

# UK Biodiversity Indicators 2018

This document supports  
B6. Pressure from invasive species

## Technical background document

Colin A. Harrower, Stephanie L. Rorke, Helen E. Roy

For further information on B6. Pressure from invasive species visit:  
<http://www.jncc.defra.gov.uk/page-4246>

For further information on the UK Biodiversity Indicators visit:  
<http://www.jncc.defra.gov.uk/page-1824>

## B6. Pressure from invasive species – technical document – May 2018

Colin A. Harrower, Stephanie L. Rorke, Helen E. Roy

Centre for Ecology & Hydrology

### Overview

There are currently 190 invasive non-native species in Great Britain that are included within the indicator for 2018. The current indicator is the result of incremental updating of an indicator initially produced in 2014. In 2014 the first indicator was created using a two stage process beginning with extent estimation using a statistical process fitted to occurrence data available through the NBN Gateway which were then validated and modified, where required, by taxonomic experts. The rationale for using a statistical process to produce extent estimates was to attempt to control for the patchy nature of the occurrence data. The expert validation in 2014 determined that the extent estimates produced algorithmically typically underestimated the true extent due to much of the occurrence data not being easily available, particularly for earlier decades, and therefore most of the estimates required revision by the taxonomic experts.

In 2015 the species list and the classification of extent (derived for the 2014 indicator) were reviewed and updated by taxonomic experts. The existing species list and the classification of extents were reviewed again in 2017 & 2018 to update the indicator. Given the inadequacies of the available occurrence data these subsequent updates of the indicator omitted the statistical estimation and the review undertaken was based on expert assessment alone.

### Species list

In 2014 the species included within the indicator was substantially expanded from the 49 species used in the [previous indicator](#) to 179. A preliminary list was produced from the GB Non-native Species Information Portal (GB NNSIP) by selecting all species in the database that were designated as having negative or strongly negative ecological effect. The information on impacts within the GB-NNSIP is not based on quantitative assessment but was a rapid assessment relying on expert opinion. Therefore, it was deemed necessary to review the initial list, again using expert opinion. In 2015 only one species was added (a clam, *Rangia cuneata*) and none were removed from the list.

In 2017 three new species, an aquatic plant (*Myriophyllum heterophyllum*) and two species of crab (*Hemigrapsus sanguineus* and *Hemigrapsus takanoi*), were added to the list, increasing the list of species included to 183. The scientific names of two species on the list were also updated in 2017 to reflect the current accepted taxonomy with *Ensis directus* being updated to *Ensis leei* and *Heterosiphonia japonica* being updated to *Dasysiphonia japonica*.

In 2018 a further seven species were added to the list increasing the number of species included in the list to 190. The seven species added were four freshwater fish (*Ameiurus melas*, *Leuciscus idus*, *Salvelinus fontinalis*, *Oncorhynchus gorboscha*), one species of ant (*Linepithema humile*), and two species of terrapin (*Emys orbicularis*, *Trachemys scripta*). In addition the scientific name for one species on the list was updated to reflect changes in taxonomy, specifically the marine algae *Neosiphonia harveyi* was renamed as *Melanothamnus harveyi*.

### Update and review in 2015, 2017 & 2018

As mentioned previously for the reviews (2015, 2017 and 2018) the modelling process, originally conducted in 2014, was not repeated but rather the species lists and extent of occurrence classifications were reviewed by taxonomic experts. For these reviews the taxonomic experts use the latest information to determine whether the existing classification of extent were still applicable or if they needed updating.

In 2015 the terrestrial and freshwater plant species were subject to extensive review using additional data holdings available through the Botanical Society of Britain and Ireland (BSBI). The indicator extent classifications were reviewed by BSBI experts and the extent scores adjusted if the botanical experts felt it was justified. This resulted in changes to the classification of 48 plant species across all decades, 27 of which had amendments in the last decade. These amendments were mainly decreases in extent but with one species (*Egeria densa*) assigned an increase in extent over one decade. Three plant species were considered to have decreased in extent by two categories within the classification. Consequently the overall net change to the indicator in 2015 was a decrease in extent classifications.

