classification was produced for the field course, and for use in the initial survey.

4.2 Initial survey of Welsh watersheds

Following the field course, the majority of Welsh watersheds were surveyed for beaver habitat quality in the period 5th June – 30th July, based on the classification outlined in Appendix 1. The major exception was the waters of the Severn/Wye watershed, which drain most of central Wales. This river system flows into England, in which a major part of its basin lies. Reintroduction of beavers to the Welsh sections of the watershed would in effect be to reintroduce them also to England, necessitating a survey of that part of the river and cooperation in all stages of any reintroduction plan with the responsible authorities in England. This would greatly increase the complexity and expense of any reintroduction programme. It was therefore considered most practical and appropriate to consider only river systems either contained entirely within the borders of Wales, or (in the case of the Dee) where only short sections of the river are outside Welsh jurisdiction.

This survey was intended as a rapid appraisal, with the purpose of identifying 5 river systems for more detailed consideration. In the event 6 river systems were selected. Although they flow into a joint estuary, the E. and W. Cleddau watersheds are separated by a considerable stretch of tidal water, into which beavers are known to be reluctant to venture (Halley & Rosell 2002), so that from a reintroduction point of view they should be considered separate systems.

Following a meeting of the survey team on 1st August 2008 the following river systems were selected for more detailed consideration:

Glaslyn; Dee; Rheidol; Teifi; Eastern Cleddau; Western Cleddau

The Six Candidate Rivers

Figure 18. The six rivers selected for detailed study of the ecological feasibility of beaver reintroduction.

4.3 Focal watershed assessments

A more detailed assessment of the 6 rivers named above was carried out by DJH in conjunction with individual fieldworkers familiar with the given river system. Fieldwork was conducted in the period 1-15th August 2008, and combined with map and remote sensing information (Google Earth) in the overall assessment. Remote sensing was of a resolution sufficient to distinguish individual animals the size of sheep, or individual shrubs.

Habitat was assessed both qualitatively and using a modification of the Allen Habitat Suitability Index Model for beavers (Allen 1983), developed for the N. American beaver *C. canadensis*. Based on this and mapping work, a rough estimate of the potential beaver population for each watershed was made, though it must be emphasised that these figures should not be considered exact and probably err on the side of conservatism (see discussion).

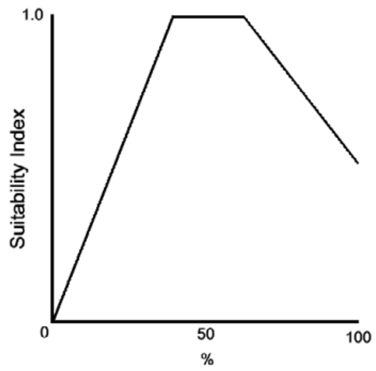
4.3.1 Modified Allen food resource index

The Allen index (Allen 1983) scores a number of factors relevant to beaver foraging habitat quality to generate a suitability index from 0-1, based on vegetation extending 200m from the water's edge. The full model also scores hydrological features as a separate index; however, the values suggested seem somewhat arbitrary and are to some degree in conflict with observations from Europe. We do not feel that the quantifications provided on hydrology are sufficiently reliable to be a trustworthy guide to habitat suitability, and have preferred a more traditional approach, assessing waters as unsuitable if they are either too steep (evidence indicates beavers do not as a rule settle on waters with a fall of more than c.2m in 100m), too fast, or too turbulent (composed mainly of white water). In practice these variables are usually quite closely correlated.

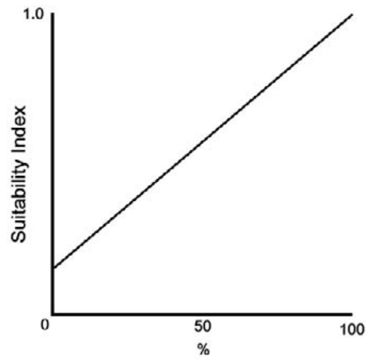
While 200m is the extreme range of beaver foraging from water, in fact >90% of Eurasian beaver activity occurs within 20m of the water's edge (see above), and beavers in many places survive on considerably less than that width of suitable riparian vegetation. We have accordingly modified the model using vegetation within 20m as standard.

In the original model, alder species (Alnus sp.) are considered to be a preferred forage species. In Europe, much evidence indicates that the species, while eaten, is avoided compared to other common riparian species (Haarberg & Rosell 2006; Rosell & Pedersen 1999). We have therefore excluded alder from the list of preferred deciduous tree species under factor V5 (below).

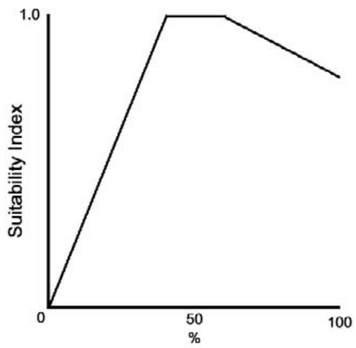
The variables of the Allen index relevant to the areas investigated in this report are:



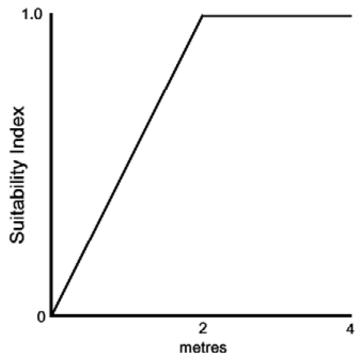
V$_1$: % tree canopy closure



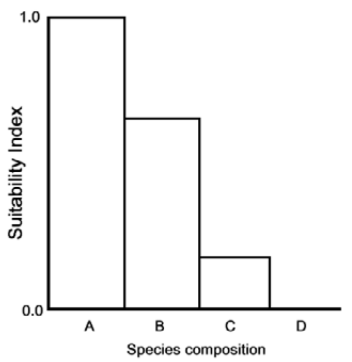
V$_2$ % trees deciduous and 2.5-15cm bole at breast ht.



V$_3$ % shrub crown cover



V$_4$ Average height of shrub canopy



V$_5$ Species composition of woody vegetation

A) Dominated (>50%) by willow (Salix spp.) and/or poplar (Populus spp.)
B) Dominated by other deciduous species
C) Dominated by coniferous species
D) Pure conifer

A metric is derived from these indices:

Habitat Suitability Index (HSI) for food supplies, calculated according to the following formula:

$[(V_1 \times V_2)^{0.5} \times V_5]^{0.5} + [(V_3 \times V_4)^{0.5} \times V_5]^{0.5}$

Summer food is assumed to be superabundant relative to winter food supplies.

Allen index values were calculated for varying stretches of watersheds of similar riparian character.

4.3.2 Estimating potential populations

The estimates we give here are intended only as a general guide to what may be expected. They are more useful in comparing relatively between rivers, or river sections, than as a guide to the exact carrying capacity of the habitat; as noted, although *average* beaver territories in fairly good quality habitat are about 3km of bankside, very much smaller territories are known; and very much larger territories in poor habitat. We assume that in good habitat beaver territories will average 1 per 3 linear km of bankside; in less good habitat 1 per 4.5km, and in relatively poor (but still suitable) habitat 1 per 6km (Rosell & Pedersen 1999). This may be a relatively conservative figure, given the much milder climate and much longer growing season in Wales compared to Scandinavia or most of the current beaver range in continental Europe. It does however provide a relative yardstick with which to compare the probable relative population sizes of the river systems.

5 Results

5.1 Focal watershed assessments

5.1.1 Glaslyn

The Glaslyn drains much of the southern Snowdon massif. The watershed upstream of Pont Aberglaslyn is in general unsuitable for the species given the steep gradient of the stream. However, the lower part runs through lower gradients where beaver settlement would be possible.

Speaking broadly, the lower Glaslyn can be divided into three sections as regards beaver habitat.

The first section is the regulated floodplain at the mouth of the river. Dominated by grass meadows, the site is protected from tidal surges by floodgates and is subject to strong fluctuations in water levels, much of the area being submerged at high water levels.

An important consideration which remains unclear is the extent to which the water in this section has a tidal, i.e. salt water, component. Beavers, while they exceptionally have been known to inhabit brackish water, with access to fresh water for drinking, generally avoid non fresh waters. This may render much of this area unsuitable for beavers. The irregular flooding of the area, while a factor beavers can cope with (Sieber *et al.* 2001; Nitsche 2001; Kurstjens & Bekhuis 2003), is also a disadvantage.

The vegetation is dominated by grasses, with woody vegetation confined to some peripheral areas. In summary, this area is relatively low quality habitat for beavers, as reflected in the Allen index value of 0.49 for winter food suitability. If the water is regularly brackish to any extent, the area may be unsuitable as beaver habitat. The strong fluctuations in water level are also a disadvantage, although beavers do live at many sites with similar fluctuations (Halley & Rosell 2003; pers. obs.)

After a short transitional section, where the riparian vegetation strip is in any case very narrow, the river section upstream from the floodplain, from c. SH 595398 to Pont Aberglaslyn, is relatively slow-flowing, meandering, and predominantly of laminar flow. The water is of optimal depth, and the bankside in general well wooded with suitable deciduous species, albeit often in a relatively narrow riparian strip. The overall impression is of good to excellent beaver habitat, containing all the main elements the species requires. Allen index values of 1.0 (Bwlch Glas) and 0.77 (Pont Croesor, Glan y Don) reflect this. The size and depth of the river would make damming both unnecessary and technically difficult for beavers to achieve, and so is unlikely to occur; any dams built would in any case be liable to being washed out in spate conditions after rain, a frequent occurrence on this river.

Side-streams on this river section are mostly short, but the lower Nanmor, Dylif and Maesgwyn tributaries would each be suitable for colonisation by beavers. Each is relatively shallow and would be likely to develop beaver dams. In places, a public road runs near the tributaries and close to their level. Ponds formed by large, deep dams might affect these roads. However, this is only true at a few points, and methods of regulating or permanently draining dams which cause conflict with human activities are well developed (Halley & Bevanger 2005). More of a risk would be of beavers being killed while crossing the road; a 1m high fence along the roadside at points where it runs close to the stream would be an effective preventive measure. Riparian vegetation is not so optimal along the tributaries, resulting an Allen index value (0.62) somewhat lower than on the main river.

