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The distribution in bankside habitats of three alien invasive plants in the U.K. in relation to the development of control strategies

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Abstract

The national distribution of *Fallopia japonica* (Japanese Knotweed), *Heracleum mantegazzianum* (Giant Hogweed) and *Impatiens glandulifera* (Himalayan Balsam) in bankside habitats is given for 1994–96 in the U.K. and contrasted with the occurrence of large stands of other nuisance plants. The typical habitats of these plants were derived by analysis of flow, channel and bank substrates from River Habitat Surveys and shows their invasion potential across the U.K. Study of the dispersal mechanisms and control techniques shows: (a) the consequences of accidental introductions to river banks from locations away from the river, (b) their further dispersal by the downstream drift of seed or fragments with their subsequent invasion, and (c) the key areas in the development of appropriate control programmes. The concentration of effort to immediate action and to small areas, especially upstream, is recommended, in preference to widespread but incomplete control.

Introduction

The occurrence of invasive bankside plants was one of the 25 sub-sets of data recorded during River Habitat Surveys (RHS) of the general physical structure of watercourses at 5560 sites in the United Kingdom in 1994–96 (Raven et al., 1997). This sub-set had been added to the main survey following the increased interest by managers with conservation interests and the absence of a national picture of their occurrences in bankside habitats. Thus, three alien invasive plants *Fallopia japonica* (Houett.) Ronse Decr., Japanese Knotweed, *Heracleum mantegazzianum* Sommier & Levier, Giant Hogweed and *Impatiens glandulifera* Royle, Himalayan or Indian Balsam, were specifically recorded as absent, present or extensive, because these were considered to be a problem at the national level (NRA, 1994; Roblin, 1994). Other vegetation surveys of the countryside noted the presence of large stands of plants of similar habit in bankside habitats (e.g. Bunce et al., 1999) which may also be considered to have a nuisance value or adverse effect on conservation interests. Initial consideration of the data set suggested that the extensive network of river corridors provides for passage of seeds of *I. glandulifera* and *H. mantegazzianum* and propagules such as stem sections or roots of *F. japonica* by downstream movement (Pysek & Prach, 1994; Raven et al., 1998). Other aspects of the current status of research on the ecology and management of these species are considered elsewhere, general studies (de Waal et al., 1994a) and by plant (Beerling et al., 1993; de Waal et al., 1994b; Tiley et al., 1996).

This paper aims to show: 1. the national distribution of these three alien invasive species on the banksides of U.K. watercourses; 2. their characteristic or preferred habitat; 3. comparison with large stands of nuisance plants of similar habit; and 4. the results of a study of the dispersal mechanisms and control techniques applied in one of 26 Environment Agency areas of England and Wales in which these plants are all widely distributed.

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Materials and methods

The River Habitat Survey was undertaken in 1994–96 to collect data on a range of features describing the physical habitat of selected 0.5 km lengths of river in the U.K. RHS sites were selected on a stratified random basis from 10 × 10 km squares of the Ordnance Survey national grid system and provide a representative distribution of sites throughout the UK. Although three sites per grid square were chosen in England and Wales and undertaken in 1994–96 (totalling 4530 sites), two from N. Ireland for 1995–96 (246) and one from Scotland undertaken over two years 1995–96 (778), comparisons were presented on a one site per square basis. Some bias may exist in the random selection of sites, for example, in Scotland, the constraint was imposed that sites should be selected from locations within 3 km of a road or track. The species *F. japonica*, *H. mantegazzianum* and *I. glandulifera* were specifically recorded as 'absent', 'present' or 'extensive' on the bank face or bank top as defined by the RHS methodology (Environment Agency, 1997). 'Extensive' is defined as occupying more than 33% of the total bank length; the 'bank face' is the area from the edge of water to the first major break (change) in slope; and the 'bank top' is the strip of land parallel to the river, and from the bank top for a width of 5 m away from the river bank. In addition, large stands of other plants which were considered by surveyors on-site to be nuisance species, were identified and recorded for a subset of sites in England & Wales in 1995, this was extended in 1996 by the use of a list of species as a prompt to surveyors (listed in Table 2). The habitat was determined by analysis of RHS data on predominant flow type, predominant channel substrate and predominant bank material (as defined in RHS Method Manual) determined from 1 m wide transects at 50 m intervals over the 500 m sections of rivers and from general site data derived from the map-based parameters including altitude, bed slope and water quality.