In the 2017 review the alterations were primarily limited to the marine species, with a few species going up an extent category in the most recent decade. For example, *Urosalpinx cinera*, had the extent category for the three last decades (1990s, 2000s and 2010s) increased from level 1 to level 2 while the remaining decades (1960s, 1970s, 1980s) were kept at level 1. For this species there is a sparsity of records, particularly pre-1990 and also in the last couple of years, making determining the historical or current extent difficult. Experts at the Marine Biological Association considered that the range reported post-1994 suggested multiple populations were established more than 10km from the suspected source therefore warranting an upgrade in extent. The lack of data pre-1990 makes it difficult to determine what the extent was during this period therefore it was kept at the lowest category. It was noted however that the species was adversely affected by tri-butyl tin pollution (used on small vessels and banned in the UK in 1987), might account for a period of genuine rarity before the 1990s however it is also possible that it was simply under-recorded/reported in this period.

During the 2018 review seven additional species were added to the list. A few of these species; two terrapin species (*Trachemys scripta* and *Emys orbicularis*) and 3 species of freshwater fish (*Ameiurus melas*, *Leuciscus idus*, *Salvelinus fontinalis*); have been present in the UK for several decades but were previously excluded from the list as they are not considered to be established, e.g. not reproducing in the wild and therefore not self-sustaining. This year it was decided that as species such as these fall within extent level 1 (Not or scarcely established), are often long-term residents, and are believed to be having a negative impact on native biodiversity that they should be included in the list. The addition of these species will have had no effect on the main indicator figure (B6i) which only shows numbers of species in extent levels 3 and 4, but will have increased the numbers of species in extent level 1 across all decades in the underlying data and also in the supplemental figure (B6ii). Another species of freshwater fish (*Oncorhynchus gorboscha*) was also added to the list. This species had occasionally been recorded in the UK historically (e.g. a few records in 1970s) has recently been recorded a number of times in different locations in Scotland including the capture of spent/post-spawning females suggesting possible reproduction in the wild. The final addition to the list was the ant *Linepithema humile* for which a colony was found in Fulham.

The review of the existing species on the list in 2018 resulted in the extent levels for the current decade being increased for a small number of freshwater and terrestrial species based on the evaluation of new data. In a limited number of cases the classifications for one or more decades were modified based on a re-evaluation of the existing data rather than the

addition of any additional data. Some of these reassessments led to an increase (e.g. *Rattus rattus*, *Oxyura jamaicensis*, *Spiraea salicifolia x douglasii* = *S. x pseudosalicifolia*) in one or more of the decadal time periods, while other (e.g. *Amelanchier lamarckii*, *Spiraea douglasii*, *Spiraea salicifolia*) led to a reduction in the extent level. These changes will have had an effect upon the indicator for these two environments, particularly for the current decade.

