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Risk assessment on import of Australian redclaw crayfish to Norway

Opinion of the Panel on Animal Health and Welfare of the Norwegian Scientific Committee for Food Safety

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Risk assessment on import of Australian redclaw crayfish to Norway

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Assessed and approved

The opinion has been assessed and approved by Panel on Animal Health and Welfare. Members of the panel are: Brit Hjeltnes (chair), Øivind Bergh, Edgar Brun, Knut Egil Bøe, Carlos Goncalo Afonso Rolhas Fernandes das Neves, Jacques Godfroid, Roar Gudding, Kristian Hoel, Cecilie Mejdell, Stein Mortensen, and Espen Rimstad (Panel members in alphabetical order after chair of the panel)

Acknowledgment

The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) has appointed a working group consisting of both VKM members and external experts to answer the request from the Norwegian Food Safety Authority and the Norwegian Environment Agency. Project leader from the VKM secretariat has been Angelika Agdestein, Dean Basic, Maria Gulbrandsen Asmyhr and Tron Gifstad. The members of the working group Øivind Bergh (Panel on Animal Health and Welfare), Carlos Goncalo Afonso Rolhas Fernandes das Neves (Panel on Animal Health and Welfare), Kjetil Hindar (Panel on Alien Organisms and trade in Endangered Species (CITES)), Helga Høgåsen (Norwegian Veterinary Institute), Anders Jelmert (Panel on Microbial Ecology) and Trude Vrålstad (Norwegian Veterinary Institute) are acknowledged for their valuable work on this opinion. The Panel on Alien Organisms and trade in Endangered Species (CITES) and the Panel on Microbial Ecology are acknowledged for comments and views on this opinion. VKM would like to thank Stein Ivar Johnsen for his contribution to chapter 1. VKM would also like to thank Lucy Robertson for proofreading the manuscript.

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.

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Summary

The Norwegian Food Safety Authoruty (NFSA) and the Norwegian Environment Agency (NEA) requested the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) for an opinion of potential risks to aquatic animal health and biodiversity in Norwegian fauna, associated with import of Australian redclaw crayfish (*Cherax quadricarinatus*) to Norway for aquaculture. A working group was established including members from the Panel on Animal Health and Welfare, the Panel on Alien Organisms and trade in Endangered Species (CITES), the Panel on Microbial Ecology, external experts from the Norwegian Veterinary Institute, and the VKM staff.

NFSA and NEA intend to use the report to evaluate applications related to aquaculture and for applications related to the Regulation on alien organisms. Further, the report will also be used to assess and potentially update or change relevant legislation.

The Australian redclaw crayfish, hereafter referred to as redclaw, is a relatively large freshwater crayfish, originating in tropical Australia and Papua New Guinea. This species has biological characteristics that make it well suited for aquaculture. Redclaw can be legally imported for use as an ornamental species in aquariums. However, it is currently not used for aquaculture in Norway.

Redclaw is widely translocated out of its native range globally, and is considered an invasive alien species. The species has limited tolerance for low temperatures and thus seems unlikely to establish reproductive populations under Norwegian climate conditions. However, there are concerns of negative impacts on native fauna. Hitchhiker organisms and infectious agents could potentially accompany import of redclaw, and, unless managed, may pose risks to biodiversity and aquatic animal health.

VKM used several methods to assess the risks related to animal health and biodiversity. Initially, the working group used the screening method AS-ISK to assess redclaws potential of becoming an invasive species in Norway. The screening was followed by a full risk assessment using a general method for ecological risk assessment. The Norwegian Biodiversity Information Centre (NBIC) uses this method when compiling the Norwegian black list of invasive species. VKM was asked to adopt a 50 years perspective in the assessment.

The working group considered two scenarios for the ecological risk assessment. **Scenario 1:** Aquaculture activity is limited to a few locations in Norway with limited production. According to this scenario, escaped redclaw is unlikely to enter natural streams. **Scenario 2:** Aquaculture activity grows rapidly in numbers, production output and geographical range. In this case, escapes may occur frequently in multiple locations throughout the year, elevating the risk of negatively affecting Norwegian biodiversity.

The assessment of aquatic animal health risks associated with import of redclaw was based on requirements of the EEA agreement and guidelines from the World Organization for Animal Health (OIE). VKM identified those pathogenic agents causing diseases for which there is sufficient scientific knowledge to be defined as hazards. The working group focused on pathogenic agents that can be introduced with redclaw itself, assuming that the containers used for redclaw transport are clean and disinfected. Redclaw was also regarded as a hazard itself, as an alien species in Norway.

Four disease-causing agents were identified as hazards: *Cherax quadricarinatus* Bacilloform Virus (CqBV), White Spot Syndrome Virus (WSSV), the oomycete *Aphanomyces astaci* and the fungus *Batrachochytrium dendrobatidis* (*BD*). Redclaw or related crayfish species can be infected or act as carriers of these pathogens. For several other microbial agents and hitchhiker organisms that might be associated with redclaw, scientific knowledge gaps prevent conclusions regarding hazard status being reached.

Based on the initial screening, redclaw was classified as having medium risk, justifying the necessity of a full risk assessment. Based on the NBIC method, the redclaw itself has a low invasive potential and would most likely have minor ecological effects on native biodiversity. However, considering the hazard identification described above, the redclaw may introduce a number of pathogenic agents that could have detrimental impacts on native fauna, including several species on the Norwegian redlist. Introduction of pathogenic agents to native fauna is highly weighted in the NBIC framework. VKM concludes, based on the NBIC method, that the combination of low invasive potential, but large ecological effects caused by the introduction of pathogens puts the redclaw in the category "potential high risk" under current climate and **Scenario 1.** Taking into account increased temperatures caused by future climate change as well as **Scenario 2,** the invasive potential of redclaw will increase from "low" to "limited", which will result in the classification "high risk".

The risk associated with the introduction of CqBV with imported redclaw is considered as extremely low, with some uncertainty related mainly to the unknown, although unlikely, susceptibility of Norwegian crustaceans to the disease.

The risk associated with the introduction of WSSV, the agent of White spot disease lethal to a number of marine and freshwater crustacean species, is considered as high. However, there is some uncertainty, related to the effect of WSSV on Norwegian crustaceans under Norwegian water temperature conditions.

Crayfish plague is already established in Norway in a few areas, after introduction of infected signal crayfish. This disease has wiped out entire populations of the redlisted noble crayfish. As *Aphanomyces astaci* (the agent that causes crayfish plague) may be transferred from redclaw to areas that are currently plague-free, the risk of spreading crayfish plague through import of redclaw is considered high in the absence of specific mitigation measures.

BD occurs throughout Australia and Asia, and has also reached Africa, the American continent and parts of Europe, but to date, has not been reported in Norway. Amphibian species are declining at an alarming rate globally, with over 200 species reported as extinct due to *BD*, and many more under threat of extinction. The risk of introducing *BD* with redclaw from an endemic area is considered high in the absence of specific mitigation measures.

OIE recommendations exist for WSSV and crayfish plague, and may reduce the risk to extremely low. Specific measures should be developed for *BD*, as OIE recommendations do not include carrier species. Possible management measures to avoid the entry of known pathogens include quarantine in both exporting and importing countries, and the use of specific screening tools, if available. If introduced into a farm, direct exposure of susceptible species from contact with pathogens from the farm will be reduced by mandatory treatment of wastewater, as stated in the regulation for exotic species. Additional biosecurity measures are necessary to avoid the spread through the disposal of sick or dead animals, and through the distribution of live or untreated individual animals to the market.

Very few ecological studies of tropical species under temperate environments have been published, making predictions on the consequences of reproductive ability and establishment of redclaw in Norwegian conditions difficult. VKM also recognizes a number of uncertainties and data gaps related to health risks. For example, the lack of scientific data regarding susceptible species makes it difficult to predict the risks associated with many pathogens. VKM cannot exclude that redclaw are carriers of yet unknown pathogens where the consequences to aquatic animal health and biodiversity in Norwegian fauna cannot be predicted.

Key words: Australian red claw crayfish, *Cherax quadricarinatus*, import, aquaculture, biodiversity, infectious agents, Norwegian Scientific Committee for Food Safety, Norwegian Environment Agency, Norwegian Biodiversity Information Centre, Alien Species Invasiveness Screening Kit, World Organisation for Animal Health, entry

Sammendrag

Vitenskapskomiteen for mattrygghet (VKM) har på oppdrag fra Mattilsynet og Miljødirektoratet utført en vurdering av potensiell risiko for biologisk mangfold og akvatisk dyrehelse ved innførsel og oppdrett av australsk rødklokreps (Australian redclaw crayfish, *Cherax quadricarinatus)* i Norge. VKM utnevnte en tverrfaglig prosjektgruppe bestående av medlemmer fra faggruppene for dyrehelse og dyrevelferd, fremmede organismer og handel med truede arter (CITES) og mikrobiell økologi, eksterne eksperter fra Veterinærinstituttet, samt VKMs sekretariat for å besvare oppdraget.

Mattilsynet og Miljødirektoratet skal bruke rapporten fra VKM til å evaluere søknader i forbindelse med akvakultur og søknader som faller inn under forskrift om fremmede organismer, samt evaluering og eventuell endring av relevant regelverk.

Australsk rødklokreps er en forholdsvis stor kreps som kommer fra tropiske deler av Australia og Papua New Guinea. Arten har en rekke biologiske egenskaper som gjør at den er velegnet for oppdrett. Det er lovlig å importere arten til Norge for bruk i akvarier, men den er til dags dato ikke tillatt brukt til oppdrett i Norge.

I tillegg til i opphavsområdene i Australia og Papua New Guinea er arten i utstrakt bruk i oppdrett i mange land. Arten regnes som en invaderende art, men er ikke tolerant for lave temperaturer. Det er derfor usannsynlig at den kan etablere seg under norske forhold.

Import av australsk rødklokreps kan likevel tenkes å få negative følger for lokal fauna. Arten kan potensielt ha med seg en rekke følgeorganismer, som patogener og parasitter. Uten spesielle tiltak for å forhindre spredning av disse, vil dette kunne utgjøre en risiko for biologisk mangfold og akvatisk dyrehelse.

Den tverrfaglige prosjektgruppen har benyttet seg av flere ulike metoder for å vurdere risiko for dyrehelse og biologisk mangfold. Risikoen for negative følger for biologisk mangfold ble vurdert ved hjelp av en innledende screening etterfulgt av en full økologisk risikovurdering. Screeningmetoden AS-ISK brukes som et hjelpemiddel til å vurdere om fremmede arter potensielt kan ende opp som invaderende arter. Den fulle risikovurderingen ble utført ved hjelp av en generell norsk metode som Artsdatabanken benytter i sine økologiske risikovurderinger av fremmede arter. VKM ble bedt om å utføre vurderingene i et 50-års perspektiv.

For den økologiske risikovurderingen ble det satt opp to scenarier basert på hvor hyppig krepsen tenkes brukt i oppdrett i Norge. **Scenario 1:** Oppdrett av australsk rødklokreps foregår kun noen få steder og med svært begrenset produksjon. I følge dette scenariet er det lite sannsynlig at krepsen kommer seg ut i norsk natur. **Scenario 2:** forekomsten av oppdrettsanlegg med australsk rødklokreps øker, både i geografisk utbredelse og produksjon. I dette tilfellet vil risikoen for gjentatte rømninger gjennom året og på mange ulike steder øke, noe som kan resultere i en negativ effekt på norsk biologisk mangfold.

Vurderingen av risiko for negative effekter på dyrehelse er basert på kravene som stilles i EØS-avtalen, samt retningslinjene fra Verdens dyrehelseorganisasjon (OIE). Basert på disse retningslinjene identifiserte VKM en rekke patogener/smittestoffer som potensielle farer. En forutsetning som lå til grunn for fare-identifisering var at krepsen selv kunne ha med seg patogener og parasitter. Kontainere til oppbevaring av krepsen ble antatt å være tilstrekkelig rene og desinfiserte. I tillegg til at en rekke smittestoffer ble vurdert som en fare, ble også krepsen i seg selv vurdert til å være en fare. Dette skyldes at arten ikke forekommer naturlig i Norge.

Fire patogener ble identifisert som potensielle farer: *Cherax quadricarinatus* Bacilloform Virus (CqBV), White Spot Syndrome Virus (WSSV), eggsporesoppen *Aphanomyces astaci* og soppen *Batrachochytrium dendrobatidis* (*BD*). Rødklokreps eller beslektede krepsarter kan være smittebærere. Det er i tillegg en rekke andre patogener som potensielt kan følge med ved import av australsk rødklokreps. Datagrunnlaget er for dårlig til at man kan si noe mer om hva slags fare disse kan utgjøre.

Basert på screeningen med AS-ISK-metoden ble rødklokreps klassifisert som medium risiko. Det ble derfor gjennomført en full økologisk risikovurdering. Ifølge Artsdatabankens metode har rødklokreps i seg selv lite invasjonspotensiale og liten økologisk effekt på lokalt biomangfold. Som beskrevet i fareidentifiseringen, kan arten ta med seg en rekke skadelige patogener som vil kunne ha negative følger for lokal fauna, inkludert flere rødlistede arter. Kombinasjonen av lite invasjonspotensial, men stor økologisk effekt som følge av introduksjon av patogener, gjør at VKM på bakgrunn av Artsdatabankens metode konkluderer med at rødklokreps klassifiseres som «potensielt høy risiko» under nåværende klima og **scenario 1.** Tar man høyde for fremtidige klimaendringer med temperaturøkning og legger **scenario 2** til grunn, vil krepsens invasjonspotensial kunne øke fra lite til begrenset. I **scenario 2** vil rødklokreps klassifiseres som «høy risiko».

Risikoen ved at importert kreps har med seg CqBV ansees som ekstremt lav. Det er noe usikkerhet knyttet til om norske krepsdyr er mottagelige for CqBV.

Risikoen for at importert kreps har med seg WSSV, smittestoffet som forårsaker hvitflekksykdom, som er dødelig for en rekke salt- og ferskvann krepsdyrarter, anses som høy, men det er usikkerhet knyttet til effekten av WSSV på norske krepsdyrarter under norske temperaturforhold.

Krepsepest er allerede etablert i flere områder i Norge, som et resultat av at signalkreps er innført til landet. Krepsepest har ført til at flere populasjoner av den rødlistede arten edelkreps er utryddet. Det er eggsporesoppen *Aphanomyces astaci* som forårsaker krepsepest. VKM anser at det er høy risiko for at import av australsk rødklokreps kan føre til at *Aphanomyces astaci* spres til områder som er fri for sykdommen så fremt det ikke settes i verk spesifikke tiltak

BD er utbredt i Australia og Asia, og har i tillegg også nådd Afrika, det amerikanske kontinent og deler av Europa men er foreløpig ikke rapportert i Norge. Globalt reduseres utbredelsen av amfibier drastisk, og over 200 arter er rapportert utryddet som en konsekvens av *BD*. Risikoen for å introdusere *BD* sammen med australsk rødklokreps ansees som høy så fremt det ikke settes i verk spesifikke tiltak.

Verdens dyrehelseorganisasjon (OIE) anbefaler en rekke risikoreduserende tiltak mot spredning av WSSV og *Aphanomyces astaci*. Iverksetting av slike tiltak vil kunne redusere risikoen til veldig lav. Det er behov for å utvikle spesifikke tiltak for *BD*, siden OIEs anbefalinger ikke inkluderer arter som er bærere av sykdommen. Forslag til forvaltningstiltak for å unngå innføring av kjente patogener inkluderer karantene både i eksport og import land, samt bruk av spesifikke screening verktøy når slike er tilgjengelig.

