Swedish Agency for Marine and Water Management

Risk assessment of American lobster (*Homarus americanus*)

Swedish Agency for Marine and Water Management Report 2016:4

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Preamble

American lobster (*Homarus americanus*) Pest Risk Assessment has been produced following the scheme:

- GB non-native organism risk assessment scheme, version 5 which was 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). The pest risk assessment scheme constructed by the European and Mediterranean Plant Protection Organisation (EPPO, 1997 and in prep.) provided the basis for the Great Britain NonNative Organism Risk Assessment scheme. The EPPO scheme closely follows the international standard for phytosanitary measures (ISPM 11) on pest risk analysis produced by the International Plant Protection Convention (IPPC) (FAO, 2003). IPPC standards are recognised by the Sanitary and Phytosanitary Agreement of the World Trade Organization (WTO, 1994). More information on the scheme is provided at www.nonnativespecies.org/downloadDocument.cfm?id=158.
- Additional analysis have been made on
    - Potential impacts on ecosystem services
    - Potential socio-economic impacts including if live *H. americanus* is introduced and established in the risk assessment area, management costs so far and costs if *H. americanus* is introduced and established and also impacts from a ban on live imports of *H. americanus*.

H. americanus Pest Risk Assessment has taken into account the following recommendations and criteria:

- The Convention on Biological Diversity (CBD) precautionary approach towards non-native species and promotion of the use of robust and good quality risk assessment to help underpin this approach (COP 6 Decision VI/23).
- The Marine Strategy Framework Directive (MSFD, 2008/56/EU), accordance with Article 3(5) impacts that result from invasive alien species should be managed, where feasible, so that the achievement of good environmental status (GES) for the biodiversity descriptors (1, 3, 4 and 6) is not compromised.
- The Water Framework Directive (2000/60/EG) does not explicity mention alien speices although alien species are faced as one potentially 'significant anthropogenic pressures. While the text of the Directive does not explicitly mention alien species the presence of alien species detracts from the concept of 'naturalness' that underlies the Directive.
- The risk assessment is into compliance with the criteria in the invasive alien species EU-regulation, Regulation (EU) No 1143/2014 of the

European parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species[1].

- World Organisation for Animal Health (OIE) Guidelines for assessing the risk of non-native animals becoming invasive (2011)[2]

H. americanus Pest Risk Assessment has taking into account published risk assessment and analysis, these are:

- GBNN Pest risk analysis for *H. americanus*[3]. Published on NNSS website September 2015. Great Britain non-native organism risk assessment scheme Version 3.3. Risk assessment area: Great Britain coastal waters. Evaluation: risk of entry: likely, risk of establishment: likely, risk of spread: intermediate, impacts major. *Conclusion*: high
- Norwegian biodiversity information centre risk assessment for *H. americanus*[4]; categorized as a high risk. Used when notified WTO to ban national import of live *H. americanus* to Norway.
- Invasive Species Compendium datasheet on *H. americanus* (CABI 2013)[5]
- NOBANIS factsheet on *H. americanus* (van der Meeren et al. 2010)[6]

H. americanus Pest Risk Assessment is conducted at the scale of Sweden, but uses examples from other countries, mainly Norway and Great Britain. The results and conclusions are relevant for the European Atlantic coast with similar eco-climatic conditions.

The Pest Risk Assessment was referred for consideration by relevant Swedish state authorities and universities. It was also reviewed several independent researchers and experts. Their comments have been taken into account in the final version of the risk assessment. The risk assessment was approved by the responsible authorities for invasive alien species: the Swedish Environmental Protection Agency and the Swedish Agency for Marine and Water Management.

Authorities: National Board of Trade (Kommerskollegium); Swedish Board of Agriculture (Jordbruksverket); Swedish Environmental Protection

[1] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R1143&from=EN

[2] http://www.oie.int/en/our-scientific-expertise/specific-information-and-recommendations/invasive-alien-animal-species/

[3] http://www.nonnativespecies.org/index.cfm?sectionid=51

[4] http://databank.artsdatabanken.no/FremmedArt2012/N14309

[5] http://www.cabi.org/isc/datasheet/79674

[6] https://www.nobanis.org/globalassets/speciesinfo/h/homarus-americanus/homarus_americanus.pdf

Agency (Naturvårdsverket); National Food Agency (Livsmedelsverket); The Swedish Species Information Centre (ArtDatabanken); National Veterinary Institute (Statens Veterinärmedicinska Anstalt); Swedish University of Agriculture Sciences (Sveriges Lantbruksuniversitet)

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A previous version of the risk assessment has been pre-reviewed by the Scientific Forum, EU: regulation 1143/2014, as well as by some of the experts named above.

Aquabiota water research AB and Enveco miljöekonomi AB have contributed with main parts in Annex 2.

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H. americanus Pest Risk Assessment was adopted in 4th of December 2015. The Pest Risk Assessment was revised in February 2016 and in April 2016 after comments from the Scientific Forum and questions/comments forwarded by the EU-commission (Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species).

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Summary

	Risk	Confidence	Comments
Entry	*Likely*	*Medium*	About 13 thousand metric tons of live American lobsters (*Homarus americanus)* are yearly imported mainly by flight transport for human consumptions from Canada and the USA to the European countries. The imports are registered at EU-boarder via products border inspections post (BIP). Despite national prohibitions to release or hold *H. americanus* in net cages, information campaigns, money reward for live caught animals and governmental controls, there have been recorded findings of live *H. americanus* in Sweden as well as in a number of other European countries including Denmark, Ireland, Norway and Great Britain. The introduction pathways into the sea are escapes from net cages, accidental release and disposal.
Establishment	*Likely*	*Medium*	In Europe, individuals have been found in Sweden, Great Britain and in Norway. In 2014 a high number (n=26) of *H. americanus* were reported inside the Gullmar Fjord, Sweden. Four of the females that were caught, were ovigerous. One of these females carried hybrid eggs, which has also been reported from Norway in 2010. These findings in the Gullmar fjord might be an indication of *H. americanus* as a permanent resident with possibilities of both hybridisation with the local *H. gammarus*, and establishing a subpopulation in the area. Once the species is established it will be impossible to eradicate.
Spread	*Medium*	*Medium*	Given the human involvement with the movement of *H. americanus* between land-based holding facilities, markets and restaurants based all over the risk assessment area, in addition to their own dispersal, it would seem likely that they would disperse rapidly along the European Atlantic coast. Although, *H. americanus* is more migratory than *H. gammarus*, natural spread is likely to be slow. The natural dispersal capability will however exceed any management attempt to control its spread.
Impacts (ecological, economic and social)	*Major*	*Medium*	*H. americanus* can hybridize with the *H. gammarus*, leading to fertile or sterile offspring. The hybrids might be fast growing and viable and thus potentially increase the competition for food, habitat and mates. If the hybrids are fertile, they might quickly establish a population on their own. If they are sterile, they might still pose a severe threat to *H. gammarus*, as they might interfere with the mating. They are also long-lived and many thus compete with both *H. gammarus* and *H. americanus* for resources for a long time, probably outcompeting them both. Males of *H. gammarus* might waste their sperm on barren hybrids, leading to decreased reproduction in the pure-bred species. The introduction of *H. americanus* into the area of risk assessment may transfer several contagious diseases that *H. gammarus* is susceptible to, for example, Gaffkemia, a lethal bacterial blood disease. Disease could enhance the potential of the *H. americanus* to establish due to a certain resistance to the disease. The result would be catastrophic for the native lobster.

			H. americanus may out-compete native lobster for shelter and food resulting in a reduction in numbers of *H. gammarus* as the lack of resources impacts on recruitment. *H. americanus* can affect other commercially important species that share a similar habitat, for example the edible crab (*Cancer pagarus*) and Norway lobster (*Nephrops norvegicus*), but also species in greater depths, as squat lobsters and deep water crabs (50-300m depth). *H. americanus* is a potential vector for introduction of other invasive alien species, such as barnacles, polychaetes, nematodes, foraminifera's, copepods etc. An establishment of *H. americanus* will, considering the above, give negative effects on recreational fishing, the fishing industry and the export market, especially in coastal communities and may also affect the tourism industry in the northern part of the risk assessment area negatively. The discussion is found in Annex 2. Once established, *H. americanus* will affect national programmes for increasing populations of *H. gammarus*. If *H. americanus* invade established or future reserves for H. *gammarus* such reserves will be contra productive.
Conclusion of risks: high (*confidence: medium*) A ban on live import of *H. americanus* to Europe is considered to be required and will protect the risk assessment area from being invaded by this species, as alternative measures are estimated as being not enough risk reducing enough, or economically and technically feasible. The discussion on alternative measures is found in sections 3.04 and 4.05 of this risk assessment. Norway has banned import of live *H. americanus* from the 1st of January 2016. *Additional questions*: Climate: *H. americanus* is plastic, considering a higher variety in habitats, broader range of temperature and salinity compared to *H. gammarus*. *H. americanus* are hence presumed to have potential advantage over *H. gammarus* as an effect of climate change. Potential impacts of *H. americanus* on ecosystem services (supporting, provisioning, regulating, and cultural) in the risk assessment area are presented in Annex 1. Potential socio-economic impacts including if live *H. americanus* is introduced and established in the risk assessment area, management costs so far and costs if *H. americanus* is introduced and established and also impacts from a ban on live imports of *H. americanus* are presented in Annex 2.			

Stage 1 Organism information and screening

Section A - Organism Information

1 - What is the reason for performing the risk assessment?

A request is made for a risk assessment of the organism.

Comments: The American lobster (*Homarus americanus*) is found predominantly on the East coast of North America and Canada. The import of live wild caught *H. americanus* into European countries was made economically profitable with the development of the transatlantic jet aircraft (Alderman 1996).

Live *H. americanus* has been captured in the sea in several European countries. This has raised concerns about possible impact on stocks of the native European lobster (*H. gammarus*), as well as on other native crustacean species. These introductions present potential risks of disease transmission, hybridization, and/or competition for resources. More specifically, hybrids can contribute to a reduced recruitment of the *H. gammarus,* compete with the *H. gammarus* or may result reduced cuticle thickness of *H. gammarus*. *H. americanus* is also a known potential carrier of several contagious and lethal diseases that *H. gammarus* is susceptible to. For example, Gaffkemia, a lethal bacterial blood disease has led to outbreak in holding facilities for imported *H. americanus* in Europe (Wiik et al. 1987; Mortensen 2002). *H. americanus* is also a potential vector for introduction of other invasive alien species, such as barnacles, polychaetes, nematodes, foraminifera's, copepods etc. Moreover, *H. americanus* may out-compete the native lobster for shelter and food, with consequences of reduced recruitment of the native lobster. This would have a significant negative effect on populations of the native lobster and could lead to a severe population decline or even extinction. *H. americanus* can affect other environments or commercially important species that share a similar habitat, for example the edible crab (*Cancer pagarus*) and Norway lobster (*Nephrops norvegicus*), but also species in greater depths, as squat lobsters and deep water crabs (50-300m depth). In Great Britain, 26 live *H. americanus* has been recorded between 1988 and 2011 (Johnson P, Marine Management Organisation, Great Britain pers. comm. 2015). All have been identified based on morphology. The majority have been captured on the south coast of England, as well as one finding in Scotland. 50% of the reports were made in 2010, and the majority were from two locations along the south coast of England. However, 361 individuals of *H. americanus* were released into Great Britain waters as a result of faith based animal releases on the 15th of June 2015 (Stebbling P, pers. comm. 2015). A recapture fishery was started on the 16th of June performed by commercial fishermen and under some periods of a specifically chartered vessel operating under direction of UK government. There was a bounty scheme in operation for some of this period. 133 individuals were captured, three of them were females carrying eggs.

Information on *H. americanus* landed in other locations between 2011 and 2015 has not been complied yet.

The first live *H. americanus* in Norwegian waters was recorded in 1999 and since then 29 individuals have been verified by DNA (Agnalt A-L pers. comm. 2015). All lobsters had been captured along the coast; near the cities of Oslo, Sandefjord, Larvik, Kristiansand, Bergen and Ålesund. Seven of the females were ovigerous including two females with hybrid eggs in 2010 and 2015. In 2010 also several specimens were infected with the feared epizootic shell disease (ESD) (Sandlund N., pers. comm. 2015).

In Sweden, 32 live *H. americanus* has been found on the west coast between 2008 and 2015 (Öresland V. pers. comm. 2015), of which 27 were DNA verified. 19 were found in the Gullmar fjord. Four of the females caught in 2014 were ovigerous, including one female with genetically confirmed hybrid eggs.

All specimens are captured in commercial and recreational fisheries. The number of identified specimens is therefore believed to be an underestimate.

An establishment of *H. americanus* will, considering the above, give negative effects on recreational fishing, the fishing industry and the export market, especially in coastal communities and may also affect the tourism industry in the northern part of the risk assessment area negatively. Once established, it will affect national programmes for increasing populations of *H. gammarus*. If *H. americanus* invade established or future reserves for H. *gammarus* such reserves will be contra productive.

2 - Name organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?

Homarus americanus (H. Milne Edwards, 1837); Arthropod, Crustacean, Malacostraca, Decapod, Pleocyemata, Nephropidea

Comments: There is some debate as to the reliability of the taxonomic methods currently used in Great Britain to correctly identify *H. americanus* due to the occasional occurrence of ventral spines on the rostrum of *H. gammarus* and variations in colour. Molecular techniques have been used in Norway to distinguish between 'unusual' lobsters with spines and 'true' *H. americanus* (Jørstad *et al*. 2007; 2011). This technique eliminates false positives; 108 suspect *H. americanus* have been found in Norway between 2000 and 2015 with 29 of these being confirmed as *H. americanus* (Agnalt A-L, pers. comm. 2015). However, the occurrence of sub-rostral spines is rare in Great Britain waters (Addison and Bannister, 1994), with no suspect lobsters having been reported to date. It is rare in Norway as well, occurring in 1-2% (Agnalt A-L, pers. comm. 2015). Since *H. americanus* might also have no spines under the rostrum, molecular testing is the only positive verification of *H. americanus,* including hybrids. Several of the reported landings in Great Britain of *H. americanus* in 2010 were identified by the Natural History Museum, London using key morphological characters and deposited in the reference collection (NHM reg. 2010.1087), so material is available from some samples for molecular analysis if required.

3 - If not a single taxonomic entity, can it be redefined?

NA

4 - Does a relevant earlier risk assessment exist (give details of any previous risk assessment)?

Yes, Great Britain carried out a risk assessment in 2011 by using a not yet fully developed model and the risk assessment area limited to Great Britain coastal waters. This risk assessment is prepared mainly on the basis of this previous risk assessment (GBNN 2011). Also on Invasive Species Compendium datasheet on *H. americanus* (CABI 2013), NOBANIS factsheet on *H. americanus* (van der Meeren et al. 2010), Norwegian biodiversity information centre risk assessment[7], as well as on new publications and other relevant information.

5 - If there is an earlier risk assessment is it still entirely valid, or only partly valid?

Please see question 4.

6 - Where is the organism native?

The native range of *H. americanus* is the American north-eastern coast and waters from Cape Hatteras, Carolina in USA to Labrador, Newfoundland and Straits of Belle Isle in Canada (Table 1).

7 - What is the current global distribution of the organism?

Except for the native distribution of the *H. americanus* in the western Atlantic, there have been efforts to introduce the species into a number of locations over the years. *H. americanus* have also been occasionally been captured in the Atlantic region in Europe (Table 1 and 2).

There have been attempts to transplant this species to the west coast of North America, but success has been limited. Efforts to transplant lobsters to the Pacific Ocean date to 1873 and to 1889 for the states of California and Washington, respectively (Rathbun 1892), but nothing resulted from these early attempts. In the early 1970s, California again attempted to develop a *H. americanus* fishery along its coast. However, following concerns that *H. americanus* would displace *Panulirus interruptus*, release of wild *H. americanus* was not recommended. In Canada, transplantation of *H. americanus* to the east coast of Vancouver Island was attempted as early as 1896 and in 1905 and 1908 (Fraser 1916); no information is available on the fate of these lobsters as there was no controlled observation following transplantation. In 1973, the Canadians discontinued a 6-year trial in which *H. americanus* was relocated to the waters off British Columbia. The decision to drop the project was attributed to economics.

There have also been introductions of *H. americanus* to Japan, France and Italy. Releases of H. *americanus* was made into waters off Japan as early as 1915, but was not successful. However, recent experiments (Kittaka et al. 1983;

[7] http://databank.artsdatabanken.no/FremmedArt2012/N14309

Kittaka 1984) with *H. americanus* showed successful reproduction in cages and in large pools. It was found breeding in local waters of Sanriku in the 1980s, but this has not been monitored by the Japanese fisheries (Kittaka J, pers. comm. in CABI 2013). In France during the 1970s purebred *H. americanus* and hybrid *H. americanus*/*H. gammarus* were produced for release as genetically marked specimens to test whether release of juveniles could add to the native stock (Adouine and Leglise, 1972; Latrouite and Lorec, 1991).

H. americanus has occasionally been captured in Northern European waters (Jørstad et al. 2006; van der Meeren et al. 2010). The pathways are not known. However, as the distance over the Atlantics is too large for larval drift as well as adult movement there is no natural explanations for the introductions. In other words, we humans are the cause of these introductions.

In total 29 individuals have been DNA verified and captured in Norwegian waters as reported at the end of 2015 (Agnalt pers. comm. 2015). Figure 1a shows captured records in Norwegian waters between 1999 and 2015; b) in British waters (between 1988 and 2011, in Stebbing et al. 2012) and c) in Swedish waters (between 2008 and 2015).

In Great Britain, confirmed identification of 26 live *H. americanus* have been recorded captured between 1988 and 2014 (Johnson, P. Marine Management Organisation, Great Britain pers. comm. 2015). In addition, 133 out of 361 individuals have been captured after the faith based release on 15th June 2015. The majority of the landings have been on the south coast of England, as well as one finding in Scotland. Aside from the large release in June 2015, 50% of the reports were made in 2010, and the majority were from two locations along the south coast of England. One ovigerous female was collected in 1995. Figure 1b shows captured records in British waters between 1988 and 2011 (in Stebbing et al. 2012). A large number, over 300 individuals were illegally released in the sea in southern. Parts of them have been successfully recaptured (Stebbing pers. comm. 2015).

In Sweden, 32 live *H. americanus* have been DNA verified and all have been recorded captured on the west coast from 2008 and to 2015 (Öresland, V. pers. comm. 2015). Of these, 19 were found in the Gullmar fjord in 2014. Ovigerous females have been collected, one in 1995 and four in the Gullmar Fjord in 2014. One of the ovigerous females caught in 2014 was carrying hybrid eggs. Figure 1c shows capture records in Swedish waters between 2008 and 2015.

The first observation in Denmark was in December 2006 (Jørstad et al., 2007a).

