Information about GB Non-native Species Risk Assessments

The Convention on Biological Diversity (CBD) emphasises the need for a precautionary approach towards non-native species where there is often a lack of firm scientific evidence. It also strongly promotes the use of good quality risk assessment to help underpin this approach. The GB risk analysis mechanism has been developed to help facilitate such an approach in Great Britain. It complies with the CBD and reflects standards used by other schemes such as the Intergovernmental Panel on Climate Change, European Plant Protection Organisation and European Food Safety Authority to ensure good practice.

Risk assessments, along with other information, are used to help support decision making in Great Britain. They do not in themselves determine government policy.

The Non-native Species Secretariat (NNSS) manages the risk analysis process on behalf of the GB Programme Board for Non-native Species. Risk assessments are carried out by independent experts from a range of organisations. As part of the risk analysis process risk assessments are:

- Completed using a consistent risk assessment template to ensure that the full range of issues recognised in international standards are addressed.
- Drafted by an independent expert on the species and peer reviewed by a different expert.
- Approved by an independent risk analysis panel (known as the Non-native Species Risk Analysis Panel or NNRAP) only when they are satisfied the assessment is fit-for-purpose.
- Approved for publication by the GB Programme Board for Non-native Species.
- Placed on the GB Non-native Species Secretariat (NNSS) website for a three month period of public comment.
- Finalised by the risk assessor to the satisfaction of the NNRAP.

To find out more about the risk analysis mechanism go to: www.nonnativespecies.org

Common misconceptions about risk assessments

To address a number of common misconceptions about non-native species risk assessments, the following points should be noted:

- Risk assessments consider only the risks posed by a species. They do not consider the practicalities, impacts or other issues relating to the management of the species. They therefore cannot on their own be used to determine what, if any, management response should be undertaken.
- Risk assessments are about negative impacts and are not meant to consider positive impacts that may also occur. The positive impacts would be considered as part of an overall policy decision.
- Risk assessments are advisory and therefore part of the suite of information on which policy decisions are based.
- Completed risk assessments are not final and absolute. Substantive new scientific evidence may prompt a re-evaluation of the risks and/or a change of policy.

Period for comment

Draft risk assessments are available for a period of three months from the date of posting on the NNSS website*. During this time stakeholders are invited to comment on the scientific evidence which underpins the assessments or provide information on other relevant evidence or research that may be available. Relevant comments are collated by the NNSS and sent to the risk assessor. The assessor reviews the comments and, if necessary, amends the risk assessment. The final risk assessment is then checked and approved by the NNRAP.

*risk assessments are posted online at:
https://secure.fera.defra.gov.uk/nonnativespecies/index.cfm?sectionid=51
comments should be emailed to nnss@fera.gsi.gov.uk

GB NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME

For more information visit: www.nonnativespecies.org

	Name of Organism:	***Pacifastacus leniusculus* - Signal crayfish**	
	Objectives:	Assess the risks associated with this species in GB	
	Version:	FINAL 29/03/11	
N	**QUESTION**	**RESPONSE**	**COMMENT**
1	What is the reason for performing the Risk Assessment?		Signal crayfish were first introduced into England for aquaculture in the late 1970s and have spread extensively since then. The species has been on Schedule 9 of the Wildlife and Countryside Act as a pest species since 1992. The Keeping of Live Fish (Crayfish) Regulations 1996 (SI 1996 No 1104) should prevent it being spread to "no-go" areas in England and Wales and Prohibition of Keeping of Live Fish (Crayfish) (Scotland) Order 1996 should have stopped it spreading there. A licence is not required for keeping of signal crayfish in parts of England that in 1996 had many wild populations. Exempt areas were identified by postcode and these covered much of southern and eastern England. It was unable to address established populations in other areas in which any introductions were banned by the Regulations. In practice, the species is still increasing its geographic range through natural expansion in river catchments and canals and some deliberate and accidental introductions within the Risk Area, especially in Scotland. The risk assessment considers likelihood of further spread and risks to other species and habitats.
2	What is the Risk Assessment area?	GB	
3	Does a relevant earlier Risk Assessment exist?	NO OR UNKNOWN (Go to 5)	
4	If there is an earlier Risk Assessment is it still entirely valid, or only partly valid?		
	Stage 2: Organism Risk Assessment SECTION A: Organism Screening		
5	Identify the Organism. Is the organism clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	YES (Give the full name & Go to 7)	Animalia, Arthropoda, Crustacea, Astacida, Astacidae, *Pacifastacus leniusculus* (Dana, 1852).
6	If not a single taxonomic entity, can it be redefined?		
7	Is the organism in its present range known to be invasive, i.e. to threaten species, habitats or ecosystems?	YES (Go to 9)	
8	Does the organism have intrinsic attributes that indicate that it could be invasive, i.e. threaten species, habitats or ecosystems?	YES or UNCERTAIN (Go to 9)	
9	Does the organism occur outside effective containment in the Risk Assessment area?	YES (Go to 10)	Individuals can easily escape from most or all waterbodies where populations establish, because they can climb very well through or over mesh screens, through culverts and even over land, (Holdich *et al.* , 1995). Once established in ponds or streams efforts to eradicate them by trapping or intensive manual removal have been consistently unsuccessful and have not prevented spread (Peay and Hiley, 2001; Holdich *et al.* , 1999); many attempts in period from early 1990s to 2007 ongoing. Extensive expansion of range from first introduction in mid-1970s to date, ongoing (Sibley *et al.* , 2002).
10	Is the organism widely distributed in the Risk Assessment area?	YES & Future conditions/management procedures/policies are being considered (Go to 19)	The ranging is increasing in Britain (Sibley, 2003; unpublished data Martin Christmas, Environment Agency, February 2007).
11	Does at least one species (for herbivores, predators and parasites) or suitable habitat vital for the survival, development and multiplication of the organism occur in the Risk Assessment area, in the open, in protected conditions or both?	YES (Go to 12)	A wide range of suitable habitat is available in Britain in all but the most mountainous, acidic areas or badly polluted areas. There is no limit on the available food sources for this omnivorous species.
12	Does the organism require another species for critical stages in its life cycle such as growth (e.g. root symbionts), reproduction (e.g. pollinators; egg incubators), spread (e.g. seed dispersers) and transmission, (e.g. vectors)?	NO (Go to 14)	
13	Is the other critical species identified in question 12 (or a similar species that may provide a similar function) present in the Risk Assessment area or likely to be introduced? If in doubt, then a separate assessment of the probability of introduction of this species may be needed.		
14	Does the known geographical distribution of the organism include ecoclimatic zones comparable with those of the Risk Assessment area or sufficiently similar for the organism to survive and thrive?	YES (Go to 16)	Signal crayfish originated in northwestern USA (Oregon/Washington), but has been very widely distributed across biogeographic regions within the USA, in Japan and across Europe from Spain and Portugal to Finland and other Baltic states and increasingly recorded in Eastern Europe (Souty-Grosset *et al.* 2006); in Britain there are records from sites from Cornwall to Highland Region. The whole of Risk Assessment area is within the ecoclimatic zone for signal crayfish.
15	Could the organism establish under protected conditions (e.g. glasshouses, aquaculture facilities, terraria, zoological gardens) in the Risk Assessment area?	YES (Go to 16)	Present in a small number of commercial fish farms, though most populations are in seminatural ponds, lakes, rivers and canals with no containment.
16	Has the organism entered and established viable (reproducing) populations in new areas outside its original range, either as a direct or indirect result of man's activities?	YES (Go to 17)	First introduced into fish farms at about 300 sites in late 1970s to 1990s. Commercial production generally failed, registered farms were down to 99 in 1994 (Holdich *et. al.* , 1995) and to 5 by 2006 (Alistair Scott, CEFAS, pers. comm., 2006). Escaped populations thrived and expanded however. Wild harvest continues and is considered to be the major source of further introductions, together with a smaller proportion of accidental introduction with fish.
17	Can the organism spread rapidly by natural means or by human assistance?	YES (Go to 18)	It is spreading by natural means in all watercourses to which it has been introduced or escaped. Deliberate human introduction in banned areas is difficult to prove but does occur, e.g. in Yorkshire an introduction to a headwater stream in a wood by the holders of shooting rights *c.* 2000 (Neil Guthrie, Environment Agency, pers. comm.), in North Esk catchment Aberdeenshire by a fishery manager (unsuccessful prosecution brought, failed on legal error); in River Greta, Cumbria by would-be wild harvesters (Gail Butterill, Environment Agency, pers. comm.), in Huddersfield by owners of a golf course for weed control.