5.1.1.1 Concluding remarks: Glaslyn

The potential population on this river is not large. In the absence of detailed research predictions can only be very general, but assuming 3km of shoreline per territory, there is room for about 5 territories on the main river between the floodplain and Pont Aberglaslyn; 1-2 more on the floodplain should it not be too brackish, and one each on the Nanmor, Dylif and Maesgwyn tributaries, or about 8-10 groups (c. 26-32 individuals, assuming the average group size at 3.2 (Rosell & Pedersen 1999). This figure may be somewhat larger if the mild climate and long growing season affect average territory size. There are, however, many places in Europe where small beaver populations are found in limited habitat patches without interchange with other areas, where beaver populations have persisted for decades and appear to be capable of doing so indefinitely.

5.1.2 Dee

The river Dee is c. 170km long and drains a catchment of c. 1820 km2. The river rises in the hills around Bala Lake and runs ENE through its upper and middle courses, turning NE where it briefly forms the border with Shropshire in England, then N through a salient of Wales and thereafter along the border with Cheshire. The river becomes tidal at Farndon, a little upstream of the point where it flows wholly into England. Above Bala Lake the river is rapid and habitat generally unsuitable for beavers; below it the Dee is too wide and deep to be dammed throughout its course.

Bala Lake is 6.4km long and 1.6km wide. A deep, glacial valley lake, it contains little aquatic vegetation, but the shoreline is well wooded, at the downstream end containing a large component of willow. The shoreline of the lake is somewhat irregular, providing sites sheltered from wave action in which burrow construction or lodge building would be possible. The shoreline of the lake is c. 13.9km in total length.

Figure 19. Bala Lake from Llanyul.

The NE end of the lake is excellent habitat, with a large proportion of willows. The riparian strip on the main sides of the lake are good quality,except towards the SW end, where the strip is either narrow or absent. The shallow water at the SW shore itself, however, is good habitat, marshy with patches of willow scrub. The lake should be capable of supporting 3-4 territories: one based at the NE end (Allen index 0.95), one centring on the higher quality riparian vegetation on the shoreline at Llangower (Allen index 0.75), and one at the SW end (Allen index 0.84); with perhaps a further territory on the central section of the NW shore (Allen index 0.73), though locally suitable lodge/burrow sites sheltered from wave action are limited.

Figure 20. Bala Lake, NE shore

Afon Treweryn and Llyn Celyn. The Afon Treweryn is a tributary of the upper Dee, reaching its confluence with the main river at SH936355, just below the outlet from Bala Lake. Most of the river is fast flowing, with in general a 'strainer' flow between large rocks, except in spate conditions. Water flow is regulated by the large Llyn Celyn dam upstream and very unstable. Most of the river is therefore unsuitable beaver habitat. The exception is the 1.1km of the lower river behind the regulating weir at SH931359, just above the confluence. Because of the weir, the water is ponded back and laminar in flow. Bankside vegetation is mainly highly suitable deciduous woodland. However, the total available habitat, 2.2km of bankside, rather small for a beaver territory though within the known range in good habitat, which would also be rather isolated from the main river because of the weir and associated fencing. While beavers might disperse past this, it precludes the possibility of a single territory including waters both sides of the weir. There may be room for 1 territory here, especially if waters upstream of the ponded back reach are available periodically at higher water. Llyn Celyn itself has some suitable bankside habitat, although mostly it is treeless. It is a reservoir with water levels subject to extreme fluctuations, which would leave any lodge or burrow constructed a long way from the water's edge for much of the time. In addition, the dam is a formidable barrier to dispersal, as is, to a lesser extent, most of the course of the Treweryn below it, due to flow characteristics. Colonisation of Llyn Celyn must be regarded as very unlikely.

Upper Dee This long section of river runs from the outlet to Bala Lake (SH929351) to the beginning of the Llangollen Gorge at Horseshoe Falls (SJ195433). Despite its length, 43km of river course, it is fairly uniform in broad-scale habitat characteristics. The river winds through a shallow agricultural valley with a narrow bottom and relatively steep sides. This renders tributary streams for the most part short, and in the main unsuitable hydrologically for beaver settlement.

Fig 21. Upper Dee at Carrog Bridge (left) and Llanderfel Bridge (right). Typical habitat for this section of the river. The riparian strip is narrow, but good quality. Water flow is rapid, but within beaver tolerances, at Carrog; slower and close to optimal at Llanderfel.

Exceptions are noted below. There is an almost continuous, but narrow, riparian strip, sometimes composed of a single line of mature trees with a herbaceous understory, more often a narrow strip of bushes, small trees, and herbaceous vegetation. At irregular, but fairly frequent, intervals the riparian strip widens out to more substantial areas of woodland or willow scrub. It is likely that these areas would form the focal sites of territories, with territories extending from there into adjacent sections of suitable, but less favourable, habitat. This distribution makes estimating likely populations particularly difficult, as there is a probable interplay between the natural centres of beaver territories (which would be occupied first, as beavers in the population development phase strongly select the best habitat patches – Halley & Rosell 2002), and whether the distances between them are large enough to permit a suboptimal territory to exist between high-quality habitat patch centred territories, especially as early-established territories tend to be larger than ‘necessary’ and established borders to persist over time (Campbell et al 2005). The overall Allen Index is 0.41. Examining the river stretch using a combination of site visits and satellite imagery detects 13 clearly suitable habitat patches on which a territory could be based. This is one family group per 6.6km, similar to our assumed ‘poor habitat’ density and in line with expectations extrapolated from the Allen index, but nevertheless seems rather low. Assuming densities averaging one group per 4.5km, the projected density for intermediate quality habitat, results in an estimate of 19 territories, which may be more realistic. We must reiterate, however, that these figures are subject to considerable uncertainties (see Methods), though they do provide a general indication and a relative comparison with other rivers or section of the Dee. In any case, the quantity of suitable or better habitat is considerable, and the population which this section of the river could support reflects this.

Afon Hirnant Flows into the Dee from the south at SH949366. Although relatively long, this tributary is both rapid, with numerous small waterfalls, and unstable. It is unlikely that beavers would be able to establish on this tributary.

Afon Trystion Flows into the Dee from the east at SJ052410. The river is generally too steep for beavers to colonise. There is a small dam at SJ066405 impounding a reservoir, which has good habitat on its banks. Colonisation would require dispersing past waterfalls and the dam, and then the available habitat is not large, the banksides of the reservoir being 0.48km in length, which is unlikely to be enough to support a beaver family group. Colonisation must be regarded as unlikely; an establishment would likely only be temporary given the probable depletion of the restricted available food.

Afon Alwen flows into the Dee from the NW at SJ060425. In contrast to most tributaries of the upper Dee, the Alwen has suitable flow characteristics (mainly pool and riffle) for beaver settlement. A wooded riparian strip of variable width is continuous, Allen index 0.55. It is difficult to assess at what point the hydrology becomes unsuitable for beavers, as the change to a more upland flow type is gradual, but at least the first 8km upstream from the confluence appear to be suitable. Densities here would probably be intermediate, estimated at one group per 4.5km of bankside, so probably hosting c.3-4 family groups. Damming would be likely on this stream.

Llangollen Gorge. From Horseshoe Falls to Pont Cysllte (SJ268420). Although the foraging habitat along this section of the Dee is generally very good, the river is much too rapid to be suitable for beaver settlement. While dispersal through this area downstream will be easy, dispersing upstream would be much harder, and would involve walking along the bankside, often steep, for long sections. The gorge may therefore form a partial one-way barrier to dispersal. However, given the amount of available habitat upstream, this is unlikely to have any consequences for subpopulation persistence.

Pont Cysllte – Bangor on Dee (SJ387454). 27.6km. The hydrology along this section gradually changes from pool and riffle with some more rapid stretches, to laminar flow; all, however, is within the hydrological tolerance of beavers. Bankside vegetation is generally very good, with broad riparian strips of deciduous woodland and scrub predominating, interspersed with shorter areas of narrower riparian strips backed by fields. This stretch can support a considerable population of beavers, estimated at about 18-19 family groups.

Afon Ceiriog is a tributary stream, reaching the Dee from the south at SJ317395. The river is fast flowing, subject to powerful spates, and generally unsuitable hydrologically for beaver settlement. There are several weirs along the river which might hinder beaver dispersal. It forms the border with England for much of its length.

Long Wood / Rock Dingle streams Three streams on the English bank of the river, which unite shortly above their common confluence with the Dee at SJ339405. All three streams are fringed with woodland, but are too steep for beaver settlement.

Knolton Stream. This stream flows through a narrow incised valley forming the border with England for much of its length, reaching the Dee at SJ350411. The gradient of this stream appears to be suitable for beavers, and the habitat, wooded on both sides, is good. There is about 2.8km of suitable stream length, which could accommodate 1-2 territorial family groups. The stream is narrow and shallow and damming would be likely.

Nant-y-Lladron streams. Two small streams uniting shortly above their joint confluence with the Dee from the west at Nant-y-Lladron, SJ357436. There are about 2.4km of suitable banks, partly a narrow riparian strip, wider towards the confluence, and partly woodland on the upper part of both streams. One beaver territory could be established here, with damming likely.

Afon Cleiwedog. This small river runs into the Dee from the west at SJ409473. About 17.5km of the river is suitable hydrologically for beavers, before becoming too steep west of Coedpoeth. The lower reaches of the river run between agricultural fields, with only a narrow wooded strip. From Erddig Country Park on the southern outskirts of Wrexham upstream (c.8km), habitat improves, with a generally wider strip of woodland, mainly deciduous. Allen index is estimated at 0.6. There is room for c. 6-8 beaver families along the river, with colonisation likely at the upper end first given the better habitat. Most of the upper course is used for public amenity access and is close to heavily populated areas. This may provide scope for associated recreational and educational developments, but may also expose beavers to potential for casual harassment where their den sites and, if built, dams, are obvious. Damming is likely along the upper course especially.