Table 1 The global distribution of *H. americanus.*

Country	Distribution	Origin	First/Last record	Reference	Notes
SEA AREAS					
Atlantic, Northeast	Present, few occurrences	Not native		*Jørstad et al. 2011; van der Meeren et al. 2010; Agnalt et al. 2012;Stebbing et al. 2012*	
Atlantic, Northwest	Present	Native		*Boothroyd & Ennis, 1992*	
Pacific, Eastern Central	Absent, formerly present	Not native		*Rathbun, 1892; Fraser, 1916; Ford & Krekorian, 1973; Ghelardi & Shoop, 1972*	
Pacific, Northwest	Absent, unreliable record	Not native		*Kittaka et al., 1983; Kittaka, 1990*	Not reported since 1990
ASIA					
Japan	Present only in captivity/cultivation	Not native		*Kittaka, 1984*	Grown for possible sea
Honshu	Localised	Not native	-/1984	*Kittaka, 1984*	
NORTH AMERICA					
Canada	Localised	Native		*Holthuis , 1991*	
British Columbia	Absent, formerly present	Not native		*Rathbun 1892; Fraser 1916; Ghelardi & Shoop, 1972*	
New Brunswick	Widespread	Native		*Holthuis , 1991*	
Newfoundland and Labrador	Widespread	Native		*Holthuis , 1991*	
Nova Scotia	Widespread	Native		*Holthuis , 1991*	
Prince Edward Island	Widespread	Native		*Holthuis , 1991*	
Quebec	Widespread	Native		*Holthuis , 1991*	

USA	Localised	Native		*Holthuis 1991*	
California	Localised	Not native		*Rathbun, 1892; Ford & Krekorian, 1973*	
Connecticut	Widespread	Native		*Holthuis, 1991*	
Hawaii	Present	Not native		*Nicosia and Lavalli, 1999*	
Maine	Widespread	Native		*Holthuis , 1991*	
Massachusetts	Widespread	Native		*Holthuis , 1991*	
New Hampshire	Widespread	Native		*Holthuis , 1991*	
New Jersey	Widespread	Native		*Holthuis , 1991*	
New York	Widespread	Native		*Holthuis , 1991*	
North Carolina	Present	Native		*Holthuis , 1991*	
Rhode Island	Widespread	Native		*Holthuis , 1991*	
Washington	Localised	Not native		*Rathbun , 1892*	
EUROPE					
Denmark	Present, few occurrences	Not native	2006	*Anonymous, 2007*	1 specimen found in December 2006
Great Britain	Present, few occurrences	Not native	1988/2011	*Stebbing et al. 2012; Johnson, pers. comm. 2015*	26 specimens found, data 2011-2015 are not complied. 361 specimens released in 2015, where 133 of them were recaptured.
Iceland	Present, few occurrences	Not native		*van der Meeren et al., 2010*	2 specimens in total, one in 1960 and one in 1965

Norway	Present, few occurrences	Not native	1999/2015	*Jørstad et al. 2006; van der Meeren et al., 2000; Jørstad et al. 2011; van der Meeren et al. 2010*	29 specimens found
Sweden	Present, few occurrences	Not native	2008/2015	*Jørstad et al., 2011; Öresland pers. comm.2015*	32 specimens found

Table 2 Introduced *H. americanus*

Introduced: to/from	**Year**	**Reason** (pathway cause)	**Introduced by**	**Established in wild**	**References**
California/ USA	1873, 1970	Aquaculture			*Ford & Krekorian, 1973; Rathbun, 1892*
Canada/ Canada	1896, 1965	Aquaculture			*Fraser, 1916; Ghelardi & Shoop, 1972*
Canada/ Canada	1989	Unknown			*Boothroyd & Ennis, 1992*
Denmark	2007	Aquaculture			*Anonymous, 2007*
France	1972-1976				*Latrouite & Lorec, 1991*
Iceland	1960-1965	Aquaculture			*Jørstad et al., 2011; van der Meeren et al., 2010*
Italy/USA		Aquaculture			*Wickins & Lee, 2002*
Japan/USA or Canada		Live food or feed trade, smuggling		Natural reproduction	*Kittaka et al. 1983; Kittaka, 1984; 1990*
Norway	1990-2015	Live food	Unknown		*Jørstad et al., 2011; van der Meeren et al., 2000; van der Meeren et al., 2010, Agnalt et al. 2012*
Oceania/USA			Unknown		
Sweden	2008-2015	Live food			*Sciences Institute of Marine Research, Swedish University of Agriculture (2015)*
Great Britain /Europe	2011	Live food			*Stebbing et al., 2012*
Washington/USA	1889	Aquaculture			*Rathbun, 1892*

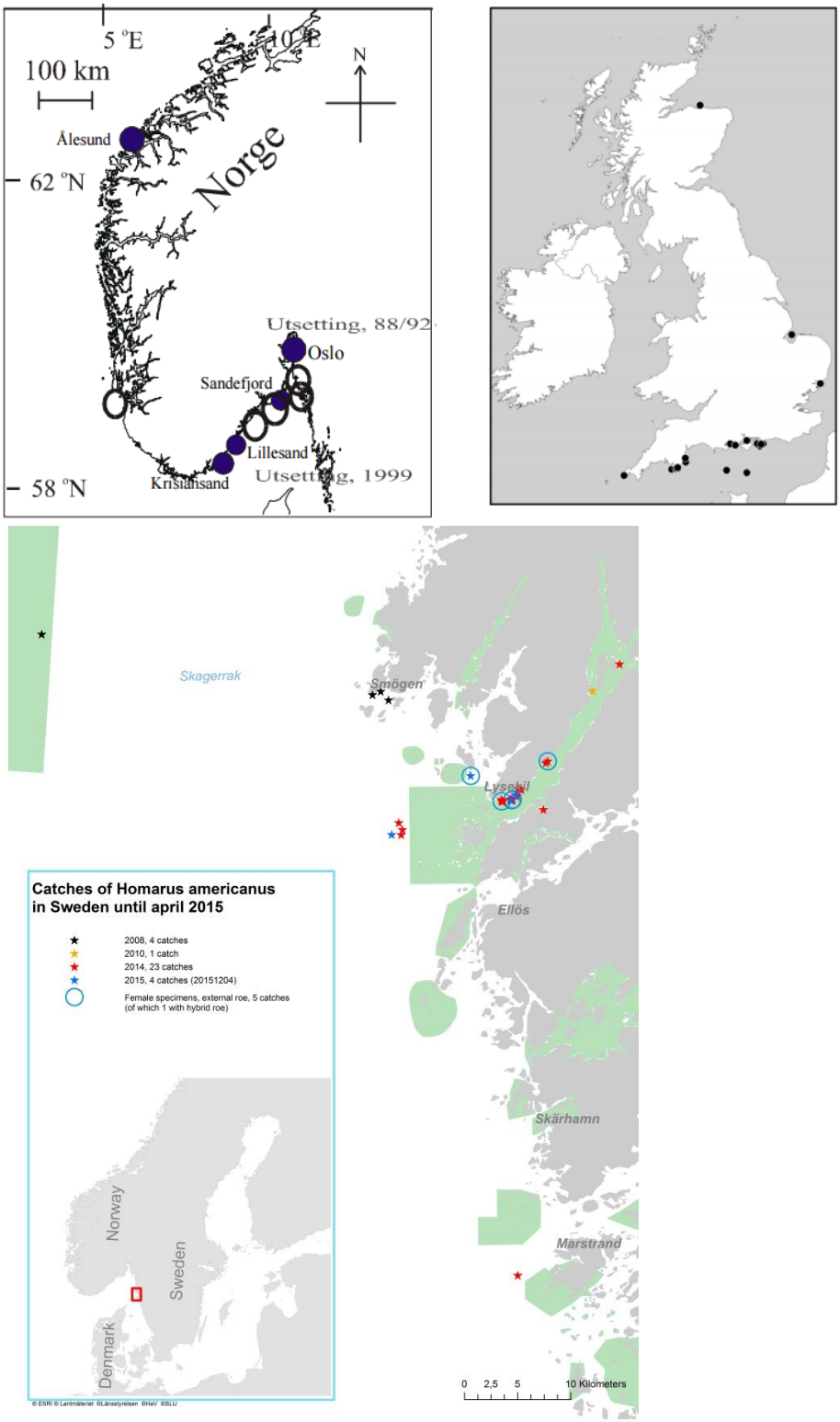

Figure 1 The maps shows captured records of *H. americanus* in: **a)** Norwegian waters (between 1999 and 2001; in van der Meeren et al. 2001); **b)** in British waters (between 1988 and 2011, in Stebbing et al. 2012) and **c)** in Swedish waters (between 2008 and 2015, detailed information in Table 3).

Table 3 Records of *H. americanus* in Swedish waters, with capture dates, depths of captures, bottom types, carapax length, weight and sex (Sciences Institute of Marine Research, Swedish University of Agriculture, 2015).

Date	**E**	**N**	**Depth (m)**	**Bottom type**	**Carapax length** (mm)	**Weight** (g)	**Sex/eggs**	**Rubber band**
16/05/2008	6479489	247685	140-180	mud	103		female	no rubber band
26/09/2008	6473803	278844		rock	84		male	no rubber band
23/10/2008	6474126	279618		rock	80		female	1 red rubber band
28/10/2008	6473313	280358	17	rock	84		male	2 red rubber band
20/10/2010	6474164	299581	20	rock	100	750	male	no rubber band
15/08/2014	6464262	292450		rock	104	835	male	no rubber band
08/09/2014	6476684	302125	37	mud	87	520	female	2 white fresh rubber band
10/09/2014	6464890	292875	38	mud	88	525	male	2 green fresh rubber band
23/09/2014	6463976	291828	18	rock	103	835	male	no rubber band
23/09/2014	6463953	291883	25	rock	97	740	male	no rubber band
24/09/2014	6467563	295360	33	mud	91	600	female with eggs ?	two white rubber bands
26/09/2014	6464363	292363		rock	99	740	male	no rubber band
28/09/2014	6463946	291964	9	rock	108	900	male	
29/9/2014	6463948	292049	18	rock	102	755	female with eggs	
30/09/2014	6463907	291975	15-20	rock	101	765	female with eggs	no rubber band
30/09/2014	6467401	295174	20	rock	100	715	male	no rubber band
02/10/2014	6464019	291832	15-20	rock	102	750	male	no rubber band
05/10/2014	6463018	294954		rock				no rubber band
09/10/2014	6463933	290973		rock	103	855	male	no rubber band
11/10/2014	6464985	292676		rock	98	725	female	no rubber band

02/11/2014	6463782	291131	25	rock	121	1305	male	
07/11/2014	6463804	291017	25	rock/mud	92	580	female with eggs	green rubber band
25/11/2014	6464974	292562	20	rock	97	770	female	
27/11/2014	6419247	292540	27	rock	117	1435	male	no rubber band
10/12/2014	6463846	291123	25	rock/mud	111	1125	male	no rubber band
17/12/2014	6460648	281552	30	rock	96	810	male	no rubber band
01/11/2014	6460668	280653	ca 30	rock				
01/11/2014	6464397	292356	-	-				
09/10/2015	6461122	281673	25-30	rock	97	695	female	
08/10/2015	6461786	281326						
01/11/2015	6466217	288095	ca 30	rock				
01/11/2015	6463948	291911					female with eggs	no rubber band
23/11/2015	6479489	247685		rock	116	1315	female with eggs	no rubber band
23/11/2015	6473803	278844		rock	120	1480	male	no rubber band

9 - Is the organism known to be invasive anywhere in the world?

For invasive species in general, there are often some years between initial introduction and establishment (Drake and Williamson 1986). The lag phase has been observed in other decapod Crustaceans in Europe, such as the Chinese mitten crab (*Eriocheir sinensis*, H. Milne Edwards 1853), where there was a significant gap between initial introduction and subsequent population explosion (Clark et al. 1998; Herborg et al. 2003, 2005). *H. americanus* in the risk assessment area could be going through a similar lag phase. The annual import of *H. americanus* from north-eastern America to EU countries is 13-15 thousand metric tons (Table 6 and 7). This provides opportunities for both intentional and accidental releases in new regions. Even if ovigerous females are protected in the fisheries in North-America, females may spawn in the holding facilities. Larvae hatched in holding facilities without barriers from the sea may drift into the sea in areas outside the species natural range. Adult *H. americanus* recently found in waters in Great Britain may originate from escape from holding facilities or from unauthorized releases (Stebbing et al. 2012; Green et al., 2013). Landings of ovigerous females are banned both in Norway and Sweden, but it is known that they can spawn in captivity after

being captured. *H. americanus* females can produce multiple clutches over at least the two years following one mating and can therefore be reproductive for some years even without the presence of a mate (Aiken and Waddy, 1995).

The two homarid species exhibit many general similarities in morphology, genetics and physiology. After the eggs have hatched, they go through three pelagic larval stages. Before metamorphosing into a postlarvae settles on the sea floor where it spends its time as juvenile and adult. The homarids are long-lived (50-100 years), large-sized, omnivorous animals that can tolerate a wide temperature and salinity range. The North American stock of *H. americanus* has a large geographic distribution, with the majority of the stock being in-shore with little migration. A small stock is found offshore at the Grand Banks. This stock undertakes large migrations seasonally (Factor 1995). The larvae hatch close to shore and females spawn typically every second year, but depend on female size and possibilities.

Due to the high market value, several attempts at transplanting this species have been conducted, with no apparent success. All of these transplants were in regions without native homarid lobster species except for the one in France during the 1970s. Live export is the major vector for distribution of this species today. It has been recorded in the risk assessment area since 1988. In 2010, introduced lobsters with ESD and carrying hybrid offspring were detected in Norwegian waters. No ecological impacts have been seen, but spread of disease to native lobsters is thought to be one of the highest threat factors.

Many imported *H. americanus* carry encrusting organisms, like barnacles and polychaetes with a potential for being invasive species themselves.

The fecundity of *H. americanus* is dependent on the size of the female, which can produce from a few thousand to several tens of thousands eggs per clutch. Smaller females tend to moult and spawn every second year, while larger females can produce egg-clutches two years in a row before moulting the third year (Talbot and Helluy 1995). Due to the many years it takes from hatching to birth, population growth rates are slow, but if all life stages are established, it will be impossible to eradicate the species from invaded areas. Successful hatching of *H. americanus* or hybrid larvae may accelerate the rate of geographic spread as larvae are transported through currents during the weeks to months they are pelagic (Factor 1995). Studies have shown that the incubation period of the eggs is shorter in *H. americanus* compare to *H. gammarus* at comparable temperatures (Eriksson S, pers. comm. 2015). Thus, there is a risk that *H. americanus* larvae in the risk assessment area may hatch earlier in the season and thereby have an advantage to the native species larvae.

There is evidence suggesting that *H. americanus* and *H. gammarus* could hybridise and produce live, fast growing, vigorous offspring (Audouin and Leglise 1972; Hedgecock *et al.* 1977; Carlberg *et al.* 1978). In some cases, the offspring has become sterile (Talbot et al. 1984), while in other studies the hybrid offspring has produced a second generation (Kittaka, J pers. comm. in CABI 2013). In Norway and in Sweden, where female H. americanus caught in the wild were carrying hybrid eggs, there is clear evidence that interspecific mating takes place in the wild or alternatively, they held together and mated in captivity and then escaped or released (Agnalt A.L pers. comm. 2014).

There is also evidence that *H. americanus* have larger claws relative to body size and may out-compete *H. gammarus* for resources, such as food and shelter (van der Meeren et al. 2000, 2008) should there be a shortage of these resources. It is not known if hybrids also are stronger competitors than *H. gammarus*. Hybrids might have inherited characteristics from both parents (Kittaka pers. comm. in CABI 2013, see also 2.05). The hybrids may be able to compete with the *H. gammarus* for resources.

H. americanus is ranked as the top-ten highest-risk future alien invasive species in Great Britain (based on their likelihood of arrival, establishment and impact on native biodiversity over the next 10 years) derived from consensus-building among experts (Roy et al. 2014). In Roy et al. (2015), *H. americanus* is one of the marine species with highest score when ranking potential negative impact on biodiversity within the EU, including likelihoods for arrival, establishment, impact and spread.

Section B - Organism screening

10 - Have you been asked to carry out a screening assessment?

Yes

11 - Does the organism have intrinsic attributes that indicate that it could be invasive (refer to Pheloung WRA, FSK, etc.)?

H. americanus has biological characteristics often associated with invasiveness; grow to a larger size, are more fecund, are more adaptive, being found in a broader range of habitats when compared with *H. gammarus* (van der Meeren et a. 2000; van der Meeren and Uksnøy 2000). *H. americanus* are also known to have seasonal long-distance migrations and are hence able to disperse and spread relatively long over a short-time period (Campbell 1985; 1986). Furthermore, they are long-lived, competitive and aggressive (Factor 1995).

H. americanus females have been found with hybrid eggs in Norway and in Sweden (Agnalt et al. 2012), but it is not yet known if this offspring is fertile or not due to long maturation times in lobsters. Earlier findings on hybrid fertility are so far inconclusive (see point 9 above).

H. americanus can carry various diseases and parasites. Gaffkemia, a lethal bacterial blood disease, has led to outbreaks in *H. americanus* holding facilities in Europe (Wiik et al. 1987; Mortensen 2002). ESD has become a major problem for *H. americanus* in their natural southern range, north to Rhode Island and Massachusetts, USA (Castro et al. 2012). *H. americanus* found in Norwegian waters have been caught with shell damages, similar to the symptoms of this disease (Karlsbakk et al. 2011). Some developed the symptoms in aquariums after being caught, but two specimens with the symptoms were caught in October 2009, in Norwegian waters (van der Meeren 2008). The cuticle in subadult *H. americanus* is thinner than in *H. gammarus* and more susceptible to damage and shell disease (Davies et al 2014). Hybrids in general receive a mix of phenotypic characters from its parents. Mixing the two homarid phenotypes may decrease cuticle thickness and thereby lower lobster resilience to disease and physical damage.

Many imported *H. americanus* carry with them encrusting organisms, like barnacles and polychaete that have no harmful effect on the lobsters, but have a potential for being invasive species themselves and carry pathogens (Martin and Britayev 1998). A recent study in Sweden also showed that live imported *H. americanus* obtained from a local fish dealer had a range of different epibionts species among their gills (nematodes, polychaetes, copepods, foraminiferas, etc. (Öresland, V. pers. comm. 2015).

12 - Is the organism present in the Risk Assessment Area in containment from which it is likely to escape?

Yes, live *H. americanus* are imported to the risk assessment area. In Sweden, Norway and Great Britain it is forbidden to release or hold live *H. americanus* in the sea due to national laws. *H. gammarus* are held live in containment facilities in the sea, and it is impossible to control for illegal storage. Full details and explanations are provided elsewhere in the risk assessment.

13 - Are there conditions present in the Risk Assessment Area that would enable the organism to survive and reproduce? Comment on any special conditions required by the species.

