Vitenskapskomiteen for mat og miljø
Norwegian Scientific Committee for Food and Environment

VKM Report 2021: 02

Assessment of the risk to Norwegian biodiversity from import and keeping of crustaceans in freshwater aquaria

Scientific Opinion of the Panel on Alien Organisms and Trade in Endangered Species of the Norwegian Scientific Committee for Food and Environment

VKM Report 2021: 02
Assessment of the risk to Norwegian biodiversity from import and keeping of crustaceans in freshwater aquaria.

Scientific Opinion of the Panel on Alien Organisms and trade in Endangered Species (CITES) of the Norwegian Scientific Committee for Food and Environment
15.02.2021

ISBN: 978-82-8259-356-4
ISSN: 2535-4019
Norwegian Scientific Committee for Food and Environment (VKM)
Postboks 222 Skøyen
0213 Oslo
Norway

Phone: +47 21 62 28 00
Email: vkm@vkm.no

vkm.no
vkm.no/english

Cover photo: Mohammed Anwarul Kabir Choudhury/Mostphotos.com

Suggested citation: VKM, Gaute Velle, Lennart Edsman, Charlotte Evangelista, Stein Ivar Johnsen, Martin Malmstrøm, Trude Vrålstad, Hugo de Boer, Katrine Eldegard, Kjetil Hindar, Lars Robert Hole, Johanna Järnegren, Kyrre Kausrud, Inger Måren, Erlend B. Nilsen, Eli Rueness, Eva B. Thorstad and Anders Nielsen (2021). Assessment of the risk to Norwegian biodiversity from import and keeping of crustaceans in freshwater aquaria. Scientific Opinion of the Panel on Alien Organisms and trade in Endangered Species (CITES) of the Norwegian Scientific Committee for Food and Environment. VKM report 2021:02, ISBN: 978-82-8259-356-4, ISSN: 2535-4019. Norwegian Scientific Committee for Food and Environment (VKM), Oslo, Norway.

Assessment of the risk to Norwegian biodiversity from import and keeping of crustaceans in freshwater aquaria

Preparation of the opinion

The Norwegian Scientific Committee for Food and Environment (Vitenskapskomiteen for mat og miljø, VKM) appointed a project group to draft the opinion. The project group consisted of one VKM member, four external experts and a project leader from the VKM secretariat. Two exsternal referees commented on and reviewed the draft opinion. The VKM Panel on Alien Organisms and Trade in Endangered Species (CITES) evaluated and approved the final opinion.

Authors of the opinion

The authors have contributed to the opinion in a way that fulfils the authorship principles of VKM (VKM, 2019). The principles reflect the collaborative nature of the work, and the authors have contributed as members of the project group and/or the VKM Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM.

Members of the project group

Gaute Velle – Chair of the project group and Chair of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) NORCE Norwegian Research Centre; 3) Department of Biosciences, University of Bergen

Lennart Edsman – External expert. Affiliation: Department of Aquatic Resources, Swedish University of Agricultural Sciences (SLU Aqua)

Charlotte Evangelista – External expert. Affiliation: 1) Department of Biosciences, University of Oslo (UiO – IBV), 2) Norwegian University of Life Sciences (NMBU)

Stein Ivar Johnsen – External expert. Affiliation: Norwegian Institute for Nature Research (NINA)

Martin Malmstrøm – Project leader, VKM staff. Affiliation: VKM.

Trude Vrålstad – External expert. Affiliation: The Norwegian Veterinary Institute (NVI).

Members of the Panel on Alien Organisms and Trade in Endangered Species (CITES) that contributed to the assessment and approval of the opinion

Hugo de Boer – Member of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) Natural History Museum, Oslo.

Katrine Eldegard – Member of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) Norwegian University of Life Sciences (NMBU), Ås.

Kjetil Hindar – Chair of the project group and member of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) Norwegian Institute for Nature Research (NINA), Trondheim.

Lars Robert Hole – Member of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) The Norwegian Meteorological Institute, Bergen.

Kyrre Kausrud – Member of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) The Norwegian Veterinary Institute (NVI), Oslo.

Johanna Järnegren – Member of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) Norwegian Institute for Nature Research (NINA), Trondheim.

Inger Måren – Member of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) Department of Biological Sciences, University of Bergen.

Erlend B. Nilsen – Member of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) Norwegian Institute for Nature Research (NINA), Trondheim.

Eli Rueness – Member of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biosciences, University of Oslo.

Eva B. Thorstad – Member of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) Norwegian Institute for Nature Research (NINA), Trondheim.

Anders Nielsen – Vice chair of the Panel on Alien Organisms and Trade in Endangered Species (CITES) in VKM. Affiliation: 1) VKM; 2) Norwegian Institute of Bioeconomy Research (NIBIO); 3) Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biosciences, University of Oslo.

Acknowledgment

VKM would like to thank the referees Doctor Christopher A. Taylor (Prairie Research Institute, Illinois, US) and Doctor Nathan Edmonds (Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Lowestoft, UK) for reviewing and commenting on the manuscript. VKM emphasises that the referees are not responsible for the content of the final opinion. In accordance with VKM's routines for approval of a risk assessment, VKM received the referees' comments before evaluation and approval by the Panel and prior to publication.

VKM would also like to thank Professor Gordon H. Copp and Associate Professor Lorenzo Vilizzi (both at University of Łódź, Łódź, Poland) for valuable help with processing the AS-ISK

data, and Svein Fosså (NZB) for data on trade relevance of relevant species in Norway and abroad.

Competence of VKM experts

Persons working for VKM, either as appointed members of the Committee or as external experts, do this by virtue of their scientific expertise, not as representatives for their employers or third party interests. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

Table of Contents

Summary

Key words: Risk assessment, Crayfish, Shrimps, Crabs, Climate change, *Aphanomyces astaci*, White spot syndrome, Alien species, Biological invasion

Introduction

The Norwegian Scientific Committee for Food and Environment (VKM) was requested by the Norwegian Environment Agency to assess the risk of negative impacts to biodiversity in Norway resulting from import of crustacean decapods for keeping in freshwater aquariums.

VKM was asked to 1) list species of crayfish, crabs and shrimps that are currently kept in freshwater aquaria in Norway, and species that are likely to be kept in freshwater aquaria in Norway within the next 10 years, 2) assess the ability of the species to survive under Norwegian conditions and cause impacts on ecosystems and other species, and 3) state the potential negative effects on the biological diversity of diseases caused by pathogens, regulated under the Norwegian Food Act.

Methods

The risk assessment, without focus on pathogens, was performed in two steps. First, we used a pre-screening toolkit to identify species of crayfish, crabs and shrimps with potential to become invasive in freshwater habitats in Norway. Each species was given an invasiveness score based on 55 questions on biogeography, ecology, and climate change. In a second step, a full risk assessment, including the potential impacts of pathogens, was conducted on those species receiving the highest invasiveness score. This assessment included questions on the organism's probability of entry and pathways of entry, establishment and spread, potential impacts on biodiversity, and how climate change scenarios might affect the assessment. Likelyhood and confidence was assessed for each question. In conclusion, each species was designated as either low-, moderate-, or high risk.

Many crustacean decapod species are confirmed or suspected carriers of pathogens that can cause mass mortality among native crustaceans. The risk posed by crustaceans as carriers of pathogens may be independent of the environmental risk that they pose through ecological interactions. Therefore, the four crustacean disease pathogens that are regulated under the Norwegian Food Act, were assessed separately. These include *Aphanomyces astaci* causing crayfish plague, white spot syndrome virus (WSSV) causing white spot disease, Taura syndrome virus (TSV) causing Taura syndrome, and yellow head virus genotype 1 (YHV1) causing yellow head disease. The assessments comprised questions on the pathogen's probability of entry (as a hitchhiker organism with imported crustaceans), pathways of entry, establishment and spread, and potential impact on crustacean biodiversity. Likelihood and confidence were assessed for each question. In conclusion, each pathogen was designated as either low-, moderate-, or high risk.

In a third step, we categorized the likelihood that a crustacean species introduces a pathogen associated with a high- or moderate risk into: I) known chronic carriers, II) suspected chronic carriers, III) suspected situational carrier, IV) possible pathogen transmitters, and V) no direct or circumstantial evidence for carrier status or pathogen transmission in the genus.

Results

Based on information from the Norwegian Pet Trade Association, the project group listed 112 taxa (mainly species and some genera) of freshwater crayfish, crabs and shrimps that are relevant for trade in Norway. These included 38 crayfish taxa, 28 crab taxa, and 45 shrimp taxa. In addition, one marine crab was included.

Sixteen species of crayfish, four species of shrimps, and two species of crabs underwent a full ecological risk assessment. The probabilities of entry both into the aquarium trade in Norway, and potentially further into Norwegian nature, were based on the prevalence of the species in the aquarium trade in Norway. We assumed that all species were equally likely to escape captivity or to be released.

The four pathogens regulated under the Norwegian Food Act are either known or potential hazards to biodiversity in Norway. *A. astaci* is already present in Norway. It is regarded among the greatest threats to European freshwater crayfish, including noble crayfish (*Astacus astacus*). American freshwater crayfish are either known or suspected chronic carriers of *A. astaci*, while several crayfish species from other continents, as well as some species of crab and shrimp, may be situational carriers.

WSSV is a "non-exotic" list 2 disease. All decapods can be infected by the virus. WSSV is primarily a problem in shrimp farming in Asia, but has spread to America and more recently to Australia. WSSV can cause 100% mortality in noble crayfish at water temperatures above 20 °C. Both TSV and YHV1 are "exotic" list 1 diseases. These can infect and cause high mortality in a limited range of saltwater shrimps. There is no evidence that TSV and YHV1 pose a risk to freshwater crayfish in the Nordic climate, nor is introduction likely through aquarium trade in freshwater crustaceans.

Several other pathogens that cause crustacean dirsease are listed by the World Organization for Animal Health (OIE). These were briefly assessed, but not fully risk assessed.

Conclusions

VKM concluded that the risk of negative impacts on biodiversity caused by ecological interactions following import and private keeping of crayfish is high for *Faxonius virilis, Faxonius* spp., *Procambarus clarkii*, *P. virginalis,* and *Pacifastacus leniusculus*. These species can displace native crayfish, reduce the abundance of aquatic plants, and cause cascading effects that negatively influence invertebrates, fish, and birds. They can likely establish in Norwegian nature under the current climate conditions. The risk of negative consequences is moderate (with medium confidence) for the crayfish *Cambarellus patzcuarensis,* *Procambarus alleni*, *Creaserinus fodiens*, *Cambarellus montezumae*, *Cherax monticola*, *Cherax tenuimanus, Faxonius neglectus. Perconon gibbesi* of the crabs and *Neocaridina davidi* and *Macrobrachium rosenbergii* of the shrimps were associated with a moderate risk with medium confidence. Species associated with medium risk are omnivorous keystone species that will have at least moderate ecological impact on littoral freshwater ecosystems (medium confidence) if established in dense populations. None of the species associated with medium risk are likely to establish today. However, climate change will increase the risk for establishment and resulting ecological impact.

The risk for negative impacts caused by the crayfish plague pathogen *Aphanomyces astaci* is high with high confidence. Crayfish plague can cause up to 100% mortality, and has already eradicated several noble crayfish populations in Norway. For WSSV, the risk for negative impact is moderate with high confidence. The risks associated with TSV and YHV1 are assessed as low for Norwegian crustacean biodiversity.

According to the risk assessment of pathogens and the categorization of crustacean species based on their likelihood of being carriers of *A. astaci* and WSSV, 25 and 13 species of crayfish are associated with a high and medium risk, respectively. Four and 25 species of crabs are associated with a medium and low risk, respectively, and 14 and 31 species of shrimps are associated with medium and low risk, respectively. Notably, all species in the named genera should be regarded as belonging to the given risk category.

OIE and general literature provide information of known crustacean diseases along with known susceptible crustacean hosts. However, there is a lack of information regarding carrier status of known and unknown disease pathogens for many exotic crustaceans. In this perspective, all exotic crustaceans should be regarded as potentially infected with a known or unknown pathogen. In order to reduce the risk of spreading diseases, eggs and living or dead animals should under no circumstances be disposed of in nature. The same applies for aquarium water or any material, such as gravel or ornamental plants, that have been in contact with the animals or water in the aquarium. The current permit requirement exemption for import of freshwater organisms that can only survive at temperatures above 5 °C provides no protection against the introduction, establishment, and spread of accompanying pathogens that could cause mass mortality in Norwegian crustacean populations.

Finally, we can never predict how, or from which host species, a new disease might emerge. Many pandemics and plagues result from cross-continental pathogen-host jumps often facilitated by human transport, trade, introduction, release, or escape of alien species and associated alien pathogens.

Sammendrag på norsk

Introduksjon

Miljødirektoratet ba Vitenskapskomiteen for mat og miljø (VKM) om å vurdere risikoen for negativ innvirkning på biologisk mangfold i Norge som følge av import av krepsdyr for hold i ferskvannsakvarier. Kreps, krabber og reker tilhører orden tifotkreps.

VKM ble bedt om å 1) kartlegge hvilke arter av kreps, krabber og reker som for tiden holdes i ferskvannsakvarier i Norge, og hvilke arter som kan være aktuelle for hold i Norge det kommende tiåret, 2) vurdere artenes evne til å overleve under norske forhold, og hvorvidt de kan ha negativ innvirkning på biologisk mangfold i Norge, og 3) identifisere mulige negative effekter på biologisk mangfold forårsaket av sykdomsfremkallende organismer (patogener) som er regulert under matloven.

Metoder

Risikoen krepsdyr utgjør som bærere av sykdomsfremkallende organismer vil ofte være forskjellig fra risikoen de utgjør gjennom økologiske interaksjoner. Dermed ble det utført to risikovurderinger, en for økologiske effekter og for sykdommer.

Den økologiske risikovurderingen av krepsdyrartene ble utført i to trinn. Først benyttet vi et kartleggingsverktøy for å identifisere arter som potensielt kan bli invaderende i Norge. Her ble hver art gitt en poengvurdering for invasjonspotensial basert på 55 spørsmål om biogeografi, økologi og klimaendringer. I trinn to utførte vi en full risikoanalyse for artene med høyest poengsum. Risikovurderingen omfattet spørsmål om sannsynlighet for at arten slipper ut av akvariet, etablerer seg og sprer seg, og artens potensielle innvirkning på biologisk mangfold. Effekter av klimaendringer ble også vurdert. Graden av pålitelighet ble vurdert for hvert svar, og som konklusjon ble arten kategorisert til å kunne utgjøre lav, moderat eller høy risiko. Sannsynligheten for at en art kommer inn i Norge ble basert på hvor utbredt arten er i akvariehandelen i Norge.

Mange tifotkreps kan være bærere av sykdomsfremkallende organismer som forårsaker dødelige sykdommer hos andre stedegne arter av tifotkreps. Risikoen tifotkreps utgjør som bærere av patogener, kan være uavhengig av den miljømessige risikoen de utgjør gjennom økologiske interaksjoner. Derfor ble de fire listeførte patogenene (regulert i matloven) som forårsaker sykdom hos tiforkreps vurdert separat. Disse er *Aphanomyces astaci* som forårsaker krepsepest, hvitflekk syndrom virus (WSSV) som forårsaker hvitflekksykdom, Taura syndrom virus (TSV) som forårsaker Taura syndrom og yellow head virus genotype 1 (YHV1) som forårsaker yellow head sykdom. Hver vurdering omfattet spørsmål om hvor sannsynlig det er at den sykdomsfremkallende organismen kommer til landet ved import av krepsdyr, etablerer seg og spres videre. Vi vurderte også potensielle effekter på biologisk mangfold, og da spesielt edelkreps. Graden av pålitelighet ble notert for hvert svar, og som konklusjon ble de sykdomsfremkallende organismene kategorisert til å kunne utgjøre lav, moderat eller høy risiko.

I et tredje trinn kategoriserte vi sannsynligheten for om kreps, kraber og reker bringer med seg en gitt sykdomsfremkallende organisme assosiert med høy eller moderat risiko ut ifra om arten er: I) kjent kronisk bærer, II) mistenkt kronisk bærer, III) mistenkt situasjonsbetinget bærer, IV) potensiell overfører, eller V) ikke direkte eller indirekte bevist å være bærer eller i stand til å overføre organismen.

Resultater

Basert på informasjon fra Norges Zoohandleres Bransjeforening (NZB), identifiserte vi 112 arter (i noen tilfeller slekter) av ferskvannskrepsdyr som er relevante for handel i Norge. Disse inkluderte 38 arter og slekter av kreps, 28 arter eller slekter av krabber og 45 arter av reker. I tillegg ble en saltvannskrabbe inkludert.

Seksten krepsearter, fire rekearter og to arter av krabber ble inkludert i en full økologisk risikovurdering. I risikovurderingen identifiserte vi 15 arter eller slekter som sannsynligvis vil ha en negativ påvirkning på biologisk mangfold gjennom økologiske interaksjoner. Alle arter ble vurdert til ha lik sannsynlighet for å havne i norsk natur gjennom å rømme eller bli sluppet ut.

De fire sykdomsfremkallende organismene som er regulert i matloven utgjør kjente eller potensielle trusler for biologisk mangfold i Norge. *A. astaci* er allerede til stede i Norge og forårsaker massedødelighet hos edelkreps. Krepseps er regnet som den største trusselen for Europeisk kreps, inkludert edelkreps. Alle amerikanske arter av ferksvannskreps er enten kjente eller mistenkte kroniske bærere av *A. astaci*, mens flere arter av kreps fra andre kontinenter, samt noen arter av krabbe og reke, kan være situasjonsbetingede bærere.

WSSV er en «ikke-eksotisk» liste 2 sykdom. Alle tiforkreps kan bli infisert av viruset. WSSV er først og fremst et stor problem i rekeoppdrett i Asia, og har spredt seg til Amerika og nylig til Australia. Det er vist at WSSV medfører 100% dødelihet for edelkreps ved vanntemperatur over 20 °C.

Både TSV og YHV1 er «eksotiske» liste 1 sykdommer. Disse kan forårsake høy dødelighet hos en begrenset antall arter av tropiske saltvannsreker. TSV og YHV1 utgjør ikke en risiko for ferksvannskreps i nordisk klima, og vil sannsynlig ikke introduseres til Norge gjennom akvariehandel med ferskvannskrepsdyr. Flere andre patogener som forårsaker sykdom hos tifotkreps er listed av Verdens dyrehelse-organisasjonen (OIE). Disse ble kort vurdert, men gjennomgikk ikke full risikovurdering.

Konklusjoner

VKM konkluderer med at risikoen for negativ påvirkning på biologisk mangfold gjennom økologiske interaksjoner er høy for krepseartene *Faxonius virilis*, *Faxonius* spp., *Procambarus clarkii*, *P. virginalis* og *Pacifastacus leniusculus*. Disse artene kan fortrenge den norske edelkrepsen, redusere forekomsten av vannplanter og forårsake omfattende negative effekter på virvelløse dyr, fisk og fugler. Risikoen for negative konsekvenser er moderat, med middels pålitelighet, for krepseartene *Cambarellus patzcuarensis*, *Procambarus alleni*, *Creaserinus fodiens*, *Cambarellus montezumae*, *Cherax monticola*, *Cherax tenuimanus* og *Faxonius neglectus*. Krabben *Perconon gibbesi* og rekeartene *Neocaridina davidi* og *Macrobrachium rosenbergii* er også forbundet med en moderat risiko med middels pålitelighet. Disse er altetende nøkkelarter som vil ha moderat økologisk innvirkning på littorale økosystemer i ferskvann (middels pålitelighet), hvis de er etablert i tette bestander. Det er ikke sannsynlig at artene som har fått vurderingen middels risiko kan etablere seg i Norge i dag. Imidlertid vil klimaendringer kunne øke sannsynligheten for etablering og negative økologiske påvirkninger.

Risikoen for negative påvirkninger forårsaket av den sykdomsfremkallende organismen *A. astaci* er høy med høy pålitelighet. For WSSV er risikoen for negativ effekt moderat med høy pålitelighet. Risikoen forbundet med Taura syndrom virus og yellow head virus blir vurdert som lav, med middels pålitelighet.

Når det gjelder risikovurderingen av sykdomsfremkallende organismer og sannsynligheten spre smitte av *A. astaci* og WSSV, er 25 krepsearter ansett å ha høy risiko, mens 13 krepsearter har moderat risiko. For krabber konkluderer prosjektgruppen med at fire arter har moderat risiko, mens 25 arter har lav risiko. 14 og 31 arter av reker har henholdsvis moderat og lav risiko. Øvrige arter i slektene som vi har risikovurdert må også betraktes å tilhøre tilsvarende risikokategori.

OIE og generell litteratur gir informasjon om kjente krepsdyrsykdommer og kjente mottakelige krepsdyrverter. Imidlertid er det store kunnskapshull om bærerstatus for kjente og ukjente sykdomspatogener for mange eksotiske krepsdyr. I et slikt perspektiv bør alle eksotiske krepsdyr vurderes som potensielt smittet med et kjent eller ukjent patogen. For å redusere risiko for spredning av sykdommer, skal egg og levende eller døde dyr under ingen omstendigheter havne i naturen. Det samme gjelder akvarievann eller ethvert materiale, for eksempel grus eller prydplanter, som har vært i kontakt med dyrene eller vann i akvariet.

Unntaket fra kravet om tillatelse til import av ferskvannsorganismer som bare kan leve ved temperaturer over 5°C, gir ingen beskyttelse mot innføring, etablering og spredning av medfølgende sykdomsfremkallende organismer. Det er viktig å understreke at vi ikke kan forutsi hvordan, eller fra hvilken art, en ny sykdom kan oppstå. Mange pandemier forårsakes av at fremmede sykdomsfremkallende organismer kommer i kontakt med nye verter. Slik kontakt kan komme som følge av forflytning av organismene i forbindelse med transport, handel, utsetting eller rømming av fremmede arter som er bærere av fremmede sykdomsfremkallende organismer.

Background as provided by the Norwegian Environment Agency

The Norwegian Environment Agency has registered a growing interest in the import of various species of freshwater crayfish for aquaculture and private keeping, both from the southern and northern hemispheres. The Directorate hereby requests the Scientific Committee for Food and Environment to assess of the risk of adverse consequences for biological diversity following import of various crustaceans for keeping in freshwater aquariums.

Regulations on alien organisms under the Norwegian Nature Diversity Act, which entered into force on 1 January 2016, regulate all imports of freshwater organisms. However, exceptions have been made to the general requirement for an import permit for "heat-loving" freshwater organisms.

"Permission is not required for the import of freshwater organisms which can only live at temperatures above 5 ° C, and which are to be kept exclusively for ornamental purposes in indoor aquariums which are designed so that organisms cannot escape, ..."

In addition to the exemption for aquarium organisms being limited to those species that cannot survive below 5 °C, the regulations always require a permit when importing a number of species that are listed in Annex III to the regulations. The species in the appendix have been updated on the basis of information from the zoo industry, as well as assessments and recommendations from researchers / research institutions. However, the assessments were carried out at a time when the regulations on alien organisms had not been completed, and the assumption on which the assessments are based has changed somewhat. As a basis for application processing and any change in how the species in the future should be regulated under regulations on alien organisms. The Norwegian Environment Agency therefore needs an updated assessment of the risk of adverse consequences for biological diversity regarding the freshwater crustaceans listed in Annex III of the regulations.

The Norwegian Environment Agency has received a number of applications for the introduction of crustaceans for use in freshwater aquariums, and also sees a need for assessments of the risk of adverse consequences for biological diversity associated with these species.

In order to be prepared to process future applications, the Norwegian Environment Agency also needs a review of which other species of crustaceans that are kept in freshwater aquariums today, or which can be expected to be kept in the future, and assessments of the risk of adverse biological consequences regarding keeping these.

Terms of reference as provided by the Norwegian Environment Agency

The Norwegian Environment Agency requests the Norwegian Scientific Committee for Food and environment (VKM) to identify which species of crustaceans are currently kept, and which species are likely to be kept in the foreseeable future, in freshwater aquariums in Norway. The directorate further requests VKM to assess the risk of negative impacts on biological diversity in Norway as a result of the import and keeping of the identified species.

The Norwegian Nature Diversity Act defines biological diversity as the variability among ecosystems and species, intraspecies genetic variation and the ecological relationships between ecosystem components. The ability to survive under Norwegian conditions and possible impact on ecosystems and other species should be included in the risk assessments, as well as the likelihood that the import and keeping may cause the species to escape and spread. If there are special measures or restrictions that would affect the risk posed by the species, this must be stated.

Since pathogens that can have an impact on wild species and biological diversity are regulated under the Norwegian Food Law, it must be stated to what extent diseases are weighted and decisive for the assessments.

Given there is a cut-off temperature of 5 ºC for an exemption under the Norwegian import permit requirements, it must be stated for each risk assessment whether the species can survive below this temperature.

A grouped risk assessment may be conducted for whole families or genera, given that the risks are similar among all species.

The starting point for the risk assessments is the current climate. If any of the species and the risk they pose will be affected by the expected climate change in the period up to the year 2100, this shall, to the extent practicable with current knowledge, be stated in the risk assessments. Due to the uncertainty in the development of emissions, it is national policy that the changes due to continued high emissions should be used as a basis for climate projections, and we therefore ask that RCP 8.5 be included as one of the climate scenarios on which the assessments are based.

The risk for adverse impact on ecosystem services shall be stated, but shall not be included in the assessments of the risk of negative impacts on biological diversity.

1 Introduction

1.1 Taxonomy and biology of crustaceans

The Crustacea is a large and diverse sub-phylum of Arthropoda. It includes animals like crabs, lobsters, crayfish, shrimps, prawns, krill, woodlice and barnacles. About 52,000 species of crustaceans have been described (Martin and Davis 2001). The highest number of species and density are in marine habitats, and they also occur in terrestrial, semi-terrestrial, and freshwater habitats. Most species are motile (free-living), but some are sessile (attached to a substrate) or parasitic. Food and feeding is species-dependent and include diverse sources and feeding habits.

The Decapoda forms one of the most species-rich orders within the Crustacea. Among decapods, about 20% are freshwater species and require freshwater habitats for their survival (De Grave et al. 2008, Yeo et al. 2008). Among the Decapoda are 767 species of shrimps, 634 crayfish, 1485 crabs, and 69 species within the family Aeglidae (so called aeglid anomurans). They are present in all biogeographical regions, expect Antarctica.

The general life history of Decapoda includes: i) embryonic development within the eggs, ii) hatching as nauplius followed by free-living planktonic larvae, and iii) larval metamorphosis into juveniles that reach sexual maturity and can reproduce (Table 1.1-1).

The larval period is usually completed in 5 weeks and is divided into the nauplius-phase, the zoea-phase (including protozoea and mysis), and the decapodid-phase, each with varying numbers of stages. The number of stages denote different development strategies, from extended larval development to complete abolition of planktonic larvae and the release of juvenile-like decapods from the mother. Freshwater decapods can fully develop in freshwaters or have an amphidromous life cycle. Amphidromy is a life-history strategy characterized by adult life in freshwater and larval development in salt/brackish waters (Bauer 2011). Advantages include the abundant food supply in estuaries and nearby marine areas, avoidance of competition for resources with the adults, high dispersal, enhanced gene flow among populations, and decreased likelihood of inbreeding (Pechenik 1999). Disadvantages are the osmotic stresses and greater risks of predation among downstream-drifting larvae and upstream-migrating juveniles (Vogt 2013).

For many amphidromous species, the distance between the freshwater habitats of adults and the salt/brackish waters of larval development is a few dozen kilometres, but can be up to several hundreds of kilometres. Eggs of amphidromous species either hatch upstream and drift down to the sea, or are released to brackish waters by females that migrate from their freshwater habitats down to the estuaries.

Table 1.1-1: Developmental traits in shrimps, crabs and crayfish.

Development	Shrimps in Atyidae	Shrimps in Palaemonidae	Shrimps in other Caridae families	Primary freshwater crabs	Secondary freshwater crabs	Cray-fish
Extended planktonic development in the sea	YES (e.g., *Micratya poeyi, Atya innocous)*	YES (e.g., *Macrobrachium rosenbergii*)	Yes (e.g., *Xiphocarididae* spp.)	NO	YES (e.g., *Sesarmidae* spp., such as *Aratus pisonii*)	NO
Prolonged planktonic development in freshwaters	YES (e.g., *Atyaephyra desmaresti)*	YES	NO	NO	YES (e.g., *Eriocheir sinensis*)	NO
Abbreviated planktonic development in freshwaters	YES (e.g., *Caridina aruensis, Caridina gurneyi)*	YES (e.g., *Macrobrachium dayanum*)	YES (e.g., *Euryrhynchus* spp.)	NO	YES	NO
Suppressed larval development	YES (e.g., all species/subspecies of *Neocaridina* and *Caridina* from lakes of Sulawesi)	YES (e.g., *Palaemonetes mercedae*)	YES (e.g., *Desmocaris trispinosa*)	YES	YES (e.g., *Sesarmidae* spp.)	YES
Brood care (e.g., preparation of nests, egg care, provisioning of the offspring)	Only for *Dugastella valentina* and *Dugastella marocana*	No brooding of posthatching stages		YES	Posthatching brood care only in members of the Sesarmidae	YES

1.1.1 Crayfish

Freshwater crayfish include the superfamilies Astacoidea (Astacidea with 16 species and Cambaridae with 440 species) of the northern hemisphere and Parastacoidea (Parastacidae with 178 species) of the southern hemisphere. Freshwater crayfish are distributed from 67°N to 47°S and from lowlands to 2,800 m altitude (Vogt 2013). They can be found in a wide variety of freshwater habitats, including rivers, lakes, swamps, and caves.

Freshwater crayfish produce tens to hundreds of eggs per clutch that will hatch as juvenile-like decapods after embryonic development. Posthatching brood is ubiquitous among freshwater crayfish species, and juveniles are carried on the maternal pleopods.

Freshwater crayfish are regarded as keystone species and are known to shape the littoral zone in aquatic environments (Creed 1994, Momot 1995). As they are sensitive to pollution, they are also considered indicators of water quality (Sylvestre et al. 2002). Freshwater crayfish are ecosystem engineers and also umbrella species as they influence sediment dynamics and benefit other animals (Usio and Townsend 2001, Reynolds et al. 2013, Hessen et al. 1993).

In addition, some species of freshwater crayfish are harvested and regarded as delicacies. The European noble crayfish (*Astacus astacus*) is such a species and obtains a high price on the Scandinavian markets (Ackefors 1998, Edsman 2004, Jussila and Mannonen 2004, Johnsen et al. 2009, Bohman and Edsman 2011). Crayfish are harvested in the wild (both recreational and commercial fisheries) and from cultivation. Species like the red swamp crayfish (*Procambarus clarkii*), yabby (*Cherax destructor*), and marron (*Cherax tenuimanus*) are cultivated at a large global scale (Souty-Grosset et al. 2006).

More than one-third of the world´s freshwater crayfish species are likely threatened with population decline or extinction (Taylor 2002). The most serious threat is the spread of alien crayfish species and their associated pathogens (Holdich et al. 2009). Other factors include anthropogenic influences, like pollution and habitat loss/degradation, overharvesting, and climate change (Taylor 2002, Holdich et al. 2009, Kouba et al. 2014, Richman et al. 2015).

1.1.2 Crabs

There are 1280 species of freshwater crabs worldwide, representing 20% of all species of crabs (Camberlidge et al. 2009). Freshwater crabs (i.e., Crustacea: Decapoda: suborder Brachyura) are divided into primary (or pure/true freshwater families) or secondary freshwater crabs. Secondary freshwater species are fully adapted to freshwaters or land, but use marine habitats for moulting and reproduction (Yeo et al. 2008, De Grave et al. 2009).

Primary freshwater crabs are independent of the sea for completion of their life cycles. They include two phylogenetic lineages: the Potamoidea (Gecarcinucidae with 349 species, Potamidae with 523 species, Potamonautidae with 139 species, and Pseudothelphusidae with 276 species) and the Trichodactylidae. Families of secondary freshwater crabs are the Hymenosomatidae with 22 of 124 species in freshwater, the Varunidae with 21 of 151 species in freshwater, the Goneplacidae with 4 of 73 species in freshwater, and the Sesarmidae with 101 of 253 species in freshwater or on land.

The life cycle of primary freshwater crabs is distinctly different from secondary freshwater crabs and marine crabs as they have direct development, meaning that the larval stages occur within the egg and that juveniles hatch from the eggs (Darren et al. 2008). Post-hatching brood care is common in primary freshwater crabs and the carriage of juveniles can be prolonged over several stages. The eggs have a diameter of about 1 mm and one clutch may include a few hundred to a few thousand eggs. Large amphidromous secondary freshwater crabs can lay more than one million eggs.

Freshwater crabs are especially common in the tropics, where they can reach dense populations and a high biomass. Some species are also present in the subtropics and temperate regions. There are several species in Mediterranean Europe; for example, the Mediterranean freshwater crab, *Potamon fluviatile*, which has a natural range north to the River Po in Italy (Jesse et al. 2009). Some species are invasive. One of the most invasive species includes the Chinese mitten crab, *Eriocheir sinensis*, which has spread to northern Europe, including Norway. These crabs have a tendency towards digging and have caused damage to industrial infrastructure and dams in Germany. Although there may be potential interactions between native crayfish and crabs, no agonistic behavioural patterns have been observed in Europe to date (Mazza et al. 2017).

Freshwater crabs prefer pristine water conditions and occur in almost all tropical freshwater habitats, from fast-flowing mountain streams to stagnant ponds and swamps (Camberlidge et al. 2009, Yeo et al. 2008). They occur from 54°N to 37°S, and from lowland to 3800 m altitude (Vogt 2013). Freshwater crabs are important components of the ecosystems in tropical rivers, wetlands, caves, and semi-terrestrial habitats (Dobson et al. 2007, Rodríguez and Magalhães 2005, Yeo et al. 2008a), contributing, for example, in the recycling of nutrients and acting as integral components of food webs. The primarily semi-terrestrial species are air-breathing and burrow-living and inhabit water and land. Most freshwater crabs are omnivorous and feed on organic matter, aquatic insects, gastropods, and dead animals (Dudgeon and Cheung 1990, Maitland 2003). Due to loss and deterioration of habitats and pollution, at least one sixth of freshwater crab species are at risk of extinction (Camberlidge et al. 2009).

1.1.3 Shrimps

Many species of crustaceans are commonly referred to as shrimps. Here, we use the term shrimp for those belonging to the order Decapoda: suborder Caridea, or caridean shrimp. Freshwater shrimps belong to eight families/subfamilies within Caridea; these are numerically dominated by the Atyidae with about 500 species/subspecies and the Palaemonidae with about 950 species. The Euryhynchidae and the Desmocarididae families are composed of seven and two species, respectively (Vogt 2013).

Caridean shrimps are distributed from 52°N to 47°S and from lowlands to 3000 m altitude in a wide range of habitats including torrential mountain streams, swamps, and anchialine caves (De Grave et al. 2008, Karge and Klotz 2008). Freshwater shrimps are present in all the main biogeographical regions, expect the Antarctic. They show their highest diversity in the Oriental region (349 species and 21 subspecies), while the next most species-rich region exhibits three times fewer species (Neotropical: 109 species and 17 subspecies) and the lowest number of taxa is found in the Nearctic region (17 species and 5 subspecies) (De Grave et al. 2008).

Freshwater shrimps include mainly omnivores and herbivores, but there are also filter feeders and microphagous grazers. They play an important role in key ecosystem processes, such as organic matter decomposition and nutrient cycling. For instance, one shrimp genus (*Xiphocaris*) has been found to increase leaf-litter decomposition, transport of suspended particulate organic matter, and concentrations of dissolved organic carbon and nitrogen (Crowl et al. 2001).

Although numerous freshwater shrimp species are important components of artisanal fisheries, the giant river prawn (*Macrobrachium rosenbergii*) is used extensively in the aquaculture industry in at least 40 countries, from both its native range (India to northern Australia) and outside it (e.g., USA, Alaska, and Nicaragua) (De Grave et al. 2008). In 2009, the total annual production of freshwater shrimps was around 444,000 tonnes, with a value of US$ 2.2 billion (New and Nair 2012). The farmed production was mainly constituted of giant river prawn (around 52% of the total production), while the oriental river prawn (*Macrobrachium nipponense*) accounted for around 47% of the production (New and Nair 2012).

Nearly 28% of the world's freshwater shrimp species are threatened with extinction, and at least two species can be considered extinct (De Grave et al. 2015). Because all specimens used in the aquarium trade are wild harvested, overharvesting is a threat to shrimp species endemic to Indonesia (von Rintelen et al. 2019a). For instance, the yellow goldflake shrimp (*Caridina spinata*) and the harlequin shrimp Sulawesi (*Caridina woltereckae*) from Lake Towuti (Sulawesi) are both listed as critically endangered according to the IUCN Red List (von Rintelen et al. 2019a, von Rintelen et al. 2019b).

Freshwater shrimp have either amphidromous (i.e., extended larval development in brackish waters) or freshwater life cycles. For amphidromous species, the number of eggs per clutch can vary from tens of thousands to tens when larval development is highly abbreviated or completely supressed (e.g., Desmoricarididae, Euryrhynchidae, and Typhlocarididae).

1.2 Freshwater crustaceans native to Norway

There are no species of freshwater crabs that are native to Norway and only one shrimp species, *Palaemonetes varians*, that occurs in brackish water.

Figure 1.2-1: Noble crayfish (*Astacus astacus*) in its natural habitat in Eastern Norway. Photo: David Strand, The Norwegian Veterinary Institute.

The noble crayfish, *Astacus astacus* (Figure 1.2-1), is indigenous to Europe and is the only indigenous species of freshwater crayfish in Norway (Souty-Grosset et al. 2006).

There are currently about 470 registered populations of noble crayfish in Norway (Johnsen and Vrålstad 2017). These populations are mainly found in south-eastern Norway, and a few are also situated on the west coast and in the central part of Norway (Figure 1.2-2). Along with populations of other freshwater crayfish species indigenous to Europe, the number of noble crayfish populations has declined dramatically during recent decades, mostly due to crayfish plague (Holdich et al. 2009), but also due to anthropogenic influences, such as pollution and habitat loss. Hence, the noble crayfish is both on the international (Edsman 2010) and the national red list (www.artsdatabanken.no). There has been a national surveillance programme of noble crayfish since 2001 (Johnsen et al. 2019). In 2009, the harvested biomass of crayfish was estimated to be in the range of 8-13 tonnes (corresponding to 264,000-429,000 individuals with a mean weight of 30 g) (Johnsen et al. 2009c).

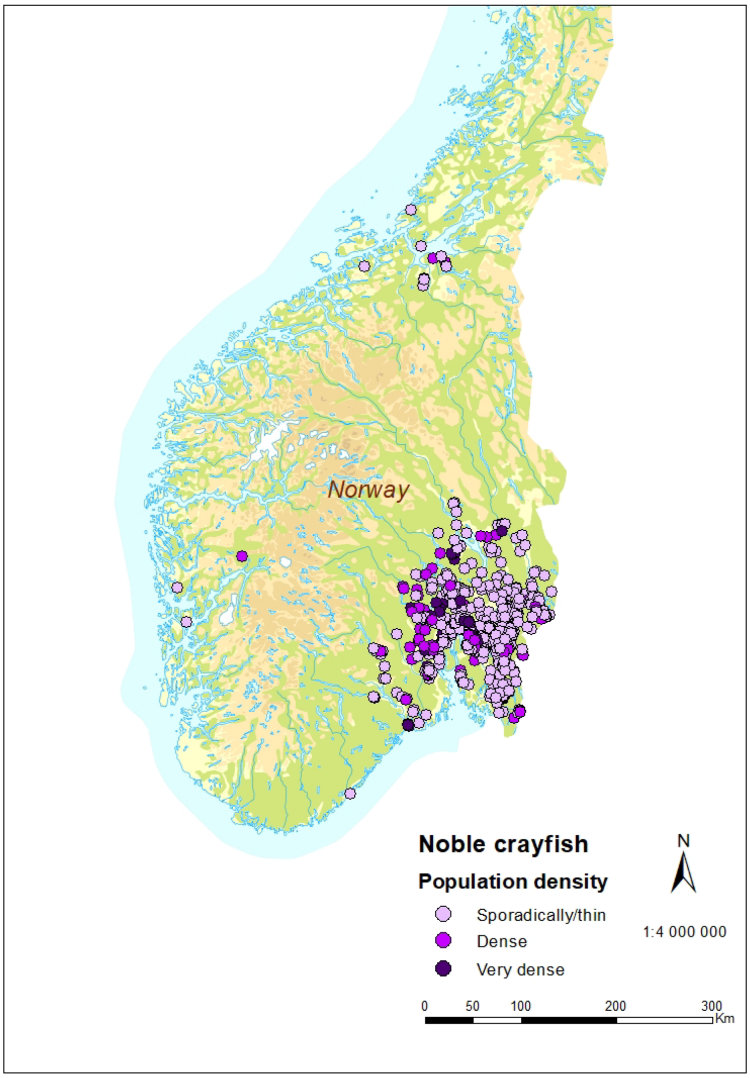

Figure 1.2-2: Distribution of noble crayfish populations in Norway.

1.3 Invasive freshwater crustaceans

1.3.1 Problems related to invasive alien freshwater crustaceans

Freshwater crustaceans account for an increasingly larger share of invasive species globally (Patokaet al., 2016). Many aquatic crustaceans produce planktonic larvae that can be moved by humans over considerable distances, for example, in ballast water of ships (Panov et al. 2004). The Chinese mitten crab (*E. sinensis*) can flourish in both marine and freshwater habitats, and most likely arrived in Europe and Norway in ballast water. Some crustaceans may be translocated when they attach to, or bore into, solid surfaces, such as on ships. Others are moved by humans as part of industrial enterprises, for example in aquaculture, for live food in restaurants, as live bait or as hitchhikers on aquarium animals, plants, or other substances (Patokaet al. 2016). Some are even introduced by management for weed control or stock enhancement, such as crayfish (Holdich and Pöckl 2007). Mechanisms of introduction are often unknown (Dobson 2012).

If the environmental and biotic conditions are within the ecological niche of an alien aquatic macroinvertebrate species, then it may multiply rapidly and become virtually impossible to eradicate in anything but a small, enclosed waterbody (Holdich et al. 1999, Peay et al. 2006). The number of invasive species in European freshwaters is therefore increasing (Holdich and Pöckl 2007, Nunes et al. 2015), suggesting that there is an imminent threat that invasive crustaceans may establish in Norway.

According to the Global Invasive Species Database (2020), 105 species of arthropods (excluding shrimps) are listed among the 371 alien and invasive animal species that negatively impact biodiversity worldwide. Of these, six species are decapods that occur in freshwaters, including the Chinese mitten crab (*E. sinensis*), Harris mud crab (*Rhithropanopeus harrisii*), rusty crayfish (*Faxonius rusticus*), virile crayfish (*Faxonius virilis*), signal crayfish (*Pacifastacus leniusculus*), and red swamp crayfish (*Procambarus clarkii*). Note that *Faxonius rusticus* and *F. virilis* were reclassified in 2017, and the genus was changed from *Orconectes* to *Faxonius.* Of these, the signal crayfish and Chinese mitten crab are already present in Norway (Johnsen et al. 2007, 2017, Norling and Jelmert 2010). Some species of freshwater shrimps are also considered invasive, such as *Neocaridina davidi*, which is indigenous to Asia and has spread to Germany through the aquarium pet trade (Schoolmann and Arndt 2018). In addition, there are several species of invasive shrimps in brackish and marine habitats.

Although it is sometimes is difficult to assess the impact of invasive species (Holdich and Pöckl (2007), they are recognized as one of the major threats to biodiversity in freshwater ecosystems (Rewicz et al. 2014, Sala et al. 2000, Lambertini et al. 2011, Caffrey et al. 2013, Fries and Tesch 1965). The introduction of alien shrimps, such as *N. davidi*, can have ecologically important consequences, including a negative impact on populations of native freshwater invertebrates (Klotz et al. 2013, Pantaleao et al. 2015) with altered structure of the meiofaunal community (Weber and Traunspurger 2016). *Neocaridina davidi* can disperse rapidly, tolerates a wide range of temperatures, and is omnivorous (Patokaet al., 2016).

Crabs, such as the Chinese mitten crab, can cause considerable damage to soft sediment banks through burrowing, which increases erosion and has negative impacts on native biodiversity (Dittel and Epifano 2009, Rudnick et al. 2005). Many species of crayfish can also have negative effects. For example, *Procambarus clarkii* and *Faxonius rusticus* can displace native crayfish, reduce the abundance of aquatic plants, and negatively influence invertebrates and fish (McCarty et al. 2006, Gherardi 2007, Wilson et al. 2004). In addition, invasive decapods are a major concern because they can be hosts to pathogens of major concern for native biodiversity, such as *A. astaci* in crayfish (OIE 2019, see also section 1.5) or can cause diseases in humans, such as the lung fluke *Paragonimus* spp. which causes paragonimiasis (Lindquist and Cross 2017) when infected crustaceans are ingested without adequate cooking.

1.3.2 Invasive crustaceans in the Nordic countries

1.3.2.1 Norway

For a long time, Norway was one of few countries in Europe without alien crayfish, but in 2006 signal crayfish, *Pacifastacus leniusculus* (Figure 1.3.2.1-1) was discovered in Dammane in Telemark and Vestfold County (Johnsen et al., 2007, see figure 1.2.4-1).

Figure 1.3.2.1-1: Signal crayfish (*Pacifastacus leniusculus)* in Eastern Norway. Photo: David Strand, The Norwegian Veterinary Institute.

Since then, signal crayfish have been found in Lake Øymarksjøen in the Halden watercourse (Daltorp 2008, Johnsen et al. 2009a, Vrålstad et al. 2011), in small golf-course ponds at Ostøya (Johnsen et al. 2009b), in the Fjelna watercourse in the southern part of Trønderlag County (Johnsen et al. 2011), in Lake Kvesjøen in the northern Tønderlag (Johnsen 2015), and in Rødensjøen (the Halden watercourse, Johnsen et al. 2017). The populations of signal crayfish in Dammane and on Ostøya were eradicated in 2008 (Sandodden and Johnsen 2010) and 2009 (Sandodden and Bardal 2010).

Based on results from a mark-recapture experiment in one of the small shallow ponds in Dammane (1346 m^2), the population of signal crayfish larger than 75 mm was estimated to be around 668 individuals, corresponding to around 0.5 individuals per m^2 (Johnsen et al. 2012). It has also been confirmed that signal crayfish are established in lakes further downstream in the Halden watercourse, and on the Norwegian side of Store Le, a lake on the border with Sweden. In 2020, signal crayfish were also found in the Glomma watercourse (Mattilsynet 2020). In all the above-mentioned discoveries, the crayfish have been confirmed as carriers of *A. astaci*.

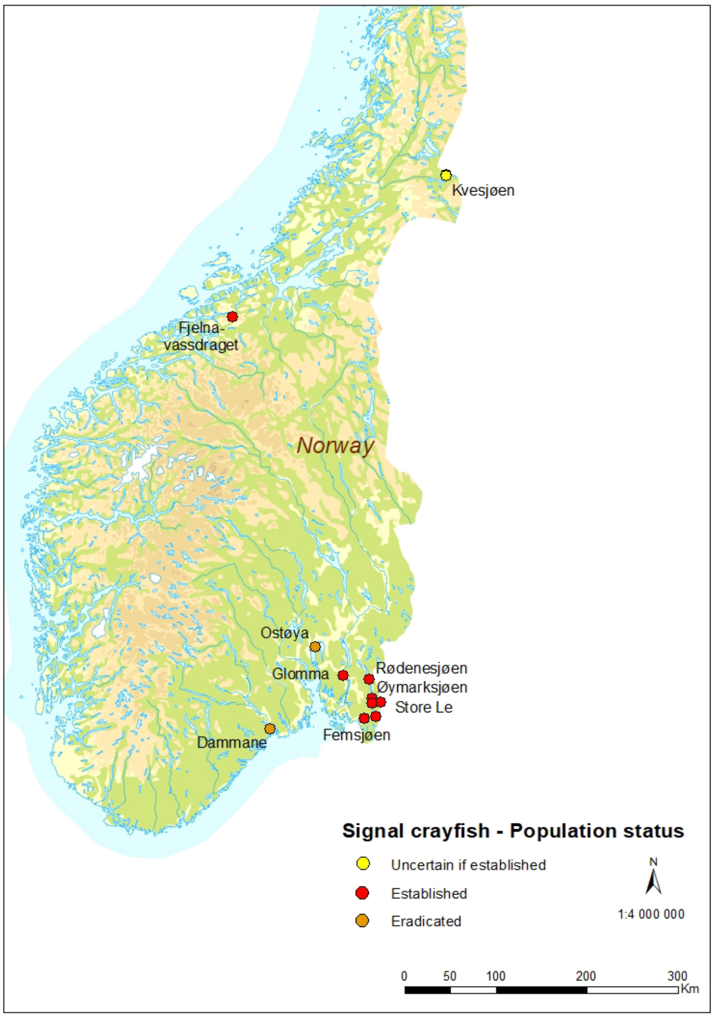

Figure 1.3.2.1-2: Distribution of known signal crayfish populations in Norway. The populations in Dammane and Ostøya are considered to have been eradicated.

The invasive Chinese mitten crab (Figure 1.3.2.1-3) has been found on seven occasions in Norway between 1976 and 2004 (Norling and Jelmert 2010, Wergeland Krog et al. 2009). It was found in the Glomma estuary and in Drammensfjorden, suggesting development in the rivers Drammenselva or Lierelva and Glomma (Johnsen et al. 2009). It has also been found in Brattøya in Halden and in Iddefjorden, and possibly also in Mandalselva. However, repeated investigations for this crab in these areas have not resulted in more findings (Wergeland Krog et al. 2009). Hence, it is uncertain whether Chinese mitten crab can complete its life cycle in Norway or was found subsequent to introductions. It is likely that the crab will establish in Norway within relatively few years, given the current rate of global warming (see section 2.4 on climate). Establishment of this species is a major concern since it has a high potential for spreading, is considered as one of the worst invasive species worldwide (Global Invasive Species Database 2020), and can be carrier of *A. astaci* (Svoboda et al. 2014a).

Figure 1.3.2.1-3: Chinese mitten crab (*Eriocheir sinensis*) in an aquarium. Photo: J. P. Petersen (Wikimedia Commons)

1.3.2.2 Sweden

There are two species of crayfish in natural waters in Sweden, the noble crayfish (*A. astacus*) and the introduced signal crayfish (*P. leniusculus*). The noble crayfish is the only native crayfish species in Sweden (Skurdal et al. 1999). Freshwater crayfish represent high cultural, recreational, social, economic, and ecological values in Sweden. It is estimated that 1500 tonnes are caught every year (Fiskeriverket 2000) at a wholesale price of around 30–40 million Euros (Bohman and Edsman 2011).

There has been a steady decline in noble crayfish populations in Swedish waters since the crayfish plague was first introduced in 1907 (Fiskeriverket and Naturvårdsverket 1998). In 1900, there were estimated to be 30,000 locations with noble crayfish populations (Fiskeriverket and Naturvårdsverket 1998), but in 1960, 50% of the original populations were extinct (Unestam 1969). In 1969, the Swedish government launched a large-scale introduction of North American signal crayfish. The fisheries administration initially had a positive attitude towards introductions of signal crayfish in order to replace those fisheries of noble crayfish lost due to the crayfish plague epidemics. More than 4,000 permits for stocking into natural waters were issued from 1960 to 1994. The alien signal crayfish stockings were actively promoted by the authorities driven by overly optimistic expectations of its productivity. Quite soon, however, the initial assumption that alien signal crayfish were immune to *A. astaci* infection was proved to be wrong (Unestam 1972). Instead, alien signal crayfish were frequently chronic carriers of the pathogen, which they then transmitted further to the naïve noble crayfish. This resulted in five times as many noble crayfish populations being lost due to crayfish plague epidemics in Sweden (Bohman et al. 2006).

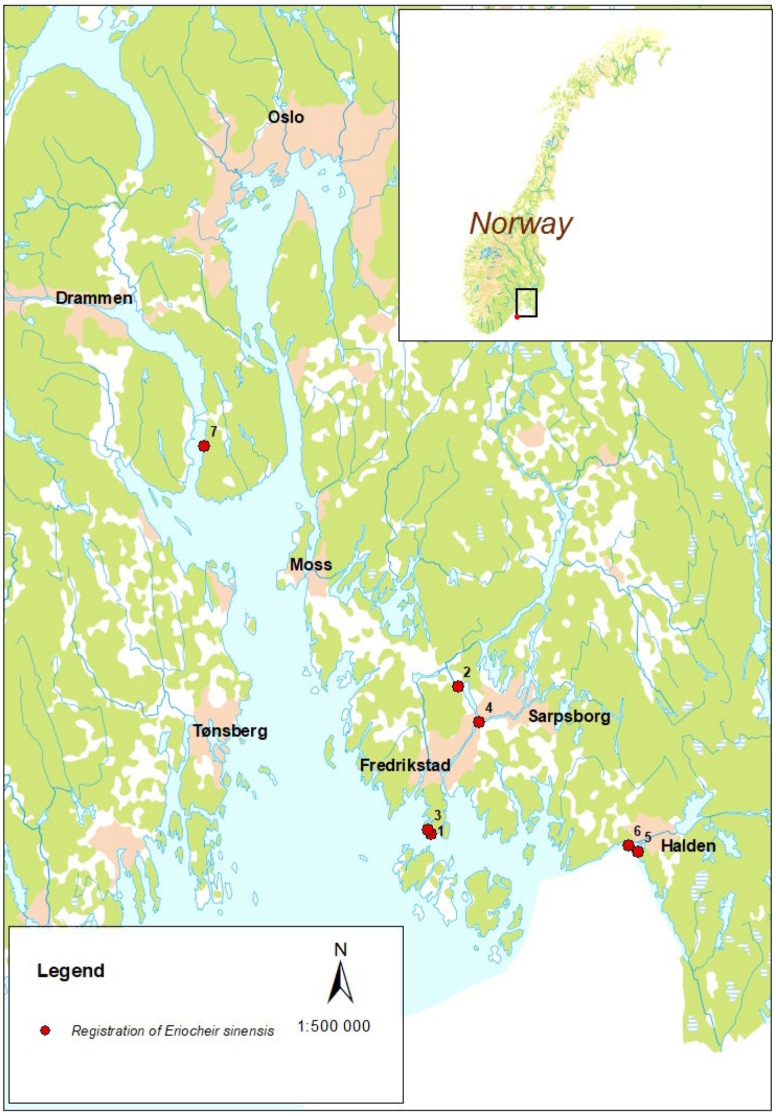

Figure 1.3.2.1-4: Records of Chinese mitten crab, numbered in chronological order, in Norway, from 1976-2004. After Schartau & Lindholm 2012.

Nonetheless, permits continued to be given for signal crayfish introductions. This attitude and the accompanying legislation did not change until 1994, after which permits for stocking signal crayfish in natural waters were not provided unless there was an established alien signal crayfish population already present based on a previous legal introduction (Edsman and Schröder 2009). By 2020, the number of sites with signal crayfish in Swedish waters had reached approximately 5,000 (Bohman 2020).

In response to EU Regulation 1143/2014 regarding invasive alien species, all introductions and farming of signal crayfish was banned in 2016. Fishing in the northern part of Sweden is also forbidden.