Results

The three alien invasive plants *F. japonica*, *H. mantegazzianum* and *I. glandulifera* are widespread in England and Wales and present in Scotland and Northern Ireland. Each species currently has a distinct preferred area but there is also much overlap (Figure 1). Thus, *F. japonica* is more common in south Wales, central north-west and south-east England, whereas *H. mantegazzianum* is widely scattered with occasional extensive areas, as is *I. glandulifera*; the latter is concentrated in the south-east and north-central midland areas of England. The overall frequencies in the U.K. based upon one occurrence per 10 × 10 km map square, are from the most frequent to the least frequent:

I. glandulifera > *F. japonica* > *H. mantegazzianum*

However, there are some regional differences with twice as much *H. mantegazzianum* in N. Ireland as in England, whereas Scotland has about a quarter as much *F. japonica* or *I. glandulifera* as England and Wales (Table 1). Extensive stands occurred on average at 13% of sites.

Table 1. The percentage occurrence of *F. japonica*, *H. mantegazzianum*, and *I. glandulifera* in countries of the U.K.

Country/Species	*H. mantegazzianum*	*F. japonica*	*I. glandulifera*
England & Wales	3.7–4.3	8.5–8.9	14.0–15.1
Scotland	3.8	2.3	3.5
N. Ireland	7	6.9	15
U.K. average	4	6.6	11

The characteristic physical habitat of bankside sites invaded by these three invasive species is predominantly (a) streams and rivers of any size but more frequently medium sized streams up to small rivers; (b) at any altitude but most frequently in lowlands less than 170 m (90%); (c) at any bed-slope but frequently shallow to 10 m per km; (d) a bad or poor water quality for *I. glandulifera* and F. japonica which are associated with urban areas; but, the habitat is independent of other factors such as the distance from source of the watercourse, the bank-top width, (Figure 2). The sites invaded were often in the less (37%) rather than in the extensively modified watercourses and, also, surprisingly, 17.6% of the 'semi-natural' sites had all three species.

Each species has a characteristic habitat despite their general wide ranging occurrences, thus, *F. japonica* is more commonly associated with the banksides of higher energy streams at higher altitudes and with larger bed substrates eg gravels or cobbles, artificial sections or more modified sections of streams (Figure 3). *I. glandulifera* and *H. mantegazzianum* are more often associated with rivers of lesser stream power, lower altitudes and with finer channel and bank