18	Could the organism as such, or acting as a vector, cause economic, environmental or social harm in the Risk Assessment area?	YES OR UNCERTAIN (Go to 19)	Harm is certain. Rapid decline in indigenous population of white-clawed crayfish *Austropotamobius pallipes* is principally due to signal crayfish, through direct competition and due to transmission of lethal crayfish plague *Aphanomyces astaci* (Holdich *et al.*, 2004). Impacts on other species and habitats also occur confirmed in Britain for benthic fish (Guan and Wiles, 1997), aquatic invertebrates (Crawford *et al.*, 2006) and macrophytes (Peay observation after biocide use), also elsewhere in Europe on macrophytes (Nystrom and Strand, 1996), invertebrates and fish (Nystrom *et al.*, 1999, Stenroth and Nystrom, 2003).
19	This organism could present a risk to the Risk Assessment area and a detailed risk assessment is appropriate.	Detailed Risk Assessment Appropriate GO TO SECTION B	
20	This organism is not likely to be a harmful non-native organism in the Risk Assessment area and the assessment can stop.		

B	SECTION B: Detailed assessment of an organism's probability of entry, establishment and spread and the magnitude of the economic, environmental and social consequences			
	Probability of Entry	**RESPONSE**	**UNCERTAINTY**	**COMMENT**
1.1	List the pathways that the organism could be carried on. How many relevant pathways can the organism be carried on?	moderate number - 2	LOW - 0	Known pathways are: 1. deliberate introduction (for wild harvest, fish food or weed control - known examples of all of these, and possibly by children); 2. accidental introduction with stocked fish - suspected cases, but difficult to prove/disprove; 3. inter-catchment spread via canals - locks are not a long-term barrier, even for white-clawed crayfish (various examples of populations in canals in England already); 4. natural colonisation of tributaries from main rivers - 100s examples; 5. accidental or deliberate release of live crayfish intended for food in restaurants - potential but not proven; 6. occasional movement by predators - a few documented cases, e.g. heron dropped live crayfish on householders roof in Nuneaton, it survived and was released into "safe" SSSI for white-clawed crayfish by an ignorant RSPCA officer in July 2005; another case signal crayfish found walking down a street in Glossop, > 500 m from nearest possible site.
1.2	Choose one pathway from the list of pathways selected in 1.1 to begin the pathway assessments.	introduction with fish.		Accidental stocking with fish is a pathway. An alternative is deliberate, illegal, stocking for wild harvest - public interest in this increased in 2006, 2007 and this may now be the main reason for new introductions. The "F-Word" television programme featuring signal crayfish led to over 700 public enquiries to the Environment Agency about stocking crayfish, the highest number recorded in a year (Heidi Stone, EA, presentation to UK white-clawed crayfish BAP Steering group 24/04/07).
1.3	How likely is the organism to be associated with the pathway at origin?	likely - 3	LOW - 0	A relatively high proportion of fish farms is thought to have signal crayfish. This is either from early commercial attempts, or because they were added to clean up detritus in tanks or ponds (Holdich, D. M, pers. comm., 2007).
1.4	Is the concentration of the organism on the pathway at origin likely to be high?	unlikely - 1	MEDIUM -1	The density of crayfish in ponds may be low 10s per square metre, but as they tend to be in refuges by day, or escape through nets, the number taken into transit with fish is likely to be low generally. If introduction is deliberate the stocking is likely to be direct to water with 10s to low 100s of crayfish at a time, although even higher stockings have been used historically.
1.5	How likely is the organism to survive existing cultivation or commercial practices?	very likely - 4	LOW - 0	Signal crayfish are capable of attaining high densities even in lakes with abundant predatory fish, as in commercial recreational fisheries (e.g. case studies in Holdich *et al.* , 1995, Peay and Hiley 2001).
1.6	How likely is the organism to survive or remain undetected by existing measures?	moderately likely - 2	MEDIUM -1	Crayfish netted out of ponds during transport of fish are quite likely to remain undetected in transit tanks. If coarse fish are moved with aquatic plants there is a higher chance of juvenile crayfish being transported.
1.7	How likely is the organism to survive during transport /storage?	very likely - 4	LOW - 0	Crayfish are certain to survive any conditions suitable for the movement of live fish. They can survive without water in humid crates for days to weeks (Peay, own observations).
1.8	How likely is the organism to multiply/increase in prevalence during transport /storage?	unlikely - 1	LOW - 0	Signal crayfish could theoretically mate in transit, but the probability is very low, even if movement occurred in autumn. In the unlikely event of mating it is certain that young would not be produced until they were introduced into a new site.
1.9	What is the volume of movement along the pathway?	minor - 1	LOW - 0	On any one occasion, there are only likely to be a small number of individual crayfish moved with stocked fish, if any. For deliberate introductions, nos. likely to be 10s to low 100s, although some historic stockings of crayfish farms involved 1000s (Holdich *et al.* , 1995).
1.10	How frequent is movement along the pathway?	occasionally - 2	LOW - 0	Environment Agency authorised 5386 fish stocking consents to 760 applicants in England and Wales (with 80% from only 20% of the applicants, mainly the major fish farms). In all, had 7.5 million fish moved, of 30 spp. (Environment Agency, 2005). There were c. 300 declared stockings of signal crayfish by potential crayfish producers in 1976-1990 (Holdich *et al.* 1995). Only 3 of these are still registered (P. Stebbing, CEFAS). A total of 14 fish farms in England and Wales are known to have signal crayfish on them, 3 of these are registered signal crayfish farms (and therefore do not sell animals for re-stocking), the others are either coarse or salmonid farms that happen to have signal crayfish on site. Of the fin-fish sites known to have signal crayfish, 6 of these sell fish for re-stocking. In 2006 a total of 221 farms sold fish for re-stocking (information 29/02/08, P Stebbing, CEFAS) so it appears that those with signal crayfish are a minority. Fish stocked out by farms are hand-sorted/graded before being dispatched and this minimises the likelihood of contamination with crayfish (P. Stebbing, CEFAS). By contrast, lake fisheries may be netted periodically to removed surplus stock, which can be used for stocking other waters and these are unlikely to be graded as carefully. Stocking to other waters is done under FR2 consent. With Environment Agency fisheries staff, risks are minimal as crayfish are caught in fish nets, but removed. Other fishery managers may not be as vigilant. The difficulty is that new signal crayfish populations are not usually detected for several to many years. Also cannot distinguish accidental from deliberate illegal introduction. Some cases in Scotland are thought to have been due to import of fish e.g. Tweed (Hunter, Tweed DSFB). A recently discovered population in a tributary of the Yorkshire Derwent (S. Penn, EA, York) may also be accidental. Deliberate introduction is probably now similar or greater source, at least into previously unaffected catchments. When new cases are detected by statutory agencies, owners may claim retrospectively that a deliberate introduction was accidental.
1.11	How widely could the organism be distributed throughout the Risk Assessment area?	very widely - 4	LOW - 0	All catchments in lowland England and Wales could be colonised and most on mainland Scotland, albeit probably not in mountain zone above 900 m. Environment Agency (2005) report indicates *c.* 250,000 still waters in the Risk Assessment area overall of which *c.* 30,000 in England and Wales are available for fisheries. EA estimate 3% are natural fisheries, 77% improved and 20% intensive; includes 19,000 still water trout fisheries, which must be stocked regularly, so can assume that most have been/will be stocked within 20 year period. Proportion of stocked sites is probably lower in Scotland. Unless stocked sites have no inflow or outflow (only a small proportion, most fishing lakes have an overflow), any signal crayfish have an escape route to colonise watercourses. This is in addition to potential for direct introduction to rivers stocked with fish. Total of 68,000 km rivers in England and Wales (presumably much greater length if include minor watercourses) and >50,000 km in Scotland. All the large catchments are likely to get at least some stocking.
1.12	How likely is the organism to arrive during the months of the year most appropriate for establishment ?	very likely - 4	LOW - 0	Crayfish could establish at any time. They tend to be torpid in winter, so would be much less likely to be netted then. However, fish stocking would not usually be done in the period November and March anyway.
1.13	How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) or other material with which the organism is associated to aid transfer to a suitable habitat?	very likely - 4	LOW - 0	Crayfish will usually be moved in water with fish, or will be packed for deliberate transport from one waterbody to another. The only indirect route would be if crayfish are supplied for restaurant use and escape, which is possible as they are good at climbing. There are anecdotal reports of escaped crayfish being hunted in kitchens as well as those of householders who decided against putting live crayfish in boiling water and released them to the wild.
1.14	How likely is the organism to be able to transfer from the pathway to a suitable habitat?	very likely - 4	LOW - 0	If movement is with fish the intended use, stocking always introduces any crayfish directly into a suitable habitat. The same is so of deliberate introduction.