During the years of large-scale introduction of signal crayfish, rumours flourished (e.g., that signal crayfish did not carry the plague, were not affected by it, and grew three times faster than the noble crayfish). These rumours, which have no real substance, still exist today, and are an underlying factor for the massive illegal introductions of signal crayfish into Sweden. Illegal introduction of signal crayfish is currently considered the major threat to the noble crayfish (Bohman and Edsman 2011, Jussila and Edsman 2020).

Figure 1.3.2.2-1: Red swamp crayfish (*Procambarus clarkii)* in its natural habitat. Photo: Luc Hoogenstein (Wikimedia commons).

Today, there are about 600 populations of noble crayfish remaining in Sweden (Bohman 2020, Jussila and Edsman 2020) - only 2% of the populations present in 1900. The noble crayfish has been listed as "Critically Endangered" on the Swedish Red List since 2010 (Gärdenfors 2010). An action plan for the noble crayfish has been adopted (Fiskeriverket and

Naturvårdsverket 2009) that aims to prevent reductions in noble crayfish stocks that are almost exclusively due to illegal introductions of signal crayfish.

Apart from the deliberately introduced signal crayfish, only two other crayfish species have been found in natural waters. *Procambarus clarkii* (Figure 1.3.2.2-1) appeared in a pond in southern Sweden in 1984 (Blindow 1984) and Marbled crayfish (*Procambarus virginalis)* (Figure 1.3.2.2-2) was found in a running water in mid-Sweden in 2012 (Bohman et al. 2013).

Figure 1.3.2.2-2: Marbled crayfish (*Procambarus viriginalis*) in an aquarium. Photo: Johannes Rusch, The Norwegian Veterinary Institute.

1.3.2.3 Other Nordic countries

The situation in other Nordic countries, regarding alien crustaceans, is intermediate between Norway and Sweden. In Denmark, the native noble crayfish is also threatened by the invasive signal crayfish, which is abundant in Denmark, although to a far lesser extent than in Sweden. Unlike Norway and Sweden, recreational and commercial fishing for crayfish is of relatively little importance in Denmark, and the distribution of freshwater crayfish has been less documented (Skov et al., 2011). Danish rivers and streams were traditionally inhabited by noble crayfish, but, more recently, Skov et al. (2011) documented that signal crayfish was widespread across Denmark and present in many of the largest rivers and most important crayfish habitats. The narrow-clawed crayfish *Pontastacus leptodactylus* (Figure 1.3.2.3-1) is also invasive in Denmark and poses a threat to noble crayfish (Agersnap et al. 2017). Although narrow-clawed crayfish originates in south-eastern Europe, it is known to displace other indigenous crayfish species when outside its natural distribution (Holdich et al. 2009, Gherardi and Holdich 1999).

In Finland, recreational and commercial fishing for crayfish is important, and the crayfish-fisheries in Finland go back at least 150 years (Jussila and Mannonen 2004). As in Sweden, the first experimental introductions to Finland of the alien signal crayfish in selected water bodies occurred at the end of 1960s (Westman 1973). These actions were taken because of the poor recovery of native crayfish (*Astacus astacus*) populations after repeated crayfish plague outbreaks. Massive introductions of signal crayfish started towards the end of 1980s (Erkamo et al. 2010), and during the 1990s and 2000s over two million signal crayfish were released into Finnish lakes and rivers, mostly in southern part of Finland (Erkamo et al., 2010; Ruokonen et al. 2018). According to the Finnish crayfish strategy, signal crayfish has a separate designated area in the southern part of Finland, but illegal stockings and, consequently, spread of the crayfish plague jeopardise the attempts to preserve and manage the noble crayfish in other areas of the country (Ruokonen et al. 2018). Nowadays, the signal crayfish can be treated as permanent resident in hundreds of Finnish lakes and rivers (Erkamo et al. 2010). However, several productive signal crayfish populations have recently collapsed, both in Southern Finland and in Sweden, indicating unexpected instability and sensitivity to environmental variation and diseases in signal crayfish (Jussila et al. 2014, Sandström et al. 2014). *Pontastacus leptodactylus* has also been introduced and exists in some lakes in eastern Finland (Kouba et al. 2014, Jussila et al. 2020); however, it constitutes only a minor threat to noble crayfish compared with the invasive and disease-carrying signal crayfish.

Figure 1.3.2.3-1: The narrow-clawed crayfish (*Pontastacus leptodactylus*) in an aquarium. Photo: Alexander Mrkvicka (Wikimedia Commons)

1.4 Freshwater crustaceans as a hobby in Norway

In Norway, based on the number of animals and specialized feed and equipment sold in pet stores, it is estimated that around 55,000-65,000 freshwater crustaceans are sold each year, according to The Norwegian Pet Trade Association (Pers. com. Svein Fosså, NZB). Around 95% of these are shrimps of the *Caridina* and *Neocaridina* genera, and the majority of these are sold to generalist aquarists that keep them in "community aquariums" together with various small fishes. However, there are some specialist keepers in Norway who keep and breed only shrimp as a hobby. Generally, shrimps are regarded as being common, in the aquarium hobby in Norway.

Aquarists keeping crabs or crayfish represent a more marginalized and specialized branch, and it is estimated that around 2,000 people in Norway keep these and that around 3,000 crayfish and 1,000 crabs are traded in Norway each year (Pers. com. Svein Fosså, NZB).

For all types of crustaceans, the vast majority of animals arrive from breeders primarily in Asia, but to some extent from the Czech Republic and Germany.

Figure 1.4.1-1: *Neocaridina* sp. In captivity. Photo: Mostphotos.com

For the *Caridina* and *Neocaridina* genera of shrimps, the demand is heavily focused on brightly coloured breeding varieties. Most varieties are now common, and readily available at a low price. However, new colour morphs can cost more than 50,000 NOK per specimen (Pet Scandinavia 3, 2018). These contribute to shrimp farming and breeding being developed and maintained as a sizeable industry in many countries (Pet Scandinavia 4, 2016 and 3, 2019). Well over one hundred of these captive-bred colour variants exist (Figure 1.4.1-1) and the demand for these means that wild-caught specimens are a niche market (Pers. com. Svein Fosså, NZB).

Figure 1.4.1-2: Vampire crabs (*Geosesarma dennerle)* in captivity. Photo: Mostphotos.com

Figure 1.4.1-3: Colour variants of *Cherax destructor* in a breeding facility. Photo: Tirawat Samattaphan/Mostphotos.com

Crabs and crayfish, especially the more colourful species within the genera *Geosesarma* (Figure 1.4.1-2) and *Cherax* (Figure 1.4.1-3), have gained popularity due to their striking appearance. In addition, miniature species, such as the "Micro crab" (*Limnopilos naiyanetri*) and dwarf crayfish of the genus *Cambarellus*, are popular due to their small size that allows them to be kept together with shrimps. Some species grow large and are kept in species-specific tanks. For the less commercially interesting species, including species not bred to enhance colour variants, wild-caught specimens are more common in the trade.

For all crustaceans, the majority of specimens are imported through pet stores, but some private import, especially of the less common species, occurs regularly (Pers. com. Svein Fosså, NZB).

1.5 Notifiable pathogens and diseases in the Decapoda

Diseases caused by pathogens that can have an impact on wild species and biological diversity are regulated under the Norwegian Food Act. Decapod crustaceans can be susceptible to, or healthy carriers of, several infectious disease pathogens, some of which may have a severe impact on crustacean biodiversity. Here, we focus on those pathogens that are listed as the disease agents of notifiable diseases in Norway (regulated under the Norwegian Food Act), EU (regulated under Council Directive 2006/88/EC), and OIE (World Organisation for Animal Health). In Norway, this concerns four pathogens that are listed either on list 1 (exotic diseases), list 2 (non-exotic diseases), or list 3 (national diseases) (see section 1.7). These pathogens are the oomycete *Aphanomyces astaci* causing crayfish plague, the white spot syndrome virus (WSSV) causing white spot disease, the yellow head virus genotype 1 (YHV1) causing yellow head disease and the Taura syndrome virus (TSV) causing Taura syndrome. The OIE also lists five other diseases (Table 1.5-1).

Table 1.5-1. Listed diseases in crustaceans in Norway, EU, and OIE. Those listed solely by the OIE are currently less relevant for European freshwaters and are not assessed in this report.

Disease	Pathogen	List status in Norway	Listed in EU	Listed in OIE
Taura syndrome	Taura syndrome virus	1 (exotic disease)	X	X
Yellow head disease	Yellow head virus genotype 1	1 (exotic disease)	X	X
White spot disease	White spot disease virus	2 (non-exotic disease)	X	X
Crayfish plague	*Aphanomyces astaci*	3 (national disease)	Not listed	X
Acute hepatopancreatic necrosis disease (AHPND)	*Vibrio parahaemolyticus* (Vp_{AHPND})	Not listed	Not listed	X
Necrotising hepatopancreatitis	*Hepatobacter penaei*	Not listed	Not listed	X
White tail disease	*Macrobrachium rosenbergii* nodavirus	Not listed	Not listed	X

Disease	Pathogen	List status in Norway	Listed in EU	Listed in OIE
Hypodermal and haematopoietic necrosis	hypodermal and haematopoietic necrosis virus	Not listed	Not listed	X
Infection with infectious myonecrosis virus	Myonecrosis virus	Not listed	Not listed	X

1.5.1 *Aphanomyces astaci*

Crayfish plague is caused by infection with the oomycete (a fungus-like eukaryote) *A. astaci,* a notifiable list 3 (national) disease that must, if suspected or found, be reported to the Norwegian Food Safety Authority immediately (FOR-2008-06-17-819). This disease is also listed by the OIE (OIE 2019a). *A. astaci* was first detected in Norway in 1971 and has been detected in several Norwegian watercourses and lakes (Vrålstad et al. 2014). The illegal introduction and spread of *A. astaci*-positive signal crayfish have expanded the area for crayfish plague in Norway during recent years. Today, there are regulations on combating crayfish plague in the Halden watercourse, Store Le, Glomma, Eidskog municipality, Mossevassdraget, Kvesjøvassdraget, and Fjelnavassdraget (Strand et al. 2020).

Crayfish plague causes mass mortalities, with up to 100% mortality rates and local extinctions, of European freshwater crayfish species. All stages of European crayfish species are highly susceptible (Table 1.5.1-1), including the noble crayfish, that is native to north-western Europe, including Norway (OIE 2019b). Australian and Asian crayfish are also highly susceptible to crayfish plague, but has only been observed in laboratory experiments (Unestam 1976).

A. astaci is native to North America and co-evolved as a parasite of North American crayfish species. North American crayfish are healthy carriers of *A. astaci*, with an immune defence that controls the *A. astaci*, such that it is no more than a benign harmless infection within the crayfish cuticle (Söderhäll and Cerenius 1999). These defence mechanisms are absent in freshwater crayfish species of other continents, resulting in rapid death following infection.

All invasive American crayfish species in Europe can carry *A. astaci*, and are often infected with different genotypes, depending on species (Grandjean et al. 2014, Kouba et al. 2014). Based on observations from North America, the OIE assumes that all North American crayfish species can be infected with *A. astaci* without development of a clinical disease, and might therefore act as lifelong carriers of the pathogen (OIE 2019b). The proven carriers are listed in Table 1.5.1-1, along with assumed carriers that are tolerant to infection.

Table 1.5.1-1 *Aphanomyces astaci* causing crayfish plague. The table below summarises the status reported for 1) known freshwater decapods in Norway that are susceptible to *A. astaci*, 2) known freshwater decapods worldwide that are susceptible to *A. astaci*, 3) decapod species reported as *A. astaci*-positive, confirmed carriers, and/or resistant to *A. astaci*, and 4) other reported vectors.

Sources: Regulation on animal health requirements for aquaculture animals and products thereof, and on the

Susceptible decapods in Norway	Susceptible decapods worldwide	Confirmed carriers and tolerant decapods	Other vector (species)
Freshwater species: *Astacus astacus*	All species of freshwater crayfish are susceptible to infection with *A. astaci*. The outcome of an infection varies depending on species. Highly to moderately susceptible species include: • *Astacus astacus* • *Astacus pachypus* • *Astacopsis gouldi* • *Astacopsis fluviatilis* • *Austropotamobius pallipes* • *Austropotamobius torrentium* • *Cambaroides japonicas* • *Cherax quadricarinatus* • *Cherax destructor* • *Cherax papuanus* • *Euastacus kershawi* • *Euastacus clydensis* • *Euastacus crassus* • *Pontastacus leptodactylus* • *Geocherax gracilis*	All North American crayfish species are assumed carriers of *A. astaci*. Some South American crayfish have also been confirmed carriers. Confirmed carrier species and resistant species include: • *Cambarus bartoni* • *Cambarus latimanus* • *Cambarus longulus* • *Cambarus acuminatus* • *Faxonius erichsonianus* • *Faxonius limosus* • *Faxonius immunis* • *Faxonius obscurus* • *Faxonius propinquus* • *Faxonius rusticus* • *Faxonius virilis* • *Faxonella clypeta* • *Pacifastacus leniusculus* • *Parastacus defossus* • *Parastacus pilimanus* • *Procambarus clarkii* • *Procambarus hayi* • *Procambarus virginalis* Crab species carriers of *A. astaci*: • *Eriocheir sinensis* • *Potamon potamios* Suspected vector/carrier shrimps • *Atyopsis moluccensis* • *Atya gabonensis* • *Macrobrachium dayanum*	Freshwater species: Fish (crayfish predators; *A. astaci* survive through the fish gut) Other vectors: Water active birds and mammals (spores spread in moist feathers and fur) Humans, in terms of wet gear (fishing equipment, canoos, boots, and live bait.)

prevention and control of certain diseases in aquatic animals (FOR-2008-06-17-819), OIE 2019b (Manual of Diagnostic Tests for Aquatic Animals; Chapter 2.2.2.), Butler et al 2020, Alderman et al. 1987, Diéguez-Uribeondo and Söderhäll 1993, Persson and Söderhäll 1983, Roy 1993, Unestam 1969a-b, Vorburger and Ribi 1999, Fernando Peiró et al. 2016, Svoboda et al. 2014a-b; Mrugala et al. 2015, 2016, 2019.

The distribution and impact of *A. astaci* in South America are unknown, but South American crayfish cannot be excluded as potential carriers of *A. astaci*. The North American crayfish *Procambarus clarkii* is invasive in South America and can carry a heat-tolerant *A. astaci* genotype (Diéguez-Uribeondo and Söderhäll 1993). So far, no mortality caused by crayfish plague has been reported from South America, but two species of native South American crayfish, *Parastacus defossus* and *P. pilimanus,* have been found to be *A. astaci* positive (Peiro et al. 2016).

Crayfish plague spreads primarily by release and spread of North American crayfish. However, when present in a water body, *A. astaci* also spreads by free-living zoospores in the water and by mechanical vectors (birds, water-active mammals and human equipment) of the infective zoospores (Vrålstad et al. 2006). *A. astaci* fed to fish with infected abdominal cuticle were still viable after passage through the gastrointestinal tract (Oidtmann et al. 2002). Thus, fish that feed on infected crayfish can potentially spread crayfish plague over considerable distances. In Norway, the spread of crayfish plague with invasive crayfish is currently limited to signal crayfish, but there is a massive spread of several alien American species of freshwater crayfish in Europe, including from crustacean releases or escapes from the aquarium trade (Kouba et al. 2014, Chucholl et al. 2015).

So far, two species of freshwater crabs, Chinese mitten crab (*E. sinensis*) and Potamon crab (*P. potamios*), have also been proven carriers of *A. astaci* (Svoboda et al. 2014a). There is no conclusive evidence that freshwater shrimps can act as carriers or vectors of *A. astaci*, but *Atyopsis moluccensis* and *Atya gabonensis* are suspected carriers, and should not be ignored as possible vectors or facilitators of pathogens if previously co-habited with carrier freshwater crayfish (Svoboda et al. 2014b, Mrugala et al. 2019).

1.5.2 White spot syndrome virus

White spot disease is caused by infection with WSSV. This is a notifiable list 2 (non-exotic) disease in Norway (FOR-2008-06-17-819), OIE (OIE 2019a), and in the EU Commission Directive 2008/53/EC. The virus has never been detected in Norway. If ever suspected or detected, the Norwegian Food Safety Authority should be notified immediately, and, if the detection is confirmed, notification to the OIE and EU is also mandatory.

WSSV is a large double-stranded DNA-virus (Hulten et al. 2001) in the genus *Whispovirus* in the *Nimaviridae* (Dey et al. 2019). It is regarded as the most serious viral pathogen in cultured penaeid shrimps, and is also associated with epizootic mortalities in prawn aquaculture. After its discovery in Southeast Asia in 1992, WSSV has spread around the world and now occurs in all shrimp-growing regions, causing mass mortality within 3-10 days following an initial outbreak in normal culture conditions (Dey et al. 2019). The global economic loss to the shrimp industry caused by WSSV has been estimated to be around USD 8-15 billion since its emergence, and is increasing by USD 1 billion yearly (Dey et al. 2019). The currently known geographical range of WSSV includes Asia, India, the Mediterranean, the Middle East, and the Americas (OIE 2019c). WSSV has not yet been detected in Europe, either in farms or in the wild, and until recently not in Australia. However, mortalities in wild Australian prawns and crabs due to WSSV was reported in January 2021[1]. It has also been detected from the Australian crayfish, *Cherax quadricarinatus,* in the aquarium trade in Europe (Mrugala et al. 2015).

According to the OIE diagnostic manual (OIE 2019c), WSSV can infect a wide range of aquatic crustaceans, including decapods (marine, brackish, and freshwater prawns, crabs, crayfish, and lobsters; Maeda et al. 1998, OIE 2019c), and no decapod species tested to date is resistant to infection with WSSV. For this reason, in the list of notifiable diseases in Norway, OIE, and EU, the susceptible hosts to WSSV are given as "All decapod crustaceans (order Decapoda)". Furthermore, all life stages are potentially susceptible, from eggs to broodstock (Lightner 1996, Venegas et al. 1999). Although all decapods seem susceptible to infection, not all develop disease. Highly susceptible species include penaeid shrimps, where

[1] https://www.abc.net.au/news/rural/2021-01-17/prawn-white-spot-virus-killing-wild-australian-prawns-and-crabs/13060200

WSSV often causes high mortality. Crabs, crayfish, freshwater prawns, spiny lobsters, and clawed lobsters can become infected, but with varying levels of mortality (Lo and Kou 1998). This can be a matter of species tolerance, but may also be associated with environmental factors, such as temperature, that might favour or disfavour disease development (Jiravanichpaisal et al. 2004).

Many decapod species can be sub-clinically infected with WSSV and are thought to be carriers. OIE lists a range of wild decapods that are known to be reservoirs of WSSV infection. This includes *Mysis* spp., *Acetes* spp., *Alpheus* spp., *Callianassa* spp., *Exopalaemon* spp., *Helice* spp., *Hemigrapsus* spp., *Macrophthalmus* spp., *Macrophthel* spp., *Metaplax* spp., *Orithyia* spp., *Palaemonoidea* spp., *Scylla* spp., *Sesarma* spp. and *Stomatopoda* spp. (OIE 2019c). These species can express the disease under suitable environmental conditions.

Non-decapod crustaceans, including copepods, rotifers, *Balanus* spp. and *Tachypleidue* spp. may apparently be healthy carriers. Marine molluscs, polychaete worms, and non-crustacean aquatic arthropods, such as sea slaters (Isopoda) and Ephydridae insect larvae, can also carry the virus mechanically without evidence of infection (OIE 2019c).

The impacts of WSSV on Norwegian crustacean biodiversity are unknown. However, challenge experiments indicate that at low water temperatures (test temperatures 4 °C and 12 °C), both signal crayfish and noble crayfish can be carriers of WSSV without developing sign of disease (Jiravanichpaisal et al. 2004). However, 100 % mortality occurred at 22 °C, 14 days post challenge for both species. Thus, if introduced, WSSV can potentially cause mass mortality in noble crayfish and other freshwater crustaceans in Norway at temperatures above 20 °C.

Table 1.5.2-1. White spot syndrome virus (WSSV) causing white spot disease. The table summarises the status reported for: 1) known freshwater and marine decapods in Norway that are susceptible to WSSV, 2) known freshwater and marine decapods worldwide that are highly susceptible to WSSV, 3) decapod species reported susceptible or presumed carriers, and 4) other reported carriers or vector species of WSSV.

Susceptible decapods in Norway	Highly susceptible decapods worldwide	Confirmed infected/carrier decapods	Other vector species
Freshwater species: • *Astacus astacus* • *Pacifastacus leniusculus* (alien) Marine species: All marine decapods	Shrimps: • *Exopalaemon orientalis* • *Macrobrachium idella* • *Macrobrachium lamerrae* • *Macrobrachium rosenbergii* • *Metapenaeus dobsoni* • *Metapenaeus ensis* • *Metapenaeus Monoceros* • *Penaeus aztecus* • *Penaeus chinensis* • *Penaeus duorarum* • *Penaeus japinicus* • *Penaeus indicus*	All decapods are regarded as susceptible to infection with WSSV, many of which can act as carriers. The list below is not complete. Shrimps: • *Mysis* spp. • *Acetes* spp. • *Alpheus* spp. • *Callianassa* spp. • *Exopalaemon* spp. • *Helice* spp. • *Hemigrapsus* spp.	Non-decapodal crustaceans can be apparently healthy carrier: • Copepods • Rotifers • *Balanus* spp. • *Tachypleidue* spp. • *Artemia salina* Other carriers/vectors: • Marine molluscs,

	• *Penaeus merguiensis* • *Penaeus monodon* • *Penaeus penicillatus* • *Penaeus setiferus* • *Penaeus semisulcatus* • *Penaeus stylirostris* • *Penaeus vannamei* • *Palaemon adspersus* • *Palaemon sirrifer* • *Palaemon styliferus* • *Parapenaeopsis stylifera* • *Scyllarus arctus* • *Solenocera indica* • *Squilla mantis* • *Trachypenaeus curvirostris* Crabs: • *Calappa lophos* • *Portunus sanguinolentus* • *Charybdis* sp. • *Helice tridens* • *Paratelphusa hydrodomous* • *Paratelphusa pulvinata* • *Sesama pictum* (pest crab) • *Scylla olivacea* • *Scylla paramamosain* • *Scylla serrata* (mud crab) Crayfish and lobsters: • *Panulirus* spp. *Faxonius punctimanus (Orconectes punctimanus)* • *Procambrus clarkii* • *Procambrus zonangulus* • *Astacus astacus* • *Pacifastacus leniusculus*	• *Macrophthalmus* spp. • *Macrophthel* spp. • *Metaplax* spp. • *Orithyia* spp. • *Palaemonoidea* spp. • *Scylla* spp. • *Stomatopoda* spp. Crabs: • *Calappa lophos* • *Sesarma* spp. Crayfish: • *Cherax destructor* • *Cherax quadricarinatus*	• Polychaete worms • Non-crustacean aquatic arthropods • Ephydridae insect larvae

Sources: Regulation on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals (FOR-2008-06-17-819), OIE 2019c (Chapter 2.2.9.), and EU (Council Directive 2006/88/EC), Baumgartner et al. 2009, Somboonna et al. 2010, Bir et al. 2017, Longshow 2011, Stentiford et al. 2009, Mrugala et al. 2015.

1.5.3 Taura syndrome virus

Taura syndrome is caused by infection with Taura syndrome virus (TSV). This is a notifiable list 1 (exotic) disease in Norway (FOR-2008-06-17-819), and the disease is also listed in OIE (OIE 2019a) and in the EU Commission Directive 2008/53/EC. The virus has never been detected in Europe. If ever suspected or detected, the Norwegian Food Safety Authority should be notified immediately, and, should the detection be confirmed, notification to the OIE and EU is also mandatory.

According to the OIE diagnostic manual (OIE 2019d), only a few crustacean hosts have been proven to be susceptible to this virus (Table 1.5.3-1). These are all species of marine shrimps. There are also a broader range of crustacean species where the evidence for susceptibility is incomplete, but where we can assume that they can be carriers. Finally, there are also some non-decapod species that have been reported to act as vectors, including barnacles, gulf killifish, birds, and aquatic insects (table 1.5.3-1; OIE 2019d). None of the Norwegian crustacean species are known to be susceptible to the virus.

Table 1.5.3-1. Taura syndrome virus (TSV) causing Taura syndrome. The table summarises the status reported for: 1) known freshwater and marine decapods in Norway that are susceptible to TSV, 2) known freshwater and marine decapods worldwide that are susceptible to TSV, 3) decapod species reported TSV-positive that either have status as presumed susceptible or presumed carriers of TSV, and 4) other reported vector species of TSV.

Susceptible decapods in Norway	Susceptible decapods worldwide	Presumed susceptible or carrier decapods	Other vector species
Freshwater species: None **Marine species: None**	Freshwater species: None Marine shrimp species: • *Metapenaeus ensis* • *Penaeus aztecus* • *Penaeus monodon* • *Penaeus setiferus* • *Penaeus stylirostris** • *Penaeus vannamei* * Marine crab species: None Marine crayfish species: None	Freshwater species: • *Macrobrachium rosenbergii* (giant river prawn) Marine shrimp species: • *Penaeus chinensis* • *Penaeus duorarum* • *Penaeus japonicus* • *Penaeus schmitti* Marine crab species: • *Callinectes sapidus* • *Sesarma mederi* • *Scylla serrata* • *Uca vocans* Non-decapod crustaceans: • *Ergasilus manicatus* (a marine/brackish water North American parasitic copepod)	Freshwater species: None Marine species: • *Chelonibia patula* (barnacles) • *Octolasmis muelleri* (barnacles) • *Fundulus grandis* (gulf killifish) Birds (gut passage): • *Larus atricilla* (gulls) • *Gallus gallus* (chickens) Aquatic insects (mechanical): • *Trichocorixa reticulata*

Sources: Regulation on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals (FOR-2008-06-17-819), OIE 2019d (Manual of Diagnostic Tests for Aquatic Animals; Chapter 2.2.7.), and EU (Council Directive 2006/88/EC). *persistent infections reported

TSV virus is currently known to be widely distributed in the shrimp-farming regions of the Americas, South-East Asia, and the Middle East (OIE 2019d). Stentiford et al. (2009) categorised EU member states into three regional types, where Norway fits into Type 1 states possessing cold-water marine borders, estuaries, and freshwaters (e.g., Northern Europe). Here, TSV is regarded to have a low susceptibility range among the native (and introduced) crustacean hosts.

1.5.4 Yellow head virus genotype 1

Yellow head disease is caused by infection with yellow head virus genotype 1 (YHV1). This is a notifiable list 1 (exotic) disease in Norway (FOR-2008-06-17-819), and the disease is also listed in OIE (OIE 2019a) and in the EU Commission Directive 2008/53/EC. The virus has never been detected in Europe. If ever suspected or detected, the Norwegian Food Safety Authority should be notified immediately, and, should the detection be confirmed, notification to the OIE and EU is also mandatory.

According to the OIE diagnostic manual (OIE 2019e), marine shrimps in Asia are primarily susceptible to this virus (Table 1.5.3-1.), in particular the giant tiger prawn (*Penaeus monodon*). A broader range of crustacean species, including blue crab (*Callinectes sapidus),* can also be assumed to be carriers, although the evidence incomplete. In addition, two freshwater decapods, red claw crayfish (*Cherax quadricarinatus*) and river prawn (*Macrobrachium sintangense*), are susceptible and can transmit the virus to other hosts. Finally, some non-decapod species have been reported to act as vectors, including copepods, barnacles, and gulf killifish (*Fundulus grandis*) (Table 1.5.3-1.; OIE 2019e). None of the Norwegian crustacean species are known to be susceptible to YHV1.

Table 1.5.4-1. Yellow head virus genotype 1 (YHV1) causing yellow head disease. A summary of the status reported for: 1) known freshwater and marine decapods in Norway that are susceptible to YHV1, 2) known freshwater and marine decapods worldwide that are susceptible to YHV1, 3) decapod species reported YHV1-positive that either have status as presumed susceptible or presumed carriers of YHV1, and 4) other reported vector species of YHV1.

Susceptible decapods in Norway	Susceptible decapods worldwide	Presumed susceptible or carrier decapods	Other vector species
Freshwater species: None Marine species: None	Freshwater species: None Marine species: • *Penaeus stylirostris* • *Palaemonetes pugio* • *Penaeus monodon** • *Metapenaeus affinis* • *Penaeus vannamei* *	Freshwater species: • *Cherax quadricarinatus* • *Macrobrachium sintangense* Marine shrimp species • *Metapenaeus brevicornis* • *Palaemon serrifer* • *Penaeus aztecus* • *Penaeus duorarum* • *Penaeus japonicus* • *Penaeus merguiensis* • *Penaeus setiferus* • *Palaemon styliferus* • *Acetes* sp. Marine crab species: • *Callinectes sapidus* Non-decapods crustaceans: • *Ergasilus manicatus*	Freshwater species: None Marine species • *Chelonibia patula* (barnacle) • *Octolasmis muelleri* (barnacle) • *Fundulus grandis* (gulf killifish)

Sources: Regulation on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals (FOR-2008-06-17-819), OIE 2019e (Manual of Diagnostic Tests for Aquatic Animals; Chapter 2.2.9.), and EU (Council Directive 2006/88/EC). *persistent infections reported.

1.5.5 Other pathogens

Freshwater crayfish can be carriers or vector of pathogens that affect other animals groups than crustaceans. Examples include infectious pancreatic necrosis virus (IPNV) which causes infectious pancreatic necrosis (IPN) primarily in farmed salmon (Halder and Ahne, 1988, Rud et al 2014) and *Batrachochytrium dendrobatidis* (BD), which causes chytridiomycosis in amphibians (VKM 2019). These aspects has not been covered further in this report, as we have focussed on crustacean pathogens and diseases.

The OIE (2019a) list many additional crustacean diseases that are not listed by Norway and EU. These are often recently described and/or include a narrow range of affected species. The pathogens causing the diseases and the affected decapods are briefly listed below.

1.5.5.1 Acute hepatopancreatic necrosis disease (AHPND)

According to the OIE manual chapter 2.2.1 (OIE 2019f), acute hepatopancreatic necrosis disease (AHPND) is a shrimp disease caused by specific and virulent strains of *Vibrio parahaemolyticus* (VpAHPND). The toxicity likely stems from a ~70-kbp plasmid (pVA1) in this VpAHPND strain, with genes that encode homologues of the *Photorhabdus* insect-related (Pir) binary toxin (probably caused by a currently undescribed bacterium). Removal of the plasmid also removes the AHPND-causing ability of VpAHPND strains. Susceptible species include *Penaeus monodon* and *P. vannamei*, and there is incomplete evidence for susceptibility in *P. chinensis* and *P. japonicus*). AHPND is characterised by sudden mass mortalities (up to 100%) in stocking grow-out ponds with larvae or juveniles, and has primarily been reported from China, Vietnam, Malaysia, Thailand, Mexico, and the Philippines (OIE 2019f).

1.5.5.2 Macrobrachium rosenbergii nodavirus (MrNV)

White tail disease is caused by *Macrobrachium rosenbergii* nodavirus (MrNV) and listed in OIE (OIE 2019g). The virus has never been detected in Europe. Larvae and juveniles of the giant river prawn (*M. rosenbergii*) are highly susceptible, and the virus was first reported in the French West Indies in 1999. It has also been reported from China, India, Chinese Taipei, Thailand, and Australia. Other presumed susceptible or carrier decapod hosts include: *P. vannamei*, *P. japonicus*, *P. indicus*, *P. monodon*, *Macrobrachium rude*, *M. malcolmsonii*, *Artemia* sp. and *Cherax quadricarinatus* (OIE 2019g).

1.5.5.3 Hepatobacter penaei

Necrotising hepatopancreatitis is caused by the gram-negative, intracytoplasmic bacterium *Hepatobacter penaei* and listed in OIE (OIE 2019h). The bacterium has never been detected in Europe. Susceptibility and mortality have been reported from juveniles, adults, and broodstock of the prawn *P. vannamei*, while species with incomplete evidence for susceptibility include *P. setiferus*, *P. duorarum*, *P. stylirostris*, *P. merguiensis*, *P. marginatus*, *P. aztecus*, *P. monodon,* and *Homarus americanus* (OIE 2019h). Infection with *H. penaei* results in acute disease in *P. vannamei*,, with mortalities up to 100%. The problem increases at high temperatures (>29 °C) and salinities (20–38 ppt). The known distribution includes the Western hemisphere in both wild and cultured penaeid shrimp (Belize, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru, United States of America, and Venezuela (OIE 2019h)).

1.5.5.4 Infectious myonecrosis virus

Infectious myonecrosis virus (IMNV) is listed under crustacean diseases in OIE (OIE 2019a). The virus has never been detected in Europe. Only a few species are known to be susceptible to infection with IMNV, including *Penaeus esculentus*, *P. merguiensis,* and *P. vannamei*. The latter might sustain IMNV infections and can act as a carrier of the virus. IMNV infections are associated with sudden high mortalities following stressful events, e.g., capture, feeding, and sudden changes in water salinity or temperature. The known distribution includes north-eastern Brazil and Indonesia (OIE 2019i).

1.5.5.5 Infectious hypodermal and haematopoietic necrosis virus

Infectious hypodermal and haematopoietic necrosis virus (IHHNV) is listed under crustacean diseases in OIE (OIE 2019a). The virus has never been detected in Europe. IHHNV is the smallest of the known penaeid shrimp viruses (OIE 2019j). Susceptible species include *Penaeus californiensis*, *P. monodon*, *P. setiferus*, *P. stylirostris,* and *P. vannamei*. *Penaeus aztecus* has incomplete evidence of susceptibility. Several additional species have been found positive in PCR tests, and might serve as carriers, including *Macrobrachium rosenbergii*, *Penaeus duorarum*, *P. occidentalis*, *P. japonicus*, *P. semisulcatus*, *Hemigrapsus penicillatus*, *Artemesia longinaruis*, *Callinectes arcuatus* and *Archirus mazatlanus*. The effects of IHHNV infections vary from acute to chronic. Acute disease involves mortalities approaching 100%. IHHNV appears to have a broad distribution, including the Americas, Asia, and Middle East (OIE 2019j).

1.6 Crustaceans as carriers of pathogens

1.6.1 In general

Crustacean diseases that are lethal for some species or groups of crustaceans are commonly carried and transmitted by other tolerant carrier crustacean species. Trade in live animals, leading to the crossing of natural borders and subsequent accidental or intended release of alien species, is beyond doubt a major driver for disease development. From a European perspective, crayfish plague is the most devastating example. As long as movements of crustaceans outside their natural range continues, new diseases might be expected to arrive. In this report, we can only assess the risk of known disease pathogens. However, new emerging diseases, arising from "hitchhiker" pathogens entering new geographic regions and encountering naïve hosts, could become an even greater threat. In addition to mortality directly caused by a pathogen, mortalities may also occur when infected animals are less able to cope with exposure to other ambient stressors (Shields 2003).

As addressed above (section 1.5), there is some knowledge about carrier species of known disease pathogens. Serial introductions of alien American crayfish to Europe led to the emergence of the most devastating wildlife crayfish disease to date – crayfish plague. All crayfish species of American origin are likely to be carriers of the crayfish plague pathogen, *A. astaci*. This has been confirmed by observation that all investigated American species that have entered Europe, also through the aquarium trade, carry a genotype of *A. astaci* (Kouba et al. 2014). The few investigations performed in the continent of origin, America, also suggest that new searches reveal crayfish species that are positive for *A. astaci*, for example *Parastacus* spp. in South America (Peiro et al. 2016). Crayfish can also be carriers of WSSV, and can be relatively resistant at water temperatures below ~20 °C. Australian *Cherax* species in the European aquarium trade were also positive when specifically tested for *A. astaci* and WSSV carrier status (Mrugała et al. 2014). Furthermore, Australian red claw crayfish (*Cherax quadricarinatus*) has been demonstrated to be susceptible to YHV1 infection, and in experimental trials, transmitted the virus to black tiger shrimp (*Penaeus monodon*) (Soowannayan et al. 2015). These examples, as well as the summary of crustacean diseases given above, suggest that there is a potentially high risk that any exotic crayfish may be infected by known or new pathogens that pose a risk to local crustacean biodiversity in Norway.

Crabs can act as carriers of several diseases, e.g., YHV1 in blue crab (*C. sapidus*); TSV in blue crab, *Uca vocans,* and *Sesarma mederi*; WSSV in *Sesarma* sp. The crayfish plague pathogen, *A. astaci,* can be carried and transmitted by the Chinese mitten crab (*E. sinensis*) and Potamon crab (*P. potamios*) (Svoboda et al. 2014a). These examples suggest that there is a risk that any exotic crab may be infected by known or new pathogens that pose a risk to local crustacean biodiversity. A number of freshwater crustaceans are also of medical interest because they are intermediate hosts of flukes in the genus *Paragonimus*, which causes human lung fluke disease (paragonimiasis) (Habe et al. 1993).

Little information is available regarding the role of freshwater shrimps as carriers of pathogens. *Macrobrachium rosenbergii* suffered mass mortalities due to white tail disease in farms in China and India (Bonami et al. 2005). The species is also known to be a carrier of (and resistant to) WSSV (Hameed et al. 2000) and to be a potential carrier of TSV. *Macrobrachium dayanum* is a potential carrier of *A. astaci*: the pathogen may grow in shrimp tissues, but it is not clear whether it can complete its life cycle in the host (Svoboda et al. 2014b). Shrimps of the genus *Neocaridina* are known to host worms of the families

Branchiobdellidae and Scutariellida (Klotz et al. 2013). A number of freshwater shrimps are susceptible to, or carriers of, WSSV (Table 1.5.2-1), but only marine shrimp species are susceptible to, or carriers of, YHV1 and TSV (Table 1.5.3-1 and 1.5.4-1). These examples, although fewer than for crabs and crayfish, suggest that there is a risk that any exotic shrimp may be infected with known or new pathogens that may pose a risk to local crustacean biodiversity.

1.6.2 In the aquarium trade

The aquarium trade is a major introduction pathway of alien aquatic species (Padilla and Williams 2004, Duggan et al. 2006, Laister et al. 2014, Patoka et al. 2015, Weiperth et al. 2020). In Europe, the growing interest from early 2000 in keeping freshwater crayfish in aquaria became a novel introduction pathway for alien crayfish species (Chucholl and Wedler 2016). Ten years after the "crayfish hype" in Germany, Chucholl and Wedler (2016) found that long-term availability of crayfish in the trade market was determined primarily by bright colouration, the ability to reproduce under warm aquarium conditions, and a preference for lentic habitats. North America and Australia, with more than 400 and 140 crayfish species, respectively, constitute hotspots for freshwater crayfish biodiversity, many of which are colourful and thus of interest to the aquarium trade (Chucholl and Wendler 2016).

In Central Europe, with Germany as a well-documented example, the "crayfish hype" led to about 120 none-native crayfish species coming into the European aquarium trade, of which several species have been released from home aquaria to European inland waters on multiple occasions. Here, they have established as invasive alien species (Kouba et al. 2014, Chucholl et al. 2015). The species includes *Cherax destructor*, *C. quadricarinatus*, *Faxonius immunis*, *F. juvenilis*, *F. virilis, Procambarus* cf. *acutus*, *P. alleni* ,and *P. fallax f. virginalis.* Red swamp crayfish (*P. clarkii*) has also been released in European waters as a result of aquarium trade, for example in the River Rhein in Germany (Chucholl and Wendler 2016), although its presence as an invasive crayfish in southern Europe primarily resulted from aquaculture activity already back in the 1970s (Souty-Grosset et al. 2006). A recent study from Hungary (Weiperth et al. 2020) reports on substantial numbers of alien crayfish species closely linked to releases associated with the pet trade/release of pets. In two natural sites, *Procambarus alleni* was found living in sympatry with the established spiny-cheek crayfish (*Faxonius limosus)*. Numerous red swamp and marbled crayfish were identified living in sympatry with *Cherax quadricarinatus*, two New Guinean *Cherax* species (*C. holthuisi* and *C. snowden*), and two undescribed species.

Mrugała et al. (2014) screened a large number of individuals of American and Australian species in aquaria stores in the Czech Republic. They found that eight American species (*Cambarellus patzcuarensis*, *Faxonius limosus, Procambarus alleni, P. clarkii, P. enoplosternum, P. fallax, P. llamasi* and *P. vazquezae*) and one Australian species (*Cherax quadricarinatus*) were positive for *A. astaci*, while the Australian species *C. quadricarinatus* was also positive for WSSV. This study pinpoints the risk for spread of crustacean diseases via the crustacean aquarium trade.

1.7 Relevant regulations

Within the EU, Council Directive 2006/88/EC has introduced controls for crustacean disease at the European level. It lists three crustacean diseases (white spot disease, yellow head disease and Taura syndrome) in recognition of their global importance in causing significant economic losses and the potential for their international transfer via transboundary trading in live animals and their products (Stentiford et al. 2010).

1.7.1 Norway

In Norway, import, release, trading, and keeping of crustaceans is regulated by "FOR-2015-06-19-716 - Regulation on alien organisms".

FOR-2015-06-19-716[2] (In Norwegian: "Forskrift om fremmede organismer"; In English "Regulation on alien organisms") regulates the import or introduction, the trading and release, as well as the unintentional spread of alien organisms. The purpose of the regulation is to "prevent the introduction, release, and spread of alien organisms that cause, or may cause, adverse consequences for biodiversity". The regulation applies to Norwegian land territory, including watercourses, Norwegian territorial waters, and Jan Mayen. The regulations do not apply to Svalbard. Below, we list some of the relevant aspects this regulation establishes

Prohibition on import (chapter 2)

- Prohibition on import (§ 5): The introduction of organisms listed in Annex I of the regulation is prohibited.
  [*Our comment: For crustaceans, this applies only to American lobster* (Homarus americanus)].
- Requirement for permission upon importation (§ 6): Permission is required for the import of organisms that are not covered by the prohibition in § 5 or the exceptions in § 7.
  [*Our comment: For crustaceans, permission is therefore required for all species that can live at temperatures at 5 °C and below*].
- Exceptions from the requirement for a permit upon importation (§ 7):
  - Permission is not required for the import of
    - organisms listed in Annex II, provided that the conditions laid down in the Annex are complied with.
      [*Our comment: No crustaceans are listed in Annex II*].
    - freshwater organisms that can only live at temperatures above 5 °C, and that are to be kept exclusively for ornamental purposes in indoor aquariums which are arranged so that organisms cannot escape, if notification is given in accordance with § 8.
  - However, a permit is required for the importation of organisms listed in Annex III.

---

[2] https://lovdata.no/dokument/SF/forskrift/2015-06-19-716

[*Our comment: Annex III lists the following crustaceans: European Dwarf Shrimp (*Atyaephyra desmaresti*), Indian river crab (*Sartoriana spinigera*), Sally Light Foot Crab (*Percnon gibbesi*) and all species of* Palaemonetes*, except* Palaemon concinnus].

- Importation pursuant to the first paragraph shall be carried out in accordance with the requirements for due diligence in Chapter V.

Chapter V: Requirements for caution and for activities and measures that may lead to the spread of alien organisms

- General requirements for diligence (§ 18), including have knowledge of the risk of adverse consequences for biological diversity that the activity and the organisms in question may entail, and of the measures that are required to prevent such consequences.
- Requirements for storage and packaging during transport (§ 21). The person responsible for the introduction or transport of organisms that may pose a risk of adverse consequences for biodiversity if they spread, shall ensure that the organisms are stored or packaged so that they cannot be released into the environment during transport.
- Requirements for measures for the maintenance of aquatic alien organisms (§ 22.). The person responsible for keeping aquatic alien organisms in garden ponds, or in aquariums and other closed containers, must ensure that water from such facilities is not emptied into the sea or watercourses, or into drains, without treatment that prevents organisms from escaping into the environment.
- Requirements for measures aimed at possible vectors and transmission routes for alien organisms (§ 24.). The person responsible for the introduction, sale, dissemination, or release of organisms shall, as far as is reasonable, initiate investigations to detect, and take preventive measures to prevent the spread of, accompanying organisms that may pose a risk of adverse consequences for biological diversity.

Our understanding of the "Regulation on alien organisms" regarding exotic crustaceans for keeping in aquarium and garden ponds, is that no species apart from American lobster are directly prohibited. Permission is required for all species that might survive below 5° C, as well as for some species listed in Annex III. Furthermore, import, transport, and storage of any exotic crustacean must happen in a risk-free way, ensuring no risk for escape or release into the environment. In the aquaria or garden ponds, the responsible person must ensure that water from such facilities is not emptied into the sea, watercourses, or drains without treatments that prevent organisms from escaping into the environment. Finally, the person responsible shall, as far as is reasonable, initiate investigations to detect, and take preventive measures to prevent the spread of, accompanying organisms that may pose a risk of adverse consequences for biological diversity. In this context, the known listed disease pathogens covered in regulation FOR-2008-06-17-819 (below, see also Table 1.5 -1) are of specific importance.

The regulation "FOR-2008-06-17-819" is authorized by the Norwegian Food Act (Matloven, LOV-2003-12-19-124), which regulate diseases caused by pathogens that can have negative impacts on wild species and biological diversity.

FOR-2008-06-17-819[3] (in Norwegian: "Forskrift om omsetning av akvakulturdyr og produkter av akvakulturdyr, forebygging og bekjempelse av smittsomme sykdommer hos akvatiske dyr"; in English "Regulation on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals".

This regulation establishes:

- the animal health requirements to be applied for the placing on the market, the importation, and the transit of aquaculture animals and products thereof;
- minimum preventive measures aimed at increasing awareness and preparedness of the competent authorities, aquaculture production business operators, and others related to this industry, for diseases in aquaculture animals;
- minimum control measures to be applied in the event of a suspicion of, or an outbreak of, certain diseases in aquatic animals.

Of particular relevance is the regulation that categorizes the most relevant aquatic diseases into 3 lists: exotic diseases (List 1), non-exotic diseases (List 2), and national diseases (List 3). Diseases within these categories relevant for crustaceans and in the scope of this report are presented in Table 1.5 -1. The listed diseases are specifically described in section 1.5, and assessed in chapter 5.

Another relevant regulation in the scope of this report is **FOR-1997-02-20-192**[4] (in Norwegian: "Forskrift om desinfeksjon av inntaksvann til og avløpsvann fra akvakulturrelatert virksomhet"; in English "Regulation on disinfection of influent and effluents waters from aquaculture facilities").

The purpose of this regulation is to prevent and limit the spread of infectious diseases in aquatic organisms through appropriate disinfection of intake water and wastewater to and from aquaculture-related activities.

Our understanding of this regulation is that it does not cover private aquaria, which is unfortunate since wastewater from aquaria with exotic / alien aquatic crustacean species poses the same risk for spread of (potentially listed, exotic, or new) crustacean diseases as wastewater from aquaculture-related activities from land-based facilities handling exotic aquatic crustacean species. The "Regulation of alien organisms" does not specifically demand disinfection of aquaria wastewater (nor garden pond wastewater), and this could lead to the unintentional release of disease pathogens.

---

[3] https://lovdata.no/dokument/SF/forskrift/2008-06-17-819

[4] https://lovdata.no/dokument/SF/forskrift/1997-02-20-192

Finally, "**FOR-201705-11-597**[5] (in Norwegian "Forskrift om forbud mot å innføre, omsette og holde eksotiske dyr"; in English: "Regulations on the prohibition of introducing, trading, and keeping exotic animals") is apparently a regulation of relevance. However, provided that we understand the regulation correctly, this concerns a ban on the introduction, trading and keeping of exotic mammals, reptiles (with certain exceptions) and amphibians. No other animal groups are mentioned.

To summarise, the relevant regulations that cover the introduction, trade, and keeping exotic / alien crustaceans in Norway are in our opinion not sufficiently clear and provide openings for the introduction of several species that might be carriers of disease pathogens. The lack of "disinfection" demand for wastewater is one of several possible unintentional pathways for the entrance of disease pathogens into Norwegian habitats.

1.7.2 Sweden

Sweden had a history of importing hundreds of tonnes of live crayfish as food, and they used to have strict import regulations. The import of live crayfish into Sweden was regulated by the Swedish regulation on import of fish, crustaceans, molluscs, or products thereof (SJVFS 1995: 125), issued by the Swedish Board of Agriculture. The import required an application and, if a permit was given, contained rules including notification to customs in advance, veterinary control at the border, and processing only at approved boiling places where the containers and water were also disinfected. When Sweden entered the EU, this legislation was challenged and, in response, all legislation concerning import of freshwater crayfish was abolished in 1997, leaving Sweden open to import from any country, regardless of species and country of origin. Thus, Sweden rapidly changed from having quite strict regulations, to being the EU country with the most open border to the import of live crayfish from non-EU countries. From within Sweden, crayfish could then be transported to other EU countries without restrictions. Proposed changes in the Species Protection Act were notified, according to the rules, to the European Commission and the World Trade Organisation for comments and opinions by the Member States. Apart for a couple of questions of technical nature that were clarified, no objections were received. In June 2003, the Government included three new paragraphs into the Species Protection Act (SFS 1998: 179) connected to the environmental legislation. They came into force in August 2003. In short, all import, transportation, and storage of any live freshwater crayfish from abroad are now prohibited. This legislation also applies to the aquarium trade (Edsman 2004).

[5] https://lovdata.no/dokument/SF/forskrift/2017-05-11-597

2 Methodology and data

2.1 Risk assessments

2.1.1 AS-ISK screening

This risk assessment was divided into two steps. First, we used a pre-screening toolkit to identify those freshwater crustacean species with the potential to become invasive in Norway. In the second step, species that were considered likely to become invasive were given a full, comprehensive risk assessment to assess their potential adverse impacts on native species and ecosystems. Pre-screening and full risk assessments were conducted primarily at the species level, but, in a few cases, at genus level.

The pre-screening toolkit used is the Aquatic Species Invasiveness Screening Kit (AS-ISK) v2.2 (Copp et al. 2020, Vilizzi et al. 2019). AS-ISK consists of a Microsoft Excel macro-enabled worksheet. The macro consists of 55 questions and related guidance. The questions are arranged into three main sections and nine categories as follows: Section on Biogeography/History (categories: Domestication/Cultivation; Climate, distribution, and introduction risk; Invasive elsewhere); Section on Biology/Ecology (categories: Undesirable (or persistence) traits; Resource exploitation; Reproduction; Dispersal mechanisms; Tolerance attributes); Section on Climate change (category: climate change). For any given taxon, completion of the 55 questions, including confidence and justification, results in an outcome score that is computed by the program that can range from a minimum of – 15 to a maximum of 57.

The crayfish, shrimps, and crabs were sorted in descending order according to the AS-ISK outcome scores. The species were sorted independently on the basis of the scores of the following criteria: I) BRA-score (Basic Risk Assessment), II) BRA + CCA (Climate Change Assessment) score, III) climatic similarity between the species native range and Norway, IV) whether the species is established in Northern Europe, V) invasive potential (i.e., established outside native area), and VI) whether the species has shown to be adaptive in its temperature requirements. For all of these, the same set of species came out as highest ranking.

We performed a full risk assessment for species with the highest AS-ISK scores, and for species in decreasing order until the full risk assessment concluded with low ecological risk. The remaining species were considered to have lower ecological risk, and for these a full risk assessment was not conducted.

Most alien freshwater crustaceans, especially crayfish, are confirmed or suspected carriers of *A. astaci* (see 1.5.1) and WSSV (see 1.5.2). As the risk posed by these species as carriers of pathogens can be independent of the environmental risk that they pose through ecological interactions, we assessed the risks associated with pathogens and diseases independently.

2.1.2 GB-NNRA

In order to conduct a full risk assessment of the species determined to have the potential to become invasive in Norway, we used a modified version of the Non-native Species Secretariat for Great Britain form (GB Non-native Risk Assessment scheme, or GB-NNRA, http://www.nonnativespecies.org/home/index.cfm), with permission to adapt the template granted by the GB-NNRA. We assessed the risk associated with 23 species.

The form was developed by a consortium of risk analysis experts in 2005, and has since been improved and refined, and then tested and peer-reviewed by risk analysis experts operating with similar forms in Australia and New Zealand (Roy et al. 2013). The GB-NNRA form complies with the Convention on Biological Diversity and reflects standards used by other forms, such as the Intergovernmental Panel on Climate Change, the European Plant Protection Organisation, and the European Food Safety Authority.

GB-NNRA is a qualitative risk assessment method, which comprises a range of questions covering all aspects requested in the Terms of Reference of this report. GB-NNRA is divided into two major sections (A and B). Only section B was used for the risk assessment in the current report. The questions cover an organism's probability of entry and the pathways of entry, establishment, and spread, the potential impact the organisms may have on biodiversity, and effects of climate change. For each question, the assessor ranks the uncertainty of their response, and also can add further comments. A wide range of organisms have previously been assessed by VKM using this method, e.g., land snails (VKM 2017) and arachnids and insects (VKM 2016).

Based on the assessment of the overall probability of establishment (based on the probability of entry, probability of establishment and spread), and potential for environmental impact on Norwegian biodiversity, the risk assessor ends the assessment with a "Conclusion of the risk assessment" placing the species (or genus) in one of the following categories; Low risk, Moderate risk or High risk (Figure 2.1-1).

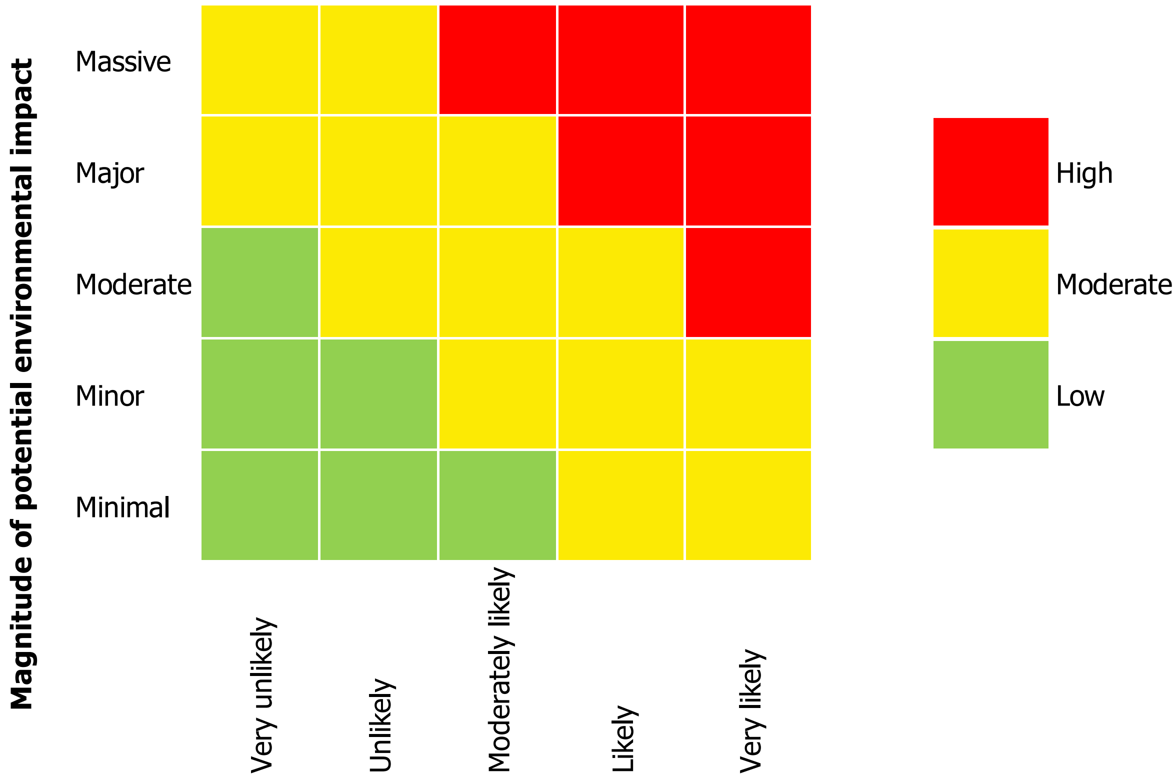

Figure 2.1-1: The conclusions of the risk assessments (Low, Moderate, or High) are based on the overall probability of establishment (which includes entry, establishment and spread) and the potential for environmental impact on Norwegian biodiversity.