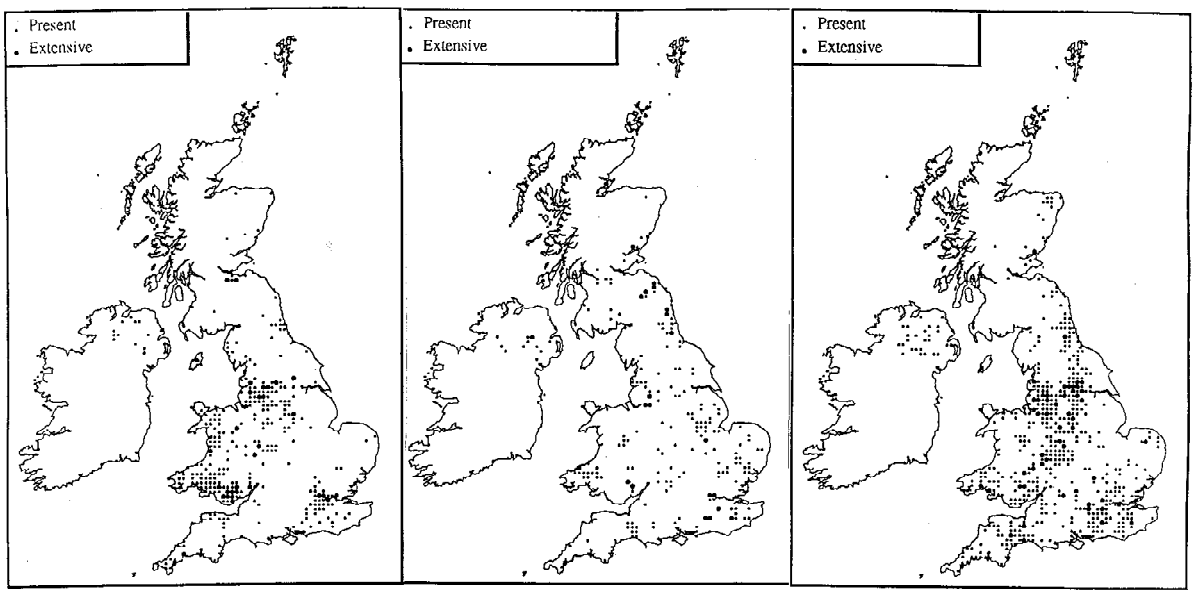

Figure 1. The occurrence of (a) *Fallopia japonica*, (b) *Heracleum mantegazzianum* and (c) *Impatiens glandulifera* in the U.K. for 1995–96 data (key: • = present; ● = extensive; data are centred on the 10 × 10 km squares).

materials, but all are found existing over a wide range of conditions presumably indicating their ability to colonise most habitats if they can initially gain access. The ability to predict the potential occurrence of these species was tested using several combinations of the RHS physical habitat data, such as bank substrate and flow, for various scales of predominance and frequency of data, but little specific predictive conditions were found despite the use of site-specific data from the regular transects. The data on habitat requirements for the plants were either too general or the plants have a very broad range of tolerance in their habitat requirements; this indicates that there is likely to be a great potential for further spread of the plants if conditions for dispersal are met.

The comparison of the frequency of stands of nuisance plants of similar habit to the invasive species, showed that there were several species which were common but only one, *Urtica dioica* L, as common as that of the invasive species. These other bankside species appeared to occur in other sites and broadly, in other areas of the country to that of the three invasives (Figure 4). The proportions of species found varied significantly between country and between years (1995 and 1996, Table 3). Few sites (2%) had more than one of these other species recorded, but did when they occurred most commonly as a combination of *U. dioica* and *P. aquilinum*, or occasionally, *R. fruticosa agg.* and *P. spinosa*.

Assessment of the problems caused by the presence of alien species

The main adverse effect is considered to be the dense and lank growth of 1–5m in height which shades out the shorter native plants that give stability to bank structure. Short vegetation especially grass, is generally preferred by river engineers (Hemphill & Bramley, 1989) as this is considered to minimise erosion of the river bank, because dense short stems and leaves become flattened in floods and protect the bank material. Taller plants especially these three invasive species, shade out short vegetation and in autumn die back, often leaving exposed bank material. Channel capacity for flood flows may also be reduced by their presence or by the effects of shoals of trapped sediment; both add to the cost of bank maintenance. In designated conservation sites, these invasive plants may outcompete native plants of defined value by reducing or destroying the valued habitat and the landscape value. Access to the river bank may be impeded. *H. mantegazzianum* is a health hazard because of its photo-sensitising sap which causes irritation, swelling and recurrent blistering (NRA, 1994).

