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:	***Procambarus clarkii* - Red Swamp Crayfish**	
	Objectives:	Assess the risks associated with this species in GB	
	Version:	FINAL 30/3/11	
N	**QUESTION**	**RESPONSE**	**COMMENT**
1	What is the reason for performing the Risk Assessment?		The red swamp claw crayfish has been distributed widely for commercial purposes outside its natural range and is known to be highly invasive, so there is potential for the existing populations to spread or provide sources for further introductions. It is already present at several sites in England and breeding (see A9 for distribution).
2	What is the Risk Assessment area?	GB	No introduced crayfish species (other than white-clawed crayfish *Austropotamobius pallipes* , which is accorded indigenous status) have been recorded in Northern Ireland so far.
3	Does a relevant earlier Risk Assessment exist?	NO OR UNKNOWN (Go to 5)	No previous risk assessment.
4	If there is an earlier Risk Assessment is it still entirely valid, or only partly valid?		
A	**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, Cambaridae, Procambarus clarkii (Girard, 1852) - red swamp crayfish
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)	Several detailed studies of the major ecological impacts elsewhere in Europe and species is expanding its range, within EU and trans-nationally (e.g. spread into Portugal from legal introduction for aquaculture in Spain, with severe impact on indigenous populations of white-clawed crayfish). Economic and other environmental damage recorded in California, Hawaii, Japan, Kenya, Spain, Portugal (Huner, 2000; Holdich, 1999) also in Garonne wetlands in France. Banned species in parts of USA (Virginia as bait, Missouri, New Hampshire all non-native spp., Florida ban on import, sale, possession or transport, Maryland ban on transport; Fishforum website, Taylor *et al.* , 2007).
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)	It is a typical R-selected species with a short life-cycle and high fecundity. At least 2 generations per year are possible at low latitudes (up to 600 eggs brooded at a time, although Stucki (2002) found lower eggs nos. in sites in Switzerland, up to 400 but average 173, *cf* 114 for signal and 39 for white-clawed crayfish). In northern Europe and arid areas there is usually only one generation per year. A study by Richter (2000) seems to indicate this is the situation in England. It is very versatile in its ecology, able to avoid climatic extremes by burrowing. It is adapted to seasonal waterbodies. Females can store sperm and breed at any time of year when conditions become favourable, so there were breeding females through much of the year in Switzerland and activity seen in March-November, longer than for native crayfish or signals (Stucki, 2002). It is a keystone species, able to utilise a wide range of plant and animal food in any aquatic or seasonally aquatic habitat it finds. If conditions are unfavourable it will either wait for better conditions or walk by water or over land to find better areas. Its most favoured habitats, seasonal wetlands, do not have any indigenous crayfish in the Risk Assessment area. Established populations in Switzerland are expanding (Frutiger *et al.* , 2002), also in Germany and northern France).
9	Does the organism occur outside effective containment in the Risk Assessment area?	YES (Go to 10)	Red swamp crayfish confirmed in 1991 in Mens Bathing Pool, Hampstead Heath, when drained by NRA (now Environment Agency), probably established a few years earlier. Populations were found in 5 ponds on Hampstead Heath in 2000 (4 in a connected group, one entirely separate on the east side), also in Regents Canal (Richter, 2000) and confirmed as breeding. Suspected source a restaurant, but unconfirmed; Grand Union Canal (EA data, Dan Ahern, identified from photographs). Record from a roadside marsh drain on approach to Tilbury, dated 1990 (Essex Biodiversity Group record, supplied by EA, Julia Stansted, EA fisheries). Also a populations reported in River Lea, but details of source not certain.
10	Is the organism widely distributed in the Risk Assessment area?	NO (Go to 11)	See above, but expected to expand populations in the waterways once populations builds up. Expansion of range expected to be slower than in Mediterranean countries due to probably only one brood/year instead of two and possibly slower rate of growth, at least when summers are cool/wet.

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)	Prefers warm summer conditions, but can grow in cool conditions and easily survive UK winters (which are much milder than in many other parts of the current introduced range). Well adapted to utilise a wide range of aquatic habitats; open water and wetlands, ponds, lakes, lowland rivers especially on clay or silt alluvium, canals, seasonally inundated wetland, reedbeds etc., managed drainage channels including agricultural fenland drains, flood relief channels and roadside ditches. Capable of tolerating eutrophication and low dissolved oxygen that would be lethal to fish, as well as occurring in clean waters. Capable of surviving in large tidal rivers, as can tolerate salinity up to 10ppt, though reproduction impaired above 5ppt (Huner, 2000). Coastal grazing marshes with ditch systems would be very favourable, though not full saltmarsh. Can survive drought conditions in deep burrows, so could colonise winterbournes and dried out wetland in summer. Burrows extend deep into banks, typically 1.5m, but can be >2m; even juveniles make burrows (though not as deep), so significant numbers would survive routine ditching operations. Although wetland drains are preferred, it has extensively colonised trout streams in Oregon and permanent lakes in many parts of the USA (see Huner, 2000 and cited authors).