Lower Dee. Bangor on Dee to Farndon. (SJ411544) c. 21.2km. The final stretch of the river before it becomes tidal, and so unsuitable for beaver settlement, runs through lowland farmland. The river forms the border with England for the lower half of this stretch, and is slow, laminar flowing, and meandering. The riparian strip is generally narrow, sometimes absent, and dominated by herbaceous vegetation, with only scattered bushes and trees. Allen index is correpondingly low, 0.29. Occupation of this area, despite the optimal hydrology, is likely to be at low densities – c. 7 family groups; and late in the process of population development.

Figure 22. Dee at Bangor on Dee. Habitat locally is excellent; however, on this section of river generally, such habitat is uncommon, the river running mainly through fields with only a narrow, mainly herbaceous, riparian strip with only isolated trees and bushes

5.1.2.1 Concluding remarks: Dee

The Dee is a large watershed and contains a considerable amount of suitable habitat, mainly on the main river, as with the important exception of the Alwen and Cleiwedog tributaries are generally hydrologically unsuitable for beaver occupation. Except on these tributaries, dam construction would neither be possible nor necessary given the size and depth of the river. The Llangollen Gorge on the main river is also unsuitable hydrologically; this would result in the beaver population being split into two subpopulations with restricted genetic flow between them. In particular, dispersal of individuals upstream through the gorge is likely to be rare, and may be in practice negligible (i.e. so uncommon that colonisation above the gorge from a population established below it might only occur once in the order of decades to centuries). Downstream dispersal would be considerably more common, though a partial barrier effect would almost certainly be evident.

The population estimate for above Llangollen Gorge is 19-28 family groups, or about 60-90 individuals; for below the gorge 33-36 family groups, or about 105-116 individuals; in total 52-64 family groups, or 165-205 individuals. This is the largest potential population of any of the rivers examined, although it is divided, as noted, into two semi-isolated subpopulations. Each subpopulation is, however, large enough to persist indefinitely, judging by numerous examples of demographically stable smaller populations on isolated river systems in Europe.

Evidence from colonisation of other river systems (Halley & Rosell 2002; Parker & Rønning 2007) suggests it would take rather over 30 years for the population to reach capacity numbers. However, for this river system especially, this would be significantly affected not only by the number of animals reintroduced, but the site(s) where they were reintroduced.

As with the Teifi (q.v., below, for a fuller discussion of the point), there is considerable potential for riparian habitat restoration along the Dee. Such measures are often recommended for other land management goals, such as water quality enhancement and benefits to angling. A side effect of any such work would be to improve beaver habitat considerably in many areas, thereby increasing the carrying capacity of the watershed.

Jurisdiction The Dee forms the border with England for part of its lower course, and flows fully into England for its final few km (although by this point it is already tidal). A reintroduction to the Welsh part of the river would necessarily affect the English part of the watershed. In Europe, beavers have frequently been unilaterally reintroduced to parts of river systems which flow from and/or to other countries; however, liaison with the relevant English authorities would clearly be at least courteous, if reintroduction to the Dee is considered further.

Figure 23. Horseshoe Falls. The floating log in the foreground (which functions to guide floating vegetation over the weir) marks the entrance to the Llangollen Canal, to left of shot. Beavers dispersing downstream would find it easier to enter the canal than to traverse the weir unless preventive measures were applied.

Llangollen Canal The Horseshoe Falls (SJ195433) is an artificial weir on the Dee at the terminal end of the Llangollen canal. The structure provides water to the canal, which is navigable from the Llangollen moorings about 2.5km ‘downstream’. At this point, entrance to the canal for dispersing beavers would be easy. It can be expected that beavers would in fact do so, as the initial stretches of the canal are fringed with habitat very suitable for beavers, and dispersal along it would be considerably easier than descending the weir.

Whether this is a potential conflict issue depends very much on the construction of the canal. Embankments which are stone or concrete lined or cored are safe from beaver burrowing; earth embankments are not. Removing trees felled into the canal might be an occasional maintenance requirement associated with beaver presence (beavers cannot direct the fall of trees, but some will of course fall in the direction of the water), but would be minor compared to the effects of a breach in an embankment.

The canal runs very close to the Dee as it runs through Llangollen Gorge for about 1.5km downstream from Horseshoe Falls, and at occasional points thereafter. The Llangollen Gorge is much too rapid for beaver settlement. This would greatly reduce the chances of beavers ascending to the canal from the river at this point.

Low fencing at the ingress to the canal at Horseshoe Falls would thus be the primary management measure for reducing the chances of beavers dispersing into the canal. Further security would be provided by fencing along the riverside adjacent to the canal above Llangollen town. Beavers are most unlikely to disperse from the river into the canal from Llangollen town and downstream, partly because the river remains unsuitable beaver habitat, as it is much too fast and turbulent until well past the point where the canal swings away from the river. In addition, the canal is separated from the river by a railway, at most points by a road, and frequently by housing, all strong barriers to dispersal. Further, beavers dispersing through the Llangollen gorge would be very unlikely to ascend the banks, their instinct being to continue down/upstream in search of calmer waters.

In the event that beavers did enter the canal, their presence would soon become evident. Various live trapping methods, especially dazzle netting at night or using Hancock traps with beaver territorial scent (readily available in Norway at c. 10GBP/bottle) and/or aspen twigs as bait, are effective (Halley & Bevanger 2005).

5.1.3 Rheidol

The Rheidol river rises in the Cambrian mountains NE of Aberystwyth. However, its upper length as far as Pontarfynach (Devil’s Bridge) is mainly very steep and unsuitable hydrologically for beaver settlement. The main exceptions, the reservoirs at Dinas and Nant-y-Moch, and the stream between them, are largely treeless, except for some commercial conifer plantations, and so also unsuitable habitat.

At Pontyfynach the course of the river, previously N-S, turns abruptly westwards and enters a U-shaped valley, with a narrow but fairly flat valley floor and steep sides, moderating somewhat closer to the river mouth at Aberystwyth. This lower course of the Rheidol is almost continuously good quality beaver habitat. The lower course can be divided into four sections:

Glanyrafon SN610584. This stretch of river extends from Eastern Penparcau at SN 599802 to Glanyrafon Station, SN 614804, c. 2km. Below Eastern Penparcau the river runs through Aberystwyth town and becomes tidal. Habitat here is generally excellent, well wooded with patches of herbaceous vegetation on both sides of the river downstream of Glanyrafan Bridge, continuously on one side and about 50% on the other side downstream. Allen index for food supply is 0.73. There is clearly habitat for at least one territory, and probably two, on this stretch of river.

Rheidol Shingles and Backwaters SSSI with adjacent river stretches, SN623810. This stretch extends from Glanrafon Station to a point on the river near Pentre farm, SN636808. It is excellent beaver habitat throughout, with abundant willow scrub, and an active, meandering river with backwaters and oxbows. The main river course is about 2.25km long, but backwaters increase this length by c.1.2km, or c.7.9km of bankside in all. The Allen index for food supply is 1, ie, optimal. This area should provide habitat for 2-3 beaver groups; most likely the higher figure given its exceptional quality.

Figure 24. Rheidol Shingles and Backwaters SSSI. Optimal beaver habitat, with abundant bushy growth of willow and a good ground layer.

Tair Llyn SN666785. The river from opposite Pentre Farm to the Cwm Rheidol reservoir weir (SN693795), including the ponds at Tair Llyn. The river stretch is c.9.5km (or c.19km of river-bank); the four ponds at Tair Llyn have a combined bankside length of c.2.6km.

There is much excellent habitat over this section as well, but it is not continuous, areas of optimal woodland or willow scrub alternating with narrow riparian strips backed by pasture. The ponds at Tair Llyn occupy much of an area bounded on three sides by a large meander of the Rheidol, coming within 10-30m of the riverbank at several points. Although beavers are generally reluctant to travel far from water, these distances are so short that, in the absence of fencing, beavers will be able to cross routinely from river to pond. The Allen index is 0.88, reflecting the dominance of willow in the riparian vegetation; however, given the clumped nature of optimal habitat, and its spacing on the river, we consider territories are likely to be established centred on the main patches of optimal habitat, leaving insufficient space for territories in the less optimal habitat between. This would yield four territories on this stretch of river, with possibly a fifth in addition on the Tair Llyn ponds.

Cwm Rheidol Reservoir SN695794. The river is crossed by a large weir at SN693795, too high for beaver to climb, followed 120m upstream by a large concrete dam (see below for remarks on the effect of this structure on beaver dispersal).

Behind the dam is Cwm Rheidol reservoir, which narrows gradually back into the Rheidol river. There is a further system of weirs at SN709789. The river gradient becomes too steep for beaver occupation a little below Rhiwfron Halt, at SN726783. The shoreline distance between the dam and the upper weirs is c. 4.75km; from the upper weirs to the upper limit of water suitable for beaver occupation is c.2km of river, or 4km of bankside.

Cwm Rheidol reservoir is largely fringed with deciduous woodland on its south bank; the north bank is predominantly pasture with a narrow strip of bushes along the shoreline. The river upstream of the second weir has a riparian strip of bushes, broadening upstream, and with occasional patches of woodland on the south bank. The Allen Index value for winter food supply is 0.62. There should therefore be room for one beaver territory in Cwm Rheidol and one above the upper weirs.

Beavers are known to have difficulty traversing larger weirs and dams (Halley & Rosell 2002). The weir and dam combination at SN693795 has also a road running along the north bank closely adjacent, which is bounded by a fence beavers would not be able to cross. This is connected by a low wall to the dam itself. On the north side, a wall runs from the dam into an open field for sheep grazing; the field is bounded on two sides by a track and is fenced except on the reservoir side. This combination of obstacles would require beavers to take a circuitous route of at least 500m on land to disperse either up or downstream; beavers, as mentioned, generally avoid travelling more than 20m from water if it can be avoided, and of course would have no way of knowing the shortest route to pass the obstacles, or to regain the river. It is highly probable, therefore, that the dam and weir will be a strong barrier to dispersal up and downstream. The upper weir above the reservoir is, however, narrow and mimics a natural cataract in its properties. It may be traversed by a 60m trip along the immediate bankside, uninterrupted by fencing, and is unlikely to form a significant barrier to dispersing animals.