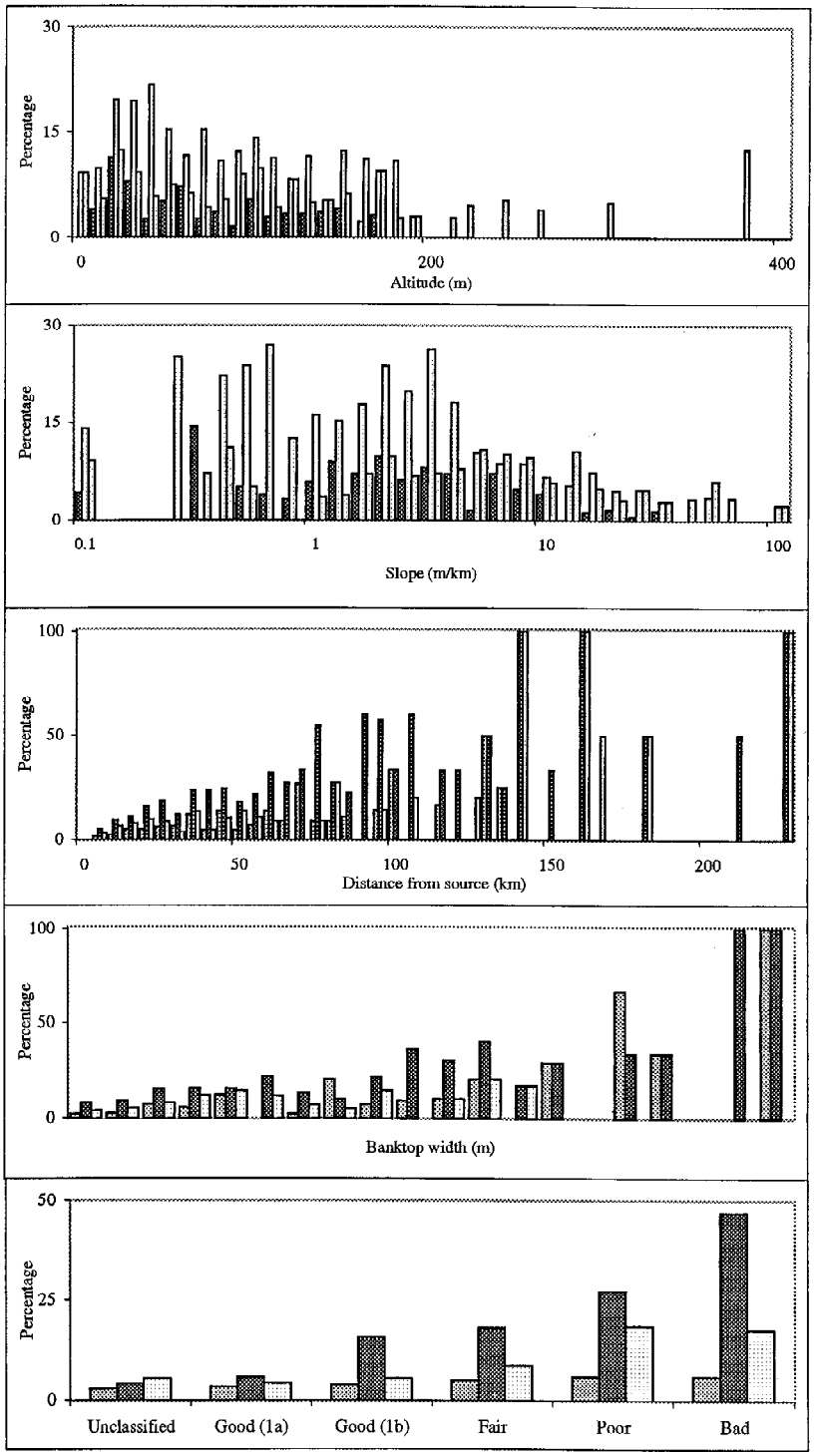

Figure 2. The percentage occurence of *Heracleum mantegazzianum, Impatiens gladulifera* and *Fallopia japonica,* in each RHS map-based dataset of (a) altitude, (b) slope of stream-bed (c) distance from source of watercourse, (d) bank-top width of watercourse in bands of 5 m to 100 m and (e) water quality class (1985), in the U.K. [key: *Heracleum mantegazzianum* (mid-stipple), *Impatiens gladulifera* (dark stipple) and *Fallopia japonica* (light stipple)].

