

UK NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME Version 3.3

Prepared by CABI Bioscience (CABI), Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Centre for Ecology and Hydrology (CEH), Central Science Laboratory (CSL), Imperial College London (IC) and the University of Greenwich (UoG) under Defra Contract CR0293, February 2005.

NOTE: This template contains minimal help and background. Please refer to the User Manual and examples of best practice when using this scheme.

	Name of Organism, Pathway, Receptor or Policy	Crassostrea gigas - Pacific oyster	
	Objectives:	Assess the risks associated with this species in GB	
	Authors, Date, Draft:		
N	QUESTION	RESPONSE	COMMENT
1	What is the reason for performing the Risk Assessment?		
2	What is the Risk Assessment area?	GB	Shallow inlets and bays/estuaries amount to 283,060 hectares (JNCC), mudflats/sandflats in 290,000 hectares (JNCC). Wadden Sea is considered to be mudflats and amounts to 10,000km ² (Wikipedia).
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)	Phyla: Mollusca; Class: Bivalvia; Order: Ostreoida; Family: Ostreidae; Genus/species: <i>Crassostrea gigas</i>
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?	NO or Uncertain (Go to 8)	
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)	Marine invertebrate spreadsheet score of 42.
9	Does the organism occur outside effective containment in the Risk Assessment area?	YES (Go to 10)	
10	Is the organism widely distributed in the Risk Assessment area?	YES & Future conditions/management procedures/policies are being considered (Go to 19)	
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)	Suitable habitats exist for <i>C. gigas</i> throughout the UK .
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)	
15	Could the organism establish under protected conditions (e.g. glasshouses, aquaculture facilities, terraria, zoological gardens) in the Risk Assessment area?	NO (Go to 20)	
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)	
17	Can the organism spread rapidly by natural means or by human assistance?	YES (Go to 18)	
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)	
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	Further aquaculture introductions. Spread via tidal currents. Larvae can travel up to 1300km.
1.2	Choose one pathway from the list of pathways selected in 1.1 to begin the pathway assessments.	B.6 aquaculture/mariculture		
1.3	How likely is the organism to be associated with the pathway at origin?	very likely - 4	LOW - 0	<i>C. gigas</i> is brought to the UK and bred as a commercial species within the open marine environment.
1.4	Is the concentration of the organism on the pathway at origin likely to be high?	very likely - 4	LOW - 0	<i>C. gigas</i> are farmed in high densities.
1.5	How likely is the organism to survive existing cultivation or commercial practices?	likely - 3	LOW - 0	Spatfall has been witnessed outside of the commercial fishing areas. Natural spatfall found in several UK sites.
1.6	How likely is the organism to survive or remain undetected by existing measures?	likely - 3	MEDIUM -1	Current control measures are destructive to the environment. As a benthic species with other marine bivalves chemical controls are deemed inappropriate.
1.7	How likely is the organism to survive during transport /storage?	likely - 3	MEDIUM -1	Farmed oysters can survive several days during transportation to consumers/the market place. In the natural environment <i>C. gigas</i> survives tidal exposure.
1.8	How likely is the organism to multiply/increase in prevalence during transport /storage?	unlikely - 1	MEDIUM -1	Requires submersion within water and conspecifics to spawn.
1.9	What is the volume of movement along the pathway?	moderate - 2	MEDIUM -1	According to the Shellfish Association GB figures, the UK produced 1016 tonnes of farmed pacific oysters in 2004, with a female potentially spawning 50-60 million eggs (NIMPIS, 2002).
1.10	How frequent is movement along the pathway?	often - 3	LOW - 0	Frequency of oyster farming is continuous. Spawning, whilst temperature dependant, it is annual and occurs in the summer months.
1.11	How widely could the organism be distributed throughout the Risk Assessment area?	widely - 3	MEDIUM -1	Suitable habitats exist for <i>C. gigas</i> throughout the UK with 290,000 hectares of mudflats/sandflats and 283,060 hectares of shallow bays and inlets. A variety of biotic and abiotic factors will affect the successful spawning and recruitment of <i>Crassostrea gigas</i> , but the most important of these seem to be temperature, and where temperature has increased the oysters have spread more readily.
1.12	How likely is the organism to arrive during the months of the year most appropriate for establishment ?	very likely - 4	LOW - 0	Organism is already present within the marine environment and as such is present during times of optimal environmental conditions required for spawning and natural spatfall.
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?	likely - 3	MEDIUM -1	Introduction of <i>C. gigas</i> for aquaculture will allow the further spread. Processing and consumption is unlikely to aid transfer.
1.14	How likely is the organism to be able to transfer from the pathway to a suitable habitat?	likely - 3	MEDIUM -1	Dependant on suitable environmental conditions such as temperature. These optimal temperature conditions have already occurred in, and aided transfer within, the Wadden Sea, and several sites in the south west of the UK.