Some minor alterations to the wall and fence arrangements on the north side of the dam would provide a direct overland corridor between the reservoir and the pool immediately below (between dam and weir); however, the banks on either side of the weir are small cliffs and impassable. A ‘beaver ladder’, as constructed on similar French river weirs, has been shown to be effective in permitting beavers to traverse them. Installing such a device would require moderate expense and the cooperation of the riparian owner. Failing this, the area above the dam would be to a large extent isolated from the downstream reaches.

5.1.3.1 Concluding remarks: Rheidol

The Rheidol below the Cwm Rheidol dam contains sufficient habitat, mostly of very high quality, for c. 7-10 territories, or c. 22-32 animals. If the habitat above the dam is included, 9-13 territories (c. 29-42 animals). The topography of the valley is such that dispersal out of it to other river systems is unlikely, except on a very long timescale. If beavers were reintroduced here, the population would resemble that of many similar smaller watercourses in Europe, which although not large appear to be indefinitely viable.

This population could in theory be boosted by habitat restoration on suitable stretches of the Dinas and Nant-y-Moch reservoirs, the stream connecting them, and the stream running in to the upper of the two reservoirs. In all this comprises c.22km of bankside, enough for about 7 family groups in good habitat. The degree to which the reservoirs would be suitable would also depend on the extent of fluctuations in water levels. Measures to promote connectivity past the large man-made dams at each reservoir would also be necessary. Habitat restoration on the north bank of Cwm Rheidol reservoir would also enhance carrying capacity.

The nature of the current landscape is such that the only potential significant conflict with human activities would be at the Tair Llyn ponds, which are managed for intensive sport fishing. Beavers would likely be compatible with this land use both biologically and commercially (as forming an additional attraction). However, if beavers were not desired at the site, low fencing around the perimeter of the river meander would prevent colonisation. Damming is unlikely anywhere on this river: the main river is large and subject to strong variations in discharge, while the steep, U-shaped form of the valley means that the relatively few side streams are not habitable for any length, and in any case usually run through treeless field margins before reaching the riparian strip by the main river. Dispersal of beavers outside this river would be especially unlikely, given the steep terrain and significant distances over unsuitable, open terrain to the nearest other habitable waters.

The valley supports a considerable tourist industry, and there would be scope for wildlife tourism related to the beaver.

5.1.4 Teifi

The Teifi river rises in the Cambrian mountains NE of Pontrhydfendigaid and runs in a generally southwesterly direction to Cardigan, with a total length of about 120km. The total catchment is about 1008km^2. The upper 10km of the river, above Pontrhydfendigaid, is generally of high gradient and is unsuitable as beaver habitat. Below this point, the river enters the main valley and the extensive marshlands of Cors Caron (Tregaron Bog). Here the river is very sluggish and meandering, and the flat terrain subject to seasonal flooding. Below Pont Einon (SN 671613) the gradient becomes somewhat steeper, mainly of pool-and-riffle character with some mildly rapid stretches. The river becomes tidal below Cilgerran Castle (SN195432). Another significant marshland area, the Teifi Marshes, is found just below Cilgerran; the degree of salinity of water there is unknown but of importance, as beavers are known to dislike brackish waters (see above).

Most of the main river is therefore hydrologically suitable for beavers, and historically this is the last river on which beavers were reported to survive in Wales, by Giraldis Cambrensis in 1188 (see above; Coles 2007). Elsewhere in Europe, the last refuges of beavers have tended to be in extensive marshland areas (Halley & Rosell 2002), and it is probably the presence of Cors Caron on the Teifi which allowed beavers to persist inconspicuously in difficult terrain (for humans) on this watershed after they had become extinct elsewhere.

The beaver-suitable length of the river from Pontrhydfendigaid to Cilgerran can be broadly divided into three sections for further consideration, the Cors Caron marshlands, the middle course of the river, and the lower river from Llechryd to the estuary at Cardigan.

Cors Caron The Cors Caron Special Area of Conservation (SAC) covers 862ha (http://www.jncc.gov.uk/protectedsites/SACselection/sac.asp?EUCode=UK0014790), of which 2% is standing water, 70% bog, marsh, water-fringed vegetation, and fen; 21% Humid/mesophile grassland, and 7% deciduous woodland. The area is much modified by drainage and attempts at drainage. Many of the most modified sections are subject to an extensive programme of hydrological rehabilitation aimed at elevating and stabilising water levels adjacent to the core surviving raised bog. Cors Caron is largely owned by CCW, with several farming tenancies. The main agricultural use is seasonal rough grazing.

This area represents the largest single unit of actually or potentially suitable beaver habitat in all of Wales. Currently it would be capable of supporting a number of beaver territories; in addition, much of the planned restoration work, in particular the rediversion of the Teifi into its natural, uncanalised course (Paul Culyer, CCW, pers. comm.) would tend to increase the amount of habitat available. This would be very significantly enhanced if the re-establishment of riverine fringes of willow carr and other deciduous shrubs and trees were encouraged.

Water levels at Cors Caron fluctuate considerably, but well within levels which beavers can tolerate.

Figure 25. Cors Caron. The photograph shows a typical section of this large site, dominated by marshland vegetation interspersed with patches and larger areas of willow-dominated scrub woodland. This area is in general good beaver habitat and could support a number of beaver territories. If desired, relatively limited habitat management measures (mainly encouraging regrowth of riparian deciduous scrub and woodland strips) could significantly enhance the carrying capacity for beavers.

The marshland area contains a large number of ditches cut to encourage drainage in the past, and now generally choked with aquatic plants. Aquatic plants are a preferred food for beavers. Ditches would be likely to be taken into use as movement corridors, and may also form the centres of beaver territories where suitable foraging habitat exists, together with burrow/lodge sites next to sufficiently deep water. Where ditches are shallow but running in deeper cuts, it is quite likely that beavers may construct small ‘plug’ dams to facilitate movement. These have the effect of raising the water level within the existing ditch cut without creating a pond, and of retaining water in drought conditions.

Within the overall area, a number of sites stand out as particularly suitable as beaver habitat. The pond at the *Main Hide* on the Teifi at SN 685626 is extremely good beaver habitat, combining still water of constant depth with abundant, willow-dominated deciduous trees, rich aquatic vegetation, and varied bankside forbs. The pond is perhaps somewhat small for a beaver territory by itself. However, water flows out from the pond via a small weir below the adjacent boardwalk into a drainage ditch, which flows past a patch of willow-dominated woodland into the Teifi. If the weir were slightly adapted so that the current c. 75cm ‘step’ over which the water runs were made into a ramp, this site would be the single best potential beaver territory,in habitat quality terms, that DJH observed in all of Wales in the course of the study. The Allen Index score of this site is 1 for winter food supply, indicating optimal habitat. [5]

Figure 26. The pond by the main hide at Cors Caron. Optimal habitat for beavers, with a varied and abundant, high quality food supply and stable, still waters.

Figure 27. The stream exit from the pond by the main hide, running below the boardwalk. Currently impassable to beavers, if the step over which the water flows were converted to a ramp it would connect to good quality habitat on the downstream ditch and river Teifi.

Cruglas (centring on SN694647) is a large patch of willow scrub, about 20ha in extent, in the northern part of the central marsh. Two separate streams run through the scrub into the Teifi; upstream of the willow on both streams are a number of ponds. Each of these streams should be capable of supporting a beaver territory, which might also include a stretch of the Teifi as well. The Allen Index winter food scores for both these sites, reflecting the good and varied food supply, are 1, i.e. optimal habitat.

[5] This site is much frequented by the public; however, beavers often live in suburban locations in Norway and elsewhere, and there have become very tame, ignoring people more than about 10m away (Figures 3, 10).

*Fflur and Top Flash***.** The Fflur is a tributary stream of the Teifi, flowing in from the NE. At SN703647 it lies adjacent to Top Flash, a lagoon fringed by willow carr. There are a number of vegetation-choked ditches leading into the Fflur in the vicinity which would provide access to further patches of willow and birch dominated scrub and woodland. The Allen index winter food score is again 1. The site is high quality beaver habitat, and would support a family group.

Figure 28. Ditch at Cors Caron, ultimately draining to the Teifi. The mix of willow-dominated scrub and bankside forbs, sedges and grasses would be good foraging habitat for beavers.

Beyond these four sites, all of which are of the quality that beavers would be likely to settle on early in any reintroduction, the remainder of the waterways in Cors Caron are at the least acceptable as beaver habitat, with generally abundant non-woody food sources and with clumps of trees, scattered bushes, and larger areas of generally scrubby woodland occurring throughout the site. It is difficult to estimate the likely carrying capacity of the site exactly, given the inherent uncertainties of such estimates and the unknown effect of the very mild climate on winter food requirements (mainly tree bark). Assuming one group per 3 km of bankside, in addition to the territories identified above, would yield a population of about eight families, or about 26 individuals.

The potential population size at Cors Caron could be significantly enhanced by moderate habitat management measures, in particular encouraging the restoration of willow and other deciduous trees in riparian situations, particularly within 0-10m of permanent-water banksides. Beavers prefer bushy growth of coppice type, and in many situations both create and maintain areas of beaver coppice by continued cropping (see Figures 10, YY). Exclosure and planting in appropriate locations would produce a suitable stand within a few years.

Naturally any such measures would have to be integrated with an overall management plan, and we do not by any means intend to suggest that the area would be unsuitable without such interventions. However, with such habitat management, Cors Caron should be capable of supporting perhaps twice the population it might currently sustain, or around 12-16 family groups. More interventionist management, such as creating more ponds like the one at the main hide, would increase this figure further.