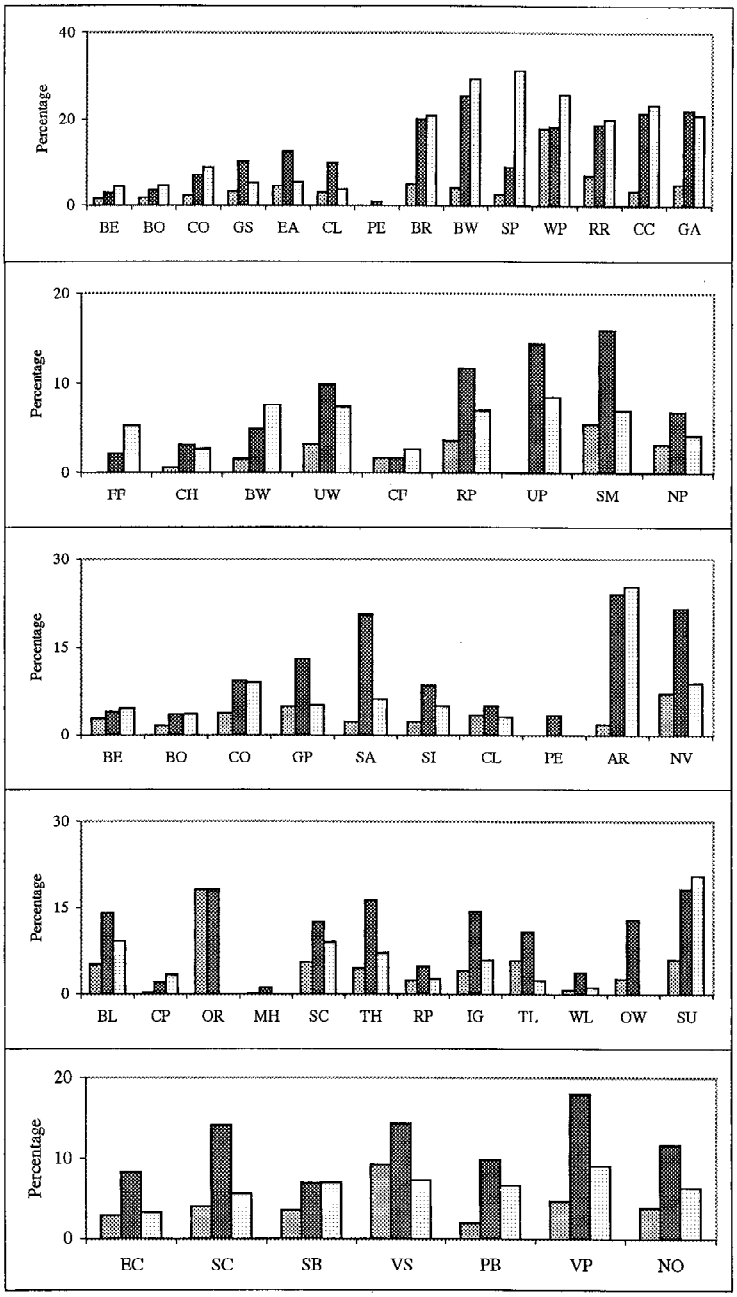

Figure 3. The percentage occurrence of *Heracleum mantegazzianum*,*Impatiens glandulifera* and *Fallopia japonica*, in each RHS type of predominant (a) bank material, (b) flow type (c) channel substrate, (d) bankside land class and (e) bank feature in the U.K. [key: *Heracleum mantegazzianum* (mid-stipple), *Impatiens glandulifera* (dark stipple) and *Fallopia japonica* (light stipple); **bank material** – bedrock (BE), boulders (BO), cobbles (CO), gravel-sand (GS), earth (EA), clay (CL), peat (PE), and artificial – brick or laid stone (BR), builders waste (BW), sheet piling (SP), wood piling (WP), rip-rap (RR), concrete (CC) and gabion (GA); **flow types** – free-fall (FF), chute-flow (CH), broken standing-waves (BW), unbroken standing waves (UW), chaotic (CF), rippled (RP), upwelling (UP), smooth (SM), and 'no perceptible flow' (NP); **channel substrate** – bedrock (BE), boulders (BO), cobbles (CO), gravel-pebble (GP), sand (SA), silt (SI), clay (CL), peat (PE), artificial (AR) and 'not visible' (NV); **bankside land class** – broadleaf or mixed woodland (BL), coniferous plantation (CP) orchard (OR), moorland or heath (MH), scrub (SC), tall herbs or rank vegetation (TH), rough or improved pasture (RP), improved or semi-improved grassland (IG), tilled land (TL), wetland (WT), open water (OW) and suburbans or urban development (SU); **bank feature** – eroding cliff (EC), stable cliff (SC), unvegetated (<50%) side bar (SB), vegetated (>50%) side bar (VS), unvegetated point bar (PB), vegetated point bar (VP) and no obvious feature (NO)].

Table 2. The percentage occurrence by year of large stands of nuisance and other species of similar habit to the three invasive plants, recorded in some bankside habitats in U.K.

Specific and common names of plant	Occurrence at RHS sites				