	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	Spreading within the estuarine marine environment to other estuaries nearby.
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	Salinity gradients will vary within estuaries. <i>C. gigas</i> is tolerant of wide ranges of salinity (Chu <i>et al.</i> , 1996) and other abiotic factors are unlikely to limit distribution. Suitable substrata are varied with <i>C. gigas</i> being found on rocky shores as well as more traditional oyster/mussel reefs.
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	very many - 4	LOW - 0	As a benthic bivalve there are many suitable habitats. The primary habitats for forming reefs are seen to be shallow intertidal mudflats as per the Wadden sea. <i>C. gigas</i> may live both in intertidal and subtidal habitats. In the Wadden Sea, it mainly lives in the intertidal in the same zone as blue mussels. Pacific oyster larvae may settle on all kind of natural and artificial hard substrates, such as mollusc shells, living molluscs, wood, stones, concrete and others.
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?	frequent - 3	LOW - 0	
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		
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	<i>C. gigas</i> is seen to outcompete both the native oyster (<i>O. edulis</i>) and the blue mussel (<i>M. edulis</i>), and has been found to reduce suitable habitat for cockles (Diedrich, 2006).
1.21	How likely is it that establishment will not be prevented by natural enemies already present in the Risk Assessment area?	moderately likely - 2	MEDIUM -1	There is some conflicting information between Australian reports (NIMPIS, 2002; Shatkin <i>et al.</i> , 1997) and European reports (Wadden Sea). Pacific oysters are consumed by a variety of marine animals such as Asteroid echinoderms, boring gastropods, boring bivalves, spionid polychaetes, <i>Carcinus maenas</i> in the intertidal, benthic feeding fish, lobsters in the subtidal zone, black ducks, eider ducks, and wading birds (NIMPIS, 2002). In the Wadden Sea, however, predation seems to be very limited. Unlike blue mussels, oysters are only consumed by a few species and suffer little predation. Energy flow of an oyster reef is thus anticipated to be highly different from mussel beds and not directed to higher trophic levels. Oyster reefs are apparently of little value for mussel eating birds and especially eider ducks <i>Somateria mollissima</i> cannot make use of the oysters (Diedrich, 2006; Nehls & Buttger, 2007).
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		
1.23	How likely is it that existing control or husbandry measures will fail to prevent establishment of the organism?	likely - 3	LOW - 0	Existing controls are predominantly detrimental to other marine organisms in the area. Current husbandry practices are unlikely to prevent establishment, although internationally the use of triploidy has been effective. Current existing controls have failed to prevent establishment in some areas.
1.24	How often has the organism been recorded in protected conditions, e.g. glasshouses, elsewhere?	N/A		
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	As in other bivalves, Pacific oysters have pelagic larvae spending 3 to 4 weeks in a free-swimming phase. Larvae can travel distances of up to 1300km.
1.26	How likely is it that the organism's capacity to spread will aid establishment?	very likely - 4	LOW - 0	Whilst the thermal conditions in Northern Europe were thought to be beyond optimal for <i>C. gigas</i> , natural spatfall has occurred. Therefore it is very likely that the organism's ability to spread via spawning will aid establishment (Spencer <i>et al.</i> , 1994).
1.27	How adaptable is the organism?	adaptable - 3	MEDIUM -1	<i>C. gigas</i> can survive in a wide range of temperature, salinity, dissolved oxygen, and pH conditions (Eno <i>et al.</i> , 1997; NIMPIS, 2002).
1.28	How likely is it that low genetic diversity in the founder population of the organism will not prevent establishment?	unlikely - 1	MEDIUM -1	There are a number of founder populations and it is thought that natural spat from France has settled in UK waters (River Teign) (Child <i>et al.</i> , 1995).
1.29	How often has the organism entered and established in new areas outside its original range as a result of man's activities?	many - 3	LOW - 0	Throughout the North Sea, Wadden Sea, and Atlantic coasts <i>C. gigas</i> has been able to establish itself as a result of natural spatfall within mariculture (Nehls & Buttger, 2007; NIMPIS, 2002).
1.30	How likely is it that the organism could survive eradication campaigns in the Risk Assessment area?	likely - 3	LOW - 0	The majority of eradication campaigns would involve destruction of the organism in the environment and it is likely that this would result in environmental degradation, including non target species.
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	Given the correct environmental conditions i.e. temperature and substrata, it is very likely that <i>C. gigas</i> will spread through natural migration or anthropogenic activities.