Figure 29. Felled tree showing coppice regrowth. Note rebrowsing of coppice twigs, and secondary regrowth. Coppice regrowth is usually preferred to more mature growth stages. The original upper branches of the trunk have been removed and taken to the waterside (about 5m to right of shot) to eat the bark.

Middle course of the Teifi from Cors Caron to Llechryd

The course of the Teifi from its exit from Cors Caron a few hundred metres downstream from Pont Einon, runs through a shallow valley at a moderate incline. This produces a river mainly of pool and riffle character, with occasional more rapid stretches. The river is mainly fringed with a mixture of agricultural fields and riparian vegetation, with larger areas of woodland in places.

Pont Llanfair. SN622514. The habitat here is similar for about 3km upstream to pont Einon, and 5km downstream to where it adjoins the Pont Stephen stretch, below. At most points contains a good mix of willow and forbs bankside, though the riparian strip is narrow (c. 10m). Allen index of 0.84 reflects this. This remains generally good quality habitat, however; as noted about 90% of beaver activity occurs within 10m of the bankside (Elmeros et al 2003; Baskin & Sjöberg 2003). At average densities, there should be room for about 5 territories on this stretch.

Pont Stephen, Lampeter. SN581476. This stretch of river is mainly grazed to close to the river, though there is a 2m strip of grasses and forbs, with a scattering of willow and other deciduous shrubs. While suitable beaver habitat, it is not of particularly good quality. It would be likely to be occupied late in the process of population development, and at low densities. Deliberate fostering of riparian willow in the existing bankside strip would increase potential densities considerably. Similar habitat extends for about 3km upstream and 6km downstream. Assuming densities half that of better quality habitat, which may be overly conservative, we estimate about 3 territories on this stretch.

Llanybydder Bridge. SN519441. Here habitat becomes somewhat more favourable overall, stretching from Felin yr Aber c. 3km upstream, to Llanfihangel-ar-arth about 12km downstream. The riparian strip remains narrow in some places, but is considerably more dense in shrubs, mainly willow, and there are substantial patches of riverine woodland at places. The overall grade of the river becomes somewhat steeper and there are rapid stretches, but suitable pools for burrow/lodge construction are available throughout, and the river velocity is well within beaver capabilities. Allen index is 0.57. Assuming intermediate beaver densities of 1 territory/4.5km of bankside, this stretch would support c. 6-7 territories.

Llandysul. SN419406. Stretching from Llanfihangel-ar-arth to Pentrecagal, this section of river is about 19km in length. Similar in most respects to the Llanybydder stretch, riparian woodland of optimal or greater depth becomes significantly more common, and elsewhere fringing scrub with a strong willow component, though sometimes narrow, is almost continuous. The Allen index for this stretch is 0.62. Rapid stretches of river become more common, and some of these are fast enough that beavers would have to walk on the bankside to move upstream; this may to some extent offset the impovement in foraging habitat, as it may render some forage less easily available. Nevertheless, it should be capable of supporting beavers at ‘intermediate’ densities, that is, one territory per c. 4.5km of bankside, or c. 8 territories in all.

Newcastle Emlyn SN308408. This river section, from Pentrecagal to Cwm-cou, c.8km, returns to a generally lower gradient, with wide meanders. Grazed fields extend to the river bank in some places, thought there is generally a narrow strip of forbs, grasses, bushes and trees - mainly in a single line along the riverbank, backed by fields. Trees are predominanty mature, though hedgerows leading back from the river would provide localised patches of woody forage of optimal stem diameters (<5cm), where they occur. Patches of riparian woodland broader than this are short and uncommon. Although stream flow characteristics are close to optimal, the food resource is not abundant and we consider beaver could occupy the area only at low densities, and would likely do so only late in the process of population development. The overall Allen index value is 0.32, reflecting mainly the low availability of woody vegetation of optimal size over this stretch. We estimate the potential population of this stretch at c. 2 territories.

Cenarth SN269416*.* This section, from Cwm-cou to Llechryd, c. 12km, resumes a more rapid character. Bankside vegetation alternates between narrow, shrub-dominated strips of vegetation backed by fields, and riparian woodlands wider than normal beaver foraging distances (ie, >20m). The woodlands generally contain a good understory of saplings and bushy vegetation of favoured beaver size classes. The Allen index for this stretch is 0.67.

Stretches of rapids occur, but the river is predominantly of pool-and-riffle or laminar flow, within the normal swimming capabilities of beaver. The scale of alternation between riparian woodland and shrub-dominated strips is commensurate with the scale of beaver territories. Densities here should reach intermediate densities, one territory/4.5km of bankside, or c. 5 territories.

Middle Teifi Tributaries

Tributaries of the middle Teifi are generally short and of mainly steep gradient. As noted, beavers do not usually occupy streams with a fall of more than 2m, exceptionally 2.5m, in 100m (a gradient of 2%, exceptionally 2.5%); most Teifi tributaries are not, therefore, suitable for permanent settlement, though territorial beavers living on adjacent parts of the main river, dispersing animals, and nonterritorial ‘floaters’ may be present temporarily. Where streams have a significant stretch where the gradient is lower, usually relatively short and in their lower course, this is generally associated with a landscape of pastoral fields, heavily grazed, with only a very narrow (typically 1 bush wide) riparian strip or none at all. This would be poor quality habitat. The lower sections of such streams might nevertheless form part of a larger territory primarily based on the main river. This may be possible at *Afon Brennig*, confluence with the Teifi at SN673588; *Nant Ceiliog* SN501424; *Rhyddlan stream* SN493429; and *Nant Bargod* SN348405. In only 5 cases do we consider that there may (though there may not) be sufficient habitat to support a family group based on the stream itself: the *Llandewi stream*, confluence with the Teifi SN640458; *Afon Grannell* SN335462; *Afon Tyweli* SN411401; *Afon Ceri* SN295419; and *Afon Mirwaun* SN257423.

Judging by beaver behaviour elsewhere, any low-quality territories on smaller streams would not be permanently occupied. As poor quality habitat, such tributaries would tend to be occupied only late in the process of population development.

These tributaries are generally small and shallow, and damming would be likely to occur if they were occupied. Our investigations suggest that this may occur on up to 9 of the middle Teifi tributaries, mentioned above. Evidence from elsewhere in Europe suggests that it is unlikely that all, or even most, would be dammed at any one time. If damming were as common as on beaver-habitable tributaries on the capacity-population Numedalslågen river system in Norway, for example, there would be one active dam per 14.3km of suitable tributary (Parker & Rønning 2007), or on average less than one dam (as all the habitable sections tributaries put together do not have that length of stream course). Given the generally low quality of the habitat on beaver habitable sections of tributaries, most dams are likely to be relatively temporary structures on the Teifi watershed.

Lower Teifi from Llechryd to Teifi Marshes

Cilgerran Gorge. SN195432. From Llechryd Bridge to Rose Hill Farm, c.5.5km. The Cilgerran Gorge is continuously fringed with excellent beaver foraging habitat, being heavily wooded on both sides, with a good understory of saplings and shrubs of optimal stem diameters. Although the banks are steep sided, water flow is laminar and stream velocities well within beaver capabilities. The Allen index score for the gorge is 0.73. The tidal limit is at Cilgerran Castle , SN195432. The major factor affecting the suitability of this stretch of river is the salinity of the river below this point – although affected by tidal movements, fresh water is likely to be ponded back at high tide for some distance below this point, rather than replaced by estuarine water. The gorge runs for about 3km above Cilgerran Castle, and there beavers should be able to live at normal densities, or c. 2 territories. Assuming the gorge waters to remain fresh as far as the first mud flats at Rose Hill / Teifi Marshes, a distance of 2.5km, another 1-2 territories could be established there.

Figure 30. Teifi Marshes.

Teifi Marshes SN188453. Similarly to Cilgerran Gorge, the extent to which the waters at this site are affected by tidal influences, and the degree to which beavers can adapt to brackish conditions, are likely to determine the degree to which this site is occupied. Vegetationally, the site is close to optimum beaver habitat, containing a large area of Willow Carr and achieving an Allan Index score of 1.00. Much of the marsh is said to be freshwater in character; assuming this is the case, and in particular that the area to the west of the access road to the Wildlife Centre (ie further from the estuary) is essentially fresh water, there should be room for 4-6 beaver territories, the habitat here being measurable in terms of area rather than length of bankside. Most of this area is a nature reserve, and there is a well-equipped wildlife centre on site. This site would therefore have considerable potential for beaver related wildlife tourism.

5.1.4.1 Concluding remarks: Teifi

Although varying in quality, the entire main course of the Teifi from Cors Caron downstream is suitable as beaver habitat. Excluding those areas of the lower Teifi possibly subject to tidal effects, which may deter beavers from establishing, our overall estimate for the potential population, which we believe to be relatively conservative, is 39-45 family groups, or about 125-144 individuals, plus nonterritorial ‘floaters’. Assuming the lower Cilgerran Gorge and Teifi Marshes were also suitable, the estimate rises to 44-53, or about 140-170 individuals. This is a substantial population, the second largest of any of the rivers examined, and unlike the Dee would not be divided into two semi-isolate subpopulations. A population of this size also allows for some flexibility of management, as management measures causing a decline in habitat quality, or making a site unviable, would not have serious consequences for the viability of the beaver population as a whole.

Most, though not all, tributaries of the Teifi do not seem to be suitable as habitat for beavers, either because they are too steep for beavers to occupy, or, where gradients are suitable, the habitat is generally poor, predominantly agricultural fields with only a very narrow or nonexistent riparian strip. Exceptions are noted above. Damming would probably be a late developing phenomenon, occurring as populations reach capacity and more desirable territories are fully occupied. Dams would mainly be relatively ephemeral structures, lasting only a few years. Where the territory was based on the main river, dams on side streams would not be crucial to the viability of the territory. Further, territories based on dammed tributaries would likely be population ‘sinks’. The possible management option of allowing removal or retention of dams at landowner discretion would not therefore impact the conservation status of the population.