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)	Currently the most global crayfish species, introduced on all continents except Australia and Antarctica, sub-tropical to temperate zone and has proved capable of establishing populations in a wide range of aquatic habitats across the world (e.g. Japan, mainland China, Philippines, South Africa, Kenya). Within Europe, present in Tenerife, Sicily, Sardinia, Majorca, Spain, Portugal, Italy, Switzerland, France, northern Germany, Netherlands as well as England (Souty-Grosset *et al.* , 2006). For maximum commercial production, summer temperature of 22-30^oC is optimal, but growth and reproduction possible in cooler conditions, e.g. in Netherlands (climatically equivalent to south and east England). Confirmed breeding in England in 2000, (Richter and Wiles, 2001). Can survive in much colder winter than in England, e.g. under ice in Germany (Dehus *et al.* ,1999), also introduced into northern USA (Idaho, Ohio - Huner, 2000).
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)	*P. clarkii* is permitted to be kept in protected conditions in the UK under Import Live Fish Act general licence, in the short term only, principally when intended as food for human consumption. The extent of illegal trading or keeping of aquarium specimens is not known, although the species has several colour variants and is considered to be attractive at least by aquarists in the USA (J. Huner, pers. comm., Huner, 2002). Has been found illegally in trade by Fish Inspectorate, CEFAS since 1996, one of a dozen crayfish species illegally traded (information from Paul Stebbing, CEFAS, website article Practical Fishkeeping). Traders are likely to be easier to detect than individual hobbyists.
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)	Original range in eastern south-east USA. Extended for commercial aquaculture elsewhere in USA, central and south America, several parts of Africa, Japan, China, Taiwan. Currently present in 13 countries/regions of Europe by human introduction and subsequent spread.
17	Can the organism spread rapidly by natural means or by human assistance?	YES (Go to 18)	Both.
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)	Both - harm as a vector for crayfish plague and for other diseases of crayfish, e.g. chronic vibriosis (suspected but unconfirmed as reason for mortality in *Astacus leptodactylus* in 2000 which were in contact with *P. clarkii* in Hampstead Heath ponds (Richter, 2000). White Spot Syndrome Virus (WSSV) was confirmed in farmed and wild populations of *P. clarkii* in Louisiana (Romaine and McClain, 2007), a disease of marine shrimps and prawns. It had been identified as a potential risk by Edgerton (2004) when it was found crayfish could be infected, due to the use of marine crustaceans in fish farms and crayfish culture ponds. Native white-clawed crayfish are potentially susceptible. The disease is not known in Europe yet, but use of shrimp in fish food is a potential source as the virus survives freezing. Any diseases in existing populations of *P. clarkii* in UK have not been investigated. However, the main issue with *P. clarkii* is the potential for environmental and economic harm from invasion of watercourses and wetlands, including farmed grazing areas.
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?	few - 1	LOW - 0	1. The only legal route into Britain is as live food intended for human consumption to wholesalers and restaurants. 2. Aquarium-keeping is banned, but could easily be done by individuals via the Channel Tunnel, ferries or mail from suppliers inside the EU. This is also so if *P. clarkii* was intended for illegal use as angling bait (very much less likely). 3. Deliberate illegal introduction to sites for future wild harvest would most likely be either diversion of stock supposed to be for human consumption, or obtained from one of the existing sites in England. Currently, wild harvest is all signal and Turkish crayfish, but red swamp crayfish may have future potential.
1.2	Choose one pathway from the list of pathways selected in 1.1 to begin the pathway assessments.	Release of crayfish intended for food		There are no restrictions on, or documentary requirements for, imports of live crustacean from other Member States (CEFAS website accessed 25/02/08). This is the probable source of populations in London (Hampstead Heath), but not possible to confirm. Release of unwanted aquarium specimens (kept illegally) is probably equally likely.
1.3	How likely is the organism to be associated with the pathway at origin?	very likely - 4	LOW - 0	Boxes of chilled live crayfish are sold for food and can be purchased in London markets. Keeping red swamp crayfish as an aquarium species is illegal, but private purchase from an EU source is not.
1.4	Is the concentration of the organism on the pathway at origin likely to be high?	very likely - 4	LOW - 0	Sold as single species consignments so concentration at origin is 100%. It is possible (although unlikely) that some imported sources also contain a closely related species, the white river crayfish *P. zonangulus*. The latter did not do well in Spain, but co-exists with *P. clarkii* in Egypt (Souty-Grosset *et al.*, 2006).
1.5	How likely is the organism to survive existing cultivation or commercial practices?	very likely - 4	LOW - 0	Mortality is low in transport for sale.
1.6	How likely is the organism to survive or remain undetected by existing measures?	very likely - 4	LOW - 0	In this case it is the deliberate release of crayfish that is likely to go undetected until there is an abundant population living in the wild.
1.7	How likely is the organism to survive during transport /storage?	very likely - 4	LOW - 0	Crayfish can survive days to weeks in cool damp conditions.
1.8	How likely is the organism to multiply/increase in prevalence during transport /storage?	unlikely - 1	LOW - 0	Crayfish could mate in transport/storage but if stock is chilled, mating would be unlikely. Young would not be produced in transit, but females mated in advance could certainly produce eggs once introduced to suitable conditions.