	E & W		Scotland	N. Ireland	U.K.
	1995	1996	1995/6	1995–96	
Urtica dioica L., Nettle	11.2	27.6	2		16.8
Pteridium aquilinum Gled. -Scop., Bracken	2.0	2.6	20		2.9
**Rhododendron ponticum* L., Rhododendron	0.6	1.4	9		1.3
Aegopodium podograria L., Ground Elder	0.2	0.2	9		0.6
Rubus fruticosa agg., Bramble,		1.2			0.5
**Symphoricarpos albus* (L.)Blake, Snowberry		0.2		2.8	0.3
**Mimulus guttatus* DC., Monkey flower		0.1	6		0.2
Prunus spinosa L., Thornbushes, Blackthorn		0.7			0.2
Petasites spp., Butterbur		0.1			0.1
**Pseudosasa* spp., Bamboo		0.1			0.1
Prunus lusitanica. Laurel,		0.2		0.4	0.1
Cirsium spp., Thistle,		0.2			0.1
Other occasional species	2.2	0.1			2.2
Numbers of sample sites	899	1064	100	246	2063

Table 3. Functions of Environment Agency areas with an interest in the problems of invasive weeds in the area

Interested parties	**Reasons**
Flood defence	Routine maintenance
	Heavy maintenance
	Capital works
	Erosion after winter die-back
	3rd party applications for development and consents
	Control of invasives at Agency installations
Hydrology	Interference with flows from excessive or decaying vegetation
	Control of invasives at Agency installations
Emergency work unit	Implications for all work on the ground.
	Control programmes
	Control of invasives at Agency installations
Environment protection	Herbicides to water – WQ (inc spray irrigation)
Water resources	Herbicides to water – WQ (inc spray irrigation)
	Impoundments (capital works)
Waste regulations	Consent to carry
	Application to landfill – management of site to prevent further spread
Customer service centre	Conditions to be attached to planning application and consent approvals.
All functions	Site visits = Awareness of problems for the Agency
Ecology	Spreading distribution and invasion of designated sites