Yes, the conditions in the risk assessment area would enable the organism to survive and reproduce, as temperature and salinity conditions, as well as food resources and habitats required by the *H. americanus* are similar to their native conditions. It is therefore most likely that the *H. americanus* may be able to establish populations in the risk assessment area, given the chance. See Table 4 for details.

Caught of live female *H. americanus* in Swedish and Norwegian coastal waters carrying hybrid eggs would suggest that under certain conditions mixed-species breeding can take place in the risk assessment area.

Table 4 Some of *H. americanus* habitat requirements are specified below: a) habitat; b) natural enemies and c) water tolerance. The requirements would reflect the conditions in the area of risk assessment.

a) Habitat

CATEGORY	HABITAT	PRESENCE
Brackish	Estuaries	Secondary/tolerated habitat
	Lagoons	Secondary/tolerated habitat
Littoral	Coastal areas	Principal habitat
	Intertidal zone	Secondary/tolerated habitat
	Intertidal zone	Secondary/tolerated habitat
	Intertidal zone	Secondary/tolerated habitat
	Mud flats	Secondary/tolerated habitat
	Mud flats	Secondary/tolerated habitat
	Mud flats	Secondary/tolerated habitat
Marine	Benthic zone	Principal habitat
	Benthic zone	Principal habitat
	Benthic zone	Principal habitat
Other	Stored products	Secondary/tolerated habitat

b) Natural Enemies

Natural enemy	Type	Life stages	References
Anguilla rostrata	Predator	Adult/Fry	*Anonymous, 1996*
Cancer pagurus	Predator	Adult/Fry	*Anonymous, 1996*
Dyspanopeus sayi	Predator	Adult/Larval/Fry	*Barshaw & Lavalli , 1988*
Gadus morhua	Predator	Adult/Fry	*Anonymous, 1996; Brander, 1994*
Tautogolabrus adspersus	Predator	Adult/Larval/Fry	*Barshaw & Lavalli , 1988*

c) Water Tolerances

Parameter	Minimum value	Maximum value	Status	Life stage
Depth (m b.s.l.)	1	>500	Tolerance	
Dissolved oxygen (mg/l)	>0.2-1.2		Tolerance	All stages
Salinity (part per thousand)	8.0	>35	Tolerance	Adult
Salinity (part per thousand)	15-17	>35	Tolerance	Larval
Water temperature (ºC temperature)	5	20	Preference	Adult
Water temperature (ºC temperature)	-1	30,5	Tolerance	Adult
Water temperature (ºC temperature)	21	27	Optimum	Larval

14 - Does the global 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, the known geographical distribution of *H. americanus* includes ecoclimatic zones comparable with those found in the risk assessment area, which could allow the organism to survive and thrive. *H. americanus* thrives in habitats with an average water temperature in the coldest month > 0 ^{o}C and < 18 ^{o}C and > 10 ^{o}C in the warmest month (Factor 1995).

15 - Has the organism established viable (reproducing) populations anywhere outside of its native range?

Wild *H. americanus* has been reported from a number of European countries including Denmark, Great Britain, Ireland, Norway and Sweden (e.g. CABI 2013), but also in France in 2003 (International Council of the Exploration of the Sea (ICES), Reports of the Working Group on Introductions and Transfers of Marine Organisms 2001-2008). *H. americanus* has also been deliberately introduced into a number of locations over the years, including the Pacific coast of American and Japan (Kittaka 1984) with the idea of stock enhancement (CABI 2013; van der Meeren *et al.* 2010), but with no success. In France, 1 300 juvenile hybrids of *H. gammarus*/*H. americanus* were released into the Bay of Biscay in 1975, but no monitoring of the area to evaluate the impact on the local stock of this release has been conducted (Audouin 1981). *H. americanus* has not been found to have established viable populations outside of its native range, as to date. Females carrying hybrid eggs have, however, been found in Norwegian and Swedish waters. The genetically identification of hybrid eggs are direct proof that breeding has taken place in the wild between a *H. americanus* female and a *H. gammarus* male. Ovigerous female *H. americanus* are not normally exported for human consumption, and whatever sperm they might carry with them in the spermatheca from North America will be *H. americanus* sperm. Thus, the only way to get a *H. americanus* female with hybrid eggs in the wild is if copulation with a *H. gammarus* male has taken place. Given the sporadic nature of the landing of *H. americanus*, the limited geographical locations in which they have been found, and the nature of the animals (banded with little or no bio-fouling and of a similar size), it would seem unlikely that animals to date are from a breeding population. It is more likely that the reported animals are from recent releases, but only a proportion of the total animals released may have been caught, while those not caught may go on to form established populations in the future. In Sweden, some of the *H. americanus* are more than double the minimum size required for import (Öresland pers. comm. 2015). The proof of reproduction in the risk assessment area can first be confirmed when lobsters smaller than the import size start to appear.

16 - Can the organism spread rapidly by natural means or by human assistance?

Yes, *H. americanus* have been shown to regularly migrate to deeper waters during colder periods, some populations migrate as far as 322 km and return back to shallow water areas during warmer temperatures. Campbell (1986) showed that 75% of animals used in a mark-recapture study moved <15 km, 7% moved >30 km and a maximum recorded movement of 322 km, suggesting that Smith et al. (2001) showed that 95% of animals used in a mark-recapture study moved on average <3.8 km over an 862 day period, with a maximum distance range of 45 km.

Given the nature of the trade in *H. americanus*, where animals are imported and then distributed to holding facilities, restaurants and for private sales (for example to boat owners), human activities will be the quickest form of dispersal. Live *H. americanus* is even sold as souvenirs to tourists at the

international airport in Boston and possibly also in the lobster fishing regions of eastern Canada. This species cannot cross oceans by any natural vector. See Table 5.

Successful hatching of larvae (either *H. americanus* or hybrid) will potentially accelerate the geographic spread and each female may have a (effective) fecundity of tens of thousands of hatching larvae. Although currents strongly influence larvae horizontal distribution, larvae are not passive drifters and may influence their displacement in the water column (Factor 1995).

Table 5 Pathways of introduction of live *H. americanus* to the area of risk assessment.

Cause	Notes	Long distance	Local	References
Aquaculture	USA	Yes		*Kittaka, 1984a-c; Kittaka, 1990*
Escape from confinement/ garden escape	Live export/import, Aquaculture	Yes		*Jørstad et al., 2011; Stebbing et al., 2012; van der Meeren et al., 2010*
Intentional release		Yes		*Kittaka, 1984a-c*
Live food/feed trade including deliberate release and		Yes		*Jørstad et al., 2011; Stebbing et al., 2012; van der Meeren et al., 2010; Öresland pers. comm. 2015 Stebbing pers. comm. 2015*
Research		Yes		*Kittaka, 1984a-c*
Smuggling	USA, Canada to Europe	Yes		*Jørstad et al., 2011; van der Meeren et al., 2010*

17 - Could the organism as such, or acting as a vector, cause economic, environmental or social harm in Europe?

Yes, *H. americanus* could cause environmental, economic and social harm. The extent of harm depends on what scenario for establishment of the species is the most likely; one that implies that the total stock of *H. americanus* is kept constant, or one that means a severely decreased stock.

H. americanus are known to carry to potentially lethal diseases (Gaffkemia) and ESD and may also carry other pathogens (virus, bacteria, fungi and parasites) that may infect the *H. gammarus* and cause declines in their population or even its extinction. Parasites may be invasive in themselves, and epibionts can also be a vector of diseases between lobsters or other crustaceans. In addition, *H. americanus* has biological characteristics often associated with invasiveness; they grow to a larger size and are more fecund (van der Meeren et al. 2008), are more adaptive (phenotypically plastic), being found in a broader range of habitat when compared with the *H. gammarus* (Factor 1995; Mercer et al. 2001). Furthermore *H. americanus* may also be found in a greater depth range than the *H. gammarus* and thereby compete with other crustaceans for food and shelter, as well as affect the whole ecosystem. Full details and explanations are provided elsewhere in the risk assessment.

Environmental harm can be caused by the impacts of *H. americanus* through hybridization between *H. americanus* and *H. gammarus* which may produce live, fast growing, vigorous offspring (Talbot et al. 1984; Kittaka pers. comm., in CABI 2013). Even if the offspring should turn out to be infertile, lobsters are long-lived species, thus the hybrids' impact on environment and on the reproduction success of *H. gammarus* might be severe. A mix of genotypes as well as phenotypes could result in lowered reproductive output within the whole lobster stock (regardless of species) if e.g. conspecific cues for mating are lost. The two species appear to prefer their conspecifics in mating (van der Meeren et al.2008). However as female *H. americanus* with hybrid eggs have been found in the wild, the smaller the native *H. gammarus* population is, the more likely it is that also female *H. gammarus* with hybrid eggs will occur. *H. americanus* genes thus potentially "hid" in *H. gammarus* females´ hybrid eggs are much less likely to be found since this is not currently monitored. The reproduction of *H. gammarus* is poorly understood.

Economic harm can be caused in terms of losses of incomes, job opportunities, recreational values and existence values (the value of preserving a resource even if one does not use it). Economic harm can also be caused by effects on other parts of the ecosystem. If fishing of *H. gammarus* is severely affected by the introduction and establishment of *H. americanus* losses of incomes and job opportunities among fishermen are expected if the fishermen cannot shift to fishing of other species. However, at least for Swedish fishermen the size of lost incomes does not necessarily have to be very dramatic since lobster fishing is rarely their main source of income.

Recreational values will also be negatively affected if *H. americanus* is established. If the total stock of lobster will stay constant, there is evidence from other sectors and activities suggesting that when given a choice, a native species will be valued higher by all, or most, users. However, in some parts of the risk assessment area it will be extremely difficult to discern between the native and the invasive lobster. Hence, if the total lobster stock is kept more or less constant, an introduction of *H. americanus* will not necessarily have any grave impacts on the recreational fishery. If the total stock of lobster decreases, official statistics estimates from Sweden suggest that the total lost values in recreational fishery would be 18.9 million SEK/year. This is however based primarily on the wholesale market price of the catch and does not take recreational, cultural heritage and existence values into account. There is much evidence to suggest that the value of recreational fisheries may well be more than twice, or even three times more, than what has been reported in official statistics. Thus, the economic losses of lost opportunities for recreational fishing of lobster will likely be much higher than suggested by official statistics.

The development of the future cost of management of *H. americanus* depends on whether or not an establishment of the species in the risk assessment area takes place, and if so, the response from the authorities. Assuming that establishment is avoided, then the costs will remain at the present levels. These costs are mainly associated with food security and animal welfare inspections in holding and processing facilities. If on the other hand, an establishment occurs, then the response from the authorities is expected to be either; 1) the establishment is "accepted" and the management costs remains at

the present levels as above, or 2) an attempt is undertaken to stop the spreading of the species by means of intensive fishing with the ultimate goal of eradication. This response is unlikely to be successful because of the ability of *H. americanus* to migrate to deep waters out of reach of fishing efforts. The costs for the intensified fishing effort could nevertheless be expected to be high, as it will include a great number of fishermen and vessels for a significant amount of time. Also, costs will also include marketable remuneration for captured "suspicious *H. americanus*" to ensure that all findings are reported.

Social harm can be caused in local coastal areas where lobster fishing is currently an important tradition and has a strong social value, which is the case for example in some coastal areas of Norway and Sweden. Many villages on the west coast of Sweden are today facing a declining resident population. Armbrecht (2014) discusses these values and concludes that not only the fishing per se is valuable but also the fact that tourists can walk along the quays of the fishing villages, seeing fish being landed, being able to buy fish etc. These values are partially covered by the market value of tourism in these areas. Unfortunately, there is no clear answer to how these values would be affected by the introduction and establishment of *H. americanus*.

Stage 2 - Detailed assessment

Section A – Entry

1.01 - How many active/future pathways are relevant to the potential entry of this organism?

Few

Comments: The main route of entry of live *H. americanus* into Europe is via imports from North America and Canada. Large quantities (≈ 13 thousand metric tons) of *H. americanus* are exported live from north-eastern America into the EU each year. This provides opportunities for both intentional and accidental releases in new regions. Even if berried females are protected in the fisheries, females spawning in the holding facilities are exported. Larvae hatched in holding facilities without barriers from the sea may drift into the sea. Adult *H. americanus* recently found in waters of Great Britain may originate from escape from holding facilities or from unauthorized releases (Stebbing et al. 2012; Green et al., 2013). Landing of berried females is banned in Norway, but it is known that they can spawn in captivity after being caught. *H. americanus* females can even produce multiple clutches over at least two years following one mating and can therefore be reproductive for some years even without the presence of a mate (Aiken and Waddy, 1995). Females without eggs may still carry live sperm in their sperm pockets (spermatheca) and can produce pure-bred offspring until they moult (Aiken and Waddy, 1995).

There are both large and small importers that keep live lobster for sale in holding facilities for restaurants and fish dealers, from which the public can also buy live lobsters. This possibility increases the potential risks of introduction into the wild, even though it is forbidden to hold live *H. americanus* in cages in the sea. Evidence also exists suggesting the *H. americanus* have escaped from land based holding facilities, and have been deliberately released by animal activists and by people unaware of the environmental consequences of releasing these animals. There is also anecdotal evidence to suggest that passenger liners and other vessels have thrown live *H. americanus* overboard as waste. In addition, individuals concerned with the death of lobsters unused in restaurants have been known to release them to the wild.

1.02 - List significant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways.

Comments: Imports for human consumption from North America directly into Sweden (pathway into EU/EES), or movement from another European member country into Sweden (pathway between EU/EES states) followed by either:

- Accidental release or disposal from holding facilities (entry into the wild), or

- Deliberate release, including disposal from boats, animal activists, good intentioned individuals (entry into the wild).

1.03 - Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?

Comments: Live *H. americanus* is imported for sale. Intentional release of the *H. americanus* into open waters is prevented in national laws for Denmark, Norway, Great Britain and Sweden. Furthermore, national action plans for biodiversity (ratification of the Convention on Biological Diversity, appendix 10.1) and international trade agreements are in place, with similar import-laws in the four countries, requiring veterinary certificates and including a prohibition of release of lobsters in coastal waters.

In Norway and Sweden there is a monitory reward for any caught and positively identified *H. americanus*. Most of the public aquaria and the Institute of Marine Research (IMR) collaborate to inform the public and receive all possible specimens delivered by professional and recreational fishermen. All findings are to be analysed genetically by the IMR and registered. Improved control routines have been employed for control of imported lobsters as well as fishmongers and the fish markets. Still, it is a problem that live *H. americanus* imported into an EU country are regarded as *Homarus* and cannot be traced as a species in the trade statistics if sold on to a second EU country.

When the first *H. americanus* were identified in Sweden and in Norway, it caught the public attention and was followed by a broad media interest. The ensuing part governmental, part media driven information campaigns have successfully educated the public about the two lobster species and their differences. However, as long as live *H. americanus* can be legally imported, there is a risk that someone will violate the legislations, accidentally or intentionally, and release more *H. americanus* in the risk assessment area.

1.04 - How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?

Very likely
Confidence: very high

Comments: Between 2005 and 2014 there have been a yearly import of 13 209 metric tons (in average) of live lobsters (*Homarus sp.,* i.e. *H. americanus)* to the EU countries from Canada and the USA (Eurostat 2015). USA had the largest exports, an average 8 799 metric tons yearly, to EU countries. Canada had an average yearly export of 4410 metric tons to EU countries in the same period. Belgium, Germany, Spain, France, Great Britain, Italy, the Netherlands, Sweden and Denmark are the main importers.

Exports to the EU countries from Canada and USA are presented in Table 6 and Table 7 respectively.

Table 6 Imports of live lobster (*Homarus sp.)* in metric tons from Canada to EU (28 states) between 2005 and 2014 (Eurostat 2015).

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Austria	10	14	15	9	8	1	0	0	0	0
Belgium	1481	1607	1708	1284	1709	1713	1621	1488	1420	1649
Bulgaria	0	0	0	0	0	0	0	0	0	0
Cyprus	3	2	3	2	2	0	2	1	2	4
Czech republic	14	12	12	8	5	7	10	10	3	3
Germany	406	239	371	515	404	244	308	311	394	295
Denmark	57	55	58	43	40	38	54	62	59	32
Estonia	0	0	0	0	0	0	0	0	0	0
Spain	1173	990	1052	1055	1056	446	142	247	151	179
Finland	6	6	4	0	1	10	5	6	5	5
France	419	428	429	448	779	570	495	510	516	523
Great Britain	676	708	696	517	329	274	263	273	227	786
Greece	29	28	32	32	32	20	16	7	7	8
Hungary	0	0	0	0	0	0	0	0	0	0
Ireland	17	7	5	1	26	13	3	1	3	0
Italy	590	502	527	505	380	470	373	515	461	497
Lithuania	0	0	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	0	0
Latvia	0	0	0	0	0	0	0	0	0	0
Malta	3	6	7	6	3	2	0	0	0	1
The Netherlands	119	109	125	120	142	148	106	97	164	255
Poland	2	2	1	3	3	4	4	2	0	0
Portugal	13	5	10	10	6	5	4	2	3	1
Romania	0	0	0	0	3	1	0	1	0	0
Sweden	169	147	136	134	164	140	128	77	69	102
Slovenia	0	0	0	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0	0	0	0
Croatia	0	0	0	0	0	1	0	0	1	0
EU28 (total)	**5184**	**4867**	**5190**	**4692**	**5091**	**4107**	**3535**	**3609**	**3485**	**4340**

Table 7 Imports of live lobster (*Homarus sp.)* in metric tons from USA to EU (28 states) between 2005 and 2014 (Eurostat 2015).

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Austria	1	2	7	7	1	0	0	0	0	0
Belgium	71	46	37	28	33	1	50	110	136	146
Bulgaria	3	3	5	6	5	4	5	5	6	6
Cyprus	0	0	0	0	1	0	0	2	4	3
Czech republic	0	1	2	4	0	0	0	2	2	
Germany	231	264	216	154	131	172	197	185	133	79
Denmark	0	1	1	0	0	0	2	1	11	29
Estonia	0	0	0	0	0	0	0	0	0	0
Spain	1943	2664	2796	3128	2928	3466	3498	2855	2740	2541
Finland	0	0	0	0	0	0	0	0	0	1
France	1693	1897	1750	1931	1724	1841	1983	1751	1969	1651
Great Britain	127	119	135	132	162	299	245	370	733	761
Greece	1	2	1	4	2	9	13	17	16	19
Hungary	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	4	3	3	2
Italy	2877	3216	3141	3537	3890	3708	3872	3196	3074	3183
Lithuania	0	0	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	0	0
Latvia	0	0	0	0	0	0	0	0	0	0
Malta	0	1	0	0		1	1	0	2	3
The Netherlands	78	48	33	36	8	22	104	97	41	17
Poland	0	0	0	0	0	0	0	5	2	1
Portugal	0	0	0	10	0	0	0	0	0	0
Romania	0		4	8	8	8	10	9	9	9
Sweden	21	46	85	83	91	137	179	203	221	182
Slovenia	0	0	0	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0	0	0	0
Croatia	4	5	5	5	4	4	4	4	0	0
EU28 (total)	**7051**	**8314**	**8217**	**9072**	**8989**	**9673**	**10168**	**8816**	**9101**	**8632**

Since large importers of live *H. americanus* only are found in a few number EU-countries there are exports between states within Europe. Sweden is used as an example (Table 8) to illustrate imports (metric tons) of live lobster (*Homarus sp.)* from other EU/EES countries between 2005 and 2014 (Statistics Sweden 2015).