Lovpålagt rensing av avløpsvann (som nevnt under forskrift om eksotiske arter) vil kunne bidra til å unngå at utsatte arter kommer i kontakt med patogener. I tillegg er det nødvendig med ytterligere biosikkerhetstiltak for å unngå at sykdom spres gjennom døde og syke dyr, og gjennom omsetting av livdyr og ubehandlede dyr.

Det er få økologiske studier av tropiske arter under tempererte forhold, noe som gjør det vanskelig å forutsi hvorvidt australsk rødklokreps kan etablere seg og reprodusere under norske forhold. VKM påpeker også at det er en rekke usikkerheter og kunnskapshull relatert til helserisiko. For eksempel er det mangel på vitenskapelige data om hvilke arter som eventuelt ville rammes av mange av patogenene beskrevet i denne rapporten. VKM kan ikke utelukke at rødklokreps er bærere av til nå ukjente patogener hvor konsekvenser for biologisk mangfold og akvatisk dyrehelse i Norge ikke kan forutses.

Abbreviations and/or glossary

Abbreviations

ALOP = Appropriate level of protection

AS-ISK = Alien Species Invasiveness Screening Kit

BD = Batrachochytrium dendrobatidis

BRA = Basic risk assessment

CCA = Climate-change adjusted

CEFAS = Centre for Environment, Fisheries & Aquaculture Science

CITES = Convention on International Trade in Endangered Species of wild fauna and flora

CqBV = *Cherax quadricarinatus* bacilliform virus

CqPV = *Cherax quadricarinatus* parvovirus/parvo-like virus

EEA = The European Economic Area

FAO = The Food and Agriculture Organization of the United Nations

IBV =Intranuclear bacilliform virus

ICES = The International Council for the Exploration of the Seas

IPCC = Intergovernmental Panel on Climate Change

IRA = Import risk analysis

IUCN = The International Union for Conservation of Nature NBIC = Norwegian Biodiversity Information Centre (In Norwegian: Artsdatabanken)

NFSA = The Norwegian Food Safety Authority (In Norwegian: Mattilsynet)

NEA = The Norwegian Environment Agency (In Norwegian: Miljødirektoratet

OIE = World Organization for Animal Health

PSU = Practical salinity units

RA = Recipient area

RCP = Representative Concentration Pathway

RLO = Rickettsia-like organisms

UV = Ultraviolet

VKM = The Scientific Committee for Food Safety (In Norwegian: Vitenskapskomiteen for Mattrygghet

WSD = White spot disease

WSSV = Whitespot syndrome virus

WTO = The World Trade Organization

YHV = Yellowhead virus

Glossary

American crayfish = freshwater crayfish species native to America

Black List = The Norwegian Black List presents alien species in Norway with ecological impact assessments

Detrivorous = an organism that obtain nutrients by consuming detritus (decomposing organic matter)

Dimitic = dimictic lakes are lakes that mix from the surface to bottom twice each year

“Horizon scanning” techniques = desk research, helping to develop the big picture behind the issues to be examined

Noble crayfish = *Astacus astacus*

(North American) Signal crayfish = *Pacifastacus leniusculus*

Oomycete = water mould, a distinct phylogenetic lineage of fungus-like eukaryotic microorganisms

Redclaw = Australian red claw crayfish, *Cherax quadricarinatus*

Red List = The Norwegian Red List for species that are at risk of going extinct in Norway.

Warm-monomitic = warm-monomictic lakes are lakes that never freeze, and are thermally stratified throughout much of the year.

Background as provided by the Norwegian Food Safety Authority and the Norwegian Environment Agency

Background

The Australian redclaw crayfish (*Cherax quadricarinatus*) is commonly used in aquaculture and has recently garnered interest as a potential candidate for land-based aquaculture in Norway.

Establishment of new aquaculture facilities for this species in Norway requires permission from the Norwegian Food Safety Authority. The Norwegian Food Safety Authority assesses all aspects of redclaw farming with respect to impact on fish health and welfare.

Introduction of *Cherax quadricarinatus* for aquaculture purposes requires permission under the Regulation on alien organisms, pursuant to the Norwegian Nature Diversity Act. To evaluate applications under this regulation, the Norwegian Environment Agency requires assessments of the risks of negative impacts on native biodiversity associated with import and farming of this species. The possible introduction of hitchhiking organisms should be taken into account when addressing risks to biodiversity. Biodiversity is here defined as the diversity of ecosystems, species and genetic variations within species, and the ecological relationships between these components (see the Norwegian Nature Diversity Act § 3). If permission is granted, the Norwegian Environment Agency may put forward terms and conditions that are deemed necessary in order to prevent negative impacts on native biodiversity.

The Norwegian Environment Agency and the Norwegian Food Safety Authority request VKM to carry out assessments of the potential risks stemming from import and farming of Australian redclaw. Given that there is a large overlap between the two assignments, both issuing agencies have requested VKM to answer the terms of references in a single report.

Terms of reference as provided by the Norwegian Food Safety Authority

The Norwegian Food Safety Authority requests VKM to assess factors of relevance to animal health in relation to import and farming of Australian redclaw crayfish (*Cherax quadricarinatus*), restricted to risks of pathogen and infectious disease transfer.

The Norwegian Food Safety Authority requests VKM to provide answers to the following questions:

a. Which pathogens could potentially be introduced by the import of redclaw crayfish to Norway? What is the risk of disease outbreaks amongst Norwegian native fauna caused by such pathogens? The risk is to be assessed regardless of exporting country.

b. What is the risk of infection among Norwegian native fauna, given that the farmed animals are set in quarantine before being released within the aquaculture facility?

c. What is the risk of infection for Norwegian native fauna stemming from the import of Australian red claw, given that the crayfish is released into aquaculture facilities that:

i. Filter and drain the wastewater through a public wastewater facility.

ii. Fulfils the requirements for disinfecting intake water and effluent water, as stated by the regulation relating to cleaning and disinfection of intake water to, and effluent water from aquaculture-related operations.

d. In addition to the measures stated in c, are there further measures that may reduce the risk of infection, or are there methods for treating the wastewater of an aquaculture facility that may be better suited to reducing the risk of pathogen transfer to native fauna stemming from the import of Australian redclaw?

The request includes neither import of Australian redclaw crayfish for ornamental purposes nor further placing on the market.

Terms of reference as provided by the Norwegian Environment Agency

The Norwegian Environment Agency requests the Norwegian Scientific Committee for Food Safety (VKM) to undertake an assessment of the risks of adverse impacts on biodiversity in Norway stemming from the import and keeping of Australian redclaw crayfish (*Cherax quadricarinatus*) for aquaculture purposes. Possible risks caused by the introduction of harmful "hitchhiker organisms" should be included in the assessment.

VKM should consider whether precautionary measures, such as quarantine and/or treatment of wastewater from aquaculture related activities, would influence the risk of adverse impacts on biodiversity. In addition, VKM should consider whether there are other measures that could be carried out to reduce the risk.

The timeframe for the risk assessment of adverse impacts on biodiversity should be 50 years, or 5 generations for organisms with a generation time of more than 10 years.

If the Australian redclaw crayfish is likely to affect ecosystem services and/or may be particularly affected by climate change beyond the specified time frame, this should be stated in the report, but should not be included as a part of the actual risk assessment.

1 Introduction

1.1 Australian redclaw crayfish

The Australian red claw crayfish *Cherax quadricarinatus* (von Martens, 1868) is a freshwater crayfish of the family Parastacidae (*Decapoda, Malacostraca*). Other common names are Queensland red claw, redclaw, tropical blue crayfish, freshwater blueclaw crayfish. Throughout this report, redclaw is used as a short name.

Redclaw is a relatively large freshwater crayfish, with males exhibiting bright red colouring on the margins of their large claws. It can reach a maximum weight of 650 g (males bigger than females). It can be distinguished from other crayfish by size, colour and the presence of four distinct anterior ridges (carinae) of the carapace.

The redclaw is native to the upper reaches of rivers in northeastern (tropical) Australia and in Papua New Guinea. Within its native range, it is listed as 'LC; Least Concern' in the 2009 The International Union for Conservation of Nature (IUCN) Red List. Its preferred habitat is in high turbidity, slow moving streams or static water holes (billabongs) that characterize the rivers of northeastern Australia. These are flushed seasonally with monsoonal wet season rains, which may wash the redclaw downstream. Redclaw displays a strong tendency to move upstream to the preferred habitat, and to avoid being stranded in the lower river reaches that often dry up during the dry season. Its preferred temperature range is 23 ºC to 31 ºC. Reproduction occurs at temperatures above 23 ºC, but a period of cooler temperatures (16-22 ºC) may be needed before reproduction, followed by a temperature increase to induce spawning (http://www.dpi.nsw.gov.au/fishing/aquaculture/publications/species-freshwater/freshwater-crayfish-aquaculture-prospects). Adult redclaw are opportunistic feeders but primarily detritivores. Juvenile redclaw are carnivores, with zooplankton as their main diet.

Female redclaw brood their eggs for six to ten weeks, depending on temperature. Most produce between 300 and 800 eggs per brood. There may be between three to five broods during the breeding season. Hatchlings resemble the adult form and remain attached to the underside of the female for several weeks before progressively becoming independent. Time to sexual maturity is 6-12 months in captivity and probably longer in the wild.

Redclaw aquaculture has been established for more than 25 years. The species has several biological attributes that make it well suited to aquaculture. Total aquaculture production is still quite small. The main producing countries are Australia, Mexico, Ecuador, Argentina, and Uruguay; redclaw farming activities are also known to exist in Belize, China, Indonesia, Israel, Morocco, Panama, Spain and the United States of America (USA). Recent figures (2014-2015) for aquaculture production of redclaw in Australia are modest (around 70 tonnes per year) and do not seem to have changed much since the mid-1990s. Worldwide, the average annual production for the years 1989 to 2014 is 141 tonnes (FAO FishStat;

http://www.fao.org/fishery/culturedspecies/Cherax_quadricarinatus/en), with three peak production years at around 400 tonnes and two recent years (2010-2011) at around 60 tonnes (these figures do not include a growing production in southern China). Most of the aquaculture production takes place in ponds, probably because growth rate is density dependent and decreases at higher production densities, as occurs in tanks. Another factor recognized by the Food and Agriculture Organization of the United Nations (FAO) is that commercial tank feed does not provide the same growth rate as the bottom material of ponds, with its mix of decaying material and microorganisms.

Redclaw is considered an invasive alien species. It has established feral populations in other parts of Australia, South Africa, Mexico, Jamaica, Puerto Rico, Zambia and Singapore. Feral populations are likely due to escapes (or intentional release) from aquaculture production or aquarium trade/culture, and they have been reported from climatic zones that are not very different from that of the species' native range (tropical and sub-tropical). Since redclaw has relatively high sensitivity to low temperatures, feral populations are less likely in waters where temperature falls below 10 ºC for months. The first report of a feral population in Europe was from Lake Topla in Slovenia in 2009 (Jaklic & Vrezec 2011). Lake Topla is a thermal lake, but experiences temperatures as low as 5 °C during winter, and Slovenian waters, in general, belong to the temperate climatic zone. We do not know how well this Lake Topla population thrives, but the individuals that have been caught seemed to belong to a sex- and age-structured population, apparently in the growth phase of colonization. This implies that they reproduce in this habitat with the potential to sustain and even spread. However, observations of redclaw in Lake Topla were in habitat regions with temperatures between 21 and 31 °C (up to 40 °C), and Jaklic & Vrezec (2011) consider it unlikely that the redclaw will establish in other lakes/rivers in Slovenia that are not fed by thermal springs. Redclaw has been assessed by IUCN (2010) as being of Least Concern. There are no major threats impacting this species or its habitat, and therefore it is unlikely to experience significant population declines.

Specimens of redclaw have also been recorded in the wild in Germany, the Netherlands, and England, but these occurrences were short-term and probably only represent individuals released from aquaria (Holdich et al. 2009). In Norway, import, release and sale of freshwater crayfish are generally banned through "FOR-2015-06-19-716 - Regulation on foreign organisms" (https://lovdata.no/dokument/SF/forskrift/2015-06-19-716) and require separate permits for importation. However, an exception from the import ban states that "*no permit is required upon importation of freshwater organisms if they can only live at temperatures above 5 ° C, and are exclusively held for ornamental purposes in indoor aquariums that are arranged so that organisms cannot escape, if notification is given in accordance with § 8*". Thus, Australian *Cherax* spp. are interpreted as being legal for ornamental purposes in Norway (http://www.nzb.no/fremmed-arter/fa2/) and are available in aquarium shops and on the private market (e.g., at finn.no). To our knowledge, redclaw has never been recorded in the wild in Norway. In Sweden, there has been a ban on imports of all exotic crayfish species for a decade. Here, the species protection regulation (Artskyddsförordningen 2007:545) § 18 states "it is prohibited to import into Sweden live freshwater crayfish of the species within the families *Astacidae*, *Cambaridae* and *Parastacidae*. The ban applies to all crayfish life stages.”. Sweden was the European country held responsible for the irreversible introduction of the crayfish plague agent, *Aphanomyces astaci* genotype group B, in 1907, and which, since being introduced, has resulted in the rapid destruction of populations of noble crayfish in Sweden and elsewhere.

In Norway, the closest relatives to redclaw are one native species, the noble crayfish *Astacus astacus*, and one introduced (alien) crayfish, the signal crayfish *Pacifastacus leniusculus*. Their biology is compared with the biology of redclaw in Table 1.1-1.

Table 1.1-1. Comparative biology of *Cherax quadricarinatus, Astacus astacus* and *Pacifastacus leniusculus* (Souty-Grosset et al, 2006; Kouba et al, 2014)

	C. quadricarinatus	*P. leniusculus*	*A. astacus*
Geographical distribution	Native to northwestern Queensland, N. territory of tropical Australia, and southeastern Papua New Guinea. Spread to several countries in Asia, Africa and America.	Endemic to northwestern USA and southwestern Canada. Spread to 29 European countries.	Indigenous to Europe, but has been widely spread, both naturally and by humans, after the last ice age. Confirmed presence in 39 European countries.
Phylogeny	Superfamily Parastacoidea, originating in Gondwanaland	Superfamily Astacoidea, originating in Laurasia	Superfamily Astacoidea, originating in Laurasia
Size and growth	Grows rapidly. Maximum size: 350 mm, and 650 g	Moderate growth rate. Maximum size 170 mm.	Slow to moderate growth rate. Maximum size: 180 mm, seldom > 150 mm.