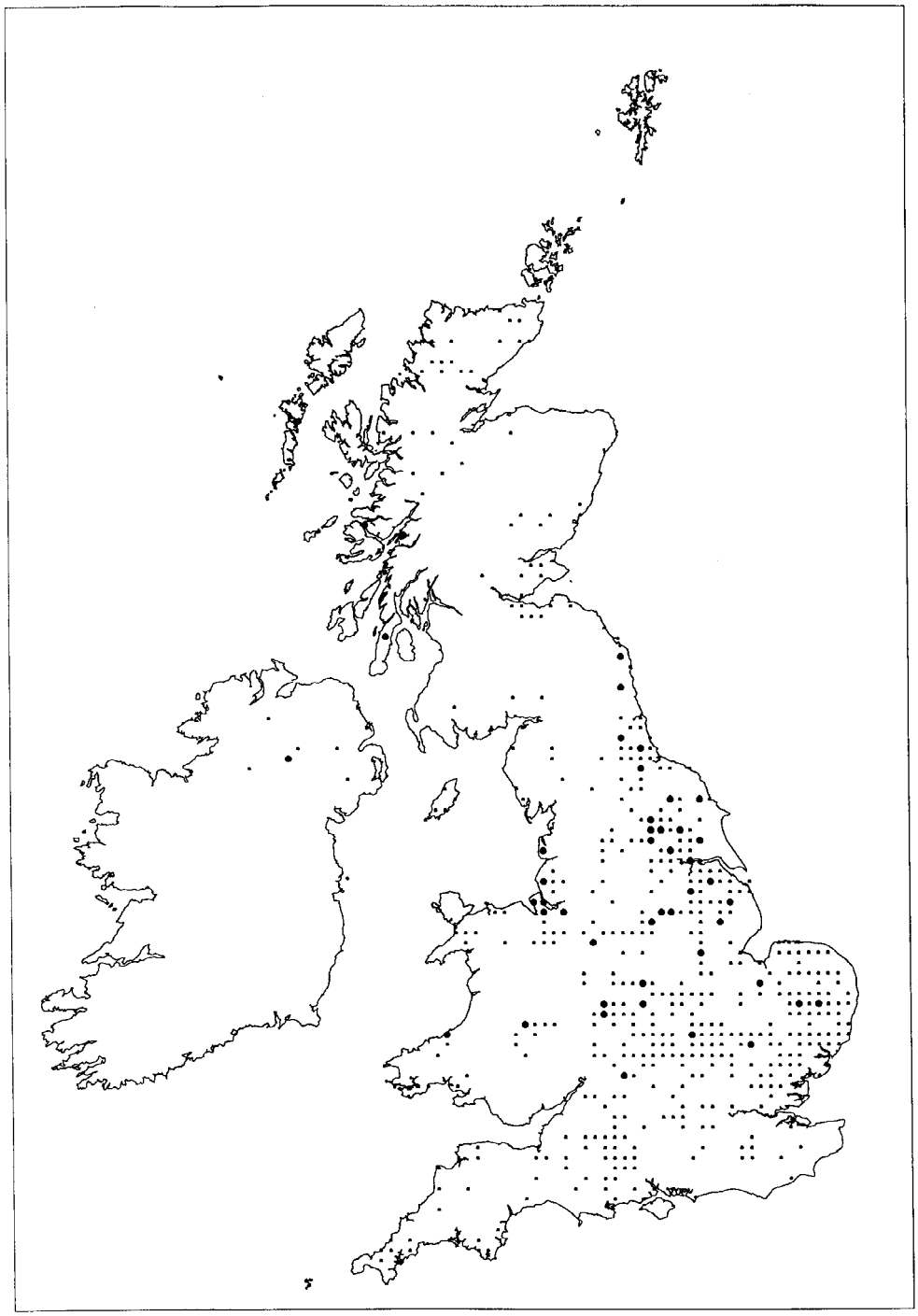

Figure 4. The occurrence of large stands of nuisance and other plants of similar habit to the three invasive plants recorded in some bankside habitats in U.K. (key: • = present; ● = extensive; data are centred on the 10 × 10 km squares).

A number of different dispersal mechanisms have been observed but not quantified, during the course, and as a result, of normal river maintenance in the Mersey catchment of north-west England. Dispersal mechanisms include:

1. by water: seeds (*I. glandulifera* and *H. mantegazzianum*) and fragments (*F. japonica*) are carried downstream, thus reducing dispersal in the upper catchment is critical for effective control;
2. by vegetation management of watercourse banks: routine maintenance of bankside vegetation by hand and machinery has a high potential for spreading at seed time (*H. mantegazzianum*, *I. glandulifera*); *F. japonica* fragments are spread by flailing;
3. by transfer of material and associated actions: by loss from footware to footpaths and roads; by vehicles, especially their wheels when travelling between on- and off-road sites; by movement of agricultural machinery from field edges to mid-field sites; by seeds during mowing, ploughing etc.;
4. by movement of animals especially cattle;
5. by recreational activities eg. golfing including footware, trolleys and vehicle wheels around sites and between sites;
6. by clearance for site management or development; on-site spoil movements; removal of affected spoil and incidental spread. In the U.K., the Wildlife and Countryside Act (1981) prohibits transfer to other wild sites; thus for capital works and removal of potentially contaminated spoil from sites, conditions should always attached to the 'consents' granted to applications for development as part of the planning process (Table 3);
7. natural dispersal by the plants includes aerial projection of seeds and wind dispersal. Seeds of *I. glandulifera* and *H. mantegazzianum* can be carried or thrown for 5 metres when enhanced by air turbulence.

The study of the control programme of the southern area of the North-west region of the Environment Agency which started in 1995 found that there were two principal problem areas for the control of *H. mantegazzianum*, the River Bollin (South of Manchester) and the River Croal (North of Bolton) through to Salford on the River Irwell, although small populations were being controlled on several other watercourses. Currently the funding for this control of c. 250 km is £30 000 per annum from the Flood Defence revenue and this rate has been projected for the three years (1999–2002) for the continuing herbicide (glyphosate) spraying programme on all river populations. A considerable amount of effort and time has also been expended in liasing with land owners, local authorities and various agencies who manage land on which this plant was growing at a distance from the river system. So to achieve meaningful success on the rivers, the off-river colonies need to be controlled with the same vigour as is being applied to bankside colonies.

Discussion and recommendations

This survey of the U.K. confirms and extends the previous data on distribution and gives detail on the habitat requirements of these three plants. Although site-specific details about colonies were not necessarily coincident, the general nature and variability of short sections of watercourse (500 m) were available for comparison. Colonies were, however, found on a wide range of habitats and although some differences between species were revealed, use of these data in predictions produced little useful data on the susceptibility of sites. The conclusion, which is pessimistic, is that almost all U.K. river banksides are susceptible to invasion by one or more of these species. This emphasises the importance of the need for having measures in place for early and appropriate control to reduce the colonisation, particularly at upstream sites and from adjacent land, by these undesirable species of plant and reveals the degree of vulnerability of river systems to wider infestation.

Large bankside stands of other nuisance species were never very common and appeared to lie in other areas of the country to those of the invasives. *Urtica dioica* was much more common than any other species being recorded by many surveyors, but its presence on banksides may relate more to adjacent land uses especially resulting from nitrogen-enrichment activities. Stands of these plants are present in the general countryside, as is *Fallopia japonica*, but do not seem to use water courses for dispersal or even as a preferred habitat.

The fundamental policy of control upon finding a new colony is for immediate and appropriate action. Firstly, following identification of a new colony, a mechanism must be in place to initiate immediate control because it is easiest and cheapest to control colonies at an early stage of their development. Secondly, the general policy should be: to contain

plant material and treat on site; to start immediately; to treat from upstream to downstream; to ensure that a long-term management policy has been formulated and which includes survey; to fully control isolated colonies; and never to consider partial or incomplete control measures.

Although it is recognised that it may be impractical to control all colonies immediately, it is important that a progressive series of measures are planned and progressed at a sufficiently rapid rate. Each species has different priorities for control, thus for:

1. *Heracleum mantegazzianum*. The main objective is to prevent flowering before taking control of the colony. Larger areas or infrequently visited sites are best treated chemically but physical control may be more environmentally-sound for small populations but only if frequent attention can be given through the year.
2. *Impatiens glandulifera*. The main objective is to prevent flowering. Chemical control is effective but hand pulling or hoeing at frequent intervals from early in the season can also be used.
3. *Fallopia japonica*. Chemical control is best in most circumstances because of the nature of the extensive root system which can readily regenerate new plant growth after physical disturbance and even after chemical application.

Specific details of control are given elsewhere (e.g. NRA, 1994).

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