### Invasive non-native species included in Indicator in 2018

Environment	Common Name	Scientific name
Freshwater	Black bullhead	<i>Ameiurus melas</i>
Freshwater	Turkish crayfish	<i>Astacus leptodactylus</i>
Freshwater	water fern	<i>Azolla filiculoides</i>
Freshwater	goldfish	<i>Carassius auratus</i>
Freshwater	a mollusc	<i>Corbicula fluminea</i>
Freshwater	Northern river crangonyctid	<i>Crangonyx pseudogracilis</i>
Freshwater	New Zealand pigmyweed	<i>Crassula helmsii</i>
Freshwater	demon shrimp	<i>Dikerogammarus haemobaphes</i>
Freshwater	killer shrimp	<i>Dikerogammarus villosus</i>
Freshwater	quagga mussel	<i>Dreissena bugensis</i>
Freshwater	zebra mussel	<i>Dreissena polymorpha</i>
Freshwater	large-flowered waterweed	<i>Egeria densa</i>
Freshwater	Canadian waterweed	<i>Elodea canadensis</i>
Freshwater	Nuttall's waterweed	<i>Elodea nuttallii</i>
Freshwater	European pond terrapin	<i>Emys orbicularis</i>
Freshwater	bloody-red mysid	<i>Hemimysis anomala</i>
Freshwater	floating pennywort	<i>Hydrocotyle ranunculoides</i>
Freshwater	a polychaete	<i>Hypania invalida</i>
Freshwater	Italian alpine newt	<i>Ichthyosaura alpestris</i>
Freshwater	curly waterweed	<i>Lagarosiphon major</i>
Freshwater	least duckweed	<i>Lemna minuta</i>
Freshwater	pumpkinseed	<i>Lepomis gibbosus</i>
Freshwater	sunbleak	<i>Leucaspius delineatus</i>
Freshwater	Orfe	<i>Leuciscus idus</i>
Freshwater	American bullfrog	<i>Lithobates catesbeianus</i>
Freshwater	Uruguayan hampshire-purslane	<i>Ludwigia grandiflora</i>
Freshwater	parrot's feather	<i>Myriophyllum aquaticum</i>
Freshwater	Broadleaf watermilfoil	<i>Myriophyllum heterophyllum</i>
Freshwater	Pink salmon	<i>Oncorhynchus gorbuscha</i>
Freshwater	rainbow trout	<i>Oncorhynchus mykiss</i>
Freshwater	spinycheek crayfish	<i>Orconectes limosus</i>
Freshwater	virile crayfish	<i>Orconectes virilis</i>
Freshwater	signal crayfish	<i>Pacifastacus leniusculus</i>
Freshwater	marsh frog	<i>Pelophylax ridibundus</i>
Freshwater	Jenkins' spire snail	<i>Potamopyrgus antipodarum</i>
Freshwater	white river crayfish	<i>Procambarus acutus</i>
Freshwater	red swamp crayfish	<i>Procambarus clarkii</i>

## B6. Pressure from invasive species

Environment	Common Name	Scientific name
Freshwater	topmouth gudgeon	<i>Pseudorasbora parva</i>
Freshwater	a mollusc	<i>Rangia cuneata</i>
Freshwater	duck-potato	<i>Sagittaria latifolia</i>
Freshwater	Brook charr	<i>Salvelinus fontinalis</i>
Freshwater	zander	<i>Sander lucioperca</i>
Freshwater	wels catfish	<i>Siluris glanis</i>
Freshwater	Red-eared terrapin	<i>Trachemys scripta</i>
Freshwater	Italian crested newt	<i>Triturus carniflex</i>
Freshwater	African clawed frog	<i>Xenopus laevis</i>
Marine	swim-bladder nematode	<i>Anguillicoloides crassus</i>
Marine	harpoon weed (algae)	<i>Asparagopsis armata</i>
Marine	compass sea squirt	<i>Asterocarpa humilis</i>
Marine	an acorn barnacle	<i>Austrominius modestus</i>
Marine	algae	<i>Bonnemaisonia hamifera</i>
Marine	a tunicate	<i>Botrylloides diegensis</i>
Marine	a tunicate	<i>Botrylloides violaceus</i>
Marine	Japanese skeleton shrimp	<i>Caprella mutica</i>
Marine	green sea fingers	<i>Codium fragile subsp. fragile</i>
Marine	a coelenterate	<i>Cordylophora caspia</i>
Marine	a tunicate	<i>Corella eumyota</i>
Marine	Pacific oyster	<i>Crassostrea gigas</i>
Marine	slipper limpet	<i>Crepidula fornicata</i>
Marine	algae	<i>Dasysiphonia japonica</i>
Marine	a tunicate	<i>Didemnum vexillum</i>
Marine	a crustacean	<i>Dyspanopeus sayi</i>
Marine	a mollusc	<i>Ensis leei</i>
Marine	Chinese mitten crab	<i>Eriocheir sinensis</i>
Marine	an annelid	<i>Ficopomatus enigmaticus</i>
Marine	an amphipod	<i>Gammarus tigrinus</i>
Marine	algae	<i>Grateloupia turuturu</i>
Marine	Asian shore crab	<i>Hemigrapsus sanguineus</i>
Marine	brush-clawed shore crab	<i>Hemigrapsus takanoi</i>
Marine	an annelid	<i>Hydroides elegans</i>
Marine	an annelid	<i>Hydroides ezoensis</i>
Marine	an amphipod	<i>Monocorophium sextonae</i>
Marine	a mollusc	<i>Mytilopsis leucophaeata</i>
Marine	algae	<i>Melanothamnus harveyi</i>
Marine	dwarf crab	<i>Rhithropanopeus harrisi</i>
Marine	wire weed	<i>Sargassum muticum</i>
Marine	a bryozoan	<i>Schizoporella japonica</i>
Marine	leathery sea squirt	<i>Styela clava</i>
Marine	a bryozoan	<i>Tricellaria inopinata</i>
Marine	Japanese kelp, wakame	<i>Undaria pinnatifida</i>
Marine	American sting winkle	<i>Urosalpinx cinerea</i>