Table 8 Global imports (metric tons) of live lobster (*Homarus sp.)* to Sweden from countries other than Canada (in Table 6) and United States of America (in Table 7) between 2005 and 2014 (Statistics Sweden 2015).

YEAR/COUNTRY	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Belgium	0	0	0	0	0	0	0	1	1	0
Denmark	2	3	2	3	4	6	12	11	14	29
France	0	0	0	0	0	0	0	0	0	2
Iran	0	0	0	0	0	1	0	0	0	0
Ireland	4	2	0	0	0	0	13	9	9	5
Island	0	0	1	0	1	1	0	1	0	6
The Netherlands	0	0	0	13	0	0	17	36	37	56
Norway	11	10	23	7	6	10	10	14	10	6
Spain	0	0	0	0	0	0	0	0	1	0

Given the low number of *H. americanus* reported from the risk assessment area in comparison to the quantities imported, the escape of animals from holding facilities would appear to occur infrequently. Several *H. americanus* found in 2010 in Great Britain and in 2008 and 2014 in Sweden are near to or directly linked with existing holding facilities, giving a high level of confidence in the association. In Scotland there is little evidence that the animal escaped from a tank facility or was recruited from the wild; it was more likely to have resulted from an inadvertent release.

1.05 - How likely is the organism to enter Europe undetected or without the knowledge of relevant competent authorities?

Unlikely
Confidence: Medium

Comments: There are controls on importing lobsters from third countries. These controls apply to all live crustacean shellfish, their eggs and gametes. All imports must be licensed. Live *H. americanus* has its own product group code (03062210).

Imports of live *H. americanus* enter the European market via products border inspection posts (BIP).

However, once they have entered into the EU *H. americanus* is much harder to control, and despite in many cases there being national legislation in place governing the holding of the species, escapes/releases are still occurring on a regular basis.

There is an internal marked governed by the same rules that aim to enable goods, persons, capital and services top move freely within European Economic Area (EEA) and the three EEA EFTA states (Iceland, Liechtenstein and Norway). There are no restrictions on, or documentary requirements for imports of live lobsters within the area.

The stocks of the native *H. gammarus* are quite small compared to the *H. Americanus* stocks and the price and demand for live lobsters is high in Northern Europe. Experts recommend implementing the first line of defence, with import restrictions to the EU/EES, since it is very difficult to control spread once the animals have been imported (Meeren et al. 2010).

Animals are sold to other retail outlets and holding facilities by the original importer. Holding facilities can be found in a number of locations, including restaurants, markets, supermarkets, and purpose-built facilities. Holding facilities are found throughout the risk assessment area, and are of varying quality. There is evidence to suggest that escapes have occurred from holding facilities that have not been maintained properly. It is also suspected that moribund animals which are discarded into coastal waters subsequently survive. Where there is a market demand which cannot be met via sales of *H. gammarus*, internal movements for trade may occur where the trader is ignorant of statute (e.g. certification and the need for a licence to import), the risks of holding both species together in a tank system and appropriate disposal and effluent discharge.

1.08 - How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?

Likely
Confidence: Medium

Comments: If reports of *H. americanus* are used as an indicator of how often the pathway may breakdown, then a very small proportion of the total number of imported *H. americanus* transfer from holding facilities to the wild. However, there is clear evidence to link holding facilities with the release of *H. americanus* into the wild.

In Great Britain, Norway and in Sweden, there are several incidences where holding facilities most likely have been implicated in the release of *H. americanus* into the wild. There are also clear mechanisms by which the potential risk posed by holding facilities could be reduced. While there is clear evidence that some lobsters have been released from illegal holding tanks, either due to bad maintenance or disposal of excess or moribund animals into open waters, the closing of this particular pathway may only reduce, rather than stop, *H. americanus* being found in the wild, as there are other pathways by which they can still enter open waters. However, given that holding facilities will contain the vast majority of the *H. americanus* in Great

Britain at any one time, it is thought that the control of this pathway could significantly reduce the animals entering into Great Britain waters.

1.09 Do other pathways need to be considered?

Comments: No. However, the disposal of mortalities, moribund animals and those not due to be consumed is another pathway that could result in the transfer of disease to native stocks.

End of pathway related questions.

1.10 - Estimate the overall likelihood of entry into risk assessment area based on this pathway?

Likely
Confidence: Medium

Comments: Collected data relating to the findings of *H. americanus* in Swedish waters, as well as in Great Britain and in Norway would suggest that relatively low, but increasing numbers of animals have found their way into open waters despite national prohibitions and information campaigns. However, it can be assumed that more animals are released or escape than are caught. The steady build-up of numbers in open waters may result in the establishment of breeding populations over time. Overall likelihood of entry is very high also in the future, as it is practically impossible for the government to control if someone keeps/puts live *H. americanus* in the sea.

Stage 2 - Detailed assessment

Section B – Establishment

2.01 - Is the organism well established in the area of risk assessment (if there is any uncertainty answer 'unsure')?

Comments: No/unsure. An indication of establishment may be if larvae start to appear in the pelagic (e.g. in plankton samples), and subadults are caught in the fishing industry (e.g. in pots for fishing large decapod crustaceans). The early benthic stages (i.e. juveniles of ≈ 2-10 cm total length) are generally not conspicuous within monitoring or fishing activities, thus we have to actively look for this particular life stage in likely habitats (cobbles etc.) (Factor 1995). There are no surveys aimed to detect larvae, early benthic phase, or adolescent phases of *H. americanus,* but there are surveys that sample plankton for other purposes. Since it has not been possible to find European lobster early benthic phase in Europe despite considerable efforts (Linnane et al 2001), it might be difficult also to find *H. americanus* early juveniles. Since lobsters do not grow particularly fast, this may still take years after an actual establishment.

2.02 - How likely is it that the organism will be able to establish in the area of risk assessment based on the similarity between climatic conditions in the area of risk assessment and the organism's current global distribution?

Very likely
Confidence: high

Comments: The east coast of America and the European Atlantic region share very similar climates. If sufficient numbers of *H. americanus* were to enter European waters then it is likely that populations would establish. As trade increases so does the risk, which makes it important to identify and mitigate those risks to minimise the likelihood of establishment. Hatching *H. americanus* have been recorded at temperatures from 12.2°C and was most intensive 20°C. In the field, bottom temperatures at first occurrence of stage (I) larvae in plankton samples range from 4.2°C to 13.9°C. Larval and post-larval development is temperature dependent (Ennis 1995). Within its natural geographical range, adult *H. americanus* inhabits regions where temperatures can be as low as 5°C or as high as 20°C. The thermal tolerance of lobsters is broad, from -1°C to 30.5°C and they can survive abrupt temperature increases and decreases (Lawton and Lavalli 1995). See also information in table 4c.

Increased water temperatures due to climate change may effect the potential spread of *H. americanus* slightly since it seems to be moderately temperature dependent. The larval stage is the most sensitive.

2.03 - How likely is it that the organism will be able to establish in European countries based on the similarity between other abiotic conditions in the area of risk assessment and the organism's current global distribution?

Very likely
Confidence: high

Comments: The similarity between the east coast of American and the European Atlantic region waters would make establishment very likely. In-shore populations of juvenile and adult are found on mud, cobble, bed-rock, peat-reefs, rocks on sand and eelgrass-beds. Off-shore populations are found on similar substrates as well as on clay (Lawton and Lavalli 1995). All stages of *H. americanus* have a tolerance to low levels of dissolved oxygen >0.2-1.2 mg/l. the salinity tolerance for adult stages is 8->35 ppt and for larvae 15->35 ppt. The depth tolerance in its natural range is 1->500 m. See also information in table 4c.

2.04 - How likely is the organism to encounter habitats necessary for the survival, development and multiplication of the organism in the area of risk assessment?

Very likely
Confidence: very high

Comments: H. americanus share very similar habitat preferences with native *H. gammarus*. Therefore, there is a high risk that they will compete for habitats and shelters. This is supported by the fact that the reported findings of *H. americanus* have been made by lobster fishermen catching *H. gammarus*. There are no specific species requirements by *H. americanus* for their establishment beyond the requirements of the native *H. gammarus*, thus establishment is likely to occur.

2.05 - How likely is it that establishment will occur despite competition from existing species in the area of risk assessment?

Very likely
Confidence: very high

Comments: *H. americanus* grow faster and have relatively larger claws and are more heavily built than *H. gammarus* (Wolff 1978). Since claw sizes are important for dominance (Atema and Voigt 1995), they will be dominant over similar and even slightly larger *H. gammarus* individuals. However, the native *H. gammarus* are more aggressive and would therefore be able to keep *H. americanus* at a distance as long as there is no competition for a scarce but important food resource (van der Meeren et al. 2000). It is common for hybrids to show high levels of aggression combined with traits from both parents. In hybrid lobsters bred in Japan, juveniles were reported to grow at least as fast as *H. americanus* while they were at least as aggressive as the *H. gammarus* (Kittaka, pers comm., in CABI 2013). It would therefore seem likely that

populations of *H. americanus* or hybrids would become established despite competition from native species. Hybrids may also be sterile (e.g. Carlberg et al. 1978), which complicate the picture further. In addition, *H. americanus* may establish in deeper water (> 500 m) that *H. gammarus* normally do not occupy (Squires 1990). Thus, undetected *H. americanus* can exist in deeper habitats, especially hard bottoms where there is no fishing activity.

The current status of *H. gammarus* stock is at a record low (Sundelöf et al. 2013), which would minimize competition between the species and increases the likelihood of successful establishment in the risk assessment area.

2.06 - How likely is it that establishment will occur despite predators, parasites or pathogens already present in the area of risk assessment?

Very likely
Confidence: high

Comments: H. americanus and *H. gammarus* are very similar species, although *H. americanus* has a thinner shell and would thereby have a lower tolerance to pathogens. There are no known diseases in *H. gammarus* not found in *H. americanus*, but the contrary is the case. *H. americanus* has a slightly higher tolerance for Gaffkemia and thereby there is an increased risk for lethal infections in the native stocks. *H. americanus* in the risk assessment area would therefore be exposed to the same pathogens as *H. gammarus* and cope with them in a similar manner. It would also be likely that the *H. americanus* will be targeted by the same predators as the native lobster. It can therefore be assumed that *H. americanus* will be able to survive in the same areas as *H. gammarus,* as it is likely that the same limiting factors will affect both species in a similar manner.

2.07 - How likely is it that establishment will occur despite existing management practices in the area of risk assessment?

Very likely
Confidence: very high

Comments: Despite commercial catching of *H. americanus* keeping their numbers down, it is likely that only a small proportion of the *H. americanus* released into the risk assessment area are subsequently removed in this manner. In Sweden there is a reward for *H. americanus* findings in the recreational and commercial fishery. However, there is evidence to suggest that *H. americanus* are not yet well established in the risk assessment area. If this had happened it would be expected that an increasing number of animals of varying sizes would be found over an expanding geographical region. At this point, it would be expected that fishermen would report a decrease in *H. gammarus* catches and the presence of *H. americanus* in catches, corroborating the theory that *H. americanus* would outcompete *H. gammarus*.

In Great Britain, if the Lobster Control of Deposit Order/Wildlife and Countryside Act were implemented more rigorously, then this would reduce the introduction of more animals into the wild.

In Sweden, Denmark and Norway, despite management practice, annual information campaigns and media reports, new findings of *H. americanus* in the risk assessment area are reported continuously. A major concern is the ovigerous females that have been caught carrying either pure-bred *H. americanus* or hybrid eggs.

2.08 - How likely is it that management practices in the area of risk assessment will facilitate the establishment of the organism?

Unlikely
Confidence: high

Comments: The presence of *H. americanus* in Sweden as well as the around the European Atlantic coast is still scarce and patchy, with no proven establishments. Some fishing efforts have been made to find live specimens in close areas to large findings (i.e. Gullmar fjord, Sweden) or after deliberate releases (Great Britain), but with low or none success.

Adult *H. americanus* are caught by recreational and commercial fisheries. However, *H. americanus* are more likely to use deeper water where fishing for *H. gammarus* does not occur. This means that the *H. americanus* will be protected from fishing and the chance of discovery is limited. Nonetheless, the first *H. americanus* fished in Swedish waters was accidentally taken by a trawler at 160 m depth (Table 3). The somewhat overlapping phenotypes of the two homarid species, difficulties finding juvenile individuals plus the small (but not implausible) likelihood of *H. gammarus* carrying hybrid eggs are three additional areas where *H. americanus* genes may currently be disguised.

2.09 - How likely is it that biological characteristics of the organism would allow it to survive eradication campaigns in the area of risk assessment?

Moderately likely
Confidence: very high

Comments: In the marine environment, prevention seems to be the only feasible alternative. With current understanding, eradication of established species is not feasible, but there have been some successes in the early stages of introduction (e.g. the eradication of *Caulerpa taxifolia* in California, Anderson, 2005).

Eradication programmes in the marine environment are notoriously difficult to implement and depleting local populations will be impossible in practice. However, in the same way that many crustacean fisheries can be fished to a point of extinction, requiring the implementation of management strategies, it would seem possible for *H. americanus* to be trapped equally rigorously.

Immediate import bans to these countries will decrease the risk for permanent establishment and need for eradication programmes.

The somewhat overlapping phenotypes of the two homarid species, plus the small (but not implausible) likelihood of *H. gammarus* carrying hybrid eggs are two additional areas where *H. americanus* genes may currently be disguised and thereby protected from discovery and eradication.

2.10 - How likely is it that the biological characteristics of the organism will facilitate its establishment?

Likely
Confidence: very high, see above

Comments: Although *H. americanus* has many biological characteristics often associated with invasiveness, it has not to date been proven to establish outside its native range. However, the long generation time of the *H. americanus* makes detection of an early establishment difficult. Some of the characteristics that make it more prone to invade are: they grow to a larger size, are more fecund, are more adaptive, forage for the same selection of food and seek similar shelters when adult, while also being found in a broader range of habitats when compared with the *H. gammarus,* which may be displaced (van der Meeren et al. 2000). Furthermore, they are long-lived, aggressive and competitive. Some *H. americanus* populations are known to undertake long-distance migrations.

2.11 - How likely is it that the organism's capacity to spread will facilitate its establishment?

Very likely
Confidence: very high

Comments: Given the mobile and migratory nature of *H. americanus* and the amount of suitable habitat available to them in the risk assessment area, this would aid in establishment.

2.12 - How likely is it that the organism's adaptability will facilitate its establishment?

Very likely
Confidence: very high

Comments: The species is found over a broad geographical range, which suggests that it can adapt to a variety of environmental conditions. It also has relatively broad tolerances to e.g. salinity and temperature differences.

2.13 - How likely is it that the organism could establish despite low genetic diversity in the founder population?

Likely
Confidence: high

Comments: There are three stocks of lobster in U.S. waters - Gulf of Maine, Georges Bank, and Southern New England (NOAA 2015). It is assumed that the “founder individuals” come from a legal fishery in North America that have been imported to Europe. Thus, the genetic diversity in the founder population probably reflects the diversity found in the North American fishery over the last time period. By continuing to import live *H. americanus* there is a further possibility for addition of genetic material over time. *H. americanus* females may mate with several males resulting in multiple paternities in her brood (Waddy et al. 1995). However, there is still a possibility that a population established in the risk assessment area from only a few individuals could cause genetic problems such as founder effects.

2.14 - Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in the area of risk assessment? (If possible, specify the instances of invasion elsewhere in the justification box.)

Moderately likely
Confidence: medium

Comments: There have been previous deliberate attempts to establish *H. americanus* populations, for example in the Pacific Coast of America and in Japan (Kittaka 1984a, 1984c). However, these attempts have not been systematically followed up or been reported from fisheries. Hence, the success of these attempts and the status of any resulting *H. americanus* populations are not sufficiently known.

There are occurrences of failed establishment in some well-known invasive alien species (e.g. Lodge 1993, Marchetti et al. 2004; Copp et al. 2007). This is no guarantee that the same species is not successfully invasive in another place and time. Thus, the fact that successful establishment of *H. americanus* in these occurrences has not been proven does not exclude that it may successfully establish in the risk assessment area.

H. americanus have not invaded elsewhere, but are found with increasing regularity in especially British, Swedish and Norwegian waters, during a relatively short time period (since late 1990´s). It is feared that populations of *H. americanus* may be forming in these countries. However, when there is a large escape of lobsters within a small area (like in the Gullmar Fjord in Sweden in 2014), the chance for establishing a subpopulation probably increases dramatically, compared to sporadic escapes over time and large areas. The long generation time of *H. americanus* and the cryptic lifestyle of its early juveniles make detection of an early establishment difficult.

2.15 - If the organism does not establish, then how likely is it that transient populations will continue to occur?

Likely
Confidence: high

Comments: H. americanus have been reported from waters in Great Britain since 1988, in Norway since 1999, in Denmark 2006 and in Sweden since 2008. It would therefore seem unlikely for this to stop unless there is a change in management strategy and it is prohibited to import live *H. americanus*. Recent data would suggest that these numbers are increasing, with possible transient populations leading to further establishment. This is likely to increase with the development of trade.

2.16 - Estimate the overall likelihood of establishment (mention any key issues in the justification box).

Likely
Confidence: medium

Comments: Establishment seems likely if measures are not taken. Although it may take several years for numbers to build up to sufficient levels for noticeable populations to form, the continual introduction of small numbers of animals from the pathways discussed will facilitate this process.

It is very likely that an establishment is underway in e.g. the Swedish Gullmar Fjord. A high number (n=19) of lobsters were found inside the fjord in 2014, most of them within a small area directly connected to a non-fishing area where escapes from illegal holdings (net cages in the sea) are suspected. Females with berried eggs (n=3) and also hybrid eggs (n=1) were identified and some of the lobsters found weighed up to 1.3 kg while some of the smaller ones still had the exporter's rubber band around their claws. This indicates that the larger *H. americanus* might have been within the protected area for at least 2 years. No *H. americanus* were reported from just outside this protected area before 2014. One should bear in mind that the number of lobsters reported is probably only the tip of the iceberg. There is an ongoing fishing project in order to find out if there are more *H. americanus* in the Gullmar Fjord (Öresland, V. pers. comm. 2015).

Section C - Spread

3.01 - In what proportion (%) of 10km squares in the area of risk assessment could the organism establish?