2.1.2.1 Modified GB-NNRA protocol used for crustacean species

The unaltered version of the EU NON-NATIVE SPECIES RISK ANALYSIS – RISK ASSESSMENT TEMPLATE V1.0 (27-04-15) can be found here: http://www.nonnativespecies.org/index.cfm?pageid=143. The adapted version used for all risk assessments in the current report is provided below, and the specific changes made to the original template are listed in Appendix I.

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles, or adult animals.			
QUESTION	**RESPONSE [choose one entry, delete all others]**	**CONFIDENCE [choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this	Unlikely	Low Medium	

pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Moderately likely Likely	High	
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely Moderately likely Likely	Low Medium High	
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Unlikely Moderately likely Likely	Low Medium High	

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway, based on the similarity between climatic conditions in Norway and the organism's current distribution?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
2.2. How likely is it that the organism will be able to establish in Norway, based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
2.4. How widespread are habitats or species necessary for the survival, development, and multiplication of the organism in Norway?	Very isolated Isolated Moderately widespread Widespread Ubiquitous	Low Medium High	
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Very unlikely Unlikely Moderately likely Likely	Low Medium High	

	Very likely		
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	[insert text]	Low Medium High	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Very unlikely Unlikely Moderately likely	Low Medium	

	Likely Very likely	High	

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minimal Minor Moderate Major Massive	Low Medium High	
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal Minor Moderate Major Massive	Low Medium High	
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Minimal Minor Moderate Major Massive	Low Medium High	
4.4. 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 Norway?	Minimal Minor Moderate Major Massive	Low Medium High	
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	[insert text + attach map if possible]	Low Medium High	
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Minimal Minor Moderate Major Massive	Low Medium High	

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENTS

QUESTION	RESPONSE	CONFIDENCE	COMMENTS
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Minimal Minor Moderate Major Massive	Low Medium High	
5.2. How much impact does the organism have as a vector for white spot syndrome virus (WSSV)	Minimal Minor Moderate Major Massive	Low Medium High	
5.3. How much impact does the organism have as a vector for other parasites or pathogens?	Minimal Minor Moderate Major Massive	Low Medium High	
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Minimal Minor Moderate Major Massive	Low Medium High	

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	[insert text]	Low Medium High	
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	[insert text]	Low Medium High	

RISK SUMMARIES for [species name]			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Unlikely Moderately likely Likely	Low Medium High	
Summarise Establishment	Unlikely Moderately likely	Low Medium	

	Likely	High	
Summarise Spread	Unlikely Moderately likely Likely	Low Medium High	
Summarise impact from pathogens/ parasites	Minimal Minor Moderate Major Massive	Low Medium High	
Summarise Ecological Impact	Minimal Minor Moderate Major Massive	Low Medium High	
Conclusion of the risk assessment	Minimal Minor Moderate Major Massive	Low Medium High	

2.1.2.2 Modified GB-NNRA protocol used for pathogens

For the risk assessment of crustacean pathogens, we used another version of the GB-NNRA protocol that had been modified for assessing pathogens on amphibians in Norway. This is described in detail in VKM Report 2019:4 (VKM 2019). That protocol was slightly modified to adapt to the scope of pathogens in the context of global freshwater crustacean aquarium trade. The adapted version used for all risk assessments of pathogens in the current report is provided below.

LIKELIHOOD OF ENTRY			
Important instructions: • Entry is the introduction of an organism into Norway. Not to be confused with spread, the movement of an organism within Norway. • In the context of this report, only entry through the crustacean aquarium trade is considered. Furthermore, this risk assessment should only be used for consideration of crustacean species that are regarded possible carriers. • For organisms that are already present in Norway, only complete the section for current active pathways of entry or, if relevant, potential future pathways. The entry section need not be completed for organisms that have entered previously and have no current pathways of entry.			
Question	**Response**	**Confidence**	**Comment**

1.1. How many active pathways are relevant to the potential entry of this organism? (If there are no active pathways or potential future pathways respond N/A and move to the Establishment section)	none **very few (1-3)** few (4-6) moderate number (7-10) many (11-20) very many (20+)	Low Medium High	
1.2. List relevant pathways through which the organism could enter. Where possible give details about the specific origins and end points of the pathways. For each pathway, answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary).		Low Medium High	

Pathway name:	Aquarium trade		
Question	**Response**	**Confidence**	**Comment**
1.3. Is entry along this pathway intentional (e.g., the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?		Low Medium High	
1.4. How likely is it that the organism will travel along this pathway from the point(s) of origin, multiple times (>10) over the course of one year? Subnote: Under comment, discuss how likely the organism is to get onto the pathway in the first place.	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: Under comment, consider whether the organism could multiply along the pathway.	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	

1.6. How likely is the organism to survive existing management practices during passage along the pathway?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
1.7. How likely is the organism to enter Norway undetected?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
1.10 Summarized likelihood of the organism entering a suitable habitat in Norway through this pathway	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	

LIKELIHOOD OF ESTABLISHMENT			
Question	**Response**	**Confidence**	**Comment**
2.1. How likely is it that the organism will be able to establish in Norway, based on the similarity between climatic conditions in Norway and the organism's current distribution?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between	Very unlikely Unlikely	Low Medium High	

other abiotic conditions in Norway and the organism's current distribution?	Moderately likely Likely Very likely		
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, terraria, zoological gardens) in Norway? Subnote: gardens are not considered protected conditions	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
2.4. How widespread are habitats or species necessary for the survival, development, and multiplication of the organism in Norway?		Low Medium High	
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
2.7. How likely is it that the organism could establish despite low genetic diversity in the founder population?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances of invasion in the comments box).	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	

2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comment box).	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	

LIKELIHOOD OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
Question	**Response**	**Confidence**	**Comment**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread).	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread).	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comment box to indicate any key issues).		Low Medium High	

LIKELIHOOD OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each set of questions starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (i.e., past and current impacts) from potential future impacts.			
Question	**Response**	**Confidence**	**Comment**
4.1. How much environmental harm is caused by the organism within its existing geographical range, excluding Norway?	Minimal Minor Moderate Major Massive	Low Medium High	
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal Minor Moderate Major Massive	Low Medium High	
4.3. How much impact does the organism have, as food, as a host, or as a symbiont or a vector for other damaging organisms (e.g., diseases)?	Minimal Minor Moderate Major Massive	Low Medium High	
4.4. How much impact do other factors have, (factors which are not covered by previous questions; specify in the comment box)	Minimal Minor Moderate Major Massive	Low Medium High	
4.5. 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 Norway?		Low Medium High	
4.6. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).		Low Medium High	
4.7. Estimate the expected impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present).	Minimal Minor Moderate Major Massive	Low Medium High	

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
Question	**Response**	**Confidence**	**Comment**
5.1. What aspects of climate change (in a 50-years perspective), if any, are most likely to affect the risk assessment for this organism?		Low Medium High	
5.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions		Low Medium High	

RISK SUMMARIES			
Question	**Response**	**Confidence**	**Comment**
Summarise Entry	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
Summarise Establishment	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
Summarise Spread	Very unlikely Unlikely Moderately likely Likely Very likely	Low Medium High	
Summarise Ecological Impact	Minimal Minor Moderate Major Massive	Low Medium High	
Conclusion of the risk assessment	Low Medium Highj	Low Medium High	

2.1.3 Rating and descriptions

In order to provide clear justification of the ratings given in the risk assessment template, the Panel used ratings and adapted versions of the descriptors from Appendix E in the Scientific Opinion of the European Food Safety Authority (EFSA, 2015). A description of the ratings used can be found in Tables 2.1.3-1 – 2.1.3-10 below.

Table 2.1.3-1 Rating of likelihood of entry into Norwegian nature.

Rating	Descriptors
Unlikely	The likelihood of entry would be low because: • The species is probably not imported to Norway yet, but is available in global trade, AND • a (very) limited number of individuals is expected to be in trade
Moderately likely	The likelihood of entry would be moderate because: • the species is most probably imported to Norway, OR • a moderate number of individuals is expected to be in trade
Likely	The likelihood of entry would be high because: • the species is known to be imported to Norway, AND • a relatively large number of individuals is expected to be in trade

Table 2.1.3-2 Rating of the likelihood of establishment.

Rating	Descriptors
Very unlikely	The likelihood of establishment would be very low because: • environmental conditions are unsuitable throughout Norway, • of the absence or very limited availability of required foods (including host plants), • the occurrence of other considerable obstacles prevents establishment.
Unlikely	The likelihood of establishment would be low because: • environmental conditions are unsuitable in most parts of Norway, • of the limited availability of required foods (including host plants), • the occurrence of other obstacles prevents establishment.
Moderately likely	The likelihood of establishment would be moderate because: • environmental conditions are suitable in a few areas of Norway, • required foods (including host plants) are abundant in a few areas of Norway, • no obstacles to establishment occur.
Likely	The likelihood of establishment would be high because: • environmental conditions are suitable in some parts of Norway, • required foods (including host plants) are widely distributed in some areas of Norway, • no obstacles to establishment occur; • Alternatively, the species has already established in some areas of Norway.
Very likely	The likelihood of establishment would be very likely because: • environmental conditions are suitable in most parts of Norway, • required foods (including host plants) are widely distributed in Norway, • no obstacles to establishment occur; • Alternatively, the species has already established in Norway.

Table 2.1.3-3 Rating of the likelihood of spread.

Rating	Descriptors
Very unlikely (minimal)	The likelihood of spread would be very low because: • the species has limited spreading capabilities, • highly effective barriers to spread exist (*e.g.*, patchy distribution of habitats), • required foods and nesting resources are not, or are very rarely, present in the area of possible spread.
Unlikely	The likelihood of spread would be low because: • the species has limited spreading capabilities, • effective barriers to spread exist (*e.g.*, patchy distribution of habitats), • required foods and nesting resources are occasionally present.
Moderately likely (moderate)	The likelihood of spread would be moderate because: • the species has limited spreading capabilities, • partly effective barriers to spread exist, • required foods and nesting resources are abundant in some parts of the area of possible spread.
Likely (major)	The likelihood of spread would be high because: • the species has effective ways to spread, • no effective barriers to spread exist, • required foods and nesting resources are abundant in some parts the area of possible spread.
Very likely	The likelihood of spread would be very high because: • the species has effective ways to spread, • no effective barriers to spread exist, • required foods and nesting resources are widely present in the whole risk assessment area.

Table 2.1.3-4 Rating of the assessment of impact.

Rating	Descriptors
Minimal	No impact on local biodiversity.
Minor	Potential impacts on local biodiversity are within normal fluctuation.
Moderate	Impacts may cause moderate reductions in native populations.
Major	Impacts may cause severe reductions in local populations with consequences for local biodiversity and ecosystem functions and services.
Massive	Impacts may cause severe reductions in local biodiversity (local extinctions), with severe consequences for ecosystem functions and services.

Table 2.1.3-5 Ratings used for describing the level of confidence.

Rating	Descriptors
Low	Most information is missing on the species distribution, ecological requirements, and climate tolerance. Subjective judgement may be introduced without supporting evidence. Unpublished data are frequently used.
Medium	Some information is missing on the species distribution, ecological requirements, and climate tolerance. Subjective judgement is introduced with supporting evidence. Unpublished data are sometimes used.
High	Information is available on the species distribution, ecological requirements, and climate tolerance. No subjective judgement is introduced. No unpublished data are used.

Rating and descriptions for the assessment of the crustacean pathogens follows those used in VKM Report 2019:4 (VKM 2019), with minor modifications. A description of the ratings used can be found in Tables 2.1.3-6 – 2.1.3-10 below.

Table 2.1.3-6 Rating of the likelihood of entry.

Rating	Descriptors
Very unlikely	The likelihood of entry would be very low because the pathogen: • is undocumented in the export countries/region, • is host specific, • cannot survive outside it's hosts.
Unlikely	The likelihood of entry would be low because the pathogen: • is rare in the exporting country or continent, • can only infect two or three species, • has poor survival outside it's hosts (up to one hour).
Moderately likely	The likelihood of entry would be moderate because the species: • is established in some parts of the exporting country or continent, • is mostly host specific, but can also infect a few other species, • can survive outside its host for short periods.
Likely	The likelihood of entry would be high because the species: • is established in several areas of the exporting country or continent, • can infect a restricted range of species, • can survive for several hours outside its hosts.
Very likely	The likelihood of entry would be very high because the species: • is common in the exporting country or continent, • is a generalist pathogen, • can survive for longer periods (weeks) outside its hosts.

Table 2.1.3-7 Rating of the likelihood of establishment.

Rating	Descriptors
Very unlikely	The likelihood of establishment would be very low because: • of unsuitable environmental conditions in Norway, • of the absence, or very limited availability, of required hosts, • the occurrence of other considerable obstacles prevents establishment.
Unlikely	The likelihood of establishment would be low because: • of the unsuitable environmental conditions in most parts of Norway, • of the limited availability of required hosts, • the occurrence of other obstacles that hinder establishment
Moderately likely	The likelihood of establishment would be moderate because: • environmental conditions are suitable in a few parts of Norway, • required hosts are abundant in only a few parts of Norway, • there are only minor obstacles to establishment.
Likely	The likelihood of establishment would be high because: • environmental conditions are suitable in some parts of Norway, • required hosts are widely distributed in some parts of Norway, • no obstacles to establishment are present.
Very likely	The likelihood of establishment would be very high because: • environmental conditions are suitable in most parts of Norway, • required hosts are widely distributed in Norway, • no obstacles to establishment are present.

Table 2.1.3-8 Rating of the likelihood of spread.

Rating	Descriptors

Very unlikely	The likelihood of spread would be very low because: • the pathogen can only spread through specific infected hosts, • highly effective barriers to spread exist (e.g., patchy distribution of appropriate habitats), • required hosts are not, or very rarely, present in the area of possible spread.
Unlikely	The likelihood of spread would be low because: • the pathogen can only spread through a limited range of infected hosts, • effective barriers to spread exist (e.g., patchy distribution of appropriate habitats), • required hosts are only occasionally present.
Moderately likely	The likelihood of spread would be moderate because: • the pathogen can spread through a wide range of hosts, but not due to human activity, • partly effective barriers to spread exist (mosaic landscape of suitable habitats), • required hosts are usually present, but at a low abundance.
Likely	The likelihood of spread would be high because: • the pathogen spreads easily through a wide range of hosts and, to some degree, can be spread by human activity, • no effective barriers to spread exist, • required hosts are always present, but at a low abundance.
Very likely	The likelihood of spread would be very high because: • the pathogen spreads easily through a wide range of hosts and can easily be spread by human activity, • no effective barriers to spread exist, • required hosts are always present, and at high abundance.

Table 2.1.4-9 Rating of the assessment of impact.

Rating	Descriptors
Minimal	No known impact on local biodiversity.
Minor	Potential impact on local biodiversity, but only occasional deaths of individuals.
Moderate	Impact may cause moderate reductions in native populations.
Major	Impact may cause severe reductions in local populations with consequences for local biodiversity and ecosystem functions and services.
Massive	Impact may cause severe reductions in local biodiversity (local extinctions), with severe consequences for ecosystem functions and services.

Table 2.1.3-10 Ratings used for describing the level of confidence.

Rating	Descriptors
Very low	There is very little or no published data on the topic. Only expert judgement used.
Low	Available information on the topic is limited, and mostly expert judgements used.

Medium	Some published information exists on the topic, but expert judgements also used.
High	There is considerable published information, and expert judgements are in concurrence.
Very high	The topic is very well debated in peer-reviewed journals, and international reports. Expert judgements are in concurrence.

2.2 Literature search

Some of the species considered in this risk assessment have been studied quite extensively, while there is a lack of scientific information for others. Furthermore, some studies on the focal species are of little relevance for an environmental risk assessment. Examples are descriptive studies on morphology and courting behaviour. The confidence given for each species in the risk assessment reflects the available scientific literature of relevance to the risk assessment. High confidence is associated with species that have been extensively studied on aspects relevant to the risk assessment and low confidence for species where scientific information is lacking. A list of the references used in the risk assessment is provided for all species.

Key sources of scientific literature have been ISI Web of Science and Google Scholar. Thorough searches in these databases, primarily by use of species names (or synonyms) or common names, has been used to identify relevant literature. In some instances, additional literature has been found by searching in the reference list of relevant published articles. For all crustacean species listed in Tables 3.1.1 – 3.2.3, a specific search was conducted in ISI Web of Science, combining scientific and common names with search the terms" disease", "parasite", "pathogen", "virus", "bacteria", and the names of the pathogens that cause notifiable, listed crustacean diseases (see section 1.4 on pathogens). If no hits were retrieved, the same combination of terms were used in a Google Scholar search.

We also conducted a general Google search, using the species names or English common names. These searches sometimes revealed webpages with relevant information. Some webpages were linked to databases maintained by experts or governmental organizations, such as WMSDB, AnimalBase, Encyclopaedia of Life, Global Invasive Species Database (IUCN), IUCN Red List, U.S. Fish and Wildlife Service, and the Animal Diversity Web. These databases were useful as they sometimes provide a summary of ecological knowledge for a species and give references to relevant scientific literature. Google searches also returned a limited number of hits from private webpages and websites or literature intended for aquarists. Some good private sites include Aquarium advisor, Fishipédia, and Nanocaridina. These sites often provide experience-based species-specific information on how to keep freshwater crustaceans, such as requirements and preferences for food, and temperature and humidity needs, as well as information on reproduction (e.g., number of eggs per clutch).

Finally, the experts involved in this assessment used their extensive databases of relevant scientific literature.

2.3 Earlier risk assessments of freshwater crustaceans (with regards to Norway)

Some of the species that we assess here, have also been assessed elsewhere. The Norwegian Pet Trade Association (NZB) evaluated the potential risk associated with several freshwater crustaceans and other invertebrates in "Vurdering av akvatiske organismer for positivlister" in 2010 (Fosså 2010). The same species were also assessed by Kjærstad (2011) in "Faglig risikovurdering av ferskvannsinvertebrater for akvarie- og hagedamhold". Both risk assessments focused on ecological impacts, and to a lesser extent considered the risk associated with pathogens.

The risk associated with the marine crab, *Percnon gibbesi,* was assessed both by The Norwegian Biodiversity Information Centre (NBIC) and the Norwegian Institute of Marine Research (IMR). NBIC concluded that there is low risk associated with this species (Jelmert et al. 2018), while IMR propose an import ban of any living specimens of the species (IMR 2011).

VKM assessed the risk of negative impact on biodiversity from import of the red claw crayfish (*Cherax quadricarinatus*) for use in aquaculture in Norway (VKM, 2016). VKM concluded that the species has low invasive potential, but may cause large ecological effects by the introduction of pathogens. Red claw was assessed to present a potential high risk under current climates and low aquaculture activity, and high risk under future climates and high aquaculture activity.

Several of the species relevant for trade in Norway have been assessed in Sweden (e.g., *Faxonius rusticus, F. immunis, F. limosus, F. virilis, Pacifastacus leniusculus, Procambarus acutus, P clarkii,* and *P. virginalis*). There was a high over all risk associated with all species (Strand et al. 2018).

2.4 Climate considerations

2.4.1 Temperature as driver of species distributions

Most of the species that we have assessed have a native distribution in tropical and subtropical regions. The climate in these regions is warmer than in Norway, which is situated in temperate (southernmost Norway), boreal (southern to mid Norway) and low Arctic (northern Norway) ecoregions. Physiological processes, such as rates of growth and development, are often strongly temperature dependent (Buisson et al. 2013, Parmesan and Yohe 2003). Temperature therefore governs the presence and relative abundances of invertebrates (Velle et al. 2010). The implication is that species with tropical and subtropical native distributions require more accumulated degree-days to develop than are available in

Norway and are not likely to establish here. However, it should be added that there is inevitably some uncertainty involved since the ability of acclimation is rarely known. Furthermore, climate and land-use changes will likely cause drastic shifts in species distribution and can dramatically influence the future of biodiversity (Bellard et al. 2013).

Although most crayfish species from tropical and subtropical climates will be unlikely to survive and establish in Norway, they can, if intentionally or accidentally introduced to a Norwegian habitat during the warmer season (late spring to early autumn), survive long enough to transmit infectious pathogens. Thus, even if they die at temperatures below 5 °C, they can potentially spread pathogens and cause outbreaks of disease and extinctions of Norwegian populations of freshwater crustaceans. The exception from the requirement for a permit upon importation of alien organisms that cannot survive below 5 °C (§ 7 of the Regulation on alien organisms, see section 1.7), provides no protection against the introduction, establishment, and spread of accompanying pathogens. Of highest concern is the introduction of the crayfish plague pathogen (*A. astaci*) to new locations in Norway, but also the WSSV that that can infect all marine and freshwater decapods. The virus can be sustained in latent infections, and then cause high mortality rates when the temperature rises above 20 °C. Many lakes and crayfish habitats in Norway presently have periods of sufficient duration when the water temperatures are above 20 °C and permit the white spot desase to cause crayfish mass mortalities.

2.4.2 Future climates

Some species will survive in future climates of Norway when the length of the growing season increases, and the winters become less harsh (Iacarella et al. 2015). In this respect, the warmest areas of Norway are of most interest. The globally averaged combined land and ocean surface temperature shows a warming of 0.85 °C over the period 1880 to 2012, for which multiple and independently produced datasets exist (IPCC 2013). The rate of the warming has accelerated towards the present. Future climate change is expected to vary heterogeneously between and within regions and according to season. Currently, the warmest annual mean temperatures (8.0 °C) and mildest winters occur in coastal southern Norway (climate period 1971-2000, Figure 2.4-1).

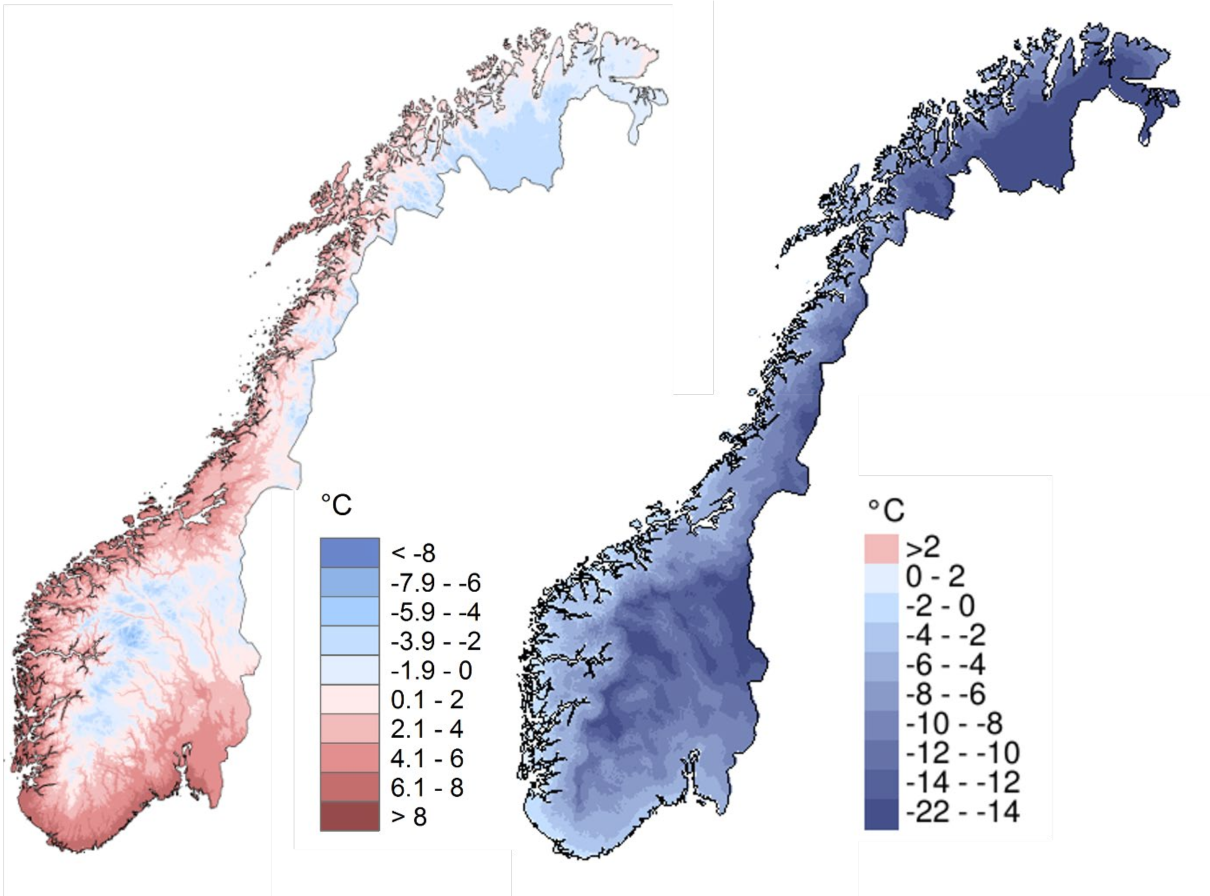

Figure 2.4-1: Average annual air temperatures (left) and minimum winter temperatures (right; December, January, February) for Norway for the climate reference period 1971-2000. The maps were downloaded from https://klimaservicesenter.no.

The warmest summer temperatures are in the southern part of Østlandet and the coastal areas of Sørlandet, with an average of 16 °C. Given the CO_2 emission scenarios RCP 4.5 and RCP 8.5, warm areas can expect an annual temperature increase of about 2.5 and 4.5 °C, respectively, by the climate period 2071-2100 (Figure 2.4-2; Source: klimaservicesenter.no). The increase is expected to be highest during the winters. Given the model errors involved (about +/-1.3 °C for the climate period 2071-2100) and a precautionary principle, VKM assumes an annual mean temperature of 12.5 °C for Norway in 2071-2100, which is in accordance with scenario RCP8.5. Using this scenario has been recommended by the Norwegian Biodiversity Information Centre (Sandvik et al. 2015) and in national policy that addresses future climates. According to this scenario, the warmest winter temperatures will occur in coastal areas of western and southwestern Norway, with an average of 5.0 to 6.5 °C. The minimum temperatures during the winter will increase from about 0 to 2 °C at the present to about 5 °C in year 2100.

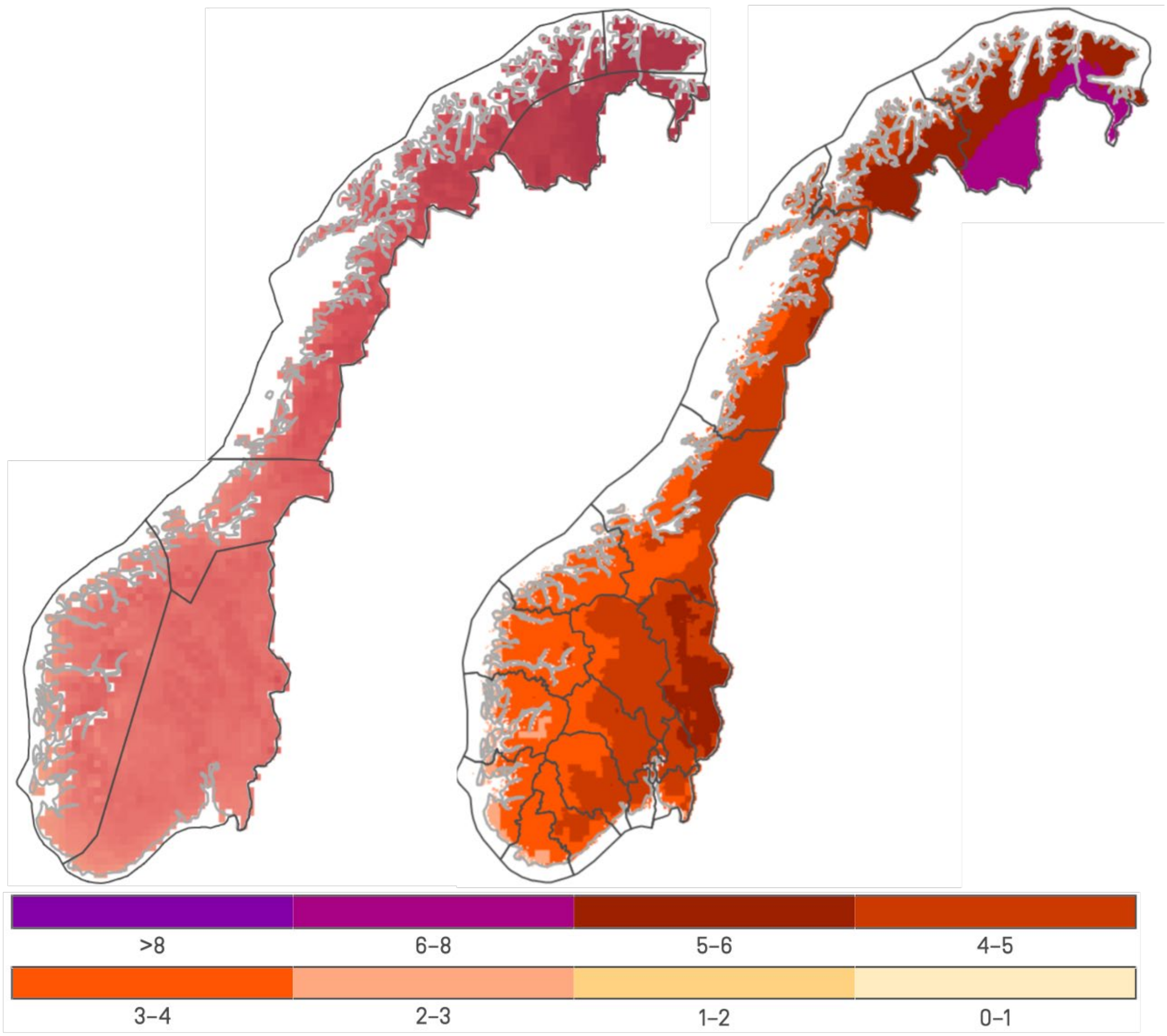

Figure 2.4-2. Projected change in average annual air temperatures (°C; left) and minimum winter temperatures (°C; right; December, January, February) for Norway from 1971-2000 to 2071-2100 using the greenhouse gas emission scenario RCP 8.5. The maps were downloaded from https://klimaservicesenter.no.

The summer temperatures are expected to increase by about 4 °C towards year 2100 in the warmest areas of Norway. The implication is that some limited coastal areas in southern Norway may experience average summer air temperatures of 20 °C. Given the highly significant relationship between air and littoral water temperatures in lakes (Livingstone and Lotter 1998), lakes and water bodies in large areas in southern Norway will experience temperatures of sufficient warmth and for sufficient duration for WSSV to cause crayfish mass mortalities.

3 Species relevant for import and private keeping in Norway

Based on information from the the Norwegian Pet Trade Association - NZB (Appendix II), we identified 112 species (or in some cases genera) of freshwater crustaceans relevant for trade in Norway. These include 38 species of crayfish (from three different families), 29 species (of which six are representatives of a genus) of crabs (from eight different families), and 45 species of shrimp (from six different families). In addition, the seawater crab *P. gibbesi* was included as this is listed on Appendix III of the Norwegian Nature Diversity Act as a species that can only be imported with a special permit.

The project group also obtained trade-relevance data for these species, which we used as a proxy for the likelihood of these species being kept in aquaria in Norway today. The species assessed are listed alphabetically below. Importantly, many of these species exist in several colour variants ("morphs" of phenotypes) that were assessed as one.

Table 3-1: Species likely to be in trade in Norway today, listed alphabetically.

Group	Species
Crayfish	*Cambarellus (Cambarellus) patzcuarensis*
	Cherax holthuisi
	Cherax peknyi
	Cherax quadricarinatus
	Cherax tenuimanus
	Faxonius virilis or other species of the genus *Faxonius* (formerly *Orconectes*)
	Procambarus alleni
	Procambarus clarkii
	Procambarus paeninsulanus
	Procambarus virginalis
Crabs	*Ceylonthelphusa kandambyi*
	Clibanarius africanus
	Geosesarma bicolor
	Geosesarma sp.
	Geosesarma tiomanicum
	Lepidothelphusa spp.
	Limnopilos naiyanetri
	Metasesarma aubryi
	Metasesarma spp.
	Neosarmatium meinerti
	Parasesarma eumolpe
	Parathelphusa bogorensis
	Parathelphusa pantherina
	Percnon gibbesi (listed in Annex III of the Regulation of alien organisms)

	Perisesarma spp.
	Potamonautes lirrangensis
	Pseudosesarma moeschii
	Pseudosesarma spp.
	Syntripsa matannensis
Shrimps	*Atya gabonensis*
	Arachnochium mirabile
	Atyaephyra desmarestii (listed in Annex III of the Regulation of alien organisms)
	Atyoida pilipes
	Atyopsis moluccensis
	Caridina babaulti
	Caridina brachydactyla
	Caridina breviate
	Caridina brevicarpalis
	Caridina caerulea
	Caridina cantonensis
	Caridina dennerli
	Caridina gracilirostris
	Caridina logemanni
	Caridina mariae
	Caridina multidentata
	Caridina parvidentata
	Caridina propinqua
	Caridina richtersii
	Caridina rubropunctata
	Caridina serratirostris
	Caridina simoni
	Caridina spinata
	Caridina woltereckae
	Desmocaris trispinosa
	Lancaris kumariae
	Macrobrachium assamense peninsulare
	Macrobrachium dayanum
	Macrobrachium dienbienphuense
	Macrobrachium gracilirostre
	Macrobrachium lanchesteri
	Macrobrachium pilimanus
	Macrobrachium rosenbergii
	Neocaridina davidi
	Neocaridina palmata
	Tenuipedium palaemonoides
	Xiphocaris elongate

Table 3-2: Species likely to be in trade in Norway in the foreseeable future (alphabetically).

Group	Species
Crayfish	*Cambarellus (Cambarellus) chapalanus*
	Cambarellus (Cambarellus) montezumae
	Cambarellus (Pandicambarus) diminutus
	Cambarellus (Pandicambarus) ninae
	Cambarellus (Pandicambarus) puer
	Cambarellus (Pandicambarus) schmitti
	Cambarellus (Pandicambarus) shufeldtii
	Cambarellus (Pandicambarus) texanus
	Cherax boesemani
	Cherax communis
	Cherax destructor
	Cherax lorentzi
	Cherax monticola
	Cherax papuanus
	Cherax preissii
	Cherax pulcher
	Cherax snowden
	Creaserinus fodiens
	Faxonius neglectus
	Faxonius spp.
	Pacifastacus leniusculus
	Procambarus braswelli
	Procambarus cubensis
	Procambarus llamasi
	Procambarus ouachitae
	Procambarus pubescens
	Procambarus spiculifer
	Procambarus vazquezae
	Procambarus versutus
Crabs	*Aegla platensis*
	Chiromantes angolense
	Heterochelamon tessellatum
	Ilyoplax spp.
	Lepidothelphusa cognetti
	Parathelphusa spp.
	Potamon fluviatile
	Sartoriana spinigera (listed in Annex III of the Regulation of alien organisms)
	Sayamia bangkokensis
	Sesarmops intermedius
Shrimps	*Arachnochium kulsiense*
	Euryrhynchus amazoniensis
	Halocaridina rubra

Macrobrachium agwi
Macrobrachium idae
Macrobrachium scabriculum
Paracaridina zijinica
Paratya compressa

4 Invasiveness scores

The invasiveness (BRA-) score of the relevant crayfish species ranged from 22.5 to 6, and from 32.5 to 16 when climate change was taken into account (BRA + CCA-score). For crabs, the BRA-scores ranged from 14 to -7, and from 24 to -3 when climate change was taken into account. And lastly, the BRA-score of shrimps ranged from 18.5 to -4, and 24.5 to 0 when climate change was taken into account. The complete AS-ISK assessment results are available as an online supplement at VKM.no. Species that were subjected to a thorough risk assessment using GB-NNRA (see 2.1.2) are listed in Table 4-1.

Table 4-1: Invasiveness scores for species of crayfish, crabs and shrimps with the highest scores from the AS-ISK screening. BRA: basic risk assessment, BRA + CCA: basic risk assessment + climate change assessment. The species are sorted according to their BRA + CCA- score.

Group	Species	BRA	BRA + CCA
Crayfish	*Pacifastacus leniusculus*	41	49
	Faxonius virilis (representing *Faxonius (Orconectes)* sp.)	35	45
	Faxonius neglectus	32	42
	Procambarus clarkii	26	36
	Procambarus virginalis (former *P. fallax. viriginalis*)	29	33
	Cherax quadricarinatus	22.5	32.5
	Cherax destructor	22.5	32.5
	Cherax tenuimanus	21	31
	Cherax monticola	15	25
	Cambarellus (Cambarellus) patzcuarensis	14.5	24.5
	Cherax holthuisi	14	24
	Cherax peknyi	14	24
	Cherax preissii	14	24
	Creaserinus fodiens	14	24
	Procambarus alleni	13.5	23.5
	Cambarellus (Cambarellus) montezumae	13	23
Crabs	*Percnon gibbesi*	14	24
	Sayamia bangkokensis	6	10
Shrimps	*Macrobrachium rosenbergii*	18,5	24.5
	Atyaephyra desmarestii	18	24
	Neocaridina davidi	13.5	23.5
	Macrobrachium dayanum	11	23

5 Assessment of infectious crustacean pathogens

5.1 HAZARD IDENTIFICATION

Four pathogens that cause known, notifiable, and listed diseases were identified as potential hazards to biodiversity in Norway. These are: *A. astaci* that causes crayfish plague (see 1.5.1), WSSV (see 1.5.2) that causes white spot disease, TSV (see 1.5.3) that causes Taura syndrome and YHV1 (see 1.5.4) that causes yellow head disease. These were assessed using GB-NNRA (See Appendix III for complete risk assessment).

The other crustacean diseases listed by OIE (section 1.5.5) were not assessed. These are often recently described and/or affect a narrow range of mostly marine species in tropical and subtropical areas of limited relevance to freshwater crustaceans. No Norwegian crustacean species are currently known to be susceptible to these diseases.

Two of the assessed pathogens, *A. astaci* and WSSV, can be a severe hazard to crustacean biodiversity. Specifically, *A. astaci* can cause up to 100 % mortality in native populations of noble crayfish (*A. astacus*) and has already eradicated several noble crayfish populations in Norway. WSSV, on the other hand, is not yet known in Norway. According to current knowledge and OIE, white spot disease can potentially cause mass mortalities in all decapod species, both freshwater and marine species. Some species are relatively tolerant to the virus under certain climatic conditions, but the susceptibility of different species is still mostly unknown. The severity of white spot disease is temperature dependent, with up to 100 % mortality for both noble crayfish and signal crayfish at water temperatures above 20 °C. At water temperatures below 12 °C, these crayfish can be infected but not diseased.

TSV and YHV1 are listed as exotic diseases in Norway and EU, indicating that they have not been introduced to, or, at least, not observed in, Europe. These viruses are known to infect a limited range of marine shrimps and create local outbreaks in tropical and subtropical regions. They are also infectious at water temperatures far above normal summer temperatures in Norwegian waters, and the range of known susceptible host species does not include Norwegian or European crustaceans. However, any introduction of exotic notifiable diseases, regardless of presumed host effect, should be avoided.

5.2 HAZARD CHARACTERIZATION

The magnitude of impact in Norway for *A. astaci* is limited to the red-listed noble crayfish, and, geographically, to those regions in Norway where this species is present (see Figure 1.2-2). WSSV will most likely impact severely on noble crayfish when the water temperatures exceed 20 °C, which can often happen in the south-eastern parts of Norway during the summer months. However, this virus can also impact a large range of other marine and freshwater decapod crustaceans (shrimps, crabs, lobster, etc; see Table 1.5.1-2 for details), and even other non-decapod crustaceans of importance, e.g., for ecosystem food-webs.

The potential harm caused by these pathogens in Norway ranges from potential eradication or reduction of the noble crayfish populations (for *A. astaci* and WSSV, respectively) to reduction of Norwegian crustacean biodiversity in general, both marine and freshwater species (for WSSV). It is not expected that TSV and YHV1 would cause an adverse impact on Norwegian crustacean biodiversity (Appendix III). However, if introduced and discovered, these might result in economic implications and demands for surveillance programmes. It would also change the current status of "exotic" disease (list 1), which, by definition, states the absence of the pathogen in Europe. Both Norwegian and EU regulations would demand monitoring programmes and eradication actions to re-establish freedom from these disease if TSV and YHV1 is introduced.

Under the current conditions found in Norway the project group assess that:

- *A. astaci* can have a **massive impact**, with **high confidence**
- WSSV can have a **moderate impact**, with **high confidence**
- TSV can have **minimal impact**, with **medium confidence**
- YHV1 can have **minimal impact**, with **medium confidence**

5.3 LIKELIHOOD

The likelihood of entry of these pathogens to Norway depends on the likelihood of import of carriers of the disease, and is thus closely linked to the host species and the number of imported specimens. The likelihood of establishment and spread in Norwegian ecosystems have been assessed independently for these four species (See Appendix III for details). Under the current conditions in Norway, the project group assesses that the overall likelihood of entry, spread, and establishment are:

- **Very likely to likely**, with **high confidence**, for *A. astaci*
- **Likely to moderately likely**, with **high confidence**, for WSSV
- **Very unlikely**, with **medium confidence**, for TSV
- **Unlikely**, with **medium confidence**, for YHV1

5.4 RISK CHARACTERIZATION

In sum, the project group concludes that the four pathogens assessed as being potential hazards are characterized by the following risks:

- **High risk**, with **high confidence**, for *A. astaci*
- **Moderate risk**, with **high confidence**, for WSSV
- **Low risk**, with **medium confidence**, for TSV and YHV1

6 Freshwater crustaceans as potential hazards to biodiversity

6.1 Potential impact from the import and keeping of crayfish

6.1.1 Ecological impact

The ecological impact of each species was assessed using GB-NNRA. See Appendix IVa for individual assessments.

6.1.1.1 HAZARD IDENTIFICATION

Alien crayfish species have the potential to cause several ecological impacts if they establish in Norway. *Procambarus clarkii* and *Faxonius rusticus* are shown to displace native crayfish, reduce the abundance of aquatic plants, and negatively influence invertebrates and fish (Lodge et al. 2000, McCarty et al. 2006, Gherardi 2007, Wilson et al. 2004, Rodriguez et al. 2005). Once introduced, *P. clarkii* can graze heavily on macrophytes, which may start a trophic cascade in wetland ecosystems, leading to turbid conditions and loss of plants, macroinvertebrates, amphibians, and plant-eating birds (Rodriguez et al. 2005).

Signal crayfish, even at moderate densities, may have a strong effect on stream invertebrate-community structure (Nyström and Pérez 1998, Stenroth and Nystrøm 2003). Guan and Wiles (2002) found that signal crayfish may out-compete benthic fish species for shelter, which caused an inverse correlation between the density of bullhead (*Cottus gobio*) and the density of signal crayfish. Peay et al. (2010) found that signal crayfish reduced the recruitment and growth of salmonid fish in running water in England. Predation on salmon eggs and fry has also been reported for the signal crayfish (Edmonds et al. 2011) This suggests potential negative impacts may also be expected for native fish in Norway.

It is also worth noting that signal crayfish may wipe out native noble crayfish populations due to superior competitive abilities and reproductive interference (Westman et al. 2002); however, this would take a few decades. In addition, some species (e.g., *Procambarus clarkii*) dig burrows and has been shown to alter local ecosystems in riverbeds, streams, and lakes (Souty-Grosset et al. 2006).

Predation by alien crayfish on native benthic invertebrates and amphibian larvae can potentially also occur in most, or all, of the potential regions of establishment, although restricted to the distribution of amphibian populations for the latter. The consequences of predation can be detrimental to local populations of sessile and slow-moving species, like leeches (Olsen et al. 1991, Stenroth and Nystrøm 2003). This is especially critical for threatened species, like salamanders (*Lissitriton vulgaris* and *Triturus cristatus*) and freshwater pearl mussel (*Margaritafera margaritafera*) (Nyström et al. 1997, Sousa et al. 2019).

6.1.1.2 HAZARD CHARACTERIZATION

Alterations to local ecosystems through digging and other behavioural traits would not be restricted to specific regions within the potential area of establishment. However, few species are likely to be impacted from this type of behaviour, and the project group assesses that the consequences in this regard will be **minor** with **high confidence** from importing and keeping crayfish .

Predation by alien crayfish will presumably affect a number of macroinvertebrate species, regardless of where in Norway the entry happens. However, the negative effect will be primarily in those areas where amphibians, especially salamanders, are present. The project group therefore assesses that the overall consequences of predation to be **moderate** to **major** with **medium confidence**.

Competition for food and space with noble crayfish will only be a relevant hazard in those areas where native crayfish populations are established (See figure 1.2-1). Depending on which species is introduced (regarding size, fecundity etc.), the project group assess the overall consequences of competition by alien crayfish to be **moderate** to **major** with **medium confidence**.

6.1.1.3 LIKELIHOOD

We assessed the likelihood of entry into Norway based on how likely the species are to be in the aquarium trade in Norway (see 3.1.1 for species likely to be in trade now, and 3.2.1 for additional species that are likely to enter the trade in the foreseeable future). The likelihood of entry into Norwegian nature was also assessed to be equal to the likelihood of a species being in trade, implying that all species are equally likely to escape or to be released. The likelihood of establishment and spread were assessed for each species and range from very unlikely to very likely (See Appendix IVa for details and confidence).

The likelihood of interacting with organisms that can be harmed depends on the nature of a specific hazard. For species affected by behavioural traits (e.g., digging) and predation, VKM assess this to be likely with medium confidence. As the distribution of these captive crayfish in Norway is not restricted to any specific region, whereas noble crayfish are predominantly distributed in the South-Eastern parts of Norway, at least half of any escapes of releases are likely to happen in areas with native crayfish. The project group therefore assesses that the likelihood of a negative impact on biodiversity from competition for food and space is **moderately likely** with **medium confidence**.

6.1.1.4 RISK CHARACTERIZATION

The project group concludes that the risk of negative impacts on biodiversity caused by ecological interactions following import and private keeping of freshwater crayfish is:

- **High,** with **medium to high confidence**, for: *Procambarus clarkii*, *P. virginalis*, *Pacifastacus leniusculus* and *Faxonius virilis* (as a representative of other *Faxonius* species, i.e., *F. rusticus, F. immunis, F. limosus,* and *F. juvenilis*)
- **Moderate,** with **medium confidence,** for: *Cambarellus patzcuarensis, Procambarus alleni*, *Creaserinus fodiens*, *Cambarellus montezumae*, *C. monticola*, *C. tenuimanus,* and *Faxonius neglectus*
- **Low,** with **medium confidence,** for: *Cherax destructor, C. holthuis, C. perknyi, C. preissi,* and *C. quadricardinatus.*
- All other species were assessed with AS-ISK only. These have not been assigned a risk, but are regarded as unproblematic in terms of their potential effect on biodiversity through ecological effects.

6.1.2 Impact as transmitters of pathogens

The impact of each species as transmitters of pathogens was assessed using GB-NNRA. See Appendix IVa for individual assessments.

6.1.2.1 HAZARD IDENTIFICATION

Four pathogens were identified as potential hazards to biodiversity in Norway should they be introduced as hitchhikers with imported freshwater crayfish: *A. astaci*, WSSV, TSV, and YHV1. See 1.5.1 – 1.5.4 for in depth description and 5.1 – 5.4 for risk assessment. Two of these (*A. astaci* and WSSV) were assessed to constitute a high risk and a moderate risk, with high confidence, respectively. The two others, TSV and YHV1, were assessed to constitute low risk with medium confidence. Consequently, only *A. astaci* or WSSV are evaluated for crayfish below.

6.1.2.2 HAZARD CHARACTERIZATION

As described in section 5, *A. astaci* can cause up to 100 % mortality and has already eradicated several noble crayfish populations in Norway. It is carried and transmitted primarily by North American crayfish that all are natural chronic carriers of the pathogen. The best-known examples are from alien invasive species in Europe (*P. leniusculus*, *P. clarkii*, *F. limosus*, *F. virilis*, *P. virginalis*) that threaten native European species as they carry and transmit the crayfish plague pathogen (Holdich et al. 2009, Kouba et al. 2014). Although largely unexplored in their native continent, all American crayfish should, in our opinion ,be regarded as suspected carriers based on the general experience that all American crayfish introduced to Europe are carriers (OIE 2019b, Holdich et al. 2009, Kouba et al. 2014, Keller et al. 2014, Mrugala et al. 2015, Tilmal et al. 2019). Furthermore, species in South America have also been shown to carry the pathogen, e.g., *Parastacus* spp. (Peiro et al. 2016).

Crustacean species from continents other than the Americas may also carry and transmit *A. astaci*. These can be susceptible crayfish species with higher tolerance than European crayfish, which implies that they can carry a latent infection for some time before they eventually become diseased and die. This is a relevant scenario for the Australian *Cherax* species. Although *A. astaci* does not occur in Australia, both *C. destructor* and *C. quadricarinatus* have been shown to have persistant infections for longer than the European species, and have also been found infected in a European setting, both in the aquarium trade and nature (Mrulaga et al 2015, 2016).

WSSV is suspected to infect all decapod species, both marine and freshwater, and cause high mortality rates provided that water temperatures are sufficiently high. As mentioned above (section 5), WSSV is assumed to become lethal for noble crayfish at water temperatures above 20 °C. In theory, all decapods could be potential carriers of WSSV as all decapods are regarded as susceptible (OIE 2019c). In this context, it is important to consider the WSSV status in the import region, and species from regions with known WSSV would constitute a greater risk than those from regions without known WSSV reports. This has not been specifically evaluated in this report. We have primarily concentrated the risk assessment towards species with known reports of WSSV infection and, consequently, suspected carrier status. More specifically for crayfish, representatives within the genera *Astacus, Faxonius*, *Procambarus*, *Pacifastacus,* and *Cherax* have been proven to become infected with WSSV, and, to variable degrees, have the potential to act as carriers, with the reservation that disease development might depend on water temperature and species-specific immune-related characteristics.

It might be worth mentioning that some species of crayfish including *Faxonius* and *Cambarus* can be intermediate hosts for the lung fluke parasite *Paragonimiasis kellicotti* that causes lung fluke disease (paragonimiasis) in humans (Diaz 2013; Johannesen and Nguyen, 2016).

6.1.2.3 LIKELIHOOD

The likelihood of these pathogens entering Norway correlates with the number of individual hosts imported. Very little is known regarding the expected prevalence. However, if only one individual is infected from the area of origin, then all cohabited individuals can rapidly become infected during common transport and keeping.

If introduced to stores, private aquaria, and/or garden ponds, the pathogens can spread into Norwegian nature, primarily through three pathways: 1) An infected crustacean is released into nature, and the pathogen spreads to other native hosts. 2) An infected crustacean escapes into nature, and the pathogen spreads to other native hosts. 3) The pathogen is released into nature via untreated aquarium water in which one or several infected crustacean hosts have been kept. It is not straightforward to assess the likelihood associated with each of these pathways. However, one single event can potentially cause the introduction of a pathogen that will devastate native crayfish species for an indefinite period, until, in the worst-case scenario, (local) extinction.

Taking into account that these pathogens may spread to Norwegian nature through discarded aquarium water, the likelihood of pathogens entering nature is significantly higher than for species that act as carriers. In sum, the likelihood of pathogen entry into a suitable habitat in Norway through private import is assessed by the project group to be **moderately likely** with **medium confidence**.

Establishment requires that the pathogens interact with a suitable host. In Norway, *A. astaci* is already established in alien populations of signal crayfish (*P. leniusculus*) and has additionally wiped out several populations of noble crayfish. New introductions and establishment can take place in populations of the native noble crayfish (*A. astacus*), which are abundant in the south-eastern parts of Norway (see Figure 1.2-2). If not spread further, the pathogen will eventually burn out after all noble crayfish hosts are dead. For WSSV, any freshwater and marine decapod, and probably also non-decapod crustaceans, can become infected and therefore probably likely sustain WSSV in natural habitats. In sum, the project group therefore assesses that the likelihood of establishment in Norway to be **moderately likely** with **high confidence** for *A. astaci* and **likely** with **medium confidence** for WSSV, given that the pathogens have entered Norwegian nature.

The likelihood of further spread is high and unavoidable within a water system. According to Norwegian regulation FOR-2008-06-17-819 (Regulation on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals), restrictions and the demand for preventive measures to control further spread can be implemented to minimize spread between water systems. Such measures may involve restrictions/bans regarding crayfish fishing, disinfection of gear, fishing equipment, boats etc. To control further spread, all users of the waters should be informed about, and adhere to, the restrictions. This is often difficult to achieve. Furthermore, birds and mammals can act as vectors between neighbouring water systems, which is a pathway beyond human control. Should *A. astaci* or WSSV be established, the project group assesses it to be **likely** with **medium to high confidence** that the pathogens spread, regardless of the host that originally brought the pathogen into the country.

6.1.2.4 RISK CHARACTERIZATION

The risks associated with *A. astaci* and WSSV were considered to be high and moderate, respectively (see section 5). Hence, we place all crayfish species relevant for trade in Norway into five categories according to the likelihood that they introduce *A. astaci* and WSSV (Tables 6.1.2.4-1 and 6.1.2.4-2). A brief elaboration of each category is given below, including an evaluation of the risk posed as pathogen carrier. This also takes into account the impact of each pathogen. For the evaluation, if one species within a genus is proven to be within one of the categories, then all species in that genus are placed in the same category.

I) Known chronic carriers. These include, for example, the North American crayfish species proven consistently to carry *A. astaci*. For WSSV, this category is not known for any crayfish, but may occur for some species, such as the shrimp *Penaeus monodon*. The risk posed as pathogen carrier is assessed to be:

a. **High**, with **high confidence**, for *A. astaci*

b. **Moderate**, with **high confidence**, for WSSV

II) Suspected chronic carriers for *A. astaci* include all American crayfish. For WSSV, suspected chronic carriers include specific species with congeners. The risk posed as pathogen carrier is assessed to be:

a. **High**, with **medium confidence**, for *A. astaci*

b. **Moderate**, with **medium confidence**, for WSSV

III) Suspected situational carriers. These can become infected and carry the pathogen (at least for a period of time) if cohabited with, or living in sympatry with, chronic carriers or diseased crustaceans. For example, *Cherax* spp. with regards to *A. astaci* and WSSV (see Section 6.1.2.2). The risk posed as pathogen carrier is assessed to be:

a. **Moderate**, with **medium confidence**, for *A. astaci*

b. **Low**, with **medium confidence**, for WSSV

IV) Possible pathogen transmitters. There is incomplete evidence for infections and carrier status, but circumstantial evidence of infection or, at least, vector status. For *A. astaci*, this is mostly relevant for decapods other than crayfish. For WSSV, all decapods are possible pathogen transmitter susceptible to infection, but the likelihood would depend on WSSV status in the export country/region. The risk posed as pathogen carrier is assessed to be:

a. **Moderate**, with **low confidence**, for *A. astaci*

b. **Low**, with **medium confidence,** for WSSV

V) No direct or circumstantial evidence for carrier status or pathogen transmission in the genus. Category V is used if there is a lack of reports or other circumstantial evidence. Importantly, category V does not imply the species is proven as non-carrier. A lack of reports reflects a lack of studies, and also a lack of observed problems. The risk posed as pathogen carrier is assessed to be: **very low**, with **low confidence**, for both pathogens.