	C. quadricarinatus	*P. leniusculus*	*A. astacus*
Body morphology	Smooth carapace with spines on shoulder behind cervical groove. Four distinct anterior ridges (carinae) of the carapace. Chelae smooth and straight. Blue colour, mottled with beige and red on joints and body. Mature males exhibiting bright red colouring on the margins of their large claws.	Smooth carapace and no spines on shoulder behind cervical groove. Robust chelae with a white-turquoise patch on top of junction of fixed and moveable finger. Colour may vary, but often brownish.	Carapace with various degree of granulation. Row of spines on shoulder behind cervical groove. Beige or black in colour, but blue and red varieties are known.
Life cycle	Probable life-span of 4-5 yrs. It can reach sexual maturity within 7 months (110-120 g) in its native range.	May live up to 20 years. Typical life cycle of a member of the crayfish family Astacidae. Reaches maturity after 2-3 yrs at lengths of 60-90 mm.	May live up to 20 years. Typical life cycle of a member of the crayfish family Astacidae. Females reach maturity after 16 months-5 yrs at lengths of 62-85 mm. Males may mature at lengths of 60-70 mm.
Habitat	Turbid water, slow moving streams, and static water holes	Small and large rivers and lakes	Small and large rivers and lakes
Temperature (optimal)	23-31 ºC	Probably in the same range as *A. astacus*.	15-24 ºC
Feeding habits	Detrivorous	Omnivorous	Omnivorous
Predators	Fish, birds, mustelids	Fish, birds, mustelids	Fish, birds, mustelids
Diseases	Susceptible to crayfish plague. In its native range, it may suffer and be host to a variety of protozoa, bacteria and viruses.	Natural carrier/host of *A. astaci* (crayfish plague). It may suffer and be host to a variety of protozoa, bacteria and viruses.	Highly susceptible to crayfish plague. It may suffer and be host to a variety of protozoa, bacteria and viruses.
IUCN category	Least concern (LC)	Least concern (LC)	Vulnerable

	C. quadricarinatus	*P. leniusculus*	*A. astacus*
Captured/farmed fisheries	Mostly from farming	Yes (especially in western USA, Sweden and Finland)	Yes (in many European countries, especially in Sweden, Finland and Norway)
Aquaculture production	In Australia, annual production is *c*. 70 tonnes; worldwide it is *c*. 140 tonnes.	Yes	Yes

1.2 Crustaceans in Norway

The aquatic organisms most likely to be affected by the introduction of redclaw to Norway are other crustacean species. This chapter provides a short presentation of relevant species and their known importance.

1.2.1 Freshwater crayfish

The noble crayfish has its natural range in Europe, where it occurs in 39 countries (Holdich et al, 2009). The natural immigration route of the noble crayfish to Norway probably included two watercourses along the southeastern border to Sweden (Huitfeldt-Kaas, 1924). The main distribution area is in fresh waters around the Oslofjord (Figure 1.3). In addition, a few localities are known in western Norway and in mid-Norway. In total, 599 localities with noble crayfish have previously been registered in Norway over time. Most of them are due to human-assisted transfer of live specimens. However, during the past 30-40 years, about 70% of the noble crayfish populations have either been lost or highly reduced. Today, about 375 populations are still known to be active (Johnsen, 2013; http://www.miljostatus.no/Edelkreps/).

1.2.2 Marine crayfish

Two species of seawater crustaceans may be in comparable, although not identical, segments of the market, the European lobster *Homarus gammarus* and the Norway lobster (in Norwegian “Sjøkreps”) *Nephrops norvegicus.* Both are relatively common along the coast of Southern Norway. Landing statistics of the two species are provided in Figures 1.2.2-1 and 1.2.2-2. In addition, there is import of the American lobster, *Homarus americanus*, which have occasionally escaped. This species is also a known host for several pathogenic organisms, in particular the bacterium *Aerococcus viridans,* the causative agent of gaffkemia, which is pathogenic to the European lobster, *H. gammarus*. A wide range of crustaceans exists in the Norwegian marine environments.

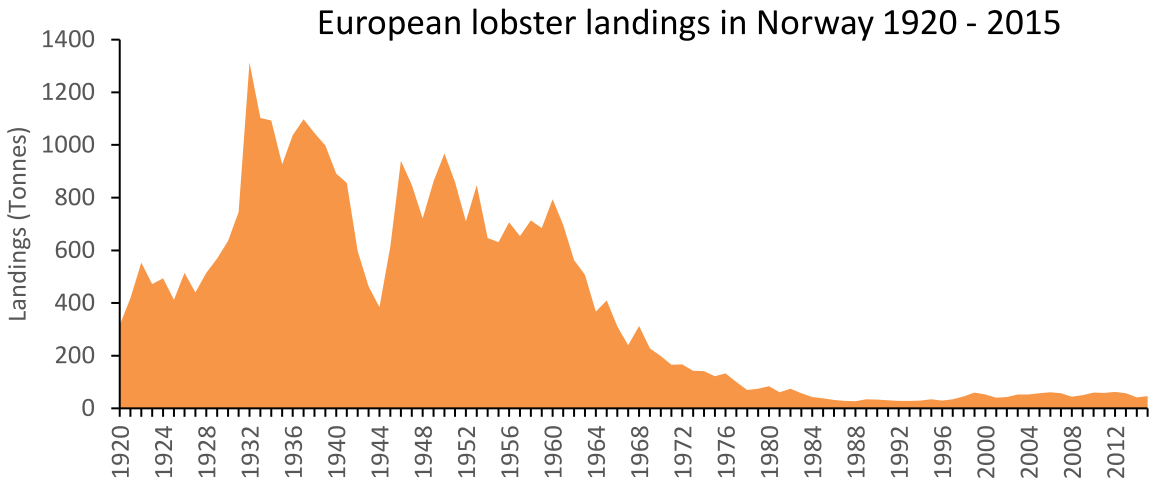


Figure 1.2.2-1. Landing statistics of European lobster, *Homarus gammarus* in Norway. Sources Agnalt (2008), Directorate of Fisheries, Bergen Norway

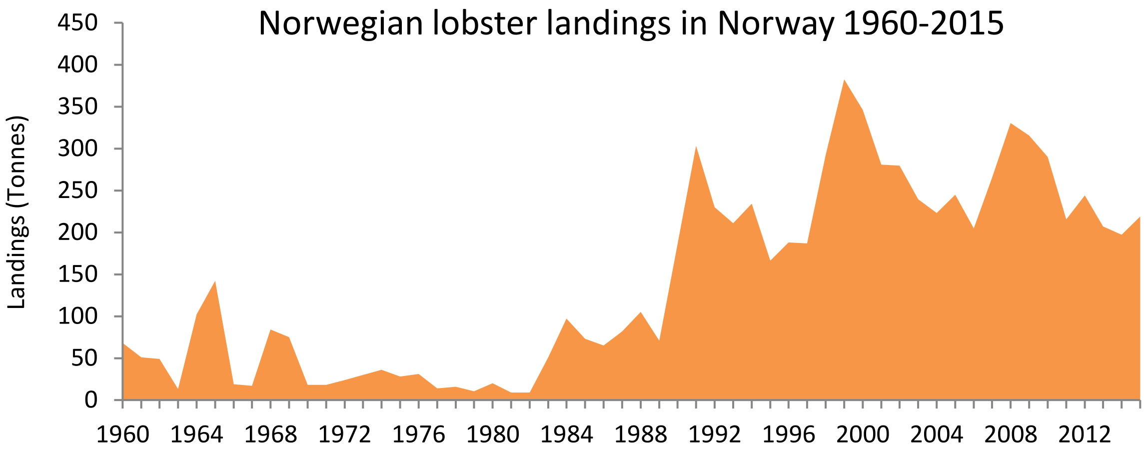


Figure 1.2.2-2 Landing statistics of Norway lobster, *Nephrops norvegicus* in Norway. Source: Directorate of Fisheries, Bergen, Norway.

1.3 Previous experiences with introduction of crayfish to Europe and Norway

The North American signal crayfish (*Pacifastacus leniusculus*), introduced to Sweden from California in 1960 (Johnsen & Taugbøl 2010; (Bohman et al., 2011)), is currently present in 29 European countries, including Norway (Kouba et al., 2014). Introduction of signal crayfish has never been allowed in Norway, and, until 2007, Norway was believed to be among the few countries in Europe without signal crayfish. From 2007, signal crayfish have been recorded in six locations in Norway (Figure 1.3-1), of which five results from illegal introductions. These include Dammane in Telemark county (Johnsen., et al 2007), Øymarksjøen and Rødenessjøen in the Halden watercourse close to the Swedish border, in Østfold county (Vrålstad et al, 2011; http://www.vetinst.no/sykdom-og-agens/krepsepest), Ostøya in the Oslofjord in Akershus county (Johnsen et al., 2009), Skittenholvatnet in Sør-Trøndelag county (Johnsen et al., 2013), and Kvesjøen in Nord-Trøndelag county (Johnsen, 2015). The sixth location is Lake Store Le in Østfold county, a border lake between Norway and Sweden where signal crayfish probably migrated from an illegally introduced population on the Swedish side of the border. Eradication measures have been successfully implemented in two of the Norwegian locations (Dammane; Sandodden and Johnsen, 2010, and Ostøya; Sandodden and Bardal, 2010), leaving four locations that still host signal crayfish.

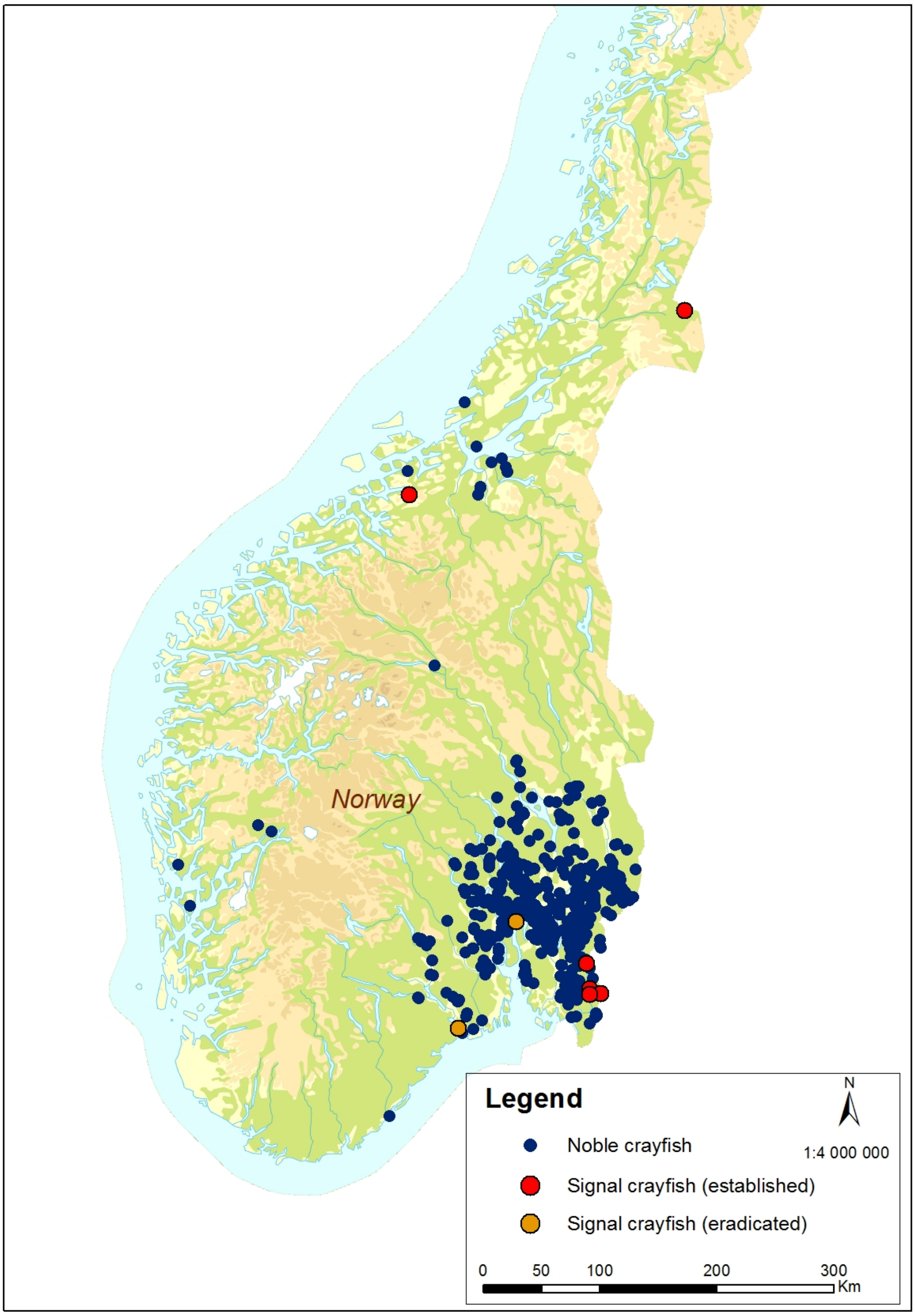


Figure 1.3-1. Geographical distribution of indigenous noble crayfish (blue) and alien signal crayfish (red) in Norway. Two previous populations of signal crayfish have been successfully eradicated (orange). From Stein Ivar Johnsen, Norwegian Institute for Nature Research, with permission through Norge digital.

In Norway, the annual catch of noble crayfish has been approximately 10-12 tonnes since around 1990. The maximum catch reached 40 tonnes in 1966, of which were exported to Sweden (Johnsen, 2013).

The signal crayfish is on the Norwegian Black List for introduced species (Gederaas et al. 2012), characterized as having a Very High risk to native biodiversity, mainly because of its carrier status for the crayfish plague (see below). There is no fishery for signal crayfish in Norway. In Sweden, the annual catch of signal crayfish is around 200 tonnes annually (Edsman & Engdahl 2015).

There are numerous examples of microorganisms that are natural, harmless commensals on plants and animals of one continent, but when naïve hosts on new continents are exposed to these microbes, serious symptoms result, leading to new diseases (Adlard et al., 2015; Engering et al., 2013; Fisher et al., 2012). For crayfish, the leading example is crayfish plague, caused by the oomycete *Aphanomyces astaci*. The disease first emerged in Europe in the 1860s. Research has verified North America as being the originating continent and North American crayfish as the source of infection (healthy carriers) (Söderhäll and Cerenius, 1999; Unestam, 1972). Three different North American freshwater crayfish species were introduced to Europe, each carrying host-specific genotype groups of *A. astaci* that are all aggressive pathogens on European freshwater crayfish (Grandjean et al., 2014; Holdich et al., 2009). The introduction of different crayfish species to Europe was largely for economic reasons, but became uncontrolled due to natural and anthropogenic spread (Gherardi et al., 2009; Holdich et al., 2009). Ecologically and economically important native European freshwater crayfish species, including the noble crayfish (*Astacus astacus*) that is native to Europe, are therefore seriously threatened (Holdich et al., 2009). In addition to biodiversity loss, this results in a negative impact on ecosystem function and cultural services, and forces the introduction of legal regulations that affect the public and create conflicts between economic interests, public traditions, and wild-life protection. The development of mitigation strategies by decision-makers, at both national and European levels, is therefore a challenge (Holdich et al., 2009; Holdich et al., 2005).

In Sweden, noble crayfish populations declined steadily from 1907 when the first wave of crayfish plague (*A. astaci* genotype group A) reached the country. Then, in the in the 1960s, the Swedish government launched a large-scale introduction of an “equivalent” North American freshwater species – the signal crayfish (*Pacifastacus leniusculus*) (Bohman et al., 2011). This species was known to be resistant against crayfish plague, but has subsequently been found to be a chronic carrier of the highly aggressive genotype group B/Ps1 of *A. astaci* (Söderhäll and Cerenius, 1999). In under 50 years, signal crayfish has been able to dominate in Sweden, largely due to illegal stockings, while about 97% of the original Swedish noble crayfish populations are lost (Bohman et al., 2011). The presence of signal crayfish in 29 European countries, together with several other species of introduced American crayfish carrying *A. astaci*, like *Procabmarus clarkiia* and *Orconectes limosus*, are clearly the most serious threats to European freshwater crayfish (Kouba et al., 2014; Holdich et al, 2009).