1.9	What is the volume of movement along the pathway?	minor - 1	MEDIUM -1	TV celebrity chefs and greater public access to freshwater crayfish as food has started to increase the number of restaurants serving crayfish and greater public demand. Red swamp crayfish is still viewed as a luxury item and although processed *P. clarkii* is relatively inexpensive, the number of restaurants using live *P. clarkii* is probably still relatively low. Also signal crayfish *Pacifastacus leniusculus* is probably more widely available and is being increasingly harvested from the wild by commercial trappers. Most live *P. clarkii* are likely to be used in the London area or other urban centres. There are few known wild populations so far. This means either most restaurants use all they purchase or dispose of them appropriately or they bin live crayfish, but these are either taken to landfill or predated by rats before they can find a watercourse. The biggest risk would be deliberate release of live crayfish by householders who discovered they were too sentimental to boil live food. The same risk would apply to aquarium pets. Escapes are also possible (website ABC news 2006, aquarium hobbyists forum, 2005).
1.10	How frequent is movement along the pathway?	rarely - 1	MEDIUM -1	There appears to have been little movement so far, but the risks increase as the demand for freshwater crayfish increases. A feature on crayfish in 'The F-Word' television programme led to over 700 enquiries to the Environment Agency from the public about crayfish trapping or farming (Heidi Stone, National Fisheries Policy Officer, pers. comm.). This was for signal crayfish, but if red swamp crayfish starts to spread in canal system there is more risk of introductions.
1.11	How widely could the organism be distributed throughout the Risk Assessment area?	widely - 3	LOW - 0	*P. clarkii* could be sold for food anywhere in the risk assessment area. The proportion escaping or being deliberately released is probably very small, based on distribution to date, but expansion of existing populations is likely and the risk of further introductions, accidental or deliberate will also increase. DEFRA provides guidance to restaurants etc. on appropriate storage and disposal of crayfish, but it is not mandatory.
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 including *P. clarkii* can arrive and establish at any time of year. In northern Europe, it appears that they only have one brood a year. In Hampstead Heath ponds mating is mainly in spring, spawning in July-August and young hatch in August to early October. They overwinter and breed the following year. By contrast, signal crayfish usually take at least 2 years to reach sexual maturity and white-clawed crayfish can take 2 years, but 3 is more usual.

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?	moderately likely - 2	MEDIUM -1	Live crayfish intended for food are very good at climbing and could escape. *P. clarkii* can walk for 100s m overland and survive for extended periods out of water. Distances of up to 3 km have been recorded in a night (Souty-Grosset *et al.* , 2006), although it has not been observed doing so in northern Europe (few studies). If red swamp crayfish escape, they are vulnerable to being crushed in urban environments or predated, but if they avoided this, they could wander widely until they find a suitable habitat and will do this naturally in wetlands that dry out. (Website ABC news item reported *P. clarkii* loose in streets of Stuttgart).
1.14	How likely is the organism to be able to transfer from the pathway to a suitable habitat?	moderately likely - 2	LOW - 0	If release is deliberate, it is very likely to be into an aquatic habitat that is suitable. If release/escape is accidental, the likelihood is very low, as access to watercourses will be limited and risk of damage or predation by rats in urban areas would be relatively high.

	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?	similar - 3	LOW - 0	Much of England has conditions that are suitable for breeding, especially in the south and in warm years. In northern England, Wales and Scotland, *P. clarkii* could easily survive the winters, but the summers are cool and definitely suboptimal. It is likely that reproduction would be less in northern and western areas, but it should not be assumed that it could not occur. Embryo development is not arrested until temperature is below 10^{o}C (Souty-Grosset, *et al.*, 2006)
1.16	How similar are other abiotic factors that would affect establishment in the Risk Assessment area and in the area of present distribution?	similar - 3	LOW - 0	*P. clarkii* has proven ability to thrive in many habitats similar to those found in the Risk Assessment area. It is found in a wide range of still and flowing waters, and is highly tolerant of eutrophication and seasonal drying.
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.	many - 3	LOW - 0	There is abundant suitable habitat for *P. clarkii* and it is capable of utilising a very wide range of food.
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	Suitable habitats are available in most river catchments in lowland England. Slow-flowing lowland rivers on soft substrates, canals, drainage ditches, lakes, ponds, fens and marshes would all be very suitable habitat, often with a high degree of connectivity that could be exploited by expanding populations of *P. clarkii.*
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	No other species are required.
1.20	How likely is it that establishment will not be prevented by competition from existing species in the Risk Assessment area?	likely - 3	MEDIUM -1	*P.clarkii* would outcompete white-clawed crayfish *Austropotamobius pallipes* in most habitats, probably all habitats, even if the red swamp crayfish were not carrying crayfish plague. *P. clarkii* was found to be dominant in agonistic interactions with similar-sized *A. pallipes* (Gherardi *et al.*, 1999). There is an element of uncertainty at the upland limits of white-clawed crayfish in northerm England, where the combination of cooler summers and steeper gradient, stony streams might slow or prevent colonisation by *P. clarkii* in sub-optimal habitat. There is a greater degree of uncertainty about the outcome of competition with signal crayfish *Pacifastacus leniusculus*. Some studies have shown *P. clarkii* is dominant over *P. leniusculus* in competitions for shelter (Richter, 2000). In field conditions, where *P. leniusculus* attains greater size it may dominate, but *P. clarkii* has been shown to be more aggressive and can attain higher abundance. Long term outcomes are not certain and will probably be influenced by climatic factors and habitat type. *P. leniusculus* may have the advantage where it has prior establishment, flowing stony rivers, cool conditions. *P. clarkii* would have advantages in southern areas, wetlands and low-lying areas of intensive arable, e.g. Lincolnshire and Cambridgeshire Fens. In the San Francisco area, where both species have been introduced there is overlap of range, but not enough information yet to see outcome of competition.