Environment	Common Name	Scientific name
Marine	a bryozoan	<i>Watersipora subatra</i>
Terrestrial	pirri-pirri-bur	<i>Acaena novae-zelandiae</i>
Terrestrial	bear's-breech	<i>Acanthus mollis</i>
Terrestrial	tree-of-heaven	<i>Ailanthus altissima</i>
Terrestrial	mandarin duck	<i>Aix galericulata</i>
Terrestrial	garden lady's-mantle	<i>Alchemilla mollis</i>
Terrestrial	red-legged partridge	<i>Alectoris rufa</i>
Terrestrial	few-flowered garlic	<i>Allium paradoxum</i>
Terrestrial	rosy garlic	<i>Allium roseum</i>
Terrestrial	Egyptian goose	<i>Alopochen aegyptiacus</i>
Terrestrial	juneberry	<i>Amelanchier lamarckii</i>
Terrestrial	great brome	<i>Anisantha diandra</i>
Terrestrial	berberis sawfly	<i>Arge berberidis</i>
Terrestrial	New Zealand flatworm	<i>Arthurdendyus triangulatus</i>
Terrestrial	late michaelmas-daisy	<i>Aster laevis x novi-belgii = A. x versicolor</i>
Terrestrial	narrow-leaved michaelmas-daisy	<i>Aster lanceolatus</i>
Terrestrial	common michaelmas-daisy	<i>Aster novi-belgii x lanceolatus = A. x salignus</i>
Terrestrial	a flatworm	<i>Australoplana sanguinea</i>
Terrestrial	Canada goose	<i>Branta canadensis</i>
Terrestrial	eagle owl	<i>Bubo bubo</i>
Terrestrial	Buddleia	<i>Buddleja davidii</i>
Terrestrial	heath star moss	<i>Campylopus introflexus</i>
Terrestrial	feral goat	<i>Capra hircus</i>
Terrestrial	hottentot-fig	<i>Carpobrotus edulis</i>
Terrestrial	sika	<i>Cervus nippon</i>
Terrestrial	bladder-senna	<i>Colutea arborescens</i>
Terrestrial	red-osier dogwood	<i>Cornus sericea</i>
Terrestrial	wall cotoneaster	<i>Cotoneaster horizontalis</i>
Terrestrial	entire-leaved cotoneaster	<i>Cotoneaster integrifolius</i>
Terrestrial	Himalayan cotoneaster	<i>Cotoneaster simonsii</i>
Terrestrial	montbretia	<i>Crocasmia aurea x pottsii (C. x crocosmiiflora)</i>
Terrestrial	fallow deer	<i>Dama dama</i>
Terrestrial	thorn-apple	<i>Datura stramonium</i>
Terrestrial	purple dewplant	<i>Disphyma crassifolium</i>
Terrestrial	russian-vine	<i>Fallopia baldschuanica</i>
Terrestrial	black-bindweed	<i>Fallopia convolvulus</i>
Terrestrial	Japanese knotweed	<i>Fallopia japonica</i>
Terrestrial	plant hybrid	<i>Fallopia japonica x sachalinensis = F. x bohemica</i>
Terrestrial	giant knotweed	<i>Fallopia sachalinensis</i>
Terrestrial	feral cat	<i>Felis catus</i>
Terrestrial	shallon	<i>Gaultheria shallon</i>
Terrestrial	edible dormouse	<i>Glis glis</i>
Terrestrial	rhododendron leafhopper	<i>Graphocephala fennahi</i>
Terrestrial	Brazilian giant-rhubarb	<i>Gunnera manicata</i>