Norway was one of the last countries in Europe to be impacted by crayfish plague. The first crayfish mass mortalities date back to 1971 in River Vrangselva, then the River Glomma and the Halden watercourses were affected in 1987 and 1989, respectively. The outbreaks lacked confirmative diagnoses but crayfish plague was strongly suspected. Retrospective consideration based on molecular evidence from historical data, indicates that all mass mortalities of native freshwater crayfish in Norway, as far back as the 1970s, can be attributed to crayfish plague (Vrålstad et al., 2014). The first outbreak was caused by the *A. astaci* genotype group A/As that entered Europe in the 1860s with no known host, while all subsequent outbreaks can be attributed to genotype group B/Ps1 that is carried and transmitted by signal crayfish (Vrålstad et al., 2014), which were illegally introduced in several locations (see above). In larger natural systems, invasive species are often well established by the time that they are detected, and then it is often too late for control or eradication efforts. The Halden watercourse in Norway is a good example, as it has been estimated that signal crayfish was present, but unnoticed, in the lake for around 20 years, before being detected there in 2008 (Vrålstad et al., 2011). This location is now one of the major crayfish plague infection sources in Norway.

The emergence of crayfish plague in Europe was unforeseeable, based on knowledge at that time. It is therefore important to bear in mind that a risk assessment focusing on known diseases of an exotic crayfish species only evaluates known risks. The real hazards are not always predictable.

1.4 Methods for environmental risk assesement

1.4.1 Literature search

Following different literature searches on the crayfish species and taxon name(s) in the international (English) literature, and in international, Norwegian and Swedish crayfish management bodies, a more structured literature search was conducted on 31st August 2016. The Norwegian BIBSYS database on www.oria.no was searched for the words and combination of words: (redclaw OR "red claw" OR "Cherax quadricarinatus" OR "Astacus quadricarinatus" OR "blue crayfish" OR blueclaw) invas*. This search gave 14 scientific papers on the invasion biology of *Cherax quadricarinatus*. Two additional searches were done by replacing invas* with risk or temperat*, and these resulted in 11 and 58 references, respectively.

In addition, we searched for papers using the so-called “horizon scanning” techniques to assess environmental issues that may need to be addressed in the future (Sutherland & Woodroof 2009). Here, we have investigated the literature that lists potentially invasive species in Great Britain (Roy et al. 2014) and Belgium (Gallardo et al. 2016) as a supplement to our own classification of risk.

1.4.2 Scope of the risk assessment

The environmental risk assessment was carried out using two different methods; one risk identification (screening) method and one full environmental risk assessment method. These must be seen in conjunction with the method for health risk assessment outlined in chapter 1.5, which is based on guidelines from the World Organization for Animal Health (OIE, 2016).

Initially, a screening method based on the Alien Species Invasiveness Screening Kit (AS-ISK) for non-native freshwater fishes (Copp et al. 2005, Copp 2013) was used. The method is originally adapted from the Weed Risk Assessment tool kit, and modified to incorporate freshwater invertebrates (AS-ISK) by Tricarico et al. (2010). As a well-known test group, crayfish species were selected as an invertebrate taxon for scoring invasiveness of various species in Italy (Tricarico et al. 2010. The screening method was used to determine whether the organism is potentially invasive before initiating a full risk assessment (Copp et al., 2015)

The second method used here is a system for ecological risk assessment of alien species in general, used by the Norwegian Biodiversity Information Centre (NBIC; in Norwegian: Artsdatabanken www.artsdatabanken.no) when developing the Norwegian Black List (Gederaas et al. 2012). Their method builds on a generic method for ecological risk assessments of alien species, developed by Sandvik et al. (2013, 2015), and was used here as a framework for a qualitative risk assessment.

Both the NBIC and the AS-ISK systems are semi-quantitative, in that invasiveness is grouped according to a system of categories for a number of questions related to the biology of the species and the habitat in which it is released.

1.4.3 The AS-ISK system for screening

The AS-ISK system is based on answering 55 questions related to the biology, history of establishment, spread and ecological effects of non-native invertebrate species (Tricarico et al. 2010). Some of these questions have Yes/No answers whereas others (like climate tolerance) have scores (0-low, 1-intermediate, 2-high). All the answers are accompanied by an evaluation of the degree of certainty in the evaluation. Having answered all the questions, a total score is calculated by which the species being evaluated is assigned to a particular risk category. Each response option is associated with a numerical score, ranging from 0 to 3, where

0 – Low confidence (2 out of 10 chance)

1 – Medium confidence (5 out of 10 chance)

2 – High confidence (8 out of 10 chance)

3 – Very high confidence (9 out of 10 chance).

Having answered all the questions, a BRA (Basic Risk Assessment) score (Scale -20 – (+)60) is derived according to which the species being evaluated is assigned to a risk category. The CCA (Climate Change Adjusted) scores are given at a scale -32 – (+)80).

The specific questions are listed in appendix I.

1.4.4 The NBIC system for risk assessment

The NBIC system for ecological risk assessment uses two axes for characterization of risk: the first axis is invasion potential and the second axis is ecological effect. Within this system (each axis grouped from low or not known to high) five categories of ecological risk are identified: no known impact, low impact, potentially high impact, high impact and severe impact (Sandvik et al. 2013). Only an organism that is considered as belonging to one of the latter two categories results in that species being recognized as belonging to the Norwegian Black List.

The modified NBIC system for ecological risk assessment of alien species in Norway makes use of the following criteria for evaluation (Sandvik et al. 2015):

<u>Invasion potential</u> is based on:

Criterion A – the population median longevity, which is the time until there is a 50% probability…that the population resulting from escapees of the introduced species, is extinct.

Criterion B – the rate of range expansion of the alien species, which is the rate of increase in the radius of a circle whose area represents the total range area.

Criterion C – the maximum percentage coverage of a particular habitat (in Norwegian: naturtype, see Halvorsen et al. 2015) – this criterion is evaluated alone, to capture types of establishment and spread that are restricted to a particular habitat.

Whereas criteria A and B are usually multiplied to estimate an invasion potential, criterion C may be used alone for habitat-specific invasions.

<u>Ecological effect</u> is evaluated according to six criteria for assessing ecological and genetic effects of an alien species:

Criterion D – documented or likely effects on native biodiversity represented by threatened species or key species; the interactions may be direct through competition, predation, or parasitism (or transfer of other disease organisms), or indirect through allelopathy or trophic cascades.

Criterion E is of the same type as for D, and has the same strength of impact, but concerns affected species that are not key species or threatened species.

Criterion F – documented or likely effects on threatened or rare habitats, measured as a percentage change in the area of each particular habitat.

Criterion G – documented of likely effects on other habitats.

Criterion H – documented or likely transfer (introgression) of genetic material to a native species, occurring locally or regionally, or being a threatened/key species or not.

Criterion I – documented or likely transfer of disease agents (parasites or pathogens) such that the prevalence of the disease agent is increased, or infects new species, or that the disease agent itself is new. Information pertinent to this criterion is evaluated according to requirements of the EEA agreement and guidelines from the World Organization for Animal Health (OIE 2016) described in chapter 1.5-1.6 and addressed in detail in chapters 2.2 and 3.6.

The current threshold values for each of these criteria are listed in in the Appendix of Sandvik and colleagues (2015).

1.4.5 Exapnsion in redclaw aquaculture

In chapter 3, we performed an ecological risk evaluation according to two contrasting scenarios. The first scenario is one in which the industry itself does not expand, but is limited to one or a few aquaculture locations in southeastern Norway, with transport of individual redclaws into and out from these location(s). The second scenario assumes growth in the aquacultural production of this species, so that there is geographical and numerical expansion of the industry (more locations used, higher density of individuals) and a potentially higher risk of entry of cultured individuals into natural environments.

1.5 Method for health risk assessment

1.5.1 Literature search

We consulted recent reviews on crayfish diseases in general (Edgerton et al., 2002; Longshaw, 2011) and diseases of Australian redclaw crayfish in particular (Saoud et al, 2013). All disease searches were conducted using Thomson Reuters Web of science and Scopus.

For viral diseases, the following terms were used in different combinations: [viral diseases OR virus OR white spot disease OR taura OR yellow head OR bacilliform virus AND crayfish OR redclaw OR Australian redclaw OR Cherax OR quadricarnatus OR Cherax quadricarnatus]; [crayfish OR redclaw OR Australian redclaw OR Cherax OR quadricarnatus OR Cherax quadricarnatus AND disease OR diagnostics OR epidemiology].

For bacterial diseases, the following search terms were used in different combinations: [Australia AND Crayfish OR Cherax OR redclaw AND disease AND bacteria OR Coxiella OR Rickettsia OR Vibrio OR infection OR diagnostics].

For fungi, microsporidia and oomycetes, the following search terms were used in different combinations: [Australia AND Crayfish OR Cherax OR redclaw AND fungi OR Fusarium OR Batrachochytrium AND disease OR diagnistics]; [Australia AND Crayfish OR Cherax OR redclaw AND microsporidia OR Thelohania OR Vavraia AND disease OR diagnostics]; [Australia AND Crayfish OR Cherax OR redclaw AND oomycetes OR Aphanomyces OR Saprolegnia AND disease OR diagnostics].

For other parasites, the following search terms were used in different combinations: [Australia AND Parasites AND crayfish]; [Crayfish OR Cherax OR redclaw AND Ichthyosporea OR Psorospermium]; [Crayfish OR Cherax OR redclaw AND Parasites AND Ciliates OR Metazoa OR Platyhelminthes OR Acanthocephala OR Nematoda OR Digenea].

1.5.2 Scope of the risk assessment

The current assessment of health risks in aquatic organisms associated with the import of redclaw to Norway, is based on requirements of the EEA agreement and guidelines from the World Organization for Animal Health (OIE). This science-based evaluation process is consistent with Norwegian Government policy and Norway's rights and obligations under the World Trade Organization's (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures.

Norway's appropriate level of protection (ALOP) is considered to reflect community expectations through government policy, aimed at reducing risks to a very low level, but not zero. If the level of risk associated with an importation is deemed to exceed the ALOP, risk management measures are proposed to reduce the risk to an acceptable level. This is done to allow the Norwegian Food Safety Authority (NFSA) to make informed management decisions related to protecting animal health.

The present risk assessment is generic, which means that it provides a frame to evaluate the risk of any commercial imports of live redclaw to Norway, and that it can be used to assist risk managers in deciding upon appropriate protection measures.

The scope includes importation from any country for commercial purpose. Therefore, the hazard identification considers whether the agent is present in any country outside Norway. Once an agent is defined as a hazard, the entry assessment component assumes, for the purposes of risk assessment, that the pathogenic agents of concern are present in the source countries. Country or zone freedom from particular pathogenic agents is considered in the context of potential risk management measures.

The working group notes that there may be other potential pathways by which disease agents, associated with redclaw, may be introduced in Norway, such as via individual crayfish imported for ornamental purposes. Consideration of such pathways is outside the scope of this risk assessment.

Only consequences related to aquatic animal health and environmental impacts are considered in this assessment. Risks to human health are outside its scope.

1.5.3 Validity of the risk assessment

The present assessment is valid as long as the assumptions made are valid. The risk assessment should be updated if:

- Relevant changes occur in the health situation or in relevant regulations and management measures, both in exporting countries and Norway;
- Relevant changes in knowledge occur;
- Any other new relevant information is provided, that is not taken into account in this report.

1.5.4 OIE guidelines for import risk assessment

The OIE develops normative documents relating to rules that Member Countries can use to protect themselves from the introduction of diseases and pathogens, without setting up unjustified sanitary barriers.

Guidelines for import risk analysis (IRA), including risk assessment, are published in the Aquatic Animal Health Code, Chapter 2.1 (OIE 2016).

As stated in the guidelines:

> "The importation of aquatic animals and aquatic animal products involves a degree of disease risk to the importing country. This risk may be represented by one or several diseases or infections.
>
> The principal aim of import risk analysis is to provide importing countries with an objective and defensible method of assessing the disease risks associated with the importation of aquatic animals, aquatic animal products, aquatic animal genetic material, feedstuffs, biological products and pathological material. The principles and methods are the same whether the commodities are derived from aquatic and/or terrestrial animal sources. The analysis should be transparent. This is necessary so that the exporting country is provided with clear reasons for the imposition of import conditions or refusal to import.
>
> Transparency is also essential because data are often uncertain or incomplete and, without full documentation, the distinction between facts and the analyst's value judgements may blur."

The agents considered include those found in redclaw, as well as those found in other crustaceans and likely to exist in redclaw, based on present knowledge. They may or not affect redclaw, which may serve as healthy carrier to diseases of other aquatic species.

According to the OIE Handbook for risk analysis (OIE 2004; OIE 2010), the criteria for defining a pathogenic agent as a hazard are:

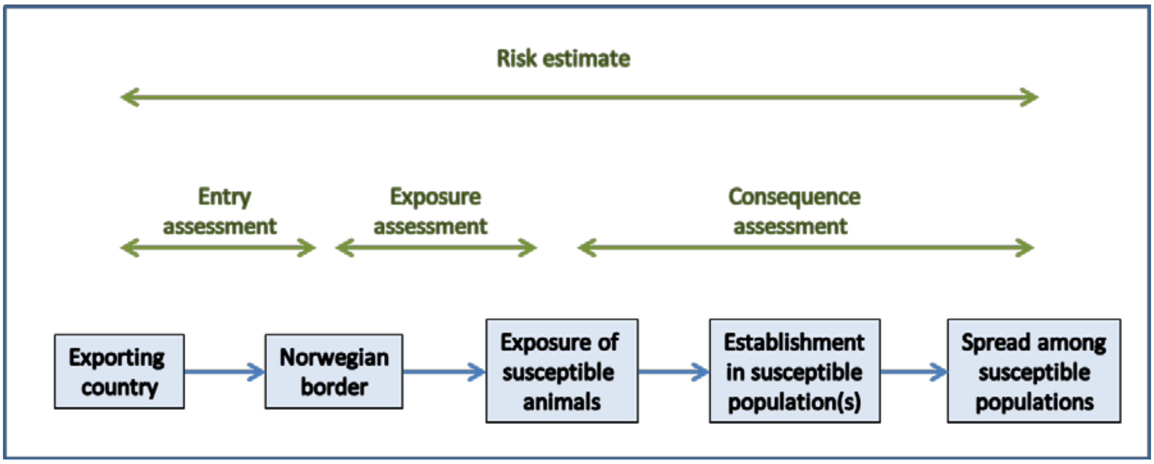
1) Redclaw or accompanying commodities are a potential vehicle, and
2) The agent is present in the exporting country , and
3) The agent is either
   a) Absent in Norway, or
   b) Present in a less virulent form, or
   c) Present only in certain zones or compartments, or
   d) Subject to an official control programme

The evaluation of the Aquatic Animal Health Services, surveillance and control programmes, and zoning and compartmentalisation systems are important inputs for assessing the likelihood of hazards being present in aquatic animal populations.

Crayfish populations are rarely screened, and knowledge about crayfish diseases, as well as diagnostic tools, is limited compared with that on many other farmed animal species. Here, we identified as hazards only those pathogenic agents for which sufficient scientific knowledge exists to classify them as such. A number of pathogenic agents with insufficient knowledge were not classified as hazards, although their status remains unknown. This does not follow the precautionary principle, but the absence of knowledge also means that conducting a risk assessment for these agents is not possible. This needs to be recognized when considering the final import risk assessment.

A risk assessment is performed for each hazard identified. It consists of four steps: entry assessment, exposure assessment, consequence assessment and risk estimate (Fig.1.5.4-1).

Figure 1.5.4-1. Components of risk assessment.



Estimates are based on information available in the scientific literature, unpublished data, and the expert judgment of IRA team members.