11-33%
Confidence: low

Comments: The risk assessment area includes the European Atlantic territorial waters. The potential area of establishment is assumed to be corresponding to or greater than the current spread of *H. gammarus*.

Habitat choice is the main basis for this judgement. Establishment depends on how *H. americanus* is restricted by the habitat. In-shore populations of juvenile and adult are found on mud, cobble, bed-rock, peat-reefs, rocks on sand and eelgrass-beds. Off-shore populations are found on similar substrates as well as on clay (Lawton and Lavalli 1995).

Adult *H. americanus* may also migrate to deeper waters during winter months and can travel long distances (Lawton and Lavelli 1995). Although *H. americanus* have a greater capacity to spread than native lobster, the process will still be slow. Successful hatching of larvae (either pure-bred *H. americanus* or hybrid) will potentially enhance the geographic spreading. The planktonic larvae may influence their displacement in the water column and thereby their horizontal distribution (Ennis 1995).

The proportion of habitats is a qualitative estimate by European lobster experts. Our intention was to make a quantitative analysis, but the bottom substrate data for the European coastline needed to evaluate Homarid lobster habitats are not available for all countries, see for example the European database Emodnet[8].

In summary, the assessment is that *H. americanus* may colonize the same habitats as *H. gammarus*, as well as deeper bottom habitats.

3.02 - How important is the expected spread of this organism in the area of risk assessment by natural means? (Please list and Comments on the mechanisms for natural spread in the justification box)

Moderate
Confidence: high

Comments: Once subpopulations start to establish themselves in various parts of the risk assessment area their distribution areas will gradually increase over time. Secondary introductions can be observed for all new invading species. Generation times of *H. americanus* are relatively long and migratory rate is slow (Factor 1995).

[8] http://www.emodnet-seabedhabitats.eu/default.aspx

3.03 - How important is the expected spread of this organism in the area of risk assessment by human assistance? (Please list and Comments on the mechanisms for human-assisted spread in the justification box.)

Rapidly
Confidence: medium

Comments: H. americanus are held throughout the area of risk assessment. Although they enter the risk assessment area through a limited number of routes they are rapidly dispersed by humans. Until now, the main spread of *H. americanus* has been due to humans and this will most likely continue (if not live import is prohibited or other action are taken) until subpopulations are established after that natural spread will then be increasingly more important.

3.04 - Within the area of risk assessment, how difficult would it be to contain the organism?

Very hard
Confidence: low

Comments: It is impossible to eradicate lobsters in their young life stages, and the only way to try and contain the organism is if the numbers of mature lobsters can be kept low. Eradication of a fully established stock with lobsters of all life cycles thus cannot be accomplished. To mitigate the establishment of a full stock of lobsters in all life cycles, it is of vital importance to prevent the entry of new mature individuals.

In Sweden, it is not allowed to hold live *H. americanus* in net-cages in the sea. However, this still takes place and it is not economically feasible to carry out inspections of all potential sites were this could take place illegally. Sites with in-water holding tanks and lobster traps are known to exist during the seasonal lobster fishery at large numbers and in very remote areas. In Sweden there has also already been massive information efforts directed towards importers, fish dealers and the public. Even if they have some effect, awareness programs are by no means a guarantee against the introduction of *H. americanus*.

In Great Britain, more rigorous implementation of legislation, such as the Lobster Control of Deposit Order and the Wildlife and Countryside Act, may be an effective manner by which the animals can be contained. However, this would still not negate other illegal pathways for lobster introductions, but an awareness raising programme may prevent some deliberate releases by well-intentioned individuals or ill-informed traders.

In Norway, it is allowed for fishmongers to import live *H. americanus*, as long as they are kept in land-based tanks where the outlet water is thoroughly rinsed. The *H. americanus* must be boiled before they are brought to the market. It is not allowed for live imported *H. americanus* to be held in the sea. Approvals are still given and illegal holdings occur, increasing the possibility for escapes.

3.05 - What proportion (%) of the area in the risk assessment area suitable for establishment, if any, has already been colonised by the organism?

0% -10%
Confidence: low

Comments: It is not known if there are any subpopulations in the risk assessment area (meaning that the subpopulation is reproducing successfully). However, in the Swedish Gullmar Fjord it is possible that a subpopulation may be established during the coming years (see above). One female was carrying hybrid eggs (*H. gammarus*/*H. americanus*). All the observations of *H. americanus* are within less than 10% of the natural range of *H. gammarus*.

The release of *H. americanus* and hybrids to the Bay of Biscay in the 1970's was not followed up by monitoring. Released lobsters and their offspring may still be present in those areas.

3.06 - What proportion of the area in the risk assessment area are suitable for establishment, if any, do you expect to have been invaded by the organism five years from now (including any current presence)?

0-10%
Confidence: low

Comments: It is remarkably difficult to answer this question for the time being. However, the chance that new subpopulations will be established will increase if *H. americanus* continues to be reported from the risk assessment area. Findings of *H. americanus* have been made in Norway near larger cities with live fish sales and international airports. In Sweden, findings have mainly been near coastal towns, in close vicinity of each other, where *H. americanus* is sold live to the public and restaurants by local fish dealers. In case *H. americanus* is released/escapes from just one more unique location it will significantly add to the distribution pattern of releases. However, generation times of *H. americanus* are relatively long and migratory rate is slow (Factor 1995).

3.07 - What other time frame would be appropriate to estimate any significant further spread of the organism in the risk assessment area? (Please comments on why this time frame is chosen.)

10 years
Confidence: low

Comments: Escapees and breeding individuals have been confirmed. With no action taken to detain further spread any timeframe longer than 10 years is not useful for monitoring.

3.08 - In this time frame, what proportion of the endangered area (including any currently occupied areas) is likely to have been invaded by this organism?

11%-33%
Confidence: low

Comments: It is remarkably difficult to answer this question, for the same reason as above. However, applying the same logic, that there will be change but it will be slow, the proportion above is proposed.

3.09 - Based on the answers to questions on the potential for establishment and spread in the risk assessment area, define the area endangered by the organism. Be as specific as possible (if available, provide a map showing the area most likely to be endangered).

Confidence: medium

Comments: The areas of greatest risk are mud, rock and gravel bottoms from the coast to depths of >500 m in all territorial waters of the EU Atlantic coast (i.e. Sweden, Denmark, Germany, the Netherlands, Belgium, Great Britain, Ireland, France, Spain, Portugal). It is impossible to do a quantitative analysis on bottom substrate data around the European coastline (e.g. Homarid lobster habitats) as those data are not available for use. Areas suitable for *H. gammarus* populations are potential habitats for *H. americanus*, and the American species can also live in deeper waters than *H. gammarus*. There is also an unquantifiable risk from establishments holding lobsters, where animals and their products may be disposed of inappropriately into the sea.

3.10 - Estimate the overall potential for future spread for this organism in the risk assessment area (using the justification box to indicate any key issues).

Medium
Confidence: medium

Comments: Given the human involvement with the movement of *H. americanus* between holding facilities, markets and restaurants based all over the risk assessment area, in addition to their own dispersal, it would seem likely that they would disperse rapidly along the European coast.

Section D - Impact

4.01 - How great is the economic loss caused by the organism within its global distribution (excluding the risk assessment area), including the cost of any current management?

Minor
Confidence: medium

Comments: Since *H. americanus* is a native species in the North American parts of the global distribution area, not considered to be causing any economic losses, management costs are expected to be associated with fisheries and thus excluded from this compilation. Several attempts at transplanting this species have been undertaken in regions without native homarid lobster species. For example, there have been reports of *H. americanus* in Japanese waters which is the result of several transplantation attempts. The latest attempt was undertaken in the 1980s resulting in a breeding population in the local waters of Sanriku. This has however not been followed up by the Japanese fisheries (Kittaka J, pers. comm. in CABI 2013). No information indicating economic loss or management costs associated with the *H. americanus* in Japan has been found. There has also been an unsuccessful attempt to transplant *H. americanus* into Italian waters, no information on economic loss or management costs associated with the *H. americanus* in Italy has been found.

4.02 - How great has the economic cost of the organism been in the risk assessment area from the time of introduction to the present? Exclude any costs associated with managing the organism from your answer.

Minor
Confidence: high

Comments: The economic loss caused by the physical presence of *H. americanus* in the risk assessment area is likely to be minimal at the moment.

4.03 – How great is the economic cost of the organism likely to be in the future in the risk assessment area? Exclude any costs associated with managing the organism from your answer.

Major
Confidence: low

Comments: It is likely that continued introductions and possible establishment of *H. americanus* will lead to diminished *H. gammarus* population through new diseases, parasites, hybridization and competition between the two lobster species. Hence, the future economic cost will be dependent upon these factors and whether or not *H. americanus* will be able to establish local subpopulations. There is a high risk that a subpopulation is already established

in the Gullmar Fjord on the Swedish west coast. However, no *H. americanus* under import size have been caught in Sweden so far.

It is uncertain how the fishery for *H. gammarus* would be affected by an establishment of *H. americanus* in the risk assessment area. In Annex 2 two possible scenarios that are possible if no action against continued introduction of *H. americanus* are outlined and discussed. Both scenarios are compared to a baseline scenario of no significant change to the current situation, i.e. no established stock of *H. americanus*.

If Scenario A below is true, then presumably the impact on the economic cost would be 'minimal' or 'minor'. However, scenario B is the worse of the two scenarios, so following the precautionary principle, the impact above is scored as major and confidence low to reflect the uncertainty.

> ***Scenario A:*** *H. americanus is established and through the spread of diseases, hybridisation, competition for habitat etc. the stock of H. gammarus is severely reduced or extinguished. Through an increase of H. americanus there is no or little change in the total stock of Homarid lobsters.*
>
> ***Scenario B:*** *H. americanus is established and through the spread of diseases, hybridisation, competition for habitat etc. both the stock of H. americanus and H. gammarus is severely reduced or extinguished. The total stock of Homarid lobsters is thus expected to decrease. Several lobster experts (see list of reviewers) find this alternative most likely.*

At present the probability of these two future scenarios cannot be estimated since we do not have any comparable situation in marine European waters. As a comparison, the introduction of signal crayfish (*Pacifastacus leniusculus*) to Swedish inland waters has caused considerable economic loss to the noble crayfish (*Astacus astacus*) fishery. Noble crayfish populations have locally become extinct and the species is now considered endangered (EN) in Sweden. Gren et al (2007) estimate the net damage cost to society due to the presence of signal crayfish in Swedish waters to 336-552 million SEK per year.

In the past 70 years, the total annual European landings of lobster have varied between 1.6 and 4.8 thousand metric tons (Prodöhl et al. 2006; FAO 2015). In Sweden recreational fishery is of greater importance than commercial fishery for *H. gammarus*. In 2013, about 25 metric tons were landed in commercial fisheries, at a value of about 4.6 million SEK (Statistics Sweden, 2014). The official statistics for commercial fisheries can be compared to corresponding figures for Swedish recreational lobster fisheries, with estimated landings of 101 metric tons at a value of 18.9 million SEK in 2013 (Statistics Sweden, 2014).

Finally, lobster fishery is also an important part of the regional tourism industry on the Swedish west coast. The Eco Tourism Association of Sweden (Swedish Board of Agriculture, 2015) estimates that around 30 firms are directly involved in "lobster tourism". They charge ca 850 SEK/per person for half a day of fishing. For further details for current values for *H. gammarus* fisheries, see Annex 2.

4.04 - How great have the economic costs of managing this organism been in the risk assessment area from the time of introduction to the present?

Minor
Confidence: medium

Comments: The economic cost for potential pathways management controls (e.g. in the Great Britain, re-establishment of the Lobster Control of Deposit Order), in addition to annual awareness-raising campaigns, inspection controls of the holding facilities and possibly a reward process for those reporting *H. americanus*, have until now been of minor/moderate cost.

The Nordic countries are all parties to the Convention on Biological Diversity[9] and have as such made adjustments in their national legislation to prevent introduction and spreading of alien and invasive species. With regards to *H. americanus,* all three countries have implemented regulations against keeping live individuals in net-cages. In Sweden, the control of the regulation is an integrated part of the general compliance check of all fishing regulations carried out by i.e. The County Administrative Boards (near shore fishing), The Coast Guard (offshore fishing), Swedish Agency for Marine and Water Management (control of landings) and the Police. The management costs of *H. americanus* related to compliance checks is therefore believed to have been of minor importance until now. It is assumed that the same is valid for the rest of the Nordic and other relevant European countries. This assumption is supported by an analysis of economic costs related to alien species in Norway (Magnussen et al. 2015) stating no cost for direct mitigation actions in 2013 and that only 0.35 MNOK was spent on investigations regarding *H. americanus* in the period between 2006 and 2014.

4.05 - How great is the economic cost of managing this organism likely to be in the future in the risk assessment area?

High
Confidence: minimum

Comments: Prevention of introduction and establishment of *H. americanus* is the only realistic approach for managing *H. americanus* in the risk assessment area. It can be concluded that measures taken in Sweden until now, such as information campaigns, prohibition to keep live lobsters in sea cages and rewards on catches of *H. americanus*, has not been satisfactory, in reducing the risk of introduction and establishment of *H. americanus*. It is estimated that scaling up current measures such as information campaigns and rewards for catches would not have a significantly large effect in risk reduction.

Increasing the number of inspections and compliance checks to the extent that the appropriate level of protection would reached is estimated as not being economically or practically feasible, i.e. due to limited government resources.

[9] https://www.cbd.int/

The future management costs for *H. americanus* in the risk assessment area is dependent on whether or not the species is established, and if so, the response in terms of mitigation actions from the authorities. The possibility of eradication or limiting the spread of *H. americanus*, should it establish would be virtually impossible. One might imagine two plausible scenarios:

1. The introduction is "accepted" and the management costs as described above will remain at the present levels, mostly associated with food security and animal protection controls in the processing industry, not specifically aimed at *H. americanus*.
2. The authorities attempt to halt the establishment, i.e. by eradication of the species or limiting the spread by means of
   a) intensive fishing of *H. americanus* in areas of establishment,
   b) intensified controls of the regulation against keeping *H. americanus in* sea cages to minimize the risk of escapes.

Scenario 1 implies no change of the current management costs. Scenario 2a would increase the risk of damaging H. gammarus populations, and might not be effective as H. americanus can migrate over long distances and might move out of the fishing area. It would also involve a significant number of fishermen and vessels conducting protective fishing during the part of the year when *H. americanus* is active in the same habitat as *H. gammarus*. The "protective" fishing will probably need to continue for a long period of time because of winter migration of *H. americanus* to greater depths, where traditional fishing techniques are more difficult or impossible.

The costs for the protective fishing (2a) will be significant for an unknown number of years and it is difficult to say whether the goal to eradicate *H. americanus* all together will be successful. If in addition the effort to control the compliance with the regulation against keeping *H. americanus* in sea cages (2b) is increased, this will also result in increased management costs.

Management strategies to prevent losses caused by Gaffkemia in holding facilities would likely be major. In Great Britain for example, there are currently no management programs in place to control *H. americanus*, apart from the requirement for licensed introductions and prohibition of release within the Wildlife and Countryside Act.

4.06 - How important is environmental harm caused by the organism within its global distribution?

Minor
Confidence: low

Comments: There have been previous deliberate attempts to establish *H. americanus* populations, for example in the Pacific coast of America and in Japan (Kittaka 1984a, 1984c). However, these attempts have not been systematically followed up or been reported from fisheries. Hence, the success of these attempts and the status of any resulting *H. americanus* populations are not sufficiently known. There are occurrences of failed establishment in some well-known invasive alien species (e.g. Lodge 1993, Marchetti et al. 2004;

Copp et al. 2007). This is no guarantee that the same species is not successfully invasive in another place and time. Thus, the fact that successful establishment of *H. americanus* in these occurrences has not been proven does not exclude that it may successfully establish in the risk assessment area.

4.07 - How important has the impact of the organism on biodiversity* been in the risk assessment area from the time of introduction to the present?

Minor
Confidence: medium

Comments: The first *H. americanus* were found in the area of risk assessment about 25 years ago. The findings have been relative few and geographically spread, however, the findings are incidental indicating that the numbers of individuals in the area of risk assessment can be higher. We do not see the effects of any hybrid or established *H. americanus* populations at present, which implies that it is not too late to take measures to prevent the establishment.

4.08 - How important is the impact of the organism on biodiversity likely to be in the future in the risk assessment area?

Major
Confidence: medium

Comments: H. americanus will most likely have an impact on native lobsters due to the overlap in niche use. The impact of *H. americanus* is likely to be broader than this as it has a greater niche range in its natural range. Other decapods, such as edible crabs (*Cancer pagarus*) and Norway lobster (*Nephrops norvegicus*), do inhabit niches that overlap with those potentially inhabited by *H. americanus*, so there may be an impact. However, how an invasive alien species behaves outside of its natural range is not always predictable due to the release and/or changes in pressures, the state of the population and environmental differences. There is a risk that pathogens carried by *H. americanus* will be spread by other decapods, including those that are not of commercial interest. In this way, the pathogen could be more rapidly spread in the environment.

Some of the previously trapped and exhibited *H. americanus* in Norway developed symptoms similar to the destructive ESD, which has caused major damage to local USA lobster fisheries (van der Meeren 2007; Stevens, 2009). In 2010, two infected female *H. americanus* were trapped in Norwegian waters were diagnosed with ESD (Hauge, 2010a; Karlsbakk et al., 2011; Sandlund et al., 2011). Disease transmission to native species is one of the most threatening factors of H. *americanus* introduction. However, one could also argue that this susceptibility would leave *H. americanus* at a disadvantage compared to *H. gammarus*, and could in fact be hindering them from establishing or spreading in Europe.

Hybridization between *H. americanus* and *H. gammarus* may threaten the genetic integrity of the native lobster species. One berried *H. americanus* trapped in Norway with embryos that turned out to be *H. americanus* x *H. gammarus* (Hauge, 2010b, Agnalt et al. 2012). One female berried with hybrid eggs were found in Norway in 2015 and in Sweden in 2014 (Agnalt pers. comm. 2015).

Except for these serious, but rare observations, no evidence of ecologically negative consequences are found in the field. However, in Europe *H. americanus* and *H. gammarus* have similar sheltering behaviour and omnivorous diet (Nicosia and Lavalli, 1999) and may therefore compete for shelter and food. Experiments have shown that *H. gammarus* females tend to select *H. gammarus* males for mating partners, so the possibility for hybridisation is regarded as low (van der Meeren et al., 2008) although in some instances it may happen when the male and female have no conspecific partner available at mating time (Kittaka J and Mercer JP, pers. comm. in CABI 2013). Thus, the lower the native stock of *H. gammarus*, the more likely hybridization is.

4.09 How important has alteration of ecosystem function* caused by the organism been in the risk assessment area from the time of introduction to the present?

Minor
Confidence: low

Comments: No reports of adverse effects on the ecosystem are available so far.