Evidence from colonisation of other river systems (Halley & Rosell 2003; Parker & Rønning 2007) suggests it would take about 30 years for the population to reach capacity numbers, though this would obviously be significantly affected by the number of animals reintroduced.

The potential population size could be boosted significantly by management measures, primarily improving the availability of riparian woodland, especially willow carr. Creating wooded riparian strips, for other management reasons, is recommended by a number of land management, angling, and conservation bodies. This would have the side effect of creating a large amount of high quality beaver habitat. We do not mean to suggest that the river would be unsuitable without such management, and other management interests may well be considered higher priorities; we merely wish to point out that there is considerable potential in this respect. As a return to a more natural regime at Cors Caron marshes is already the goal of the proprietor, CCW, enhancement of beaver habitat at that site would most likely be both achievable and compatible with other management goals.

5.1.5 Western Cleddau

The W. Cleddau rises near Mathry in Pembrokeshire at c. 100m asl, and runs in a roughly southerly direction to the estuary at Haverford-west. The landscape is largely rolling, relatively gentle in relief, and agricultural in character. A relatively short river, of about 25km in length.

Llangloffan Fen SM905319 near the headwaters of the W. Cleddau is a nature reserve composed mainly of reed beds and willow carr. It is excellent beaver habitat, with an Allan Index value of 1.0 for winter food supply.

This is a classic site on which beaver habitat alteration would be both likely and desirable, given the management goals of the nature reserve. The site is flat, and the stream heavily vegetated. It is highly likely that beavers would build dams at this site, which would serve to break up the habitat and restore some earlier successional stages, in a shifting manner. Beavers would certainly clear the stream and side ditches of vegetation to facilitate movement. Large areas of reeds on site would be broken up by beavers clearing swimming trails through them. In the woodland, the very flat terrain suggests that it is likely that canals would be dug from existing water to reach willow and other food sources, again breaking up and diversifying the habitat.

There is room for 3 beaver families at this site. It would also be achievable to fence this site to permit beaver habitat management without a general reintroduction to the watershed, if that were considered desirable, in a manner that would not impede more agile animals such as badgers.

Figure 31. Wet woodland at Llangloffan Fen. Beaver would be likely to build dams and canals at this site to facilitate foraging. This would break up the habitat and lead to more variation in successional stages.

Figure 32. The W. Cleddau at Llangloffan Fen, with the nature reserve boardwalk visible to right of picture. The stream is narrow and overgrown, fringed with reed beds and willow carr. This is typical of the type of location in which considerable habitat modification would be likely. Beavers would clear vegetation from the main channel to permit movement, break up reedbeds by establishing channels through them, and likely construct dams and canals to obtain access to areas of willow across the flat fen landscape.

Welsh Hook SM934277. This stretch of river, from Llangloffan Fen to the entrance to entrance to Treffgarne Gorge at Lower Danbarch, is about 7km in stream length. The banksides are generally well wooded with deciduous trees, interspersed with wet meadows. Stream flow is mainly of pool and riffle character, with some longer stretches of laminar flow. The woodland is generally of a tall shrubby nature, with a good ground layer of saplings and forbs, though the average bole diameter is perhaps a little large to be optimal for beavers; the river itself contains much aquatic vegetation. The Allen index value for winter food is high, at 0.70. In a few places, gardens of country houses adjoin the river directly. While the lawns of such gardens are of little interest to beavers, there may be a small risk that ornamental or fruit trees could be felled. Wire fences around the bole to 1.5m high, or painting the bole with a mix of paint (usually bark-coloured or clear) and sand, would prevent beaver gnawing of individual trees, while a 1m high fence along the riverbank would prevent beaver access.

Figure 33. Typical vegetation on the Welsh Hook section of the W. Cleddau. Abundant bushy growth with a good ground layer, and much aquatic vegetation. High quality foraging habitat for beavers.

This stretch of the river should be able to support beavers at normal densities, one family to 3km bankside, or 4-5 in total, with a further territory on the similarly vegetated lower Afon Anghof, just above Wolf's Castle (c. SM960273)

Treffgarn Gorge SM 960244. This stretch, c. 3km from Lower Danbarch to the railway bridge at Treffgarne, is well wooded, but the stream flow is too fast and rocky for beavers to establish permanently, though 'floater' individuals can disperse through, and perhaps temporarily live in some of the pools between the rapid sections.

Treffgarn Quarries pond SM 958240 lies only c. 150m from the W. Cleddau at the lower end of Treffgarne Gorge, in a disused quarry. The pond is fringed with qood quality woodland, mainly shrubby in character. It is, however, separated from the river by the main A40(T) trunk road, with no clear drainage into it. Were beavers able to find the site, despite its relatively small size (0.42km of bankside), it would likely be able to support a territory given the quality of the vegetation and the stable water levels.

Wolfsdale Hill SM952217. This short stretch of river, from the railway bridge at Treffgarne to map reference SM947212, is 3km in length. The river resumes mainly laminar flow and gently meanders. There is a good riparian strip of shrubs, greater than 20m in depth, along much of both banks, interspersed with field magins with narrower riparian strips. There are three streams which enter the river from the west along this stretch, each with similar bankside vegetation, of c. 2.8, 1.1, and 2.1km suitable stream length respectively. The Allen Index for these sites is 0.77. The main river should be able to support two family groups on this stretch. The two longer side stream habitat patches would also support a family group, and the shorter one probably would, for 2-3 additional territories. Damming would be likely along the tributary streams, which are shallow. However, they run in narrow clefts where the topography is such that this would produce narrow, linear pools, deepening the existing stream course, rather than broadening the watercourse into ponds.

Spittal Brook Flows into the W. Cleddau from the east at SM961234. Bankside habitat is largely riparian woodland and scrub in a strip c.40-60m wide on each bank, extending for c. 5.7km from the confluence. Good beaver habitat, likely to be dammed given the narrow and shallow stream. There is habitat for 3-4 family groups here at capacity populations.

Lower W. Cleddau. SM941188. This stretch consists of the remainder of the river from SM947212 to the first of the bridges at Haverfordwest, SM953159, after which banks are built up and the river emerges into the tidal estuary, both unsuitable habitat. The length of this section is c. 3.75km.

The river here is of mainly laminar flow with a few riffles, and flows through agricultural countryside. For most of the length there is a riparian strip of 10-30m in width, dominated by grasses and forbs though with a significant element of shrubs, predominantly willow. In some places, fields abut the river directly or with only a single line of shrubs on the river bank. Overall, the Allen index value remains high at 0.74, because willows are preferred forage and remain relatively common, and the habitat strip is mainly wide enough for a good food supply. We estimate that two beaver families could establish territories along this stretch of the main river.

Figure 34. Typical habitat on the lower W. Cleddau. Mainly laminar flow with small riffles and a riparian strip 10-30m wide (c. 10m in this photograph) dominated by vascular plants but with a strong element of shrubby willow and other trees. This is good habitat for beavers, if not so optimal as the stream above Treffgarne Gorge.

In addition to the main river, there are several tributary streams offering narrow, but generally well wooded, riparian strips along this stretch. Proceeding upstream from Haverfordwest, these are:

The Pelcombe Stream, flowing into the W. Cleddau from the west at SM953169. A branching stream largely bordered by a wooded riparian strip with an abundant ground layer of between 10 and 30m on both sides. Total suitable stream length 9.2km, excluding a 0.9km stretch below Pelcombe Bridge where there is little or no riparian strip. The stream is well vegetated and of laminar flow, Allen Index 0.73. At normal water levels beavers can move along it unhindered, but it is narrow and damming may occur, especially further up the catchment. This is generally good habitat for beavers, and would probably host c. 5-6 beaver territories.

Camrose Brook and Knock Brook, uniting shortly before their joint confluence with the W. Cleddau at SM940188. These two streams are very similar to the Pelcombe Stream, see above, in general characteristics and have the same Allen Index value, 0.73. c. 10.3km of suitable stream length; c. 6 family groups at capacity. As with the Pelcombe stream, the construction of dams would be likely.

Figure 35. Typical habitat on the Pelcombe stream. Well wooded with an abundant ground layer and much aquatic vegetation. Good habitat for beavers; damming is likely given the narrow stream course and shallow water.

Rudbaxton Water and Poyston Water. Two streams joining about 500m from the W Cleddau, flowing from the west and meeting the W Cleddau at SM945198. Togther they have about 7km of suitable bankside habitat. Again similar to the Pelcombe Stream, but woodland on both sides of the stream is almost continuous and the depth of the riparian strip greater, usually around 50-70m. Trres are on average rather more mature, though there is a good ground layer with saplings in most places. Allen index 0.68. There are three small ponds along the watercourse, all fringed with woodland and with abundant aquatic vegetation. Again, good beaver habitat, where damming is likely given the small size and shallow depth of the watercourse. The habitat available should be capable of supporting 4-5 family groups.

5.1.5.1 Concluding remarks: Western Cleddau

Despite its relatively short length, the estimated potential population for the Western Cleddau is as many as 29-34 family groups. This is because very much of the watershed consists of suitable vegetation, with only relatively short unsuitable stretches, and because of the unusually large number of long tributary streams with hydrography and riparian vegetation well suited to beaver settlement. Damming is likely to be relatively common on this watershed, as so much of the potential habitat lies by the side of narrow and relatively shallow tributary streams. In most places this would be unlikely to cause conflicts with human landuse, as the riparian strips are fairly broad, and exist largely because the land is unsuitable for other purposes; however, it is possible that some beaver ponds may cause inconvenience to some human land uses. The perception of conflict may also be higher than the actual conflict, measured economically, given the novelty of beaver activity in Wales and the unfamiliarity of the public with the immediate consequences of dams in a wooded landscape, such as standing dead timber, however valuable for conservation purposes they may be. Educational activities in advance of likely dam construction would be useful in this respect.