	Spread	RESPONSE	UNCERTAINTY	COMMENT
2.1	How rapidly is the organism liable to spread in the Risk Assessment area by natural means?	intermediate - 2	MEDIUM -1	This is very dependant on optimal temperature conditions (Song <i>et al.</i> , 2007), but in recent years and using case studies such as the Wadden Sea and the Yealm estuary, the spread is likely to be increasingly rapid. The spread of the Pacific oyster in the Wadden Sea follows the classic pattern of biological invasions with a long phase of stagnancy followed by a fast increase (Diedrich <i>et al.</i> , 2005; Nehls & Buttger, 2007; Spencer <i>et al.</i> ,1994). A small founder generation has to reach a certain size before a fast growth is possible. However, in the case of the Pacific oyster, it is likely that the recent spread is facilitated by changing environmental conditions, especially an increase in summer temperatures (Nimpis, 2002).
2.2	How rapidly is the organism liable to spread in the Risk Assessment area by human assistance?	slow - 1	HIGH -2	This is dependant on the licencing of further oyster farms and movement of seed beds etc.
2.3	How difficult would it be to contain the organism within the Risk Assessment area?	very difficult - 4	LOW - 0	Controlling release of natural spatfall will involve closed systems, which are not currently used by the vast majority of shellfish farming, or would involve the use of triploidy within the species. This is unlikely to affect areas where <i>C. gigas</i> is already established.
2.4	Based on the answers to questions on the potential for establishment and spread define the area endangered by the organism.			Areas with suitable substrate, temperature, and salinity conditions are potentially endangered by <i>C. gigas</i> . This includes areas used for the wild harvest of cockles, mussels and native oysters.