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	*P. clarkii* has established to nuisance abundance in areas with many of the same fish, bird and mammal predators as Britain. Stucki (2002) recorded *P. clarkii* in sites with coarse fish, including pike. Frutiger and Muller, 2002 had a reduction in trap CPUE when a large number of eels was added to a pond, but later couldn't catch eels and did not indicate whether the effects were sustained - unlikely if eels dispersed.
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)	N/A	LOW - 0	Management of rivers, canals and lakes shows similar range of types in Britain as in other parts of Europe, although there is no growing of rice (which is a favoured habitat of *P.clarkii* in Italy and Spain, where it causes major economic damage).
1.23	How likely is it that existing control or husbandry measures will fail to prevent establishment of the organism?	very likely - 4	LOW - 0	Once *P. clarkii* reaches a river or wetland there is a high probability the species will establish, or will continue moving until more favourable conditions are reached. In Spain there were reported cases of use of organophosphate insecticides to rice fields in an effort to control or eradicate *P.clarkii,* but there are no documented cases of successful eradication and there have been indirect mortalities of birds as a consequence (MacKenzie, 1986). Frutiger and Muller (2002) showed even in a small pond, trapping had minimal effect on population size, as did Jarboe and Romaire, 1995. This was attributed to breeding females being present for much of the year, able to top up the population.
1.24	How often has the organism been recorded in protected conditions, e.g. glasshouses, elsewhere?	frequent - 3	LOW - 0	*P. clarkii* is sometimes reared intensively in hatcheries, but there are none in Britain.
1.25	How likely is the reproductive strategy of the organism and duration of its life cycle to aid establishment?	likely - 3	LOW - 0	Up to 600 eggs can be produced, embryo development 2-3 weeks at 22^{o}C and populations can contain individuals that are incubating or carrying juveniles throughout most or all of the year, allowing them to reproduce at the first opportunity. Even in Britain, juveniles are likely to breed at 1 year old, so populations can expand rapidly if conditions are favourable.
1.26	How likely is it that the organism's capacity to spread will aid establishment?	likely - 3	LOW - 0	*P. clarkii* has high fecundity, rapid growth and early sexual maturity (1 year), faster than other freshwater crayfish established in Britain.
1.27	How adaptable is the organism?	adaptable - 3	LOW - 0	Due to introductions, the most widespread crayfish in the world, surviving in a wide range of habitats and climatic conditions.

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	Populations have been started from very small numbers of founders - one fertilised female may be enough.
1.29	How often has the organism entered and established in new areas outside its original range as a result of man's activities?	very many - 4	LOW - 0	Exploited for aquaculture around the world and soon living in the wild everywhere it has been introduced in USA, Central America, South America, Europe, Africa, China and other parts of east and south Asia. In USA it is now present on east and west coasts and north to Idaho and Ohio (Huner, 2002). Within Europe it has established and spread in Tenerife, Portugal, Spain, Italy, Sardinia, Sicily, Majorca, Switzerland, Germany including north-east Germany, France all regions, Netherlands and a few sites in England (Souty-Grosset *et al.* , 2006). This has always been due to human activities.
1.30	How likely is it that the organism could survive eradication campaigns in the Risk Assessment area?	very likely - 4	LOW - 0	Intensive trapping is ineffective (Frutiger *et al.* , 1999) and is the usual method of sustainable harvest. Agricultural doses of insecticides in rice culture have sometimes caused mortality, but not eradication (Huner, 2002). No methods used in Europe so far have either eliminated a population or prevented spread. In principle, treatment with biocides would be technically possible in the ponds (though possibly not socially acceptable), but with populations now in waterways, the species is beyond effective containment. Published studies from the USA have concentrated on accidental poisoning of crayfish from insecticides used in co-cultivation of rice. There are unpublished reports of unauthorised deliberate use of synthetic pyrethroids in Spain to reduce damage to rice crops by crayfish, but there appears to be no work to investigate the success or otherwise.
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)?	likely - 3	LOW - 0	Transient populations are not very likely, as *P. clarkii* stands a high chance of establishing successfully if it reaches suitable habitats. Continued legal import of live crayfish is a potential source of accidental or deliberate introductions.