Table 6.1.2.4-1: Status of *A. astaci* and WSSV for crayfish species in trade in Norway as of today. Status I = Known chronic carrier, II = Suspected chronic carrier, III = suspected situational carriers, IV = possible pathogen transmitter, and V = no direct or circumstantial evidence for carrier status or pathogen transmission.

The overall risk posed as pathogen carrier follows the description given for categories I-V above.

Pathogen	*A. astaci*					*WSSV*					Summary	
Status	**I**	**II**	**III**	**IV**	**V**	**I**	**II**	**III**	**IV**	**V**	**References**	**Overall risk posed as pathogen carrier**
Cambarellus patzcuarensis	X								X		4,7,8	High
Cherax holthuisi			X					X			4,5,8,10	Moderate
Cherax peknyi			X					X			4,5,8,10	Moderate
Cherax quadricarinatus			X					X			4,5,8,10	Moderate
Cherax tenuimanus			X					X			4,5,8,10	Moderate
Faxonius virilis	X							X			2,7,8,10,13	High
Procambarus alleni	X							X			1,2,7,8,9,10	High
Procambarus clarkii	X							X			1,2,7,8,9,10	High
Procambarus paeninsulanus	X							X			1,2,7,8,9,10	High
Procambarus virginalis	X							X			1,2,3,7,8,10	High

References: 1 = Baumgartner et al. 2009, 2 = Holdich et al. 2009, 3 = Keller et al. 2014, 4 = Mrugala et al. 2015, 5 = Mrugala et al. 2016, 6 = Mrugała et al. 2019, 7 = OIE 2019b, 8 = OIE 2019c, 9 = Royo et al. 2004, 10 = Stentiford et al. 2009, 11 = Svoboda et al. 2014a, 12 = Svoboda et al. 2014b, 13 = Tilmans et al. 2014.

Table 6.1.2.4-2: Status of *A. astaci* and WSSV for crayfish species relevant for trade in Norway in the foreseeable future. Status I = Known chronic carrier, II = Suspected chronic carrier, III = suspected situational carriers, IV = possible pathogen transmitter, and V = no direct or circumstantial evidence for carrier status or pathogen transmission.

Pathogen	*A. astaci*					*WSSV*					Summary	
Status	**I**	**II**	**III**	**IV**	**V**	**I**	**II**	**III**	**IV**	**V**	**References**	**Overall risk posed as pathogen carrier**
Cambarellus chapalanus	X								X		4,7,8	High
Cambarellus montezumae	X								X		4,7,8	High
Cambarellus diminutus	X								X		4,7,8	High
Cambarellus ninae	X								X		4,7,8	High
Cambarellus puer	X								X		4,7,8	High
Cambarellus schmitti	X								X		4,7,8	High
Cambarellus shufeldtii	X								X		4,7,8	High
Cambarellus texanus	X								X		4,7,8	High
Cherax boesemani			X					X			4,5,8,10	Moderate
Cherax lorentzi			X					X			4,5,8,10	Moderate
Cherax communis			X					X			4,5,8,10	Moderate
Cherax monticola			X					X			4,5,8,10	Moderate
Cherax papuanus			X					X			4,5,8,10	Moderate
Cherax preissii			X					X			4,5,8,10	Moderate
Cherax destructor			X					X			4,5,8,10	Moderate
Cherax pulcher			X					X			4,5,8,10	Moderate
Cherax snowden			X					X			4,5,8,10	Moderate
Creaserinus fodiens		X							X		7,8	High
Faxonius n. chaenodactylus	X							X			2,4,7,8,10	High
Pacifastacus leniusculus	X							X			2,7,8,10	High
Procambarus braswelli	X							X			1,2,7,8,9,10	High
Procambarus cubensis	X							X			1,2,7,8,9,10	High
Procambarus ouachitae	X							X			1,2,7,8,9,10	High
Procambarus llamasi	X							X			1,2,7,8,9,10	High
Procambarus pubescens	X							X			1,2,7,8,9,10	High
Procambarus spiculifer	X							X			1,2,7,8,9,10	High
Procambarus vazquezae	X							X			1,2,7,8,9,10	High
Procambarus versutus	X							X			1,2,7,8,9,10	High

References: 1 = Baumgartner et al. 2009, 2 = Holdich et al. 2009, 3 = Keller et al. 2014, 4 = Mrugala et al. 2015, 5 = Mrugala et al. 2016, 6 = Mrugała et al. 2019, 7 = OIE 2019b, 8 = OIE 2019c, 9 = Royo et al. 2004, 10 = Stentiford et al. 2009

6.2 Potential impact from the import and keeping of crabs

6.2.1 Ecological impact

The ecological impact of each species was assessed using GB-NNRA. See Appendix IVb for individual assessments.

6.2.1.1 HAZARD IDENTIFICATION

Crabs can occur in large numbers and are difficult to control. Alien crabs can cause considerable damage to soft sediment banks through burrowing, which increases erosion (Dittel and Epifano 2009, Rudnick et al. 2005). Although few species are likely to be directly negatively impacted from this type of behaviour, ecological effects caused by habitat alterations are often unforeseen.

Native freshwater crabs are absent in Norway. If introduced, crabs can compete with invertebrates and fish for food and habitat, and potentially cause ecosystem change and habitat alteration by grazing. We can also expect competition between crabs and native crayfish. However, no agonistic behavioural patterns have been observed between crabs and crayfish in Europe so far (Mazza et al. 2017).

P. gibbesi is a strictly herbivorous seawater species, able to take both soft and tough algal meals (Guillén et al. 2016). This makes it unique among native crabs in Norway, suggesting little competition with native crabs. It can compete with other grazers in the upper infralittoral, such as sea urchins and molluscs (Puccio et al. 2006).

6.2.1.2 HAZARD CHARACTERIZATION

Alteration of local ecosystems through digging and potentially other behavioural traits by alien crabs would not be restricted to any specific regions within the potential area of establishment. In sum, the project group assesses that the consequences in this regard will be **minor** with **medium confidence.**

Predation by alien crabs on native fauna can potentially occur in most, or all, of the potential regions of establishment. The consequences of predation can potentially influence local populations of threatened species. The project group therefore assesses that the overall consequences of predation to be **moderate** with **medium confidence**.

Competition between crabs and native crayfish will only occur in areas of co-existence (see Figure 1.2-1 for the distribution of native crayfish). The project group assesses that the overall consequences of competition in freshwaters to be **minor** with **medium confidence**. Impacts in marine ecosystems may occur in all coastal areas of establishment of *P. gibbesi*. The project group assesses that negative impact on biodiversity in marine ecosystems from competition for food and space are **moderate** with **low confidence.**

6.2.1.3 LIKELIHOOD

The likelihood of entry into Norway is based on how likely it is that each of the assessed species is traded in Norway (see 3.1.2 for species likely to be in trade now, and 3.2.2 for additional species that are likely to enter the trade). The likelihood of entry into Norwegian nature is assessed to be equal to the likelihood of a species being in trade, implying that all species are equally likely to escape or be released. There is a risk that *P. gibbesi* also can enter by shipborne transport (Coutts et al. 2003). Such spreading will most likely occur from the Mediterranean, which is the nearest area where the species is present. However, we disregard such pathways here since the focus is on impacts as a result of import and keeping in aquaria. The likelihood of entry is **moderately likely** with **medium confidence** for *P. gibbesi* and *Sayamia bangkokensis*. The likelihood for establishment and spread is **unlikely** with **medium confidence** for *P. gibbesi* and **very unlikely** with **high confidence** for *S. bangkokensis* (See Appendix IVb for details).

The likelihood of negative impacts on biodiversity through ecological interactions depends on the nature of a specific trait, such as grazing, digging, or predation. The distribution of crabs in captivity is not restricted to any specific region. Interaction with native fauna in freshwaters through predation and competition can potentially occur in all regions of establishment. For *P. gibbesi,* impacts due to grazing may occur in all coastal areas of establishment. The project group assesses the overall likelihood of both predation and competition to be **likely** with **medium confidence**.

6.2.1.4 RISK CHARACTERIZATION

The project group concludes that the risk of negative impacts on biodiversity caused by ecological interactions from import and private keeping of crabs are:

- **Moderate**, with **medium confidence**, for *Percnon gibbesi*
- **Low**, with **medium confidence**, for *Sayamia bangkokensis.*
- All other species were assessed with AS-ISK only. These have not been assigned a risk, but are regarded as unproblematic in terms of their potential effect on biodiversity through ecological effects.

6.2.2 Impact as transmitters of pathogens

The impact of each species as transmitters of pathogens was assessed using GB-NNRA. See Appendix IVb for individual assessments.

6.2.2.1 HAZARD IDENTIFICATION

A. astaci, WSSV, TSV, and YHV1 were identified as potential hazards to biodiversity in Norway, should they be introduced as hitchhikers with imported freshwater crabs (see 1.5.1 – 1.5.4 for descriptions and 5.1 – 5.4 for risk assessments). *A. astaci* and WSSV were associated with high risk and moderate risk, respectively, with high confidence. TSV and YHV1 were associated with low risk with medium confidence. Consequently, only *A. astaci* or WSSV were evaluated for crabs. However, introduction of all exotic diseases should be avoided, regardless of ecological risk. Note, for example, that YHV1 and TSV are found in blue crab (*Callinectes sapidus*), and TSV is found in fiddler crab (*Uca vocans*) and *Sesarma mederi.*

6.2.2.2 HAZARD CHARACTERIZATION

For full hazard characterization of *A. astaci* and WSSV, including impact on Norwegian crustacean biodiversity, see sections 5 and 6.2. It was long believed that the host range of *A. astaci* was restricted to freshwater crayfish. However, it has been demonstrated that the catadromous Chinese mitten crab (*E. sinensis*) also can acquire and transmit *A. astaci* in its freshwater state, without developing the disease itself. Transmission has been demonstrated in aquaria settings (Schrimpf et al 2014), while the positive carrier status has been demonstrated for crabs living in sympatry with chronically infected csignal crayfish in Sweden (Svoboda 2014a). Also, Potamon crab has been demonstrated to carry *A. astaci* when living in habitats with infected American crayfish (Svoboda 2014a). No other crab species has been tested. The absence of reports does not, therefore, necessarily reflect that a species cannot be a carrier.

Several crab species have been verified as carriers of WSSV, e.g., *Sesarma* sp., *Scylla serrata,* and *Uca pugilator* (Kanchanaphum et al. 1998), which can contain high viral loads without developing the disease. Some freshwater crabs, like *Parathelphusa* spp., are susceptible to the virus (Sánchez-Paz 2010) and can act as situational carriers for a limited period before developing the disease.

We have assessed the risk associated with crabs as pathogen carriers. Few of the crab genera relevant for trade today, or in the foreseeable future, are known carriers of *A. astaci* and WSSV. These include *Potanom* spp. for *A. astaci* and *Parathelphusa* spp, for WSSV. However, precautionary measures should be taken for all exotic crabs considered for import to Norway (see section 7).

In addition, some species of crabs can have parasites of concern for human health, such as the lung fluke disease (paragonimiasis) in *Sayamia germaini* (Shih et al. 2011.

The project group assesses the overall consequences of pathogens and diseases in freshwaters caused by crabs to be **minor** with **low confidence**, *A. astaci* and WSSV.

6.2.2.3 LIKELIHOOD

The likelihood of *A. astaci* and WSSV entering Norway correlates with the number of individual infected crabs that are imported. For crabs, we lack knowledge on expected prevalence. However, if only one individual is infected, then all cohabited individuals can rapidly become infected during common transport and keeping.

If introduced to stores, private aquaria, and/or garden ponds, the pathogens can be transferred to Norwegian nature through: 1) an infected crab being released into nature. 2) an infected crab escaping into nature. 3) The pathogen is released into nature via non-treated discarded aquarium water in which one or several infected crabs have been kept (see section 6.1.2.3 for details).

The likelihood of the pathogens entering nature via discarded aquarium water is significantly higher than for the other pathways. However, in contrast to freshwater crayfish, only a few crabs of relevance to aquarium trade are currently known as situational carriers.

In sum, the project group assesses that the likelihood that pathogens enter a suitable habitat in Norway through private import of crabs to be **unlikely** to **very unlikely** with **low confidence**.

Establishment require that the pathogens interact with a suitable host. None of the pathogens, in particular WSSV, require the crab host for further establishment and spread after entering Norwegian nature. Freshwater and marine decapods, and most likely also non-decapod crustaceans, can become infected with WSSV and probably sustain the pathogen in natural habitats. In Norway, *A. astaci* is already established in alien populations of signal crayfish (*P. leniusculus*). New introductions and establishment can take place in populations of the native noble crayfish (*A. astacus*).

In sum, VKM therefore assess that the likelihood of establishment in Norway is **moderately likely** with **high confidence** for *A. astaci* and **likely** with **medium confidence** for WSSV, given that the pathogens have entered Norwegian nature.

The likelihood of further spread is high and unavoidable within a water system. Restrictions and the demand for preventive measures to control further spread can be implemented to minimize spread between water systems (Norwegian regulation FOR-2008-06-17-819). Spread may, nevertheless, still be difficult to prevent, because birds and mammals can also act as vectors between neighbouring water systems.

Should *A. astaci* or WSSV be established, it is **likely** with **medium to high confidence** that the pathogens spread, regardless of the host that originally brought the pathogen into Norway.

6.2.2.4 RISK CHARACTERIZATION

Confirmed and suspected carriers of pathogens identified as hazards to biodiversity in Norway, *A. astaci* and WSSV, are listed for crabs in tables 6.2.2.4-1 and 6.2.2.4-2. Here, we use similar categories as described for crayfish (section 6.1.2.4): I) known chronic carriers, II) suspected chronic carriers, III) suspected situational carriers, IV) possible pathogen transmitters, and V) no direct or circumstantial evidence for carrier status or pathogen transmission in the genus. For the evaluation, should one species within a genus be proven to belong to one of these categories, then all species in the genus have been placed in the same category.

Table 6.2.2.4-1: Status of *A. astaci* and WSSV for crab species in trade in Norway today. Status I = Known chronic carrier, II = Suspected chronic carrier, III = Suspected situational carrier, IV = Possible pathogen transmitter, and V = No direct or circumstantial evidence for carrier status or pathogen transmission. For assessment of overall risk, see 6.1.2.4.

Pathogen	*A. astaci*					*WSSV*					Summary	
Status	**I**	**II**	**III**	**IV**	**V**	**I**	**II**	**III**	**IV**	**V**	**References**	**Overall risk posed as pathogen carrier**
Ceylonthelphusa kandambyi					X				X		8	Low
Clibanarius africanus					X				X		8	Low
Geosesarma bicolor					X				X		8	Low
Geosesarma sp.					X				X		8	Low
Geosesarma tiomanicum					X				X		8	Low
Lepidothelphusa spp.					X				X		8	Low
Limnopilos naiyanetri					X				X		8	Low
Metasesarma aubryi					X				X		8	Low
Metasesarma spp.					X				X		8	Low
Neosarmatium meinerti					X				X		8	Low
Parasesarma eumolpe					X				X		8	Low
Parathelphusa bogorensis					X			X			8,14	Moderate
Parathelphusa pantherina					X			X			8,14	Moderate
Percnon gibbesi					X				X		8	Low
Perisesarma spp.					X				X		8	Low
Potamonautes lirrangensis					X				X		8	Low
Pseudosesarma moeschii					X				X		8	Low
Pseudosesarma spp.					X				X		8	Low
Syntripsa matannensis					X				X		8	Low

References: 8 = OIE 2019c, 14 = Sánchez-Paz 2010

Table 6.1.2.4-2: Status of *A. astaci* and WSSV for crab species relevant for trade in Norway in the foreseeable future. Status I = Known chronic carrier, II = Suspected chronic carrier, III = Suspected situational carrier, IV = Possible pathogen transmitter, and V = No direct or circumstantial evidence for carrier status or pathogen transmission. For assessment of overall risk, see 6.1.2.4.

Pathogen	*A. astaci*					*WSSV*					Summary	
Status	**I**	**II**	**III**	**IV**	**V**	**I**	**II**	**III**	**IV**	**V**	**References**	**Overall risk posed as pathogen carrier**
Aegla platensis					X				X		8	Low
Chiromantes angolense					X				X		8	Low
Heterochelamon tessellatum					X				X		8	Low
Ilyoplax spp.					X				X		8	Low
Lepidothelphusa cognettii					X				X		8	Low
Parathelphusa spp.					X			X			8,14	Moderate
Potamon fluviatile			X						X		8,11	Moderate
Sartoriana spinigera					X				X		8	Low
Sayamia bangkokensis					X				X		8	Low
Sesarmops intermedius					X				X		8	Low

References: 8 = OIE 2019c, 11 = Svoboda et al 2014a, 14 = Sánchez-Paz 2010

6.3 Potential impact from the import and keeping of shrimps

6.3.1 Ecological impact

The ecological impact of each species was assessed using GB-NNRA. See Appendix IVc for individual assessments.

6.3.1.1 HAZARD IDENTIFICATION

Ecological impacts of many invasive shrimps on local biodiversity can be difficult to detect because they may have long-term consequences that take years to become apparent (Kawai and Cumberlidge 2016). The impacts of freshwater shrimp on native fauna/flora are expected to be size- and density-dependent, with large species (e.g., *Macrobrachium* sp.) and/or species with high fecundity, causing more damage than small species (e.g., dwarf *Caridina* sp.) and/or species with low fecundity. Depending on their feeding strategy, shrimp species can utilize numerous resources, such as invertebrates, detritus, and macrophytes. Unlike dwarf shrimps, large species are likely to predate on amphibians.

Some alien shrimp species can alter local fauna through both direct predation and competition for food. Predation by the invasive shrimp, *Neocaridina davidi,* can have negative impact on populations of native freshwater invertebrates (Klotz et al. 2013, Pantaleao et al. 2015) and alter the structure of the meiofaunal community (Weber and Traunspurger 2016). However, the overall predation pressure exerted by *N. davidi* on meiofauna is less than that described for other macroinvertebrate predators, such as insect larvae and juvenile shore crabs (Weber and Traunspurger 2016). Amphidromous species (e.g., *Macrobrachium rosenbergii*) can also impact marine biodiversity, but information from the literature is lacking.

6.3.1.2 HAZARD CHARACTERIZATION

Predation by alien shrimps on native fauna can potentially also occur in most, or all, of the potential regions of establishment. The consequences of predation can potentially influence local populations of threatened species. The project group therefore assess the overall consequences of predation to be **moderate** with **medium confidence.**

6.3.1.3 LIKELIHOOD

The likelihood of entry into Norway is based on how likely it is that each of the assessed species is traded in Norway (see 3.1.3 for species likely to be in trade, and 3.2.3 for additional species that are likely to enter the trade in the foreseeable future). The likelihood of entry into Norwegian nature is assessed to be equal to the likelihood of a species being in trade, implying that all species are equally likely to escape or be released. *N. davidi* is extremely popular as an aquarium pet in Europe. It is considered invasive as it can disperse rapidly, tolerate a wide range of temperatures, and is omnivorous (Patokaet al. 2016). It has spread from Asia and is present in the River Rhine drainage system in Germany, albeit in a thermally polluted stream (Schoolmann and Arndt 2018). Until 2015, this was the only record of the occurrence of *N. davidi* in the European wild (Lipták and Vitázková 2015). *Atyaephyra desmarestii* and *Macrobrachium dayanum* are invasive in Central Europe and Germany, respectively. The spread of *A. desmarestii* is facilitated by canals.

The establishment and spread of *M. rosenbergii* and *M. dayanum* in Norway are **very unlikely** with **high confidence**, while the establishment and spread of *N. davidi* and *A. desmarestii* are **moderately likely** with **medium/low confidence**.

The distribution of shrimps in captivity is not restricted to any specific region. Interactions with native fauna/flora through predation and competition can also occur in all regions of the establishment. The project group assesses the overall likelihood of both predation and competition (for food and space) to be **likely** with **medium confidence**.

6.3.1.4 RISK CHARACTERIZATION

The project group concludes that the risk of negative impacts on biodiversity caused by ecological interactions from the import and private keeping of shrimp are:

- **Moderate**, with **medium confidence**, for *Macrobrachium rosenbergii* and *Neocaridina davidi*
- **Low**, with **medium confidence**, for *Macrobrachium dayanum* and *Atyaephyra desmaretii*.
- All other species were assessed with AS-ISK only. These have not been assigned a risk, but are regarded as unproblematic in terms of their potential effects on biodiversity through ecological effects.

6.3.2 Impact as transmitters of pathogens

The impact of each species as transmitters of pathogens was assessed using GB-NNRA. See Appendix IVc for individual assessments.

6.3.2.1 HAZARD IDENTIFICATION

A. astaci, WSSV, TSV and YHV1 were identified as potential hazards to biodiversity in Norway, should they be introduced as hitchhikers with imported freshwater shrimps (see 1.5.1 – 1.5.4 for descriptions and 5.1 – 5.4 for risk assessments). *A. astaci* and WSSV were associated with high risk and moderate risk, with high confidence. TSV and YHV1 were associated with low risk with medium confidence. Consequently, as for crayfish and crabs, only *A. astaci* or WSSV were evaluated for shrimps. However, introduction of all exotic diseases should be avoided regardless of ecological risk, and many shrimp species are susceptible to, and potential carriers of, YHV1 and TSV, as well as many of the other OIE-listed diseases that have been the subject of less attention in this report (Table 1.5-1 – other pathogens). These mostly include marine species.

Little information is available regarding the role of freshwater shrimps as carriers of pathogens. Mass mortalities of *Macrobrachium rosenbergii* due to white tail disease have been reported in farms in China and India (Bonami et al. 2005). The species is also a potential carrier of TSV. TSV is widely distributed in the shrimp-farming regions of the Americas, South-East Asia, and the Middle East. *Macrobrachium sintangense* has been proven to be susceptible to, and able to transmit, YHV1 to other hosts. Shrimps of the genus *Neocaridina* are known to host worms of the families Branchiobdellidae and Scutariellida (Klotz et al. 2013).

6.3.2.2 HAZARD CHARACTERIZATION

For full hazard characterizations regarding *A. astaci* and WSSV, including impacts on Norwegian crustacean biodiversity, see sections 5 and 6.2. We have assessed the risk associated with shrimps as pathogen carriers.

Very few of the shrimp genera relevant for trade today, or in the foreseeable future, are known carriers of either *A. astaci* or WSSV. There is no conclusive evidence that shrimps carry and transmit *A. astaci*, and shrimps are regarded as resistant to the pathogen. However, some studies suggest that some shrimp species may act as transmitters or even situational carriers of *A. astaci*., should they co-habit with diseased crayfish or chronic carriers, such as American crayfish. For example, Svoboda et al. (2014b) found that *Macrobrachium dayanum* and *Neocaridina davidi* could act as potential transmitters of *A. astaci* as the pathogen may grow in shrimp tissues. However, it is not clear whether it can complete its life cycle in this host. Furthermore, Mrugala et al. (2019) detected *A. astaci* in bodies and exuviae of *Atyopsis moluccensis* and *Atya gabonensis* after exposure to *A. astaci* zoospores, and demonstrated transmission of infection to crayfish.

Furthermore, *Macrobrachium* spp. are susceptible to WSSV and can be experimentally infected (Stentiford et al. 2009, Sánchez-Paz 2010). They can therefore be categorized as situational carriers of WSSV (see below).

6.3.2.3 LIKELIHOOD

The likelihood of *A. astaci* and WSSV entering Norway correlates with the number of infected shrimps imported. We lack knowledge on expected prevalence, and also on the likelihood that cohabited individuals can aquire the infection during common transport and keeping. However, we assume that this could happen.

If introduced to stores, private aquaria and/or garden ponds, the pathogens can be transferred to Norwegian nature through: 1) An infected shrimp being released into nature. 2) An infected shrimp escaping into nature. 3) The pathogen is released into nature via non-treated discarded aquarium water in which one or several infected shrimps have been kept (see section 2.1.2.3 for details).

The likelihood of the pathogens entering nature via discarded aquarium water is significantly higher than for the other pathways. However, only a few shrimp species of relevance to the aquarium trade are currently suspected to act as possible transmitters or situational carriers.

In sum, the project group assesses the likelihood that pathogens entering a suitable habitat in Norway through private import of shrimps to be **unlikely** to **very unlikely** with **low confidence**.

Should the pathogen enter a habitat through the pathways described above, establishment requires that the pathogens interact with a suitable host. None of the pathogens, in particular WSSV, require the shrimp host for further establishment and spread after entrance into Norwegian nature. Freshwater and marine decapods, and most likely also non-decapod crustaceans, can become infected with WSSV and probably sustain the pathogen in natural habitats. In Norway, *A. astaci* is already established in alien populations of signal crayfish (*P. leniusculus*). New introductions and establishment can take place in populations of the native noble crayfish (*A. astacus*).

In sum, the project group assesses that the likelihood of establishment in Norway is **moderately likely** with **high confidence** for *A. astaci* and **likely** with **medium confidence** for WSSV, given that the pathogens have entered Norwegian nature.

Similar to the assessment for crayfish and crabs, the likelihood of further spread is high and unavoidable within a water system. Restrictions and the demand for preventive measures to control further spread can be implemented to minimize spread between water systems (Norwegian regulation FOR-2008-06-17-819). Spread may, nevertheless, still be difficult to prevent, because birds and mammals can also act as vectors between neighbouring water systems.

Should *A. astaci* or WSSV be established, it is **likely** with **medium to high confidence** that the pathogens spread, regardless of the host that originally brought the pathogen into Norway.

6.3.2.4 RISK CHARACTERIZATION

Confirmed and suspected carriers of pathogens identified as hazards to biodiversity in Norway, *A. astaci* and WSSV, are listed for shrimps in tables 6.3.2.4-1 and 6.3.2.4-2. Here, we use similar categories as described for crayfish (section 6.1.2.4): I) known chronic carriers, II) suspected chronic carriers, III) suspected situational carriers, IV) possible pathogen transmitters, and V) no direct or circumstantial evidence for carrier status or pathogen transmission in the genus. For the evaluation, should one species within a genus be proven to belong to one of the categories, then all species in the genus is placed in the same category.

Table 6.3.2.4-1: Status of *A. astaci* and WSSV for shrimp species in trade in Norway as of today. Status I = Known chronic carrier, II = Suspected chronic carrier, III = Suspected situational carrier, IV = Possible pathogen transmitter, and V = No direct or circumstantial evidence for carrier status or pathogen transmission. For assessment of overall risk, see 6.1.2.4.

Pathogen	*A. astaci*					*WSSV*					Summary	
Status	**I**	**II**	**III**	**IV**	**V**	**I**	**II**	**III**	**IV**	**V**	**References**	**Overall risk posed as pathogen carrier**
Arachnochium mirabile					X				X		8	Low
Atya gabonensis				X					X		6,8	Moderate
Atyaephyra desmarestii					X				X		8	Low
Atyoida pilipes					X				X		8	Low
Atyopsis moluccensis				X					X		6,8	Moderate
Caridina babaulti					X				X		8	Low
Caridina brachydactyla					X				X		8	Low
Caridina breviata					X				X		8	Low
Caridina brevicarpalis					X				X		8	Low
Caridina caerulea					X				X		8	Low
Caridina cantonensis					X				X		8	Low
Caridina dennerli					X				X		8	Low
Caridina gracilirostris					X				X		8	Low
Caridina logemanni					X				X		8	Low
Caridina mariae					X				X		8	Low
Caridina multidentata					X				X		8	Low
Caridina parvidentata					X				X		8	Low
Caridina propinqua					X				X		8	Low
Caridina richtersii					X				X		8	Low
Caridina rubropunctata					X				X		8	Low
Caridina serratirostris					X				X		8	Low
Caridina simony					X				X		8	Low
Caridina spinata					X				X		8	Low
Caridina woltereckae					X				X		8	Low
Desmocaris trispinosa					X				X		8	Low
Lancaris kumariae					X				X		8	Low
Macrobrachium a. peninsulare				X				X			8,10,12	Moderate
Macrobrachium dayanum				X				X			8,10,12	Moderate
Macrobrachium dienbienphuense				X				X			8,10,12	Moderate
Macrobrachium gracilirostre				X				X			8,10,12	Moderate
Macrobrachium lanchesteri				X				X			8,10,12	Moderate
Macrobrachium pilimanus				X				X			8,10,12	Moderate
Macrobrachium rosenbergii				X				X			8,10,12	Moderate
Neocaridina davidi				X					X		8,12	Moderate
Neocaridina palmata				X					X		8,12	Moderate
Tenuipedium palaemonoides					X				X		8	Low
Xiphocaris elongata					X				X		8	Low

References: 6 = Mrugala et al 2019, 8 = OIE 2019c, 10 = Stentiford et al 2009, 12 = Svoboda et al 2014b, 14 = Sánchez-Paz 2010

Table 6.3.2.4-2: Status of *A. astaci* and WSSV for shrimp species relevant for trade in Norway in the foreseeable future. Status I = Known carrier, II = Suspected carrier, III = Not shown to be transmitting the pathogen. For assessment of overall risk, see 6.1.2.4.

Pathogen	*A. astaci*					*WSSV*					**Summary**	
Status	**I**	**II**	**III**	**IV**	**V**	**I**	**II**	**III**	**IV**	**V**	**References**	**Overall risk posed as pathogen carrier**
Arachnochium kulsiense					**X**				**X**		8	Low
Euryrhynchus amazoniensis					**X**				**X**		8	Low
Halocaridina rubra					**X**				**X**		8	Low
Macrobrachium agwi				**X**				**X**			8,10,12	Moderate
Macrobrachium idae				**X**				**X**			8,10,12	Moderate
Macrobrachium scabriculum				**X**				**X**			8,10,12	Moderate
Paracaridina zijinica					**X**				**X**		8	Low
Paratya compressa					**X**				**X**		8	Low

References: 8 = OIE 2019c, 10 = Stentiford et al 2009, 12 = Svoboda et al 2014b

7 Potential impacts on ecosystem services

Although freshwater crayfish are more sought-after in Sweden, crayfish also represent cultural, recreational, social, economic, and ecological values in Norway. In a study by Johnsen et al. (2009c), the annual harvest of legal-sized crayfish was estimated to be in the range of 8-13 tonnes. They estimated the annual local economic value in the range of 3.8-7.7 million NOK (4.1-9.6 million NOK when inflation adjusted).

Based on the study by Johnsen et al. (2009c), Magnussen et al. (2014) estimated the annual social-economic loss from signal crayfish and crayfish plague to be in the range of 7.1-18.2 million NOK (8.9-22.7 million NOK when inflation adjusted). The main effects on ecosystem services from the introduction of signal crayfish and/or crayfish plague are listed below.

Provisioning ecosystem services:

- Reduced production of noble crayfish. Will not be compensated by harvesting of signal crayfish, as this is banned in Norway (Magnussen et al. 2014).
- In Sweden, the introduction of signal crayfish incurred a cost rather than a benefit, even from a purely fisheries and national economic perspective, regardless of the massive negative impacts on biodiversity (Gren et al. 2009).

Regulating ecosystem services:

- Crayfish have the potential to accelerate organic matter decomposition (Alp et al. 2016), and from there, to alter the whole carbon cycle. If signal crayfish are introduced to sites that are historically free of crayfish, the food chains may be altered by predation on benthic invertebrates and fish eggs (Magnussen et al. 2014).
- Regarding regulating services, it should be added that some species of crayfish, such as red swamp crayfish, and crabs, such as the Chinese mitten crab, may burrow and cause considerable damage to river banks and earth levees, resulting in less resilience to flooding (Magnussen et al. 2014).

Cultural ecosystem services:

- Decreased recreational value with reduced populations of noble crayfish (Magnussen et al. 2014).

Supporting ecosystem services:

- Reduced biodiversity by depletion of noble crayfish. Altered biodiversity if signal crayfish enter localities historically free of crayfish (Magnussen et al. 2014).

8 Risk-reduction measures

8.1 Diseases

OIE and general literature provide information of known crustacean diseases along with known susceptible crustacean hosts. However, the knowledge gaps are huge regarding carrier status of known and unknown disease pathogens for many exotic crustaceans. In this perspective, all exotic crustaceans should be regarded potentially infected with a known or unknown pathogen. Precautionary measures should be taken for all alien crustacean species.

To reduce the risk to biodiversity in Norway, it is important to ensure that no alien crustaceans, or eggs thereof, enter Norwegian nature and that specimens in private keeping are free from pathogens or diseases. Screening and quarantining new specimens will reduce the chance of introducing pathogens. It is important to stress that quarantine alone, for the purpose of hindering the entrance of pathogens in general, and *A. astaci* and WSSV in particular, provides only false security in the absence of pathogen screening. The highest likelihood of pathogen import occurs when pathogen-tolerant crustaceans (chronic or situational carriers) are accompanied by pathogens without displaying clinical or visible signs of infection or disease. In order to reduce the risk of spreading diseases, eggs and living or dead animals should under no circumstances be disposed of into nature. The same applies for aquarium water or any material, such as gravel or ornamental plants, that have been in contact with the animals or water in the aquarium.

8.2 Screening for pathogens

An effective way of reducing the chance of introducing pathogens is to screen for them during quarantine of all new imports before they are sold. Screening for the listed disease pathogens that are covered in this report, not only *A. astaci* and WSSV, but also the exotic diseases, TSV and YHV1, can be accomplished by molecular tests (qPCR) according to the OIE recommendations (2019 b,c,d,e). Such screening requires that a representative number of individuals are sacrificed. Alternatively, instead of killing specimens, screening for genetic traces of pathogens can be performed on the water in which the specimens are kept. This is referred to as detection of environmental DNA (or RNA for RNA-viruses). The method is increasingly used for surveillance purposes in monitoring programmes, including the national monitoring programme for *A. astaci* (Strand et al. 2029, 2020). This could be mandatory for all imported cohorts (group of animals), and would largely reduce the risk of pathogen import with exotic crustaceans.

Importantly, such screening will only prevent sale of crustaceans with known pathogens. Unknown pathogens can, theoretically, be discovered by molecular metagenomic analyses of exotic crustaceans or holding water. However, this is expensive, and it is difficult to foresee future outcomes, e.g., which unknown microorganisms will be harmless or harmful.Further, also known pathogens with minor impact in its area of origin, could cause great harm when introduced into new habitats with naïve hosts, e.g. *Gyrodactylus salaris* that became a massive problem for Atlantic salmon in Norway when introduced in the 1970s (Bakke and Harris, 2007). Even thogh a molecular screening could reveal such "minor impact pathogens", change from minor to major impact in new areas cannot be foreseen.

8.3 Quarantine

In addition, private persons should quarantine new specimens before adding them to their aquaria. Quarantined specimens should be placed in a separate aquarium and observed to make sure they are not sick and do not infect healthy specimens already in place in the main aquarium. In order to recognize diseases, it is helpful to acquire knowledge on symptoms of diseases and be congnisant with the normal appearance and behaviour of a species. The specimens should be observed regularly, particularly looking for abnormal signs, such as spots, body film, loss of colour, or unusual behaviour. Importantly, however, this will only reduce the risk of adding pathogens to a private aquarium. Quarantine alone will not reveal pathogens that might be associated with tolerant carrier species. Instead, screening is needed to reduce the risk of introducing pathogens that may cause harm to Norwegian biodiversity.

8.4 Wild-caught specimens

Although many aquarium crustaceans are raised in captivity, some are collected in the wild. Wild-caught specimens may have a higher chance of carrying both known and unknown disease pathogens. Crustaceans (including crabs, shrimp, and crayfish) can host a wide range of pathogens and parasites, and we often lack knowledge on causes of mortality. For example, relatively little is known about viruses of wild crustaceans (Stentiford 2012). Pathogens form a natural component of any ecosystem, highlighting that extra care and screening measures should be taken when acquiring wild-caught specimens.

8.5 Disposal of specimens and disinfection

Crustacean eggs and living or dead animals should, under no circumstances, be disposed of in nature. The same applies for spill water or any material, such as gravel or ornamental plants, that have been in contact with the animals or water in the aquarium. It can also be effective to sterilize the water and equipment to kill disease-causing organisms and pathogens. This should be done using Virkon S, chlorine, saltwater, ethanol, complete desiccation, or boiling (Johnsen and Taugbøl, 2017). Note that some pathogens, including *A. astaci*, will not be eliminated by ultraviolet sterilizers, and some pathogens may survive contact with saltwater or freezing.

Diseases may also be transmitted in crustacean feed. This pathway was likely responsible for the emergence of WSSV in penaeid shrimps in Asia that were fed imported frozen crabs (Stentiford 2012), indicating that freezing is not sufficient. As a risk-reducing measure, raw frozen crustaceans should not be used as feed as the virus survive freezing; using boiled crustaceans should be safe.

8.6 Information campaigns

Information campaigns are important risk-reducing measures, both regarding the risk of exotic crustaceans entering Norwegian nature, as well as the risk of unintended introduction of pathogens. Although import of certain exotic crustaceans is legal, there is a large body of information regarding criteria and responsibilities in the legal framework (c.f. the regulation regarding alien species) that must be followed. The legal framework is complex when the risk of importing pathogens is also considered. A leaflet or guide with information to help both professional and hobby aquarists is urgently needed that should cover regulations, requirements, consequences of (illegal) release, and provide advice to reduce the risk of pathogen-import and dissemination to natural habitats.

9 Uncertainties

9.1 Taxonomic and nomenclature uncertainties

A risk assessment may be compromised if a taxon was not correctly identified by those that provided ecological information for the risk assessment, of by the end users of the risk assessment. Stable taxonomy and nomenclature are essential for communication, understanding biological diversity, conservation work, and identification of problems with invasive species.There are two parallel, but closely connected, uncertainties regarding taxonomy and nomenclature.

The first concerns the lack of modern taxonomic revision. We can not be certain on the number of species within a taxonomic group or on how species within the group are related. For example, some specimens may be variants (morphology or colour) within a species, whereas others will form separate species.

The second deals with nomenclature. Many names are synonyms (different names given to the same species), mostly due to new descriptions of previously described and named species. Some genera have been revised and given new names. A minor problem is homonymy (the same name given by different authors for different species).

9.2 Uncertainties relating to the species' general biology

Several abiotic and biotic factors determine the habitat selection, natural distribution, and ability to spread to and colonize new areas for any particular species. The chitinous exoskeleton of crustaceans is reinforced with calcium salts, implying that they need access to calcium. Many habitats in Norway do not have calcareous rock and are therefore not suitable for crustaceans with high calcium demands.

Many species of crustaceans are food generalists, feeding on dead or living plants and animals. Some species may have more specific demands, but, in most cases, this is poorly described. Generally, species that are ecologically less specialized with respect to environmental factors (climate, calcium, and food) have wider distributions – and should be able to colonize new areas more easily. Niche width and tolerance to disturbances were assessed in the AS-ISK screening, but are frequently poorly known.

The nature of ecological interactions, such as competition and predation, normally vary depending on the evolutionary context and environmental conditions in which they occur. As a result, ecological interactions are often difficult to define and measure (Harrison and Cornell 2008, Ricklefs 2008). This suggests that it may be difficult, and sometimes impossible, to foresee ecological interactions between species that normally do not have a shared native range, such as interactions between alien and native species. Impacts of most alien species are poorly understood (Jeschke et al. 2014) and there are large uncertainties relating to the impacts of alien species.

9.3 Uncertainties relating to climatic tolerance and niche

Climate influences the distribution of most species and is an integral factor when assessing the likelihood of establishment and spread of alien species in Norway. Based on the distribution of species and biomes on Earth, there is limited overlap between species in tropical and subtropical regions, and species at high latitudes, such as Norway. It is therefore fair to assume that tropical and subtropical crustacean species will be unlikely to be able to establish and spread in Norway. Some temperate species may potentially survive in Norway. However, the exact climatic tolerance of most of the crustaceans that we have assessed is poorly known. Hence, there are uncertainties involved when we assess the likelihood of survival of a species in Norway based on the similarities between climate conditions in the species' native range and the climate of Norway, both now and for year 2100.

9.4 Uncertainties relating to future climates

Several factors create uncertainties in climate projections based on greenhouse gas emission scenarios. First, we lack knowledge about the sensitivity of the climate system on Earth. Second, the general circulation models used to model future climates have limitations (ICPP 2013). Projections that follow scenarios with low emissions, such as RCP4.5, are, in general, more certain than projections that follow scenarios with high emissions, such as RCP8.5. Also, the upper boundary of the climate projections is beset with larger uncertainties than the lower boundary. In attempting to cancel out uncertainties in the general circulation models, many researchers have chosen to base climate projections on an ensemble of models. VKM has adopted projections made by the Norwegian Centre for Climate Services (Norsk klimaservicesenter) that are based on an ensemble of ten different climate models (Hanssen-Bauer et al. 2015).

The projected mean annual temperature for Norway in 2100, under scenario RCP8.5, is 5.0 °C with an upper boundary (90th percentile) of 6.3 °C and a lower boundary (10th percentile) of 3.8 °C (https://klimaservicesenter.no/faces/mobile/scenarios.xhtml, accessed 06.01.2021). The uncertainties of the projected winter- and summer temperatures are about the same as the uncertainties for annual temperature.

9.5 Uncertainties relating to diseases

We lack fundamental knowledge on key aspects of the life history of important pathogens and on the mortality associated with certain agents (Shields 2003). Improved knowledge on pathogens may help mitigate their spread and impact. The risk for introducing WSSV through trade of exotic crustaceans is high, since this virus is suspected to be able to infect all decapod species. How this virus will affect Norwegian crustacean biodiversity, should it become established, is highly uncertain, but some studies suggest it could become severe in warm summers, both for freshwater and marine crustaceans. Furthermore, although TSV, YHV1 and other notifiable crustacean pathogens in the OIE were not evaluated as "high risk" for Norwegian crustaceans and climates, this is assessed with low confidence in the absence of scientific studies. Viruses adapt quickly through mutations (Longdon et al. 2014), which might enable a virus to target new hosts and/or become more virulent and/or adapt to other climate- and temperature conditions.

A general trait with infectious emerging diseases, is that the pathogens causing the diseases are commonly unknown until they are discovered and described for the first time after the emergence of unexplained disease - that might include mass mortality (Fisher et al. 2012, Karesh et al. 2005). This was the case of crayfish plague, which emerged as a consequence of a cross-continental host jump of an unknown pathogen. The pathogen was later described as the oomycete *A. astaci,* which spread from resistant American crayfish to naïve European crayfish (Söderhäll and Cerenius 1999). The catastrophic results strongly suggest that we should always acknowledge the potential of introducing, in fact creating, new diseases when allowing the import of live alien crustaceans. However, we can never predict how, or from which species, a new disease might emerge. We know that many pandemics and plagues result from cross-continental pathogen host jumps facilitated by human transport, trade, and/or introduction or unintentional release or escapes of invasive species (Fisher et al. 2012, Karesh et al. 2005, Longdon et al. 2014, Sheele et al. 2019, Ogden et al. 2019). In such circumstances, the transport host itself might not establish on the new continent, while the new disease pathogen might well establish and spread.

10 Conclusions (with answers to the terms of reference)

10.1 Risk of negative impact on biodiversity in Norway from import and keeping of relevant species of freshwater crustaceans

Freshwater crustaceans imported for private keeping in freshwater aquaria can pose a threat to biodiversity in Norway by at least two main routes. First, if a species enters, establishes, and spreads in Norwegian nature, it can negatively affect biodiversity through ecological interactions. Examples include predation on native species, competition for food and space, and reproductive interference (see 10.1.1 and 10.1.2). Secondly, the imported species can pose a threat by carrying and transmitting pathogens, some of which pose a high risk to Norwegian crustacean biodiversity (see 10.1.3).

Importantly, in order to pose a threat due to ecological interactions, the species need to escape captivity (intentional or unintentional release). They also need to end up in a suitable habitat in order to establish and spread. Although a series of more or less likely events need to occur, such events are not uncommon; they have already occurred worldwide on several occasions. However, the species can pose a threat as carriers of pathogens, even without escaping. This is because the pathogens can enter nature in Norway through the disposal of aquarium water.

10.1.1 Risk posed by crayfish in regard to the species biology and the potential ecological impact

With regard to ecological effects, alien crayfish primarily pose a threat to the red-listed native noble crayfish (*A. astacus*). Although crayfish plague is the main threat to this species, some alien species can decimate local populations of noble crayfish through competition for food and space, and through reproductive interference (in the case of signal crayfish). This risk assessment suggests that all alien crayfish species can have a moderate impact on biodiversity, although the likelihood of this happening is very low. There is a higher likelihood associated with larger species and species with a high fecundity. These may potentially severely alter the biological community of freshwater ecosystems through predation and behavioural traits, should they enter and establish in a suitable habitat (see 6.1.1.1 and 6.1.1.2 for details, and 6.1.1.3 for an assessment of the likelihood of these events).

The risks posed by the species with the greatest potential for negative impact, as assessed by AS-ISK (see 2.1.1 and Table 4-1) and GB-NNRA (see Appendix IVa), are shown in Figure 10.1.1-1. All other species were assessed using AS-ISK only. These have not been assigned a risk value, and are considered to have a low potential to affect biodiversity in Norway through ecological interactions.

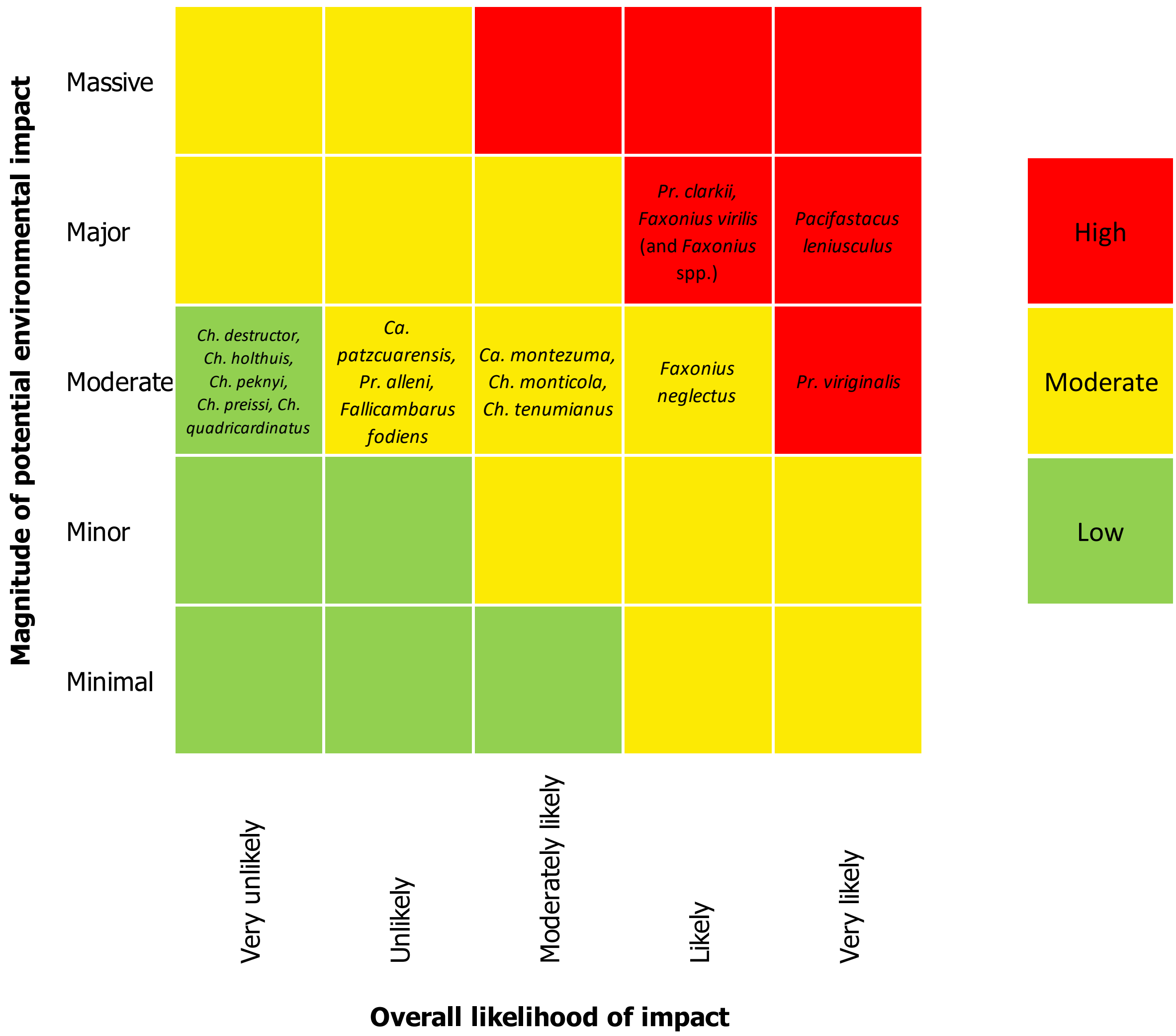

Figure 10.1.1-1: Risk of negative impact on biodiversity in Norway posed by each of the risk assessed crayfish species. *Ca.* = *Cambarellus*, *Ch.* = *Cherax,* and *Pr.* = *Procambarus*.

10.1.2 Risk posed by crabs and shrimps in regard to the species biology and the potential ecological impact

There are no native freshwater crab or shrimp species in Norway. Hence, the impact on native biodiversity through ecological interactions from imported crabs and shrimps are of lesser concern than for crayfish. However, both crabs and shrimps can, to some degree, compete for food and space with native crustaceans and other species with overlapping niches. There are at least three species of invasive crabs and caridean shrimps in Europe that can have antagonistic effects. These include Sally lightfoot (*P. gibbesi*), Chinese mitten crab (*E. sinensis* – not assessed in this report) and Red cherry shrimp (*N. davidi*) (see 6.2.1.1 and 6.3.1.1). As with all alien species, should they establish, crabs and shrimps may pose a threat to a number of species in Norway, but especially endangered species (in this case, especially macroinvertebrates). Importantly, the majority of crab and shrimp species in the aquarium trade are tropical species and therefore very unlikely to establish in Norway (see 6.2.1.3 and 6.3.1.3). Only two species are potentially able to establish, given predicted climate changes towards year 2100. The risks posed by the species with the greatest potential for negative impact (following the risk ranking from AS-ISK, see 2.1.1 and Table 4.1-1, and the GB-NNRA risk assessment, see Appendix IVb and IVc) are shown in Figure 10.1.2-1. All other species were assessed with AS-ISK only. These have not been assigned a risk, and are considered to have a low potential to affect biodiversity in Norway through ecological interactions.

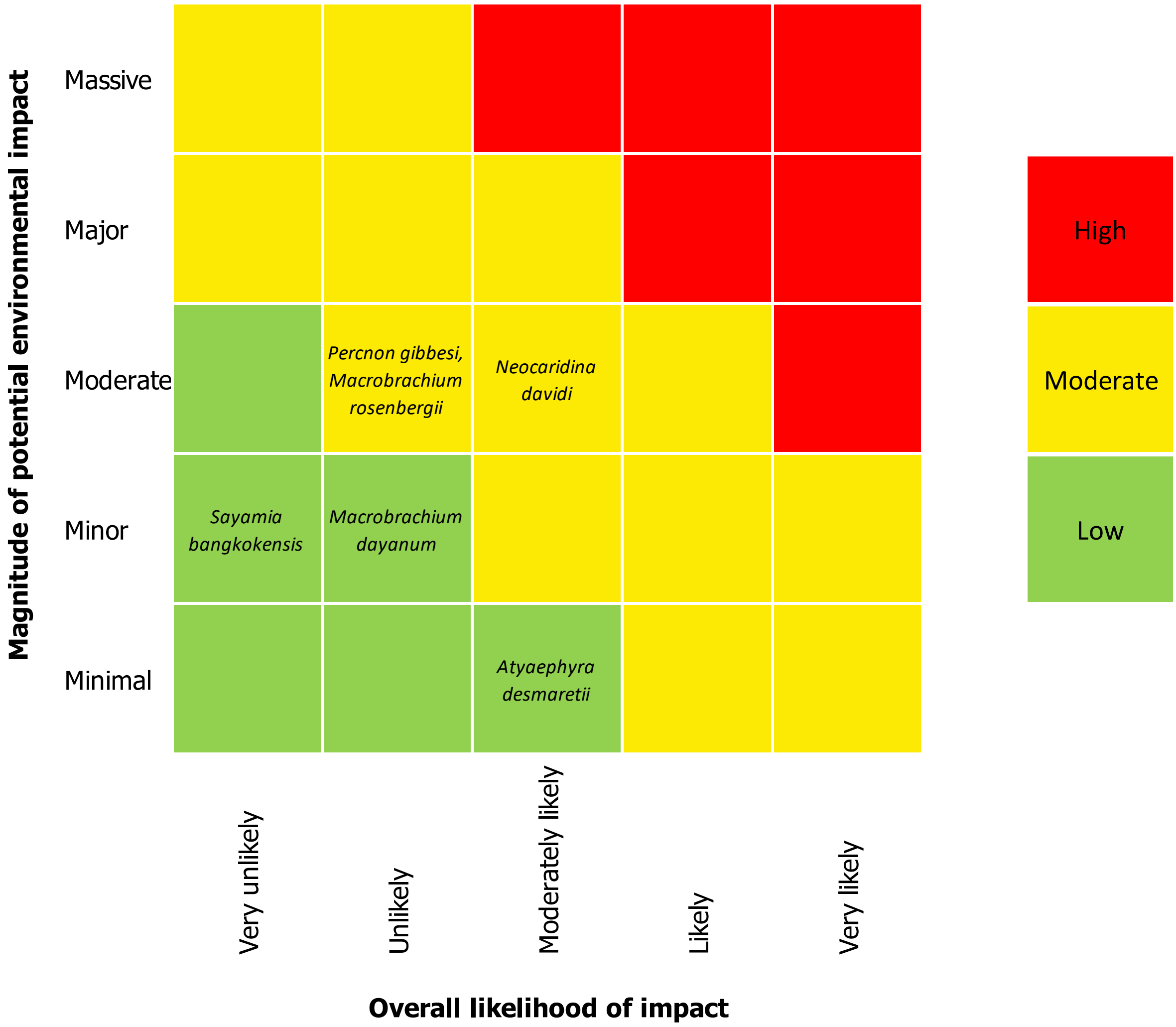

Figure 10.1.2-1: Risk of negative impact on biodiversity in Norway posed by each of the risk assessed crab and shrimp species.