	Impacts	RESPONSE	UNCERTAINTY	COMMENT
2.5	How important is economic loss caused by the organism within its existing geographic range?	moderate - 2	HIGH -2	In the Wadden Sea it has affected mussel, native oyster and cockle beds, resulting in many studies to ascertain the economic impacts. One of the results is that temperature may play a key role in determining the balance between mussels, and hot summers will favour oyster reproduction, while cold winters will lead to high mussel recruitment in the following summer. Cockles are considered to be more resilient due to mobility but some evidence has been found that <i>C. gigas</i> alters both reefs and substrate (Diedrich, 2006).
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	HIGH -2	In the Wadden Sea it has been thought to affect mussel and cockle beds, resulting in losses in these commercial fisheries (Diedrich, 2006; Nehls & Buttger, 2007). Because of the morphology of the shell it has also affected tourism, the sharp shells potentially damaging people. Given the current value of wild mussel fisheries of £2.0 million, native oysters of £0.1 million, and cockles of £10.1 million (all values for wild harvest, 2004 (shellfish.org.uk)), economic loss could represent £12.2 million per year in an absolute scenario. However, in terms of community structure no species losses were observed in a 2006 report (Diedrich, 2006). It also concluded that Blue mussels are able to coexist with Pacific oysters in their reefs, and Pacific oyster reefs offer species of blue mussel beds an alternative habitat. Blue mussel fisheries in the Wadden may be affected by the spread of the Pacific oyster in the future from two reasons. Firstly, Pacific oysters may settle on culture lots and overgrow the blue mussels. At present, it seems to be unlikely that this will be a major problem for the fisheries, as Pacific oysters apparently rarely settle on young blue mussels and in general do not settle in high densities in the subtidal. As blue mussel cultures are stocked with young seed mussels and are located always in the subtidal it seems at present to be unlikely that they might be overgrown by Pacific oysters. Second, oysters may be present on seed mussel beds and make it impossible to fish purely for blue mussels.
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	MEDIUM -1	Although reports are contradictory as to the ability of <i>C. gigas</i> to substantially alter the environment through out-competition, or to minimise commercial stocks, there is a risk that overtime, mussel seedbeds will be difficult to fish because of the presence of oysters. There is also a risk that cockle beds will be affected, through the substrate changing to oyster reefs from mud/sand flats resulting in economic consequences for cockle fishers.
2.8	How great a reduction in consumer demand is the organism likely to cause in the Risk Assessment area?	minor - 1	MEDIUM -1	Large oyster reefs are difficult to walk on and can cause damage to shoes etc, so consumer demand on the aesthetic level may be affected. In terms of consumer demand for the shellfish products, there is evidence for a shift towards native species and environmental protection as a motive in consumer demand but this is unlikely to have a major effect.
2.9	How likely is the presence of the organism in the Risk Assessment area to cause losses in export markets?	moderately likely - 2	HIGH -2	The cockle fishery is predominantly for export, and as such should this fishery be affected it will result in negative consequences for export markets. Native oysters and mussels that are for export may also be affected.
2.10	How important would other economic costs resulting from introduction be? (specify)	minor - 1	MEDIUM -1	Other economic costs are likely to be tourism based, through oyster reefs being difficult to walk on; this has had an affect in the Wadden Sea. There is a possibility that further costs could be faced through the alteration of marine substrates, and bird watching. The latter is based on species such as the Eider duck and Oystercatcher finding the Pacific oyster unpalatable, and other would-be predators also finding <i>C. gigas</i> unpalatable in the Wadden Sea, Netherlands coast, areas of the North Sea, and the French Atlantic coast.