Since an importing country may decide to permit the importation using the appropriate sanitary standards recommended for a given hazard in the Aquatic Code, eliminating the need for a risk assessment for that hazard, the existing sanitary standards are also described.

Entry assessment

Entry assessment evaluates the pathways and likelihood of entry into Norway, after quarantine.

In this assessment we have considered the pathway depicted in Figure 1.5.4-2. The import of infection into Norway requires that ALL the following events occur:

1. The exporting population (farm) is infected, AND

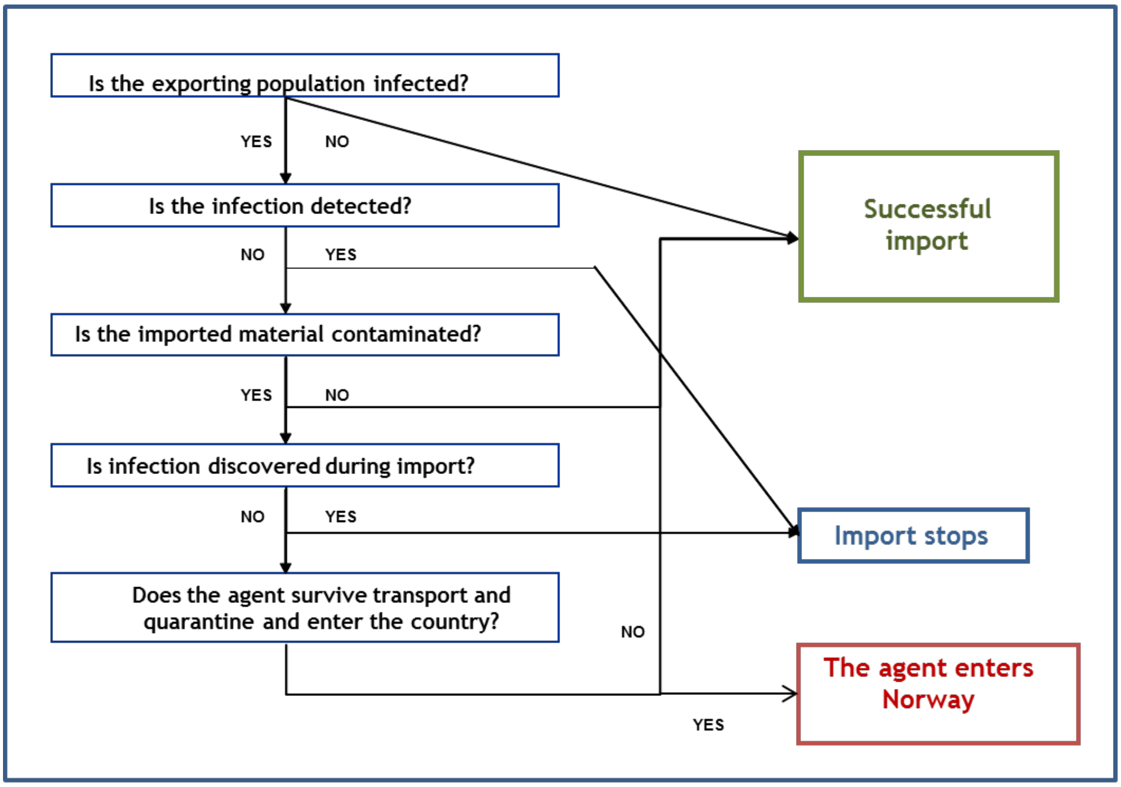
2. The infection is not detected at the time of export, AND

3. The material imported (live redclaw and accompanying commodities) are infected/contaminated, AND

4. The infection in the imported material is not detected during the import procedures, AND

5. The pathogen survives transport and quarantine and enters the country.

Figure 1.5.4-2. Scenario tree for entry.



Elements of interest are therefore:

- Prevalence of infection in exporting countries: farm prevalence, infection pressure
- Detection of infection in exporting farms
- Likelihood that imported redclaw are infected, or the accompanying material is contaminated
- Import procedures that may detect infection/contamination
- Import conditions that may inactivate infection/contamination

When assessing the likelihood of each step, the previous ones are assumed to have been met.

Exposure assessment

Exposure assessment considers whether susceptible species in Norway would be exposed to the agent, should the agent enter the country with imported redclaw.

Elements of interest are therefore:

- Existence of susceptible species in Norway

- Pathways for direct exposure from the farm: biosecurity measures at the farm
- Pathways for exposure after the redclaw have been sold by the farm: use of the redclaw produced and associated restrictions.

Consequence assessment

In the consequence assessment, we assess the possible health consequences to aquatic organisms from exposure to the agent.

Elements covered here are:

- Direct health effects on aquatic organisms
- Possibility of establishment and spread in the Norwegian population
- Possibilities for detection and control

Risk estimation

The final risk estimation is based on both the probability of introducing the disease and on the magnitude of the consequences.

1.5.5 Terminology

Here a qualitative risk assessment was performed, using specific terminology to describe the estimated likelihood of unwanted events to occur, their estimated consequences should they occur, and the uncertainty in our estimates.

Likelihood

The terminology for likelihood (Table 1.5.5-1) is based on the one used by Biosecurity Australia (Biosecurity Australia 2009), which has a long experience in implementing import risk analysis and undertaking generic IRAs.

Table 1.5.5-1. Nomenclature for qualitative likelihoods.

Likelihood	Descriptive definition
High	The event would be very likely to occur
Moderate	The event would occur with an even probability
Low	The event would be unlikely to occur
Very low	The event would be very unlikely to occur
Extremely low	The event would be extremely unlikely to occur
Negligible	The event would almost certainly not occur

We consider negligible likelihood to be so small that, in practical terms, it can be ignored.

When likelihoods are combined in a linear manner, which means that both need to occur simultaneously, the matrix of «rules» for combining likelihoods are as shown in Table 1.5.5-2.

Table 1.5.5-2. Matrix of «rules» for combining linear descriptive likelihoods.

	High	**Moderate**	**Low**	**V. low**	**E. low**	**Negligible**
High	High	Moderate	Low	V. low	E. low	Negligible
Moderate		Low	Low	V. low	E. low	Negligible
Low			V. low	V. low	E. low	Negligible
V. low				E. low	E. low	Negligible
E. low					Negligible	Negligible
Negligible						Negligible

When likelihoods are combined in a parallel manner, which means that at least one of the event is necessary (for example, parallel pathways of exposure), the resulting likelihood is at least as big as the largest one.

Consequences

The terminology for consequences is adapted from that used by Biosecurity Australia (2009). Consequences may be expressed at local, regional and/or national levels.

Unlikely to be discernible: the impact on aquatic animal health will not be distinguishable from normal day-to-day variation.

Minor significance: the impact on aquatic animal health will be recognizable, but minor and reversible.

Significant: the impact on aquatic animal health will be serious and substantial, but reversible and unlikely to affect either the economic viability or the intrinsic value of aquatic animal populations.

Highly significant: the impact on aquatic animal health will be extremely serious and irreversible and likely to affect either the economic viability or the intrinsic value of aquatic animal populations.

Risk

The likelihood of entry and exposure was combined with the consequences given exposure into a "risk" estimate (Table 1.5.5-3). The following risk matrix was used:

Table 1.5.5-3. Risk estimate.

Likelihood/ Consequences	Negligible	Extremely low	Very low	Low	Moderate	High
Unlikely to be discernible	Negligible	Negligible	Negligible	Extremely low	Very low	Low
Minor significance	Negligible	Extremely low	Extremely low	Very low	Low	Moderate
Significant	Negligible	Extremely low	Very low	Low	Moderate	High
Highly significant	Negligible	Low	Moderate	High	High	High

Uncertainty

Unless the conclusions are based on solid scientific information, the uncertainty of our estimates is graded as follows:

Some uncertainty: the conclusion is based on indirect information from limited available information

High level of uncertainty: the conclusion is based on expert's opinions, in the absence of specific information

1.6 OIE recommendations for the importation of Crustaceans

The OIE Aquatic Animal Health Code (2016) has developed recommendations for a number of diseases in crustaceans. These apply to all species of crayfish in all three crayfish families (Cambaridae, Astacidae and Parastacidae), including therefore redclaw. These are described in chapter 9 of the code[1] and concern the following diseases:

Chapter 9.1. Crayfish plague (Aphanomyces astaci)

Chapter 9.2. Infection with yellow head virus

Chapter 9.3. Infectious hypodermal and haematopoietic necrosis

Chapter 9.4. Infectious myonecrosis

Chapter 9.5. Necrotising hepatopancreatitis

Chapter 9.6. Taura syndrome

[1] http://www.oie.int/index.php?id=171&L=0&htmfile=titre_1.9.htm

Chapter 9.7. White spot syndrome virus

Chapter 9.8. White tail disease

Four of them (Crayfish plague, Yellowhead virus White tail disease and White spot syndrome virus) are, based on available information and literature, relevant assessment as hazards for redclaw. Conditions for each of these diseases are described in Appendix II.

1.7 Norwegian regulations

Official Norwegian regulations are relevant within the scope of this report and are here briefly summarized below:

- FOR-2008-06-17-819 Forskrift om omsetning av akvakulturdyr og produkter av akvakulturdyr, forebygging og bekjempelse av smittsomme sykdommer hos akvatiske dyr – 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 on Table 1.7-1.

- FOR-1997-02-20-192 Forskrift om desinfeksjon av inntaksvann til og avløpsvann fra akvakulturrelatert virksomhet – Regulation on disinfection of influent and effluents waters from aquaculture facilities

The purpose of this regulation is to prevent and limit the spread of contagious diseases in aquatic organisms through appropriate disinfection of intake water and wastewater to and from aquaculture-related activities. Of special relevance to this report is article 10 that regulates the requirements to be fulfilled by land-based facilities handing exotic aquatic species.

FOR-2010-11-11-1458 Forskrift om etablering og drift av karanteneanlegg for akvakulturdyr – Regulation on establishing and managing quarantine facilities for aquaculture species. This regulation aims at promoting good health for aquatic species, sets a quarantine period of 40 days for crustaceans (§14) and requires water influents and effluents to be handled according to FOR-1997-02-20-192 (Appendix III).

- FOR-2008-06-17-822 Forskrift om drift av akvakulturanlegg – Regulation on management of aquaculture facilities

The regulation aims to promote profitability and competitiveness within the aquaculture industry according to the framework of sustainable development, to contribute to wealth creation on the coast, and to promote the health of aquaculture animals and protect the welfare of fish. Of special relevance for this report, is that this regulation is concerned with the handling and destruction of dead aquaculture specimens (§16).

- FOR-2015-06-19-716 Forskrift om fremmede organismer - Regulation on alien organisms

The purpose of the regulations is to prevent the import, stocking, and spread of alien organisms that have, or may have, adverse effects on biodiversity.

Table 1.7-1. Listed crayfish diseases in Norway ((from FOR-2008-06-17-819; https://lovdata.no/dokument/SF/forskrift/2008-06-17-819) and known susceptible species along with other OIE-listed crustacean diseases.

Agent	Disease	Known susceptible freshwater decapods	Known susceptible marine decapods
List 1 – Exotic diseases			
	Taurasyndrom	-	*Penaeus setiferus*, *P. stylirostris* *P. vannamei*
	Yellow head disease	-	*Penaeus aztecus, P. duorarum, P. japonicus, P. monodon, P. setiferus P. stylirostris, P. vannamei*
List 2 – Non-exotic diseases			
White spot disease virus (WSSV)	White spot diseases	All species of freshwater decapods	*All species of marine decapods*
List 3 – National diseases			
Aphanomyces astaci	Crayfish plague	*Astacus astacus*	-

2 Hazard identification

2.1 Redclaw as an environmental hazard

Redclaw may be considered as a hazard as it is a species that is exotic to Norway; thus, the environmental risk associated with its introduction should be evaluated. In addition, it may introduce pathogens that may have an impact on aquatic animal health and, ultimately, on aquatic ecosystems. Both systems for environmental risk assessment used here have assessment points related to the role of redclaw as a host or vector of disease agents. In addition, this aspect is addressed in detail in the health risk assessment.

Tolerance of low temperatures is the most important biological trait for ecological risk identification of redclaw. If it can be established that temperatures in aquatic environments in Norway are too low for long-term survival (and reproduction) in the wild, then the ecological risk will be restricted to watercourses and locations with artificially elevated temperatures, such as effluent water from aquaculture and aquaria, the latter of which is less likely due to relatively small volumes. Short-term survival in the wild will necessitate an ecological risk assessment in those locations where repeated escapes to the wild would facilitate the presence of redclaw for extended periods of the year. For these reasons, temperature considerations are addressed as a background for the ecological risk assessment.

2.2 Pathogenic agents

We focus here on pathogenic agents that can be introduced with the redclaw themselves. It is assumed that the amount of water necessary for survival of the redclaw during transport is minimal, and that pathogenic agents not related to redclaw, but that could be present in water from endemic places, are sufficiently few to be regarded as negligible. It is also assumed that containers used for transport are clean and disinfected, so that their role in disease spread is negligible.

Furthermore, the focus in this section is limited to only those pathogenic agents that, with a few exceptions, are known to infect redclaw. Due to the low number of studies of redclaw, this list of pathogenic agents is probably not comprehensive. In particular, for some of the OIE-listed diseases for crustaceans, information regarding redclaw is scant or non-existent, so it is impossible to assess these diseases further.

2.2.1 Viral infectious agents in redclaw

Although several viruses have been reported from crayfish, these reports often constitute single events, with little or restricted information on isolation, pathology, or epidemiology. The low number of specific cell lines makes isolation a challenging task, and available diagnostic tools might also lack the specificity and sensitivity that are necessary to detect new threats. Some of these viruses have been reported on redclaw and classified either as specific to this species or originating from other crustaceans. The current list of viruses that may be introduced with redclaw is based on several reports and two detailed reviews by Longshaw (Longshaw, 2011) and Saoud (Saoud et al., 2013).

Cherax quadricarinatus bacilliform virus (CqBV)

Virus type and virulence strains

CqBV is a crustacean intranuclear bacilliform virus (IBVs). IBVs are double-stranded DNA viruses and although several have been described in different crustacean species, lack of molecular and immunological data makes its taxonomical classification difficult (Stentiford et al., 2004). There are contradictory reports on the impact of this virus; some studies refer to the lack of mortalities or clinical disease (Anderson and Prior, 1992; Romero and Jiménez, 2002) and others refer to retarded growth and low mortalities, although without macroscopic lesions (Edgerton et al., 2002; Groff et al., 1993). However, its high prevalence in several studies suggests reduced pathogenicity and the possibility of asymptomatic carriers being able to spread the infection over long periods of time (Saoud et al., 2013). We did not identify any reports of CqBV transmission to other crustacean species, although the possibility has been raised by Hauck et al. (Hauck et al., 2001).

Occurrence in potential exporting countries

CqBV was first reported in redclaw in 1992 in northern Australia by Anderson and Prior (Anderson and Prior, 1992), and has since been identified in other areas of Australia, as well as in USA, Chile, and Ecuador (Edgerton and Owens, 1999; Groff et al., 1993; Hauck et al., 2001; Romero and Jiménez, 2002). The virus has not been reported in Europe and, to our knowledge, no specific management measures are in place against this virus in Australia or elsewhere.

Occurrence and management measures in Norway

CqBV has never been identified in Norway. There is no surveillance system in place, and redclaw can be infected and carry CqBV without showing any signs of disease. Although the possibility that CqBV has been imported previously with redclaw imported for aquaria cannot be excluded, the absence of reported cases in Norway and Europe suggest that the presence of the virus in Norway can be considered as unlikely.