10.1.3 Risk posed by freshwater crustaceans as vector of pathogens

Several pathogens are associated with freshwater and marine crustaceans (see Table 1.5.1). Four of these were considered in this assessment to pose a potential risk; *A. astaci* causing crayfish plague in all freshwater crayfish apart from American crayfish, WSSV causing white spot disease in all freshwater and marine decapods, TSV causing Taura syndrome in a narrow range of marine tropical shrimps, and YHV1 causing yellow head disease, also in a narrow range of marine tropical shrimps. Of these, *A. astaci* and WSSV were assessed regarding their potential impact on biodiversity in Norway (see Chapter 5).

All species were assigned a risk category based on the likelihood of impact: I) known chronic carriers, II) suspected chronic carriers, III) suspected situational carriers IV) possible pathogen transmitters, and V) no direct or circumstantial evidence for carrier status or pathogen transmission in the genus (Figure 10.1.3-1). The assigned category is found in Tables 6.1.2.4-1 and 6.1.2.4-2 for crayfish, Tables 6.2.2.4-1 and 6.1.2.4-2 for crabs, and Tables 6.3.2.4-1 and 6.3.2.4-2 for shrimps.

All freshwater crayfish species in trade today, or relevant for future trade, were associated with **high risk** and **moderate risk** as vectors of pathogens, as they occupy the categories ranging from "known chronic carriers " of *A. astaci* to "possible transmittors" of *A. astaci*. **We assess all American species of crayfish to have high risk, and the Australian species (i.e., *Cherax* spp.) to have moderate risk**.

Of the freshwater crab species in trade today, or relevant for future trade, ***Potamon* spp.** (suspected situational carrier of *A. astaci*) and ***Parathelphusa* spp.** (suspected situational carrier of WSSV) were assigned **moderate risk** as vectors of pathogens.

Of the freshwater shrimp species in trade today, or relevant for future trade, ***Macrobrachium* spp.** (possible transmittors of *A. astaci* and suspected situational carrier of WSSV) and ***Atya* spp.**, ***Atyopsis* spp.**, and ***Neocaridina* spp.** (possible transmittors of *A. astaci*) were assigned **moderate risk** as vectors of pathogens.

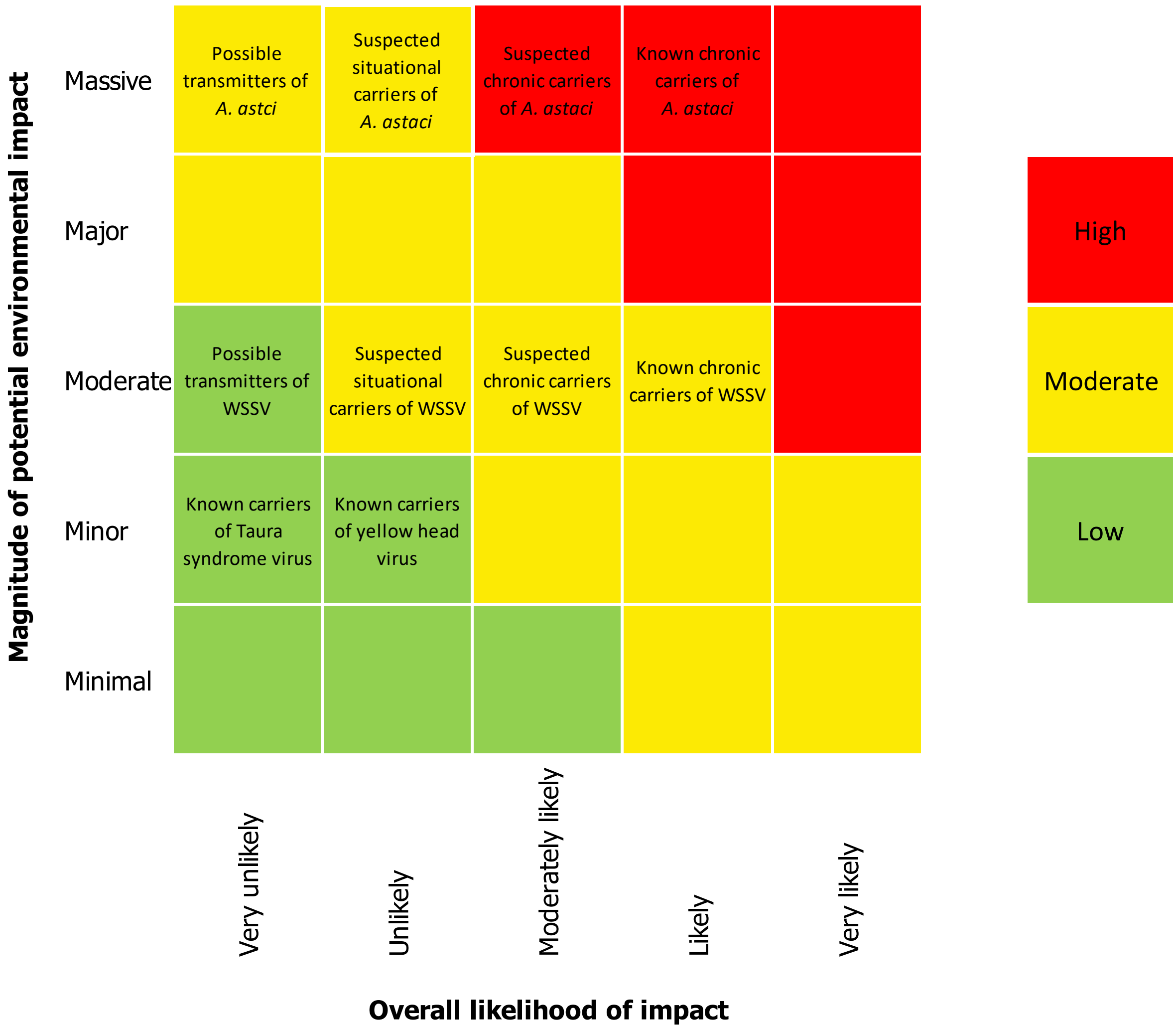

Figure 10.1.3-1: Overview of the assessed risk of negative impact on biodiversity in Norway from transfer of pathogens from freshwater crustaceans following import and private keeping. Pathogens include *Aphanomyces astaci* causing crayfish plague, white spot syndrome virus (WSSV) causing white spot disease, Taura syndrome virus (TSV) causing Taura syndrome and yellow head disease virus genotype 1 (YHV1) causing yellow head disease.

10.2 Species that can survive temperatures below 5 °C

As required by the terms of reference, we have assessed the ability of the various relevant species to survive at temperatures below 5 °C. Although many species of organisms may survive for short periods (days) at temperatures below 5 °C, they may not survive for weeks or months. The critical issue is whether alien organisms are be able to complete a full life cycle, which affects whether the species can become established in Norwegian nature. Hence, we have assessed the ability to survive average temperatures colder that 5 °C for a full winter season (3 months: December, January, and February), as this may be a natural bottleneck for the establishment of some alien species in Norwegian nature. However, many species that live in freshwaters, such as crayfish, can survive at low temperatures during the winter as they are using habitats below the thermocline in lakes. Here, the temperature rarely increases above 4 to 5 °C. For crayfish, temperatures during summer are perhaps more critical than winter temperatures. Summers need to be sufficiently warm to ensure juvenile development and survival (recruitment). An old "rule of thumb" states that three summer months with average temperatures above 15 °C may be needed for a noble crayfish population to establish (Abrahamsson 1972). However, crayfish populations have been found in streams further north than would be expected from the ambient temperature (Pursiainen and Erkamo 1991, Bohman 2021). In general, there is a lack of information on thermal preferences for most (94%) crayfish species (Westhoff and Rosenberger 2016). Table 10.2-1 lists the species, of those assessed in this report, that has any potential of surviving winter temperatures in Norway.

In the context of risk to Norwegian biodiversity, it is more important to consider the risk of pathogen introduction. Crustaceans that do not survive at temperatures below 5 °C could still spread accompanying pathogens, which, in turn, might cause mass mortality in Norwegian crustacean populations. There are many examples, including the first introduction of *A. astaci* (genotype A) to Europe in the 1860s, where *A. astaci* spread all over Europe in a period of nearly 100 years, while the (still unidentified) American crayfish host species never established in Europe (Söderhäll and Cerenius 1999, Vrålstad et al. 2014).

Table 10.2-1: Expert judgement regarding survival of relevant crustacean species at temperatures below 5 °C during winter (December, January, and February). The species are categorized according to their occurrence in trade in Norway, both currently and in the future. The remaining species in this risk assessment will likely not survive below 5 °C during winter.

Crayfish currenty kept	Can survive below 5 ºC
Cambarellus patzcuarensis	MAYBE
Cherax quadricarinatus	MAYBE
Cherax tenuimanus	MAYBE
Faxonius virilis	YES
Faxonius spp.	YES
Procambarus alleni	MAYBE
Procambarus clarkii	YES
Procambarus paeninsulanus	MAYBE
Procambarus virginalis	YES
Crayfish relevant for future keeping	
Cambarellus montezumae	MAYBE
Cambarellus texanus	MAYBE
Cherax monticola	MAYBE
Faxonius neglectus	YES
Faxonius spp.	YES
Pacifastacus leniusculus	YES
Crabs currenty kept	
Percnon gibbesi	MAYBE
Shrimps currenty kept	
Neocaridina davidi	MAYBE

10.3 Impact of climate change on the assessment of risk to biodiversity in Norway

The present climate of Norway is probably too cold for the establishment and spread of most of the species that we have assessed. In the perspective of climate change towards year 2100, it seems likely that more alien species will be able to establish. The consequences are a greater risk of impact on biodiversity in Norway through ecological effects and through spread of pathogens.

WSSV can be sustained in latent infections, and then cause high mortality rates when temperatures rise above 20 °C. Many lakes in Norway presently have water temperatures above 20 °C for a sufficient period to allow WSSV to cause crayfish mass mortalities. Given an increase in temperatures associated with climate change, water bodies and crayfish habitats in large areas in southern Norway will experience water temperatures of sufficient warmth and for sufficient durations for WSSV to cause crayfish mass mortalities. Importantly, WSSV might also reduce populations of non-decapod crustaceans, although knowledge is scanty. Should this occur, crustaceans that constitute important elements of food-webs could be affected, which, in turn, could alter the ecosystems.

10.4 Potential impact on ecosystem services

Introduction of alien crustaceans and pathogens can have several impacts on ecosystem services. Alien species of crayfish and crabs may burrow, causing considerable damage to riverbanks and earth levees, resulting in less resilience to flooding. Alien organisms may also cause reductions in the populations of noble crayfish, which represent cultural, recreational, social, economic, and ecological values in Norway.

If the listed disease pathogens are introduced through import of exotic crustaceans, regulations involving bans and restrictions may be implemented in order to control the disease development and further spread. These are likely to have knock-on effects on human recreational activities and the tourist industry.

11 Data gaps

The availability of data on freshwater crustacean species and pathogens is highly variable. Some species and pathogens have been extensively studied, while there is little, if any, information for other species. General data gaps include:

- With respect to taxonomy, there is a need for further taxonomic research and for stabilization of species names within the focal taxa groups. Some scientific names still being used for some commercially and privately traded species and that we have assessed here, are no longer valid.
- Species-specific temperature tolerance data, and especially lower tolerance limits.
- Knowledge of species distribution for some of the taxa assessed in this report.
- Knowledge on the ecological impacts of crustaceans.
- Knowledge on the pathogens spread by crustaceans, both regarding the species of crustaceans and the species of pathogens.
- Knowledge on the impacts of the pathogens spread by crustaceans, including impacts on ecosystems and human health.
- Knowledge on the potential carrier status of pathogens for the majority of species relevant for import. A lack of pathogen reports does not reflect proven pathogen absence, but rather an absence of relevant studies on the topic.
- The performance and impact of assumed low-risk tropical diseases, such as TSV and YHV1, in a cold climate, including the virus's ability to react, mutate, and adapt to new temperature ranges, climate conditions, and hosts.

References

Abrahamsson S. (1972). Fecundity and growth of some populations of *Astacus astacus* Linné in Sweden. Report from the Institute of Freshwater Research, Drottningholm 52: 23-37.

Ackefors H. (1998). The culture and capture crayfish fisheries in Europe. World Aquaculture Magazine 29, 18-67.

Agersnap S, Larsen WB, Knudsen SW, Strand D, Thomsen PF, Hesselsøe M and Møller PR. (2017). Monitoring of noble, signal and narrow-clawed crayfish using environmental DNA from freshwater samples. PLoS One, 12(6), e0179261.

Alp M, Cucherousset J, Buoro M and Lecerf A. (2016). Phenological response of a key ecosystem function to biological invasion. Ecol Lett, 19: 519-527.

Bakke TA, Cable J and Harri, PD. (2007). The biology of gyrodactylid monogeneans: the "Russian-doll killers". Advances in parasitology, 64, 161-460.

Baumgartner WA, Hawke JP, Bowles K, Varner PW and Hasson KW. (2009). Primary diagnosis and surveillance of white spot syndrome virus in wild and farmed crawfish (*Procambarus clarkii, P. zonangulus*) in Louisiana, USA. Diseases of aquatic organisms, 85(1), 15-22.

Bir J, Howlader P, Ray S, Sultana S, Khalil SI and Banu GR. (2017). A critical review on white spot syndrome virus (WSSV): A potential threat to shrimp farming in Bangladesh and some Asian countries. International Journal of Microbiology and Mycology, 6(1), 39-48.

Blindow I, Hamrin SF and Larson P-E. (1984). Förekomst av *Procambarus clarkii* i Skåne hösten 1984. Limnologiska Institutionen, Lunds Universitet, Lund, Sweden.

Bohman P. (2021). Swedish Crayfish Database. Swedish University of Agricultural Sciences, Department of Aquatic Resources. http://www.slu.se/kraftdatabasen [accessed 2021-01-17]

Bohman P, and Edsman L (2011). Status, management and conservation of crayfish in Sweden: results and the way forward. Freshwater Crayfish 18:19–26.

Bohman P, Edsman L, Martin P, and Scholtz G. (2013). The first Marmorkrebs (Decapoda: Astacida: *Cambaridae*) in Scandinavia. BioInvasions Records, 2(3), 227-232.

Bohman P, Nordwall F and Edsman L. (2006). The effect of the large-scale introduction of signal crayfish on the spread of crayfish plague in Sweden. Bulletin Français de la Pêche et de la Pisciculture 380-381:1291–1302.

Bojko J, Behringer DC, Moler P, Stratton CE and Reisinger L. (2020). A new lineage of crayfish-infecting Microsporidia: The *Cambaraspora floridanus* n. gen. n. sp.(Glugeida:

Glugeidae) complex from Floridian freshwaters (USA). Journal of invertebrate pathology, 171, 107345.

Bonami J-R, Shi Z, Qian D and Sri Widada J. (2005). White tail disease of the giant freshwater prawn, *Macrobrachium rosenbergii*: separation of the associated virions and characterization of MrNV as a new type of nodavirus. Journal of Fish Diseases 28:23-31.

Buisson L, Grenouillet G, Villéger S, Canal J, Laffaille P. (2013) Toward a loss of functional diversity in stream fish assemblages under climate change. Global Change Biology 19: 387-400.

Caffrey JM, Baars JR, Barbour JH, Boets P, Boon P, Davenport K et al. (2014). Tackling invasive alien species in Europe: the top 20 issues. Management of Biological Invasions, 5(1), 1.

Choi HJ, Kwon HC, Jung HJ and Kang YJ. (2018). Survey of viral and bacterial pathogens in ornamental aquatic crustaceans imported into South Korea. Aquaculture, 495, 668-674.

Chucholl C and Wendler F. (2017). Positive selection of beautiful invaders: long-term persistence and bio-invasion risk of freshwater crayfish in the pet trade. Biological Invasions, 19(1), 197-208.

Copp G and Vilizzi L. (2020). Aquatic Species Invasiveness Screening Kit (AS-ISK) v2.2.

Coutts ADM, Moore KM, Hewitt CL. (2003). Ships' sea-chests: an overlooked transfer mechanism for non-indigenous marine species? Marine Pollution Bulletin, 46:1504-1515.

Creed RP. (1994). Direct and Indirect Effects of Crayfish Grazing in a Stream Community. Ecology 75(7), 2091-2103.

Crowl TA, McDowell WH, Covich AP and Johnson SL. (2001). Freshwater shrimp effects on detrital processing and nutrients in a tropical headwater stream. Ecology, 82(3), 775–783.

Cumberlidge N, Ng PK, Yeo DC, Magalhães C, Campos MR, Alvarez F. et. al. (2009). Freshwater crabs and the biodiversity crisis: importance, threats, status, and conservation challenges. Biological Conservation, 142(8), 1665-1673.

DAISIE (2009) Handbook of Alien Species in Europe. Springer, Dordrecht, The Netherlands

Daltorp J. (2008). Rapport prøvekrepsing i Øymarksjøen 2008. Utmarksavdelingen i Akerhus og Østfold, rapport 4-2008.

De Grave S, Cai Y, Anker A. (2008). Global diversity of shrimps (Crustacea: Decapoda: *Caridea*) in freshwater. Hydrobiologia; 595: 287–293.

De Grave S, Smith KG, Adeler NA, Allen DJ, Alvarez F, Anker A and Wowor D. (2015). Dead Shrimp Blues: A Global Assessment of Extinction Risk in Freshwater Shrimps (Crustacea:

Decapoda: *Caridea*). PLOS ONE, 10(3), e0120198.

Delsinne T, Lafontaine R-M, Beudels RC, Robert H. (2013). Risk analysis of the Louisiana Crayfish *Procambarus clarkii* (Girard, 1852). - Risk analysis report of non-native organisms in Belgium from the Royal Belgian Institute of Natural Sciences for the Federal Public Service Health, Food chain safety and Environment. 63 p.

Dey BK, Dugassa GH, Hinzano SM and Bossier P. (2020). Causative agent, diagnosis and management of white spot disease in shrimp: A review. Reviews in Aquaculture, 12(2), 822-865.

Diaz JH. (2013). Paragonimiasis acquired in the United States: native and nonnative species. Clinical Microbiology Reviews, 26(3), 493-504.

Diéguez-Uribeondo J and Söderhäll K. (1993). *Procambarus clarkii* Girard as a vector for the crayfish plague fungus, *Aphanomyces astaci* Schikora. Aquaculture Research, 24(6), 761-765.

Dittel AI, Epifanio CE (2009) Invasion biology of the Chinese mitten crab *Eriocheir sinensis*: a brief review. Journal of Experimental Marine Biology and Ecology 374: 79–92.

Dobson MK, Magana AM, Lancaster J, Mathooko JM. (2007). Aseasonality in the abundance and life history of an ecologically dominant freshwater crab in the Rift Valley, Kenya. Freshwater Biology 52, 215–225.

Dudgeon D, Cheung CPS. (1990). Selection of gastropod prey by a tropical freshwater crab. Journal of Zoology 210, 147–155.

Edmonds NJ, Riley WD and Maxwell DL. (2011). Predation by *Pacifastacus leniusculus* on the intra-gravel embryos and emerging fry of *Salmo salar*. Fisheries Management and Ecology, 18(6), 521-524.

Edsman L. (2004). The Swedish story about import of live crayfish. Bulletin Francaise de la Pêche et Pisciculture 372-373:281– 288.

Edsman L and Schröder S. (2009). Åtgärdsprogram för flodkräfta 2008–2013 (*Astacus astacus*). Report nr. 5955. Fiskeriverket och Naturvårdsverket, Drottningholm, Sweden.

Edsman L, Füreder L, Gherardi F and Souty-Grosset C. (2010). *Astacus astacus*. The IUCN Red List of Threatened Species 2010.

Erkamo E, Ruokonen T, Alapassi T, et al. (2010). Evaluation of crayfish stocking success in Finland. Freshwater Crayfish 17: 77–83.

Fisher MC, Henk DA, Briggs CJ, Brownstein JS, Madoff LC, McCraw SL and Gurr SJ. (2012). Emerging fungal threats to animal, plant and ecosystem health. Nature, 484(7393), 186-194.

Fiskeriverket and Naturvårdsverket (1998). Action plan for the conservation of the noble crayfish in Sweden. Järvi T and Thorell L (eds), Fiskeriverket and Naturvårdsverket, Göteborg and Stockholm.

Fiskeriverket (2000). Fiske 2000 – En undersökning om svenskarnas sport- och husbehovsfiske. ISSN 1404-8590.

Forskrift om omsetning av akvakulturdyr og produkter av akvakulturdyr, forebygging og bekjempelse av smittsomme sykdommer hos akvatiske dyr https://lovdata.no/dokument/SF/forskrift/2008-06-17-819

Fosså S. (2010). Sluttrapport for prosjektet «Vurdering av akvatiske organismer for positivlister» DNs ref. 08040055. Norsk Zoobransjehandlers Forening, 52pp.

Fries G, and Tesch FW. (1965). Der Einfluss des Massenvorkommens von *Gammarus tigrinus*. Sexton auf Fische und niedere Tierwelt in der Weser. Archiv für Fischereiwis-senschaften 16, 133–150

Gherardi F, Holdich DM. (1999). Crayfish in Europe as Alien Species. Crustacean Issues. CRC Press;. ISBN-10: 9054104694.

Gherardi F. (2007). Understanding the impact of invasive crayfish. In: Gherardi (ed) Biological invaders in inland waters: Profiles, distribution, and threats, Springer. 507–542.

Global Invasive Species Database (2020). Downloaded from http://www.iucngisd.org/gisd/search.php on 05-11-2020

Grandjean F, Vrålstad T, Dieguez-Uribeondo J, Jelić M, Mangombi J, Delaunay C and Petrusek A. (2014). Microsatellite markers for direct genotyping of the crayfish plague pathogen *Aphanomyces astaci* (Oomycetes) from infected host tissues. Veterinary Microbiology, 170(3-4), 317-324.

Gren M, Isacs L and Carlsson M. (2009). Costs of alien invasive species in Sweden. AMBIO: A Journal of the Human Environment, 38(3), 135-140

Guan R-Z, and Wiles PR. (2002). Ecological Impact of Introduced Crayfish on Benthic Fishes in a British Lowland River. Conservation Biology 11(3): 641-647.

Guillén JE, Jiménez S, Triviño A, Soler G, Martínez J, and Gras D. Assessment of the effects of *Percnon gibbesi* in taxocenosis decapod crustaceans in the Iberian southeast (Alicante, Spain).

Gärdenfors U. (2010). The 2010 Red List of Swedish Species. ArtDatabanken, SLU, Uppsala, Sweden.

Habe S, Lai KP, Agatsuma T, Ow-Yang CK and Kawashima K. (1993). Crab hosts for

Paragonimus westermani (Kerbert, 1878) in Malaysia. Japanese Journal of Tropical Medicine and Hygiene, 21(3), 137-142.

Halder M and Ahne, W. (1988). Freshwater crayfish *Astacus astacus*—a vector for infectious pancreatic necrosis virus (IPNV). Diseases of Aquatic Organisms, 4, 205-209.

Harrison S and Cornell H. (2008). Toward a Better Understanding of the Regional Causes of Local Community Richness. Ecology Letters 11, 969-979.

Hessen DO, Kristiansen G and Skurdal J. (1993). Nutrient release from crayfish, and its impact on primary production in lakes. Freshwater Crayfish 9: 311-317.

Holdich DM, Gydemo R and Rogers WD. (1999). A review of possible methods forcontrolling nuisance populations of alien crayfish. Pages 245–270 in F. Gherardi andD. M. Holdich, editors. Crayfish in Europe as alien species: How to make the best of abad situation? A. A. Balkema, Rotterdam, The Netherlands.

Holdich DM, Reynolds JD, Souty-Grosset C and Sibley PJ. (2009). A review of the ever increasing threat to European crayfish from non-indigenous crayfish species. Knowledge and Management of Aquatic Ecosystems , 394-395: 46 pp.

Holdich DM and Pöckl M. (2007). Invasive crustaceans in European inland waters. In Biological invaders in inland waters: Profiles, distribution, and threats (pp. 29-75). Springer, Dordrecht.

Iacarella JC, Dick JTA, Alexander ME and Ricciardi A. (2015) Ecological impacts of invasive alien species along temperature gradients: testing the role of environmental matching. Ecological Applications 25:706-716.

IPCC. (2013). Climate Change 2013: The Physical Science Basis, IPCC Working Group I Contribution to AR5, Cambridge University Press, Cambridge, UK. pp. 1535.

Jelmert A. (2011). Risikovurdering av marine arter som benyttes i forskning, økotoksikologiske analyser, undervisning og akvakultur, og som omsettes til akvarister og som levende sjømat i Norge.

Jelmert A, Gulliksen B, Oug E, Sundet J og Falkenhaug T (2018). *Percnon gibbesi*, vurdering av økologisk risiko. Fremmedartslista 2018. Artsdatabanken. Hentet (2021, 10. januar) fra https://www.artsdatabanken.no/fab2018/N/3365

Jeschke JM, Bacher S, Blackburn TM et. al. (2014). Defining the impact of non-native species. Conservation Biology, 28(5), 1188-1194.

Jesse, R., Pfenninger, M., Fratini, S., Scalici, M., Streit, B., & Schubart, C. D. (2009). Disjunct distribution of the Mediterranean freshwater crab *Potamon fluviatile*—natural expansion or human introduction?. Biological Invasions, 11(10), 2209.

Jiravanichpaisal P, Söderhäll K and Söderhäll I. (2004). Effect of water temperature on the immune response and infectivity pattern of white spot syndrome virus (WSSV) in freshwater crayfish. Fish & shellfish immunology, 17(3), 265-275.

Johannesen E and Nguyen V. (2016). *Paragonimus kellicotti*: a lung infection in our own backyard. Case reports in pathology, 2016.

Johnsen SI, Taugbøl T, Andersen O, Museth J and Vrålstad T. (2007). The first record of the non-indigenous signal crayfish *Pasifastacus leniusculus* in Norway. Biological Invasions 9:939-941.

Johnsen S and Taugbøl T. (2017). Kreps og krepsing. Brosjyre utarbeidet for Miljødirektoratet og Mattilsynet. Available from:https://www.miljodirektoratet.no/globalassets/publikasjoner/m227/m227.pdf

Johnsen SI, Dervo B, and Lein K. (2009). Økonomiske konsekvenser for edelkrepsfisket ved innførsel av signalkreps, krepsepest og vasspest - NINA Rapport 318. 35pp

Johnsen SI, Strand D, Vrålstad T and Wivestad T. (2009). Introdusert signalkreps på Ostøya i Bærum kommune, Akershus. Kartlegging og krepsepestanalyse. Norsk institutt for naturforskning (NINA), Lillehammer. - NINA Rapport 499. 17pp.

Johnsen SI, Strand D and Toverud Ø. (2009). Kartlegging av signalkreps i Øymarksjøen, Haldenvassdraget - Utbredelse og bestandsstatus- NINA Rapport 522. 18pp.

Johnsen SI, Strand D, Hansen M, Biering E and Vrålstad T. (2011). Signalkreps og krepsepest i Skittenholvatnet og Oppsalvatnet, Hemne kommune - Kartlegging, vurdering av spredningsrisiko og forslag til tiltak. - NINA Rapport 753. 27pp.

Johnsen SI. (2015). Signalkreps i Kvesjøen, Lierne kommune - kartlegging, spredningsrisiko og forslag til tiltak – NINA Rapport 1093. 13pp.

Johnsen SI, Sandodden R, Museth J and Skurdal J. (2012). Mark-Recapture Experiments with Baited Traps and Toxic Chemicals. Freshwater Crayfish 19(1): 63-68.

Johnsen SI and Vrålstad T. (2017). Edelkreps (*Astacus astacus*). Naturfaglig utredning og forslag til samordning av overvåkingsprogrammene for edelkreps og krepsepest. Lillehammer: Norsk institutt for naturforskning. NINA rapport 1339. 39pp.

Johnsen SI, Jensen T and Kjærstad G (2018). *Acheta domestica*, vurdering av økologisk risiko. Fremmedartslista 2018. Artsdatabanken. Hentet (2020, 29. november) fra https://www.artsdatabanken.no/Fab2018/N/2473

Johnsen SI, Strand DA, Rusch J and Vrålstad T. (2019). National surveillance of noble crayfish and the spread of signal crayfish – presentation of surveilance data and population status. NINA Report 1761.

Jussila J, and Edsman L. (2020). Relaxed attitude towards spreading of alien crayfish species affects protection of native crayfish species: Case studies and lessons learnt from a fennoscandian viewpoint. Freshwater Crayfish, 25(1): 39-46.

Jussila J, Maguire I, Kokko H, Tiitinen V, and Makkonen J. (2020). Narrow-clawed crayfish in Finland: *Aphanomyces astaci* resistance and genetic relationship to other selected European and Asian populations. Knowledge & Management of Aquatic Ecosystems, (421), 30.

Jussila J and Mannonen A. (2004). Crayfisheries in Finland, a short overview. Bulletin Français de la Pêche et de la Pisciculture, (372-373), 263-273.

Jussila J, Makkonen J, Kokko H, Mäkinen P. (2014). Numerous population crashes of wild signal crayfish (*Pacifastacus leniusculus*) in Southern Finland. Freshwater Crayfish 20(1): 73–79. doi: 10.5869/fc.2014.v20-1.73

Karesh WB, Cook RA, Bennett EL and Newcomb J. (2005). Wildlife trade and global disease emergence. Emerging infectious diseases, 11(7), 1000.

Kjærstad G. (2017). Faglig risikovurdering av ferskvannsinvertebrater for akvarie- og hagedamhold. NTNU Vitenskapsmuseet, 13pp.

Klotz W, Miesen FW, Hüllen S, Herder F. (2013) Two Asian freshwater shrimp species found in a thermally polluted stream system in North-Rhine-Westphalia, Germany. Aquat. Invasions, 8; 333-339.

Kouba A, Petrusek A, Kozák P. (2014). Continental-wide distribution of crayfish species in Europe: update and maps. Knowledge and Management of Aquatic Ecosystems;413:05.

Lambertini M, Leape J, Marton-Lefèvre J, Mittermeier RA, Rose M, Robinson JG, Stuart SN, Waldman B, Genovesi P. (2011). Invasives: a major conservation threat. Science. 333(6041):404-5.

Lasenby DC, Northcote TG, Fürst M. (1986). Theory, practice, and effects of Mysis introductions to North American and Scandinavian lakes. Canadian Journal of Fisheries and Aquatic Sciences 43, 1277–1284.

Lindquist HDA and Cross JH. (2017). 195 - Helminths. In Cohen, J., W. G. Powderly & S. M. Opal (eds) Infectious Diseases (Fourth Edition). Elsevier, 1763-1779.e1.

Lipták B and Vitázková B. (2015). Beautiful, but also potentially invasive. Ekologia Bratislava, 34; 155-162.

Lo CF and Kou GH. (1998). Virus-associated white spot syndrome of shrimp in Taiwan: a review. Fish Pathol., 33, 365–371.

Lodge DM, Taylor CA, Holdich DM and Skurdal J. (2000). Non-indigenous crayfishes threaten

North American freshwater biodiversity: lessons from Europe. Fisheries 25, 7–20

Longdon B, Brockhurst MA, Russell CA, Welch JJ and Jiggins FM. (2014). The evolution and genetics of virus host shifts. PLoS Pathog, 10(11), e1004395.

Longshaw M. (2011). Diseases of crayfish: a review. Journal of invertebrate pathology, 106(1), 54-70.

Magnussen K, Lindhjem H, Pedersen S and Dervo B. (2014). Samfunnsøkonomiske konsekvenser av fremmede arter i Norge: Metodeutvikling og noen foreløpige tall. Vista Analyse AS. Rapportnummer 52.

Maitland DP. (2003). Predation on snakes by the freshwater land crab *Eudaniela garmani*. Journal of Crustacean Biology 23 (1), 241–246.

Mazza G, Tricarico E, Cianferoni F, Stasolla G, Inghilesi A, Zoccola A, and Innocenti G. (2017). Native crab and crayfish co-occurrence: First evidence in Europe. Biologia. 72.

McCarthy JM, Hein CL, Olden JD and Vander Zanden MJ. (2006). Coupling long-term studies with meta-analysis to investigate impacts of non-native crayfish on zoobenthic communities. Freshwater Biol. 51:224-235.

Momot WT. (1995). Redefining the role of crayfish in aquatic ecosystems. Reviews in Fisheries Science 3(1), 33-63.

Moodie EG, Le Jambre LF and Katz ME. (2003). *Thelohania parastaci* sp. nov.(Microspora: Thelohaniidae), a parasite of the Australian freshwater crayfish, *Cherax destructor* (Decapoda: Parastacidae). Parasitology Research, 91(2), 151-165.

Mrugała A, Kozubíková-Balcarová E, Chucholl C, Resino SC, Viljamaa-Dirks, S, Vukić J and Petrusek A. (2015). Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions, 17(5), 1313-1326.

Mrugała A, Veselý L, Petrusek A, Viljamaa-Dirks S and Kouba A. (2016). May Cherax destructor contribute to *Aphanomyces astaci* spread in Central Europe?. Aquatic Invasions, 11(4).

Mrugała A, Buřič M, Petrusek A and Kouba A. (2019). May atyid shrimps act as potential vectors of crayfish plague?. NeoBiota, 51, 65.

New MB, and Nair CM. (2012). Global scale of freshwater prawn farming. Aquaculture Research, 43(7), 960–969.

Norling P and and Jelmert A (2010). Fremmede marine arter i Oslofjorden. NIVA Rapport Nr. 5919.

Nunes A, Tricarico E, Panov V, Cardoso A and Katsanevakis S. (2015). Pathways and gateways of freshwater invasions in Europe. Aquatic Invasions. 10. 359-370.

Nyström P, Axelsson E, Sidenmark J and Brönmark C. (1997). Crayfish predation on amphibian eggs and larvae. Amphibia-Reptilia, 18(3), 217-228.

Nyström P and Pérez JR. (1998). Crayfish predation on the common pond snail (*Lymnaea stagnalis*): the effect of habitat complexity and snail size on foraging efficiency. Hydrobiologia 368, 201–208.

Oidtmann B, Heitz E, Rogers D and Hoffmann RW. (2002). Transmission of crayfish plague. Diseases of aquatic organisms, 52(2), 159-167.

OIE 2019a. Aquatic Animal Health Code. CHAPTER 1.3. Diseases listed by OIE. https://www.oie.int/index.php?id=171&L=0&htmfile=chapitre_diseases_listed.htm. Accessed 08.01.2021

OIE 2019b. Manual of Diagnostic Tests for Aquatic Animals. Chapter 2.2.2. Infection with *Aphanomyces astaci* (Crayfish plague). https://www.oie.int/index.php?id=2439&L=0&htmfile=chapitre_aphanomyces_astaci.htm. Accessed 08.01.2021

OIE 2019c. Manual of Diagnostic Tests for Aquatic Animals. Chapter 2.2.8. Infection with white spot syndrome virus. https://www.oie.int/index.php?id=2439&L=0&htmfile=chapitre_wsd.htm. Accessed 08.01.2021

OIE 2019d. Manual of Diagnostic Tests for Aquatic Animals. Chapter 2.2.7. Infection with Taura syndrome virus. https://www.oie.int/index.php?id=2439&L=0&htmfile=chapitre_taura_syndrome.htm. Accessed 08.01.2021

OIE 2019e. Manual of Diagnostic Tests for Aquatic Animals. Chapter 2.2.9. Infection with yellow head virus genotype. https://www.oie.int/index.php?id=2439&L=0&htmfile=chapitre_yellow_head_disease.htm. Accessed 08.01.2021

OIE 2019f. Manual of Diagnostic Tests for Aquatic Animals. Chapter 2.2.1. Acute hepatopancreatic necrosis disease. https://www.oie.int/index.php?id=2439&L=0&htmfile=chapitre_ahpnd.htm. Accessed 08.01.2021

OIE 2019g. Manual of Diagnostic Tests for Aquatic Animals. Chapter 2.2.6. Infection with *Macrobrachium rosenbergii* nodavirus. https://www.oie.int/index.php?id=2439&L=0&htmfile=chapitre_wtd.htm. Accessed 08.01.2021

OIE 2019h. Manual of Diagnostic Tests for Aquatic Animals. Chapter 2.2.3. Infection with

Hepatobacter penaei (Necrotising hepatopancreatitis). https://www.oie.int/index.php?id=2439&L=0&htmfile=chapitre_necrotising_hepatopancreatitis.htm. Accessed 08.01.2021

OIE 2019i. Manual of Diagnostic Tests for Aquatic Animals. Chapter 2.2.5. Infection with infectious myonecrosis virus. https://www.oie.int/index.php?id=2439&L=0&htmfile=chapitre_infectious_myonecrosis.htm. Accessed 08.01.2021

OIE 2019j. Manual of Diagnostic Tests for Aquatic Animals. Chapter 2.2.4. Infection with infectious hypodermal and haematopoietic necrosis virus. https://www.oie.int/index.php?id=2439&L=0&htmfile=chapitre_ihhn.htm. Accessed 08.01.2021

OIE 2020. Listed diseases, infections and infestations in force in 2020 https://www.oie.int/animal-health-in-the-world/oie-listed-diseases-2020/

Ogden NH, Wilson JR, Richardson DM, Hui C, Davies SJ, Kumschick S and Pulliam JR. (2019). Emerging infectious diseases and biological invasions: a call for a One Health collaboration in science and management. Royal Society open science, 6(3), 181577.

Olsen TM, Lodge DM, Capelli GM and Houlihan RJ. (1991). Mechanisms of impact of an introduced crayfish (*Orconectes rusticus*) on littoral congeners, snails, and macrophytes. Canadian Journal of Fisheries and Aquatic Sciences 48, 1853–1861.

Panov VE, Krylov PI, and Riccardi N. (2004). Role of diapause in dispersal and invasion by aquatic invertebrates. Journal of Limnology 63 (Supplement 1), 56–69.

Pantaleao JAF, Gregati RA, da Costa RC, Lopez-Greco LS, Negreiros-Fransozo ML. (2015). Post-hatching development of the ornamental 'red cherry shrimp' *Neocaridina davidi* (Bouvier, 1904) (Crustacea *Caridae*, *Atyidae)* under laboratorial conditions. Aquac. Res. pp. 1-17

Parmesan C and Yohe G. (2003). A globally coherent fingerprint of climate change impacts across natural systems. Nature 421: 37-42

Patoka J, Bláha M, Devetter M, Rylková K, Čadkova Z and Kaluos L. (2016). Aquariumhitchhikers: attached commensals imported with freshwater shrimps via the pettrade. Biol. Invasions 18, 457–461.

Peay S, Hiley PD, Collen P and Martin I. (2006). Biocide treatment of ponds in Scotland to eradicate signal crayfish. Bulletin de Francais de la Peche et de la Pisci-culture 380–381, 1363–1379.

Peay S, Holdich DM and Brickland J. (2010). Risk assessments of non-indigenous crayfish in Great Britain. Freshwater Crayfish, 17(1), 109-122.

Peay S, Guthrie N, Spees J, Nilsson E and Bradley P. (2010). The impact of signal crayfish (*Pacifastacus leniusculus*) on the recruitment of salmonid fish in a headwater stream in Yorkshire, England. Knowledge and Management of Aquatic Ecosystems, (394-395), 12.

Peiró DF, Almerão MP, Delaunay C, Jussila J, Makkonen J, Bouchon D and Souty-Grosset C. (2016). First detection of the crayfish plague pathogen *Aphanomyces astaci* in South America: a high potential risk to native crayfish. Hydrobiologia, 781(1), 181-190.

Pet Scandinavia. (2014). Lovlige ferskvannskreps i Norge. Skandinavisk bransjetidsskrift for zoobransjedrift; 2:38-41

Pet Scandinavia. (2016). Reker som handelsmodell – det kan fungere!. Skandinavisk bransjetidsskrift for zoobransjedrift; 4:4-8

Pet Scandinavia. (2018). Rekefarmer på Taiwan. Skandinavisk bransjetidsskrift for zoobransjedrift; 3:44-45

Pet Scandinavia. (2019). Reker som forretningside – Das Garnelenhaus i Hamburg. Skandinavisk bransjetidsskrift for zoobransjedrift; 3:36-38

Puccio V, Relini M, Azzurro E, Orsi Relini L. (2006). Feeding habits of *Percnon gibbesi* (H. Milne Edwards, 1853) in the Sicily Strait. Hydrobiologia, 557: 79-84.

Pursiainen M and Erkamo E. (1991). Low tempertaures as limiting factor for the noble crayfish (*Astacus astacus*) populations. Finn. Fish. Res. 12: 179-185.

Rewicz T, Grabowski M, Macneil C and Bacela-Spychalska K. (2014). The profile of a 'perfect' invader – the case of killer shrimp, *Dikerogammarus villosus*. Aquatic Invasions. 9. 267-288.

Reynolds J, Souty-Grosset C and Richardson A. (2013). Ecological Roles of Crayfish in Freshwater and Terrestrial Habitats. Freshwater Crayfish 19, 197-218.

Ricciardi A, Avlijas S and Marty J. (2012). Forecasting the ecological impacts of the Hemimysis anomala invasion in North America: Lessons from other freshwater mysid introductions. Journal of Great Lakes Research. 38. 7-13.

Richman N et al. 2015. Multiple drivers of decline in the global status of freshwater crayfish (Decapoda: Astacidea). Phil. Trans. R. Soc. B 370: 20140060.

Ricklefs RE. (2008) Disintegration of the Ecological Community. American Naturalist 172, 741-750.

Rodriguez CF, Becares E, Fernandez-Alaez M and Fernandez-Alaez C. (2005). Loss of diversity and degradation of wetlands as a result of introducing exotic crayfish. Biological Invasions 7(1):75-85.

Rodríguez G and Magalhães C. (2005). Recent advances in the biology of the Neotropical freshwater crab family Pseudothelphusidae (Crustacea, decapoda, *Brachyura*). Revista Brasileira de Zoologia 22 (2), 354–365.

Roy H, Schonrogge K, Dean H, Peyton J, Branquart E, Vanderhoven S, Copp G, Stebbing P, Kenis M, Rabitch W, Essl F, Schindler S, Brunel S, Kettunen M, Mazza L, Nieto A, Kemp J, Genovesi P, Scalera R and Stewart A. (2013). Invasive alien species – framework for the identification of invasive alien species of EU concern, Natural Environment Research Council.

Royo F, Andersson G, Bangyeekhun E, Múzquiz JL, Söderhäll K and Cerenius L. (2004). Physiological and genetic characterisation of some new *Aphanomyces* strains isolated from freshwater crayfish. Veterinary microbiology, 104(1-2), 103-112.

Rud Yu P, Maistrenko MI, Bezusiy OL and Buchatskiy LP. (2014). Experimental infection of freshwater crayfish (*Pontastacus leptodactylus*) with infectious pancreatic necrosis virus. Bulletin of Problems Biology and Medicine, 113, 70-74.

Rudnick DA, Chan V, Resh VH (2005) Morphology and impacts of the burrows of the Chinese mitten crab, *Eriocheir sinensis* H. Milne Edwards (Decapoda, Grapsoidea), in south San Francisco Bay, California, USA. Crustaceana 78: 787.

Ruokonen T, Sjövik R, Erkamo E, Tulonen J, Ercoli F, Kokko H and Jussila J. (2018). Introduced alien signal crayfish (Pacifastacus leniusculus) in Finland : uncontrollable expansion despite numerous crayfisheries strategies. Knowl. Manag. Aquat. Ecosyst., 419, 27.

Sala OE, Chapin III FS, Armesto JJ, Berlow E et al. (2000). Biodiversity: global biodiversity scenarios for the year 2100. Science. 287. 1770-1774.

Sahul Hameed AS, Charles MX and Anilkumar M. (2000). Tolerance of *Macrobrachium rosenbergii* to white spot syndrome virus. Aquaculture, 183(3–4), 207–213.

Sánchez-Paz A. (2010). White spot syndrome virus: an overview on an emergent concern. Veterinary research, 41(6), 43.

Sandodden R and Bardal H. (2010). Bekjempelse av signalkreps (*Pasifastacus leniusculus*) på Ostøya i Bærum kommune.Veterinærinstituttets rapportserie 1-2010.

Sandodden R and Johnsen SI. (2010). Eradication of introduced signal crayfish *Pasifastacus leniusculus* using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Sandström A, Andersson M, Asp A, Bohman P, Edsman L, Engdahl F, Nystöm P, Stenberg M, Hertonsson P, Vrålstad T, Graneli W. (2014). Population collapses in introduced non-indigenous crayfish. Biological Invasions 16(9):1961– 1977.

Sandvik H, Gederaas L, Moen TL and Skjelseth S. (2015). Veileder fremmede arter 2017: risikovurdering av økologisk påvirkning versjon 0.9, Artsdatabanken Trondheim, Norway.

Schartau AK and Lindholm M. (2012). Kinaullhåndskrabbe, *Eriocheir sinensis*. Artsdatabankens faktaark ISSN1504-9140 nr. 222

Scheele BC, Pasmans F, Skerratt LF, Berger L, Martel AN, Beukema W and Canessa S. (2019). Amphibian fungal panzootic causes catastrophic and ongoing loss of biodiversity. Science, 363(6434), 1459-1463.

Schoolmann G, and Arndt H. (2018). Population dynamics of the invasive freshwater shrimp *Neocaridina davidi* in the thermally polluted Gillbach stream (North Rhine-Westphalia, Germany). Limnologica. 71. 1-7.

Schuwerack PM, Lewis JW and Jones PW. (2001). Pathological and physiological changes in the South African freshwater crab *Potamonautes warreni* Calman induced by microbial gill infestations. Journal of Invertebrate Pathology, 77(4), 269-279.

Shields JD. (2003). Research priorities for diseases of the blue crab Callinectes sapidus. Bull. Mar. Sci. 72, 505–517.

Shih H-T, Shy J-Y, Naruse T, Hung HT, Yeo D and Ng P. (2011). Introduction of an indochinese freshwater crab *Sayamia germaini* (Crustacea: Brachyura: Gecarcinucidae) to Taiwan: Morphological and molecular evidence. Raffles Bulletin of Zoology. 59. 83-90.

Skov C, Aarestrup K, Sivebæk F, Pedersen S, Vrålstad T, and Berg S. (2011). Non-indigenous signal crayfish *Pacifastacus leniusculus* are now common in Danish streams: preliminary status for national distribution and protective actions. Biological Invasions, 13(6), 1269-1274.

Skurdal J, Taugbøl T, Burba A, Edsman L, Søderbäck B, Styrrishave B, Tuusti J, Westman K. (1999). Crayfish introductions in the Nordic and Baltic countries. In: Crayfish in Europe as alien species. Gherardi F, Holdich DM (eds.). A.A. Balkema, Rotterdam, The Netherlands.

Soes DM, Koese B. (2010). Invasive freshwater crayfish in The Netherlands: A preliminary risk analysis. EIS Nederland. EIS2010-01, 69 p.

Somboonna N, Mangkalanan S, Udompetcharaporn A, Krittanai C, Sritunyalucksana K and Flegel TW. (2010). Mud crab susceptibility to disease from white spot syndrome virus is species-dependent. BMC research notes, 3(1), 1-12.

Soowannayan C, Nguyen GT, Pham LN, Phanthura, M and Nakthong N. (2015). Australian red claw crayfish (*Cherax quadricarinatus*) is susceptible to yellow head virus (YHV) infection and can transmit it to the black tiger shrimp (*Penaeus monodon*). Aquaculture, 445, 63-69.

Sousa R, Nogueira JG, Ferreira A, Carvalho F, Lopes-Lima M, Varandas S and Teixeira A. (2019). A tale of shells and claws: The signal crayfish as a threat to the pearl mussel *Margaritifera margaritifera* in Europe. Science of the Total Environment, 665, 329-337.

Souty-Grosset C, Holdich DM, Noël PY, Reynolds JD and Haffner P. (2006). Atlas of Crayfish in Europe. Muséum national d'Histoire naturelle, Paris. Patrimoines naturels.

Svoboda J, et al. (2014a). The crayfish plague pathogen can infect freshwater-inhabiting crabs. Freshw Biol, 59: 918-929.

Svoboda J, Mrugała A, Kozubíková-Balcarová E, Kouba A, Diéguez-Uribeondo J and Petrusek A. (2014b). Resistance to the crayfish plague pathogen, *Aphanomyces astaci*, in two freshwater shrimps. Journal of Invertebrate Pathology, 121, 97–104.

Stentiford GD, Bonami JR and Alday-Sanz V. (2009). A critical review of susceptibility of crustaceans to Taura syndrome, Yellowhead disease and White Spot Disease and implications of inclusion of these diseases in European legislation. Aquaculture, 291(1-2), 1-17.

Stentiford GD, Scott A, Oidtmann B and Peeler E. (2010). Crustacean diseases in European legislation: implications for importing and exporting nations. Aquaculture 306, 27–34.

Stentiford G. (2012). Diseases in aquatic crustaceans: Problems and solutions for global food security Preface. Journal of invertebrate pathology. 110. 139.

Strand DA, Johnsen SI, Rusch JC et al. (2019). Monitoring a Norwegian freshwater crayfish tragedy: eDNA snapshots of invasion, infection and extinction. J Appl Ecol; 56: 1661– 1673.

Strand D, Rusch J, Johnsen SI, Tarpai A, Vrålstad T. 2020. The surveillance programme for *Aphanomyces astaci* in Norway 2019. Annual Report 2019. ISSN 1894-5678. Norwegian Veterinary Institute, 16 pp.

Strand M, Aronsson M and Svensson M. (2018). Klassificering av främmande arters effekter på biologisk mångfald i Sverige – ArtDatabankens risklista. ArtDatabanken Rapporterar 21. ArtDatabanken SLU, Uppsala. 46 pp.

Sylvestre S, Sekela M, Tuominen T and Moyle G. (2002). Water quality assessment of agricultural and residential run-off using the crayfish *Pacifastacus leniusculus* in British Columbia, Canada. Freshwater Crayfish 13(1), 383-395.

Söderhäll K and Cerenius L (1999) The crayfish plague fungus: History and recent advances. Freshwater Crayfish 12:11-35.

Tilmans M, Mrugała A, Svoboda J, Engelsma MY, Petie M, Soes DM and Petrusek A. (2014). Survey of the crayfish plague pathogen presence in the Netherlands reveals a new *Aphanomyces astaci* carrier. Journal of invertebrate pathology, 120, 74-79.

Unestam T. (1969). Resistance to the crayfish plague in some American, Japanese and European crayfishes. Report of the Institute of Freshwater Research, Drottningholm 49:202–209.

Unestam T. (1972). On the host range and origin of the crayfish plague fungus. Report of the Institute of Freshwater Research, Drottningholm 52:199–203.

Unestam T. (1976). Defence reactions in and susceptibility of Australian and New Guinean freshwater crayfish to European-crayfish-plague fungus. Australian J. Exp. Bio. Med. Sci; 53, 349-359.

Usio N and Townsend CR. (2001). The significance of the crayfish *Paranephrops zealandicus* as shredders in a New Zealand headwater stream. Journal of Crustacean Biology 21(2), 354-359.

van Hulten MC, Witteveldt J, Peters S, Kloosterboer N, Tarchini R, Fiers M and Vlak JM. (2001). The white spot syndrome virus DNA genome sequence. Virology, 286(1), 7-22.

Velle G, Brodersen KP, Birks HJB et al. (2010) Midges as quantitative temperature indicator species: Lessons for palaeoecology. The Holocene 20: 989–1002

Vilizzi L, Copp GH, Adamovich B. et al. (2019) A global review and meta-analysis of applications of the freshwater Fish Invasiveness Screening Kit. Rev Fish Biol Fisheries 29, 529–568.

VKM. (2016) Risk assessment on import of Australian redclaw crayfish to Norway Opinion of the Panel on Alien Organisms and Trade in Endangered Species (CITES) of the Norwegian Scientific Committee for Food and Environment. VKM report 2016:64.

VKM. (2017). Assessment of the risk to Norwegian biodiversity from the import and keeping of terrestrial gastropods in terraria. Opinion of the Panel on Alien Organisms and Trade in Endangered Species (CITES) of the Norwegian Scientific Committee for Food and Environment. VKM report 2017:33.

VKM. (2019). Assessment of the risk to Norwegian biodiversity from the pathogenic fungi *Batrachochytrium dendrobatidis* (Bd) and *Batrachochytrium salamandrivorans* (Bsal). Opinion of the Panel on Alien Organisms and Trade in Endangered Species (CITES) of the Norwegian Scientific Committee for Food and Environment. VKM report 2019:4.

von Rintelen K, Wowor D and Klotz W (2019a). *Caridina spinata*. The IUCN Red List of Threatened Species2019: e.T197754A139141338.

von Rintelen K, Wowor D and Klotz W (2019b). *Caridina woltereckae*. The IUCN Red List of Threatened Species 2019: e.T197697A139141832.

Vrålstad T, Håstein T, Taugbø T, Lillehaug A. (2006). Krepsepest - smitteforhold i norske vassdrag og forebyggende tiltak mot videre spredning. Veterinærinstituttets rapportserie 6. ISSN 1890-3290. 25pp.

Vrålstad T, Johnsen SI, Fristad RF, Edsman L and Strand D. (2011). A potent infection reservoir of crayfish plague now permanently established in Norway. Diseases of Aquatic

Organisms in press.

Vrålstad T, Strand DA, Grandjean F, Kvellestad A, Håstein T, Knutsen AK and Skaar I. (2014). Molecular detection and genotyping of *Aphanomyces astaci* directly from preserved crayfish samples uncovers the Norwegian crayfish plague disease history. Veterinary Microbiology, 173(1-2), 66-75.

Wang TC, Nai YS, Wang CY, Solter LF, Hsu HC, Wang CH and Lo CF. (2013). A new microsporidium, *Triwangia caridinae* gen. nov., sp. nov. parasitizing fresh water shrimp, Caridina formosae (Decapoda: Atyidae) in Taiwan. Journal of invertebrate pathology, 112(3), 281-293.

Weber S and Traunspurger W. (2016). Influence of the ornamental red cherry shrimp *Neocaridina davidi* (Bouvier 1904) on freshwater meiofaunal assemblages. Limnologica - Ecology and Management of Inland Waters. 59. 10.1016/j.limno.2016.06.001.

Weiperth A, Bláha M, Szajbert B, Seprős R, Bányai Z, Patoka J and Kouba A. (2020). Hungary: a European hotspot of non-native crayfish biodiversity. Knowledge & Management of Aquatic Ecosystems, (421), 43.

Wergeland Krog OM, Olsen JB and Gollasch S. (2009). Ullhåndskrabbe *Eriocheir sinensis* (H.Milne Edwards, 1853) påvist i Iddefjorden - status for arten i Norge. Fauna 61/1-2: 27-33.

Westhoff JT and Rosenberger AE. (2016). A global review of freshwater crayfish temperature tolerance, preference, and optimal growth. Reviews in fish biology and fisheries, 26(3), 329-349.

Westman K. (1973). The population of crayfish, Astacus astacus L. in Finland and the introduction of the American crayfish Pacifastacus leniusculus Dana. Freshwater Crayfish 1: 41–55.

Westman K, Savolainen R and Julkunen M (2002). Replacement of the native crayfish *Astacus astacus* by the introduced species *Pacifastacus leniusculus* in a small, enclosed Finnish lake: a 30-year study. Ecography 25(1):53-73.