	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	The rate of spread varies. In an irrigation ditch in Tuscany, radio-tagging showed movement of 1.1-4.6 m/day (Gherardi *et al.* 2002). By contrast a population in rice fields in southern Spain spread at up to 4 km/day (Gherardi and Barbaresi, 2000). Rates in the UK are likely to be much slower than in Spain. Once a dense population builds up in an areas, rates may be comparable with those for signal crayfish where habitat is suitable, i.e. 1-2 km a year. Even with only one brood a year, reproduction is likely to be at least similar to signal crayfish and probably higher, albeit individuals don't live as long as adult signal crayfish. The populations in Hampstead Heath are in enclosed ponds. Colonisation from those ponds is probably limited both by concrete revetting in some of the ponds (poor habitat) and by extensive culverting through London to the River Thames (also unsuitable for burrowing). The rate of spread in the Regent and Grand Union canals does not appear to have been studied. Regent Canal is connected to the River Lee and upstream to rivers Ash, Rib and Stort. The Grand Union has most potential for spread as it is on the major canal network: Thames at Brentford to River Nene, Oxford Canal, Worcester and Birmingham, Birmingham and Fazeley, River Soar, River Trent and in theory to Manchester and northern canals. Conditions are most favourable in south and east rather than northwest. Of main concern would be access to River Nene and from there into Cambridgeshire Fenland. Potential access to Ouse Washes SSSI and other wetland sites via extensive networks of low-lying drains. Current status of Tilbury population is not known, but may have scope to spread into the grazing marshes of Thames, including SSSIs. Overland spread could occur by *P. clarkii* walking over land from high density areas (low likelihood except in favourable wetland habitat), or by being dropped by herons (definite cases known for signal crayfish). Even with no more deliberate or accidental introductions, there is potential for expansion of range to watercourses and wetlands in Eastern England and potentially towards Midlands. New introductions, from crayfish intended for human consumption or aquaria, are most likely in urban areas.
2.2	How rapidly is the organism liable to spread in the Risk Assessment area by human assistance?	intermediate - 2	MEDIUM -1	The incidence of introductions appears to be low, but the risk is likely to increase if consumption of freshwater crayfish becomes more popular (as appears to be happening) and as the existing populations extend their range or increase in number, i.e. *P. clarkii* becomes more accessible. Although only one tropical crayfish species *Cherax quadricarinatus* is allowed in aquaria, crayfish species may not be correctly identified by sellers or purchasers. CEFAS has recorded at least 12 species illegally traded since 1996.
2.3	How difficult would it be to contain the organism within the Risk Assessment area?	very difficult - 4	LOW - 0	The flexibility of breeding in *P. clarkii* means several studies (e.g. Frutiger and Muller, 2002; Jarboe and Romaire, 1995) have shown the ineffectiveness of trapping on this species of crayfish, even in enclosed sites and a high intensity of traps. Although biocide trials have been carried out with natural pyrethrum on signal crayfish in small, controlled sites (Peay *et al.*, 2006), there is no certainty that this would be as effective on a species capable of making deep burrows, because the pyrethrum breaks down readily, so a high dose would be needed - and may not be fully effective on *P. clarkii* even then - it would not work well on exposed, but potentially occupied burrows in wetland. Synthetic pyrethroids have a better chance of success in field use, but the much longer persistence in aquatic systems is also a greater environmental risk. *P. clarkii* coexists in a wide range of countries and habitats with a very wide range of predators. Some effect on abundance is likely in some circumstances, but not eradication - it appears no eradication by predation has been recorded with *P. clarkii*. No diseases or parasites are available that would not have similar or greater risk to European native crayfish. Furthermore with legal aquaculture operations in parts of Europe, development of such measures would be unlikely to be approved. Male sterilisation would have minimal chance of success in such a highly mobile and fecund species.
2.4	Based on the answers to questions on the potential for establishment and spread define the area endangered by the organism.	still waters, wetlands and lowland flowing water mainly in England	LOW - 0	Lowland wetlands would be at greatest risk of ecological impact. Low-lying areas in southern and eastern England and canals would be at greatest risk of colonisation with potential for economic impact.

	Impacts	RESPONSE	UNCERTAINTY	COMMENT
2.5	How important is economic loss caused by the organism within its existing geographic range?	major - 3	LOW - 0	Major economic impact in rice-growing areas, due to grazing (e.g. Anastacio and Marques, 1996) and damage of drainage/irrigation systems. Commercial European production of red swamp crayfish in southern Europe is relatively low, estimated at around 3000-5000t/yr (Souty-Grosset *et al.* , 2006) and a small number of producers enjoy economic benefits, but the economic impact of damage amounts to £100s millions/year (D. M. Holdich, F. Gherardi, pers. comm.). There is some uncertainty of the economic cost within Europe.
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?	moderate - 2	MEDIUM -1	No rice is grown in UK. *P. clarkii* might affect production of reed, but this is a very minor crop. If *P. clarkii* gets into seasonally wet grasslands, burrowing and grazing would affect the pastures. Burrowing might increase surface drainage, but throwing up soil would open up bare ground for colonisation by pasture weeds. Populations of *P. clarkii* can move > 40 t/ha/yr of soil and can move 7500 cm^3 within a few days (Gherardi, 2002). Where burrowing was extensive, localised collapses could require more frequent sub-soiling, harrowing and rolling. Newly re-seeded grassland would be palatable to crayfish, with seedlings being pulled out. Damage would probably be localised adjacent to ditches, lakes and wetlands; similar to the impact of rabbits, although without equivalent options for control. Burrows up to 2m deep have been recorded - a threat to drainage systems and clay-cored dams.