Conclusion

CqBV can be introduced with redclaw. It is unlikely that CqBV is currently present in Norway. As there are several reports of CqBV in exporting countries, CqBV can be defined as a hazard within the scope of this report.

Cherax quadricarinatus parvovirus / parvo-like virus (CqPV)

Parvoviruses are single-stranded DNA viruses and several have been described in different Australian *Cherax* spp. A first report in 2000 in Australia showed limited mortality associated with this virus (Edgerton et al., 2000), however Bowater and colleagues described a mass mortality event in juveniles in Australia in 2002, with crayfish showing soft shells and being anorexic and weak (Bowater et al., 2002). Gills, cuticular epithelium, and epithelial cells of the gut seem to be the most infected tissues. To our knowledge there are no reports of CqPV transmission to other crustacean species.

Occurrence and management measures in exporting countries

CqPV has been solely reported in Australia in the two events described above. To our knowledge, no specific management measures are in place against this virus in Australia or elsewhere.

Occurrence and management measures in Norway

CqPV has never been reported in Europe, and it is unlikely that this virus is present in Norway.

Conclusion

The limited number of reports suggests that CqPV are of minor significance, but their effects on European crayfish are unknown. Limited information prevents further risk assessment and therefore CqPV could not be considered as a hazard within the scope of this report.

Yellowhead virus (YHV)

Yellowhead Disease is caused by Yellowhead Virus (YHV - genotype 1), which is one of six known genotypes in the yellowhead complex of viruses, which is classified as a single species in the genus *Okavirus*, family *Roniviridae*, order *Nidovirales*. YHV infects shrimps and prawns, particularly the giant tiger prawn (*Penaeus monodon*), one of the two major species of farmed shrimp, in which it is highly lethal and contagious (OIE, 2016). As YHV causes an important disease with severe economic consequences, it is listed by both the OIE and the EU, the latter classifying it as an exotic disease. A study by Soowannayan and colleagues (2015) showed that Australian redclaw can be infected horizontally with YHV at sufficient levels to allow transmission to black tiger prawns. This indicates the potential for redclaw acting as a reservoir host, with the risk of transmission to other decapod species.

Occurrence and management measures in exporting countries

YHV is present in several countries, especially in Southeast Asia, and strict management measures are in place for when outbreaks occur. The disease has never been reported in natural conditions in Australian redclaw. YHV has never been reported in Europe. There are well defined criteria for diagnostics by the OIE - Manual of Diagnostic Tests for Aquatic

Animals Chapter 2.2.8 (OIE, 2009), and both the OIE – Aquatic Animal Health Code Chapter 9.2 (OIE, 2015) and the European Union – "Council Directive 2006/88/EC of 24 October 2006 on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animal" (EU, 2006) have described a set of management, control and eradication measures that should be enforced in the event of an outbreak.

Occurrence and management measures in Norway

YHV has never been reported in Norway.

Conclusion

YHV has never been found in Australian redclaw under natural conditions and therefore it is not considered as a hazard within the scope of this report.

White spot syndrome virus (WSSV)

White spot syndrome virus (WSSV) is a double-stranded DNA virus belonging to the genus *Whispovirus* within the *Nimaviridae* family and is widely considered to be the most serious viral pathogen in cultured penaeid shrimps, as well as being associated with epizootic mortalities in prawn aquaculture. White spot disease (WSD) generally results in high mortality in susceptible hosts, with clinical signs often reaching 100 %. The characteristic white spots are not always present. Survivors may carry the virus for life and may pass the virus to their progeny by vertical transmission (Stentiford et al., 2009). To date, no susceptible decapod crustaceans have been reported to be resistant (OIE, 2009). Persistent infection occurs commonly and lifelong infection has been shown (Lo and Kou, 1998). Viral loads during persistent infection can be extremely low and potentially undetectable by the available diagnostic tests (Lo and Kou, 1998).

The controversy around whether Australian redclaw is a susceptible species was resolved by experimental studies (Soowannayan and Phanthura, 2011; Wang et al., 2012) that confirmed *Cherax quadricarnatus* susceptibility to WSSV. The first study (Soowannayan and Phanthura, 2011) showed that redclaw is susceptible to WSSV infection by injection or by feeding with WSSV-infected giant tiger shrimps and that this can lead to high mortality. It also showed that WSSV could be transmitted to giant tiger shrimps within 4 days after co-habitation with WSSV-infected red claw. The second study (Wang et al., 2012) demonstrated that WSSV infection of redclaw leads to changes in gill enzyme activity and markedly damaged gill epithelium. Both studies therefore not only emphasize the harm caused by WSSV to redclaw, but also demonstrate the risk of this species serving as a reservoir and transmission vehicle to other decapods when grown in close proximity.

Occurrence and management measures in exporting countries

WSSV was first described in China and Taiwan in 1991 and subsequently spread throughout Asia, reaching the American continent in 1999. It is now also present in the Middle East and some outbreaks in southern Europe have been reported (Stentiford and Lightner, 2011). The OIE - Manual of Diagnostic Tests for Aquatic Animals Chapter 2.2.6 (OIE, 2009) provides some well-defined criteria for diagnostics, and both the OIE – Aquatic Animal Health Code Chapter 9.7 (OIE, 2015) and the European Union – "Council Directive 2006/88/EC of 24 October 2006 on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animal" (EU, 2006) have proscribed a set of management, control, and eradication measures to be enforced in the event of an outbreak. White Spot Disease (WSD) is listed as a non-exotic disease in EC Directive 2006/88.

Although there have been no confirmed outbreaks in Europe, a recent study screened ornamental crayfish for several pathogens and identified WSSV in Australian redclaw by PCR in two different locations in Germany (Mrugała et al., 2015). This shows the potential of this disease agent entering and spreading to either production populations or wild decapod populations via the ornamental trade, which is much less regulated than the aquaculture sector.

Occurrence and management measures in Norway

WSSV has not been identified in Norway to date and WSD has never been reported.

Conclusion

Redclaw has been shown to be susceptible to infection by WSSV. As Norway is free from WSSV, this pathogen is considered as a hazard within the scope of this report.

Other viral agents

Several other viral agents have been either reported in natural conditions in Australian redclaw or have been studied under experimental conditions. A summary of the most relevant of these is presented in Table 2.2.1-1. Given the lack of scientific information about these viruses in redclaw, as well as the lack of epidemiological evidence of their importance, they are not considered as hazards within the scope of this report.

Table 2.2.1-1 – Other viral agents reported in Australian redclaw.

Virus / Disease name	Taxonomy	Brief description	Geographical occurrence	Pathogenicity / clinical symptoms	In Norway?	Management measures	References
Penaeus merguiensis densovirus - ***Pmerg*****DNV**	Tentative ly placed in the *Parvoviridae* family –genus *Densovirus*	Redclaw can be cross-infected with this prawn virus and become a short-time carrier; it does not replicate in redclaw	Only described experimentally	In an experimental infection mortality occurred quickly but no histopathological changes observed	No	None	(Fauce and Owens, 2007)
Spawner-isolated mortality virus	Tentatively placed in the *Parvoviridae* family	Prawn virus that can infect Australian redclaw, resulting in possible reduction in yield production of juveniles	Described in experimental settings and in a natural infection in Australia	Virus identified in the nuclei of many tissue cells. No clinical signs	No	None but a risk to consider in international quarantine regimes	(Fraser and Owens, 1996; Owens and McElnea, 2000)
Cherax quadricarnatus reolike virus - CqRV	*Reoviridae*	Redclaw- specific virus that can cause mild clinical symptoms in juveniles	Single case of natural infection in Australia and experimental trial	Virus found on the hepatopancreatic tubules. Reddened appendages and mouthparts.	No	None	(Edgerton et al., 2000; Hayakijkosol and Owens, 2011)
Giardia-like virus - CGV	*Totiviridae*	Infection of juveniles mostly	Limited mortalities in episodes in northern Australia	Hypertrophic hepatopancreocytes	No	None	(Edgerton and Owens, 1997; Edgerton et al., 1994; Poulos et al., 2006)
Macrobrachium rosenbergii nodavirus - MrNV	*Nodaviriae*	Causative agent of White tail disease.	Described in experimental settings only	Red claw show low susceptibility to infection	No	Regulated by OIE and EU	(Hayakijkosol et al., 2011)
Cherax quadricarnatus iridovirus - CqIV	*Iridoviridae*	Recent discovered virus – effect on redclaw not currently elucidated	Identified only once in China.	High mortalities observed in single experimental study	No	None	Xu et al., 2016

2.2.2 Bacterial infectious agents in redclaw

Bacterial agents that have been isolated from crayfish include Gram-negative *Acinetobacter, Aeromonas, Citrobacter, Flavobacterium, Pseudomonas,* and *Vibrio* and Gram-positive *Bacillus, Corynebacterium, Micrococcus, and Staphylococcus* (Edgerton et al., 2002; Longshaw, 2011). The known conditions are asymptotic bacteraemia and bacterial septicaemia. Asymptotic bacteraemia refers to the presence of mixed bacterial populations in the haemolymph of apparently healthy crayfish, and is assumed to occur as a result of environmental stress (Edgerton et al., 2002). Bacterial septicaemia involves opportunistic infections in which the crayfish typically are lethargic and exhibit lack of muscle tone (Edgerton et al., 2002). There are few, if any, serious crayfish diseases caused by bacteria, but opportunistic bacterial infections of crayfish can lead to mortality in both farmed and wild animals, in particular under stressful environmental conditions. The bacterial pathogens that have been reported in redclaw are *Coxiella cheraxi* and *Vibrio mimicus* (Longshaw, 2011; Saoud et al., 2013).

Coxiella cheraxi

There are many reports of "Rickettsia-like infections" or "Rickettsia-like organisms" (RLOs) in cultured Australian redclaw. The RLOs are small, pleomorphic, rod-shaped, coccoid bacteria, most of which are Gram-positive and intracellular (Saoud et al., 2013). Tan and Owens (2000) described a new RLO that was isolated from *C. quadricarinatus* as *Coxiella cheraxi* (Rickettsiaceae). *C. cheraxi* was confirmed as the aetiological agent of mortalities in farmed *C. quadricarinatus*, with 100 % mortality at 28 °C, and 80 % mortality at an ambient temperature of 24 °C. Horizontal transmission through food and water was confirmed, but with much lower mortalities. Reports on systemic intracellular bacterial infection from Ecuadorian *C. quadricarinatus* is likely to be closely related to *C. cheraxi* , based on the pathology, morphology, and localisation of the infection (Longshow, 2011). Romero and Jimenez (2002) regarded this disease as the most important and virulent redclaw pathogen in Ecuador.

Occurrence in potential exporting countries

RLOs of redclaw, including *Coxiella cheraxi*, have been reported from freshwater streams in northern Australia and production farms in Queensland, Australia and Ecuador (Bower and Romero, 2009). The prevalence and distribution cannot be confirmed as there are only a few published reports, and there are no simple diagnostic tests yet published. The reports refer to gross signs, histology, and pathology (Bower and Romero, 2009), or cultivation in yolk-sac followed by 16S sequencing (Tan and Owens, 2000). There are no published reports of *C. cheraxi* in Europe and, to our knowledge, no specific management measures are in place against *C. cheraxi* in Australia or elsewhere.

Occurrence and management measures in Norway

Coxiella cheraxi has never been identified in Norway, but no surveillance system in place in Norway nor in the rest of Europe. We therefore have no indications regarding its presence or absence in Norway. Redclaw can be infected and carry *C. cheraxi* without showing any signs of disease, especially at lower temperatures. but our current knowledge suggests that *C. cheraxi* will not cause mortality epidemics under European conditions.

Conclusion

Coxiella cheraxi can be introduced with redclaw. Existing reports suggest that mortality caused by *C. cheraxi* in Australian redclaw is primarily a problem under cultured conditions and at high water temperatures, and the limited number of reports suggest that the agent is of minor significance. *C. cheraxi* could occur widely in Norway without having been diagnosed, and is therefore not considered a hazard within the scope of this report.

Vibrio mimicus

Vibrio mimicus was originally described by Davis et al. (1981) as a sucrose-negative variant of biochemically atypical *V. cholera*. There are some reports from Australia on mortality in cultured redclaw associated with *V. mimicus* infection (Saoud et al., 2013), and there are also reports on systemic disease caused by *V. mimicus* in commercially cultured redclaw. *V. mimicus* can act as an opportunistic pathogen causing systemic infections following stress from high crayfish densities (overcrowding) or poor water quality. *V. mimicus* may occur in a variety of seafoods, including crayfish, and is also frequently isolated from environmental samples in South America, including water, sediments, and plants (Guardiola-Avila et al., 2016). According to Eaves and Ketterer (1994), the agent has also been associated with human gastroenteritis following ingestion of improperly cooked crayfish, and there are many reports on *V. mimicus* associated with human diseases such as gastroenteritis, ear infections, and severe cholera-like diarrhoea (Guardiola-Avila et al., 2016).

Occurrence in potential exporting countries

Vibrio mimicus was first reported in reclaw in 1994 from New South Wales and southeast Queensland, Australia (Eaves and Ketterer, 1994). It has also been isolated from the water at the washing step in a freezing shrimp company in Mexico (Guardiola-Avila et al., 2016). According to Hasan et al (2010), the natural habitat of *V. mimicus* is similar to that of *V. cholerae*, and includes aquatic ecosystems, where it has been found both as free-living and in association with zooplankton, crustaceans, filter-feeding molluscs, turtle eggs, and fish. Reports of *V. mimicus* from a variety of seafood suggest a widespread distribution in Asia, Australia, and America. It is probably present in Europe, either in natural aquatic environments or due to seafood import. We are not aware of management measures in exporting countries that are of relevance to the export of live crayfish. The main concern is seafood safety, which is not the subject of this document.

Occurrence and management measures in Norway

Vibrio bacteria are found in Norwegian waters, but it is rare that *Vibrio* from water in Norway cause disease in humans or animals. According to the Norwegian Food Safety Authority, there are mainly three *Vibrio* species that can make food unsafe: *V. cholerae, V. parahaemolyticus, and V. vulnificus*, all three regarded as zoonotic agents (http://www.mattilsynet.no/mat_og_vann/smitte_fra_mat_og_drikke/bakterier_i_mat_og_drikke/fakta_om_vibrio.4211) *Vibrio mimicus* is very closely related to *V. cholera*, and produces an enterotoxic haemolysin that targets intestinal epithelial cells, affecting ion transport and leading to gastro-enteritis and diarrhoea (Austin, 2010). To our knowledge, there are no management measures of *V. mimicus* in Norway, but there are many diagnostic tests available for *Vibrio* screening and identification.

Conclusion

It is not unlikely that *V. mimicus* is present in Norway, for example as a result of seafood import. Although *V. mimicus* could be introduced to Norway with redclaw it is not considered a hazard within the scope of this report.