Wilson KA, Magnuson JJ, Kratz TK and Willis TV. (2004). A long term rusty crayfish (*Orconectes rusticus*) invasion: dispersal patterns and community changes in a north temperate lake. Can. J. Aquat. Sci. 61:2255-2266.

Yeo DCJ, Ng PKL, Cumberlidge N, Magalhães C, Daniels SR, Campos MR. (2008). A global assessment of freshwater crab diversity (Crustacea: Decapoda: Brachyura). In: Balian, E.V., Lévequè, C., Segers, H., Martens, M. (Eds.), Freshwater Animal Diversity Assessment. Hydrobiologia, vol. 595, pp. 275–286.

Appendix I

Modifications made to the GB-NNRA protocol for risk assessment of terrestrial crustaceans intended for private keeping in aquaria.

The unaltered version of the EU NON-NATIVE SPECIES RISK ANALYSIS – RISK ASSESSMENT TEMPLATE V1.0 (27-04-15) can be found here:
http://www.nonnativespecies.org/index.cfm?pageid=143

Specific changes made to the original version of the GB-NNRA questionnaire:

EU chappeau: Removed entirely as our focal area is solely Norway.

Section A: Removed entirely; we used the Aquatic Species Invasiveness Screening Kit (AS-ISK) for this purpose

Section B: Several aspects are deleted, others are subject to minor alterations, and some are merged to better fit the purpose. In all instances "Europe" is changed to "Norway". We have removed all questions related to economic impact as these are not relevant in the context of negative impact on biodiversity. For the sections "Probability of spread" and "Probability of impact" the questions have been rephrased in an attempt to improve the language and to increase precision, and to make them better suited for this particular type of risk assessment. The scale of responses here is also changed and now follows the scale used in most of the questions under "Probability of entry" and "Probability of establishment". The scale of "Uncertainty" is reduced to three levels: "low", "medium" and "high" as the information available on the species we assessed is too course to allow for a finer scale of uncertainty. See list of detailed alterations below.

Probability of entry
1.1. Pathways removed since the assessment is restricted to crustaceansin private holding in aquariaaquaria.

1.2. Removed since the assessment is restricted to crustaceans in aquaria.

1.3. Removed, the pathway is always intentional.

1.4. Slightly altered (now numbered 1.1).

1.5. Removed since survival is depending on environmental conditions and treated under Probability of Establishment.

1.6. Removed since the assessment is restricted to crustaceans in aquaria.

1.7. Removed, the pathway is always intentional.

1.8. Removed since the assessment is restricted to crustaceans in aquaria and may escape or be released at any time of the year.

1.9. Altered to transfer from the pathway to Norwegian nature (now numbered 1.2).

1.10. Removed, the pathway is always intentional.

1.11. Altered to entry into Norwegian nature (now numbered 1.3).

Probability of establishment
1.12. As is (now numbered 2.1).

1.13. As is (now numbered 2.2).

1.14. As is (now numbered 2.3).
1.15. As is (now numbered 2.4).
1.16. Removed, none of the species assessed require particular host organisms.
1.17, 1.18, 1.19, 1.21. Merged (now numbered 2.5).
1.20. Removed.
1.22. 1.23 Merged (now numbered 2.6).
1.24. Removed.
1.25. As is (now numbered 2.7)
1.26. As is (now numbered 2.8).
1.27. Removed.
1.28. As is (now numbered 2.9).

Probability of spread
2.1. As is (now numbered 3.1).
2.2. As is (now numbered 3.2).
2.3. Re-phrased (now numbered 3.3).
2.4. As is (now numbered 3.4).
2.5. Removed. None of the species assessed have established in Norway.
2.6. Removed. None of the species assessed have established in Norway.
2.7. Removed. None of the species assessed have established in Norway.
2.8. Removed. None of the species assessed have established in Norway.
2.9. As is (now numbered 3.5).

Probability of impact
2.10. Deleted. Not possible to assess economic impact based on the limited information available.
2.11. Removed. Not possible to assess economic impact based on the limited information available.
2.12. Removed. Not possible to assess economic impact based on the limited information available.
2.13. Removed. Not possible to assess economic impact based on the limited information available.
2.14. Removed. Not possible to assess economic impact based on the limited information available.
2.15. Rephrased (now numbered 4.1).
2.16. Removed. None of the species has established in Norway.
2.17. Removed. None of the species have established in Norway.
2.18. Removed. None of the species have established in Norway.
2.19. Removed. None of the species have established in Norway.
2.20. Removed. None of the species have established in Norway.
2.21. Removed. None of the species have established in Norway.
2.22. Rephrased (here numbered 4.2).
2.23. Removed. Potential impact on human health is covered in the risk analyses under question number 4.3.
2.24. Removed "as food, as a hos, or a symbiont" and moved to new section (point 5.3)
2.25. Rephrased (now numbered 4.3).
2.26. As is (here numbered 4.4).
2.27. Rephrased (here numbered 4.5)

Additional number 4.7 with summary of impact: Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present).

Added new section on probability of impact as vector of pathogenic agens:

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**UNCERTAINTY**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?			
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)			
5.3. How much impact does the organism have as a vector for other pathogens?			
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).			

Additional questions – climate change
3.1 As is, but added that we are assessing climate until year 2100 (now numbered 6.1).
3.2 Removed. The focal perspective is climate until year 2100

3.3 As is, but added a list of aspects to be assessed is added, namely: establishment, spread, impact on biodiversity, and impact on ecosystem functions (here numbered 6.2).

Additional questions – Research
Removed.

Risk summaries
Added "Summarise impact from pathogens/ parasites"

Appendix II

Ferskvannskrepsdyr i akvariehandelen, med hovedvekt på hva som er tilgjengelig i/fra Norge

Det er ikke tatt stilling til gjennom hvilke salgskanaler artene kommer inn til Norge, og både zoohandel, postordre og privatimporter er mulige kilder. Kun arter som lever overveiende i ferskvann er tatt med i oversikten; marine og terrestriske arter er utelatt. Det garanteres ikke at listen er komplett.

Listen er utarbeidet av Svein A. Fosså (svein.fossa@nzb.no), Norges Zoohandleres Bransjeforening, i april 2020.

Takson [1]	Handelsrelevans [2]	Merknad
ASTACIDEA		
Astacidae		
Astacus astacus	0	En vakker blå fargeform er tilgjengelig i internasjonal handel, også i Europa. Det foreligger ingen indikasjon på at
Pacifastacus leniusculus	1	
Cambaridae		
Cambarellus spp.	3	
Cambarellus chapalanus	0	
Cambarellus diminutus	1	
Cambarellus montezumae	0	
Cambarellus ninae	0	
Cambarellus patzcuarensis	3	Svært etterspurte dvergkreps; særlig i en knall-oransje avlsform, men det
Cambarellus puer	1	
Cambarellus schmitti	0	
Cambarellus shufeldtii	0	
Cambarellus texanus	1	
Cambarus spp.	0	
Fallicambarus fodiens	0	
Faxonius neglectus chaenodactylus	0	
Orconectes spp.	1	
Procambarus alleni	2	
Procambarus clarkii	3	Stort antall fargerike avlsformer, primært i

Procambarus braswelli	0	
Procambarus cubensis	0	
Procambarus fallax f.	3	
Procambarus llamasi	0	
Procambarus ouachitae	0	
Procambarus peninsularis	2	
Procambarus pubescens	0	
Procambarus spiculifer	0	
Procambarus vasquezae	0	
Procambarus versutus	0	
Parastacidae		
Cherax spp.	3	En eller flere sterkt blåfargede arter av usikker artstilhørighet, med opprinnelse Papua New Guinea,
Cherax boesemani	1	
Cherax communis	1	
Cherax destructor	1	Forekommer i flere avlsformer med handelsnavn som f.eks. 'Blue
Cherax holthuisi	2	
Cherax lorentzi	1	
Cherax monticola	0	
Cherax papuanus	1	
Cherax peknyi	2	Flere avlsformer med handelsnavn som f.eks. 'Fire Claw', 'Blue Claw', 'Blue
Cherax preissii	1	
Cjerax pulcher	1	
Cherax quadricarinatus	3	
Cherax snowden	1	Flere avlsformer, derriblant 'Irianto Red'.
Cherax tenuimanus	2	

CARIDEA		
Atyidae		
Atya spp.	3	
Atya gabonensis	3	
Atyaephyra desmarestii	2	
Atyoida pilipes	2	
Atyopsis moluccensis	3	
Caridina spp.	3	Mange arter og avlsformer i handelen med usikker artstilhørighet, trolig også mange hybrider. Aktuelle handelsnavn inkluderer 'Sulawesi algereke', 'Taiwanesisk algereke', 'Humlereke', 'Black Fancy Tiger', 'Black Panda', 'Blue Panda', 'Raccoon', 'Red Fancy Tiger', 'Red Pinto', 'Black Pinto', 'Black Zebra
Caridina babaulti	3	Arten forekommer i flere avlsformer som selges under handelsnavn som
Caridina breviata	3	
Caridina brachydactyla	2	
Caridina brevicarpalis	2	
Caridina caerulea	2	
Caridina cantonensis	3	Flere avlsformer.
Caridina dennerlii	3	
Caridina gracilirostris	3	
Caridina logemanni	3	Arten forekommer i flere avlsformer som selges under handelsnavn som f.eks. 'Red Bee', 'Black Bee', 'Super White Bee', 'Snow White Bee', 'Golden
Caridina mariae	3	Arten forekommer i flere avlsformer med handelsnavn som
Caridina multidentata	3	Handelsnavn 'Amano-reke'
Caridina pareparensis parvidentata	2	
Caridina propinqua	3	

Caridina rubropunctata	2	
Caridina serrata	3	
Caridina serratirostris	2	
Caridina simoni simoni	2	
Caridina spinata	2	
Caridina trimaculata	2	
Caridina woltereckae	2	
Halocaridina rubra	0	
Jonga serrei	0	
Lancaris spp.	2	
Lancaris kumariae	2	
Micratya poeyi	0	
Neocaridina spp.	3	Mange arter og avlsformer i handelen
Neocaridina davidi	3	Arten forekommer i et stort antall avlsformer som selges under handelsnavn som f.eks. 'Green Jade', Chocolate', 'Red', 'Red Rili', 'Orange Rili', 'Carbon Rili', 'Blue Carbon Rili', 'Red Sakura', 'Red Onyx', 'Black Sakura',
Neocaridina denticulata sinensis	2	
Neocaridina palmata	2	
Neocaridina zhangjiajiensis	2	
Paracaridina spp.	2	Stort antall avlsformer av usikker artstilhørighet, som sleges med
Paracaridina zijinica	1	
Paratya compressa	0	
Potimirim spp.	0	
Desmocarididae		
Desmocaris trispinosa	2	
Euryrhynchidae		
Euryrhynchus amazoniensis	0	

Palaemonidae		
Arachnochium kulsiense	0	
Macrobrachium spp.	3	
Macrobrachium agwi	0	
Macrobrachium assamense	2	
Macrobrachium dayanum	2	
Macrobrachium	3	
Macrobrachium esculentum	0	
Macrobrachium	2	
Macrobrachium horstii	0	
Macrobrachium idae	1	
Macrobrachium jaroense	0	
Macrobrachium lanchesteri	2	
Macrobrachium mirabile	2	
Macrobrachium peguense	0	
Macrobrachium pilimanus	2	
Macrobrachium rosenbergii	3	
Macrobrachium	0	
Palaemon spp.	3	Flere tropiske arter med usikker
Palaemon concinnus	1	
Palaemonetes spp.	1	
Tenuipedium	2	
Typhlocarididae		
Euryrhynchus amazoniensis	0	
Xiphocarididae		
Xiphocaris elongata	2	

BRACHYURA		
Dotillidae		
Ilyoplax spp.	0	
Gecarcinucidae		
Ceylonthelphusa	2	
Lepidothelphusa spp.	2	
Lepidothelphusa cognetti	1	
Sartoriana spinigera	1	
Sayamia bangkokensis	1	
Syntripsa matanensis	2	
Parathelphusa spp.	0	
Parathelphusa pantherina	3	
Hymenosomatidae		
Limnopilos naiyanetrii	3	
Potamidae		
Heterochelamon	1	
Potamon fluviatile	1	
Potamonautidae		
Potamonautes lirrangensis	1	
Potamonautes orbitospinus	3	
Sesarmidae		
Chiromantes angolense	0	
Geosesarma spp.	2	
Geosesarma bicolor	2	
Geosesarma bogorensis	2	
Geosesarma tiomanincum	2	
Metasesarma spp.	2	
Metasesarma aubryi	2	

Neosarmatium	2	
Perisesarma spp.	2	
Perisesarma eumlope	2	
Pseudosesarma spp.	2	
Pseudosesarma	3	
Sesarmops	1	
ANOMURA		
Aeglidae		
Aegla platensis	1	
Diogenidae		
Clibanarius africanus	2	

[1] **Takson** er angitt med slektsnavn og (der det er kjent) artsnavn. For tilfeller der arter tilhørende slekten finnes i handelen uten noenlunde sikker ID til artsnivå er slekten oppført med epitetet «spp». Jeg har ikke lagt noe arbeid i å kontrollsjekke nomenklatur, mulige synonymer og familietilhørighet mot nyeste revisjoner.

[2] **Handelsrelevans** er angitt på en skala fra 0 til 3, hvor 3 angir at den helt sikkert har blitt importert til Norge, 2 at det er overveiende sannsynlig, og 1 at det er grunn til å tro at den kan finnes i Norge. 0 angir at den sannsynligvis ikke er importert til Norge ennå, men at den finnes i handelen i verden for øvrig.

Appendix III

11.2 *Aphanomyces astaci*

Table A1-1

LIKELIHOOD OF ENTRY			
Important instructions: • **Entry is the introduction of an organism into Norway. Not to be confused with spread, the movement of an organism within Norway.** • **In the context of this report, only entry through crustacean aquarium trade is considered. Further, this risk assessment should only come into consideration for crustacean species that is regarded possible carriers** • **For organisms which are already present in Norway, only complete the entry section for current active pathways of entry or if relevant potential future pathways. The entry section need not be completed for organisms which have entered in the past and have no current pathways of entry.**			
Question	**Response**	**Confidence**	**Comment**
1.1. How many active pathways are relevant to the potential entry of this organism? (If there are no active pathways or potential future pathways respond N/A and move to the Establishment section)	none **very few (1-3)** few (4-6) moderate number (7-10) many (11-20) very many (20+)	**high**	**In the context of this report, only entry through crustacean aquarium trade is considered**

1.2. List relevant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways. For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary).	Anthropogenic – pet trade with subsequent release of animals or aquarium water		Table A1-2

Table A1-2

Pathway name:	Anthropogenic – pet trade		
Question	Response	Conf.	Comments
1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?	accidental	very high	Crustacean hosts might be invisibly infected with *A. astaci*, either because they are disease free carriers of the pathogen (like American freshwater crayfish, some freshwater crabs and other reasonably tolerant crayfish species), or recently infected susceptible crayfish species prior to developing signs of disease

1.4. How likely is it that the organism will travel along this pathway from the point(s) of origin, multiple times (>10) over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.	likely	high	Very likely that *A. astaci* will get on to the pathway in the first place. "likely" assume regular events of aquarium trade take place that involves infected animals
1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	very likely	high	*A. astaci* survive in its hosts (it is a parasite living in the exoskeleton of the carrier crayfish), and might spread to uninfected individuals sharing ambient water with the infected host
1.6. How likely is the organism to survive existing management practices during passage along the pathway?	very likely	very high	There is no applied management practices for this pathogen, unless the host is eradicated.
1.7. How likely is the organism to enter Norway undetected?	very likely	very high	Unless new practices are implemented involving molecular screening tests for *A. astaci* prior to entry, the pathogen will enter Norway undetected accompanying infected crustacean hosts
1.8. How likely is the organism to arrive during the months of	very likely	very high	*A. astaci* can survive, establish and infect new hosts regardless of season – only a

the year most appropriate for establishment?			bit slower in the winter months compared to summer. Time of arrival is therefore not an issue
1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	moderately likely	very high	This will require an illegal release of a infected crustacean pet animals into a habitat hosting Noble crayfish, or in close vicinity to such a habitat
1.10 Summarized likelihood of the organism entering a suitable habitat in Norway through this pathway	Likely	very high	Release of pet crustaceans is well documented in Europe. Although banned in Norway, this anthropogenic behavior can be expected to take place.

Table A1-4

LIKELIHOOD OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	very likely	very high	It is already established in South-Eastern Norway, and also in Sweden, Finland and more or less the entire Europe. There is reduced likelihood for establishment in the North – but that is connected to host limitations and not the pathogen. The Northernmost documentation of *A. astaci* in Norway is on illegally

			introduced signal crayfish in the northern part of Trøndelag (Lierne)
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	very likely	very high	It is already established. *A. astaci* evolved with North American crayfish, and some of the known genotypes tolerate the same climatic conditions as in the Northern countries. There is one known heat-tolerant genotype of *A. astaci* adapted to warm-water crayfish. For this, the effect on noble crayfish in the Norwegian climate is unknown.
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, terraria, zoological gardens) in Norway? Subnote: gardens are not considered protected conditions	very likely	moderate	If entering together with a crustacean host, it is very likely that *A. astaci* is maintained along with its hosts both in aquaria shops, enclosed aquaria exhibitions, public and private aquaria.
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread in South-Eastern Norway	high	The distribution of potential hosts/susceptible species is given in Fig. 1.2-1. The distribution is related to noble crayfish habitats, which creates a somewhat patchy

			distribution, but would also include waterways that connect to noble crayfish habitats
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	likely	high	The management practise should in case start prior to establishment. Hindering entrance is the key. If first introduced to the habitat, the availability to crayfish hosts would determine establishment. It would not establish without hosts. The management practices to get rid of *A. astaci* would involve eradication programs for the hosts, which is very devastating to the ecosystem and expensive. No known organisms pose a threat to *A. astaci* (in terms of predation, parasitism or similar).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment?	very likely	high	It is a global species, inhabiting a wide range of habitats and climatic conditions. The distribution of *A. astaci* is determined by the distribution of its hosts.
2.7. How likely is it that the organism could establish despite low genetic diversity in the founder population?	very likely	high	*A. astaci* is clonal, asexually reproducing and very efficiently infecting hosts regardless of low genetic diveristy

2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is to establish in Norway? (If possible, specify the instances in the comments box.)	very likely	high	It has been established in Norway since the 1970s, and the number of affected crayfish populations and habitats are steadily increasing – mostly as a result of illegal spread of A. astaci carrying signal crayfish. Aquarium species with the potential to carry *A. astaci* would increase the number of possible sources
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comment box).	very likely	high	The same comment as above. Further, freshwater crabs have been shown to serve as *A. astaci* reservoirs. It is not sufficiently elucidated if also other crustacean species could serve as *A. astaci* reservoirs.

Table A1-5

LIKELIHOOD OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the	moderately likely	high	If present in the habitat, *A. astaci* can spread by 1) spread together with the carrier host, 2) infected noble crayfish, 3) *A. astaci* spores spread by water transport, 4) *A. astaci* spores

mechanisms for natural spread.)			spread by biological vectors (fish, birds, mammals)
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	likely	high	If present in the habitat, *A. astaci* can spread by human activities including 1) water with *A. astaci* spores moved by boats, 2) non-sterilized moist fishing gear, 3) non-sterilized moist clothing or 4) movement of infected crayfish or fish vectors
3.3. How likely is it that spread of the organism within Norway can be completely contained?	very unlikely	high	If present in the habitat, reducing or delaying spread out of the habitat might be possible, through information campaigns and disinfection of gear (Virkon S), but completely containment is very unlikely. Within the habitat – there are no ways to stop the spread of waterborne infective spores of *A. astaci*
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	The same as the distributional range of Noble crayfish	high	This is particularly in the South-Eastern Norway (Fig. 1.2-1)
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comment box to indicate any key issues).	likely	high	The history of crayfish plague in Norway since the 1970s has shown that spread is unavoidable as soon as the organism arrives. It is harder to get rid of if the American host survives and maintains the infection source

Table A1-3

LIKELIHOOD OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each set of questions starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (i.e. past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	massive	very high	*The pathogen causes mass mortality and wipes out entire populations of European freshwater crayfish. It is also an increasing threat to Asian and Australian freshwater crayfish. It causes no harm to American crayfish which is natural hosts with high tolerance to the pathogen. Mass mortalities has only been seen in Europe, with some variability in the degree of mortality for different European crayfish species. Noble crayfish populations are highly susceptible, and several Norwegian noble crayfish populations has already been eradicated by the pathogen*
4.2. How much impact would there be, if genetic traits of the organism were to be	minimal	low	Different strains of *A. astaci* have different virulence. Since the most videspread are highly

transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?			lethal, it is unlikely that other genotypes can make the situation worse
4.3. How much impact does the organism have, as food, as a host, or as a symbiont or a vector for other damaging organisms (e.g. diseases)?	minimal	low	This is a specialized parasite. In its free-living stage outside its host, *A. astaci* spreads with singe celled zoospores and infect new hosts. No reports/research exist on endoparasites, bacteria or viruses infecting these spores in *A. astaci*.
4.4. How much impact do other factors have, factors which are not covered by previous questions (specify in the comment box)	moderat e	high	If introduced, even within hosts that will not survive the Norwegian climate, *A. astaci* will have enough time to transmit to susceptible crayfish by 1) water transport of spores or 2) spread by biological vectors such as fish (A. astaci survive gut passage – and fish eat crayfish), mammals and birds (in moist furr or feathers, or 3) mechanical transport of spores by fishing gear, boats etc.
4.5. 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 Norway?	massive	high	*A. astaci* is already present in some locations in Norway, where it has eradicated the local populations of noble crayfish. If introduced to new noble crayfish habitats, it will eradicate the noble crayfish – which are regarded key stone organisms and ecosystem engineers . Noble crayfish is

			red-listed and regarded endangered due to *A. astaci*
4.6. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	South Eastern Norway	Very high	Related to the distribution of noble crayfish in Norway, which are 470 populations primarily found in the South Eastern Norway. See Fig. 1.2-1
4.7. Estimate the expected impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present).	massive	Very high	The consequences of *A. astaci* in Norway is already massive in the affected habitats. In most cases, this is due to illegal release of north American signal crayfish that are carrier of *A. astaci.*

Table A1-6

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. What aspects of climate change (in a 50 years perspective), if any, are most likely to affect the risk assessment for this organism?	Increased temperature, shorter winters.	low	*A. astaci* might have a longer time-window for effective infections. *A. astaci* spread faster in the summer months, this time-window might broaden with climate change. Other more heat-tolerant genotypes of *A. astaci* could enter and establish, thus broaden the number of virulent genotypes

5.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establishment, spread and impact on biodiversity	low	The same points as above

RISK SUMMARIES for *A. astaci*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Likely	very high	Release of pet crustaceans is well documented in Europe. Although banned in Norway, this anthropogenic behavior can be expected to take place.
Summarise Establishment	very likely	moderate	If entering together with a crustacean host, it is very likely that *A. astaci* is maintained along with its hosts both in aquaria shops, enclosed aquaria exhibitions, public and private aquaria.
Summarise Spread	likely	high	The history of crayfish plague in Norway since the 1970s has shown that spread is unavoidable as soon as the organism

			arrives. It is harder to get rid of if the American host survives and maintains the infection source
Summarise Ecological Impact	massive	Very high	The consequences of *A. astaci* in Norway is already massive in the affected habitats. In most cases, this is due to illegal release of north American signal crayfish that are carrier of *A. astaci.*
Conclusion of the risk assessment	High	High	

White spot syndrome virus (WSSV)

Table A1-1

LIKELIHOOD OF ENTRY			
Important instructions: • **Entry is the introduction of an organism into Norway. Not to be confused with spread, the movement of an organism within Norway.** • **In the context of this report, only entry through crustacean aquarium trade is considered. Further, this risk assessment should only come into consideration for crustacean species that is regarded possible carriers** • **For organisms which are already present in Norway, only complete the entry section for current active pathways of entry or if relevant potential future pathways. The entry section need not be completed for organisms which have entered in the past and have no current pathways of entry.**			
Question	**Response**	**Confidence**	**Comment**

1.1. How many active pathways are relevant to the potential entry of this organism? (If there are no active pathways or potential future pathways respond N/A and move to the Establishment section)	none **very few (1-3)** few (4-6) moderate number (7-10) many (11-20) very many (20+)	high	**In the context of this report, only entry through crustacean aquarium trade is considered**
1.2. List relevant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways. For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary).	Anthropogenic – pet trade with subsequent release of animals or aquarium water		Table A1-2

Table A1-2

Pathway name:	Anthropogenic – pet trade		
Question	Response	Conf.	Comments

1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?	accidental	very high	Crustacean hosts might be invisibly infected with WSSV, either because they are disease free carriers of the virus (like some freshwater crabs and other reasonably tolerant crayfish species in temperatures below 20), or recently infected susceptible species prior to developing signs of disease. All crustaceans can be infected. The areas with WSSV include America, Asia, Australia
1.4. How likely is it that the organism will travel along this pathway from the point(s) of origin, multiple times (>10) over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.	likely	high	Very likely that WSSV will get on to the pathway in the first place. "likely" assume regular events of aquarium trade take place that involves infected animals
1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	very likely	high	WSSV survive in its hosts, and might spread to uninfected individuals sharing ambient water with the infected host. WSSV can remain vital in dead, even in frozen animals for many months.

1.6. How likely is the organism to survive existing management practices during passage along the pathway?	very likely	very high	There is no applied management practices for this pathogen, unless the host is eradicated.
1.7. How likely is the organism to enter Norway undetected?	very likely	very high	Unless new practices are implemented involving molecular screening test for WSSV prior to entry, the pathogen will enter Norway undetected accompanying infected crustacean hosts
1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	very likely	very high	WSSV can survive, establish and infect new hosts regardless of season – although more efficient and with higher consequences in warm water during the summer
1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	moderately likely	very high	This will require an illegal release of a infected crustacean pet animals into a habitat hosting crustaceans, or in close vicinity to such a habitat. Also other organisms (shell, insects) might act as carriers/vectors, and could become infected and sustain the virus.
1.10 Summarized likelihood of the organism entering a suitable habitat in Norway through this pathway	Moderately likely	Very high	Release of pet crustaceans is well documented in Europe. Although banned in Norway, this anthropogenic behavior can be expected to take place.

Table A1-4

LIKELIHOOD OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Moderately likely	medium	WSSV is a non-exotic disease virus, sporadically observed in shrimp farms in Southern Europe. Main geographical areas include Asia, Australia, America from south to north. The virus can infect crustaceans also at low temperatures. Although less virulent at low temperatures, it is likely that the virus spread between crustacean hosts if introduced. There are also many non-crustacean vectors that could further facilitate the establishment.
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Moderately likely	medium	Although the main distribution of the virus is from tropical, sub-tropical and Mediterranean climates, there are also reports on establishment and outbreaks caused by the virus in Northern America which in many cases are comparable to the Norwegian climate and presumably similar environmental conditions

2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, terraria, zoological gardens) in Norway? Subnote: gardens are not considered protected conditions	very likely	medium	If entering together with a crustacean host, it is very likely that WSSV is maintained along with its hosts both in aquaria shops, enclosed aquaria exhibitions, public and private aquaria. WSSV has been detected on crustaceans in aquarium shops in central Europe.
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread in South-Eastern Norway	high	The distribution of potential decapod hosts is given in Fig. 1.2-1. The distribution is related to noble crayfish habitats, which creates a somewhat patchy distribution, but would also include waterways that connect to noble crayfish habitats. There are much more habitats involved when also considering non-decapod hosts and non-crustacean vectors.
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing	likely	high	The management practise should in case start prior to establishment. Hindering entrance is the key. If first introduced to the habitat, the availability to crustacean hosts

species or predators, parasites or pathogens in Norway?			would only in part determine establishment. Also other groups of animals has been reported as possible vector species. The management practices to get rid of WSSV would involve eradication programs for the hosts, which would not be possible. No known organisms pose a threat to WSSV (in terms of predation, parasitism or similar).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment?	very likely	high	It is a virus with global distribution that has spread rapidly in the shrimp farming industry since its discovery in China and Taipei in 1991. It can infect a wide range of hosts, both in freshwater and marine waters, and a wide range of genotypes are known.
2.7. How likely is it that the organism could establish despite low genetic diversity in the founder population?	very likely	high	This mechanism is not important for virus establishment and replication in the host.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is to establish in Norway? (If possible, specify the instances in the comments box.)	likely	medium	Although the main distribution of the virus is from tropical, sub-tropical and Mediterranean climates, there are also reports on establishment and outbreaks caused by the virus in Northern America which in

			many cases are comparable to Norway.
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comment box).	likely	high	The climate is not a hindrance although more common in warmer areas. Establishment in Northern America indicate that the virus also could establish in Norway. The wide host-range makes it likely that the virus easily find a suitable host.

Table A1-5

LIKELIHOOD OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	likely	medium	If present in the habitat, WSSV can spread by transmission between crustacean hosts (decapods and non-decapod crustaceans), as well as by spread via vector species of which many are mentioned (table x). The virus could also spread by infected water
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*?	likely	medium	If present in the habitat, WSSV can spread by human activities including 1) water with WSSV particles spread by boats, 2)

(Please list and comment on the mechanisms for human-assisted spread.)			non-sterilized moist fishing gear, 3) non-sterilized moist clothing or 4) movement of infected crustaceans or vectors. It is also a risk that raw frozen exotic shrimps used as bait for fishing purposes can be infected. The WSSV survive in frozen animals and can enter the habitat.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	very unlikely	medium	If present in the habitat, reducing or delaying spread out of the habitat might be possible, through information campaigns and disinfection of gear, but completely containment is very unlikely. Within the habitat – there are no ways to stop the spread of an infective virus
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	The same as the distributional range of Noble crayfish	medium	This is particularly in the South-Eastern Norway (Fig. 1.2-1). This only take noble crayfish into account. Also other non-decapod crustaceans would occasionally be adversely affected by the virus.
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comment box to indicate any key issues).	likely	medium	Due to the wide host range both in freshwater and marine habitats, it is likely that the virus could become widespread in Norway

Table A1-3

LIKELIHOOD OF ENVIRONMENTAL IMPACT

Important instructions:

- When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment.
- Each set of questions starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (i.e. past and current impacts) from potential future impacts.

QUESTION	RESPONSE	CONFIDENCE	COMMENTS
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	moderate	moderate	*Noble crayfish survive infections at temperatures below 20 degrees, but the virus can cause high mortality rates in noble crayfish in water above 20 degrees (shown in tank experiments, not in the wild). All crustaceans are susceptible to the virus, according to OIE. The impact on Norwegian crustacean biodiversity could be significant but there is few studies in relevant species.*
4.2. How much impact would there be, if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	moderate	low	Viruses mutate rapidly when infecting new hosts. If WSSV mutated to a virus with higher virulence at lower temperatures, it would become far more devastating to crustaceans in cooler climates.
4.3. How much impact does the organism have, as food, as a host, or as a symbiont or a	minimal	high	Viruses does not act as food, host, or vectors for other damaging organisms

vector for other damaging organisms (e.g. diseases)?			
4.4. How much impact do other factors have, factors which are not covered by previous questions (specify in the comment box)	moderat e	high	WSSV can infect all crustacean species, but the host responses vary from no adverse effect to death. Here, host immunity responses and environmental factors play a crucial role for the outcome of infection. Other stressors (e.g., pollution) could result in higher host susceptibility and thus higher negative impact on crustaceans
4.5. 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 Norway?	moderat e	medium	WSSV is an exotic disease virus, and the possible impact on crustacean biodiversity in Norway unknown. However, it is known that the mortality rate of noble crayfish infected with the virus goes from zero to 100% at 22 °C water temperature (the temperature range between 12 and 22 not tester). Thus, moderate reductions in native populations could be expected in warm summers. There is no other organisms known to play a role in natural control of WSSV

4.6. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	South Eastern Norway	High	Related to the distribution of noble crayfish in Norway, which are 470 populations primarily found in the South Eastern Norway. See Fig. 1.2-1 Also other non-decapod freshwater crustaceans could be affected
4.7. Estimate the expected impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present).	moderat e	medium	Same comment as for 4.5.

Table A1-6

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENC E**	**COMMENTS**
5.1. What aspects of climate change (in a 50 years perspective), if any, are most likely to affect the risk assessment for this organism?	Increased temperature, shorter winters, warmer waters.	medium	The virus is more aggressive/virulent in warm waters. This has been demonstrated by the drastic increase from zero to 100% mortality rates in infection experiments with WSSV and freshwater crayfish (such as signal crayfish and noble crayfish)

			when the water temperature was increased from 12 to 22 °C
5.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Impact on biodiversity	medium	The same points as above. Expected higher mortality rates at higher temperatures.

RISK SUMMARIES for (TSV)			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately likely	high	Release of pet crustaceans is well documented in Europe. Although banned in Norway, this anthropogenic behavior can be expected to take place.
Summarise Establishment	likely	high	The climate is not a hindrance although more common in warmer areas. Establishment in Northern America indicate that the virus also could establish in Norway. The wide host-range makes it likely that

			the virus easily find a suitable host.
Summarise Spread	likely	medium	Due to the wide host range both in freshwater and marine habitats, it is likely that the virus could become widespread in Norway
Summarise Ecological Impact	moderate	medium	WSSV is an non-exotic disease virus (list 2), and the possible impact on crustacean biodiversity in Norway unknown. However, it is known that the mortality rate of noble crayfish infected with the virus goes from zero to 100% at 22 °C water temperature (temperature range between 12 and 22 not tester). Thus, moderate reductions in native populations could be expected in warm summers. There is no other organisms known to play a role in natural control of WSSV
Conclusion of the risk assessment	Moderate	High	

11.3 Taura syndrome virus (TSV)

Table A1-1

LIKELIHOOD OF ENTRY			
Important instructions: • **Entry is the introduction of an organism into Norway. Not to be confused with spread, the movement of an organism within Norway.** • **In the context of this report, only entry through crustacean aquarium trade is considered. Further, this risk assessment should only come into consideration for crustacean species that is regarded possible carriers** • **For organisms which are already present in Norway, only complete the entry section for current active pathways of entry or if relevant potential future pathways. The entry section need not be completed for organisms which have entered in the past and have no current pathways of entry.**			
Question	**Response**	**Confidence**	**Comment**
1.1. How many active pathways are relevant to the potential entry of this organism? (If there are no active pathways or potential future pathways respond N/A and move to the Establishment section)	none **very few (1-3)** few (4-6) moderate number (7-10) many (11-20) very many (20+)	high	**In the context of this report, only entry through crustacean aquarium trade is considered**

1.2. List relevant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways. For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary).	Anthropogenic – pet trade with subsequent release of animals or aquarium water		Table A1-2

Table A1-2

Pathway name:	Anthropogenic – pet trade		
Question	Response	Conf.	Comments
1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?	accidental	very high	A few schrimp or crab species might be invisibly infected with TSV, either because they are disease free carriers of the virus, or recently infected susceptible species prior to developing signs of disease. The areas with TSV include shrimp-farming regions of the Americas, South-East Asia and the Middle East. Only known to infect marine species

1.4. How likely is it that the organism will travel along this pathway from the point(s) of origin, multiple times (>10) over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.	Unlikely	high	Relatively few known susceptible species and carriers, and these are all marine species which is not of (high) relevance to this report. It is not known if TSV can survive outside its host
1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	Moderately likely	low	TSV survive in its hosts, and might spread to uninfected individuals sharing ambient water with the infected host. It is not known if TSV can survive outside its host
1.6. How likely is the organism to survive existing management practices during passage along the pathway?	likely	medium	Applied management practices involve the breeding of resistant species and vaccination. However, this will not influence survival during passage along the pathway. If infected, the host must be eradicated to get rid of the virus.
1.7. How likely is the organism to enter Norway undetected?	unlikley	medium	It is unlikely that the pathogen enter via aquarium trade of freshwater crustaceans as it only infect marine species. It has never

			been found on cold-water species
1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	unlikley	medium	It is unlikely that the pathogen enter via aquarium trade of freshwater crustaceans as it only infect marine species. It has never been found on cold-water species
1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	Very unlikley	low	If imported in the first place, it will most likely not survive in freshwater, and it has never been found on cold-water species
1.10 Summarized likelihood of the organism entering a suitable habitat in Norway through this pathway	Very unlikely	medium	It is unlikely to enter in the first place. It is a marine shrimp virus. If it should enter, it is very unlikely that the virus 1) survive in a freshwater aquarium, and 2) survive if released into a freshwater habitat – both due to salinity and temperature. This is a warm-water marine virus only known from a few species (see table xx).

Table A1-4

LIKELIHOOD OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Very unlikely	medium	The Norwegian climate is not similar to where TVS is widespread. TSV is an exotic virus infecting marine shrimps in the Americas, South-East Asia and the Middle East. It has never observed in Europe or never reported to infect cold-water species
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Very unlikely	medium	The main distribution of the virus is from tropical and sub-tropical marine waters. It has never observed in Europe or never reported to infect cold-water species. It will most likely not survive the cold water temperatures.
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, terraria, zoological gardens) in Norway?	very ulikely	medium	If accidentally entering together with a crustacean host for freshwater aquarium trade, it will likely not survive in the first place If kept in salt water aquarium with warm temperatures, it will persist. However, this is outside the scope of this report.

Subnote: gardens are not considered protected conditions			
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Only marine habitats relevant – but they are likely not suitable	low	It will most likely not survive in any freshwater habitat, and in particular not in a Nordic country The coastline could in theory provide a suitable habitat, but is most likely devoid of suitable hosts and/or too cold for virus survival
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	unlikely	medium	The management practise will have minor effect since they are largely missing, but establishment is unlikely in the first place. See above
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment?	Very unlikely	medium	The virus is adapted to warm marine waters, infecting a narrow range of primarily shrimp species. These characteristics will not facilitate establishment in freshwater habitats in cold Norway, where the decapod present is noble crayfish.
2.7. How likely is it that the organism could establish	Unlikely	medium	Not relevant, but establishment of TSV is

despite low genetic diversity in the founder population?			unlikely regardless of genetic diversity
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is to establish in Norway? (If possible, specify the instances in the comments box.)	Very ulikely	medium	The spread of the virus is restricted to shrimp farming areas of the Americas, South-East Asia and the Middle East. It has never observed in Europe or never reported to infect cold-water species
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comment box).	Very ulikely	medium	The cold climate is a hindrance. Further, the scope of this report is freshwater crustaceans and habitats. This is a virus adapted marine warm waters and a few selected crustacean hosts in the shrimp farming areas of the Americas, South-East Asia and the Middle East

Table A1-5

LIKELIHOOD OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please	Very unlikely	medium	Will likely not establish, and for the same reason not spread.

list and comment on the mechanisms for natural spread.)			
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Unlikely	medium	Will likely not establish, and for the same reason not spread. However, for the spread to marine waters which would be the only relevant habitat – human assistance would be a prerequisite.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	likely	medium	If introduced in aquarium trade, it is likely contained in the aquarium (it it at all survive) since the likelihood for survival in a natural Norwegian habitat is very low
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	No specific area. Perhaps the coastline	low	No freshwater habitat is of relevance. Marine crustaceans would be the only relevant species, but it is not likely that TSV is a threat to cold-water species.
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comment box to indicate any key issues).	Very unlikely	medium	It will not spread in freshwater. It will likely not survive in cold marine waters.

Table A1-3

LIKELIHOOD OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each set of questions starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (i.e. past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	major	High	*High mortalities in affected shrimp farms in China, Peru, Belize, Ecuador, Costa Rica, Honduras, Thailand, Taiwan, Mexico, Nicaragua, USA. Not commonly reported in natural populations.*
4.2. How much impact would there be, if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	moderate	medium	Viruses mutate rapidly when infecting new hosts. There are already many documented genotypes of TSV, of which only TSV1 is regarded a serious disease agent. However, if new mutations could lead to a virus with higher virulence at lower temperatures, it would become far more devastating to crustaceans in cooler climates.
4.3. How much impact does the organism have, as food, as a host, or as a symbiont or a	minimal	high	Viruses does not act as food, host, or vectors for other damaging organisms

vector for other damaging organisms (e.g. diseases)?			
4.4. How much impact do other factors have, factors which are not covered by previous questions (specify in the comment box)	minimal	low	Host immunity responses and environmental factors play a crucial role for the outcome of infection. Other stressors (e.g., pollution) could result in higher host susceptibility and thus higher negative impact on crustaceans. In the case of TSV, there are still major knowledge gaps
4.5. 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 Norway?	minimal	medium	TSV is an exotic disease virus, and the possible impact on crustacean biodiversity in Norway unknown. However, it is a marine warm-water virus – survival in freshwater is not known, and no cold-water species has ever been reported infected
4.6. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Coast-line	low	If TSV should be introduced and have any potential impact, that would be in marine waters. However, it is unlikely that the virus will survive the low temperatures and find any relevant host
4.7. Estimate the expected impacts of the organism if it is able to establish and spread in Norway (despite any natural	minimal	medium	TSV represent no known threat to freshwater crustaceans in Norway.

control by other organisms, such as predators, parasites or pathogens that may already be present).			If TSV should be introduced and have any potential impact, that would be in marine waters. However, it is unlikely that the virus will survive the low temperatures and find any relevant host. No cold-water species has ever been reported infected with TSV

Table A1-6

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. What aspects of climate change (in a 50 years perspective), if any, are most likely to affect the risk assessment for this organism?	Increased temperature, shorter winters, warmer waters.	medium	The TSV virus is virulent in warm marine waters. Increased ocean temperatures will slightly increase the probability that TSV could survive in, and pose a risk to marine decapods.
5.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Impact on biodiversity	low	The same points as above. However, the temperature must increase alarmingly before the conditions are even close to the natural conditions of the virus

RISK SUMMARIES for Taura syndrom virus (TSV)			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Very unlikely	medium	It is unlikely to enter in the first place. It is a marine shrimp virus. If it should enter, it is very unlikely that the virus 1) survive in a freshwater aquarium, and 2) survive if released into a freshwater habitat – both due to salinity and temperature. This is a warm-water marine virus only known from a few species (see table xx).
Summarise Establishment	Very ulikely	medium	The cold climate is a hindrance. Further, the scope of this report is freshwater crustaceans and habitats. This is a virus adapted marine warm waters and a few selected crustacean hosts in the shrimp farming areas of the Americas, South-East Asia and the Middle East
Summarise Spread	Very unlikely	medium	It will not spread in freshwater. It will likely not survive in cold marine waters.

Summarise Ecological Impact	minimal	medium	TSV represent no known threat to freshwater crustaceans in Norway. If TSV should be introduced and have any potential impact, that would be in marine waters. However, it is unlikely that the virus will survive the low temperatures and find any relevant host. No cold-water species has ever been reported infected with TSV
Conclusion of the risk assessment	Low	Medium	

References:

11.4 Yellow head virus genotype 1 (YHV1)

Table A1-1

LIKELIHOOD OF ENTRY			
Important instructions: • **Entry is the introduction of an organism into Norway. Not to be confused with spread, the movement of an organism within Norway.** • **In the context of this report, only entry through crustacean aquarium trade is considered. Further, this risk assessment should only come into consideration for crustacean species that is regarded possible carriers** • **For organisms which are already present in Norway, only complete the entry section for current active pathways of entry or if relevant potential future pathways. The entry section need not be completed for organisms which have entered in the past and have no current pathways of entry.**			
Question	**Response**	**Confidence**	**Comment**
1.1. How many active pathways are relevant to the potential entry of this organism? (If there are no active pathways or potential future pathways respond N/A and move to the Establishment section)	none **very few (1-3)** few (4-6) moderate number (7-10) many (11-20) very many (20+)	high	**In the context of this report, only entry through crustacean aquarium trade is considered**

1.2. List relevant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways. For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary).	Anthropogenic – pet trade with subsequent release of animals or aquarium water		Table A1-2

Table A1-2

Pathway name:	Anthropogenic – pet trade		
Question	Response	Conf.	Comments
1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?	accidental	very high	Several decapod species might be invisibly infected with YHV1, either because they are disease free carriers of the virus, or recently infected susceptible species prior to developing signs of disease. The areas with YHV1 include shrimp-farming regions in a wide range of Asia, and has also been detected in Mexico. Other non-pathogenic YHV genotypes are known from Australia, Asia and Africa.

			YHV1 infect primarily marine species, but there are reports of infection from freshwater red claw crayfish *Cherax quadricarinatus* and the freshwater river prawn *Macrobrachium sintangense*
1.4. How likely is it that the organism will travel along this pathway from the point(s) of origin, multiple times (>10) over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.	Moderately likely	medium	YHV1 has been shown to infect two freshwater decapods, and infect marine decapods in freshwater culture. Can survive outside its host in aerated seawater for up to 72 hours. Survival in freshwater outside the host is not known.
1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	Likely	medium	YHV1 survive in its hosts, and might spread to uninfected individuals sharing ambient water with the infected host. It is not known if YHV1 can survive outside its host in freshwater, but it can transmit from freshwater red claw crayfish to cultivated shrimps
1.6. How likely is the organism to survive existing management practices during passage along the pathway?	likely	medium	Specific pathogen free (SPF) or PCR-negative seedstock and biosecure water and culture systems may be used to reduce the risk (and spread) of YHV1. However, while this is sometimes used in shrimp farming, the

			practice is probably not in place for aquarium trade?
1.7. How likely is the organism to enter Norway undetected?	moderately likley	medium	Only a few decapod species are relevant for freshwater aquarium trade might be relevant hosts of YHV1. For these, however, it is likely that the organisms enter Norway undetected
1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	moderately likley	medium	If (illegally) released into nature in Norway from aquarium trade, that will more likely not happen when it is ice on the water. It is not known if YHV1 can transmit to cold-water decapod species or survive in cold waters, but the virus does not survive freezing.
1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	unlikley	low	If imported in the first place, it will most likely not survive a winter in freshwater, and it has never been found to infect cold-water species
1.10 Summarized likelihood of the organism entering a suitable habitat in Norway through this pathway	Ulikely	medium	It is only moderately likely to enter in the first place. If it should enter, it is likely that the virus could survive in a freshwater aquarium. If released into a freshwater habitat – it is unlikely that the virus will encounter a susceptible host. It is not

			known if YHV1 can infect noble crayfish, but Northern Europe is not regarded a region where YHV1 will pose a threat to native decapods

Table A1-4

LIKELIHOOD OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Unlikely	medium	The Norwegian climate is not similar to where YHV1 is widespread. YHV1 is an exotic virus infecting primarily marine shrimps in Asia and Mexico. Other genotypes are known in Australia and Africa. YHV1 is reported to infect a few freshwater species. It has never observed in Europe or never reported to infect cold-water species
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Unlikely	medium	The main distribution of the virus is from tropical and sub-tropical marine waters, but it can infect and replicate in a few freshwater decapods. It has never observed in Europe or never reported to infect cold-water species. It will most likely not pose a threat to cold

			water species, and not survive the temperatures during winter.
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, terraria, zoological gardens) in Norway? Subnote: gardens are not considered protected conditions	unlikely	medium	If accidentally entering together with a crustacean host for freshwater aquarium trade, it will likely survive However, it is unlikely that YHV1 enter via freshwater crustacean aquarium trade in the first place.
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Primarily marine habitats relevant – but they are likely not suitable	low	It will most likely not survive in cold freshwater habitats in Norway in the long run. The coastline could in theory provide a suitable habitat, but is most likely devoid of suitable hosts and/or too cold for virus survival
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	unlikely	medium	The management practise will have minor effect since they are largely missing, but establishment is unlikely in the first place. See above

2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment?	Unlikely	medium	The virus is adapted to warm marine waters, although also infecting a few freshwater decapods. These characteristics will not facilitate establishment in freshwater habitats in cold Norway, where the decapod present is noble crayfish.
2.7. How likely is it that the organism could establish despite low genetic diversity in the founder population?	Unlikely	medium	Not relevant, establishment of YHV1 is unlikely regardless of genetic diversity. However, there are several YHV genotypes known from a broader range of countries than YHV1, but none of these have been found in Europe.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is to establish in Norway? (If possible, specify the instances in the comments box.)	Ulikely	medium	The spread of the virus is restricted to shrimp farming areas in Asia and Mexico, as well as some wild populations. It has never observed in Europe or never reported to infect cold-water species
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comment box).	Ulikely	medium	The cold climate is probably a hindrance. Further, the scope of this report is freshwater crustaceans and habitats. This is a virus adapted marine warm waters although it can infect a few freshwater species

Table A1-5

LIKELIHOOD OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Very unlikely	medium	Will likely not establish, and for the same reason not spread.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Unlikely	medium	Will likely not establish, and for the same reason not spread. However, for the spread to marine waters which would be the only relevant habitat – human assistance would be a prerequisite.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	likely	medium	If introduced in aquarium trade, it is likely contained in the aquarium (if it at all survive) since the likelihood for survival in a natural Norwegian habitat is very low

3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	No specific area. Perhaps the coastline	low	No freshwater habitat is of relevance. Marine crustaceans would be the only relevant species, but it is not likely that YHV1 is a threat to cold-water species.
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comment box to indicate any key issues).	Unlikely	medium	It is unlikely that the virus will spread in freshwater, but not completely ruled out since it can infect a freshwater species. It may spread, but will likely not survive in the long run in cold marine waters.

Table A1-3

LIKELIHOOD OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each set of questions starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (i.e. past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the	moderate	medium	*High mortalities (100%) in affected shrimp farms in Asia,*

organism within its existing geographic range, excluding Norway?			*in particular for Penaeus monodon. Natural YHV1 infections have been detected in P. japonicus, P. merguiensis, P. setiferus, M. ensis and P. styliferus, but there is little information available on the natural prevalence and mortality events.*
4.2. How much impact would there be, if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	moderate	medium	There are already many documented genotypes of YHV, only YHV1 is regarded highly virulent. Recent reports indicate virulence also in a newly reported YHV7 in Australia. If new mutations could lead to a YHV virus with higher virulence at lower temperatures, it would become far more devastating to crustaceans in cooler climates.
4.3. How much impact does the organism have, as food, as a host, or as a symbiont or a vector for other damaging organisms (e.g. diseases)?	minimal	high	Viruses does not act as food, host, or vectors for other damaging organisms
4.4. How much impact do other factors have, factors which are not covered by previous questions (specify in the comment box)	minimal	low	Host immunity responses and environmental factors play a crucial role for the outcome of infection. Other stressors (e.g., pollution) could result in higher host susceptibility and thus higher negative impact on crustaceans. In the case of

			YHV, there are still major knowledge gaps
4.5. 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 Norway?	minimal	medium	YHV1 is an exotic crustacean disease virus, and the possible impact on crustacean biodiversity in Norway unknown but expected to be of minor. No cold-water species has ever been reported infected
4.6. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Coast-line	low	If YHV1 should be introduced and have any potential impact, that would be in marine waters. However, it is unlikely that the virus will survive the low temperatures and find any relevant host. No cold-water species has ever been reported infected
4.7. Estimate the expected impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present).	minimal	medium	YHV1 represent no known threat to freshwater crustaceans in Norway. If TSV should be introduced and have any potential impact, that would be in marine waters. However, it is unlikely that the virus will survive the low temperatures and find any relevant host. No cold-water species has ever been reported infected with YHV1

Table A1-6

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. What aspects of climate change (in a 50 years perspective), if any, are most likely to affect the risk assessment for this organism?	Increased temperature, shorter winters, warmer waters.	medium	The YSV1 virus is virulent in warm marine waters. Increased ocean temperatures will slightly increase the probability that YSV1 could survive in, and pose a risk to marine (and freshwater) decapods.
5.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Impact on biodiversity	low	The same points as above. However, the temperature must increase alarmingly before the conditions are even close to the natural conditions of the virus

RISK SUMMARIES for Taura syndrom virus (TSV)			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Ulikely	medium	It is only moderately likely to enter in the first place. If it should enter, it is likely that the virus could survive in a freshwater aquarium. If released into a freshwater habitat – it is unlikely that the virus will

			encounter a susceptible host. It is not known if YHV1 can infect noble crayfish, but Northern Europe is not regarded a region where YHV1 will pose a threat to native decapods
Summarise Establishment	Ulikely	medium	The cold climate is probably a hindrance. Further, the scope of this report is freshwater crustaceans and habitats. This is a virus adapted marine warm waters although it can infect a few freshwater species
Summarise Spread	Unlikely	medium	It is unlikely that the virus will spread in freshwater, but not completely ruled out since it can infect a freshwater species. It may spread, but will likely not survive in the long run in cold marine waters.
Summarise Ecological Impact	minimal	medium	YHV1 represent no known threat to freshwater crustaceans in Norway. If TSV should be introduced and have any potential impact, that would be in marine waters. However, it is

			unlikely that the virus will survive the low temperatures and find any relevant host. No cold-water species has ever been reported infected with YHV1
Conclusion of the risk assessment	Low	Medium	

Appendix IVa

Appendix IVa – Modified GB-NNRA assessments of selected crayfish

Species: *Cambarellus (Cambarellus) montezumae* (Saussure 1857)

English common name: No known common name

Synonyms:

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Unlikely	Medium	Common in aquarium trade in Europe (Chucholl & Wendler 2017)
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Related species from Mexico established in Hungary (Weiperth et al. 2017).

1.3. Estimate the overall likelihood of entry into Norwegian nature.	Unlikely	Medium	

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Moderately likely	Medium	Can survive low temperatures in area of origin but year round climatic conditions usually too cold for successful reproduction in Norway. Preferred temperature in native range 10-25C but can tolerate -2C – 30C for short periods (Madrigal-Bujaidar et al. 2017)
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Moderately likely	Medium	Inhabits ponds and lakes and streams (Madrigal-Bujaidar et al. 2017).
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Moderately likely	High	Should do very well in captivity/aquaria. (Chucholl & Wendler 2017).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	medium	All freshwater habitats,

2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3. Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Moderately likely	High	Reasonable large range of distribution in Mexico and thus adapted for diverse environments. Important keystone species (Madrigal-Bujaidar et al. 2017; Limon-Morales et al. 2018).
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Unlikely	High	Has a reasonable range in Mexico but not yet established outside Mexico
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Moderately likely	medium	Closely related Mexican species established in Hungary (Weiperth et al. 2017). Can survive low temperatures in area of origin but year round climatic conditions may be too cold in Norway.

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Unlikely	medium	The species has a reasonable distribution range in area of origin in Mexico suggesting some dispersion capabilities. Climatic conditions to cold in Norway.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish and other crayfish species in aquarium trade shows that spread by humans is very common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulations against spread has had little effect for signal crayfish in Scandinavia due to the high general interest in crayfish.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Warmer freshwater habitats in the south of Norway.	medium	Eventually possible in ponds with higher temperatures.
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Unlikely	medium	Can survive low temperatures in area of origin but year round climatic conditions are too cold in Norway. (Madrigal-Bujaidar et al. 2017).