2.11	How important is environmental harm caused by the organism within its existing geographic range?	moderate - 2	MEDIUM -1	<i>C. gigas</i> is a trophic competitor for other bivalves, in the context of end-member supply limitation (Decottignes <i>et al.</i> , 2007). Other non-native species have been introduced as a result of <i>C. gigas</i> introduction. In Sylt, Wadden Sea, previously known mussel beds have now been transformed to oyster reefs within the intertidal. Pacific oysters are today found in all parts of the Wadden Sea. They form dense layers which have all the characteristics of reefs on former beds of the blue mussel <i>Mytilus edulis</i> and settle on all other kinds of hard substrates. Within the Yealm estuary, community composition within the oyster beds is found to be high, with species density also being high within those species observed.
2.12	How important is environmental harm likely to be in the Risk Assessment area?	moderate - 2	MEDIUM -1	<i>C. gigas</i> is a trophic competitor for other bivalves, in the context of end-member supply limitation (Decottignes <i>et al.</i> , 2007), and would likely impact populations of native bivalve species, including mussels and the native oyster. Other non-native species have been introduced as a result of <i>C. gigas</i> introduction and may be spread by the transportation of oysters unless care is taken. Several of these species are likely to negatively impact native species and habitats. In Sylt, Wadden Sea, previously known mussel beds and mud flats have now been transformed to oyster reefs within the intertidal zone. It is likely that similar habitats will be affected should <i>C. gigas</i> spread. A loss of mudflat, mussel beds and other habitat, resulting from the expansion of <i>C. gigas</i> reefs may impact wider ecosystems by reducing feeding sites for fish, birds and other organisms. A study in British Columbia found that while oysters and eelgrass coexist at a regional scale, eelgrass is typically absent directly seaward of oyster beds. It is concluded that the below-oyster zone is unsuitable for eelgrass growth; if a causal link exists between oyster presence in the high intertidal zone and eelgrass absence directly seaward, then expansion of feral and farmed oyster beds will result in further eelgrass loss on Cortes Island (Kelly & Volpe, 2007). It is reasonable to expect that if <i>C. gigas</i> spreads to areas where eelgrass beds exist, eelgrass loss may occur.
2.13	How important is social and other harm caused by the organism within its existing geographic range?	minor - 1	MEDIUM -1	This has been very much dependant on the impacts on coastal communities. In some areas of the Wadden Sea the coastline has become less desirable to walk on because of the sharp shells (NIMPIS, 2002). As noted above, the oysters have potentially affected eelgrass beds which will have potential impacts ecologically that may further impact economically important fish stocks.
2.14	How important is the social harm likely to be in the Risk Assessment area?	minimal - 0	MEDIUM -1	This is very much dependant on the impacts on communities that rely on commercial species such as mussels, and any resultant drop in the value of commercial stocks due to <i>C. gigas</i> .
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?	unlikely - 1	HIGH -2	There has been no evidence, to date, of <i>Crassostrea gigas</i> modifying their genetic nature. This is an area where minimal literature exists.
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?	moderately likely - 2	MEDIUM -1	Natural enemies such as the common shore crab, and barnacles will effect settlement and the spread of <i>C. gigas</i> . These predators and other natural predators such as avian species have had little effect on the rate of spread in other areas.
2.17	How easily can the organism be controlled?	very difficult - 4	LOW - 0	No options exist for management to reduce or even stop the spread of the Pacific oyster. Eradication is unlikely to be an option in many areas. From the social and economic perspective, Pacific oysters are the most important commercial oyster species in the UK and Europe. There is no compensation measure in place to reimburse the financial investment made by commercial producers into Pacific oyster cultivation (at the national and European level). Unilateral action by the UK is unlikely to be an option. Secondly, Pacific oysters occur in many other European countries (see reports of the ICES Introduction and Transfer of Marine Organisms Working Group) from where natural spread is likely to occur in the future, whether by natural spread linked to climate change or accidental introduction through human activities, e.g. leisure boats, marinas (Anon referee pers. com.).
2.18	How likely are control measures to disrupt existing biological or integrated systems for control of other organisms?	very likely - 4	LOW - 0	