5.1.6 Eastern Cleddau

The Eastern Cleddau, while similar in general character from the Western river, is separated from it by a bifurcated tidal estuary, of about 15km in length between the rivers. This is unsuitable habitat for beaver settlement, and beavers are reluctant to move through brackish or salt waters. The two rivers are therefore best treated separately. The river has two main branches, the Afon Syrynwy and the E. Cleddau proper, which meet at Pont Gelli (SM953169). The total length of beaver-navigable waters on the two main branches, including tributaries, is about 55km.

Upper Afon Syrynwy. This stretch of river extends from the upper limit of suitable habitat on the Syrynwy, at c. SN065282, to its entrance to Llys-y-fran reservoir at SN042266. The stream length is about 2.9km; however, a substantial section of the east bank, c. 1.1km, is fringed by plantation conifer forest unsuitable as beaver foraging habitat. The remaining banks are fringed by deciduous woodland, mainly of relatively slender bole diameters (an advantage for beavers), and with a dense ground layer of vascular plants and saplings, about 4.7km in total bank length. The Allen Index is 0.76, indicating good quality habitat. This stretch of river would host one, perhaps two, family groups; damming, forming linear pools of deeper water rather than ponds given the topography, would be likely, as the stream is both shallow and narrow.

Figure 36. Upper Afon Syrynwy at Farthings Hook Bridge (SN055275). Fast-flowing and relatively shallow; damming would be likely at this site. Bankside vegetation is very good for beavers.

Figure 37. Northern end of Llys-i-Frân reservoir; excellent beaver habitat.

Llys-i-Fran Reservoir SN037250. This reservoir on the Syrynwy has a total bank-side length of 8.2km, excluding the large concrete dam which impounds the water. The reservoir is mainly fringed by deciduous woodland, except for a short stretch at the SE end near the visitor centre.

Allen index values were taken for 10 transects around the reservoir (see Appendix 1), and varied from 0.53 to 0.97, ie from suitable to excellent; averaging for the whole site 0.68. The best quality habitat is at the north end, where the Syrynwy flows in, which is predominantly shallow water fringed by willow carr. Water levels are usually very stable, except in prolonged droughts. There should be sufficient habitat for c. 3 family groups here.

The dam, which is c. 320m long, and c. 30m deep from reservoir level to the river below, is likely to be a considerable barrier to beaver dispersion, especially as roads and fencing on the sides of the dam area form further hindrances. Depending on management goals, this could be made considerably more secure by erecting further, 1m high, fencing from the dam edges; or alternatively ameliorated by providing an obvious dispersal channel from reservoir level a few metres beyond the dam, to a clear downhill path to the river.

The reservoir is owned by Dŵr Cymru / Welsh Water and managed as a country park. It would be a suitable site for development of beaver tourism.

Middle Syrynwy this stretch extends from the dam at Llys-i-Fran to a point on the river, SN046223, near The Grove farm; c. 2.7km in stream length. The river at this point is mainly fringed with deciduous woodland and is moderately good beaver habitat. The stream remains relatively narrow and shallow, and damming is likely in places. Pools formed would be linear, given the topography.

Figure 38. The middle Syrynwy from the dam at Llys-y-frân. Well wooded, and good beaver habitat. Damming, forming linear pools, would be likely.

The Allen Index for the stretch is 0.60, reflecting the somewhat more mature woodland structure and so relatively lower availability of optimal bole diameter stems than the upper Syrynwy.

This stretch would support 1-2 family groups.

Lower Syrynwy from SN04662 to the confluence with the E. Cleddau at Pont Gelli (SM953169). Stream length about 6.0km. The river on this stretch has only a narrow riparian strip, often a single line of bushes, or none at all; the overall Allen index value is 0.52. However, there are some short stretches of somewhat wider riparian woodland, such as at the road ford S. of Clarbeston, where the Allen Index is 0.73. Overall, while suitable, the habitat is relatively poor in available vegetation and it would support only 1-2 territorial groups. It would probably be occupied late in the process of population development. Damming would be likely, and in the fairly flat terrain larger ponds might be created in locations with better than average food supplies for this stretch. Occupation of this stretch is likely to be shifting in nature, the beavers moving their centres of operation intermittently as immediately local food supplies become relatively depleted.

Upper E. Cleddau The Upper E. Cleddau runs out of moorland terrain which appears unsuitable for beavers into a shallow valley at Pont Hywel (SN129274). Habitat characteristics are similar for the next c.3.7km of stream course to the bridge and confluence with the Llandilo stream at Rhydwilym (SN114249). This is a shallow valley in rolling countryside with much deciduous woodland, typical of the area. Bankside vegetation is very good for beavers, Allen Index 0.73. The stream, while fairly rapid, is within beaver capabilities. Damming is likely on this stretch, as the stream is narrow and shallow; the pools produced would be linear, deepening the existing stream course without broadening it to any extent. There would probably be enough habitat here to support about 2 beaver families.

Llandilo stream. About 2.0km of stream course is suitable for beavers before the watercourse becomes too steep about SN109263. Landforms and vegetation are very similar to the upper E. Cleddau (see above), although 0.65km of the stream course runs through conifer plantations unsuitable as beaver habitat. The overall Allen Index, 0.60, reflects this. There should nevertheless be sufficient habitat for one beaver family on the stream. Damming would be likely, as the stream is small and shallow; pools formed would be of the linear type given the topography.

Lower E. Cleddau From Rhydwilym (SN129274) to the bridge at Blackpool (SN060145), beyond which the river becomes tidal and so probably unsuitable habitat for beavers, a stream course of c.15.0 km. After Rhydwilym the river flows into wooded agricultural countryside. The banks are fringed with trees or bushes almost continuously, though the riparian strip is often narrow. However, more substantial wooded or bushy fringes remain fairly common, scattered along the length of the river. With an Allen index value of 0.52, we estimate that beavers should be able to occupy this area at intermediate densities, or one family group to about 4.5km of riverbank: 6-7 territories in all. For much of this stretch damming would neither be possible given the size of the river, nor necessary given the depth.

Figure 39. Typical habitat on the lower E. Cleddau. Good vegetation in a narrow riparian strip. The smooth laminar flow is preferred by beavers, and the river at this point deep enough that damming is unnecessary.

Afon Rhyd-afallen This tributary flows into the E. Cleddau from the north at SN095207. In its lower reaches it is bordered by wooded farmland, as the lower E. Cleddau; Allen index 0.46. Upper reaches are a wooded valley similar to the Upper E. Cleddau, and have the same Allen Index value, 0.73. The stream course suitable for beaver occupation is about 5.5km. The habitat available is sufficient for 2 beaver family groups, possibly 3 if the lower stretch is occupied by a separate family group and not shared between territories based on the upper Rhyd-Afallen and on the adjacent stretch of the E. Cleddau, which is more likely. Again, damming is likely given the width and depth of the stream, forming linear pools higher up, but more pond-like pools on the lower stretches.

Holgan ponds SN076177. Three artificial ponds, apparently former gravel pits separated by narrow levees, with a combined shoreline of c. 1.1km. Small artificial islands are present on two of the three ponds, which lie adjacent to the E. Cleddau, separated by about 50m. This distance is rather far for beavers to cross as a routine movement about a territory, especially as it is over open terrain; and the vegetation around the ponds is not of good quality, mainly closely cropped grass, with a few trees and bushes. Aquatic vegetation is good, however, and the islets an obvious site for a lodge or burrow. Nevertheless, it is unlikely that beavers could colonise this site except temporarily; if they did, burrowing through the levees separating the ponds may be likely to occur. The ponds are used for commercial angling.

5.1.6.1 Concluding remarks: Eastern Cleddau

This river is similar to the Western Cleddau in general characteristics and many of the same remarks apply. The habitat available can support an estimated 17-22 beaver families. Damming would be likely to be relatively common on the watershed, given the shallow and narrow nature of both the main branches of the watershed in their upper reaches, and of tributaries throughout their lengths.

6 Discussion

Beavers are a robust species and, within the limits of their habitat requirements, adaptable. The history of beaver reintroductions demonstrates that, where hunting or other human-caused mortality is kept within limits, beaver populations can be established fairly readily and, even where populations are relatively small, persist indefinitely.

Of the six river systems examined, the *Glaslyn* is in our view the least attractive site. The potential population is rather small and some of the habitat of uncertain quality due to the likely ingress of estuarine water at irregular intervals; and there are points where likely beaver damming might cause shallow flooding on a public road. Management involving removal or regulation of dams would have a relatively larger impact here because of the small size of the population. There is no good site on the river for providing wildlife tourism opportunities for what is certain to be a reintroduction arousing considerable public interest.

The *Rheidol* river, although the potential population is relatively modest, has many factors in its favour, both from a biological and management perspective. The habitat along its length is continuously suitable as far as Devil's Bridge, and of high quality. There are several sites where public viewing might be easily arranged. However, connectivity between the river above and below Cwm Rheidol dam is currently poor and would likely be a considerable barrier to beaver movement. Management options include accepting this and confining the population to the area below the dam, or making modifications to the dam area which would allow for easier dispersal of beavers around the dam and up or down the adjacent weir. Damming is unlikely on this river system, owing to the topography, and the scope for real or perceived conflicts with human interests appears to be particularly low. The steep valley sides, and considerable distances to suitable habitat on other watersheds, make dispersal from the Rheidol catchment particularly unlikely.

The *Teifi* can host a substantial beaver population and the main river is continuously suitable habitat from Cors Caron to the estuary. Cors Caron is particularly attractive beaver habitat, and this could be enhanced considerably with relatively modest management, mainly encouraging riparian growth of willow and other deciduous bushes. The Teifi Marshes near Cardigan are also high quality habitat, and would probably be habitable, if the water is not too brackish. Both sites are nature reserves with facilities for public wildlife watching, which could fairly readily be adapted to cope with beaver-related tourism. On the other hand, relatively few of the tributaries appear to be suitable for beaver settlement, mainly because of the gradient, combined with the relatively poor habitat in those areas where the gradient is suitable. Most of the population will, therefore, be based on the main river course.