2.2.3 Fungal and oomycete infectious agents in redclaw

This section covers both fungi and oomycetes (water moulds). Oomycetes are often referred to as fungi due to their similar ecological roles and mode of nutrition, but are classified as Straminopiles together with brown algae and diatoms (Lee et al., 2012). Fungi include also microsporidia (Burki, 2014). With exception of crayfish plague, caused by the oomycete *Aphanomyces astaci,* and the microsporidian species of *Telohania* causing porcelain disease, oomycetes and fungi are typically considered to be secondary or opportunistic pathogens of freshwater crayfish (Edgerton et al, 2002; Edgerton 2002; Longshaw, 2011). There are some reports on more severe *Fusarium* infections in crayfish, for example “brown spot disease” or “burn spot disease” caused by *F. solanii* and *F. avenaceium* (Makkonen et al., 2013a, Longshaw, 2011), black gill disease caused by *F. tabacinum* (Longshaw, 2011), and “eroded swimmeret syndrome” associated with both *A. astaci* and *Fusarium* spp. infections (Edsman et al., 2015). However, the presumed causative agents are, in all cases, cosmopolitan species, and there are no reports on *Fusarium* infections in Australian freshwater crayfish. The same applies for *Saprolegnia*. These fungal genera are thus not covered in the list below. It should be noted that some American freshwater crayfish species have been found to carry the globally emerging amphibian disease, chytridiomycosis, caused by the chytrid fungus *Batrachochytrium dendrobaditis* (*BD*) (McMahon et al., 2013); Brannelly et al., 2015), with associated mortalities in challenge experiments with crayfish (McMahon et al., 2013).

Aphanomyces astaci

The oomycete *Aphanomyces astaci*, the agent of crayfish plague, is carried and transmitted by North American freshwater crayfish, including signal crayfish as one of many carriers (Holdich et al. 2009). There are two published reports on crayfish plague mortalities in Australian redclaw. In farmed redclaw reared in Sicily (Marino et al., 2014), *A. astaci* was confirmed to cause up to 30 % mortality. This is a relatively low mortality rate compared with the almost 100 % mortality that is most commonly reported for European crayfish (OIE 2015). This suggests a higher degree of resistance, and thus the possibility of redclaw acting as a carrier of this disease. Mortalities apparently rise with decreasing water temperatures (Hsieh et al., 2016), and therefore reduced mortality rates may also result from temperature preferences of the pathogen. However, Mrugala et al (2016a) compared mortality rates for noble crayfish (*Astacus astacus*) and *Cherax destructor* challenged with different genotype groups of *A. astaci*, and found that the mortality was of *C. destructor* was significantly lower than in noble crayfish for all genotype groups. They concluded that *C. destructor* may contribute to the spread of *A. astaci* in Europe under favourable conditions. Unestam (1969b) also characterized Australian *Cherax* spp., including redclaw, as being moderately resistant to *A. astaci*.

Crayfish plague outbreaks have also been reported recently from five locations of farmed redclaw crayfish in in Northern and Southern Taiwan (Hsieh et al., 2016), with mortality rates of up to 100 %. This is the first report concerning natural infection of *A. astaci* in freshwater crayfish in Asia. In these outbreaks the mortality events were also associated with the periods of the year with the coldest water temperature. Thus, redclaw seems to be more vulnerable to *A. astaci* at low temperatures, or, alternatively, the mortality is probably also dependent on the sporulation efficiency and virulence of the different genotypes of *A. astaci*, which are optimal below 20 °C for four or the five known *A. astaci* genotype groups (Diéguez-Uribeondo et al., 1995). Only one *A. astaci* genotype group (carried and tramsmitted by *Procambarus cladkii*) is highly virulent above 20 °C (Diéguez-Uribeondo et al., 1995). There is one case of *A. astaci* carrier status reported from redclaw in a pet-shop facility in Europe, where several different ornamental crayfish had acquired the infection, with no reports of mortality (Mrugala et al, 2015).

Occurrence in potential exporting countries

Crayfish plague has never been reported in Australia, and the country has a detailed disease strategy manual for crayfish plague, which is an integral part of the Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN) (http://www.agriculture.gov.au/animal/aquatic/aquavetplan/crayfish-plague#principles-of-control-and-eradication). The manual describes the disease control principles for use in response to a suspected or confirmed incursion of crayfish plague in Australia. Apart from the detection of crayfish plague in farmed Australian redclaw crayfish in Taiwan, there are no reports of crayfish plague in other parts of Asia. However, in the presence of introduced North American freshwater crayfish species (i.e. signal crayfish and red swamp crayfish; *Procambarus clarkii*) that are present in Asia (Hsieh et al., 2016), it cannot be excluded that redclaw crayfish acquire the infection but without developing disease at high water temperatures. It has recently been demonstrated that introduced American crayfish in Japan carry the crayfish plague pathogen (Mrugala et al, 2016); this is the first report that confirms the expected situation of introduction of crayfish plague to Asia through import of American crayfish.

Occurrence and management measures in Norway

Crayfish plague is a listed disease in Norway (list 3, national disease), and 6 locations in the central part Norway are presently declared as infected by the plague. These locations are regulated with zone legislations. The Norwegian Veterinary Institute has been commissioned by the NFSA to coordinate a surveillance programme for crayfish plague. This programme monitors the spread of the disease within the zones and the risk areas outside the zone by monitoring of water for *A. astaci* using PCR, according to Strand et al (2014).

Conclusion

Aphanomyces astaci genotype group B/Ps1 originating from signal crayfish is already found in Norway (Vrålstad et al., 2014), but is subject to official management measures. Australian redclaw crayfish could import the same or new genotype groups of *A. astaci* to new areas of Norway that are currently free from crayfish plague. Thus, *A. astaci* can be identified as a hazard within the scope of this report.

Batrachochytrium dendrobatidis

Batracochytrium dendrobatidis (*BD*) is a chytrid fungus that causes lethal chytridiomycosis in freshwater amphibian species. This disease emerged in Australia in the 1970s, and has later led to global declines and extinctions of amphibians, making *BD* one of the most devastating emerging wildlife pathogens ever known (Olson et al., 2013; Brannelly et al., 2015; Skerratt et al., 2016)). Crayfish can carry *BD*; McMahon et al. (2013) demonstrated zoosporangia of *BD* to occur within freshwater crayfish gastrointestinal tracts, and found that the prevalence of *BD* in crayfish was up to 29 % in field studies. Furthermore, the presence of crayfish in Colorado wetlands was a positive predictor of *BD* infections in sympatric amphibians. Experimental studies showed that *BD* could infect crayfish and that the infection could be maintained and transmitted to amphibians (McMahon et al. 2013). Additional studies have demonstrated a low prevalence of *BD* both in farmed and wild stocks of American freshwater crayfish species, indicating that crayfish could be an important vector in the spread of *BD* (Brannelly et al., 2015). The situation regarding the carrier status of redclaw for *BD* remains unknown. However, it is not unlikely that the same as seen in American crayfish could also apply to Australian freshwater crayfish. As *BD* first emerged in Australia, in the absence of other evidence, redclaw should be regarded as a possible carrier of the pathogen.

Occurrence in potential exporting countries

BD occurs throughout Australia and Asia, and has also reached Africa, America, and parts of Europe (http://www.bd-maps.net/). Australia prioritizes biosecurity and management measures regarding this disease, and current plans are available at http://www.environment.gov.au/biodiversity/threatened/publications/tap/infection-amphibians-chytrid-fungus-resulting-chytridiomycosis, and new measures are also in progress (Skerratt et al., 2016). However, management measures focus primarily on protection of the remaining amphibian biodiversity, and are unlikely to involve measures regarding crayfish export.

Occurrence and management measures in Norway

BD has never been identified in Norway, and is a notifiable OIE-listed disease (http://www.oie.int/animal-health-in-the-world/oie-listed-diseases-2016/). Although there is no on-going surveillance programme to demonstrate freedom from *BD* in Norway, the Norwegian Veterinary Institute offers molecular diagnostics for *BD*. The disease is not notifiable in Norway. Long distance transmission is considered to occur by means other than water, including translocation of animals during international trade, which is restricted in Norway. Outbreaks of chytridiomycosis in countries where the agent is present mainly occur during the cooler months and in high-altitude populations. Therefore, it would be expected that any outbreaks in Norway would be identified.

It is therefore unlikely that the agent is present in Norway.

Conclusion

Since *BD* infects American freshwater crayfish species and occurs widely in exporting countries, the possibility that redclaw also can act as a carrier of *BD* cannot be excluded. It is unlikely that *BD* is present in Norway. *BD* can therefore be identified as a hazard within the scope of this report.

Microsporidian crayfish parasites.

Microsporidiosis in freshwater crayfish, also referred to as cotton tail or porcelain disease, is caused by microsporidian parasites within the genera *Thelohania*, *Pleistophora*, *Ameson*, and *Vavraia* (Edgerton et al., 2002). These intracellular parasites infect muscle fibres of freshwater crayfish, and cause lethargy and opacity of the musculature systemically. There are several reports of mass mortalities of crayfish caused due to porcelain disease, but it is also common to find healthy populations with chronic infections at low prevalence (Imhoff et al., 2012). After crayfish plague, the disease is sometimes referred to as the most significant disease of freshwater crayfish globally (Edgerton et al., 2002). In particular *T. contejeani* is known to cause porcelain disease in freshwater crayfish occurring in Europe (Edgerton et al., 2002; Longshaw, 2011), while in Australia the closely related *T. parastaci* and *T. montirivulorum* are involved (Moodie et al., 2003a, b). *Vavraia parastacida* is also a microsporidian parasite that is known only from Australian crayfish, including redclaw (Edgerton et al., 2002).

Occurrence in potential exporting countries

There are reports of microsporidian parasites in Austalian crayfish that are not reported in Europe; these are: *Thelohania parastaci*, *T. montirivulorum*, and *Vavraia parastacida* (Moodie et al., 2003a, b; Edgerton et al., 2002). No specific management measures are in place against microsporidian parasites in crayfish in Australia or elsewhere.

Occurrence and management measures in Norway

Thelohania contejeani is common in Europe and probably also occurs in Norway, but no surveillance system is in place. There are no reports of *T. parastaci*, *T. montirivulorum,* or *Vavraia parastacida* in Europe or Norway. The absence of reported cases suggests that it is unlikely that these microsporidian parasites are present in Norway.

Conclusion

Thelohania parastaci, *T. montirivulorum,* and *Vavraia parastacida* occur in Australia and can infect Australian crayfish. It is unlikely that these microsporidian species are present in Norway. The limited number of reports suggests that these agents are of minor significance, but their effects on European freshwater crayfish are unknown. Limited information prevents further risk assessment, and this agent could therefore not be considered as a hazard within the scope of this report.

2.2.4 Ichthyosporean parasites in redclaw

Ichthyosporea (Mesomycetozoea or DRIPs), are fungal-like parasites associated with freshwater fish, amphibians, and crayfish (Longshaw, 2011). The most relevant species include those in the genus *Psorospermium*, in particular *P. haeckeli*.

Psorospermium spp.

At least four different morphotypes of *Psorospermium* have been described, two from Europe, one from USA, and one from Australia (Edgerton et al., 2002). Sporocysts of these parasites are found in connective tissue, muscles, and nerves of infected crayfish. Mortality is rare, but may occur in aquaria and during moulting periods (Longshaw, 2011). In general, the pathogenicity of *Psorospermium* spp. is uncertain. The *Psorospermium* morphotype that is reported from Australian crayfish, including redclaw, differs from *P. haeckeli* that is common in Europe (Edgerton et al., 2002; Longshaw, 2011).

Occurrence in potential exporting countries

There are reports of *Psorospermium* spp. in Australian crayfish that differ from the European *P. haeckeli* (Edgerton et al., 2002). There are no specific management measures in place against *Psorospermium* spp. in crayfish in Australia or elsewhere.

Occurrence and management measures in Norway

Psorospermium haeckeli is common in Europe and probably also in Norway, but no surveillance system is in place. The presence of the Australian *Psorospermium* species in Norway is unlikely.

Conclusion

Psorospermium spp. other than *P. haeckeli* infect Australian crayfish. The limited number of reports suggests that these agents are of minor significance, but their effects on European freshwater crayfish are unknown. Limited information prevents further risk assessment, and this agent could therefore not be considered as a hazard within the scope of this report.

2.2.5 Alveolates in redclaw

Among the alveolate group that has been reported to infect or colonize crayfish, are both Apicomplexan endoparasites and mostly commensal ciliates.

Apicomplexan crayfish parasites.

The phylum Apicomplexa is best known for the parasites responsible for serious human diseases such as malaria (some *Plasmodium* spp.) and *Toxoplasma gondii*, but there are also a few reports of apicomplexan parasites in crayfish (*Mantonella spp* and other coccidians). Their role in crayfish mortalities remains however unclear (Longshaw, 2011). The occurrence is mostly unknown, and no management measures are in place.

Conclusion

Due to the lack of sufficient scientific information, crayfish parasites in the phylum Apicomplexa are not considered as a hazard within the scope of this report.

Ciliates

Many ciliate genera occur on crayfish, but are normally not considered problematic in the wild and act mostly as ectosymbionts. In the order Sessilina, characterized by species that are attached permanently to the host, the genera occurring on crayfish include *Epistylis*, *Carchesium*, *Lagenophrys*, *Paralagenophrys*, *Zoothamnuim*, *Opercularia*, *Vorticella,* and *Cothurnia*. These are mostly commensals, although mortalities due to *Epistylis* have been reported under culture conditions, where it is an indicator of high organic load, low oxygen levels, and poor water quality (Longshaw, 2011). Another group of ciliates involve the *Tetrahymena pyriformis* species complex of at least 30 holotrich ciliates that occur both as free-living organisms and as opportunistic parasites of both vertebrate and invertebrate hosts (Longshaw, 2011). There is one report of heavy internal infections with *T. pyriformans* in moribund redclaw in a culture facility in North Queensland (Edgerton et al., 2002). From an import perspective, the aspects of most concern regarding ciliates of crayfish is that ciliates are filter feeders (Thurman et al., 2010) and can thus act as vectors for other pathogens from the import country. However, their occurrence is mostly unknown, and no management measures are in place.

Conclusion

Limited information prevents further risk assessment and ciliates are therefore not considered as a hazard within the scope of this report.

2.2.6 Metazoan parasites in redclaw

There are numerous groups of metazoan parasites associated with freshwater crayfish. The most important are the parasitic flatworms (Platyhelminthes), the spiny-headed worms (Acanthocephala), and roundworms (Nematoda). There are few, if any, reports on crayfish mortalities caused by these parasite groups. However, crayfish act often as intermediate hosts and therefore parasites that are associated with imported crayfish could be a threat to other animal groups or humans (Edgerton et al. 2002; Longshaw, 2011). There are also some ectocommensals and ectosymbionts reported in freshwater crayfish (Edgerton et al. 2002; Longshaw, 2011), of which only a few examples are covered here. These also represent non-indigenous hitchhikers, for which the potential consequences for Norwegian nature remain unknown.

Opecoelus variabilis (Digenea)

Digenean (flatworm) parasites have complex lifecycles, utilizing at least two different hosts. The adult stages most commonly occur in vertebrates, and the metacercarial stages may occur in crayfish. Digenean parasites have been reported in crayfish from Europe, Asia, Australia, and USA (Longshaw, 2011). Most reports are from USA, probably reflecting more studies on this topic for American crayfish. The few reports that exist for Australian crayfish involve *Opecoelus variabilis* (Opecoelidae). This is a digenean parasite that use snails as first intermediate host and the Australian crayfish, *Cherax depressus* and *C. dispar,* and other Australian freshwater crustaceans, as second intermediate hosts before developing to the adult stage in a wide range of freshwater fish (Cribb, 1985; Longshaw, 2011). Disease in crayfish has not been reported, but fish, in particular carnivorous fish species, can be heavily infected (Cribb, 1985). However, reports on fish mortalities caused by this parasite were not found.

Occurrence in potential exporting countries

Opecoelus variabilis has been reported from freshwater crayfish species of *Cherax* spp. in Queensland, Australia, but not from redclaw.