2.19	How likely is the organism to act as food, a host, a symbiont or a vector for other damaging organisms?	moderately likely - 2	MEDIUM -1	<p>Other invasive species have settled as a result of introducing the organism, such as: <i>Mytilicola orientalis</i>, <i>Undaria pinnatifida</i>, <i>Crepidula fornicata</i>. P.35 Nehl and Buttger (2007) gives a comprehensive list of associated introductions. In the UK we have no evidence that <i>C.gigas</i> has introduced pathogens or parasites to native aquatic animal species. However, <i>C.gigas</i> are a susceptible species for two of the three exotic molluscan pathogens listed in 2006/88 (<i>Perkinsus marinus</i> and <i>Microcytos mackini</i>, both currently found in the USA). It is not recognised as a susceptible species of the two endemic molluscan diseases, <i>Bonamia ostreae</i> and <i>Marteilla refringens</i>. There have been large scale movements of <i>C.gigas</i> and no field evidence that they have spread these diseases within the EU (e.g. by acting as mechanical vectors). The movement of Pacific oysters to France (from the US) appears to have resulted in the introduction of <i>Haplosporidium nelsoni</i> (not listed by OIE or EU) but seemingly with no identified consequences to date. We do not have evidence that <i>H. nelsoni</i> is present in the UK, but its introduction is possible since Pacific oysters are imported from France for aquaculture.</p>
2.20	Highlight those parts of the endangered area where economic, environmental and social impacts are most likely to occur			<p>It spreads through placement of hatchery-produced seed. Furthermore, local spatfall occurred in the River Blackwater, Essex, and light spatfalls registered in some estuaries of south-west England (Dart, Teign and Exe) and the Menai Strait following unusually warm summers in 1989 and 1990 (Spencer et al. 1994). Genetic evidence shows that spatfall in the River Teign originated from French stock (Child, Papageorgiou & Beaumont 1995), although it is unclear whether this was from adult specimens discarded at English sites or from larvae that crossed from the French side of the channel. Should the latter be the case, it would appear that, under favourable conditions for larval development, <i>Crassostrea gigas</i> has the capacity to spread substantial distances. Given <i>Crassostrea gigas</i>' ability to settle in a wide range of environments, environmental impacts may occur around the coast of the UK. The unusually warm summers of 1989 and 1990 were also observed in the Wadden Sea; year on year these have appeared to now be less unusual.</p>