Figure 40. Stock fencing at Bala Lake allowing regeneration. This type of fencing would also exclude beavers, except very close (<10m) to bank-sides suitable for burrowing. Beaver burrows always begin below water. Fencing with buried mesh of the type excluding rabbit burrowing would also prevent beaver burrowing from breaching fences.

The *East and West Cleddau* rivers, although disjunct, can be summarised together as they are similar in characteristics. Both are relatively small rivers in both length and discharge, but this is offset in beaver habitat terms by a relatively large number of tributaries suitable for beaver settlement. The countryside is rolling and agricultural in character; the rivers often run in shallow valleys incised into the landscape which are unsuitable for cultivation, and so have a good fringe of riparian woodland. These streams can host a surprisingly large population for their sizes given these conditions. Damming would probably be relatively common, given the shallow and relatively narrow nature of many of the tributaries. In the lower stretches of the rivers, fields often approach the river more closely and human infrastructure becomes more densely distributed. Damming here might be perceived negatively more often than in other rivers, as being more common, more noticeable, and with a greater intensity of human land use adjacent to beaver habitat.

The *Dee* can host a considerable beaver population, mainly on Bala Lake and the main river, though a small number of tributaries are habitable, particularly the Alwen and Cleiwedog. The population would be split into two parts by the Llangollen Gorge, through which dispersal, particularly upstream, would be difficult (with appropriate management this allows the possibility of a reintroduction only to the lower Dee, below the Gorge). Damming would not be possible on the main river, where the bulk of the population would be found, but may occur on tributaries. However, both subpopulations would be relatively large. The Llangollen canal draws water from the Dee at Horseshoe Falls, and its upper reaches would almost certainly be colonised by beavers unless management measures were taken to prevent it. This is the only site surveyed at which a conflict with human activities with serious economic consequences may potentially occur, as beaver burrowing through an earth levee might cause a breach expensive in terms of the direct flooding caused, the temporary closure of the canal to navigation, and repair costs. Whether this is a realistic contingency depends on the construction of the levees on raised sections of the canal (if stone or concrete lined or cored beavers cannot burrow through them), and any management measures taken to prevent colonisation. It would appear that fairly inexpensive measures would suffice, and beavers live on canals in Sweden and the Netherlands without conflict (Hartman *pers. comm.*); indeed in the Netherlands some concrete bank linings have been deliberately removed to create small bays in which beavers can build lodges (Sluiter 2003). However, a careful joint examination of this issue by beaver biologists and canal engineers would clearly be necessary if the Dee were to be considered further for a reintroduction.

The lower course of the Dee forms the border with England in places. This may involve a reintroduction in jurisdictional issues which would serve to complicate the process, though in Europe reintroductions have often been carried out on rivers with two or more countries sharing the watershed without transnational consultations.

Figure 41. Beaver activity as wildlife experience.

7 Conclusion

In terms of *ecological feasibility*, the results of this investigation are unequivocal. Beavers can successfully be reintroduced to Wales; and specifically to any of the six rivers investigated. The possible exception is the Glaslyn, given the small potential population. However, given the numerous other sites in Europe where similarly small, isolate populations appear to be persisting stably, we believe this is erring strongly on the side of caution.

7.1 Further steps

Ecological feasibility is of course only one aspect, albeit a crucial one, in assessing a reintroduction. Throughout Europe, beavers live mainly in managed ‘cultural’ landscapes – very few indeed live in anything like ‘wilderness’. This is unsurprising, as beaver preferred habitats, low gradient and alluvial landscapes, are also those preferred for agriculture and human settlement. They are in most of these places treated as an element in a managed landscape (Halley & Rosell 2002, 2003), rather than as a conserved species managed in isolation, and we suggest that further assessment of reintroduction to Wales should be viewed in these terms.

One general insight from beaver (and other) reintroductions which should also be emphasised is that, in landscapes dominated by human activities, the human element is by far the most influential in the success or otherwise of a programme. The biology of beaver reintroduction is very well known and the course of population development can be predicted with reasonable confidence. It is the (human) social aspects of reintroductions that typically require the most attention, care, and forethought.

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9 Acknowledgements

We would like to thank the following for their help with the production of this report:

Bangor University
Paul Culyer CCW
Geraint Davies EAW
Göran Hartman, Uppsala university
Lynn Hughes
Jonathon Rothwell CCW
Ian Sargent, Aigas Field Centre
Gerhard Schwab, Bund Naturschutz in Bayern e.V.

Figure 42. Beaver. Photo. Gerhard Schwab

10 Appendix: Allen Habitat Suitability Index values

Place	Map reference	Index tree canopy suitability	Index 2.5-15.2cm dbh	Index shrub crown cover	Index height shrub canopy, m.	Species composition score	Winter food index value
E Cleddau							
Upper Afon Syrynwy	SN047269	1	0.95	0	0	0.6	0.76
Llys Ifran T1	SN038247	1	0.9	0	0	0.6	0.75
Llys Ifran T2	SN039255	0	0	0.5	1	0.6	0.65
Llys Ifran T3	SN042263	1	0.6	0	0	0.6	0.68
Llys Ifran T4	SN042267	0.5	1	0	0	0.6	0.65
Llys Ifran T5	SN041265	0	0	0.8	1	1	0.95
Llys Ifran T6	SN038261	0.5	0.45	0	0	0.6	0.53
Llys Ifran T7	SN035255	0.5	0.45	0	0	0.6	0.53
Llys Ifran T8	SN034247	0.5	0.45	0	0	0.6	0.53
Llys Ifran T9	SN030249	0.5	0.45	0	0	0.6	0.53
Llys Ifran T10	SN033244	0	0	0.9	1	1	0.97
Pont Crwca	SN037227	1	0.4	0	0	0.6	0.62
Middle Afon Syrynwy	SN049222	0.9	0.4	0	0	0.6	0.60
Lower Afon Syrynwy, Ford SW of Clarbeston	SN070200	1	0.8	0	0	0.6	0.73
Lower Afon Syrynwy, general	SN079119	0.4	0.5	0	0	0.6	0.52
Upper E Cleddau	SN129274	1	0.8	0	0	0.6	0.73
Llandilo stream	SN114249	0.7	0.5	0	0	0.6	0.60
Lower E. Cleddau	SN066151	0.5	0.4	0	0	0.6	0.52
Lower Afon Rhyd-Afallen	SN095207	0.4	0.3	0	0	0.6	0.46
Upper Afon Rhyd-Afallen	SN086234	1	0.8	0	0	0.6	0.73
W Cleddau							
Llangloffan Marsh	SM904311	0	0	1	1	1	1.00
Welsh Hook	SM934277	0	0	0.8	1	0.6	0.73
Treffgarn quarry pond	SM958240	1	0.65	0	0	0.6	0.70
Wolfsdale Hill	SM952217	0	0	1	1	0.6	0.77
Lower W Cleddau	SM941188	0	0	0.3	1	1	0.74
Pelcombe Stream	SM953169	1	0.8	0	0	0.6	0.73
Camrose & Knock Brooks	SM940188	1	0.8	0	0	0.6	0.73
Rudbaxton & Poyston Waters	SM945198	1	0.6	0	0	0.6	0.68

Glaslyn

Floodplain Boston Lodge	SH585385	0.4	0.4	0	0	0.6	0.49
Bwlch Glas	SH597398	0	0	1	1	1	1.00
Pont Croesor	SH593413	1	1	0	0	0.6	0.77
Glan y Don	SH593443	0	0	1	1	0.6	0.77
Afon Maesgwyn	SH642431	0.7	0.6			0.6	0.62

Rheidol

Glanyrafon Bridge	SN610584	1	0.8	0	0	0.6	0.73
Gelli Argherad	SN623810	0	0	1	1	1	1.00
Tair Llyn	SN666785	0	0	0.6	1	1	0.88
Cwm Rheidol Reservoir	SN700794	0.7	0.6	0	0	0.6	0.62

Teifi

Pond at main hide	SN685626	0	0	1	1	1	1.00
Cruglas	SN694647	0	0	1	1	1	1.00
Pont Llanfair	SN622514	0	0	0.5	1	1	0.84
Pont Stephen	SN581476	0	0	0.1	1	0.6	0.44
Llanybydder Bridge	SN591441	0	0	0.3	1	0.6	0.57
Llandysul	SN413403	0	0	0.4	1	0.6	0.62
Newcastle Emlyn	SN307409	0.1	0.3	0	0	0.6	0.32
Cenarth	SN264416	0.7	0.8	0	0	0.6	0.67
Cilgerran Gorge	SN195432	1	0.8	0	0	0.6	0.73
Teifi Marshes	SN188453	0	0	1	1	1	1.00

Dee

Bala Lake, NE shore	SH923354	0	0	0.8	1	1	0.95
Bala Lake, Llangower Station	SH901322	0	0	0.9	1	0.6	0.75
Bala Lake, SW shore	SH889314	0	0	0.5	1	1	0.84
Bala Lake, NW shore	SH913346	0	0	0.8	1	0.6	0.73
Upper Dee	SJ046402	0.3	0.25	0	0	0.6	0.41
Afon Alwen	SJ060425	0.5	0.5	0	0	0.6	0.55
Lower Dee	SJ377436	0.1	0.2	0	0	0.6	0.29
Afon Cleiwedog, upper	SJ399485	0.7	0.5	0	0	0.6	0.60

Figure 43. Beaver. Photo: Ian Sargent

NINA Report 457

ISSN: 1504-3312
ISBN: 978-82-426-2026-2

Norwegian Institute for Nature Research
NINA head office
Postal address: NO-7485 Trondheim, NORWAY
Visiting address: Tungasletta 2, NO-7047 Trondheim, NORWAY
Phone: + 47 73 80 14 00
Fax: + 47 73 80 14 01
Organisation number: NO 950 037 687 MVA

www.nina.no

Graphic design: NINA
Cover photos: Per Jordhøy, Børre Dervo,
Knut Kringstad, Tycho Anker-Nilssen