	Probability of Establishment	RESPONSE	UNCERTAINTY	COMMENT
1.15	How similar are the climatic conditions that would affect establishment in the Risk Assessment area and in the area of current distribution?	very similar - 4	LOW - 0	Signal crayfish are known to be tolerant of climatic conditions in all parts of Risk Assessment area and indeed can survive in hotter summers and colder winters in other parts of their indigenous and introduced range. Colder areas (Souty-Grosset *et al.* , 2006) include Estonia, Latvia, Sweden, Finland and from 2007 Norway too. Examples of warmer countries include Spain, Portugal, Italy, Greece, Serbia. It appears that climatically, signal crayfish could colonise any areas of England, Wales or Scotland. A long-established population of white-clawed crayfish (similarly or less tolerant of cold conditions) exists in a loch in NW Sutherland (C. Bean, SNH pers. comm.).
1.16	How similar are other abiotic factors that would affect establishment in the Risk Assessment area and in the area of present distribution?	very similar - 4	LOW - 0	Given the very wide range of types of waterbody in which signal crayfish can survive in Britain and other parts of Europe (24 countries so far, Souty-Grosset *et al.* , 2006) there is a high degree of matching of suitable habitats. Acidity may be a limiting factor in some parts of Scotland and Wales. *Astacus astacus* can survive for prolonged periods in pH5.6, although there was slightly higher mortality in juveniles (Abrahamsson, 1972, cited McMahon, 2002). Signal crayfish are likely to be at least as tolerant. Hiley and Peay (2005) found acidity below pH2 was required to kill signal crayfish in 24 hr. Similar low acidity was found to be lethal to *Orconectes rusticus* and *Procambarus clarkii* (McMahon and Morgan, 1983). It appears signal crayfish can survive in any conditions capable of supporting fish, and with respect to anoxia can tolerate much poorer conditions. Hiley and Peay (2005) observed that signal crayfish could tolerate dissolved oxygen less than 0.5% saturated for several hours and show full recovery when conditions improved. All but the most polluted lowland waters could support signal crayfish and probably most upland waters, except in very acidic peatland. Signal crayfish can tolerate drought conditions in England, as observed by Holdich *et al.* (1995) in River Churn and Peay (pers. obs.) in Ampney Brook, dry for *c.* 13 weeks in 2003 but with live signal crayfish.
1.17	How many species (for herbivores, predators and parasites) or suitable habitats vital for the survival, development and multiplication of the organism species are present in the Risk Assessment area? Specify the species or habitats and indicate the number.	very many - 4	LOW - 0	Signal crayfish have been recorded in Britain in chalk rivers, upland limestone rivers, Pennine headwater streams, gravel pits, clay pits, quarries, canals, urban watercourses subject to moderate pollution, seasonal streams (Peay, 2003; Holdich, 2002).
1.18	How widespread are the species (for herbivores, predators and parasites) or suitable habitats vital for the survival, development and multiplication of the organism in the Risk Assessment area?	widespread - 4	LOW - 0	Potentially suitable habitats are likely to be in excess of 75% of all waterbodies in Risk Assessment area.
1.19	If the organism requires another species for critical stages in its life cycle then how likely is the organism to become associated with such species in the risk assessment area?	N/A	LOW - 0	
1.20	How likely is it that establishment will not be prevented by competition from existing species in the Risk Assessment area?	very likely - 4	LOW - 0	White-clawed crayfish is unable to compete with signal crayfish (Holdich and Domianewski, 1995; Peay and Rogers, 1999; and a growing series of other case studies). The introduced mitten crab *Eriocheir sinensis* may be able to outcompete signal crayfish, especially in tidal rivers such as River Thames, Medway and Humber. Berried female signal crayfish can survive in 21 o/oo salinity, but newly hatched juveniles only 7 o/oo salinity (Holdich *et al.* , 1997).
1.21	How likely is it that establishment will not be prevented by natural enemies already present in the Risk Assessment area?	very likely - 4	LOW - 0	Predation by brown trout, various cyprinid fish including carp, chub, pike and eel, mammals (otter, mink), and predatory bird (heron and coot) have not prevented colonisation and spread of signal crayfish in catchments in much of the Risk Assessment area.
1.22	If there are differences in man's management of the environment/habitat in the Risk Assessment area from that in the area of present distribution, are they likely to aid establishment? (specify)	very unlikely - 0	LOW - 0	There is more legislation than in some parts of mainland Europe but it is difficult to enforce. No prosecutions have been brought in England and Wales for offences involving crayfish up to 2007. In Scotland there has only been one case (in 2004, which had to be dismissed on a legal technicality, only 1 expert witness in court on the day).
1.23	How likely is it that existing control or husbandry measures will fail to prevent establishment of the organism?	likely - 3	LOW - 0	Deliberate introductions cannot be prevented. A small number of individuals is likely to be responsible for most of the introductions still being carried out and they are likely to continue to flout the law as long as they have a commercial benefit in (unauthorised) wild harvest. The ban on use of crayfish for angling bait should help to reduce the chance of accidental introduction that way. Rivers designated as SSSI for white-clawed crayfish are increasingly required to be stocked with fish only from "crayfish-free" farms. In practice, it would be difficult to check. Accidental introduction remains a likely pathway. Minimal handling of fish to reduce stress facilitates transfer of crayfish.
1.24	How often has the organism been recorded in protected conditions, e.g. glasshouses, elsewhere?	occasional - 2	LOW - 0	The number of sites of intensive aquaculture for crayfish was always low. The number of fish farms and angling lakes with crayfish is not certain. Farms do not have to declare the presence of signal crayfish if they are not farming them, or if the fish farm is within the "go" area for signal crayfish. CEFAS and Environment Agency know about the presence of crayfish in farms if it has been reported in the past. A fish farm in Wharfedale that supplies trout for stocking has signal crayfish present in the farm; a fish farm in Wensleydale has crayfish in the farm tanks and a stream, although the crayfish are not farmed. Both of these are in the "no-go" areas for signal crayfish. There are probably many more suppliers of fish which have signal crayfish present.
1.25	How likely is the reproductive strategy of the organism and duration of its life cycle to aid establishment?	very likely - 4	LOW - 0	Signal crayfish carry their eggs (200-400) throughout the winter (166-280 days), releasing live young in early summer. This means a single ovigerous female is sufficient to found a population.
1.26	How likely is it that the organism's capacity to spread will aid establishment?	very likely - 4	LOW - 0	Signal crayfish are active and mobile. If conditions are not very favourable at the point of release, they can move 100s m upstream or downstream to find favourable areas. They will also walk over land, although the maximum distance is unknown and their survival and range will depend on conditions, cover and whether they are predated by birds or predatory mammals.
1.27	How adaptable is the organism?	very adaptable - 4	LOW - 0	For an aquatic invertebrate, the signal crayfish is extremely adaptable, coping with a wide range of environmental conditions. It is more resistant to pollution incidents than many other invertebrates - signal crayfish have been observed leaving the water during passage of pollutants (Pete Hiley, Scott Wilson, pers. comm., S. Peay observations during various biocide trials).
1.28	How likely is it that low genetic diversity in the founder population of the organism will not prevent establishment?	very likely - 4	LOW - 0	Original stockings of signal crayfish into England from 1976 were secondary stockings from Sweden, which was stocked from 3 river catchments California in 1959-1960 and from Lake Tahoe in 1969, although there have been other direct stockings from the USA into other parts of Europe and possibly into Britain (Souty-Grosset *et al.* , 2006). Genetic diversity has not been any constraint on widespread colonisation so far.
1.29	How often has the organism entered and established in new areas outside its original range as a result of man's activities?	moderate number - 2	LOW - 0	In most of the countries in Europe where signal crayfish occurs it was deliberately introduced, as it was in Japan. A possible exception is Portugal, where the first establishment was by colonisation down river from stockings in Spain (Holdich, 2001).