## B6. Pressure from invasive species

Environment	Common Name	Scientific name
Terrestrial	giant-rhubarb	<i>Gunnera tinctoria</i>
Terrestrial	harlequin ladybird	<i>Harmonia axyridis</i>
Terrestrial	giant hogweed	<i>Heracleum mantegazzianum</i>
Terrestrial	bluebell	<i>Hyacinthoides non-scripta x hispanica = H. x massartiana</i>
Terrestrial	water deer	<i>Hydropotes inermis</i>
Terrestrial	dump fly	<i>Hydrotaea aenescens</i>
Terrestrial	Himalayan balsam	<i>Impatiens glandulifera</i>
Terrestrial	a flatworm	<i>Kontikia ventrolineata</i>
Terrestrial	Western green lizard	<i>Lacerta bilineata</i>
Terrestrial	yellow archangel	<i>Lamiastrum galeobdolon subsp. argentatum</i>
Terrestrial	an ant	<i>Lasius neglectus</i>
Terrestrial	Argentine ant	<i>Linepithema humile</i>
Terrestrial	American skunk-cabbage	<i>Lysichiton americanus</i>
Terrestrial	potato aphid	<i>Macrosiphum euphorbiae</i>
Terrestrial	blotched monkey flower	<i>Mimulus luteus</i>
Terrestrial	wireplant	<i>Muehlenbeckia complexa</i>
Terrestrial	Reeve's muntjac	<i>Muntiacus reevesi</i>
Terrestrial	house mouse	<i>Mus domesticus</i>
Terrestrial	ferret	<i>Mustela furo</i>
Terrestrial	American mink	<i>Mustela vison</i>
Terrestrial	monk parakeet	<i>Myiopsitta monachus</i>
Terrestrial	European rabbit	<i>Oryctolagus cuniculus</i>
Terrestrial	Bermuda-buttercup	<i>Oxalis pes-caprae</i>
Terrestrial	ruddy duck	<i>Oxyura jamaicensis</i>
Terrestrial	Virginia-creeper	<i>Parthenocissus quinquefolia</i>
Terrestrial	green alkanet	<i>Pentaglottis sempervirens</i>
Terrestrial	lesser knotweed	<i>Persicaria campanulata</i>
Terrestrial	Himalayan knotweed	<i>Persicaria wallichii</i>
Terrestrial	white butterbur	<i>Petasites albus</i>
Terrestrial	winter heliotrope	<i>Petasites fragrans</i>
Terrestrial	pheasant	<i>Phasianus colchicus</i>
Terrestrial	Austrian pin	<i>Pinus nigra</i>
Terrestrial	maritime pine	<i>Pinus pinaster</i>
Terrestrial	common wall lizard	<i>Podarcis muralis</i>
Terrestrial	spartina planthopper	<i>Prokelisia marginata</i>
Terrestrial	cherry laurel	<i>Prunus laurocerasus</i>
Terrestrial	Portugal laurel	<i>Prunus lusitanica</i>
Terrestrial	rum cherry	<i>Prunus serotina</i>
Terrestrial	biliary parasite	<i>Pseudamphistomum truncatum</i>
Terrestrial	arrow bamboo	<i>Pseudosasa japonica</i>
Terrestrial	rose-ringed parakeet	<i>Psittacula krameri</i>
Terrestrial	horse chestnut scale	<i>Pulvinaria regalis</i>
Terrestrial	Turkey oak	<i>Quercus cerris</i>
Terrestrial	evergreen oak	<i>Quercus ilex</i>