4.10 How important is alteration of ecosystem function caused by the organism likely to be in the risk assessment area in the future?

Major
Confidence: medium

Comments: Ecosystem services have been classified into four main categories: supporting, provisioning, regulating, and cultural. For more detail of the analysis, see Annex 1.

An establishment of *H. americanus* have the most negative effects on the ecosystem services: food webs, habitat (supporting services), eatables and genetic resources (provisioning services). The greatest identified risks are transmission of diseases and hybridisation between *H. gammarus* and *H. americanus*.

Hybridisation might have severe impact on the reproduction of *H. gammarus*. The hybrids might be fast growing and viable and thus potentially increase the competition for food, habitat and mates. If the hybrids are fertile, they might quickly establish a population on their own. If they are sterile, they might still pose a severe threat to *H. gammarus*, as they might interfere with the mating. They are also long-lived and many thus compete with both *H. gammarus* and *H. americanus* for resources for a long time, probably outcompeting them both. Males of *H. gammarus* might waste their sperm on barren hybrids, leading to decreased reproduction in the pure-bred species.

Parasites and epibionts travelling with the *H. americanus* also constitute a great risk to food webs. The parasites or epibionts could cause damage in themselves (such as gill damage or predation on eggs), but might also be a vector of other diseases that strikes *H. gammarus* harder than *H. americanus*. Also, hybrids could be carriers of diseases to which they are immune. Diseases in lobsters also affect lobsters as a resource, e.g. fouled shells might decrease the market value of lobster (provisioning service). Potentially, hybridisation and/or competition and/or disease transmission could lead to extinction of *H. gammarus*. This would affect biodiversity and possibly resilience (supporting services).

An important starting point for assessing the impacts on cultural services is to describe how a shift from *H. gammarus* to *H. americanus* could affect lobster fishery, which is the basis for generating cultural services such as recreation and cultural heritage.

4.11 - How important has decline in conservation status* caused by the organism been in the area of risk assessment from the time of introduction to the present?

Minor
Confidence: medium

Comments: H. americanus has at present only been found occasionally in small numbers in the risk assessment area and during a relatively short time. Thus, hybridization with *H. gammarus* is at present the only observed effect. According to Art.3 (5) of the Marine Strategy Framework Directive (MSFD, 2008/56/EU), invasive alien species introduced by human activities should be kept at levels that do not adversely alter the ecosystem. New invasive alien species introductions and increases in the abundance and spatial distribution of established invasive alien species should be prevented. In particular, impacts that result from invasive alien species should be managed, where feasible, so that the achievement of good environmental status (GES) for the biodiversity descriptors (1, 3, 4 and 6) is not compromised. It is thus, important to prevent potential harm that *H. americanus* may cause should it be established.

4.12 How important is decline in conservation status caused by the organism likely to be in the future in Europe?

Major
Confidence: medium

Comments: The English Channel, the Celtic Sea, the Atlantic coast of Ireland and the North Sea coast of Great Britain is the centre of the *H. gammarus* species distribution and Nordic waters are the borderline for the lobster distribution. Since the 1950s the Nordic lobsters stocks have decreased to a historic minimum and will probably suffer more from a strong alien competitor than the more robust stocks in waters of Great Britain (van der Meeren, pers. comm. 2015).

The historically low stock status of *H. gammarus* was caused and is maintained by intensive fishery. Perhaps this enabled early findings of *H. americanus*. However, a small native stock size in a borderline habitat further enables establishment of *H. americanus*.

In Sweden, about 80% of reported captures have been in marine protected areas (Natura 2000; The Habitats Directive (e.g. Council Directive 92/43/EEC *on the Conservation of natural habitats and of wild fauna and flora*)).

4.13 - How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within its global distribution?

Minor
Confidence: high

Comments: Human health harm issues can largely be disregarded given that diseases that typically affect lobsters are both obvious upon visual inspection and harmless to humans.

The potential social harm caused by the species within its global distribution is expected to be minor. See also parallel discussion in question 4.01 on the potential economic loss caused by the organism so far in its global distribution. *H. americanus* is a native species in North America and not considered to be causing any economic loss, there are rather the opposite. In addition to generating economic values in Canada and the United States, *H. americanus* is also expected to create social values (for example jobs) in areas where lobster fishery takes place. The areas remaining in the global distribution of *H. americanus* area after exclusion of the risk assessment area (European Atlantic coast) and North America are Italy and Japan. No information indicating social loss associated with *H. americanus* in these countries has been found. See also Annex 1.

4.14 How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within the risk assessment area?

Moderate
Confidence: medium

Comments: Human health harm issues however can largely be disregarded given that diseases that typically affect lobsters are both obvious upon visual inspection and harmless to humans.

The local lobster fishing tradition is very important in coastal areas in Sweden, but also in Norway and it has a high social value. Very few reported lobster fishing as a main source of income, among the most active fishermen lobster accounted for around two months wages. The study did find that some fishermen had taken to combining their fishing with “lobster safaris” and even more were considering doing so in the future.

It can be assumed that lobster fishing entails a range of non-use values such as bequest values (the value of preserving a resource for future generations) or existence values (the value of preserving a resource even if one does not use it). Many villages on the Swedish west coast are facing a declining resident population. Armbrecht (2014) discusses these values and concludes that not only the fishing per se is valuable but also the fact that tourists can walk along the quays of the fishing villages, seeing fish being landed, being able to buy fish etc. It is uncertain if and how the cultural lobster fishery will be effected by a possible establishment of *H. americanus*. Introduced diseases that effect the appearance of the lobster may have negative effects on its value, as would differences in e.g. coloration compared to *H. gammarus*. See also Annex 2.

There is evidence from other species that if recreational fishermen, commercial fishermen, whole sale dealers or restaurant visitors, are faced with the choice between a native species and an introduced species (and they can separate the two) they will probably value the native species higher. For example, Bishop and Romano (1998) found that hunters value the mountain hare (*Lepus timidus*) higher than the introduced brown hare (*Lepus europaeus*).

4.15 - How important is it that genetic traits of the organism could be carried to other organisms / species, modifying their genetic nature and making their economic, environmental or social effects more serious?

Major
Confidence: medium

Comments: Due to the inherent ability in both species to distinguish each other, natural mating will not take place as long as a mate of the same species is available (van der Meeren et al. 2003). However, as the stocks of *H. gammarus* are already depleted, hybridisation between *H. gammarus* and *H. americanus* might take place due to lack of conspecific mates. The hybrids might be fast growing and vigorous and thus potentially increase the competition for food, habitat and mates. Consequently, cross-species mating has occurred both in Sweden and in Norway, where female *H. americanus* have been found in the wild carrying hybrid eggs. However, there might also been cross-species mating between male *H. americanus* and female *H. gammarus,* but this is harder to detect.

Cross-species mating has been achieved in laboratories when no mate choice has been offered. Such matings produce live, fast growing and vigorous offspring (F1), with traits from both species (Adouin and Leglise, 1972; Carlberg et al. 1978; Hedgecock et al.1977; Bowser and Rosemark 1981). In some cases these were reported to be sterile, while in one laboratory they also produced an F2 generation (Kittaka, pers. comm. in CABI 2013). It is at least as serious as that hybrid in turn will get offspring.

In many European countries wild lobster stocks are at very low levels. The advice from the European project, *Genimpact* was to apply the precautionary principle for movements of *H. gammarus* for enhancement purposes as there are adaptive genetic differences among the European population. Indeed, it is

extremely likely that lobsters living at the edges of environmental tolerance for the species are adapted to some degree to these conditions.

Hybrids with a mixed genotype, in general receive a mix of phenotypic characters from their parents. For example, the cuticle in *H. americanus* is thinner than in *H. gammarus* and more susceptible to damage and shell disease (Davies et al 2014). Mixing the two homarids may thereby decrease cuticle thickness and lower lobster resistance to disease and physical damage in the hybrids.

See discussion in 4.03 on the potential economic effects of an establishment of *H. americanus* and/or hybrids and how these will depend on what scenario for the total stock of lobster is most likely, i.e. total stock is kept constant or will decrease. However, the stock of lobster will depend on different factors (diseases, competition and hybridisation), and it is out of scope here to isolate the effect of hybridisation on the economic losses. The discussion on potential social losses in 4.14 is also relevant here.

4.16 - How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?

Major
Confidence: high

Comments: It should be noted that there is generally a lack of understanding of disease in decapod crustaceans, and especially in lobsters (Shields *et al.* 2006). However, ESD has significant impact on *H. americanus* in their native range (Stevens 2009), resulting in the closure of a major fishery in southern New England. ESD has emerged (among a multitude of other syndromes and diseases) in a changing ecosystem and has rapidly become a major factor affecting lobster health and thereby yields from heavily fished populations. As ESD continues to persist in the area with a prevalence ranging between 10 and 40% depending on year and location, there has been a concurrent decrease in pre-recruit abundance and landings of this stock (Castro et al. 2012). *H. americanus* trapped in Norwegian waters have exhibited symptoms of ESD (Karlsbakk et al. 2011), with lesions containing bacteria associated with the disease (Agnalt, pers. comm. 2015). A recent study indicates that *H. americanus* may be more susceptible to ESD than *H. gammarus* (Whitten et al. 2014), although there is a need of further investigations.

Another disease of concern is Gaffkemia (caused by the bacterium, *Aerococcus viridans*), or red-tail is a bacterial disease that is enzootic in North America causing negligible harm to *H. americanus*, but can result in severe mortalities in the *H. gammarus* (Wiik et al 1987; Mortensen 2002). *H. americanus* has already introduced Gaffkemia (Kellog *et al.* 1974), which has also had significant impact in Norway (Wiik *et al.* 1987).

It is likely that *H. americanus* may carry other pathogens that we are currently not aware of. This would make establishment more likely if *H. americanus* were to introduce a disease to which they were immune and to which native lobster and/or other species where susceptible (in a similar

manner as signal crayfish and the crayfish plague). The water in which *H. americanus* are transported could also pose a significant risk if not disposed of in an appropriate manner.

4.17 - How important might other impacts not already covered by previous questions be resulting from introduction of the organism? (specify in the justification box)

Minimal
Confidence: high

Comments: None

4.18 - How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in the risk assessment area?

Major
Confidence: medium

Comments: The impacts of *H. americanus* may obviously be affected by natural factors present in the risk assessment area. However, there are no reported scientific studies on how impacts might be influenced despite natural factors affecting *H. americanus*.

4.19 - Indicate any parts of in the risk assessment area where economic, environmental and social impacts are particularly likely to occur (provide as much detail as possible, where possible include a map showing vulnerable areas).

Comments: The areas of greatest risk are mud, rock and gravel bottoms from the coast to depths of >500 m in all territorial waters of the European Atlantic coast (i.e. Sweden, Denmark, Germany, the Netherlands, Belgium, Great Britain, Ireland, France, Spain, Portugal). Areas suitable for *H. gammarus* populations are potential habitats for *H. americanus*, and the American species can also live in deeper waters than *H. gammarus*.

The experience from the recent findings in the Gullmar Fjord, Sweden, suggests that areas where subpopulations initially are likely to establish are areas close to cities, harbours and naturally enclosed areas like fjords bay areas and any areas close to human populations where fishing is not allowed (which mean that the lobsters are protected from fishing increasing the chance for establishing a subpopulation).

4.20 – Estimate the overall potential impact of this organism in the risk assessment area.

Major
Confidence: medium

Section E – Conclusion

5.01 – Estimate the overall risk of this organism in the risk assessment area.

High
Confidence: medium

Comments: There are several important points to take into consideration when one estimates the total impact of *H. americanus*. The species can already start to be, or soon become, established in the risk assessment area even if the present impact is likely low. If populations are established and the species spreads, the impact will increase. For the impact of contagious diseases, the effect is immediate and in a short time the entire of *H. gammarus* population can be affected. In conclusion:

- *H. americanus* can hybridize with the *H. gammarus,* leading to fertile or sterile offspring. This can also contribute to a reduced recruitment of the *H. gammarus*. In some experiments with hybrids they have fertile or , in others sterile. The hybrids may be able to compete with the *H. gammarus* and hybridization may also eventually result in a gradient of phenotypes between the two species, i.e. cuticle thickness that could have a negative effect on resistance to infections.
- *H. americanus* is a known potential carrier of several contagious diseases that *H. gammarus* is susceptible to. *H. americanus* can also carry other diseases that are not present in the area of risk assessment, but can have significant effects with high mortality in the native lobster. The exoskeleton in juvenile *H. gammarus* is about 25% thicker than that of *H. americanus* with the result that *H. americanus* can be more susceptible to skin diseases.
- *H. americanus* may out-compete the native lobster for shelters and food. This would have a significant negative effect on populations of the native lobster and could lead to a severe population decline or even extinction.
- *H. americanus* can affect other environments or commercially important species that share a similar habitat, for example the edible crab (*Cancer pagarus*) and Norway lobster (*Nephrops norvegicus*), but also species in greater depths, as squat lobsters and deep water crabs (50-300m depth).
- *H. americanus* is a potential vector for introduction of other invasive alien species, such as barnacles, polychaetes, nematodes, foraminifera's, copepods etc.
- An establishment of *H. americanus* will, considering the above, give negative effects on recreational fishing, the fishing industry and the export market, especially in coastal communities and may also affect the tourism industry in the northern part of the risk assessment area negatively.

Section F - Additional Questions

6.01 - What aspects of climate change, if any, are most likely to affect the risk assessment for this organism?

Confidence: medium

Comments: It is difficult to understand and predict how climate change will affect the risk assessment of *H. americanus*. *H. americanus* and the native *H. gammarus* are expected to respond similarly to climate changes, although *H. americanus* is more plastic considering its higher variety in habitats and broader range of temperature and salinity.

Climate changes, along with human-induced changes, may significantly increase the impact and broaden the range of pathogens. Diseases, as the newly emerge ESD are thought to be associated with the global climate change and a warmer climate (Cawthorn 2011).

6.02 - What is the likely timeframe for such changes?

50 years

Comments: It is difficult to understand and predict the likely timeframe for such changes, see 6.01.

6.03 - What aspects of the risk assessment are most likely to change as a result of climate change?

Comments: Temperature increase or decrease is probably the most important effect of climate changes that might affect lobsters. However, this is a very slow process and it will therefore not affect any aspects of the risk assessment within the nearest future.

6.04 - If there is any research that would significantly strengthen confidence in the risk assessment, please note this here. If more than one research area is provided, please list in order of priority.

Comments: Several research areas would significantly strengthen confidence in risk assessment regarding risk of introduction of live *H. americanus* in the risk assessment area. A priority list is difficult to present, but the most important research areas would be diseases and epibionts of both *H. americanus* and *H. gammarus* found in the risk assessment area, hybridization how new subpopulations are established and natural spread of *H. americanus*. See also the list of references.

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Annex1. Potential impacts on ecosystem services

In the analysis below, a qualitative assessment was made of potential impacts that an introduction of living *H. americanus* can have on ecosystem services. The analysis was carried out based on the Millennium Assessment (2005) and Garpe (2008). The perspective means that the ecosystem services have been classed in four main categories (supporting, provisioning, regulating, and cultural) and twelve subcategories. *Supporting services* are necessary for the production of all other ecosystem services, including services such as nutrient recycling, primary production and soil formation. *Provisioning services* describe the material or energy outputs from the ecosystems, including food, water and other resources. *Regulating services* provides benefits obtained from the regulation of ecosystem processes e.g. regulating the quality of air and soil or by providing flood and disease control. Finally, *cultural services* are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. The classification of status of the ecosystem services are based on expert judgment that was carried out in the report *Ekosystemtjänster från svenska hav – status och påverkansfaktorer* (HaV 2015).

The assessment is made according to the following scale: Possible negative effect = -2; Possible adverse effect = -1; Possible positive effect = 1; Probable positive impact = 2. The table is followed by some further reflections on the potential impacts on ecosystem services.

Table 9. Potential impacts of *H. americanus* on ecosystem services (supporting, provisioning, regulating, and cultural) in the risk assessment area.

	Qualitative description	**Effect**	**Status ES Kattegat and Skagerrak after introduction of *H. americanus***
Supporting services			
S3 Food web dynamics	Affects other crustaceans and can therefore influence the food chain in both directions.	-1	Poor
S4 Biological diversity	Hybridisation with *H. gammarus*, competition with *H. gammarus*, potential vector of foreign diseases and other invasive alien species.	-2	Moderate

S5 Habitat	Release of the species into the environment threatens to reduce the natural genetic variability of ecosystems and the natural ecosystem structure and relative species balance. Also, competition for food and resources.	-1	Poor
S6 Resilience	Affected biodiversity leads to decreased resilience.	-2	Moderate
Regulating services			
R4 Biological cleaning	A change in the relative species balance.	-1	Moderate
Provisioning services			
P1 Eatables	A direct impact on the resources of *H. gammarus* as well as other crustaceans. In 2013 25 tonnes *H. gammarus* were caught in professional fisheries in Swedish waters to the value of 4.6 million SEK (Statistics Sweden, 2014).	-2	Poor
P3 Genetic resources	If the hybridisers reduces the resource of the *H. gammarus*.	-2	Poor
Cultural			
C1 Recreation	Affects the possibility to fish *H. gammarus*. The *H. gammarus* bring in three times as much value as the *H. americanus*. The *H. gammarus* fishery estimates 101 tonnes of lobster in recreational fisheries (Swedish Statics 2014) and a value of 18.9 million SEK. Expected value of landings for lobster in 2013 was 187 SEK per kg (Swedish Statics 2014). This value does not include all of the recreational value as lobster fishing brings in terms of, inter alia, nature experiences. The recreational fishery is very important in Norway and it is calculated that 80% of the lobsters caught annually is collected by recreational fishermen (Kleiven et al. 2011).	-2	Moderate

C3 Science and education	*H. gammarus* and other native crustaceans are important for physiological, neurological, genetic, ecological, disease related and fishery based research. There are cooperation between scientists and school that use regulated lobster fishery, small experiments and a dialogue with researchers as a part of their education.	-1	Good
C4 Culture heritage	Fishing for lobster is a traditional and important on the West Coast.	-2	Moderate
C5 Inspiration	*H. gammarus* (art, fictile art. etc.)	-1	Good
C6 Nature heritage	Affects the ability to continue the tradition of fishing *H. gammarus* sin future generations.	-2	Moderate

Annex 2. Potential socio-economic impacts

Part 1 Potential socio-economic impacts if live *H. americanus* is introduced and established in the risk assessment area

In assessing the socio-economic impacts of an introduction of *H. americanus* the effects on business costs and revenues and employment should be considered. Also values not priced in a market should be considered to give the full picture of the economic effects to society. The total economic value of a natural resource affected can be divided into use values and non-use values see figure 2 below.[10] Important values relating to *H. gammarus* are the present and future revenues from commercial fishing and recreational fishing, but also the existence and bequest values of *H. gammarus* and the value associated with other potential effects on the ecosystems.