1.30	How likely is it that the organism could survive eradication campaigns in the Risk Assessment area?	very likely - 4	LOW - 0	Certain. See also 2.17 below. Trapping and manual removal tried many times in past 15-20 years, e.g. Stour at Wixoe (Wright and Williams, 2000, Smith and Wright, 2000). Rivers Ure, Clyde, Gwash, Kennet, Lee, Wharfe and others. Eradication has not been achieved and there is no evidence yet that even intensive control efforts have been sufficient to prevent further spread (e.g. removal of 10,000 crayfish from 1 km Gaddesby Brook in 2 years did not reduce spread, Sibley, 2000). Some case studies are included in Peay and Hiley (2001). An example would be R. Gwash, in which intensive manual removal of 100 man days was carried out every 6 months for 6 years in 1300 m of stream. This did not change the size distribution or detectable abundance, nor did it prevent spread (unpublished data, Rutland Conservation Volunteers and R Chadd, Environment Agency). Continuous daily trapping has been carried out on R Clyde for >4 years, with no evident reduction besides normal seasonal variation (Matt Mitchell, United Clyde Angling Protective Association Co. Ltd.). There are some intensive trapping efforts being carried out on rivers, including some of the Thames tributaries, River Lee (information from Adam Ellis, EA Thames), River Lark (Abigail Stanton-Vaughn, The Brecks Partnership). Effects on the population that is too small to trap effectively, but is capable of breeding, is not known. The intensive trapping projects going on in parts of England don't include surveys of population by other methods. This is due to practical constraints, as no one method allows estimate of total population. The best control example is from Andalucia, where trapping and manual removal were carried out daily in 1000 m of watercourse for more than 2 years (B. Nebot, Consejeria de Medio Ambiente, Granada, seen by author). 1 person full time trapping and 2 on manual removal. Within a few months, trap catches were too low to continue (98% of the catch was obtained by manual removal). Daily manual removal reduced catch to a low level of only a few 10s/day instead of many 100s/day. Bills and Marking (1988) did intensive trapping of a small enclosed pond, got reduced catch over 6 weeks. Hein *et al.* (2007) achieved a very marked reduction in trap catches of Orconectes rusticus in a 64ha springfed lake in Wisconsin within 5 years. Summer trapping effort of approximately 14,000 trap nights reduced CPUE from >10/trapday to 0.5/trapday, which modelling suggested was as low as could be achieved by sustained trapping. Very heavy continuous trapping has a small chance of reducing CPUE in rivers, though more likely in enclosed ponds. Effect on total population unknown ("stunting" achieved by Keller 1999a,b with Astacus, no large crayfish, but greatly increased total biomass). Total biocide treatment has been trialled in field with some success - gravel pit with no crayfish detected by maximum coverage of trapping 3 years after treatment (Peay *et al.* , 2006). Likely to be feasible for limited areas only. No selective biocides available.
1.31	Even if permanent establishment of the organism is unlikely, how likely is it that transient populations will be maintained in the Risk Assessment area through natural migration or entry through man's activities (including intentional release into the outdoor environment)?	very likely - 4	LOW - 0	Once signal crayfish are established in a catchment, there is a density-dependent driver for expansion, which usually happens progressively (e.g. Peay and Rogers 1999, and a repeat study by Bubb *et al.* , 2002). If crayfish die due to a pollution incident or drought in part of a catchment, further recolonisation is likely to re-establish and/or extend the range.