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	LOW - 0	But see 2.10 re impact on drainage and flood defence.
2.8	How great a reduction in consumer demand is the organism likely to cause in the Risk Assessment area?	minimal - 0	LOW - 0	No reduction in demand for reed or livestock expected.
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	No risk to export markets.
2.10	How important would other economic costs resulting from introduction be? (specify)	moderate - 2	MEDIUM -1	The biggest economic cost would be damage to drainage channels, with increased cost of maintenance. In areas managed by Internal Drainage Boards (less than 32ft above sea level) many channels for drainage and irrigation are above the level of surrounding land, e.g. Lincolnshire and Cambridgeshire Fens, parts of Kent. If these are penetrated by burrows there is the potential for collapse and flooding, as well as cost of maintenance/repairs at £10s to £100s/metre. There was evidence of burrowing at the Mens Bathing Pond, Hampstead Heath (Richter, 2000), where *P. clarkii* had burrowed down from the exposed bank behind metal sheet piling, which had then collapsed. This is in relatively unfavourable habitat. Similar impacts of burrowing would be expected in canals and canalised rivers. High potential for increased leakage from canals, some risk of bank slumping. Damage of banks leading to leakage/collapse is a major problem in rice-growing areas with red swamp crayfish (e.g. parts of California, Spain, Italy, China). Burrows much more frequently and extensively than signal crayfish, typically burrow frequency 1s to low 10s/sq. metre. With burrows up to 2 m deep, clay-core dams would be at risk of damage and possible collapse. Collapse risk is highest on dams of ornamental lakes, including heritage features, as many are below size for mandatory Reservoir Safety inspection. For larger lakes and reservoirs, dams may be partly concrete-faced and less vulnerable, but maintenance costs could still be high. Increased turbidity could be a problem for water supply reservoirs, increased operating cost in filtration. Turbidity leading to increased planktonic algae in slow-flowing rivers or reservoirs increases taste problems in chlorine-treated water for public supply. More risk of dominance by blue-green algae in rivers and lakes with dense *P. clarkii* , toxins seasonally.
2.11	How important is environmental harm caused by the organism within its existing geographic range?	major - 3	LOW - 0	See Receptor risk assessment - large changes in species composition and habitat structure in wetland ecosystems following colonisation by *P. clarkii* , including in European designated sites in France (Garonne) Spain, Portugal and Italy. For example, in Lake Chozas, NW Spain (Rodriguez *et al.* , 2003, 2005) there was a switch from clear to turbid phase; 99% plant coverage reduction, 71% losses in macroinvertebrate genera, 83% reductions in amphibian species, and waterfowl (52% reduction). Plant-eating birds were negatively affected (75% losses in ducks species). Fish and crayfish-eating birds benefit (Poulin *et al.* , 2007). Otters may also benefit from the new prey (Delibes and Adrian, 1987; Correia, 2001), while amphibian populations were reduced or lost (Cruz *et al.* , 2006). Studies show general reductions in abundance and diversity of plants and dynamics with *P. clarkii* . An indirect effect was mobilisation of polluted, but previously "locked" detritus and sediments. *P. clarkii* bio-accumulated heavy metals and other toxic materials and passed them up the foodweb to predatory birds and mammals and macroinvertebrates (Gil-Sanchez and Alba-Tercedor, 2002; Guitierrez-Yurrita *et al.* , 1998; Ilheu *et al.* , 2002, Rodriguez *et al* ., 2005). Geiger *et al.* (2005) reviewed the major changes in food web.

2.12	How important is environmental harm likely to be in the Risk Assessment area?	major - 3	MEDIUM -1	It depends on the degree of colonisation and spread of *P. clarkii* . The main impact in rivers and canals may be from burrowing. But where *P. clarkii* get into major wetlands, there is potential for major impacts on protected sites, habitats and species. Unlike eutrophication from urban discharges or agriculture, phase change due to crayfish is probably irreversible. Important designated wetlands such as the Norfolk Broads would be especially vulnerable. Bio-accumulation of heavy metals might be a risk in urban/industrial areas in England, if suitable habitats are available. Angeler *et al.* (2001) found increased ammonia and phosphate from disturbed sediments led to eutrophication. Populations in Spain and Portugal have been studied in more detail than those in northern Europe. Although climatically different, the same types of impact on wetlands can be expected in England if *P. clarkii* colonises them. Clearly, impacts on rice fields are not an issue in England. Grazing of vegetation adjacent to ditches occurs, plus burrowing, so potential for more ruderal species due to disturbance and changes in plant communities due to cutting and grazing.
2.13	How important is social and other harm caused by the organism within its existing geographic range?	minimal - 0	LOW - 0	*P. clarkii* is an intermediate or final host for a number of helminth parasites of vertebrates, but there are no recent reports of human infection because crayfish are always cooked before consumption (Huner, 2002).