Summarise Entry	very likely - 4	LOW - 0	Entry and spread into new areas is very likely due to connectivity of suitable habitat and suitable environmental conditions, and wide dispersal potential of larvae. Most likely to spread from feral populations given high dispersal potential. Spat settlement from new and existing oyster farms is possible given the right environmental conditions. Spread from food or processing activities is unlikely.
Summarise Establishment	very likely - 4	LOW - 0	Establishment is likely due to abundance of suitable habitat, favourable environmental conditions. Known to out compete native species sharing similar habitat requirements. Establishment is unlikely to be prevented by predation.
Summarise Spread	intermediate - 2	MEDIUM -1	Once established, spread is likely given the appropriate environmental conditions (primarily temperature). Further anthropogenic spread is also possible. Further spread may endanger a variety of areas around the coast, including estuaries, mudflats, eelgrass beds and rocky shores within the vicinity of existing feral and farmed populations.
Summarise Impacts	moderate - 2	HIGH -2	Primary economic loss may be through loss of mussel bed fisheries and loss of habitat for other intertidal bivalve species. Economic and social impacts may also be associated with loss of visitors to sites as oysters create a hazardous substrate. Environmental impacts are largely associated with loss of intertidal habitats, including mudflats and bivalve beds. Such impacts may affect habitats of high conservation value, including mudflats, estuaries, eelgrass beds and biogenic reefs. Spread by humans may also facilitate the spread of further non-native and 'pest' species.
For pathway/policy risk assessment Assess the potential for establishment and economic/environmental/social impacts of another organism or stop			
Conclusion of the risk assessment		MEDIUM -1	Entry and spread into endangered areas is very likely due to connectivity of suitable habitat, suitable environmental conditions and wide dispersal potential of larvae. <i>C. gigas</i> is most likely to spread from the feral population. However spat settlement from new and existing oyster farms is possible given the right environmental conditions and suitable settlement substrate. Spread from food or processing activities is unlikely. Given the quantity of suitable habitat in the UK and increasing suitability of conditions for reproduction, establishment is very likely in the endangered area. Predation and competition are also unlikely to prevent the establishment of <i>C. gigas</i> in these areas. The extremely high dispersal distance and fecundity of <i>C. gigas</i> , coupled with tolerance of wide salinity and temperature ranges and wide range of suitable habitat type, means that once established in endangered areas, spread is highly likely. This spread may however be limited by temperature. The most important economic loss is likely to be through loss of mussel bed fisheries and loss of habitat for economically important intertidal bivalve species such as cockles. Economic and social impacts may also be associated with loss of visitors to sites as oysters create a hazardous substrate. Environmental impacts are largely associated with loss of intertidal habitats, including mudflats and bivalve beds. Such impacts may affect habitats of high conservation value, including mudflats, estuaries, eelgrass beds and biogenic reefs. The loss of bird feeding grounds may also result in impacts on native bird populations. Spread by humans may also facilitate the spread of further non-native and 'pest' species.
Conclusions on Uncertainty		MEDIUM -1	Overall, the information available with which to complete this risk assessment for <i>C. gigas</i> is considered to be fairly good. Some areas require further study, particularly the source of new oyster spat in the south of England and whether or not spat is released by UK farmed stock, needs to be identified. A good amount of information about the life history of <i>C. gigas</i> is available, reflecting the commercial importance of the species. Trophic interactions, competition for space and rate of spread are quite well studied in Europe (e.g. French lagoonal and Wadden Sea studies), but less studied in the UK. Due to climatic differences and other variables, further study should be undertaken to establish whether potential impacts are similar in UK waters. Studies into the potential impacts of oysters on features of particular conservation importance (e.g. Eel grass beds and biogenic reefs) are also limited, particularly in the UK.
Should risk management options be considered?	YES (Go to Risk Management)		