	Spread	RESPONSE	UNCERTAINTY	COMMENT
2.1	How rapidly is the organism liable to spread in the Risk Assessment area by natural means?	intermediate - 2	LOW - 0	Typical rates of spread are 1-2 km/year, (Guan and Wiles, 1997b; Peay and Rogers 1999; Bubb *et al.* , 2002), but can be faster (Wright and Williams, 2000). May take several years to reach maximum density for habitat, after which increased rate of expansion of range occurs. Predation by fish occurs, but does not appear to limit expansion significantly, as signal crayfish can reach nuisance proportions in angling lakes stocked with artificially large biomass of predatory coarse fish or trout.
2.2	How rapidly is the organism liable to spread in the Risk Assessment area by human assistance?	intermediate - 2	MEDIUM -1	The number of whole catchments left in Britain that are thought to be completely free from signal crayfish is decreasing year by year, either through introductions or discovery of undetected populations (Sibley, 2003 and subsequent information). As signal crayfish can expand throughout catchments from most sites of introduction, it will require only a relatively small number of introductions, deliberate or accidental to establish founder populations in most or all remaining catchments.
2.3	How difficult would it be to contain the organism within the Risk Assessment area?	very difficult - 4	LOW - 0	There is no possibility of containing signal crayfish now it is so widely established in rivers. The only prospect is for keeping some small catchments or subcatchments free from the crayfish, the only possibility for conservation of white-clawed crayfish in England and Wales. The main issue will be to limit further introductions in Scotland. With populations now confirmed in the catchments of major rivers including Clyde, Tweed, Forth and now Tay, as well as several rivers in SW Scotland, expansion of range in these catchments is inevitable and accidental or deliberate spread to other catchments in Scotland is an increasing risk.
2.4	Based on the answers to questions on the potential for establishment and spread define the area endangered by the organism.	nearly all risk area	LOW - 0	Whole risk area except mountain and moorland.

	Impacts	RESPONSE	UNCERTAINTY	COMMENT
2.5	How important is economic loss caused by the organism within its existing geographic range?	minor - 1	HIGH -2	There has been little study of economic loss due to signal crayfish - work has concentrated on ecological effects. Most work has been done in Scandinavia, where there are socially and economically important recreational fisheries for noble crayfish and these have been lost due to outbreaks of crayfish plague.
2.6	Considering the ecological conditions in the Risk Assessment area, how serious is the direct negative economic effect of the organism, e.g. on crop yield and/or quality, livestock health and production, likely to be? (describe) in the Risk Assessment area, how serious is the direct negative economic effect of the organism, e.g. on crop yield and/or quality, likely to be?	minor - 1	MEDIUM -1	Effects are likely to be indirect, rather than direct. Impacts on bank stability, implications for maintenance flood defences. Sedimentation of fish spawning areas (Sibley, 2000).
2.7	How great a loss in producer profits is the organism likely to cause due to changes in production costs, yields, etc., in the Risk Assessment area?	minor - 1	HIGH -2	Predation of eggs and juvenile wild brown trout *Salmo trutta* appears to reduce recruitment success, which is likely to increase dependence on stocked fish and hence operating costs of angling clubs. However, as stocking farmed juvenile trout into streams where there is natural recruitment of brown trout will tend to have a competitive effect anyway, and there are many other factors determining stocking rates, any direct economic effect is uncertain. Competition between signal crayfish and juvenile salmon in winter (Griffiths *et al.* , 2004), is likely to reduce recruitment of salmon *Salmo salar* , but has not been confirmed in field conditions and it is not certain whether this would actually reduce the number of sport fish available for salmon angling. White-clawed crayfish coexist with brown trout in many rivers, some predation of eggs probably does occur. But signal crayfish reach high population densities and much higher biomass, so impacts are greater. They are also more aggressive and have stronger grip, so are likely to be more effective predators too. Direct impacts on salmonid recruitment found in a tributary of the Ribble in 2007 (Nilsson and Stenroth, unpublished data).
2.8	How great a reduction in consumer demand is the organism likely to cause in the Risk Assessment area?	moderate - 2	HIGH -2	Nuisance from crayfish taking angling bait in coarse fisheries has reduced the perceived value of some recreational fisheries (Peay and Hiley, 2004, questioned EA staff in all the regions, also evidence from angling websites) and is reported to have reduced day ticket sales at some sites. In Scotland the concern of the District Salmon Fisheries Boards is two-fold: one is that there may be direct impacts of signal crayfish on recruitment of salmon and trout. Two is that rivers with signal crayfish may be perceived as being no longer "pristine" top quality waters and this could reduce the capital asset value of angling rights. As the capital asset value of e.g. the Tay catchment is estimated at £65 million (David Summers, Tay District Salmon Fisheries Board, pers. comm., October 2006), even a small devaluation of 1-5% would be significant. Angler expenditure in Scotland is estimated at £113 million/year, of which salmon and sea trout £73 million (Radford *et al.