2.14	How important is the social harm likely to be in the Risk Assessment area?	minor - 1	MEDIUM -1	Where drainage systems are raised above surrounding land, e.g. in the Fens, burrowing could, if not identified in time, lead to breaches which would cause flooding. There is only a minor risk because the Environment Agency or IDB inspects such drains regularly and they tend to be in agricultural areas, so the threat to life and domestic property is low. But the economic cost of maintenance would be much higher.
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 are no records of hybridisation between *P. clarkii* and any other freshwater crayfish present in Europe.
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?	likely - 3	LOW - 0	*P. clarkii* may be more susceptible to predation by fish than *P. leniusculus* . Frutiger and Muller (2002) studied an enclosed sandy 1.5 ha pond in Switzerland. Intensive trapping for 2 years (at *c.* 70 traps/ha) had little effect on Catch Per Unit Effort (CPUE), but removed more of the larger crayfish, changing size distribution. By contrast stocking with fish, eels *Anguilla anguilla* and pike *Esox lucius* reduced CPUE in the first year from >3 to 0.69, mostly attributed to predation of small crayfish by eels - but eels could not be recaptured later. Pike can predate *P. clarkii* once they recognise the prey, in Ruidera Lake, Spain *P. clarkii* represented 72% prey (Elvira *et al.* , 1996). Pike and other predatory fish would be accustomed to crayfish in Britain, either from *A. pallipes* populations or *P. leniusculus* . Nonetheless, predation has not stopped expansion of *P. leniusculus* populations and would probably only slow the rate of spread of *P. clarkii, if at all.* In its natural range in USA populations survive predation by a range of predatory fish, herons, cormorants and other predatory birds, even owls, mink, otter, raccoon, alligator and predatory invertebrates that feed on juveniles. *P. clarkii* has survived predation from native and introduced fish in other parts of the world where it has been introduced, e.g. Foster and Harper, 2004. Very high CPUEs were recorded for *P. clarkii* at Hampstead Heath ponds, despite large predatory carp and other fish (Richter, 2000). Outcome of competition between *P. clarkii* and *Pacifastacus leniusculus* will probably depend on local habitat and climate. Gherardi and Cioni (2004) and Richter,(2000) found *P. clarkii* won agonistic encounters in laboratory conditions, but field conditions are more complex. In northern Europe there may be some coexistence, or else *P. clarkii* would predominate in lowlands where there is fine substrate and *P. leniusculus* in gravel and high energy stream and rivers.
2.17	How easily can the organism be controlled?	very difficult - 4	LOW - 0	No successful eradication achieved in Europe to date (Holdich *et al.* , 1999). There are no selective biocides for crayfish or even crustaceans, so any use of biocide for localised eradication would affect a wide range of other organisms, including other aquatic invertebrates and, probably at the doses necessary, fish and amphibians would be killed too. Chang and Lange (1967) used fenthion to control *P. clarkii* , a pest in Californian ricefields, an unacceptable pesticide for current use. Quaglio *et al.* (2002) showed synthetic pyrethroid ciflutrin was effective at low dosage in clean laboratory conditions - higher dosage would be necessary in field conditions. No field trial with synthetic pyrethroids has been carried out anywhere in Europe. Organophosphorous pesticides used illegally in Spain killed many birds (Mackenzie, 1986), but these highly persistent pesticides are banned from use now. Trying to limit crayfish density by intensive stocking with predatory eels would have indirect impacts on other ecology. There are significant doubts as to whether adequate density of eels could be obtained and maintained, even in enclosed waterbodies - they tend to disperse by water or even short distances over land.
2.18	How likely are control measures to disrupt existing biological or integrated systems for control of other organisms?	likely - 3	MEDIUM -1	This is not applicable to the extent that *P. clarkii* is not likely to occur in areas where integrated systems are in operation. However, any measures taken to control *P. clarkii* in wild populations would have impacts on other ecology.
2.19	How likely is the organism to act as food, a host, a symbiont or a vector for other damaging organisms?	very likely - 4	LOW - 0	*P. clarkii* is a vector for the crayfish plague *Aphanomyces astac* i, a lethal disease to indigenous white-clawed crayfish (Dieguez-Uribeondo and Soderhall, 1993).

2.20	Highlight those parts of the endangered area where economic, environmental and social impacts are most likely to occur	aquatic habitats, wetlands	LOW - 0	Greatest likelihood of colonisation and impact in southern and eastern England in slow-flowing rivers, drainage systems and wetlands, including fens and other seasonally wet areas. Many rivers are already colonised by signal crayfish, including River Lea, connected to canals with *P. clarkii* . The outcome of competition is not certain in field conditions, at least not in northern Europe. *P. clarkii* appears to win in parts of Spain, despite smaller body size. All rivers or still waters with earth substrate are expected to be damaged by burrowing.

Summarise Entry	very likely - 4	LOW - 0	1. The main risk of entry is legal import of live *P. clarkii* intended for human consumption - increasing risk if food import from mainland Europe becomes more popular. 2. Risk of illegal import for aquaria, followed by disposal, less likely, but difficult to detect or prevent. Plenty of potential for confusion of names between "red swamp" and "red-claw" (*Cherax quadricarinatus*), a tropical species and the only legal import for the aquarium trade (though *Cherax* recently confirmed as breeding in wild in Germany - hence also a risk in Britain).