## B6. Pressure from invasive species

Environment	Common Name	Scientific name
Terrestrial	brown rat	<i>Rattus norvegicus</i>
Terrestrial	black rat	<i>Rattus rattus</i>
Terrestrial	rhododendron	<i>Rhododendron ponticum</i>
Terrestrial	false-acacia	<i>Robinia pseudoacacia</i>
Terrestrial	Dutch rose	<i>Rosa 'Hollandica'</i>
Terrestrial	Japanese rose	<i>Rosa rugosa</i>
Terrestrial	Purple pitcherplant	<i>Sarracenia purpurea</i>
Terrestrial	broad-leaved bamboo	<i>Sasa palmata</i>
Terrestrial	hairy bamboo	<i>Sasaella ramosa</i>
Terrestrial	Eastern grey squirrel	<i>Sciurus carolinensis</i>
Terrestrial	alexanders	<i>Smyrniium olusatrum</i>
Terrestrial	Canadian goldenrod	<i>Solidago canadensis</i>
Terrestrial	Spiraea	<i>Spiraea</i>
Terrestrial	Billard's bridewort	<i>Spiraea alba x douglasii = S. x billardii</i>
Terrestrial	steeple-bush	<i>Spiraea douglasii</i>
Terrestrial	bridewort	<i>Spiraea salicifolia</i>
Terrestrial	confused bridewort	<i>Spiraea salicifolia x douglasii = S. x pseudosalicifolia</i>
Terrestrial	snowberry	<i>Symphoricarpos albus</i>
Terrestrial	oak processionary	<i>Thaumetopoea processionea</i>
Terrestrial	lesser periwinkle	<i>Vinca minor</i>
Terrestrial	aesculapian snake	<i>Zamensis longissimus</i>



## Analytical estimation of Area of Extent (AoE) used in 2014

### Data used

The occurrence data used in the statistical analyses conducted in 2014 were obtained from the National Biodiversity Network (NBN) Gateway, downloaded in October 2014. The analysis used all data that were publicly available from the NBN Gateway having a minimum resolution of 10km. The extracted occurrence data were divided into 10 year time slices to enable the areas of extent to be calculated independently for each decade. To be included in a dataset the start date and end date of a record needed to fall within the respective time period, therefore records which span one or more time periods were excluded.

### Analytical method

The process used to calculate the area of extent is based upon the approach recently used to develop the England Vascular Plant Red List (Stroh *et al.*, 2014). Three different methods were used to determine extent of occurrence; (1) determining the number of distinct 10km squares the species has been recorded within and then calculating the total area of these 10km squares; (2) the Minimum Convex Polygon (MCP); and (3) the alpha hull.

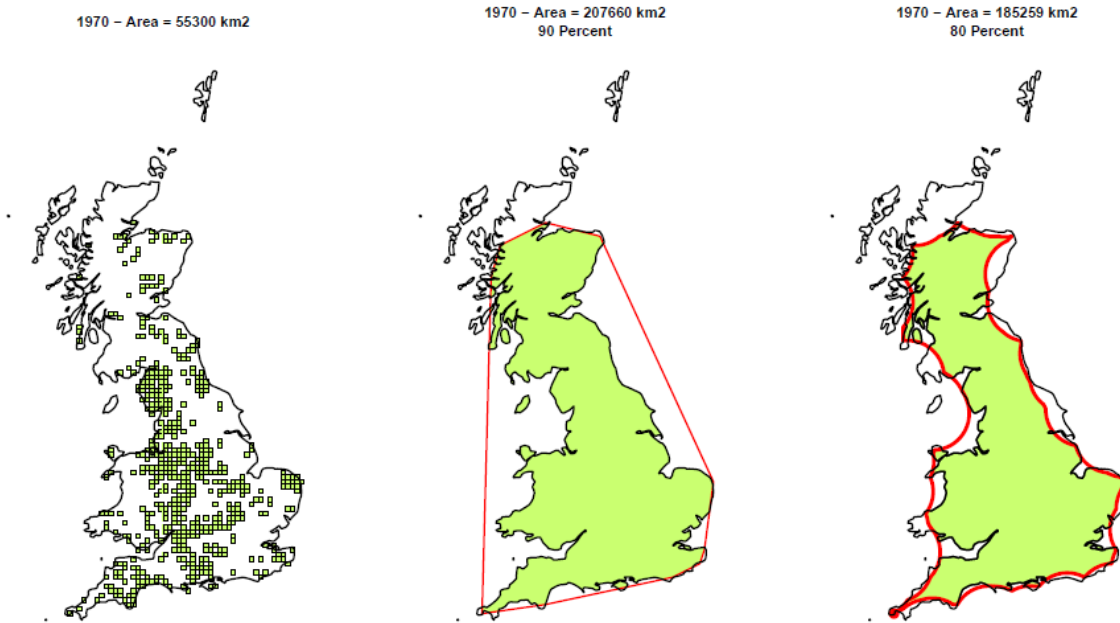
The first of these methods involves determining for each decade the number of distinct OSGB 10km squares that contained occurrence data for each species and then the total area was obtained by summing the area of these 10km squares.