* , 2005). In England and Wales annual market value of salmon rod fisheries is estimated at £128 million/year. Overall annual expenditure by anglers estimated at £2 billion total, including indirect spend on services. Total capital asset value of inland recreational fisheries in England and Wales is *c.* £3000 million, of which coarse fisheries £2.3 billion (Environment Agency, 2005). Total angler expenditure would probably not be affected, but redistribution between sites or rivers could be significant locally if perceived quality/value of fisheries with signal crayfish is less than those without. Number of anglers in England and Wales estimated by Environment Agency at 4 million.
2.9	How likely is the presence of the organism in the Risk Assessment area to cause losses in export markets?	very unlikely - 0	LOW - 0	Even if the presence of signal crayfish decreased the asset value of rivers, it is unlikely to be great enough to have any significant effect on tourism from overseas.
2.10	How important would other economic costs resulting from introduction be? (specify)	moderate - 2	MEDIUM -1	The biggest impact is likely to be increased cost of maintenance of channelised rivers and canals, due to burrowing by signal crayfish and habitat restoration on other rivers with soft substrates in order to sustain quality.
2.11	How important is environmental harm caused by the organism within its existing geographic range?	major - 3	LOW - 0	That harm is occurring is certain, but quantifying for species other than indigenous crayfish it is more difficult, due to limited information and relatively few studies.
2.12	How important is environmental harm likely to be in the Risk Assessment area?	major - 3	LOW - 0	The environmental harm is likely to be at least moderate, it may be major in some areas, especially where SSSI and SAC rivers and lakes are affected and species with restricted distribution. Predatory fish such as pike, chub and carp which can feed on crayfish benefit and some individual fish may be larger, even if there is some reduction in recruitment. Fish that depend on macrophytes for spawning and cover such as roach are expected to decline, unless they are using vegetation that is less palatable to signal crayfish. Changes in the composition of fisheries have already been observed in some rivers with abundant crayfish, e.g. Buckinghamshire Ouse (reported in Peay and Hiley, 2004). Benthic fish including bullhead *Cotus gobio* are markedly reduced by large populations of signal crayfish (Guan and Wiles, 1997) and may become locally extinct. Impacts on juvenile lamprey are possible, due to predation in spawning gravels, of the amnocoetes in river silts, or indirectly due to burrowing of banks and excessive siltation, but there is no direct evidence so far. Changes in macroinvertebrate assemblages are not readily detected in routine biological monitoring (GQA), but are starting to be recorded in at least some lowland rivers with high abundance of crayfish, (e.g. River Lambourn, Russ Money, Natural England, pers. comm. March 2007) and in special studies (Crawford *et al.* , 2006; a tributary in the Ribble catchment, Neil Guthrie, Environment Agency, pers. comm., October 2006). The slower moving macroinvertebrates are particularly affected by predation - molluscs are preferred food items. Potentially, juvenile freshwater pearl mussel could be affected if signal crayfish extend into more rivers in Scotland, either directly by predation, or indirectly through burrowing. Even in stony rivers, abundant signal crayfish change the stability of substrate (Statzner *et al.* , 2003 and Peay observations in River Wharfe). Macrophytes that are affected by grazing include charophytes, willow moss *Fontinalis antipyretica* and low-growing communities of mesotrophic to oligotrophic lakes, suh as *Littorella uniflora* (Peay observations). Even large emergents can be affected by grazing, shredding and uprooting of seedlings. Work in streams in Ribbledale and Wharfedale in 2007 (Nilsson, Stenroth and Peay, unpublished), showed the impact of signal crayfish on fish populations compared to that of white-clawed crayfish. Where signal crayfish have replaced white-clawed crayfish and now have much higher biomass, there was a very large reduction of wild brown trout and salmon recruitment, as well as a large reduction of bullhead.
2.13	How important is social and other harm caused by the organism within its existing geographic range?	moderate - 2	LOW - 0	The signal crayfish and the associated crayfish plague is the major cause of the large reduction in abundance in indigenous crayfish in Europe. Noble crayfish *Astacus astacus* and white-clawed crayfish *Austropotamobius pallipes* in particular have been badly affected by crayfish plague and competition. Signal crayfish can live in all habitats used by those species and both species have undergone major losses of range, which are likely to continue. Because of the enormous social importance of noble crayfish as recreational fisheries in Scandinavia, lost populations of noble crayfish have been replaced by introductions of signal crayfish. These are resistant to crayfish plague, but often carry the disease, further exacerbating the rate of loss of indigenous crayfish.