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minor	Low	*Not known. Low fecundity. Omnivore and may be possible as competitor and predator on mollusks, fish eggs, insects and macrophytes (Madrigal-Bujaidar et al. 2017).*
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	minimal	High	No hybridization occur.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Most crayfish species are omnivorus (Hill & Lodge 1994), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	Moderate	medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals

			and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway.	medium	
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Most crayfish species are omnivorus (Hill & Lodge 1994), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Massive	High	*Likely carrying* **Aphanomyces astaci** *since closely related species from Mexico shown to be a carrier in nature and in the aquarium trade* *(*Mrugala et al. 2015).
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Low	Potential carrier of WSSV
5.3. How much impact does the organism have as a vector for other pathogens?	Minimal	Low	
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as	Major	Medium	*Likely carrying* **Aphanomyces astaci** *since closely related species from Mexico shown to be a carrier*

predators, parasites, or pathogens that may already be present).			*in nature and in the aquarium trade (*Mrugala et al. 2015). Also, it is a possible carrier of WSSV

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in potential increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establishment, spread, impact on biodiversity, impact on ecosystem functions	High	

RISK SUMMARIES for *Cambarellus (Cambarellus) montezumae*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately likely	High	
Summarise Establishment	Moderately likely	Medium	
Summarise Spread	Unlikely	Medium	

Summarise impact from pathogens/ parasites	Major	Medium	*Likely carrying* **Aphanomyces astaci** *since closely related species from Mexico shown to be a carrier in nature and in the aquarium trade (*Mrugala et al. 2015), and possibly also WSSV.
Summarise Ecological Impact	Moderate	medium	Crayfish are regarded as omnivorus (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	High	Medium	Conclusions mainly based on pathogens.

References:

Chucholl, C., & Wendler, F. 2017. Positive selection of beautiful invaders: long-term persistence and bio-invasion risk of freshwater crayfish in the pet trade. Biological Invasions, 19(1), 197-208.

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Limon-Morales MC, Hernandez-Moreno H, Carmona-Osalde C, Rodriguez-Serna M 2018. Study of the Reproduction of Cambarellus montezumae (Saussure, 1857) Under Different Sex Relations. J Aquac Res Development 9: 556.

Madrigal-Bujaidar, E., Álvarez-González, I., López-López, E., Sedeño-Díaz, J. E., & Ruiz-Picos, R. A. 2017. The Crayfish Cambarellus montezumae as a Possible Freshwater Non-conventional Biomonitor. In Ecotoxicology and Genotoxicology (pp. 157-179).

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish *Pasifastacus leniusculus* using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Weiperth, A., Gál, B., Kuříková, P., Bláha, M., Kouba, A., & Patoka, J. 2017. Cambarellus patzcuarensis in Hungary: The first dwarf crayfish established outside of North America. Biologia, 72(12), 1529-1532.

Species: ***Cambarellus (Cambarellus) patzcuarensis*** **(Martin 2010)**

English common name: Mexican dwarf crayfish

Synonyms: Mexican Mini-Lobster

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Likely	High	Very common in aquarium trade in Europe (Mrugala et al. 2015; Patoka et al. 2015; Faulkes 2015; Chucholl & Wendler 2017).
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Established in Hungary (Weiperth et al. 2017).
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	Medium	See 1.2 above

PROBABILITY OF ESTABLISHMENT

QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Unlikely	medium	Can survive low temperatures in area of origin but year round climatic conditions are not similar in Norway. Preferred temperature 15-25C. Tolerates 10-26C. Established in Hungary (Weiperth et al. 2017).
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Moderately likely	medium	Inhabits ponds and lakes (Weiperth et al. 2017).
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Very likely	High	Does very well in captivity/aquaria. (Mrugala et al. 2015).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	medium	All freshwater habitats,
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3.

			Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Unlikely	medium	Very restricted range in area of origin in Mexico (Weiperth et al. 2017).
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Unlikely	High	Only established once in Hungary but in a warm pond (Weiperth et al. 2017).
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Unlikely	High	Can survive low temperatures in area of origin but year round climatic conditions are not similar in Norway. Established in Hungary (Weiperth et al. 2017).

PROBABILITY OF SPREAD
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Unlikely	medium	The species has a very small distribution in area of origin suggesting low dispersion capabilities.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish and other crayfish species in aquarium trade shows that spread by humans is very common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulations against spread has had little effect for signal crayfish in Scandinavia due to the high general interest in crayfish.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Warmer freshwater habitats in the south of Norway.	High	Mainly ponds with higher temperatures.
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Unlikely	medium	Can survive low temperatures in area of origin but year round climatic conditions are not similar in Norway. Established in Hungary (Weiperth et al. 2017).

PROBABILITY OF ENVIRONMENTAL IMPACT
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment.

• Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minor	Low	*Not known. Very limited geographic range and low fecundity, low competitive ability. Omnivore and may predate on mollusks, fish eggs and insects and macrophytes.*
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	minimal	High	No hybridization occurs.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Most crayfish species are omnivorus (Hill & Lodge 1994), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	Moderate	medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway.	medium	

4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Massive	High	Known carrier
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Low	Suspected carrier
5.3. How much impact does the organism have as a vector for other pathogens?	Minimal	Low	No other information
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Massive	Medium	*Devastating effects on all native European crayfish species through spread of crayfish plague. As it has been shown to be a carrier of* **Aphanomyces astaci** *in nature and in the aquarium trade (*Mrugala et al. 2015). Suspected carrier of *WSSV.*

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	Low	Results in potential increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establishment, spread, impact on biodiversity, impact on ecosystem functions	Low	

RISK SUMMARIES for *Cambarellus (Cambarellus) patzcuarensis*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately likely	Medium	
Summarise Establishment	Unlikely	High	
Summarise Spread	Unlikely	medium	
Summarise impact from pathogens/ parasites	Massive	High	*Devastating effects on all native European crayfish species through spread of crayfish plague. As it has been shown to be a carrier of* **Aphanomyces astaci** *in nature and in the aquarium trade (*Mrugala et al. 2015).

			Suspected carrier of *WSSV.*
Summarise Ecological Impact	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	High	medium	Conclusions mainly based on pathogens.

References:

Chucholl, C., & Wendler, F. 2017. Positive selection of beautiful invaders: long-term persistence and bio-invasion risk of freshwater crayfish in the pet trade. Biological Invasions, 19(1), 197-208.

Faulkes, Z. 2015. The global trade in crayfish as pets. Crustacean Research 44:75-92.

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish *Pasifastacus leniusculus* using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Weiperth, A., Gál, B., Kuříková, P., Bláha, M., Kouba, A., & Patoka, J. 2017. Cambarellus patzcuarensis in Hungary: The first dwarf crayfish established outside of North America. Biologia, 72(12), 1529-1532.

Species: *Cherax destructor* (Clark, 1936)

English common name: Yabby

Synonyms: NA

SECTION B – Detailed assessment
PROBABILITY OF ENTRY
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals

QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Unlikely	Medium	Known from the aquarium trade in Europe Lipták & Vitázková (2015)
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity.
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Unlikely	Medium	See above

PROBABILITY OF ESTABLISHMENT

QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Unlikely	High	Temperature preference lacking, but optimal growth may be as high as 28 C, Westhof and Rosenberger 2016. Does not grow at temperatures below 15 C (Souty-Grosset et al. 2006).
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Moderately likely	Medium	
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	High	Will thrive in captivity. Is one of the most cultured species of crayfish (Souty-Grosset et al. 2006).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3. Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).

2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Very unlikely	High	Temperature preference lacking, but optimal growth may be as high as 28 C, Westhof and Rosenberger 2016. Does not grow at temperatures below 15 C (Souty-Grosset et al. 2006).
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very likely	High	Already established in Southern Europe, but few reproducing populations (Souty-Grosset et al. 2006, Kouba et al. 2014).
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very unlikely	High	Unlikely due to current climatic preferences/conditions.

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**

3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Likely	High	If established, it has high dispersal capacity. Large distribution in area of origin.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish, spread by humans are common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulation against spread has had little effect.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Warmer freshwater habitats in the south of Norway.	Medium	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Very unlikely	High	Temperature preference lacking, but optimal growth may be as high as 28 C, Westhof and Rosenberger 2016. Does not grow at temperatures below 15 C (Souty-Grosset et al. 2006).

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**

4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Moderate	Medium	*High fecundity and tolerance to environmental factors makes it a possible threat (*Souty-Grosset et al. 2006).
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	High	No hybridization occurs.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	Moderate	medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway.	Medium	
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Most crayfish species are omnivorous (Hill & Lodge 1994), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Massive	High	Shown to be susceptible
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Medium	Possible carrier
5.3. How much impact does the organism have as a vector for other pathogens?	Minor	High	
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Massive	Medium	***Has been shown to be susceptible to Aphanomyces astaci and may carry WSSV, as the related C. cuadricarinatus do,*** Mrugala et al. (2015).

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in increased distribution areas.

6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	All the bullet points	High	

RISK SUMMARIES for *Cherax destructor*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Unlikely	Medium	
Summarise Establishment	Very unlikely	High	Unlikely due to current climatic preferences/conditions. Temperature preference lacking, but optimal growth may be as high as 28 C, Westhof and Rosenberger 2016. Does not grow at temperatures below 15 C (Souty-Grosset et al. 2006).
Summarise Spread	Very unlikely	High	Temperature preference lacking, but optimal growth may be as high as 28 C, Westhof and Rosenberger 2016. Does not grow at temperatures below 15 C (Souty-Grosset et al. 2006).
Summarise impact from pathogens/ parasites	Massive	Low	***May have devastating effects on all native European crayfish species mainly through spread of crayfish plague and WSSV.***

Summarise Ecological Impact	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	High	Medium	Conclusions mainly based on pathogens.

References:

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Kouba A, Petrusek A, Kozák P. Continental-wide distribution of crayfish species in Europe: update and maps. Knowledge and Management of Aquatic Ecosystems. 2014;(413):article 05. doi: 10.1051/kmae/2014007.

Liptak, B & Vitazkova, B. 2015. Beautiful, but also potentially invasive. Ekológia (Bratislava). Vol. 34, No. 2, p. 155–162. DOI:10.1515/eko-2015-0016

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus le-niusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Souty-Grosset, C., Holdich, D.M., Noël, P. Y., Reynolds, J. D. & Haffner, P. (eds.) 2006. Atlas of freshwater crayfish in Europe. Museum national d´Histoire naturelle, Paris, 187 p.

Westhof, J.T. & Rosenberger, A.E. 2016. A global review of freshwater crayfish temperature tolerance, preference, and optimal growth. Rev Fish Biol Fisheries 26:329–349.

Species: *Cherax holthuisi* (Lukhaup & Pekny, 2006)

English common name: New Guinean crayfish

Synonyms: NA

SECTION B – Detailed assessment
PROBABILITY OF ENTRY
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals

QUESTION	RESPONSE [choose one entry, delete all others]	CONFIDENCE [choose one entry, delete all others]	COMMENT
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Moderately likely	Medium	Known from the aquarium trade in Europe Lipták & Vitázková (2015). As for a lot of the *Cherax* species, with exceptions for *C. destructor*, *C. quadricarinatus* and *C. tenuimanus*, there are little available data.
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	low	Unintentional release from captivity.
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	Medium	See above

PROBABILITY OF ESTABLISHMENT

QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Unlikely	High	No data on optimal growth. Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range from 23-30 degrees along the shoreline. Cooler climate with increasing altitude, but probably far away from the climate in the RA area. https://www.climatestotravel.com/climate/papua-new-guinea
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Moderately likely	Medium	
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	High	Will thrive in captivity. Is a popular aquarium species Lipták & Vitázková (2015).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats when excluding climate.
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3.

or predators, parasites or pathogens in Norway?			Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Very unlikely	High	No data on optimal growth. Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range from 23-30 degrees along the shoreline. Cooler climate with increasing altitude, but probably far away from the climate in the RA area.
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very unlikely	High	Little is known about invasions elsewhere, newly described species. Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range from 23-30 degrees along the shoreline.
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very unlikely	High	Unlikely due to current climatic preferences/conditions.

PROBABILITY OF SPREAD

Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Moderately likely	Medium	If established, it may have high dispersal capacity.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish, spread by humans are common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulation against spread has had little effect.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Probably no habitats in Norway due to climate.	Low	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Very unlikely	High	Little is known about this species, newly described. Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range from 23-30 degrees along the shoreline.

PROBABILITY OF ENVIRONMENTAL IMPACT

Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Moderate	Low	***Little known about ecology. May carry pathogens.***
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	Medium	No hybridization is known.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	Moderate	medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway. Probably	Medium	

	none as it origins from a tropical Island.		
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Most crayfish species are omnivorous (Hill & Lodge 1994), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Massive	Medium	*May be susceptible to* **Aphanomyces astaci**
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Medium	*May carry WSSV, as the related* **C. cuadricarinatus** *do,* Mrugala et al. (2015).
5.3. How much impact does the organism have as a vector for other pathogens?	Moderate	Medium	*May carry burn-spot disease and* **A. psorospermium** *(other* **Cherax** *species are carriers, see Souty-Grosset et al. 2006. Atlas of Crayfish in Europe. Muséum national d`Histoire naturelle, Paris, 187 p.)*
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as	Massive	Medium	*Suspected carrier of both crayfish plague, WSSW and other diseases.*

predators, parasites, or pathogens that may already be present).			

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	All the bullet points	High	

RISK SUMMARIES for *Cherax holthuisi*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately likely	Medium	
Summarise Establishment	Very unlikely	High	Unlikely due to current climatic preferences/conditions.
Summarise Spread	Very unlikely	High	Little is known about this species, newly described. Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range

			from 23-30 degrees along the shoreline.
Summarise impact from pathogens/ parasites	Massive	Medium	*Suspected carrier of both crayfish plague, WSSW and other diseases and may thus have devastating effects on all native European crayfish species.*
Summarise Ecological Impact	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	High	Medium	Conclusions mainly based on pathogens.

References:

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Liptak, B & Vitazkova, B. 2015. Beautiful, but also potentially invasive. Ekológia (Bratislava). Vol. 34, No. 2, p. 155–162. DOI:10.1515/eko-2015-0016

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus le-niusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Souty-Grosset, C., Holdich, D.M., Noël, P. Y., Reynolds, J. D. & Haffner, P. (eds.) 2006. Atlas of freshwater crayfish in Europe. Museum national d´Histoire naturelle, Paris, 187 p.

Species: ***Cherax monticola*** **(Holthuis, 1950)**

English common name: NA

Synonyms: NA

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Unlikely	Medium	Several newly discovered Cherax species in New Guinea, with attractive colors. For this reason, they are harvested in the wild and used as ornamental animals. Ribeiro F.B. Crayfish: Evolution, Habitat and Conservation Strategies. Nova Science Publishers. ISBN-10: 1536169412 ISBN-13: 978-1536169416. Mostly imported after field capture. J. Patoka, L. Kalous, O. Kopecký 2015. Imports of ornamental crayfish: the first decade from the Czech Republic's perspective. Knowledge and Management of Aquatic Ecosystems (2015) 416, 04.

1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity.
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Unlikely	Medium	See above

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Moderately likely	Low	No data on optimal growth. Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range from 23-30 degrees along the shoreline. Cooler climate with increasing altitude. This species is known to occur in rivers and pools up to an altitude of 3300 m (Holthuis 1950). Thus, it may be more adapted to the climate in the RA area than other New Guienean Cherax species. But this is highly unknown. https://www.climatestotravel.com/climate/papua-new-guinea
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Moderately likely	Medium	
2.3. How likely is it that the organism will become established	Likely	High	Will thrive in captivity. Is a popular aquarium species.

in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions			
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats when excluding climate.
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3. Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Moderately likely	Low	No data on optimal growth. Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range from 23-30 degrees along the shoreline. Cooler climate with increasing altitude. This species is known to occur in rivers and pools up to an altitude of 3300 m. Thus, it may be more adapted to the climate in the RA area than other New Guinean *Cherax* species. But this is highly uncertain. https://www.climatestotravel.com/climate/papua-new-guinea
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal

			crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Moderately unlikely	Low	Little is known about invasions elsewhere, newly described species.
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Moderately likely	Low	This species is known to occur in rivers and pools up to an altitude of 3300 m. Thus, it may be more adapted to the climate in the RA area than other New Guinean *Cherax* species. But this is highly uncertain.

PROBABILITY OF SPREAD

Important notes:

- Spread is defined as the expansion of the geographical distribution of an alien species within an area.

QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Moderately likely	Medium	If established, it may have high dispersal capacity.

3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	Medium	If established, experience from signal crayfish, spread by humans are common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulation against spread has had little effect.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Probably no habitats in Norway due to climate.	Low	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Moderately likely	Low	Little is known about this species, newly described. This species is known to occur in rivers and pools up to an altitude of 3300 m. Thus, it may be more adapted to the climate in the RA area than other New Guinean *Cherax* species. But this is highly uncertain.

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its	Minor	Low	***Little known about ecology.***

existing geographic range, excluding Norway?			
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	Medium	No hybridization known.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Most crayfish species are omnivorous (Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	Moderate	medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway.	Medium	
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Massive	Medium	*May be susceptible to* **Aphanomyces astaci**
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Medium	*May carry WSSV, as the related* **C. cuadricarinatus** *do,* Mrugala et al. (2015).
5.3. How much impact does the organism have as a vector for other pathogens?	Moderate	Medium	*May carry burn-spot disease and* **A. psorospermium** *(other* **Cherax** *species are carriers, see Souty-Grosset et al. 2006. Atlas of Crayfish in Europe. Muséum national d`Histoire naturelle, Paris, 187 p.)*
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Massive	Medium	*Suspected carrier of both crayfish plague, WSSW and other diseases.*

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if	Warmer climate	High	Results in increased distribution areas.

any, are most likely to affect the risk assessment for this organism?	and shorter winters.		
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	All the bullet points	High	

RISK SUMMARIES for *Cherax monticola*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Unlikely	Medium	
Summarise Establishment	Moderately likely	Low	This species is known to occur in rivers and pools up to an altitude of 3300 m. Thus, it may be more adapted to the climate in the RA area than other New Guinean *Cherax* species. But this is highly uncertain.
Summarise Spread	Moderately likely	Low	Little is known about this species, newly described. This species is known to occur in rivers and pools up to an altitude of 3300 m. Thus, it may be more adapted to the climate in the RA area than other New Guinean *Cherax* species. But this is highly uncertain.

Summarise impact from pathogens/ parasites	Massive	Medium	*May have devastating effects on all native European crayfish species, mainly through possible spread of diseases (see above).*
Summarise Ecological Impact	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	High	Medium	Conclusions mainly based on pathogens.

References:

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Holthuis, L.B. 1950. Results of the Archbold Expeditions NO. 63 the crustacea decapoda Macrura collected by the Archbold New Guinea Expeditions. American Museum Novitates. American Museum of Natural History.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Patoka, J., L. Kalous, and O. Kopecký. 2015. Imports of ornamental crayfish: the first decade from the Czech Republic's perspective. Knowledge and Management of Aquatic Ecosystems 416, 2015: 04.

Ribeiro F.B. 2020. Crayfish: Evolution, Habitat and Conservation Strategies. Nova Science Publishers. ISBN-10: 1536169412

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus le-niusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Souty-Grosset, C., Holdich, D.M., Noël, P. Y., Reynolds, J. D. & Haffner, P. (eds.) 2006. Atlas of freshwater crayfish in Europe. Museum national d´Histoire naturelle, Paris, 187 p.

Species: *Cherax peknyi* (Lukhaup & Herbert, 2008)

English common name: Zebra crayfish or Blue claw

Synonyms: NA

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Moderately likely	Medium	Known from the aquarium trade in Europe Lipták & Vitázková (2015). As for a lot of the Cherax species, with exeptions for *C. destructor, C. quadricarinatus* and *C. tenuimanus,* there are little available data.
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity.
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	Medium	See above

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Unlikely	Low	No data on optimal growth. Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range from 23-30 degrees along the shoreline. Cooler climate with increasing altitude, but probably far away from the climate in the RA area. https://www.climatestotravel.com/climate/papua-new-guinea
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Moderately likely	Medium	
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	High	Will thrive in captivity. Is a popular aquarium species Lipták & Vitázková (2015).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats when excluding climate.
2.5. How likely is it that establishment will occur despite management practices (including	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like

eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?			signal crayfish. Spread has continued. See also 3.3. Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Very unlikely	High	No data on optimal growth. Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range from 23-30 degrees along the shoreline. Cooler climate with increasing altitude, but probably far away from the climate in the RA area.
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very unlikely	High	Little is known about invasions elsewhere, newly described species. Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range from 23-30 degrees along the shoreline.
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very unlikely	High	Unlikely due to current climatic preferences/conditions.

PROBABILITY OF SPREAD

Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Moderately likely	Medium	If established, it may have high dispersal capacity.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	Medium	If established, experience from signal crayfish, spread by humans are common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulation against spread has had little effect.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Probably no habitats in Norway due to climate.	Low	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Very unlikely	High	Little is known about this species, newly described. Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range from 23-30 degrees along the shoreline.

PROBABILITY OF ENVIRONMENTAL IMPACT

Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minor	Low	*Little known about ecology.*
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	Medium	No hybridization known.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	Moderate	medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway. Probably	Medium	

	none as it origins from a tropical Island.		
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Massive	Medium	*May be susceptible to* **Aphanomyces astaci**
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Medium	*May carry WSSV, as the related* **C. cuadricarinatus** *do,* Mrugala et al. (2015).
5.3. How much impact does the organism have as a vector for other pathogens?	Moderate	Medium	*May carry burn-spot disease and* **A. psorospermium** *(other* **Cherax** *species are carriers, see Souty-Grosset et al. 2006. Atlas of Crayfish in Europe. Muséum national d`Histoire naturelle, Paris, 187 p.)*
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control	Massive	Medium	*Suspected carrier of both crayfish plague, WSSW and other diseases.*

by other organisms, such as predators, parasites, or pathogens that may already be present).			

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	All the bullet points	High	

RISK SUMMARIES for ***Cherax peknyi***			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately likely	Medium	
Summarise Establishment	Very unlikely	High	Unlikely due to current climatic preferences/conditions.
Summarise Spread	Very unlikely	High	Little is known about this species, newly described.

			Papa New Guinea has a hot, humid and tropical climate. Average monthly air temperatures range from 23-30 degrees along the shoreline.
Summarise impact from pathogens/ parasites	Massive	Low	***May have devastating effects on all native European crayfish species, mainly through possible spread of diseases (see above).***
Summarise Ecological Impact	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	High	Medium	Conclusions mainly based on pathogens.

References:

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Liptak, B & Vitazkova, B. 2015. Beautiful, but also potentially invasive. Ekológia (Bratislava). Vol. 34, No. 2, p. 155–162. DOI:10.1515/eko-2015-0016

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus le-niusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Souty-Grosset, C., Holdich, D.M., Noël, P. Y., Reynolds, J. D. & Haffner, P. (eds.) 2006. Atlas of freshwater crayfish in Europe. Museum national d´Histoire naturelle, Paris, 187 p.

Species: *Cherax preissii* (Erichson, 1846)

English common name: Koonac or Black Tiger

Synonyms: NA

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Unlikely	Medium	Known from the aquarium trade in Europe J. Patoka et al. 2015. As for a lot of the *Cherax* species, with exceptions for *C. destructor, C. quadricarinatus* and *C. tenuimanus,* there are little available data.
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity.
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Unlikely	Medium	See above

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Unlikely	High	No data on optimal growth, but probably far away from the climate in the RA area. Originate from Australia.
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Moderately likely	Medium	
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	High	Will thrive in captivity. Is a popular aquarium species (Patoka et al. 2015).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats when excluding climate.
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3.

			Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Very unlikely	High	No data on optimal growth, but probably far away from the climate in the RA area. Originate from Australia.
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et al. 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very unlikely	High	Little is known about invasions elsewhere. No data on optimal growth, but probably far away from the climate in the RA area. Originate from Australia.
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very unlikely	High	Unlikely due to current climatic preferences/conditions.

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**

3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Moderately likely	Medium	If established, it may have high dispersal capacity.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish, spread by humans are common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulation against spread has had little effect.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Probably no habitats in Norway due to climate.	Low	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Very unlikely	High	Little data on ecology. No data on optimal growth, but probably far away from the climate in the RA area. Originate from Australia.

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**

4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minor	Low	*Little known about ecology.*
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	Medium	No hybridization known.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	Moderate	medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway. Probably none as it origins from a tropical Island.	Medium	
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill &

in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).			Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Massive	Medium	*May be susceptible to* **Aphanomyces astaci**
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Medium	*May carry WSSV, as the related* **C. cuadricarinatus** *do,* Mrugala et al. (2015).
5.3. How much impact does the organism have as a vector for other pathogens?	Moderate	Medium	*May carry burn-spot disease and* **A. psorospermium** *(other* **Cherax** *species are carriers, see Souty-Grosset et al. 2006. Atlas of Crayfish in Europe. Muséum national d`Histoire naturelle, Paris, 187 p.)*
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Massive	Medium	*Suspected carrier of both crayfish plague, WSSW and other diseases.*

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	All the bullet points	High	

RISK SUMMARIES for *Cherax preissii*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Unlikely	Medium	
Summarise Establishment	Very unlikely	High	Unlikely due to current climatic preferences/conditions.
Summarise Spread	Very unlikely	High	Little data on ecology. No data on optimal growth, but probably far away from the climate in the RA area. Originate from Australia.
Summarise impact from pathogens/ parasites	Massive	Medium	*May have devastating effects on all native European crayfish*

			species, mainly through possible spread of diseases (see above).
Summarise Ecological Impact	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	High	Medium	Conclusions mainly based on pathogens.

References:

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Patoka, J., L. Kalous, and O. Kopecký. 2015. Imports of ornamental crayfish: the first decade from the Czech Republic's perspective. Knowledge and Management of Aquatic Ecosystems 416, 2015: 04.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus le-niusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Species: *Cherax quadricarinatus* (von Martens, 1868)

English common name: Red claw, Australian red claw, Quueensland red claw, Tropical blue crayfish.

Synonyms: NA

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Likely	Medium	Known from the aquarium trade in Europe (Mrugale et al. 2015). Known to be traded in Norway
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity.
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	Medium	See above

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism’s current distribution?	Unlikely	High	Temperature preference 23-26 C (Westhof and Rosenberger 2016).
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism’s current distribution?	Moderately likely	Medium	
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	High	Will thrive in captivity. Is one of the most cultured species of crayfish (Souty-Grosset et al. 2006).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3.

			Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Very unlikely	High	Temperature preference 23-26 C, (Westhof and Rosenberger 2016).
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very likely	High	Already established in Southern Europe, but few reproducing populations (Souty-Grosset et al. 2006, Kouba et al. 2014).
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very unlikely	High	Unlikely due to current climatic preferences/conditions.

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**

3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Likely	High	If established, it has high dispersal capacity. Large distribution in area of origin.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish, spread by humans are common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulation against spread has had little effect.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Warmer freshwater habitats in the south of Norway.	Medium	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Very unlikely	High	Temperature preference 23-26 C (Westhof and Rosenberger 2016).

PROBABILITY OF ENVIRONMENTAL IMPACT
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment.

• Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.

QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minor	Low	*Little known about ecology.*
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	Medium	No hybridization known.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	Moderate	medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway. Probably none as it origins from a tropical Island.	Medium	

4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Massive	Medium	*May be susceptible to* **Aphanomyces astaci**
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Medium	*May carry WSSV, as the related* **C. cuadricarinatus** *do,* Mrugala et al. (2015).
5.3. How much impact does the organism have as a vector for other pathogens?	Moderate	Medium	*May carry burn-spot disease and* **A. psorospermium** *(other* **Cherax** *species are carriers, see Souty-Grosset et al. 2006. Atlas of Crayfish in Europe. Muséum national d`Histoire naturelle, Paris, 187 p.)*
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Massive	Medium	*Suspected carrier of both crayfish plague, WSSW and other diseases.*

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPON SE**	**CONFIDEN CE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	All the bullet points	High	

RISK SUMMARIES for *Cherax quadricarinatus*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately likely	Medium	
Summarise Establishment	Very unlikely	High	Unlikely due to current climatic preferences/conditions.
Summarise Spread	Very unlikely	High	Temperature preference 23-26 C (Westhof and Rosenberger 2016).
Summarise impact from pathogens/ parasites	Massive	Medium	*May have devastating effects on all native European crayfish species, mainly through possible*

			spread of diseases (see above).
Summarise Ecological Impact	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	high	High	Conclusions mainly based on pathogens.

References:

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Kouba A, Petrusek A, Kozák P. Continental-wide distribution of crayfish species in Europe: update and maps. Knowledge and Management of Aquatic Ecosystems. 2014;(413):article 05. doi: 10.1051/kmae/2014007.

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus le-niusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Souty-Grosset, C., Holdich, D.M., Noël, P. Y., Reynolds, J. D. & Haffner, P. (eds.) 2006. Atlas of freshwater crayfish in Europe. Museum national d´Histoire naturelle, Paris, 187 p.

Westhof, J.T. & Rosenberger, A.E. 2016. A global review of freshwater crayfish temperature tolerance, preference, and optimal growth. Rev Fish Biol Fisheries 26:329–349.

Species: ***Cherax tenuimanus*** **(Smith, 1912)**

English common name: Marron, Hairy marron and Margaret river marron.

Synonyms: NA

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Moderately likely	Medium	Seen in the fish markets, but not known from the aquarium trade in Europe or cultivation in Europe (Souty-Grosset et al. 2006, Lipták & Vitázková 2015)
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity.
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	Medium	See above

PROBABILITY OF ESTABLISHMENT

QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Moderately unlikely	Medium	Optimal growth varies from 15-24 degrees. Lower tolerance from 4-11 degrees (Westhoff and Rosenberger 2016). May thus perhaps survive in some parts of the RA area. On the other side, it is regarded as less tolerant to other environmental conditions.
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Moderately likely	Medium	
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	High	Will thrive in captivity. Is one of the most cultured species of crayfish (Souty-Grosset et al. 2006).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3.

			Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Moderately likely	Medium	Optimal growth varies from 15-24 degrees. Lower tolerance from 4-11 degrees, from references within (Westhoff and Rosenberger 2016). May thus perhaps survive in some parts of the RA area. On the other side, it is regarded as less tolerant to other environmental conditions.
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very likely	High	Already established in Southern Europe, but few reproducing populations (Souty-Grosset et al. 2006, Kouba et al. 2014).
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Moderately likely	Low	Perhaps possible due to climatic preferences/conditions.

PROBABILITY OF SPREAD

Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Unlikely	Medium	If established, it grows quite slow, and will probably not gain a large distribution area.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish, spread by humans are common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulation against spread has had little effect.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Warmer freshwater habitats in the south of Norway.	Medium	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Moderately likely	Low	Temperature conditions in Norway are not optimal.

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minor	Low	*Little known, but due to its size it has the potential to cause problems (*Souty-Grosset et al. 2006).
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	Medium	No hybridization known.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	Moderate	medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are	Warmer freshwater habitats in	Medium	

particularly likely to occur (provide as much detail as possible).	the south of Norway. Probably none as it origins from a tropical Island.		
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONS E**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Massive	Medium	*May be susceptible to* **Aphanomyces astaci**
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Medium	*May carry WSSV, as the related* **C. cuadricarinatus** *do,* Mrugala et al. (2015).
5.3. How much impact does the organism have as a vector for other pathogens?	Moderate	Medium	*May carry burn-spot disease and* **A. psorospermium** *(other* **Cherax** *species are carriers, see Souty-Grosset et al. 2006. Atlas of Crayfish in Europe. Muséum national d`Histoire naturelle, Paris, 187 p.)*

5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Massive	Medium	*Suspected carrier of both crayfish plague, WSSW and other diseases.*

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	All the bullet points	High	

RISK SUMMARIES for *Cherax tenuimanus*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately unlikely	Medium	
Summarise Establishment	Moderately likely	Low	Perhaps possible due to climatic

			preferences/conditions in some parts of Norway.
Summarise Spread	Moderately likely	Low	Temperature conditions in Norway are not optimal.
Summarise impact from pathogens/ parasites	Massive	Medium	***May have devastating effects on all native European crayfish species, mainly through possible spread of diseases (see above).***
Summarise Ecological Impact	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	High	Low	Conclusions mainly based on pathogens.

References:

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Kouba A, Petrusek A, Kozák P. Continental-wide distribution of crayfish species in Europe: update and maps. Knowledge and Management of Aquatic Ecosystems. 2014;(413):article 05. doi: 10.1051/kmae/2014007.

Liptak, B & Vitazkova, B. 2015. Beautiful, but also potentially invasive. Ekológia (Bratislava). Vol. 34, No. 2, p. 155–162. DOI:10.1515/eko-2015-0016

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus le-niusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Souty-Grosset, C., Holdich, D.M., Noël, P. Y., Reynolds, J. D. & Haffner, P. (eds.) 2006. Atlas of freshwater crayfish in Europe. Museum national d´Histoire naturelle, Paris, 187 p.

Westhof, J.T. & Rosenberger, A.E. 2016. A global review of freshwater crayfish temperature tolerance, preference, and optimal growth. Rev Fish Biol Fisheries 26:329–349.

Species: *Creaserinus fodiens* **(Cottle, 1863)**

English common name: Digger crayfish

Synonyms: *Fallicambarus fodiens*

SECTION B – Detailed assessment
PROBABILITY OF ENTRY
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals

QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Unlikely	Low	Not known from the aquarium trade in Europe, but may be a popular species.
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity.
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Unlikely	Low	See above

PROBABILITY OF ESTABLISHMENT

QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Unlikely	High	Most of the native range is further south than the RA area. However, the species are found in Ontario, Canada. (Guiasu, R.C. 2007).
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Moderately likely	Medium	
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Moderately likely	Medium	Will probably thrive in captivity.
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3. Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).

2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Moderately likely	Medium	Temperature preference lacking, but most of the native range is further south than the RA area. However, the species are found in Ontario, Canada. Guiasu, R.C. 2007.
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Moderately unlikely	Low	
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Moderately likely	Low	Temperature preference lacking, but most of the native range is further south than the RA area. However, the species are found in Ontario, Canada. Guiasu, R.C. 2007.

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**

3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Likely	Low	If established, it may have high dispersal capacity.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish, spread by humans are common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulation against spread has had little effect.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Warmer freshwater habitats in the south of Norway.	Medium	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Moderately unlikely	Low	Temperature preference lacking, but most of the native range is further south than the RA area. However, the species are found in Ontario, Canada. Guiasu, R.C. 2007.

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**

4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minimal	Low	*Not known*
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	Medium	Hybridization will probably not occur.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	Moderate	Medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway.	Medium	
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Massive	Moderate	
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Minimal	Low	
5.3. How much impact does the organism have as a vector for other pathogens?	Minimal	Low	
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Massive	Moderate	*Potential carrier of A. astaci and other diseases.*

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change?	All the bullet points	High	

• Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions			

RISK SUMMARIES for *Creaserinus fodiens*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Unlikely	Low	
Summarise Establishment	Unlikely	Low	Temperature preference lacking, but most of the native range is further south than the RA area. However, the species are found in Ontario, Canada (Guiasu, R.C. 2007).
Summarise Spread	Unlikely	Low	Temperature preference lacking, but most of the native range is further south than the RA area. However, the species are found in Ontario, Canada (Guiasu, R.C. 2007).
Summarise impact from pathogens/ parasites	Massive	Medium	***May have devastating effects on all native European crayfish species mainly through spread of crayfish plague and other diseases.***
Summarise Ecological Impact	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	High	Medium	Conclusions mainly based on pathogens.

References:

Guiasu, R.C. 2007. Conservation and diversity of the crayfishes of the genus Fallicambarus Hobbs, 1969 (Decapoda, Cambaridae), with an emphasis on the status of Fallicambarus fodiens (Cottle, 1863) in Canada. Crustaceana, 80(2): 207-223.

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus leniusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Species: *Faxonius neglectus chaendactylus* (Crandall and De Grave 2017)

English common name: Gape ringed crayfish

Synonyms: Orconectes neglectus neglectus (Faxon 1885)

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Unlikely	medium	Occurs but not very common in pet trade.
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity. Can survive harsh winters (Larsen & Magoulick 2008).
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Unlikel	Medium	See 1.2 above

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**

2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Likely	High	Survives in harsh winter conditions down to 5C. Originates from Oregon but has established within north America (Larsen & Magoulick 2008).
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Likely	medium	All freshwater habitats but mainly stream habitats (Larsen & Magoulick 2008).
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	medium	Will do well in captivity since it is in the aquarium trade.
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	medium	All freshwater habitats
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3. Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread)	Likely	medium	Survives in harsh winter conditions. Closely related species have an extensive

of the organism to facilitate its establishment in Norway?			range in area of origin in north America, into Canada and are already established in Europe (Souty-Grosset et al. 2006)
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Likely	High	Invasive in north America (Mouser et al.2019). Closely related species already established in Europe (Souty-Grosset et al. 2006, Kozak et al. 2015).
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Likely	High	Due to similar climatic conditions in area of origin and introduced range in north America. Invasive locally in north America.

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please	Moderately likely	medium	If established, it has dispersal capacity. Similar climatic

list and comment on the mechanisms for natural spread.)			conditions in north America where it has spread.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish shows that spread by humans is very common due to the high interest for freshwater crayfish.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulations against spread has had little effect for signal crayfish in Scandinavia due to high general interest in crayfish.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Warmer freshwater habitats in the south of Norway.	High	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Likely	medium	Survives in harsh winter conditions down to 5C. Climatic conditions reasonably well match conditions in Norway

PROBABILITY OF ENVIRONMENTAL IMPACT

Important instructions:

- When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment.
- Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.

QUESTION	RESPONSE	CONFIDENCE	COMMENTS
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	major	medium	*Has a record of invasiveness when translocated in north America (Mouser et al. 2019)*

4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	minimal	High	No hybridization occurs.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	moderate	Medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway.	High	
4.6. Estimate the expected impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS

QUESTION	RESPONSE	CONFIDENCE	COMMENTS
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	massive	medium	*Most likely a carrier of A.* **Aphanomyces astaci** *in nature and in the aquarium trade as for other species in this genus (Souty Grosset et al 2006;* Mrugala et al. 2015).
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Low	Suspected carrier
5.3. How much impact does the organism have as a vector for other pathogens?	Minor	Low	
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Massive	Medium	Closely related to known carriers of *A. astaci*, and suspected carrier of WSSV.

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in potential increased distribution areas in Norway.
6.2. What aspects of the risk assessment are most likely to	Establishment, spread,	High	

change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	impact on biodiversity, impact on ecosystem functions		

RISK SUMMARIES for ***Faxonius neglectus chaendactylus***			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Unlikely	medium	Successfully established outside native range in north America.
Summarise Establishment	Likely	High	Proven invasiveness, successfully established outside native range.
Summarise Spread	Likely	High	Proven invasiveness since successfully spread outside native range
Summarise impact from pathogens/ parasites	Massive	High	*Devastating effects on all native European crayfish species through spread of crayfish plague and possibly WSSV*
Summarise Ecological Impact	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	High	High	

References:

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Larson, E. R., & Magoulick, D. D. 2008. Comparative life history of native (Orconectes eupunctus) and introduced (Orconectes neglectus) crayfishes in the Spring River drainage of Arkansas and Missouri. The American Midland Naturalist, 323-341.

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mouser, J., Ashley, D. C., Aley, T., & Brewer, S. K. 2019. Subterranean invasion by gapped ringed crayfish: Effectiveness of a removal effort and barrier installation. Diversity, 11(1), 3.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus le-niusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Souty-Grosset, C., Holdich, D.M., Noël, P. Y., Reynolds, J. D. & Haffner, P. (eds.) 2006. Atlas of freshwater crayfish in Europe. Museum national d´Histoire naturelle, Paris, 187 p.

Species: ***Faxonius virilis*** **(Crandall and De Grave 2017),** as a representative for the genus Faxonius (formerly Orconectes). This genus also includes F. rusticus, F. immunis, F. limosus, F. juvenilis

English common name: Virile crayfish

Synonyms: *Orconectes virilis*

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Unlikely	medium	Known from the aquarium trade in Europe (Mrugala et al. 2015).
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity. Has an extensive range in area of origin, up to Canada. Established in Europe (Souty-Grosset et al. 2006).
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Unlikely	Medium	See 1.2 above

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Very likely	High	Survives in harsh winter conditions down to 0C. Has an extensive range in area of origin in north America, into Canada. Established in Europe (Souty-Grosset et al. 2006; Kawai et al. 2016).
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Likely	High	Inhabits a variety of abiotic conditions in area of origin (Kozak et al. 2015).
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	High	Will do well in captivity. (Souty-Grosset et al. 2006).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3.

or predators, parasites or pathogens in Norway?			Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Very likely	High	Survives in harsh winter conditions down to 0C. Has an extensive range in area of origin in north America, into Canada. Already established in Europe (Souty-Grosset et al. 2006)
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very likely	High	Already established in Europe (Souty-Grosset et al. 2006, Kozak et al. 2015).
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very likely	High	Due to similar climatic conditions in area of origin and introduced area in north America.

PROBABILITY OF SPREAD
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Very likely	High	If established, it has high dispersal capacity. Large distribution in area of origin and widely spread in north America. (Souty-Grosset et al. 2006; Kawai et al. 2016).
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish shows that spread by humans is very common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulations against spread has had little effect for signal crayfish in Scandinavia due to high general interest in crayfish.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Warmer freshwater habitats in the south of Norway.	High	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Very likely	High	Survives in harsh winter conditions down to 0C. Has an extensive range in area of origin in north America, into Canada. Established in Europe (Souty-Grosset et al. 2006; Kawai et al. 2016).

PROBABILITY OF ENVIRONMENTAL IMPACT
Important instructions:

• When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Major	medium	***Establishes in high densities, high fecundity, growth rate, and competitive ability*** *(*Souty-Grosset et al. 2006; Kozak et al. 2015).
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	minimal	High	No hybridization occurs.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	moderate	medium	Predation and competition.
4.4. 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 Norway?	Moderate	Medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway.	High	

4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Major	High	*Faxonius virilis* is one of the most widely invasive crayfish species in the USA (Larson and Olden, 2011), and has been successfully translocated outside its natural range. Populations have also been found in Mexico, Canada and Europe (UK and the Netherlands). *F. virilis* is highly mobile, fecund and tolerant of a wide range of environmental variables making the species a very successful invader (Souty-Grosset et al. 2006; Kozak et al. 2015).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Massive	High	***Has been shown to be a carrier of A. Aphanomyces astaci in nature and in the aquarium trade -*** Mrugala et al. (2015).
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Moderate	Low	Possible carrier
5.3. How much impact does the organism have as a vector for other pathogens?	Minimal	Moderate	
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in	Massive	High	***Has been shown to be a carrier of A. Aphanomyces astaci in***

Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).			*nature and in the aquarium trade -* Mrugala et al. (2015).

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in potential increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establishment, spread, impact on biodiversity, impact on ecosystem functions	High	

RISK SUMMARIES for *Faxonius virilis*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Unlikely	Medium	Proven invasiveness, large original distribution area, and successfully established outside native range
Summarise Establishment	Very likely	High	Proven invasiveness, large original distribution area, and successfully established outside native range

Summarise Spread	Very likely	High	Proven invasiveness, large original distribution area, and successfully established outside native range
Summarise impact from pathogens/ parasites	Massive	High	*Devastating effects on all native European crayfish species through spread of crayfish plague*
Summarise Ecological Impact	Major	High	*Faxonius virilis* is one of the most widely invasive crayfish species in the USA (Larson and Olden, 2011), and has been successfully translocated outside its natural range. Populations have also been found in Mexico, Canada and Europe (UK and the Netherlands). *F. virilis* is highly mobile, fecund and tolerant of a wide range of environmental variables making the species a very successful invader (Souty-Grosset et al. 2006; Kozak et al. 2015).
Conclusion of the risk assessment	high	High	Based on pathogens, proven invasiveness and adaptability to climatic conditions in Norway.

References:

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Kawai, T., Faulkes, Z., & Scholtz, G. (Eds.). 2016. Freshwater crayfish: a global overview. CRC Press.

Kozák, P., Ďuriš, Z., Petrusek, A., Buřič, M., Horká, I., Kouba, A., Kozubíková-Balcarová E. & Němečková, K. 2015. Crayfish biology and culture. University of South Bohemia in České Budějovice, Faculty of Fisheries and Protection of Waters.

Larson ER, Olden JD, 2011. The state of crayfish in the pacific northwest. Fisheries, 36:60-73.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus le-niusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Souty-Grosset, C., Holdich, D.M., Noël, P. Y., Reynolds, J. D. & Haffner, P. (eds.) 2006. Atlas of freshwater crayfish in Europe. Museum national d´Histoire naturelle, Paris, 187 p.

Species: ***Pacifastacus leniusculus*** **(Dana, 1852)**

English common name: Signal crayfish

Synonyms: NA

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Likely	High	Already established (Johnsen et. al 2019)
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Moderately likely	medium	Most likely route to nature is from already established population.
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Very likely	High	Already established.

PROBABILITY OF ESTABLISHMENT

QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism’s current distribution?	Very likely	High	Already established (Johnsen et. al 2019)
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism’s current distribution?	Very likely	High	Already established (Johnsen et. al 2019)
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	High	Has been used in aquaria and extensively in aquaculture in Sweden (Edsman & Schröder 2009).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Moderately widespread	High	May be restricted by high altitude and long winters. These limitations have been found in Sweden and Finland
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3.

			Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Very likely	High	Already established (Johnsen et. al 2019)
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Already established (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very likely	High	Already established (Johnsen et. al 2019)
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very likely	High	Already established (Johnsen et. al 2019)

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please	Very likely	High	Already established (Johnsen et. al 2019). Spread has already happened in Norway both

list and comment on the mechanisms for natural spread.)			naturally and by human introductions.
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Very likely	High	Already established (Johnsen et al. 2019). Spread has already happened in Norway both naturally and by human introductions.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulation against spread has had little effect. Spread has continued.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Possible up to 320 m altitude and up to Nordtröndelag	High	The area where it already has established (Johnsen 2015)
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Very likely	High	Spread has already happened in Norway and continues.

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	massive	High	***Has had devastating effects on all native European crayfish***

			species (Holdich et al. 2009)
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	High	No hybridization occurs.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	moderate	medium	More competitive than noble crayfish (Söderbäck 1985; Westman et al. 2002).
4.4. 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 Norway?	major	High	*Detrimental to the noble crayfish*
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Se map in (Johnsen and Vrålstad 2017).	High	In particular in the Noble crayfish distribution area
4.6. Estimate the expected impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Major	High	Likely to outcompete the noble crayfish.

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONS E**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	massive	High	*Has had devastating effects on all native European crayfish*

			species (Holdich et al. 2009) mainly through spread of crayfish plague.
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Low	Suspected carrier of WSSV
5.3. How much impact does the organism have as a vector for other pathogens?	Minor	Low	Not known
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	massive	High	*Has had devastating effects on all native European crayfish species (Holdich et al. 2009) mainly through spread of crayfish plague.*

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPON SE**	**CONFIDEN CE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in increased distribution area.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	All the bullet points	High	

RISK SUMMARIES for *Pacifastacus leniusculus*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Very likely	High	Already established
Summarise Establishment	very likely	High	Already established.
Summarise Spread	Very likely	High	Already established and further spread
Summarise impact from pathogens/ parasites	Massive	High	Devastating effects on endangered noble crayfish
Summarise Ecological Impact	Major	Medium	Will outcompete the noble crayfish due to faster growth and larger adult size, irrespective of the crayfish plague (Westman et al. 2002).
Conclusion of the risk assessment	High	High	

References:

Edsman, L., & Schröder, S. 2009. Åtgärdsprogram för flodkräfta 2008–2013 (Astacus astacus). Fiskeriverket och Naturvårdsverket. Rapport, 5955, 67.

Holdich, D. M., Reynolds, J. D., Souty-Grosset, C., & Sibley, P. J. 2009. A review of the ever increasing threat to European crayfish from non-indigenous crayfish species. Knowledge and management of aquatic ecosystems, (394-395), 11.

Johnsen, S.I. 2015. Signalkreps i Kvesjøen, Lierne kommune - kartlegging, spredningsrisiko og forslag til tiltak – NINA Rapport 1093. 13 s.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Peay, S., Johnsen, S. I., Bean, C. W., Dunn, A. M., Sandodden, R., & Edsman, L. 2019. Biocide treatment of invasive signal crayfish: successes, failures and lessons learned. Diversity, 11(3), 29.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus le-niusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Söderbäck, B. 1995. Replacement of the native crayfish Astacus-astacus by the introduced species Pacifastacus leniusculus in a Swedish Lake possible causes and mechanisms. Freshwater Biology, 33(2), 291-304.

Westman, K., Savolainen, R., & Julkunen, M. 2002. Replacement of the native crayfish Astacus astacus by the introduced species Pacifastacus leniusculus in a small, enclosed Finnish lake: a 30-year study. Ecography, 25(1), 53-73.

Species: *Procambarus alleni* (Faxon 1884)

English common name: Everglades crayfish, Electric blue crafish

Synonyms: NA

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Moderately likely	Medium	Very common in aquarium trade in Europe (Mrugala et al. 2015; Kawai et al. 2017).
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity. Individual specimens have occurred occasionally in Germany and France (Procopio 2020).
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	medium	See 1.2 above

PROBABILITY OF ESTABLISHMENT

QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Unlikely	medium	Unknown but for closely related species from same region optimal growth 22-30C, preference in the same range. References within: (Westhoff & Rosenberger 2016)
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Moderately likely	medium	Inhabits wetlands marshes, ditches and small streams. (Hendrix et al. 1998; Kozak et al. 2015).
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Very likely	medium	Does very well in captivity/aquaria.
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Moderately widespread	medium	Freshwater habitats but not the preferred temporary, freshwater bodies of water that are still or very sluggish, can tolerate brackish water, and occupies burrows during droughts (Procopio 2020).
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3.

			Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Moderately likely	medium	Adaptability not known but has a limited range in native area ((Souty-Grosset et al. 2006; Kozak et al. 2015)
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Unlikely	medium	Only established outside native range in southern California. (Procopio 2020)
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Unlikely	medium	Climatic conditions and habitat types in Norway do not favor establishment.

PROBABILITY OF SPREAD
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Unlikely	medium	The species has a limited distribution range in area of origin in Florida and climatic conditions in Norway are not favourable for spread (Procopio 2020).
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish and other freshwater crayfish species in Europe shows that spread by humans is very common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulations against spread has had little effect for signal crayfish in Scandinavia due to the high general interest in crayfish.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Warmer freshwater habitats in the south of Norway.	medium	But only for a short period.
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Unlikely	medium	Climatic conditions and habitat types in Norway do not favour spread (U.S. Fish & Wildlife Service 2017 Procambarus alleni, Ecological Risk Screening Summary).

PROBABILITY OF ENVIRONMENTAL IMPACT
Important instructions:

• When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.

QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	moderate	medium	*High densities, relatively high fecundity, growth rate, and competitive ability. Omnivore and predates on molluscs, fish eggs, insects and macrophytes (Procopio 2020).*
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	minimal	High	No hybridization occur.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	Moderate	Medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are	Warmer freshwater habitats in	High	But lacks preferred habitat types like wetlands,

particularly likely to occur (provide as much detail as possible).	the south of Norway.		ditches and temporary still ponds.
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	massive	High	*Has been shown to be a carrier of A. Aphanomyces astaci in nature and in the aquarium trade (Kozak et al. 2015;* Mrugala et al. 2015; Procopino 2020).
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Medium	Suspected carrier
5.3. How much impact does the organism have as a vector for other pathogens?	Minor	Low	Not known
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Massive	High	*Has been shown to be a carrier of A. Aphanomyces astaci in nature and in the aquarium trade (Kozak et al. 2015;* Mrugala et al. 2015; Procopino 2020).

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in potentially increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establishment, spread, impact on biodiversity, impact on ecosystem functions	High	

RISK SUMMARIES for *Procambarus alleni*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately likely	medium	Very common in aquarium trade.
Summarise Establishment	Unlikely	medium	Climatic conditions and habitat types in Norway do not favour establishment.
Summarise Spread	Unlikely	medium	Climatic conditions and habitat types in Norway do not favour spread.
Summarise impact from pathogens/ parasites	Massive	High	*Devastating effects on all native European crayfish species through spread of crayfish plague, and a*

			possible vector for WSSV.
Summarise Impact	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
Conclusion of the risk assessment	high	medium	High risk mainly as a proven vector for A. astaci and a potential vector for WSSV.

References:

Hendrix, A.N., D. Armstrong, and C. Grace. 1998. Life history, ecology, and interactions of Everglades crayfishes. National Park Service, Homestead, FL.

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Kawai, T., Faulkes, Z., & Scholtz, G. (Eds.). 2016. Freshwater crayfish: a global overview. CRC Press.

Kozák, P., Ďuriš, Z., Petrusek, A., Buřič, M., Horká, I., Kouba, A., Kozubíková-Balcarová E. & Němečková, K. 2015. Crayfish biology and culture. University of South Bohemia in České Budějovice, Faculty of Fisheries and Protection of Waters.

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Procopio, J., 2020. Procambarus alleni (Faxon, 1884): U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus leniusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Souty-Grosset, C., Holdich, D.M., Noël, P. Y., Reynolds, J. D. & Haffner, P. (eds.) 2006. Atlas of freshwater crayfish in Europe. Museum national d´Histoire naturelle, Paris, 187 p.

Westhof, J.T. & Rosenberger, A.E. 2016. A global review of freshwater crayfish temperature tolerance, preference, and optimal growth. Rev Fish Biol Fisheries 26:329–349.
www.fws.gov/fisheries/ans/erss/uncertainrisk/ERSS_Procambarus_alleni_final_December2017.pdf

Species: *Procambarus clarkii* (Girard 1852)

English common name: Red swamp crayfish

Synonyms: NA

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Likely	High	Very common in aquarium trade in Europe (Mrugala et al. 2015; Patoka et al. 2015; Chucholl & Wendler 2017). Short time occurrence in southern Swedenl (Blindow et al 1984)
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity. The most spread crayfish species in the world. Has a large range in area of origin. Well established in Europe (Souty-Grosset et al. 2006, Kozak et al. 2015).
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately Likely	Medium	See 1.2 above

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Likely	High	Survives in harsh winter conditions down to 0C. Has an extensive range in area of origin in north America. Established in Europe up to Belgium Netherlands and northern Germany (Souty-Grosset et al. 2006; Kawai et al. 2016).
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Very likely	High	Inhabits a large variety of abiotic conditions in area of origin and in introduced area (Kozak et al. 2015).
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Very likely	High	Will do well in captivity. (Souty-Grosset et al. 2006).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns),	Very likely	medium	Strict regulation against spread has had little effect on other freshwater crayfish species like

competition from existing species or predators, parasites or pathogens in Norway?			signal crayfish. Spread has continued. See also 3.3. Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Very likely	High	Excellent adaptability and capacity of spread. Already established all over the world (Souty-Grosset et al. 2006; Kozak et al. 2015)
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Low genetic diversity not a general problem for crayfish since in other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very likely	High	Already well established in Europe (Souty-Grosset et al. 2006, Kozak et al. 2015).
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very likely	High	The most commonly and successfully introduced freshwater crayfish species in the world for aquaculture (Kozak et al. 2015).

PROBABILITY OF SPREAD
Important notes:

• Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Very likely	High	If established, it has high fecundity, short generation time and good dispersal capacity. Large distribution in area of origin in north America. (Souty-Grosset et al. 2006; Kawai et al. 2016).
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish and other species shows that spread by humans is very common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulations against spread has had little effect for signal crayfish in Scandinavia due to the high general interest in crayfish.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Warmer freshwater habitats in the south of Norway.	High	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Very likely	High	Survives in harsh winter conditions down to 0C. Has an extensive range in area of origin in north America, into Canada. Established in Europe (Souty-Grosset et al. 2006; Kawai et al. 2016).