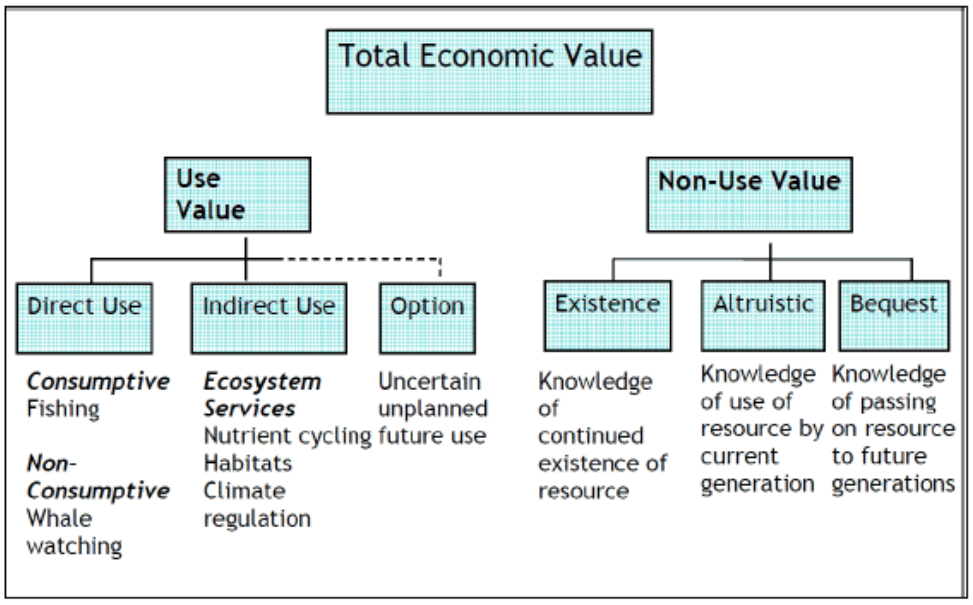

Figure 2 The total economic value of a natural resource affected can be divided into use values and non-use values.

Fishery of *H. gammarus* – current values

In Sweden, recreational fishery is greater than commercial fishery for *H. gammarus* in terms of landings. In the commercial fishery about 25 metric tons were landed at a value of about 4.6 million SEK in 2013 (Statistics Sweden,

[10] TEEB (2010), The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Edited by Pushpam Kumar. Earthscan, London and Washington

2014a), i.e. a price per kilo of 187 SEK/kilo. This represents the value in the first stage of the distribution chain and is significantly lower than the market price (450-600 SEK/kg) and the recreational fisheries value. Apart from the value of landings, the lobster fishery is a small scale fishery that contributes with employment in remote areas. The cultural values of the fishery attract tourists and hence contribute to the tourism revenues.

The estimated landings in the recreational lobster fishery were about 100 metric tons in 2013, (Statistics Sweden, 2014b). Using the price paid to the commercial fishermen for *H. gammarus* in 2013 (187 SEK/kilo) as a minimum value for the recreational fishery gives a value of 18.7 million SEK for the recreational fishery in 2013

Former Swedish Board of Fisheries (2008) estimated that around 9 000 fishermen engage in recreational lobster fishing each year with an average of 10 fishing days per person. No direct valuation studies have been performed on the Swedish lobster fishery but comparisons can be made with some other associated activities.

Lobster fishing is sometimes described as the "Moose hunting for the West Coast". Moose hunting is an important source of recreation, especially in Northern Sweden. Around 270 000 people engage in the hunting taking place primarily in September and October each year. The two activities are quite similar in that they have a fixed starting date usually surrounded by traditions and rituals, that they require quite high initial costs for participation and that the resulting "catch" only represents a relatively small portion of the total value of the activity. For moose hunting it is estimated that the actual value of the meat represents around 60 % of the total value of the hunting (IVL, 2014). If one uses the same relationship between value of the catch and total value as for moose hunting the corresponding total value of recreational Swedish lobster fishing would be 31.5 million SEK/year.[11]

Wallentin (2015) estimates the value of Swedish recreational salmon fishery based on a travel cost approach. One can argue that this provides a reasonable proxy for lobster fishing given that both types of fisheries normally require some degree of travel, initial costs for equipment etc. and some level of skill to be successful. The travel cost approach means that the value of a site or resource is evaluated based on how far people are willing to travel to experience it. He finds that consumers value the resource at 600 SEK/day, which, if assumed valid also for lobster fishery, would correspond to 54 million SEK/year.[12]

The Eco Tourism Association of Sweden (The Swedish Board of Agriculture, 2015) estimates that around thirty firms work directly with "lobster tourism". Another approach to discerning the value of lobster fishing is to observe the price that these commercial firms charge customers for the experience. Usually these are sold in packages with dinner and accommodation and given that these are also directly dependent on the availability of lobster one could choose to include them in the valuation. If one is interested only in the fishing this is

[12] 600 SEK per day use value * 10 fishing days per person * 9 000 fishermen= 54 million SEK.

offered at a cost of around 850 SEK per person for a half day[13], again a much higher valuation than the value of the catch would suggest.

In summary, based on the above one can argue that using the (whole sale) market price of the catch will underestimate the actual value of the lobster fishing resource. This will be true both for the commercial and recreational fishery. No direct valuation studies of the fishery are available, hence the true value is not known.

Introduction and establishment of *H. americanus* – potential socio-economic impacts

A large degree of uncertainty exists with regards to how the ecosystem and the supply of ecosystem services would be affected by an establishment of *H. americanus*. In the following two possible scenarios are outlined and discussed. Note that these are not exhaustive, nor mutually exclusive. Both scenarios are compared to a baseline scenario of no significant change to the current situation, i.e. no established stock of *H. americanus*. The scenarios are limited to mainly considering the effects on the Swedish lobster fishery. Other effects on the supply and value of ecosystem services (see Annex 1) are only mentioned briefly.

Scenario A:

- *H. americanus is established.*
- *Through the spread of diseases, hybridisation, competition for habitat etc. the stock of H. gammarus is severely reduced or extinguished.*
- *Through an increase of H. americanus there is no or little change in the total stock of Homarid lobsters.*

Valuation of the H. gammarus vs the H. americanus

If the total stock of lobster (*H. americanus* + *H. gammarus*) is kept constant one will have to discern if there are differences in how consumers and the industry value these two respectively. To our knowledge, for recreational lobster fishing no direct valuation studies of the species pare have been carried out, but comparisons with other associated activities can be made. Bishop and Romano (1998) for example found that hunters value the mountain hare (*Lepus timidus*) higher than the introduced brown hare (*Lepus europaeus*). Anecdotally this is true among Swedish hunters as well. They will actively seek out places where the mountain hare is abundant for the traditional driven game hunting. MacMillan and Bishop (2008) further report a negative willingness to pay for the conservation of brown hare in the Great Britain, showing the low appreciation for the introduced species among the general public.

In Sweden the stock of Noble Crayfish (*Astacus astacus*) has diminished drastically since the 1960's primarily due to the spread of crayfish plague from introduced signal crayfish (*Pacifastacus leniusculus*). Today, large efforts and costs are being invested in the preservation of the Noble crayfish (Swedish Environmental Protection Agency, 2009). That a difference in valuation exists

[13] www.evertssjobod.se

between the species is clear from the difference in market price, where the native species can cost up to four times as much as the introduced species.[14]

An important difference between the examples outlined above and lobsters is that it is generally hard to distinguish between *H. americanus* and *H. gammarus*, even though the species differs in spines on the rostrum and in coloration. Another reasonable question is whether those not directly engaged in the fishing make any distinction at all between the two species. A reasonable assumption is that if the lobsters are clearly marked as *H. americanus* or *H. gammarus* consumers will be willing to pay a premium for *H. gammarus* (which is supported by current market prices) but if they are not very few will be able to make the distinction.

In summary there is evidence to suggest that if those partaking of the lobster resource, whether they be recreational fishermen, commercial fishermen, whole sale dealers or restaurant visitors, are faced with the choice between a native species and an introduced species (and they can separate the two) they will value the native species higher. It can be assumed that if the lobster stock is kept at a constant level and if neither fishermen (recreational or professional) nor consumers are able to separate the two species the value of this stock will be constant.

Values affected other than the value of a decrease of H. gammarus and an equivalent increase in H. americanus

Apart from the fisheries- and recreational value of *H. gammarus* and *H. americanus* bequest and existence values should also be assigned to the *H. gammarus* and to the biological diversity that may be diminished as a result of the introduction of the h. americanus.[15] While these benefits are often quite small per person, the non-rival nature of these public good benefits results in simultaneous enjoyment by millions of people. Therefore, the total social benefits can be quite large.[16] Another complication is that there are some indications that *H. americanus* favours habitats at larger depths and distances from the coastline than its European counterpart. This may have a negative effect on recreational fishing of *H. americanus* because fishing usually takes place in small boats and without the use of "pot pullers" to retrieve the pots.

Finally, we know that Gaffkemia can be fatal to *H. americanus* and it will affect their appearance (Gaffkemia is also known as "pink tail") and there is plenty of evidence to suggest that consumers will place a lower value on a delicacy that has a less than perfect appearance. ESD would also affect the appearance of the lobsters, in addition to being fatal to both species.

[14] http://slipaknivar.com/butiken.ehtml/saluhallen.html (European crayfish: 850SEK/kg, Signal crayfish 299-399SEK/kg)

[15] see Annex 1 regarding potential effects on biological diversity

[16] Loomis et al (2000) Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingentvaluation survey, Ecological economics 33 (2000) 103–117

In summary:

- Evidence from other sectors and activities suggest that when given a choice a native species will be valued higher by all, or most, users.
- In the case of *H. americanus* however it seems that it will be extremely difficult to discern between the native and the invasive species.
- Hence, if the total lobster stock is kept more or less constant, an introduction of *H. americanus* will not necessarily have any grave impact on the lobster fisheries (assuming that recreational fishing is not negatively impacted by *H. americanus* seeking larger depths in the winter season).
- This conclusion however relies heavily on assumptions of no introduction of ESD (which would affect the total population), no increased difficulty for recreational fishermen in catching the lobsters and a disregard of the fact that Gaffkemia affected lobsters may be perceived as "ugly" by consumers.

- There may also be other effects on the ecosystems though, that may affect the production of ecosystem services and economic values other than the lobsters value as food and recreation (see annex 1). The existence value of the *H. gammarus* may be high.

Scenario B:

- *H. americanus is established.*
- *Through the spread of diseases, hybridisation, competition for habitat etc. both the stock of H. americanus and H. gammarus is severely reduced or extinguished.*
- *The total stock of Homarid lobsters is thus expected to decrease.*

The second scenario is more of a straightforward valuation of the Swedish lobster fishery, meaning that if we can accurately place a value on the fishery we have also derived the cost of it being lost.

The value of a loss of the European commercial and recreational lobster fisheries

Using official statistics estimates for commercial fishery and estimated value for recreational salmon fishery as a proxy[17] for recreational lobster fishery would correspond to a total economic value of 58.6 million SEK a year for the Swedish lobster fishery as described in the analysis of current values above. This value does not include the cultural values associated with small scale fishing communities or the contribution small scale fishing communities make to revenues from tourism.

The local lobster fishing tradition is very important in coastal areas in Sweden and Norway and it has a strong social value.

[17] One can argue that this provides a reasonable proxy for lobster fishing given that both types of fisheries normally require some degree of travel, initial costs for equipment etc. and some level of skill to be successful.

It can be assumed that lobster fishing also entails a range of non-use values such as bequest values or existence values. Many villages on the Swedish west coast are facing a declining resident population. Armbrecht (2014) discusses these values and concludes that not only the fishing per se is valuable but also the fact that tourists can walk along the quays of the fishing villages, seeing fish being landed, being able to buy fish etc. This partially has a market value in terms of tourism revenues. There are no estimates of the value of the Swedish small scale fisheries to the local economies. Another monetary example is from Great Britain, where it has been estimated that the cost of a complete loss of lobster fisheries would be GB PLC £26.5million in 2011 (GBNN 2011).

Other potential impacts of an introduction of *H. americanus*

One should note that impacts on other crustaceans (primarily edible crab *C. pagurus*, Norway lobster *N. norwegicus* and shrimp *P. borealis*) are not fully understood today with regards to risk of spread of diseases and the consequences of this. If diseases introduced by an establishment of *H. americanus* should turn out to have a negative impact on the stocks of other crustaceans this would imply economic and biological losses that potentially could be much larger than those for *H. gammarus*. For example both the Norway lobster and shrimp fisheries are much larger both in terms of quantity and value. There could also be indirect effects on other parts of the ecosystem if (some of) the populations of crustaceans decrease.

Human health harm issues can largely be disregarded given that diseases that typically affect lobsters are both obvious upon visual inspection and harmless to humans.

Part 2 Management costs so far and if *H. americanus* is introduced and established

The management costs related to *H. americanus* in Sweden are mainly associated with two activities; the costs related to compliance control of the regulation against keeping live lobsters in sea cages, and controls of facilities used for holding and processing of imported live lobster. The latter concerning both food security and animal protection aspects. There are in addition some costs associated with awareness campaigns launched by the Swedish Agency for Marine and Water Management regarding the role of *H. americanus* as an invasive species in the Swedish environment, and also a small reward paid by the Swedish University of Agricultural Sciences for each individual *H. americanus* that is turned in. These are however regarded as being of minor economic importance.

Costs for compliance check of regulations so far

Sweden as well as other states within the European Atlantic coast are all parties to the Convention on Biological Diversity[18] and have as such made adjustments in their national legislation to prevent spreading of alien and invasive species. With regards to *H. americanus,* for example Sweden, Norway and Great Britain have implemented regulations against keeping live individuals in sea cages. In Sweden, the control of the regulation is an integrated part of the general compliance check of all fishing regulations carried out by i.e. The County Administrative Boards (near shore fishing), The Coast Guard (off shore fishing), Swedish Agency for Marine and Water Management (control of landings) and the Police. An analysis of economic costs related to alien species in Norway (Magnussen et al. 2015) 0.35 million NOK was spent on investigations regarding *H. americanus* in the period between 2006 and 2014. According to officials at the County of Västra Götaland, the costs for controls and compliance check specifically aimed at H. americanus are low [19].

Management cost related to food security and animal protection so far

The major part of the management costs related to food security are associated with controls of holding- and processing facilities handling live crustaceans including *H. americanus*. The responsible authority in Sweden is The Swedish National food agency that tests facilities according to article 4 in the Council Directive 2006/88/EC[20]. In some cases the responsibility for the controls is delegated to municipalities, this is the case in Stockholm, Göteborg and Malmö. The regulatory controls are based on risk assessments of the processes being undertaken in the controlled facility. The fee for the controls is based on the risk assessment in addition to the amount of food being processed. In an example facility for cooking and cooling crustaceans in Göteborg in 2014 handling (cooking and cooling) one tonne of lobster, crab or cray-fish (in addition to other activities e.g. filleting of fish), the yearly cost for regulatory control by the municipal authorities will amount to 5 500 SEK[21].

The yearly import of live *H. americanus* increased from just above 200 tonnes in 2005 to 388 tonnes in 2014 (Eurostat 2015). Based on the current and historic import of live *H. americanus*, and given that the fees for controls applied in the municipality of Göteborg[22] is representative for a national

[18] https://www.cbd.int/

[19] Personal communication with Fredrik Larson (2015-09-04)

[20] COUNCIL DIRECTIVE 2006/88/EC of 24 October 2006 on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals

[21] Personal communication with Jenny Örnros at the municipal authority of Gothenburg (2015-09-07)

[22] The hourly fee charged by the municipality of Goteborg is at the moment 1 100 SEK but varies between municipalities. The fee charged by the authorities in Goteborg was used to make estimations of national costs for controls given that a majority of the Swedish cooking

average, then the cost for controls in Sweden related to *H. americanus* can be estimated to approximately 2 MSEK in 2014. For the period 2005 – 2015, the total cost in Sweden can be estimated 16 MSEK.

The largest risk of escape of lobsters is probably not that American lobsters escape from the holdings of the importers or the process industry. The largest problem is all the restaurants, fish dealers and other individuals who buy live lobsters from importers or in third hand. It is not possible for the authorities to control if these actors follow the ban on holding *H. americanus* in cages in the sea, as the authorities do not know who they are and where to look for the lobsters. If an individual decide to hold lobsters in the sea it can be anywhere along the coast.

It can be concluded that measures taken in Sweden until now, such as information campaigns, prohibition to keep live lobsters in sea cages and rewards on catches of *H. americanus*, has not been satisfactory in reducing the risk of introduction and establishment of *H. americanus*

It is estimated that scaling up current measures such as information campaigns and rewards for catches and increasing the number of inspections of lobster holdings would not have a significantly large effect in risk reduction. Checking compliance with the ban on holding live *H. americanus* in in the sea by surveillance the coast line is not economically or practically possible. Local law enforcement thus will not be enough to decrease the risk of escapes of *H. americanus* to such an extent that the risk of introduction of the species can be considered as negligible.

Management costs in case of introduction and establishment of *H. americanus*

The future management costs for *H. americanus* in the risk assessment area is dependent on whether or not the species is established, and if so, the response in terms of mitigation actions from the authorities. The possibility of eradication or limiting the spread of *H. americanus*, should it establish in the risk assessment area, would be virtually impossible. One might imagine two plausible scenarios;

1. The introduction is “accepted” and the management costs as described above will remain at the present levels, mostly associated with food security and animal protection controls in the processing industry, not specifically aimed at *H. americanus*.
2. The authorities attempt to halt the establishment, i.e. by eradication of the species or limiting the spread by means of
   a. intensive fishing of *H. americanus* in areas of establishment,
   b. intensified controls of the regulation against keeping *H. americanus in* sea cages to minimize the risk of escapes.

facilities are located in the Goteborg area and that the hourly fee charged by The Swedish National food agency is 1 020 SEK for controls of facilities outside Goteborg, Stockholm and Malmö.

Scenario 1 implies no change of the current management costs. Scenario 2a would increase the risk of damaging *H. gammarus* populations, and might not be effective as *H. americanus* can migrate over long distances and might move out of the fishing area. It would also involve a significant number of fishermen and vessels conducting protective fishing during the part of the year when *H. americanus* is active in the same habitat as *H. gammarus*. The "protective" fishing will probably need to continue for a long period of time because of the winter migration of *H. americanus* to greater depths, where traditional fishing techniques are more difficult or impossible.

The costs for the protective fishing (2a) will be significant for an unknown number of years and it is difficult to say whether the goal to eradicate *H. americanus* all together will be successful. If in addition the effort to control the compliance with the regulation against keeping *H. americanus* in sea cages (2b) is increased, this will also result in increased management costs. As sea cages can be put into the sea by many actors all along the coast, even with massive controls there is a risk that many sea cages will not be detected.