2.14	How important is the social harm likely to be in the Risk Assessment area?	moderate - 2	MEDIUM -1	The majority of people in Britain will not notice any difference in rivers and lakes due to signal crayfish, although where there is significant burrowing, erosion of river banks will be evident. Costs of river maintenance will be higher and small earth dams of impounded lakes may be more prone to leakage or failure. There is a small potential increase in flood risk from this. Signal crayfish have positive and negative impacts on angling. There is a general reduction in diversity and abundance of other species when signal crayfish take a significant proportion of total productivity in waterbodies, so some reduction in the quality of aquatic systems overall. But other actors are likely to dominate river quality overall - agricultural management, urban waste water and land drainage.
2.15	How likely is it that genetic traits can be carried to native species, modifying their genetic nature and making their economic, environmental or social effects more serious?	very unlikely - 0	LOW - 0	There has been no hybridisation between signal crayfish and any European species.
2.16	How probable is it that natural enemies, already present in the Risk Assessment area, will have no affect on populations of the organism if introduced?	very likely - 4	LOW - 0	Predation will have only a minor effect on signal crayfish.
2.17	How easily can the organism be controlled?	very difficult - 4	LOW - 0	Signal crayfish can breed at sizes below the effective limits for trapping. There are no effective ways of removing juveniles. Trials with pheromones have been less successful than conventional food baits at attracting crayfish to traps (Stebbing *et al.* , 2004), though could potentially improve trapping efficiency slightly if sufficiently developed. Male sterility considered, but not considered feasible for field (David Rogers Associates, 2005). There is no disease known that is selective to signal crayfish and there would be a high risk that an effective one would also affect European species of crayfish. There is some interest in Bacillus thuringiensis toxin (F. Alonso, Madrid; F. Gherardi, Florence, pers. comm.), but it is not yet selective to crayfish and environmental fate and suitability for use in water is not known - worth further research. If effective it would probably kill white-clawed crayfish as well. Other possibilities for eradication considered (Scott Wilson, 2006) but not developed include percussive shock treatment (by blasting) and gamma irradiation, (in principle could penetrate to crayfish in refuges in bed and banks - safety and acceptability would be major issues). There are no biocides that are selective for crayfish - signal crayfish are relatively little affected by piscicides such as rotenone. Synthetic pyrethroid insecticides are toxic to crayfish, but even more so to smaller insects and crustaceans and the field doses actually required might be toxic to fish too - there are concerns about persistence of these chemicals in sediments. Natural pyrethrum has been used on small sites (Peay *et al.* , 2006) and has low persistence, but is also broad spectrum on a range of aquatic species. If used as a single treatment with rapid recovery, its impact would be less than sustained manual removal of crayfish. Monitoring suggests eradication can be achieved by this method, but only if the whole extent of population is thoroughly treated.
2.18	How likely are control measures to disrupt existing biological or integrated systems for control of other organisms?	unlikely - 1	LOW - 0	This is not applicable.
2.19	How likely is the organism to act as food, a host, a symbiont or a vector for other damaging organisms?	likely - 3	LOW - 0	Signal crayfish frequently carry crayfish plague *Aphanomyces astaci,* a disease that is lethal to white-clawed crayfish and has been the cause of many local extinctions of the indigenous species. Some populations of signal crayfish appear not to carry crayfish plague. Signal crayfish have been expanding into areas with white-clawed crayfish in the River Wharfe for 20 year and River Ure for at least 10 years with no outbreak of plague and there are examples in other rivers too.
2.20	Highlight those parts of the endangered area where economic, environmental and social impacts are most likely to occur	throughout	LOW - 0	