References

- Chavez-Villalba, J., Cochard, J.-C., Le Pennec, M., Barret, J., Enriquez-Ciaz, M., Caceres-Martinez, C. (2003). Effects of temperature and feeding regimes on gametogenesis and larval production in the oyster *Crassostrea gigas*. *Journal of Shellfish Research* 22(3):721-731.
- Chavez-Villalba, J., Pommier, J., Andriamiseza, J., Pouvreau, Barret, J., Cochard, J.-C., Le Pennec, M. (2002). Broodstock conditioning of the oyster *Crassostrea gigas*: origin and temperature effect. *Aquaculture* 214:115-130.
- Cheney, D.P., Macdonald, B.F., Elston, R.A. (2000). Summer mortality of Pacific oysters, *Crassostrea gigas* (Thunberg): Initial findings on multiple environmental stressors in Puget Sound, Washington, 1998. *Journal of Shellfish Research* 19(1):353-359
- Chu, F. L. E., Volety, A. K., Constantin, G. (1996). A comparison of *Crassostrea gigas* and *Crassostrea virginica* - effects of temperature and salinity on susceptibility to the protozoan parasite, *Perkinsus marinus*. *Journal of Shellfish Research* 15:375-380.
- Cogne, B.B., Haure, J. & Barille, L., 2006. Spatial distribution in a temperate coastal ecosystem of the wild stock of the farmed oyster *Crassostrea gigas*(Thunberg). *Aquaculture*, 259(1-4), 249-259
- Coleman, N. (1996). Potential for the establishment of wild populations and biological risk assessment of the introduction of Pacific oysters into Victoria. Marine and Freshwater Resources Institute, Department of Natural Resources and Environment, Victoria 40 pp.
- Decottignies, P., Beninger, P.G., Rince, Y., Robins, R.J., Riera, P. (2007). Exploitation of natural food sources by two sympatric, invasive suspension feeders *Crassostrea gigas* and *Crepidula fornicata*. *Marine Ecology Progress Series*, 334, 179-192
- Decottignies, P., Beninger, P.G., Rincé, Y. & Riera, P. (2007). Trophic interactions between two introduced suspension-feeders, *Crepidula fornicata* and *Crassostrea gigas*, are influenced by seasonal effects and qualitative selection capacity. *Journal of Experimental Marine Biology and Ecology*, 342(2), 231-241
- Diederich, S. (2006). High survival and growth rates of introduced Pacific oysters may cause restrictions on habitat use by native mussels in the Wadden Sea. *Journal of Experimental Marine Biology and Ecology* 328, 211-227.
- Diederich, S., Nehls, G., van Beusekom, J.E.E., Reise, K. (2005). Introduced Pacific oysters (*Crassostrea gigas*) in the northern Wadden Sea: invasion accelerated by warm summers?. *Helgoland Marine Research* 59, 97-106.
- Eno, N.C., Clark, R.A., and Sanderson, W. 1997. Non-Native Marine Species in British Waters: A Review and Directory. Report number, pp, 1997
- Holliday, J.E., Nell, J.A. (1986). Concern over Pacific oyster in Port Stephens. *Australian Fisheries* 159(November).
- Hu, Y. P., Fuller, S. C., Castagna, M., Vrijenhoek, R. C., Lutz, R. A. (1993). Shell morphology and identification of early life history stages of congeneric species of *Crassostrea* and *Ostrea*. *Journal of the Marine Biological Association of the United Kingdom* 73, 471-496.
- Kelly, J.R., Volpe, J. P., (2007) Native eelgrass (*Zostera marina* L.) survival and growth adjacent to non-native oysters (*Crassostrea gigas* Thunberg) in the Strait of Georgia, British Columbia, *Botanica Marina*, 50, 3, 143-150.
- Matthiessen, G.C. (2001). *Oyster Culture*. Fishing News Books, Blackwell Science Ltd., Oxford.
- Mitchell, I., Jones, A., Crawford, C. (2000). Distribution of feral Pacific oysters and environmental conditions. Natural Heritage Trust Final Report NHT Project No. (FAP 13077), Natural Heritage Trust, 70pp.
- Nehls, H., & Büttger, G. (2007). Spread of the Pacific Oyster *Crassostrea gigas* in the Wadden Sea, a report for The Common Wadden Sea Secretariat, Wilhelmshaven
- Nell, J. A., Holliday, J. E. (1988). Effects of salinity on the growth and survival of Sydney rock oyster (*Saccostrea commercialis*) and Pacific oyster (*Crassostrea gigas*) larvae and spat. *Aquaculture* 68:39-44.
- Nell, J.A., Mason, C. (1991). A comparison of the biology of the sydney rock oyster (*Saccostrea commercialis*) and the pacific oyster (*Crassostrea gigas*) in Port Stephens. IN: Australasian Pacific Oyster Seminar, NSW Shellfish Association Limited, NSW1-10.
- NIMPIS, 2002. *Crassostrea gigas* species summary. National Introduced Marine Pest Information System (Eds: Hewitt C.L., Martin R.B., Sliwa C., McEnnulty, F.R., Murphy, N.E., Jones T. & Cooper, S.)
- Rajagopal, S., van der Velde, G., Jansen, J., van der Gaag, M., Atsma, G., Janssen, J.P., (2005) Thermal tolerance of the invasive oyster *Crassostrea gigas*: Feasibility of heat treatment as an antifouling option *Water Research*, 39,(18), Pages 4335-4342
- Shatkin, G., Shumway, S.E., Hawes, R. (1997). Considerations regarding the possible introduction of the Pacific oyster (*Crassostrea gigas*) to the Gulf of Maine: a review of global experience. *Journal of Shellfish Research* 16(2):463-477.

Song, Liang; Li, Xiaoxu*; Clarke, Steven; Wang, Ting; Bott, Kriston, (2007) The effect of size on the response of Pacific oysters (*Crassostrea gigas*) to changes in water temperature and air exposure, *Aquaculture International*, 15, (5), 351-362.

Spencer, B.E., Edwards, D.B., Kaiser, M.J. & C.A., R., (1994). Spatfalls of the non-native Pacific oyster (*Crassostrea gigas*) in British waters. *Aquatic conservation: Marine and Freshwater Ecosystems*, 4, 203-217.

Utting, S. D., Spencer, B. E. (1992). Introductions of marine bivalve molluscs into the United Kingdom for commercial culture - case histories. IN: Introductions and transfers of aquatic species, Selected Papers from a Symposium held in Halifax, Nova Scotia, 12-13 June 1990, (Sindermann, C., Steinmetz, B. and Hershberger, W. Eds) ICES Marine Science Symposia., Copenhagen 194 84-91.

Walne, P.R., Spencer, B.E., 1971. The introduction of the Pacific oyster (*Crassostrea gigas*) into the United Kingdom. *Shellfish Information Leaflet*, 21, 8p.,