PROBABILITY OF ENVIRONMENTAL IMPACT
Important instructions:

• When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	major	High	***Establishes in high densities, high fecundity, growth rate, and competitive ability. Omnivore and predates on molluscs, fish eggs, insects and macrophytes*** *(*Souty-Grosset et al. 2006; Kozak et al. 2015).
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	minimal	High	No hybridization occurs.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	major	High	Predation and competition. *(*Souty-Grosset et al. 2006; Kozak et al. 2015; Kawai et al. 2016)
4.4. 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 Norway?	Moderate	Medium	***May have negative impact on biodiversity through competition and predation.***
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmer freshwater habitats in the south of Norway.	High	

4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Major	High	Predation and competition. (Souty-Grosset et al. 2006; Kozak et al. 2015; Kawai et al. 2016)

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	massive	High	*Has been shown to be a carrier of A. Aphanomyces astaci in nature and in the aquarium trade (Kozak et al. 2015;* Mrugala et al. 2015). Carrier of WSSV (Baumgartner et al. 2009)
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Moderate	Low	Possible carrier
5.3. How much impact does the organism have as a vector for other pathogens?	Minor	Low	
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	massive	High	*Has been shown to be a carrier of A. aphanomyces astaci in nature and in the aquarium trade (Kozak et al. 2015;* Mrugala et al. 2015). Carrier of WSSV (Baumgartner et al. 2009)

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**

6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in potential increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establishment, spread, impact on biodiversity, impact on ecosystem functions	High	

RISK SUMMARIES for ***Procambarus clarkii***			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately Likely	medium	A proven highly invasive species with large original distribution area, and successfully established over the world in a range of different habitats.
Summarise Establishment	Very likely	High	A proven highly invasive species with large original distribution area, and successfully established over the world in a range of different habitats.
Summarise Spread	Very likely	High	A proven highly invasive species with large original distribution area, and successfully established over the world in a range of different habitats.
Summarise impact from pathogens/ parasites	Massive	High	*Devastating effects on all native European crayfish species*

			through spread of crayfish plague.
Summarise Ecological Impact	Major	High	Predation and competition. (Souty-Grosset et al. 2006; Kozak et al. 2015; Kawai et al. 2016)
Conclusion of the risk assessment	high	High	

References:

Baumgartner, W. A., Hawke, J. P., Bowles, K., Varner, P. W., & Hasson, K. W. 2009. Primary diagnosis and surveillance of white spot syndrome virus in wild and farmed crawfish (Procambarus clarkii, P. zonangulus) in Louisiana, USA. Diseases of aquatic organisms, 85(1), 15-22.

Blindow, I., Hamrin, S.F. and Larson, P-E. 1984. Förekomst av Procambarus clarkii i Skåne hösten 1984. Limnologiska Institutionen, Lunds Universitet, Lund, Sweden.

Chucholl, C., & Wendler, F. 2017. Positive selection of beautiful invaders: long-term persistence and bio-invasion risk of freshwater crayfish in the pet trade. Biological Invasions, 19(1), 197-208.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Kawai, T., Faulkes, Z., & Scholtz, G. (Eds.). 2016. Freshwater crayfish: a global overview. CRC Press.

Kozák, P., Ďuriš, Z., Petrusek, A., Buřič, M., Horká, I., Kouba, A., Kozubíková-Balcarová E. & Němečková, K. 2015. Crayfish biology and culture. University of South Bohemia in České Budějovice, Faculty of Fisheries and Protection of Waters.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Sandodden, R. & Johnsen, S.I. 2010. Eradication of introduced signal crayfish Pasifastacus le-niusculus using the pharmaceutical BETAMAX VET.®. Aquatic Invasions 5(1): 75-81.

Souty-Grosset, C., Holdich, D.M., Noël, P. Y., Reynolds, J. D. & Haffner, P. (eds.) 2006. Atlas of freshwater crayfish in Europe. Museum national d´Histoire naturelle, Paris, 187 p.

Species: ***Procambarus virginalis*** **(Lyko 2017))**

English common name: Marbled crayfish

Synonyms: *Procambarus fallax* f. *virginalis* (Martin 2010)

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Likely	High	Very common in aquarium trade in Europe (Mrugala et al. 2015; Patoka et al. 2015; Chucholl & Wendler 2017).
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Low	Unintentional release from captivity. Has occurred in Europe, Austria, UK, Germany, Netherlands, Czech, Sweden (Souty-Grosset et al. 2006, Bohman et al. 2013, Kozak et al. 2015).
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately Likely	Medium	See 1.2 above

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Likely	medium	Can tolerate temperatures in harsh winter conditions down to 1-2C, but growth and reproduction may be inferior at low temperatures (Kaldre et al. 2016). Has no natural range and no area of origin. Established in Europe up to Belgium Netherlands, Estonia and northern Germany (Souty-Grosset et al. 2006; Kawai et al. 2016 Kozak et al. 2015).
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Likely	medium	Inhabits a variety of abiotic conditions in introduced area (Kozak et al. 2015; Kawai et al. 2016).
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Very likely	High	Does very well in captivity/aquaria. Parthenogenetic so only one female needed for establishment (Souty-Grosset et al. 2006; Kawai et al. 2016).
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats
2.5. How likely is it that establishment will occur despite	Very likely	medium	Strict regulation against spread has had little effect on other

management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?			freshwater crayfish species like signal crayfish. Spread has continued. See also 3.3. Eradication of crayfish is only feasible in small waterbodies (Sandodden & Johnsen 2011).
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Very likely	High	Excellent capacity to spread through pathogenesis. Already established in Europe (Souty-Grosset et al. 2006; Kozak et al. 2015)
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Nonexistent genetic diversity. In addition other freshwater crayfish species, like signal crayfish, populations have established most likely from few individuals in Norway (Johnsen et. al 2019). Some populations established in Sweden with as few as ten individuals.
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very likely	High	Already established in Europe up to Germany and Estonia (Souty-Grosset et al. 2006, Kozak et al. 2015).
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Likely	High	Mostly due to parthenogenesis (Kozak et al. 2015).

PROBABILITY OF SPREAD
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Very likely	medium	If established, it has high fecundity and short generation time and good dispersal capacity (Souty-Grosset et al. 2006; Kawai et al. 2016).
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	medium	If established, experience from signal crayfish and other crayfish species shows that spread by humans is very common.
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Strict regulations against spread has had little effect for signal crayfish in Scandinavia due to the high general interest in crayfish.
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	Warmer freshwater habitats in the south of Norway.	High	
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Likely	medium	Can tolerate temperatures in harsh winter conditions down to 1-2C and survive (Kaldre et al. 2016). Established in Europe up to Belgium Netherlands, Estonia and northern Germany (Souty-Grosset et al. 2006; Kawai et al. 2016 Kozak et al. 2015).

PROBABILITY OF ENVIRONMENTAL IMPACT
Important instructions:

• When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.

QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	major	High	*High densities, high fecundity, growth rate, and competitive ability. Omnivore and predates on mollusks, fish eggs, insects and macrophytes (*Souty-Grosset et al. 2006; Kozak et al. 2015; Kawai et al. 2016).
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	minimal	High	No hybridization occurs.
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).
4.4. 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 Norway?	moderate	Medium	Natural predators in Norway include pike, perch, waterfowl, mink and otter will help reduce the number of individuals and reduce the potential impact.
4.5. Indicate any parts of Norway where environmental impacts are	Warmer freshwater	High	

particularly likely to occur (provide as much detail as possible).	habitats in the south of Norway.		
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	medium	Crayfish are regarded as omnivorous (e.g. Hill & Lodge 1995), and if abundant they can play an important role as transformers of energy in aquatic food webs (Momot et al. 1978).

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	massive	High	***Has been shown to be a carrier of A. Aphanomyces astaci in nature and in the aquarium trade (Kozak et al. 2015;*** Mrugala et al. 2015).
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	Low	Suspected carrier
5.3. How much impact does the organism have as a vector for other pathogens?	Minor	Low	Not known
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	massive	medium	***Has been shown to be a carrier of A. Aphanomyces astaci in nature and in the aquarium trade (Kozak et al. 2015;*** Mrugala et al. 2015).

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warmer climate and shorter winters.	High	Results in potential increased distribution areas.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establishment, spread, impact on biodiversity, impact on ecosystem functions	High	

RISK SUMMARIES for ***Procambarus virginalis***			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Likely	Medium	A proven highly invasive species successfully established in Europe up to Germany and Estonia. Short time occurrence in Sweden (Bohman et al. 2013).
Summarise Establishment	Very likely	High	A proven highly invasive species successfully established in Europe up to Germany and Estonia.
Summarise Spread	Very likely	medium	A proven highly invasive species successfully established in Europe up to Germany and Estonia.
Summarise impact from pathogens/ parasites	Massive	High	*Devastating effects on all native European*

			crayfish species through spread of crayfish plague.
Summarise Ecological Impact	Moderate	Medium	*Negative for other organisms through competition and predation.*
Conclusion of the risk assessment	high	High	Predominantly based on pathogens and invasiveness (Bohman & Edsman 2013)

References:

Bohman, P. & Edsman, L. 2013. Marmorkräftan i Märstaån. Riskanalys och åtgärdsförslag. (English title: Marmorkrebs in River Märstaån. Risk assessment and action proposals.) Aqua reports 2013:17. Sveriges lantbruksuniversitet, Drottningholm. 110 p.

Bohman, P., Edsman, L., Martin, P., & Scholtz, G. 2013. The first Marmorkrebs (Decapoda: Astacida: Cambaridae) in Scandinavia. BioInvasions Records, 2(3), 227-232.

Chucholl, C., & Wendler, F. 2017. Positive selection of beautiful invaders: long-term persistence and bio-invasion risk of freshwater crayfish in the pet trade. Biological Invasions, 19(1), 197-208.

Hill, A. M. & Lodge, D.M. 1995. Multi-Trophic level impact of sublethal interactions between bass and omnivorous crayfish. Journal of the North American Benthological society. 14(2):306-314.

Johnsen, S.I., Strand, D.A., Rusch, J. & Vrålstad, T. 2019. Nasjonal overvåking av edelkreps og spredning av signalkreps - presentasjon av overvåkingsdata og bestandsstatus – oppdatert 2019 – NINA Rapport 1761. 106 s. + vedlegg.

Kaldre K, Meženin A, Paaver T, Kawai T 2016. A preliminary study on the tolerance of marble crayfish Procambarus fallax f. virginalis to low temperature in Nordic climate. In: T Kawai, Z Faulkes, G Scholtz (eds), Freshwater Crayfish: A Global Overview, Boca Raton, CRC Press, pp 54–62

Kawai, T., Faulkes, Z., & Scholtz, G. (Eds.). 2016. Freshwater crayfish: a global overview. CRC Press.

Kozák, P., Ďuriš, Z., Petrusek, A., Buřič, M., Horká, I., Kouba, A., Kozubíková-Balcarová E. & Němečková, K. 2015. Crayfish biology and culture. University of South Bohemia in České Budějovice, Faculty of Fisheries and Protection of Waters.

Momot, W. T., Gowing, H., & Jones, P. D. 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist, 10-35.

Mrugała, A., Kozubíková-Balcarová, E., Chucholl, C., Resino, S. C., Viljamaa-Dirks, S., Vukić, J., & Petrusek, A. 2015. Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. Biological Invasions 17.5: 1313-1326.

Souty-Grosset, C., Holdich, D.M., Noël, P. Y., Reynolds, J. D. & Haffner, P. (eds.) 2006. Atlas of freshwater crayfish in Europe. Museum national d´Histoire naturelle, Paris, 187 p.

Appendix IVb

Appendix IVb – Modified GB-NNRA assessments of selected crabs

Species: *Percnon gibbesi* (H. Milne Edwards, 1853)

English common name: sally lightfoot crab, nimble spray crab

Synonyms: *Acanthopus gibbesi* (H. Milne Edwards, 1853), *Lonchophorus anceps* (Eschscholtz, 1825) *Plagusia delaunayi* (de Rochebrune, 1883) (junior synonym), *Zoea boscii* (Guérin-Méneville in de la Sagra, 1857)

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **Release/ escape from aquaria**	**CONFIDENCE**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Moderately likely	Medium	Escape or release from captivity as egg or small specimen. Brood size ranged from 254 eggs to nearly 32,000 eggs (Sciberras and Schembri, 2008). Is in trade to be used as pet
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Moderately likely	High	Escape or release as egg or small specimen

1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	Medium	It is a small species (max 3 cm) that is in trade and can produce a large number of eggs.

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **Spread by ships**	**CONFIDENCE**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Moderately likely	Medium	The crab prefer crevicolous habits and is a likely candidate for successful primary and secondary ship-borne transport (Coutts et al., 2003), especially from the Mediterranean.
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	NA	NA	
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	Medium	It is currently spreading in many regions in the Mediterranean and can occur in large numbers

PROBABILITY OF ESTABLISHMENT

QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Very unlikely	Medium	*P. gibbesi* is found over a wide latitudinal and temperature range extending from California to Chile, Florida to Brazil, and Portugal to the Gulf of Guinea. It was first found in the Mediterranean Sea in 1999, is still spreading and has reached about 41° N (Félix-Hackradt 2011).
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Likely	Medium	*P. gibbesi* inhabits a narrow subtidal zone (commonly at depths of 0-2 m), in rocky habitats where it moves to safety under boulders and in narrow crevices.
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Very unlikely	Medium	There are few, if any, such protected conditions with salt water in Norway
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	Low	All coastal waters
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	very likely	Medium	Maybe not possible to eradicate a marine species

2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Very likely	Low	*P. gibbesi* is the most invasive decapod crustacean to have entered the Mediterranean Sea.
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Likely	High	No information is available, however, the current spreading suggests that it is likely
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very likely	High	It is still spreading in the Mediterranean Sea
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Unlikely	Medium	Current temperatures are likely too cold for the species, however, it has a wide native distribution and is spreading

PROBABILITY OF SPREAD

Important notes:

- Spread is defined as the expansion of the geographical distribution of an alien species within an area.

QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Very likely	High	Can spread both by larval drift and adult movement. Has a large natural distribution, suggesting good dispersal ability
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*?	Likely	Medium	The spreading in the Mediterranean points to the role of fishing and recreational

(Please list and comment on the mechanisms for human-assisted spread.)			vessels as vectors (Yokes and Galil, 2006).
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Unlikely	Medium	The species is spreading and can occur in high density, however, it is likely too cold in Norway
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	[insert text]	Medium	Warm coastal areas in southern Norway
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Unlikely	Medium	Current temperatures are likely too cold for the species, however, it has a good ability to spread

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minor	Medium	*It can compete with other species*
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	Medium	There are no likely candidates (con-geners) for hybridization in the Norwegian fauna today

4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	Medium	It can cause ecosystem change/ habitat alteration by grazing, and compete with native species. *P. gibbesi* is a strictly herbivorous salt water species, able to take both soft and tough algal meals (Guillén et al. 2016). This makes it unique among native crabs in Norway. It can occur in high numbers and compete with other grazers in the upper infralittoral, such as sea urchins (Puccio et al. 2006) and potentially molluscs.
4.4. 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 Norway?	Minor	Low	No information is available, however the species can occur in large numbers
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).		Low	Enclosed and sheltered bays in the warmest areas of Norway
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	Medium	Unforeseen events: it can cause ecosystem change/ habitat alteration by grazing, and compete with native species. It can occur in large numbers and is difficult to control

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS

QUESTION	RESPONSE	CONFIDENCE	COMMENTS
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Minimal	Low	
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Minimal	Low	
5.3. How much impact does the organism have as a vector for other parasites or pathogens?	Minimal	Low	No information available
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Minimal	Low	It is a saltwater species and thus not expected to have impact on the native crayfish, however it may potentially act as vector for marine pathogens

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warming	High	It currently occurs down to about 15 °C. For RCP8.5, the median projection indicates an increase in annual mean temperature for Norway of 4.5 °C (span: 3,3 to 6,4 °C) to 2071-2100. Average annual sea surface temperatures in Kristiansand in southernmost Norway are now 10.2°C (climatedata.org), suggesting the conditions will be 14.7°C in year 2100

6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establish ment and spread	High	

RISK SUMMARIES for *Percnon gibbesi*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately likely	Medium	It is a small marine species (max 3 cm) that can spread on ship hulls. The species is also used as ornament and is in trade. It needs to escape from captivity or be released intentional or unintentional
Summarise Establishment	Unlikely	Medium	Current temperatures are likely too cold for the species, however, it has a wide native distribution and temperature range, and is spreading
Summarise Spread	Unlikely	Low	Current temperatures are likely too cold for the species, however, it has a good ability to spread
Summarise impact from pathogens/ parasites	Minimal	Low	
Summarise Ecological Impact	Moderate	Medium	Unforeseen events: it can cause ecosystem change/ habitat alteration by grazing, and compete with native species. It can occur in large numbers and is difficult to control

Conclusion of the risk assessment	Moderate	Low	The species will likely not establish in Norway now, but may establish in Norway by 2100. If it establishes, it may have an impact on Norwegian biodiversity

References:

Cannicci S; Badalamenti F; Milazzo M; Gomei M; Baccarella A; Vannini M, 2004. Unveiling the secrets of a successful invader: preliminary data on the biology and the ecology of the crab *Percnon gibbesi* (H. Milne Edwards, 1853). Rapports et Proces-Verbaux des Reunions Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée, 37:326.

Coutts ADM; Moore KM; Hewitt CL, 2003. Ships' sea-chests: an overlooked transfer mechanism for non-indigenous marine species? Marine Pollution Bulletin, 46:1504-1515.

Félix-Hackradt, Fabiana & Hackradt, Carlos Werner & Treviño Otón, Jorge & García-Charton, José. (2011). Continued expansion of Percnon gibbesi (Crustacea: Decapoda: Plagusiidae) into western Mediterranean waters. Marine Biodiversity Records. 3. 10.1017/S1755267210000175.

Guillén, J.E. & Santiago, Jiménez & Triviño, Alejandro & Soler, Gabriel & Joaquín, Martínez & Gras, David. (2016). Assessment of the effects of Percnon gibbesi in taxocenosis decapod crustaceans in the Iberian southeast (Alicante, Spain). Frontiers in Marine Science. 3. 10.3389/conf.FMARS.2016.05.00019.

Puccio V., Relini M., Azzurro E., Orsi Relini L., 2006. Feeding habits of Percnon gibbesi (H. Milne Edwards, 1853) in the Sicily Strait. Hydrobiologia, 557: 79-84.

Sciberras M; Schembri PJ, 2008. Biology and interspecific interactions of the alien crab *Percnon gibbesi* in the Maltese Islands. Marine Biology Research, 4(5):321-332.

Yokes B, Galil B S, 2006. Touchdown - first record of *Percnon gibbesi* (H. Milne Edwards, 1853) (Crustacea: Decapoda: Grapsidae) along the Levant coast. Aquatic Invasions. 1 (3), 130-132

Species: *Sayamia bangkokensis* (Naiyanetr, 1982)

English common name: Thai ricefield krab

Synonyms: *Somanniathelphusa bangkokensis*

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **Release/ escape from aquaria**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Moderately likely	Low	Escape or release from captivity as egg or small specimen. The species is likely in trade in Norway to be used as pet
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Moderately likely	Medium	Escape or release as egg or small specimen
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	Medium	The species is not common in trade in Norway as of 2020

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDE NCE**	**COMMENT**

2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Very unlikely	High	*S. bangkokensis* has a natural habitat in tropical central, northern, eastern, western and southern regions of Thailand. It has been spread in Thailand and introduced to Taiwan by humans (Shih et al. 2011)
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Unlikely	High	The natural habitat is in rice fields
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Very unlikely	Medium	There are few, if any, such protected conditions with rice fields in Norway
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Very isolated	High	All coastal waters
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	Medium	It may be hard to eradicate invertebrates, if they establish
2.6. How likely are the biological characteristics (including adaptability and capacity of spread)	Likely	Low	Humans has spread the species within Thailand and Taiwan (see Shih et al. 2011; ippc.acfs.go.th)

of the organism to facilitate its establishment in Norway?			
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Likely	Low	No information is available, however, many invertebrate species can establish despite low genetic diversity
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very likely	Low	Humans has spread the species within Thailand and Taiwan (see Shih et al. 2011; ippc.acfs.go.th)
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very unlikely	High	Current temperatures are likely too cold for the species and there are no rice field in Norway

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDE NCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Very unlikely	High	There are few, if any, suitable habitats in Norway
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Likely	Medium	Spreading was facilitated by humans in Thailand and Taiwan. Spreading may also be facilitated by humans that keep the species in aquariums

3.3. How likely is it that spread of the organism within Norway can be completely contained?	Likely	Medium	it is likely too few suitable habitats and too cold in Norway
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	[insert text]	High	Warm coastal areas in southern Norway
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Very unlikely	Medium	it is likely too few suitable habitats and too cold in Norway

PROBABILITY OF ENVIRONMENTAL IMPACT

Important instructions:

- When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment.
- Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.

QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	medium	Medium	*They eat rice in the seedling stage and is considered a pest*
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	minimal	Medium	There are no likely candidates (con-geners) for hybridization in the Norwegian fauna today
4.3. How much impact do other factors (which are not covered by previous questions) have?	Moderate	Low	It can cause ecosystem change/ habitat alteration by grazing, and compete with native species. It can

(Specify these other factors in the comments box)			predate on other invertebrates.
4.4. 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 Norway?	Minor	Low	No information is available, however the species can occur in large numbers
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	Warmest areas	Low	Enclosed and sheltered bays in the warmest areas of Norway
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	Low	Unforeseen events: it can cause ecosystem change/ habitat alteration by grazing. It may potentially interact wih native crayfish. However, no agonistic behavioural patterns have been observed in Europe so far (Mazza et al 2017). It can occur in large numbers and is difficult to control. It can potentially be host to diseases of concern both to humans and native crayfish

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Minor	Low	So far not known in *S. bangkokensis*. Some crabs can be infected

5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Minor	Low	So far not known in *S. Bangkokensis.* Some crabs can be infected
5.3. How much impact does the organism have as a vector for other pathogens?	Moderate	High	The congener *S. germaini* can be host to lung fluke disease or paragonimiasis in humans (Shih et al. 2011). See also question 5.4.
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Minor	Low	Crabs can have exotic diseases, e.g., yellow head virus genotype 1 in blue crab (*Callinectes sapidus*); Taura syndrome virus (TSV) in blue crab, fiddler crab (*Uca vocans*) and *Sesarma mederi;* white spot disease virus (WSSV) in *Sesarma* sp.; Crayfish plague (*A. astaci*) in Chinese mitten crab (*Eriocheir sinensis*) and Potamon crab (*Potamon potamios*) (source Svoboda, et al. 2014, www.lovdata.no). These diseases are not sufficiently known, meaning there is a risk that any exotic crabs may be infected

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPON SE**	**CONFIDEN CE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warming	High	It currently occurs in the tropics. For RCP8.5, the median projection indicates an increase in annual mean temperature for Norway of

			4.5 °C (span: 3,3 to 6,4 °C) to 2071-2100. Average annual temperatures will still be too low for the species in year 2100.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establish ment and spread	High	

RISK SUMMARIES for *Sayamia bangkokensis*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Unlikely	Medium	The species might be in trade in Norway
Summarise Establishment	Very unlikely	High	Current temperatures are likely too cold for the species, however, and there are no suitable habitats (prefer rice fields) in Norway
Summarise Spread	Very unlikely	Low	Current temperatures are likely too cold for the species, however, it has a good ability to spread
Summarise impact from pathogens/ parasites	Minor	Low	Many diseases are known to occur in crabs (e.g., Yellow head virus genotype, Taura syndrome virus, White spot disease virus and *A. astaci*). These diseases are not sufficiently known, meaning there is a risk that any exotic crabs may be infected

Summarise Ecological Impact	Minor	Low	Unforeseen events: it can cause ecosystem change/ habitat alteration by grazing, and compete with native species. It can occur in large numbers and is difficult to control. It can potentially be host to diseases of concern both to humans and native crayfish
Conclusion of the risk assessment	Low	Medium	The species will likely not have environmental impact, but is of concern because it can potentially be host to diseases in both humans and native crayfish. It is highly unlikely that the species will establish since it is tropical and prefer rice fields.

References:

Giuseppe & Tricarico, Elena & Cianferoni, Fabio & Stasolla, Gianluca & Inghilesi, Alberto & Zoccola, Antonio & Innocenti, Gianna. (2017). Native crab and crayfish co-occurrence: First evidence in Europe. Biologia. 72. 10.1515/biolog-2017-0086.

http://ippc.acfs.go.th/pest/G001/T014/INVERT004

https://lovdata.no/dokument/SF/forskrift/2008-06-17-819 and https://www.oie.int/animal-health-in-the-world/oie-listed-diseases-2020).

Shih, Hsi-Te & Shy, Jhy-Yun & Naruse, Tohru & Hung, H.-T & Yeo, Darren & Ng, Peter. (2011). Introduction of an indochinese freshwater crab Sayamia germaini (Crustacea: Brachyura: Gecarcinucidae) to Taiwan: Morphological and molecular evidence. Raffles Bulletin of Zoology. 59. 83-90.

Svoboda, J., et al. (2014). The crayfish plague pathogen can infect freshwater-inhabiting crabs. Freshw Biol, 59: 918-929. doi:10.1111/fwb.12315).

Appendix IVc

Appendix IVc – Modified GB-NNRA assessments of selected shrimps

Species: *Atyaephyra desmaretii* (Millet 1831)

English common name: NA

Synonyms: NA

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE [choose one entry, delete all others]**	**CONFIDENCE [choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Moderately likely	Medium	The expansion of the species across Europe is mainly due to the opening of canals (Danube and Rhine; Hanfling et al. 2011; Kawai and Cumberlidge 2016). The species is widely used in aquarium trade (escape or release from captivity). Individuals can reproduce within a year and egg production varied from 100-300 to 400-1250 depending on body size (Schoolman et al. 2015)
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Medium	Escape or release from captivity as egg or small individual. High reproduction but relatively small species (3 – 4 cm; Anastasiadou and Leonardos 2008)
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Likely	Medium	This small-sized species is already present in the wild in Europe and

			can produce a large number of eggs

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Very unlikely	Medium	The species is native to Southern Europe (Portugal, Spain, Tunisia, Marocco) but has been expanded to Central Europe (Danube River basin è Netherland, Germany, Poland, Austria, Czech Republic and Switzerland; Hanfling et al. 2011; Kawai and Cumberlidge 2016). Current climatic conditions between Norway and Central Europe are similar, except during summer period (cold versus warm, respectively). The species is not tolerant to harsh winter conditions (van der Velde et al. 2000)
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Likely	Medium	The species inhabits in a wide range of freshwater habitats
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	Medium	See comment 2.2 The species is easy to raise in captivity (full life cycle in freshwater habitats)
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Ubiquitous	High	All freshwater habitats but the species is not tolerant to a wide range of current velocity (Mabrouki et al. 2018)
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	Medium	No information is available but the species can persist even in low density (Schoolman et al. 2015 et al. 2015; Straka and Špaček 2009) Management practices (natural or human-facilitated) are often

			unproductive (eradication has only been successful for crustaceans in artificial ponds using a combination of chemical treatment and drainage)
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Likely	Medium	Eurythermal and euryhaline species (Fidalgo and Gerhardt 2003) Not tolerant to wide range of current velocity (Mabrouki et al. 2018). The species is associated with good water quality (Banha and Anastacio 2012). The species is able to withstand being out of water for 90 min è potential for terrestrial dispersal (Banha and Anastacio 2012). It is an omnivorous species
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Likely	Medium	The species can persist even in low density (Schoolman et al. 2015; Straka and Špaček 2009)
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Moderately likely	Medium	The species is already present in Central Europe but harsh winter conditions can limit its establishment in Norway
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Moderately likely	Medium	The species is already present in Central Europe but current winter temperatures can limit its establishment in Norway

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Likely	High	The dispersal of the species in Central Europe has been facilitated by canals è adult movement The species can tolerate desiccation (90m min; Banha and Anastacio 2012)

3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Moderately likely	Medium	Release or escape from captivity (small-sized species: 3 - 4 cm; Anastasiadou and Leonardos 2008) Vessels as vectors (e.g. shipping traffic; van der Velde et al. 2000)
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Winter conditions are likely too cold for the species
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	[insert text]	Medium	The warmest area in Norway (South - South East)
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Moderately likely	Medium	The species has abilities to spread but harsh winter conditions will likely contain its spreading in Norway

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minimal	High	The species is not considered as a threat to native fauna due to its low density (Straka, 2009; Kawai and Cumberlidge 2016) and low tolerance to harsh winter conditions (van der Velde et al. 2006)
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	Medium	There are no likely candidate or hybridization in the Norwegian fauna today
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Minimal	Low	In its introduced range, the species is not considered as a threat to native fauna (see 4.3 and 4.1) è no clear evidence for high

			competitiveness and/or high predation No information is available for its potential effect on ecosystems
4.4. 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 Norway?	Minimal	High	See 4.1, 4.3 and 4.4
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	[insert text + attach map if possible]	Low	Lentic habitats of the warmest area in Norway (S/SE)
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Minimal	Medium	The species does not occur in high densities and its effects on native fauna are not considered as important

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Minimal	Medium	
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Minimal	Medium	
5.3. How much impact does the organism have as a vector for other parasites or pathogens?	Minimal	Medium	
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Minimal	Medium	The species is not recognized for being a vector/host of pathogens

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warming + Shorter winter	High	The species is currently present in Central Europe. For RCP85, the median projection indicates an increase in annual mean temperature for Norway of 4.5°C to 2071-20100 (span: 3.3 – 6.3°C).
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establishment and Spread	High	

RISK SUMMARIES for *Atyaephyra desmaretii*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Likely	Medium	Small-sized species that is already present in Europe and can produce large number of eggs
Summarise Establishment	Moderately likely	Medium	The species is already present in Central Europe but current winter temperatures can limit its establishment in Norway
Summarise Spread	Unlikely	Medium	The species has abilities to spread but harsh winter conditions will likely contain its spreading in Norway.
Summarise impact from pathogens/ parasites	Minimal	Medium	Not known to be a carrier of any notable diseases.
Summarise Ecological Impact	Minimal	Medium	The species does not occur in high densities and its effects on native fauna are not considered as important
Conclusion of the risk assessment	Low	Medium	Future climate conditions may facilitate the establishment of the species; data are lacking to

			really assess its effect on ecosystem functions and resource communities

References:

Anastasiadou, C., & Leonardos, I. D. (2008). Morphological variation among populations of *Atyaephyra desmarestii* (Millet, 1831) (Decapoda: Caridae: Atydae) from freshwater habitats of northwestern Greece. *Journal of Crustacean Biology*, *28*(2), 8.

Banha, F., & Anastácio, P. M. (2012). Waterbird-mediated passive dispersal of river shrimp *Athyaephyra desmaresti*. *Hydrobiologia*, *694*(1), 197–204.

Fidalgo, M. L., & Gerhardt, A. (2002). Distribution of the freshwater shrimp, *Atyaephyra desmarestii* (Millet, 1831) in Portugal (Decapoda, Natantia). *Crustaceana*, *75*(11), 1375–1385.

Hänfling, B., Edwards, F., & Gherardi, F. (2011). Invasive alien Crustacea: Dispersal, establishment, impact and control. *BioControl*, *56*(4), 573–595.

Kawai, T., & Cumberlidge, N. (Eds.). (2016). *A Global Overview of the Conservation of Freshwater Decapod Crustaceans*. Cham: Springer International Publishing.

Mabrouki, Y. (2018). Case study of the freshwater shrimp *Atyaephyra desmarestii* (Millet, 1831) (Crustacea, Decapoda) in the watershed of Moulouya and eastern Morocco. *Vie Milieu*, 9.

Schoolmann, G., Nitsche, F., & Arndt, H. (2015). Aspects of the life span and phenology of the invasive freshwater shrimp *Atyaephyra desmarestii* (Millet, 1831) at the northeastern edge of its range (Upper Rhine). *Crustaceana*, *88*(9), 949–962.

Schram, F. R. (n.d.). *Ecological impact of crustacean invaders: General considerations and examples from the Rhine River*. 21.

Straka, M., & Špaček, J. (2009). First record of alien crustaceans *Atyaephyra desmarestii* (Millet, 1831) and Jaera istri Veuille, 1979 from the Czech Republic. *Aquatic Invasions*, *4*(2), 397–399.

Species: *Macrobrachium dayanum* (Henderson, 1893)

English common name: Red clawed prawn

Synonyms: NA

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE [choose one entry, delete all others]**	**CONFIDENCE [choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Moderately likely	Medium	Fecundity ranged from 43 to 195 eggs per female (mean = 99.53 ± 8.93SD; Bhuiyan et al. 2007) Escape or release from captivity
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Moderately likely	Medium	Medium-sized species; mean CL male = 16.6 mm and mean CL female = 13.5 mm
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	Medium	It is a medium-sized species that can produce a relatively large number of eggs

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Very unlikely	High	The species is native to hilly areas at the southern slope of the eastern Himalaya, and stretches from north-eastern India to Myanmar (Klotz et al. 2013). The species has been found in Germany but its dispersal to cooler parts of the

			Rhine is unlikely (Klotz et al. 2013)
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Likely	High	The species is adapted to freshwater habitats, including stream with high currents (Klotz et al. 2013)
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	High	The species is easy to raise in captivity (indoor aquaculture/aquaria)
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Isolated	High	Fully freshwater species that require warm temperature (larvae development; Klotz et al. 2013)
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	Medium	No information is available but the species has different predators including fish and birds. However, management practices (natural or human-facilitated) are often unproductive (eradication has only been successful for crustaceans in artificial ponds using a combination of chemical treatment and drainage)
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Unlikely	Medium	The species is present in Germany but only in one site (Klotz et al. 2013)
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Likely	High	Very few individuals have been found in Germany but the population still persist (but will likely disappear as soon as the source of the warm waters [i.e., a power plant] stops; Klotz et al. 2013)
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very unlikely	High	The species is present in Germany but due to its dependence on warm water temperature, its dispersal to cooler areas is unlikely (Klotz et al. 2013)

2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very unlikely	High	Current temperatures are too cold for the species

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Moderately likely	Medium	Can spread by adult movement No larvae dispersal (non-amphidromous species)
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Moderately likely	Low	No information is available, but the presence of the species in Germany is likely associated with intentional release by aquarium hobbyists (Klotz et al. 2013)
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	High	Current climatic conditions are too cold for the species
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	[insert text]	High	Even the warmest areas in southern Norway are likely too cold for the species
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Very unlikely	High	Current water temperatures are too cold for the species to survive

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**

4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minor	Medium	No reported impact (Klotz et al. 2013). But their presence nevertheless alters he diversity, and may have long-term consequences that take year to become apparent (Kawai and Cumberlidge 2016)
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	Medium	There are no likely candidate or hybridization in the Norwegian fauna today
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	Low	No information is available but potential competitive effects due its relatively large size
4.4. 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 Norway?	Moderate	Low	See 4.1 and 4.3
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	[insert text + attach map if possible]	High	All freshwater habitats located in the warmest areas of Norway (S/SE)
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Major	Low	It can cause damage to native fauna and no information is available on its control

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Major	Low	Potential vector of *Aphanomyces astaci* (Svoboda et al. 2014); the pathogen may grow in shrimp tissues but it is not clear whether it can

			complete its life cycle in such host
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Minimal	Low	
5.3. How much impact does the organism have as a vector for other parasites or pathogens?	Minimal	Low	
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	ow	Potential vector of *Aphanomyces astaci* (Svoboda et al. 2014); the pathogen may grow in shrimp tissues but it is not clear whether it can complete its life cycle in such host

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warming + Shorter winter	High	The species is dependent to warm water temperatures.
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establishment and Spread	High	

RISK SUMMARIES for *Macrobrachium dayanum*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately likely	Medium	Medium-sized species that can produce a relatively large number of eggs. The species is present in Germany but only in one site due to particularly

			warm water conditions (power plant; Klotz et al. 2013)
Summarise Establishment	Very unlikely	High	Current temperatures are too cold for the species
Summarise Spread	Very unlikely	High	Current water temperatures are too cold for the species to survive
Summarise impact from pathogens/ parasites	Moderate	Low	Potential vector of *Aphanomyces astaci* (Svoboda et al. 2014); the pathogen may grow in shrimp tissues but it is not clear whether it can complete its life cycle in such host
Summarise Ecological Impact	Minor	Low	No information is available but potential competitive effects due its relatively large size
Conclusion of the risk assessment	Moderate	Medium	Future climate conditions may facilitate the introduction of the species; potential vector of *Aphanomyces astaci*

References:

Bhuiyan, A. S., Arzu, G., & Bhuiyan, S. S. (1970). The Correlation between Fecundity with Length and Weight of *Macrobrachium dayanum* (Hall) from the River Padma, Rajshahi, Bangladesh. *Journal of Bio-Science*, *15*, 173–174.

Kawai, T., & Cumberlidge, N. (Eds.). (2016). *A Global Overview of the Conservation of Freshwater Decapod Crustaceans*. Cham: Springer International Publishing.

Klotz, W., Miesen, F. W., Hüllen, S., & Herder, F. (2013). Two Asian fresh water shrimp species found in a thermally polluted stream system in North Rhine-Westphalia, Germany. *Aquatic Invasions*, *8*(3), 333–339.

Svoboda, J., Mrugała, A., Kozubíková-Balcarová, E., Kouba, A., Diéguez-Uribeondo, J., & Petrusek, A. (2014). Resistance to the crayfish plague pathogen, *Aphanomyces astaci*, in two freshwater shrimps. *Journal of Invertebrate Pathology*, *121*, 97–104.

Species: *Macrobrachium rosenbergii* (de Man, 1879)

English common name: Giant river prawn

Synonyms: *Palaemon carcinus rosenbergii* (Ortmann, 1891), *Palaemon whitei* (Sharp, 1893), *Palaemon (Eupalaemon) rosenbergii* (Nobili, 1899), *Palaemon spinipes* (Schenkel, 1902), *Palaemon dacqueti* (Sunier, 1925)

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE** **[choose one entry, delete all others]**	**CONFIDENCE** **[choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Likely	High	Females can release up to approximatively 500 000 eggs (Silva-Oliveira et al. 2011) The species is one of the most cultured freshwater shrimps of the world and has been introduced for aquaculture in at least 40 countries but not in Europe (FAO Fishery Statistics 2006)
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Unlikely	Medium	Unintentional release (eggs or small specimens) from captivity
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	Medium	Large-sized species (max. TL 30cm) that can produce a large number of eggs, but is rarely used as pet

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**

2.1. How likely is it that the organism will be able to establish in Norway based on the similarity between climatic conditions in Norway and the organism's current distribution?	Very unlikely	High	The species is native to tropical and sub-tropical Indo-West Pacific region and has become invasive in East Africa, South America, USA, Taiwan, Martinique Island, Madagascar and Russia (Kuguru et al. 2019) The species can tolerate temperature ranged from 14 to 35°C (ERSS 2018)
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Likely	Medium	The species lives in a wide range of rivers and streams (included waterfalls) with a connection to brackish waters (amphidromous species)
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	High	The species is easy to raise in captivity (indoor aquaculture/aquaria)
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Widespread	High	All freshwater habitats with connection to brackish waters.
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	Medium	No information is available but the species has different predators including fish and birds However, management practices (natural or human-facilitated) are often unproductive (eradication has only been successful for crustaceans in artificial ponds using a combination of chemical treatment and drainage)
2.6. How likely are the biological characteristics (including adaptability and capacity of spread)	Very unlikely	High	The species is found in numerous countries but not present in Europe

of the organism to facilitate its establishment in Norway?			Amphidromous species: larval drift + adult movement to brackish waters Climate conditions can limit its establishment in the wild
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Likely	Medium	Escapes from aquaculture facilities (= with low genetic diversity) have established exotic populations (Anger 2013; Kuguru et al. 2019)
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Very unlikely	High	The species is invasive in East Africa, Brazil, Venezuela, Panama, Taiwan, Martinique Island, Madagascar, USA and Russia (Anger 2013; Kuguru et al. 2019)
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Very unlikely	High	Current climate conditions are unsuitable for this tropical/sub-tropical species (14 – 35°C)

PROBABILITY OF SPREAD			
Important notes: - Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Likely	High	Amphidromous species è females migrate downstream into estuaries + free-swimming larvae in brackish waters Terrestrial dispersal (max size male = 320mm; max size female = 250 mm) Omnivorous species. The species has a large distribution in the wild,

			suggesting high dispersal capabilities
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Very unlikely	Medium	Release or escape from captivity
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Unlikely	High	The species has effective spreading capabilities but temperature conditions will limit its reproduction/maturation (optimal temp. for growth is 29 to 31°C; ERSS 2018)
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	[insert text]	Medium	Warm freshwaters habitats with connection to brackish waters in South/South East Norway
3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Unlikely	High	Despite the good dispersal capacities of the species, climate conditions are too cold for the species

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Minimal	Medium	There is no evidence of yet serious ecological consequences following introductions of the species to new environments (Anger 2013)
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other	Minimal	Medium	There are no likely candidate or hybridization in the Norwegian fauna today

species, modifying their genetic makeup and making their environmental effects more serious?			
4.3. How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	Low	No information available, but due to its relatively large size, the species can compete with native macroinvertebrates/fish
4.4. 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 Norway?	Major	Low	See 4.1 and 4.3 The species can occur in high densities
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	[insert text + attach map if possible]	Low	All freshwater habitats located in the warmest areas of Norway (S/SE)
4.6. Estimate the expected ecological impacts of the organism if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	Medium	The species can potentially compete with native fauna

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Minimal	Low	
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Major	High	Tolerant to the infection caused by WSSV (Sahul Hameed et al. 2000) and thus can be a threat of

			spreading the disease to native species (ERSS 2018)
5.3. How much impact does the organism have as a vector for other parasites or pathogens?	Moderate	Medium	The species often has disease (e.g. TSV, white tail disease) Tolerant to the infection caused by WSSV (Sahul Hameed et al. 2000) and thus can be a threat of spreading the disease to native species (ERSS 2018)
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Moderate	Medium	

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warming + Shorter winter	High	The species currently lives in waters ranged from 14 – 35°C. For RCP85, the median projection indicates an increase in annual mean temperature for Norway of 4.5°C to 2071-20100 (span: 3.3 – 6.3°C).
6.2. What aspects of the risk assessment are most likely to change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions	Establishment and Spread	Medium	

RISK SUMMARIES for *Macrobrachium rosenbergii*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately likely	Medium	Large-sized species (max. TL 30cm) that can produce a large number of eggs. One of the most cultured freshwater shrimps of the world, but has not been introduced for aquaculture in Europe. The species is rarely used in the pet trade
Summarise Establishment	Very unlikely	High	Current climate conditions are unsuitable for this tropical/sub-tropical species (14 – 35°C)
Summarise Spread	Unlikely	Medium	Despite the very good dispersal capacities of the species, climate conditions will limit its spread
Summarise impact from pathogens/ parasites	Moderate	Low	The species often has disease (e.g. taura syndrome virus, white tail disease) and can transmit white spot virus (Sahul Hameed et al. 2000)
Summarise Ecological Impact	Moderate	Medium	The species can potentially impact ecosystem functions and community composition due to its large size
Conclusion of the risk assessment	Moderate	Medium	The species is not often used in the aquarium trade and has not been introduced to Europe, but it can have drastic consequences for native fauna and invaded ecosystems. Future climate conditions may facilitate its introduction

References:

Anger, K. (2013). Neotropical Macrobrachium (Caridea: Palaemonidae): on the biology, origin, and radiation of freshwater-invading shrimp. *Journal of Crustacean Biology*, *33*(2), 151–183.

Ecological Risk Screening Summary, Giant River Prawn (*Macrobrachium rosenbergii*) (2018) U.S. Fish and Wildlife Service

Kuguru, B. (2019). First record of giant freshwater prawn *Macrobrachium rosenbergii* (de Man, 1879) from small-scale fisheries in East Africa, confirmed with DNA barcoding. *BioInvasions Records*, *8*(2), 379–391.

Sahul Hameed, A. S., Charles, M. X., & Anilkumar, M. (2000). Tolerance of *Macrobrachium rosenbergii* to white spot syndrome virus. *Aquaculture*, *183*(3–4), 207–213.

Silva-Oliveira, G., Ready, J. S., Iketani, G., Bastos, S., Gomes, G., Sampaio, I., & Maciel, C. (2011). The invasive status of *Macrobrachium rosenbergii* (De Man, 1879) in Northern Brazil, with an estimation of areas at risk globally. *Aquatic Invasions*, *6*(3), 319–328.

Species: ***Neocaridina davidi*** **(Bouvier, 1904)**

English common name: Red cherry shrimp, but color variants are sold as ‘Green Jade’, Chocolate’, ‘Red’, ‘Red Rili’,‘Orange Rili’, ‘Carbon Rili’, ‘Blue Carbon Rili’, ‘Red Sakura’, ‘Red Onyx’, ‘Black Sakura’, ‘Blue Jelly’, ‘Blue Velvet’, ‘Blue Dream’, ‘Yellow’, ‘Yellow Fire Neon’, ‘Orange’ and ‘Bloody Mary’.

Synonyms: Neocaridina denticulata sinensis (Kemp, 1918), Neocaridina heteropoda (Liang, 2002)

SECTION B – Detailed assessment			
PROBABILITY OF ENTRY			
Important instructions: • Entry is the introduction of an organism into nature in Norway. Not to be confused with spread, which is the movement of an organism within Norway. • Entry in this context is defined as escape from captivity by (un)intentional release of eggs, juveniles or adult animals			
QUESTION	**RESPONSE [choose one entry, delete all others]**	**CONFIDENCE [choose one entry, delete all others]**	**COMMENT**
1.1. How likely is it that the organism will travel along this pathway from the point(s) of origin? Sub-note: In your comment discuss how likely the organism is to get onto the pathway in the first place	Likely	Low	The species is an extremely popular aquarium pet in Europe (Jabłońska et al. 2018) The species is present in the wild in Germany and Poland and can disperse through canals
1.2. How likely is the organism to be able to transfer from captivity to a suitable habitat or host in Norwegian nature?	Moderately likely	Medium	Relatively small-sized shrimp species (average size of females 25mm; average size of males 20 mm; Klotz et al. 2013) Producing clutches of 22.0 (± 4.0 SD) to 53.2 (± 4.3 SD) eggs depending on body size (Budi et al. 2020) that will hatch in 2-3 weeks, but females can produce new eggs almost immediately after hatching the previous ones (see ref in Debruyn 2019).
1.3. Estimate the overall likelihood of entry into Norwegian nature.	Moderately likely	Medium	Dwarf shrimp with moderate egg production, largely used in pet trade

PROBABILITY OF ESTABLISHMENT			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
2.1. How likely is it that the organism will be able to establish in Norway based on the similarity	Unlikely	Medium	The species is native to China, Korea, Vietnam and Taiwan (Weber and Traunspurger 2016)

between climatic conditions in Norway and the organism's current distribution?			but does however not originate from a tropical ecosystem: water temperature ranged from 6-8°C in winter to nearly 30°C in summer (Klotz et al. 2013). The species is invasive in Japan and Hawai (Weber and Traunspurger 2016), Turkey, Germany and nothwestern Canada (Debruyn 2019). Specimen have been found in Poland (Klotz et al. 2013; Jabłońska et al. 2018). 100% mortality in juveniles at water below 10°C or lower within two days (Debruyn 2019)
2.2. How likely is it that the organism will be able to establish in Norway based on the similarity between other abiotic conditions in Norway and the organism's current distribution?	Likely	High	The species inhabits freshwater habitats with low water velocities. Tolerant to pollution (Klotz et al. 2013) but no tolerance to salinity
2.3. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, aquaria, zoological gardens) in Norway? Sub-note: gardens are not considered protected conditions	Likely	High	The species is easy to raise in captivity (non-amphidromous species) and can tolerate a wide range of temperature
2.4. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Norway?	Ubiquitous	High	Lentic freshwater habitats
2.5. How likely is it that establishment will occur despite management practices (including eradication campaigns), competition from existing species or predators, parasites or pathogens in Norway?	Very likely	Medium	No information is available but the species has different predators including fish and birds However, management practices (natural or human-facilitated) are often unproductive (eradication has only been successful for crustaceans in artificial ponds using a combination of chemical treatment and drainage)
2.6. How likely are the biological characteristics (including adaptability and capacity of spread) of the organism to facilitate its establishment in Norway?	Unlikely	Medium	Tolerant to a wide range of temperature (including cold water; Klotz et al. 2013) but juvenile died below 10ºC

			Preferred well-oxygenated waters Omnivorous species
2.7. How likely is it that the organism could establish in Norway despite low genetic diversity in the founder population?	Very likely	High	Few specimens have been found in its introduced range (e.g., 15, 3, 3 and 9 individuals; Jabłońska et al. 2018)
2.8. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Norway? (If possible, specify the instances in the comments box.)	Moderately likely	Medium	The species is still spreading in Central Europe into the Rhine drainage (Klotz et al. 2013)
2.9. Estimate the overall likelihood of establishment in Norway (mention any key issues in the comments box).	Moderately likely	Medium	The species tolerate cold temperatures, but current temperature conditions are likely too cold in Norway (no adult mortality when water cooled to 5 ºC but juvenile died below 10ºC; Debruyn 2019)

PROBABILITY OF SPREAD			
Important notes: • Spread is defined as the expansion of the geographical distribution of an alien species within an area.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
3.1. How likely is it that this organism will spread widely in Norway by *natural means*? (Please list and comment on the mechanisms for natural spread.)	Moderately likely	High	Non-amphidromous species and limited larvae dispersal Disperal through canals and adult movement No specific tolerance to dessication Omnivorous species
3.2. How likely is it that this organism will spread widely in Norway by *human assistance*? (Please list and comment on the mechanisms for human-assisted spread.)	Moderately likely	Low	No information is available but its current distribution suggests capacity to disperse The species is widely used in ornamental pet trade è Release or escape from captivity
3.3. How likely is it that spread of the organism within Norway can be completely contained?	Very unlikely	Medium	Climatic conditions in winter will limit the spread of the species
3.4. Based on the answers to questions on the potential for establishment and spread in Norway, define the area endangered by the organism.	[insert text]	Low	Warm freshwater habitat in southern Norway (S/SE)

3.5. Estimate the overall potential for future spread for this organism in Norway (using the comments box to indicate any key issues).	Unlikely	Medium	Despite the potential good dispersal abilities of the species, temperature conditions will limit its spread in Norway

PROBABILITY OF ENVIRONMENTAL IMPACT			
Important instructions: • When assessing potential future environmental impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment. • Each section starts with the impact elsewhere in the world, then considers impacts in Norway separating known impacts to date (*i.e.*, past and current impacts) from potential future impacts.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
4.1. How much environmental harm is caused by the organism within its existing geographic range, excluding Norway?	Major	High	In the wild, possible impact on native shrimp and aquatic insects (Klotz et al. 2013) In mesocosm experiment, the species depresses the abundance, biomass and secondary production of meiofaunal assemblages (Weber and Traunspurger 2016)
4.2. How much impact would there be if genetic traits of the organism were to be transmitted to other species, modifying their genetic makeup and making their environmental effects more serious?	Minimal	Medium	There are no likely candidate or hybridization in the Norwegian fauna today
4.3 How much impact do other factors (which are not covered by previous questions) have? (Specify these other factors in the comments box)	Moderate	Medium	No information available but due to its consequences for native fauna, the species is likely a good competitor/predator
4.4. 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 Norway?	Moderate	High	See 4.1 and 4.3
4.5. Indicate any parts of Norway where environmental impacts are particularly likely to occur (provide as much detail as possible).	[insert text + attach map if possible]	Low	All freshwater habitats located in the warmest areas of Norway (S/SE)
4.6. Estimate the expected ecological impacts of the organism if it is able to	Moderate	Medium	The species can cause damages to native fauna,

establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).			which could indirectly modulate ecosystem processes

PROBABILITY OF IMPACT AS VECTOR OF PATHOGENIC AGENS			
QUESTION	**RESPONS E**	**CONFIDENCE**	**COMMENTS**
5.1. How much impact does the organism have as a vector for *Aphanomyces astaci*?	Minimal	Low	
5.2. How much impact does the organism have as a vector for White Spot Syndrom Virus (WSSV)	Minimal	Low	
5.3. How much impact does the organism have as a vector for other parasites or pathogens?	Moderate	Medium	Shrimps from the genus Neocaridina are known to host worms of the families Branchiobdellidae and Scutariellida (Klotz et al. 2013)
5.4 Estimate the expected impacts of the organism as a vector if it is able to establish and spread in Norway (despite any natural control by other organisms, such as predators, parasites, or pathogens that may already be present).	Minor	Low	

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
6.1. What aspects of climate change (up to the year 2100), if any, are most likely to affect the risk assessment for this organism?	Warming + Shorter winters	High	The species currently lives in waters with a wide range of temperature. For RCP85, the median projection indicates an increase in annual mean temperature for Norway of 4.5°C to 2071-20100 (span: 3.3 – 6.3°C).
6.2. What aspects of the risk assessment are most likely to	Establishment and Spread	High	

change as a result of climate change? • Establishment • Spread • Impact on biodiversity • Impact on ecosystem functions			

RISK SUMMARIES for *Neocaridina davidi*			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	Moderately likely	Medium	Dwarf shrimp with moderate egg production; extremely popular aquarium pet in Europe
Summarise Establishment	Moderately likely	Medium	The species tolerate cold temperatures, but current climate conditions are likely too cold in Norway (no adult mortality when water cooled to 5 ºC but juvenile died below 10ºC; Debruyn 2019)
Summarise Spread	Moderate	Low	The species has a wide range of distribution in worldwide (including Europe), but temperature conditions will limit its spread in Norway
Summarise impact from pathogens/ parasites	Minor	Low	
Summarise Ecological Impact	Moderate	High	The species can cause damages to native fauna, which could indirectly modulate ecosystem processes
Conclusion of the risk assessment	Moderate	Medium	The species is largely used in the aquarium trade and has potential for adaptation to cold temperatures. Impacts on European native fauna have been reported.

References:

Jabłońska, A., Mamos, T., Gruszka, P., Szlauer-Łukaszewska, A., & Grabowski, M. (2018). First record and DNA barcodes of the aquarium shrimp, *Neocaridina davidi* , in Central Europe from thermally polluted River Oder canal, Poland. *Knowledge & Management of Aquatic Ecosystems*, (419), 14.

Klotz, W., Miesen, F. W., Hüllen, S., & Herder, F. (2013). Two Asian fresh water shrimp species found in a thermally polluted stream system in North Rhine-Westphalia, Germany. *Aquatic Invasions*, *8*(3), 333–339.

Debruyn, A. (2019). Conservation ecology of a unique population of Lake chub (Cyprinidae; *Couesius plumbeus*): population size, movement ecology, habitat use and potential interactions with the exotic shrimp (*Neocaridina davidi* var. Red). Master thesis.

Weber, S., & Traunspurger, W. (2016). Influence of the ornamental red cherry shrimp *Neocaridina davidi* (Bouvier, 1904) on freshwater meiofaunal assemblages. *Limnologica*, *59*, 155–161.