Summarise Establishment	likely - 3	LOW - 0	Has already established, though few sites so far, but has the potential for increased rate now it occurs in canals (potential for inter-catchment transfer). Deliberate illegal movement from known sites to others for future wild harvest is a very low risk at present, but an increasing risk in future, as the number of people involved in wild harvest of signal crayfish is thought to be increasing and the species will be more readily accessible when it extends its existing range.
Summarise Spread	intermediate - 2	MEDIUM -1	If deliberately introduced, populations of *P.clarkii* could establish in most types of waterbody and wetland in the Risk Assessment area, except probably in upland rivers and bogs. However, as the species prefers warm summers, the areas most at risk are in southern and eastern England, extending to the Midlands. It lags behind signal crayfish *Pacifastacus leniusculus*, which has already established very widely in the risk assessment area since the late 1970s. It is already present in at least 2 canals, which opens up increased possibilities for natural spread between catchments.
Summarise Impacts	major - 3	LOW - 0	The greatest environmental impacts would be on high quality wetlands of local to international importance. These would be expected to be significantly degraded in quality, with changes in structure, composition and general reduction of biodiversity including reduction and loss of protected and rare aquatic species. The intensive burrowing activity of *Procambarus clarkii* is likely to be the main source of economic impact, with increased costs of maintenance throughout IDB drainage systems, canals and flood-defended rivers. This is also likely to have secondary impacts through increased erosion and siltation.
Conclusion of the risk assessment	HIGH -2	LOW - 0	Many of the watercourses that would be potentially colonised by *Procambarus clarkii* will already be thoroughly invaded by another American crayfish *Pacifastacus leniusculus* by the time *P. clarkii arrives.* The type of direct and indirect impacts on the aquatic ecosystems will be similar if *P. clarkii* displaces *P. leniusculus* in parts of the range. However, the greater propensity for burrowing means that in lowland river systems, canals and farm drainage systems, the amount of physical damage to banks is likely to be greater than with *P. leniusculus*, with impacts on riparian vegetation, siltation of fish spawning areas etc. There is a high probability that maintenance costs of these systems would be greater. More frequent and extensive repair would cost £1s to £10s/metre/year and this could be over 1000s km of waterways in the long term. Unlike *P. leniusculus, P. clarkii* often burrows from terrestrial banks down to water level and this means it can get behind sheet-piling, undermining it. The greatest environmental impacts would be if *P. clarkii* colonises important wetland sites, causing major adverse impacts, which would be irreversible. *P. clarkii* would be able to colonise wetland that are relatively suitable for signal crayfish.
Conclusions on Uncertainty		LOW - 0	There is low uncertainty on most of the risk assessment, due to a range of good quality studies having been carried out in labs and in field conditions. Most relate to commercial aquaculture of *Procambarus clarkii* and factors that affect yield and profitability. There are, however, enough European studies on the environmental and economic impacts of *P. clarkii* to have little or no doubt as to its potential for harm. There are a few uncertainties in the risk assessment area: 1. where *P. clarkii* has already established in watercourses (Regent Canal and Grand Union Canal), how abundant is it and how fast is it spreading? 2. What will be the outcome of competition between *P. clarkii* and prior established populations of *Pacifastacus leniusculus*? 3. Presence of fish populations has had little if any effect at limiting the spread of *P. leniusculus.* If *P. clarkii* are a little more susceptible is it possible to reduce the impact of *P. clarkii* (unlikely to be effective control because of the difficulty of sustaining high enough density of eels; species can survive in the presence of a wide range of predators. Nonetheless it should be investigated); 4. if new enclosed populations of *P. clarkii* are discovered, is there the scope to use natural pyrethrum biocide, as has been trialled on *P. leniusculus* (application to a pond with *P. clarkii* is being considered in Andalucia, Spain (Maria Soledad Vivas Navarro, Programa Andaluz para el Control de las Especies Exóticas Invasoras, pers. comm).

Should risk management options be considered?	YES (Go to Risk Management)		The species is banned under Schedule 9 of Wildlife and Countryside Act 1981 as amended but import for food is a significant loophole. It would be difficult to prevent legally imported live crayfish for food being released into waterbodies, although illegal. Whilst Fisheries Inspectorate does intercept *P. clarkii* for aquarium trade, it is more difficult to regulate hobbyists who may import or exchange stock. A ban on import and sale of live crayfish of any species would be helpful. The number of new introductions each year is likely to be very small, but the potential for harm from each is very large. There has been no attempt to eradicate populations so far. Prospects for control are even less likely than for signal crayfish. The buildup phase of *P. clarkii* in the first site where they were found has been slow, but the population is undoubtedly expanding now. There are already other populations established in the London area. It may already be too late to attempt to eradicate these populations. Rapid and drastic action, in particular biocide treatment, or infilling of the waterbodies, have not had any trials on *P. clarkii* in the UK, or, as yet, in other parts of Europe. It would be very difficult to obtain authorisation for such work in urban London. The record for Tilbury needs field investigation too. Rates of spread, burrow density etc. need to be investigated, as do interactions with signal crayfish when/if the distributions overlap.

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