Management strategies to prevent losses caused by Gaffkemia in holding facilities would likely be major. In Great Britain for example, there are currently no management programs in place to control *H. americanus*, apart from the requirement for licensed introductions and prohibition of release within the Wildlife and Countryside Act.

Part 3 Impacts from a ban on live import of *H. americanus*

This section discusses the types of socio-economic impacts that may result from a Swedish ban on live import of *H. americanus*. First, the current situation in the industry in terms of important actors, different uses and job opportunities is described. Next, to the extent possible, quantitative/monetary illustrations are given of how firms, profits, jobs and consumers of lobster may be affected by a ban on imports. The results are finally discussed and interpreted in terms of what they may mean in a broader EU single market/international context.

Ideally, a questionnaire targeted at major actors on the Swedish market for live *H. americanus* should be carried out. However, due to strict time limitations, this has not been feasible. Instead one longer interview has been carried out with key persons from a) one of the major Swedish importers/wholesalers, and b) the Federation of Swedish Fish Industries and Trade (FSFIT)[23], representing the business as a whole. The discussion in this section is largely based on statements made by these two key representatives of the industry. FSFIT answers for the industry as a whole, but there are likely individual differences among actors that are not reflected here.

[23] SWE: "Fiskbranschens Riksförbund", personal communication, 1st of September 2015.

In 2014 the interviewed wholesaler imported 50 tonnes of live *H. americanus*, of which 30 tonnes were distributed to the Göteborg market and 20 tonnes to the Stockholm market. The market share of the interviewed company is almost 13 %, given that total imports to Sweden were 388 tons in 2014. The wholesaler states that his business is not completely depending on live *H. americanus*, which seems to be the case for other similar actors on the Swedish market as well.

Current actors

The exporting countries are evidently key actors. In total 388 tonnes of live *H. americanus* were imported to Sweden in 2014, primarily from Canada and the USA (73 % of total imports). The remaining import of live *H. americanus* (27 %) to Sweden came from other EU countries, primarily the Netherlands and Denmark. Representatives from FSFIT explain how lobster from Canada and the United States is often delivered to the Netherlands for further transportation by truck or airplane to other EU countries. Figure 3 below shows that total imports to Sweden have been steadily increasing over the last ten years.

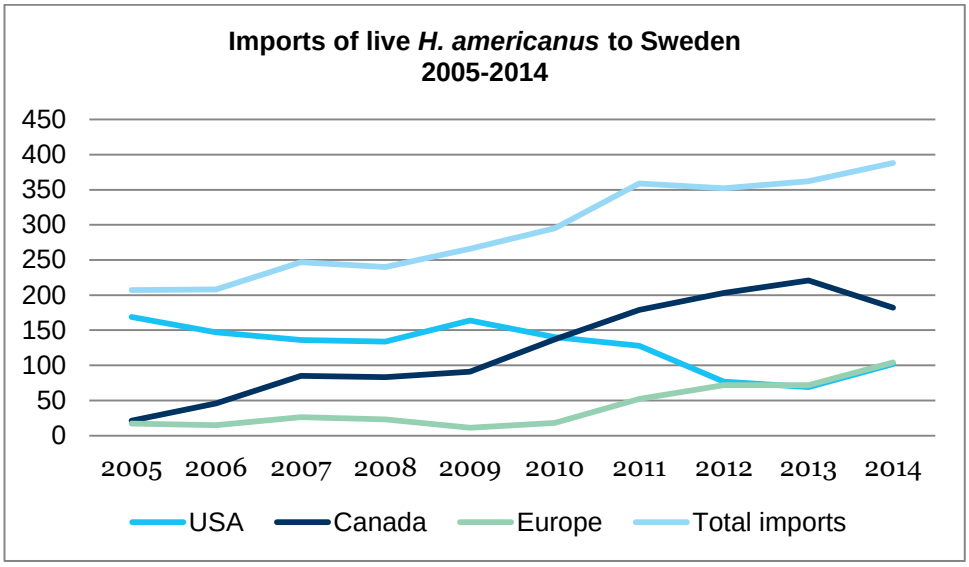

Figure 3 Total imports of live *H. americanus* 2005-2014. Source: Eurostat, 2015

The imports of live American lobster to the EU was approximately 13 000 tonnes in 2014. The main actors in import of live *H. americanus* are the importers/wholesalers, restaurants, fish dealers, event businesses and the general public. The total number of importers/wholesalers in Sweden is around 20-25, of which around 10-15 are major actors. The remaining importers/wholesalers are often small businesses. The number of restaurants, fish dealers and event businesses is difficult to estimate, although it can be mentioned that the Swedish Agency for Marine and Water Management (SwAM) carried out an information campaign in 2014 targeted at 80 such actors. Although not complete the list indicates that the numbers may be quite significant, not least because the sampled actors are all situated on the Swedish

west coast. A large portion of live *H. americanus* is also delivered to the Stockholm area.

Current uses of *H. americanus* in Sweden

According to FSFIT, the major Swedish importers/wholesalers usually cook the lobster themselves when delivered to them. Another common alternative is to let a subcontractor do the cooking and send the lobster back to the wholesaler who in turn will distribute the product to the market. The interviewed importer/wholesaler states that around 80 % of its total deliveries of *H. americanus* is cooked, and that the remaining 20 % is delivered a live. The corresponding distribution between cooked and live lobster for the industry as a whole can be assumed very similar according FSFIT, although there will naturally be some variation. Restaurants often demand live lobster, simply because they want to make their own choices regarding how to cook it. Event businesses are expected to receive a rather small share of the total deliveries of live lobster. However, it is difficult to estimate the amount since these businesses often fall under the broad category of "restaurants", which makes them hard to identify.

The Swedish sales of lobster (*H. gammarus* + *H. americanus*) increase significantly in the period of around 20 September-January, peaking during the New Year's weekend. The interviewed wholesaler explains that during this time of the year the total sales of *H. gammarus* (cooked and live) is usually around 300 kg, which can be compared to the amount of *H. americanus* (cooked and live), which is around 9-10 tonnes. Evidently the supply of *H. gammarus* cannot, on its own, meet the total Swedish demand. The reasons for this are:

1. The legal period of catching *H. gammarus* in Sweden is around 20 September - 30 April. The consumer demand for lobster however varies during the course of the year and *H. gammarus* is only available when fishing for the species is allowed.
2. The commercial landings of *H. gammarus* (25 tonnes) is very small compared to the total import of *H. americanus* (388 tonnes)
3. Restaurants often demand lobster of certain sizes, e.g. rather 450 gr than two kg. The market for *H. gammarus* in Sweden cannot guarantee that lobsters of different sizes are provided. This can however be achieved by imports of live *H. americanus*. In Canada and the USA lobsters of varying sizes are held in tanks, which make *H. americanus* very adaptable to actual market demand.

Current job opportunities

One important socio-economic aspect, at least from a local economy perspective, is to what extent jobs are generated from import of *H. americanus*. FSFIT cannot give an estimate of the numbers of jobs, but explains in general terms what kind of competences are involved at different steps of the import process from when the lobster arrives in Sweden to when it arrives at its final

destinations (restaurants, fish dealers, etc.). The process roughly consists of nine main steps:

1. Dealing with the goods at the airport in Sweden, for example when unloading and transporting to cooling room
2. Forwarder agent who prepares documentation for the goods before going through customs inspection
3. Veterinary control of the goods, i.e. examination of documentation and spot checks of lobsters
4. Customs inspection
5. Collection of goods cleared through customs
6. Transportation to importer/wholesaler
7. Reloading and transportation for further preparation (cooking)
8. Transportation back to importer/wholesalers
9. Repacking and transportation to fish dealers etc.

The above process generates a number of jobs, although it is hard to say to what extent they are due specifically to import of *H americanus*. For example, the interviewed importer/wholesaler does not have own staff that are specialized in just handling *H. americanus* and this is likely also the case for other Swedish importers. Likewise, staff at the airport and transportation firms (e.g. veterinarians, customs inspectors, drivers etc.) naturally has many kinds of tasks – not just related to live import of *H. americanus*. Still, it is evident that the import process requires some administration, knowledge regarding existing regulations, and also skills for handling the lobster when it is in the holding tank.

Potential socio-economic impacts of a ban on imports

A quantitative/monetary example is now given to demonstrate what the potential impacts from a ban on imports could mean for import firms and their profits, jobs and consumers of lobster. Finally, the results are reflected upon from a broader European single market/international perspective.

Profits

Actors in the Swedish lobster industry state that they will lose profits if there is a ban on *H. americanus*. What is a likely scenario for the monetary size of this loss? In order to find out two main pieces of information are needed:

1. Information about the total size of revenues from sales of *H. americanus*. This can be simplified as total imports (kg) * market price (SEK/kg).
    a. Based on the average purchase price paid to the importers/wholesalers, which is currently around 250 SEK/kg, this means that the total revenue of import can be estimated to

97 MSEK/year.[24] The price for consumers in shops, restaurants etc. is higher, around 300-400 SEK/kg or more.

2. Information about the total size of costs associated with import of live *H. americanus*. Here we need to know more about the types of costs and ideally also the size of these. It may be difficult to have firms report about the size of their costs, but a listing of potential cost types in qualitative terms is anyhow a necessary first step, that itself gives useful information:
    a. The cost of purchasing the lobster, i.e. the price that importers have to pay to the exporters. Based on this price, FSFIT estimate the total value of live import of *H. americanus* to 40 MSEK/year for the Swedish market, which gives an average price of around 110 SEK/kg.
    b. Investment, maintenance and service. The interviewed importer/wholesaler has invested in holding tanks for keeping live lobster. The direct cost for this investment is around 300 000-500 000 SEK, to which costs for maintenance, services and salt of around 25 000-30 000 SEK/year must be added. Although the main purpose of the tanks is to keep imported live *H. americanus*, they can also be used for other species. FSFIT judges that other similar actors have made the same kind of investments, and that their costs thus probably are of about the same size.
    c. Cost of labour, education and increased administration.

The value added from sales of *H. americanus* in Sweden is thus more than 50 MSEK/year, when calculated roughly as the difference between the importers' total revenues from sales and their costs for purchasing live *H. americanus*.

The above example does not take into account the fact that the market value of lobster sold by restaurants and fish dealers is much higher (around 300-400 SEK/kg), i.e. that some of the imported lobster will generate higher revenues. Thus, the presented total revenue for the industry as a whole can be expected to be underestimated.

The values added include costs for the employees, depreciation of investments and the profit made by the firm. The total material input costs can be expected as underestimated because the costs associated with permits; controls, cost of maintenance and salt etc. are not included. Regarding investment costs, if it can be assumed that all 20-25 importers in Sweden, just like the interviewed actor, have invested in similar tanks that would imply a total investment cost of 6-12.5 MSEK. Based on the total amount of live lobster sold by the interviewed importer (50 tonnes), the cost of maintenance and service is 0.2-0.3 %. If extrapolated to the total Swedish import of 388 tonnes, this means 200-300 thousand SEK for the industry as a whole.

Systems for holding are/can be used for store other live aquatic marine or freshwater species such as mussels, editable crab, etc. Importers may store

[24] 388 tonnes*250 =97 000 000 SEK

several different live crustaceans, so it is possible to use the holdings for other species. It is not evident though that there will be a demand for substitute fresh water species from holdings to compensate for the loss of income from a ban on import of live *H. americanus*.

In summary, the presented estimate of current value added in the industry (around 50 MSEK/year) gives an idea of the size of value added that could be lost if a ban on imports is realized. Since market prices as well as demanded amount will vary over time and across different parts of the sector, the figure must be interpreted with care. Also, the complete picture could be clearer if the costs associated with import were more precise.

Jobs

The industry is concerned that a ban on imports will have a negative impact on jobs. Again, an example can help illustrate what the potential impacts on jobs might be. Assuming that on average 0.5 person in each of the 20-25 import firms is working with tasks relating to import of live *H. americanus*, in total 10-13 people are involved. In addition, if the nine steps of the import process described above (e.g. unloading and transportation from airport, preparation of documentation, veterinary control, customs inspection etc.) are assumed to generate on average one job opportunity associated to each importer, then the total number of jobs generated in Sweden are around 30-40. To this should be added jobs in restaurants, event businesses, fish dealers, shops etc. For restaurants, catering, gastronomy and fish dealers in general there are substitutes on the market, both frozen *H. americanus* as well as other type of live/frozen seafood delicacies and, regarding restaurants, meat delicacies. Therefore it is reasonable to believe that the effect in terms of employment and profits in the restaurant/catering/fish dealer-business as a whole will be neglible. There are a relatively small number of more specialized restaurants though that may be more affected for example lobster event businesses and restaurants specialized in fresh lobster plates. As for the potential impacts of a ban on restaurants, there is a concern that this will also affect purchases of other shellfish since the “shellfish concept” may become weaker and less attractive. It is also possible that with a decrease in the supply of fresh lobster, the attractiveness of other crustaceans will increase. The indirect effects on sectors such as airlines and the customs companies should be relatively small considering the relatively small share of *H. americanus* of total goods traded. For example the total volume of goods transported in EU (28 countries) by air 2014 was 14,327,403 tonnes.[25]

Finally, it should be stressed that a ban on live imports would potentially be beneficial in terms of profits and jobs if the commercial fishery of *H. gammarus* is positively affected by the ban in terms of higher prices on *H. gammarus*.

[25] EU air transport of goods http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=ttr00011&plugin=1

Effects on value added and employment att the EU-level

An illustration of the magnitude of effects on the EU-level can be given using the estimated effects on the Swedish market. Assuming the same proportion of costs in relation to revenues and number of employees per tonne of *H. americanus* imported as for the Swedish importers: The loss in value added at the EU-level from a turnover of €100-200 million can be estimated to €50-100 million, and the number of persons affected working with tasks related to import *of H. americanus* to be 1000-1300 persons (with an import of 13 000 tonnes of live *of H. americanus*).

Decreased market supply

The industry emphasizes the fact that live import of *H. americanus* makes lobster available for more people, since the commercial landings of *H. gammarus* are too small to meet the total demand on the Swedish market. A likely impact of a ban is thus that the total market supply of lobster will decrease, prices of *H. gammarus* will increase which in turn has a negative impact on consumers.

Sweden is used as an example in the risk assessment. In Sweden, commercial fishing accounts for a smaller proportion of the *H. gammarus* fishing mortality, i.e. lobster fishery is an avocation. In Sweden it is prohibited for recreational fishermen to sell their catch. Lobster fisheries are regulated in the Swedish national law with legal minimum size limits and it is prohibited to collect females carrying eggs. Fishing for lobster may only be made with lobster trap. Recreational fishermen can have a maximum of 14 lobster pots per person and fishermen maximum 50 per person. Lobster fishing is prohibited from May 1 to 07.00 on the first Monday after the 20th September. There are three smaller protected areas for research purposes where it is prohibited to fish for lobster throughout the year.

From IUCN webpage for *H. gammarus: There are a number of local and national regulations in place to prevent over-exploitation of the European Lobster fishery. A number of countries have imposed national minimum legal size limits, closed fishing seasons, and have prohibited the collecting of berried females. In an effort to protect lobster spawning potential in some areas, berried females caught may be V-notched on the tail before being returned to the sea. Under local by-laws or voluntary bans, such lobsters may not be landed until the V-notch has grown out (M. Bell. pers. comm. 2010). As of January 2002 an EU wide minimum legal size of 87 mm (CL) was imposed (Cobb and Castro 2006).*

An increase in price may increase the fishing pressure on *H. gammarus* if regulations are not adjusted to take into account that increased profitability will attract more fishermen/will increase the days at sea fishing *for H. gammarus*. For the long term viability of the lobster fisheries it should be in the interest of the decision makers to keep the lobster population at least at maximum sustainable yield.

Potential impacts on EU single market

Since 73 % of the live import of *H. americanus* originates directly from countries outside the EU, the potential impacts of a Swedish ban on the EU single market are expected to be minor or moderate. Of the remaining 27 % of the total Swedish imports, the Netherlands and Denmark stands for 82 % of the export. Thus, if single market impacts from a Swedish ban can be expected, they would likely occur in these two countries. The kind of impacts would for example be lost profits for export firms if they cannot find substitute markets and lost job opportunities if a decreased workload for staff at the export companies, airports, transportation firms etc. can be expected.

Potential impacts on international trade - the case of Canada

The imports of *H. americanus* to the EU come from Canada and the USA. Below in table 10, European imports in 2014 of *H. Americanus* from Canada and the USA are listed.[26]

Table 10 Imports of H. americanus from Canada and USA to the EU in 2014. Source the European Commission Export helpdesk

Exporting country	Live or frozen import	Weight in tonnes	CN code	Value, EUR	Price per kilo, EUR
Canada	Live	4323	03062210	51,679,418	11,95
Canada	Frozen	3734	030612	40,260,169	10,78
USA	Live	8624	03062210	100,570,813	11,66
USA	Frozen	217	030612	4,152,929	19,13

AIPCE-CEP[27] figures on the Canadian lobster export to the EU are lower than the figures above: average volume of 2,780 tons/year (2010-2014), average value 44,367,520 Canadian Dollar/year (2010-2014) (= 30 million EUR/year), which gives an average price of about 11 EUR per kilo. The European Commission have received figures from the US referring to a transatlantic trade value of 196 million US Dollar/year (= 172 million EUR/year), which is a bit higher than the figures from the European commission help desk in the table above (a total of 197 million EUR). There are also data from Eurostat that differ from the figures mentioned above.[28]

[26] European Commission Export Helpdesk, http://exporthelp.europa.eu

[27] AIPCE-CEP represents the Fish Processing and Trading National Associations from Belgium, Denmark, Finland, France, Germany, Ireland, Italy, NL, Poland, Portugal, Spain, Sweden and UK.

[28] http://ec.europa.eu/eurostat/web/international-trade/data/database

According to the European Commission trade statistics there does not appear to be a large price difference between the imports of live and frozen lobster.

The *H. americanus* fisheries in the US mainly operate in the Gulf of Maine. In Canada the lobster fishery operates in five out of ten provinces. Below a brief description of the importance of the lobster fishery is made for the case of Canada.

The lobster industry is important for hundreds of small communities in five out of ten provinces in Canada. Lobster fishery is carried out by 9 500 independent enterprises, employing around 30 000 harvesters. Further, hundreds of companies are involved in purchase, process and export of live lobster. The total value of exported lobster products exceeded 1.5 billion CAD in 2014 (around 9,3 billion SEK). The corresponding figures for 2015 are expected to be even higher. The main destinations of Canadian exports are the United States, EU and Japan, in total more than 50 countries. Processed products constitute 60 % of the total value. According to Statistics Canada the total value of Swedish imports of live lobster was 12 MSEK in 2014, representing an increase of nearly 5 MSEK compared to the year before.

A lot of Canadian lobster is transported to Sweden via Boston, and the value of live lobster sent this way from the United States was 22 MSEK in 2014 (personal communication with the Embassy of Canada, 2015-09-21).

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