The second method involved calculating the MCP for the occurrence data for each decade. The MCP is defined as the smallest polygon in which no internal angle exceeds 180 degrees and which contains all the sites of occurrence. The MCP is often criticised due to the tendency for non-suitable areas to be included within the shape, especially when fitted to areas in which there are large areas of unsuitable habitat surrounded by suitable habitat. To reduce the extent to which this problem affected the areas estimated, a secondary polygon was created by intersecting the MCP polygon with the land mass of Great Britain (or a 50km wide coastal region in the case of marine species) and the area (in km<sup>2</sup> and also as a percentage of the total land/marine buffer area of Great Britain) of this polygon was then calculated.

The third method fitted an alpha hull to the occurrence data for each decade. Alpha hulls are a generalisation of the convex polygon and have been suggested to be more suitable to species distributions than Minimum Convex Polygon, especially for irregularly shaped species ranges (Burgman & Fox, 2003). Alpha hulls are created by a Delaunay triangulation of the data points (joining all points so that no lines intersect between points) and then selectively removing lines from this triangulation based on the value of a parameter  $\alpha$ . The smaller the value of  $\alpha$  the finer the resolution of the hull produced. As  $\alpha$  increases the alpha hull will approach the MCP. There is no ideal value of  $\alpha$ , rather the choice depends upon the quality of the data and the aims of the study. For the indicator analyses an  $\alpha$  value of 80,000 was used. In order to minimise the inclusion of unsuitable habitat the alpha hull was also intersected with the land mass of Great Britain (or 50km wide coastal region for marine species) to produce a new hull for which the area (in km<sup>2</sup> and also as a percentage of total land/marine buffer area of Great Britain) was calculated.

### Expert validation & modification

A series of maps and area estimates was produced for each invasive non-native species from these analyses. An example of the maps produced, in this case *Elodea canadensis*, is given in Figure 1 below.



**Figure 1** Example area of extent maps for *Elodea canadensis* using data from the 1970-1979 time period. The first map shows the 10km occurrence data, the second map shows the Minimum Convex Polygon (outlined by a red line) and its intersection with the land (green filled region) and third map shows the alpha hull (outlined by a red line) and its intersection with the land (green filled region). The labels above each map give the total area of distinct 10km squares, the area of the MCP/GB land intersection and the area of the alpha hull/GB land intersection respectively.

The species maps and area estimates were circulated to the relevant taxonomic or environmental experts along with a spreadsheet containing initial classifications, within the four extent categories used in B6ii, of the decadal distributions for each species. The initial classification was achieved using the area estimates from the alpha hull / GB intersection polygon because this resulted in the most conservative estimates which provided a guide for the experts. Experts were asked to review the maps and area estimates, alongside any additional data sources available to them where relevant, to determine whether the classification in the spreadsheet represented an accurate picture of the species distribution for each decade. Where the experts deemed a category value to be a poor representation they were asked to modify the category to the value they considered to accurately reflect the extent. It is these expert modified classifications of extent that were used in final figures present in the indicator.

## References

Burgman, M.A., & Fox, J.C. (2003) Bias in species range estimates from minimum convex polygons: implications for conservation and options for improved planning. *Animal Conservation*, 6(01), 19–28.

Stroh, P.A., Leach, S.J., August, T.A., Walker, K.J., Pearman, D.A., Rumsey, F.J., Harrower, C.A., Fay, M.F., Martin, J.P., Pankhurst, T., Preston, C.D. & Taylor, I. (2014) A Vascular Plant Red List for England. Botanical Society of Britain and Ireland, Bristol.