Summarise Entry	likely - 3	LOW - 0	Signal crayfish are already present in England Wales and mainland Scotland. The probability of further imports of this crayfish species is low. The most likely pathways are from existing sites within the Risk Assessment area to areas currently unaffected. These are, in descending order: 1. accidental introduction with stocked fish; 2. deliberate illegal introduction for wild harvest or weed control; 3. illegal use as angling bait; 4. escape or deliberate release of surplus live crayfish intended for human consumption. Environment Agency fisheries staff know/suspect examples of illegal introductions in most/all regions, e.g. St John River/River Greta, Cumbria, 2006, anonymous tipoff that intro was done for wild harvest, on way to do the "Scottish seeding", illegal introductions into rivers in SW Scotland (N Guthrie, EA, Scottish info from P Collen, FRS). Site in Ribbledale, bailiffs know was done by two individuals for casual wild harvest on shooting trips. River Aire, initially suspected use of angling bait, but some circumstantial evidence for wild harvest (P Bradley, Univ Sheffield). Introduction to pond on golfcourse, Huddersfield was for weed control (J. Brickland, Peak Ecology, formerly EA). Intro Tweed tributary claimed by riparian owner to be accidental with stocked fish (J Hunter, Tweed Fisheries Board). Gwash intro by landowner for fish food, against EA advice (R.Chadd, EA). Drumtochty, North Esk intro to fishing ponds for harvest/trout food admitted by J Andrews, without landowner knowledge, subsequently denied when prosecuted. Former gravelpit in Wensleydale, owner put in crayfish for own harvest (in no-go area), subsequently said he gave crayfish to various friends with ponds/lakes locally, possibly even after EA started trying to control in R Ure (Clare Williams, EA, York).
Summarise Establishment	very likely - 4	LOW - 0	There are few reported instances when any deliberate introduction of signal crayfish has failed (one unconfirmed one is from upper reaches of River Ivel, where a lake owner said he put in signal crayfish in 1980s, but didn't get a crop. Site hasn't been surveyed to check if absent or just at low abundance (Amanda Proud, Ouse and Ivel Project). The crayfish are resilient and versatile and have a high probability (est. >90%) of establishing at any waterbody they manage to enter.
Summarise Spread	intermediate - 2	LOW - 0	Most to all catchments in England, Wales and Scotland could be colonised except in mountainous, very acidic or polluted areas, including rivers, canals and a high proportion of still waters (all those with a connection to a watercourse or used for angling).
Summarise Impacts	major - 3	LOW - 0	
Conclusion of the risk assessment	HIGH -2	LOW - 0	Signal crayfish are here in Britain and causing environmental impacts already. There is no doubt that the geographic range and abundance will increase as natural spread extends along watercourses where signal crayfish have established. In areas where there is extensive colonisation there is no possibility of eradication. In a few instances it may be possible to eradicate new colonies, but only if detected soon enough and in relatively small, controllable sites - total biocide (natural pyrethrum) is currently the only viable option for eradication. In the long term, research might provide other options, but there are long lead times - during which signal crayfish are guaranteed to increase their range in Britain. There is a possibility of reducing, but NOT eradicating individual populations of signal crayfish, in relatively small, enclosed sites by trapping, provided it is done intensively and continuously - but there is limited benefit to this, except perhaps reduction of nuisance to anglers. Intensive trapping in rivers might also have some impact on abundance, but would be of value only if it is maintained continuously in ALL of the range of signal crayfish in each whole catchment, otherwise it is ineffectual, as well as expensive. Any reduction or cessation of effort would cause complete loss of any previous benefit, probably within 1-2 years. The minimum effort required is likely to be 2 people full time/km for ever and for ALL km potentially affected in each catchment - which may be an expanding extent, if even intensive effort does not prevent spread. The author is not aware of any proven cases as yet in which control efforts have prevented spread. Required effort would probably be much higher initially, at least in large watercourses and lakes with abundant
Conclusions on Uncertainty		LOW - 0	There is low uncertainty on most aspects, because the species has been well studied, there is plenty of evidence of it spread in Britain and other parts of Europe and the pathways are well known. There is moderate uncertainty about the best method of calculating the economic impact of signal crayfish, especially in relation to other factors that influence a) requirement for capital/maintenance work on rivers, b) determine river quality overall c) determine capital asset value of freshwater fisheries and d) some environmental receptors cannot be assigned an economic value - e.g. what is the value of having bullhead in a stream?
Should risk management options be considered?	YES (Go to Risk Management)		Yes, risk management options should be considered. If they are not, white-clawed crayfish (Bern Convention, EC Habitats Directive) will probably become extinct in Britain, as the species can only survive in isolation from signal crayfish. Other species and habitat quality will also be adversely affected in many areas, but not as badly. Options to consider include: a ban on all wild harvest (strongly recommended); biocide treatment to eradicate signal crayfish at the small number of major suppliers of fish for stocking; handling practice so wild-netted fish for stocking are held in floating cages to allow signal crayfish to climb out before fish are moved. There is an urgent need to find a

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