Occurrence and management measures in Norway

Opecoelus variabilis has never been identified in Norway, and there no management measures are in place.

Conclusion

Opecoelus variabilis may infect Australian crayfish, but it remains unknown whether this also applies to redclaw. The species has a broad range of freshwater fish as definitive host. Should *O. variabilis* be introduced to Norway, it could represent a hazard to freshwater fish. However, we did not find published information on mortalities due to *O. variabilis*. Limited information prevents further risk assessment, and this agent could therefore not be considered as a hazard within the scope of this report.

Polymorphus biziurae (Acanthocephala)

Acanthocephalans are obligate parasites with complex lifecycles, typically involving an invertebrate host and a vertebrate host, where the invertebrate host can be insects or crustaceans, and the vertebrate hosts can be mammals, birds, or fish. The only species of acanthocephalan reported from Australian crayfish is the larval stages of *Polymorphus biziurae* in *Cherax destructor* (Edgerton et al. 2002). Further information about this parasite is not available.

Conclusion

Limited information prevents further risk assessment, and this agent could therefore not be considered as a hazard within the scope of this report.

Diceratocephala boschmai (Temnocephalida)

Diceratocephala boschmai (Temnocephalida) is an ectosymbiont flatworm that is widely distributed on *Cherax* spp. in Australia, including redclaw (Ngamniyom et al., 2014). There are no reports of adverse effects from *D. boschmaiwhich* on these crayfish species. The first record of Australian redclaw in South Africa, additionally demonstrated that the non-indigenous crayfish also hosted the non-indigenous temnocephalan flatworm parasite, *D. boschmai* (du Preez and Smit, 2013). Both species were in full breeding condition, and further spreading of both non-indigenous species were predicted, including spread of the flatworm to other indigenous aquatic invertebrates. Transloactions of temnocephalids, including *D. boschmai*, due to introduction of redclaw have been reported from Thailand and also other countries with warm water and tropical climates (Ngamniyom et al., 2014). We did not find any reports of *D. boschmai* in Europe.

Occurrence in potential exporting countries

Diceratocephala boschmai is widely distributed on *Cherax* spp. including redclaw, in Australia, and has also reported to have been translocated, together with its redclaw host, from Australia to Asia (Thailand and Japan; Ngamniyom et al., 2014; Edgerton et al., 2002), South Africa (Swaziland; du Preez and Smit, 2013), and South America (Uruguay; Volonterio, 2009). In general, temnocephalids are mostly found in the tropics and in the southern hemisphere (Edgerton et al., 2002).

Occurrence and management measures in Norway

Diceratocephala boschmai has never been identified in Norway, and there no management measures are in place.

Conclusion

Diceratocephala boschmai infects redclaw and has been reported to have been translocated together with redclaw to several countries with warm climates. It is thus likely that redclaw could bring *D. boschmai,* and other non-indigenous trematodes, into Norway, but it is unlikely that the climate will allow establishment and reproduction. However, should successful establishment occur, the consequences cannot be predicted based on the current knowledge available.

Limited information prevents further risk assessment, and this agent was therefore not considered as a hazard within the scope of this report.

Gnathostoma spinigerum (Nematoda)

Many parasitic nematodes have complex lifecycles, often with several hosts, and with invertebrates and vertebrates acting as intermediate hosts, and vertebrates acting as definitive hosts (Longshaw, 2011). There are a few reports of nematodes from crustaceans, including the nematode *Gnathostoma spinigerum*. This is a human pathogen (foodborne zoonosis) causing gnathostomiasis, which is characterized as an emerging imported disease (Herman and Chiodini, 2009), for which the main risks for acquisition are consumption of raw or undercooked freshwater fish. The nematode has been reported in crustaceans from Japan (Miyazaki, 1954), but has not been reported from *Cherax* spp. in Australia.

Conclusion

Limited information prevents further risk assessment, and this agent was therefore not considered as a hazard within the scope of this report.

2.3 Summary of hazard identification

Based on present knowledge, four pathogenic agents are classified as a hazard within the scope of the Terms of Reference. Live redclaw may introduce these agents, and they fulfil criteria 2 and 3 of the OIE regulations:

- The agent is present in the exporting country (which for this generic risk assessment means at least one potential exporting country), and
- The agent is either

a) Absent in Norway, or
b) Present in a less virulent form, or
c) Present only in certain zones or compartments, or
d) Subject to an official control programme

The four identified hazards are:

Viruses:

- *Cherax quadricarinatus* bacilliform virus (CqBV)
- White spot syndrome virus (WSSV)

Bacteria: None

Fungi and oomycetes:

- *Aphanomyces astaci*
- *Batracochytrium dedrobaditis (BD)*

Parasites: None

It must be emphasized that several agents that could be present in redclaw could not be defined as hazards due to the lack of scientific information. These include, among others, a range of platyhelminths, nematodes, acanthocephela, ciliates, apicomplexan crayfish parasites, *Psorospermium*, microsporidian crayfish parasites, and CqPV.

Their status remains unknown, and this must be recognized when assessing the potential risks from the introduction of redclaw to Norway.

3 Risk assessment

3.1 Entry assessment of redclaw

Australian redclaw crayfish are sold in Europe, including Norway, via the ornamental trade. This trade includes not only aquaria shops, but also online shopping (i.e. offered for sale on internet trading platforms such as www.finn.no), where redclaw may be sent across Norway using postal services ("Norgespakke" in Norwegian). The current legislation allows imports of exotic crayfish for use in aquaria or when it can be demonstrated that the organism does not tolerate temperatures below 5 °C. The ornamental trade is beyond the scope of this risk assessment.

Should redclaw be introduced to Norway for aquaculture production, then the numbers of animals may increase rapidly. Entry into Norwegian waters may occur if the redclaw escape during import, from the quarantine station, from the production facility, or during live transport from these facilities to restaurants and markets where the animals are sold for consumption. Filtering and chemical treatment of effluent water will reduce the likelihood of release into the environment.

Redclaw is mainly grown in extensive outdoor ponds or enclosures, and under temperature regimes fairly similar to those occurring in its natural habitat. In Norway, a suitable temperature regime will most likely only be achieved indoors. Escape of crayfish individuals from a production facility into surrounding natural waters is considered a rare event, but as escapes have been reported from comparable large-scale production facilities (closed freshwater hatcheries for juvenile salmon and rainbow trout), this should not be considered impossible. Transport of live crayfish to other facilities and to the market is also a possible source of escape into the natural environment.

We utilize two possible scenarios in our evaluation:

Scenario 1: Redclaw aquaculture in future is limited, occurring only in a few locations with low production. In this case, the ecological risk assessment is limited in scope because escaped individuals are unlikely to enter natural streams, except in the rare events of escape locally (due to errors in redclaw handling during production or transport). Using the terminology of invasion biology literature (Catford et al., 2009), we term this scenario *low propagule pressure*.

Scenario 2: Redclaw aquaculture experiences rapid future growth in the number and geographical range of localities and in the amount of production within each production facility. In this case, escapes may occur at a number of locations and at several points in time throughout the year, and an assessment of the ecological consequences is needed, even if natural reproduction is not possible. This scenario has an analogous situation in salmonid aquaculture in Norway. Although rainbow trout (*Oncorhynchus mykiss*) have only occasionally been found to reproduce successfully in nature in Norway (Hindar et al., 1996), and are no longer deliberately released into the wild, they can still be found throughout the year in many locations because of leakage from a high number of aquaculture facilities. We term this scenario *potentially high propagule pressure*.

3.2 Temperature considerations

Redclaw is a tropical species, but has been successfully cultured in temperate as well as in tropical regions. The optimum temperature range for redclaw growth and reproduction is between 23 °C and 31 °C (Lawrence and Jones, 2002). In ponds, mortalities may occur if temperatures remain below 10 °C or above 35 °C for extended time periods. Redclaw in Israeli ponds were reported to have approximately 60 % survival over a period of 118 days when temperatures dropped below 10 °C for six days (Karplus et al., 1998). The same authors reported from reviewed literature that redclaw could survive at 3 °C for short periods of time, or at 5 °C for three weeks, but that they became immobile at 6-7 °C, and that prolonged exposure to temperatures below 10 °C was associated with high mortality.

The thermal niche of redclaw has been modelled by Larson and Olden (2012) using temperature information from the native and non-native distribution areas of redclaw. One problem with such an exercise is that information on the locations where redclaw has been introduced, is very limited. The authors therefore generated plausible distributions of this data-poor species by extrapolation from the much better known crayfish species *Pacifastacus leniusculus* and *Procambarus clarkia*, for which the thermal niches in both the native and the non-native distribution areas could be described. From this, a map of the geographical distribution of the modelled thermal niche of redclaw was generated (Figure 3.2-1). Their maps do not include any European countries (Larson and Olden, 2012).

It should also be noted that the well-documented records of established feral populations of redclaw lie either within the tropical climate zone (e.g. Costa Rica, Ecuador, and Singapore) or the subtropical temperature zone (e.g. South Africa, Mexico, Israel, New South Wales). Lake Topla in Slovenia is a geographical anomaly due to its geothermal supply of heated water.

In its natural habitat, (Northern tropical Australia and Papua New Guinea) redclaw appears to have maintained its population within the tropical zone, despite few obvious natural barriers. Feral populations (likely escapees from human activities) have been recorded in Northern New South Wales (which is within the subtropical zone)

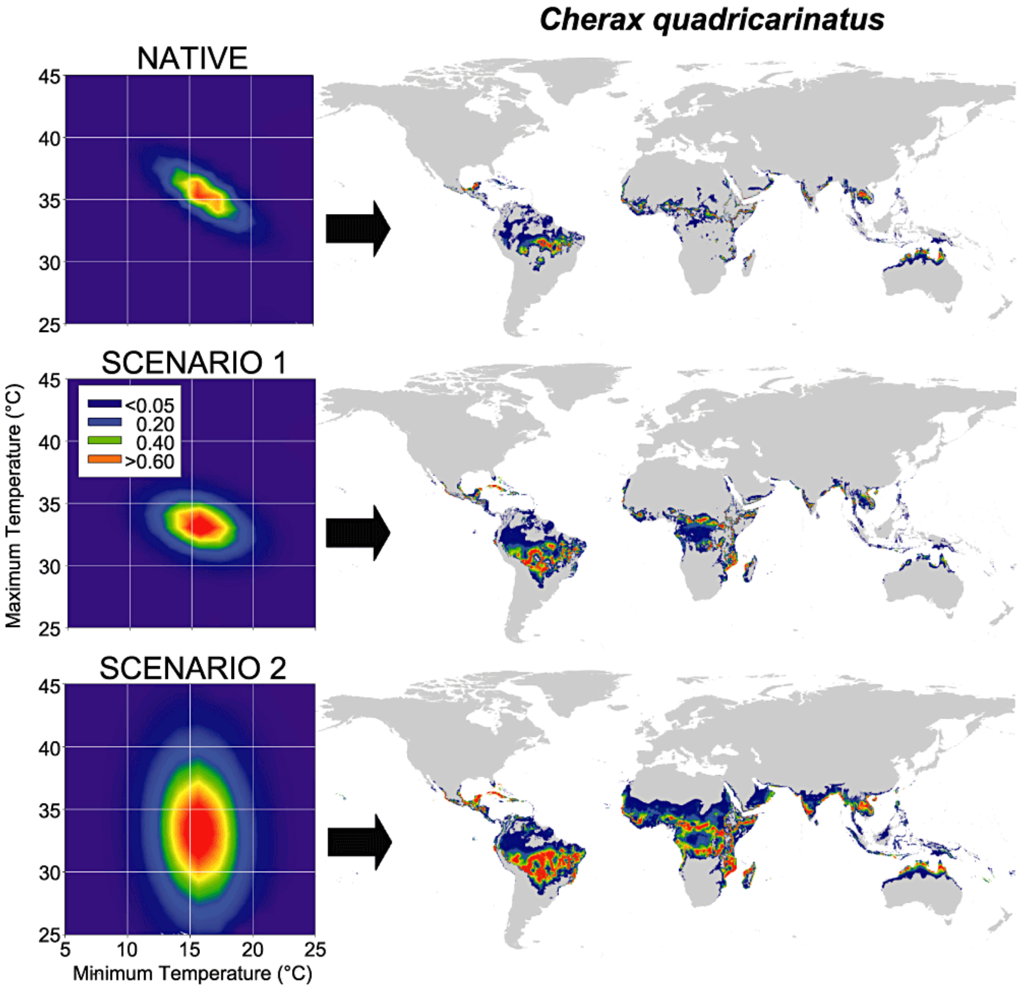


Figure 3.2-1. Geographical distribution on the thermal niche of redclaw (taken from Larson and Olden, 2012).

The temperature requirements for natural reproduction, at above 23 °C, are at the very high end of those registered in Norwegian freshwater localities. This temperature is reached only for a period of a few days or weeks in a few localities in southern Norway, and may not be reached on an annual basis.

In a future climate scenario where air temperature increases are believed to be in the range of 2 °C to 5 °C within the next 50 years, the conditions for natural reproduction are likely to be met at some locations in southern Norway. The NBIC (Sandvik et al., 2015, Table 2) suggests using the Representative Concentration Pathway (RCP) 4.5 or the RCP 8.5 greenhouse gas projections (Hanssen-Bauer et al., 2015). The numbers indicate the projected radiative forcing (W/m^2) for year 2100. Under this forcing, the summer temperatures in southeastern Norway in 2066 are suggested to experience average increases from 1.9 °C to 2.6 °C (Table 3.2-2).

Table 3.2.-2. Modelled climate change (increase in temperature, precipitation, and growing season days) from the period 1971 - 2000 and towards year 2066 under the greenhouse gas concentration trajectories RCP 4.5 (emission peak 2040 – 2050, then decline) and RCP 8.5 (business as usual). These two scenarios are recommended by the IPCC. The projections are based on an ensemble of ten different climate models. Source, including uncertainties in the projections: klimaservicesenter.no and VKM (2016).

	Annual °C	Summer °C	Winter °C	Annual ppt %	Winter ppt %	Summer ppt %	Growing season days
Norway RCP 4.5	2.2	2.0	2.5	6.7	5.6	10.5	0-60
Southern/Eastern Norway RCP 4.5	2.0	1.9	2.4	2.4/6.0	6.7/17.2	1.6/2.3	0-60*
Norway RCP 8.5	3.3	2.9	3.5	10.7	7.1	12.5	0-60
South-eastern Norway RCP 8.5	3.0	2.6	3.2	6.6/10.2	6.7/17.2	1.5/2.3	30-60

Summer= June, July, August; winter = December, January, February. *Small areas in southernmost Norway may experience up to 60 days increase.

Whereas estimates on future atmospheric temperatures can be inferred from the IPCC scenarios, the corresponding temperature regimes in running and stagnant freshwater systems (of several depths and water flux) would be quite challenging to predict accurately.

The first documented population of redclaw in Europe is from Lake Topla in Slovenia (Jaklic & Vrezec, 2011), where the first individual was found in 2009. This is a thermally-fed oxbow lake where redclaw has been found in locations up to 40 °C. Other parts of the lake may have winter temperatures down to 5 °C (January and December averages). However, the 15 specimens trapped in the lake were located in parts of the lake with temperatures between 21°C and 31 °C (Jaklic & Vrezec, 2011). Another possible establishment in the temperate region is the Sea of Galilee, Israel (Snovsky and Galil, 2011). Here a large specimen was found in January 2011. Winter temperatures in this lake are usually at or above 10 °C. Temperature ranges recorded in January and February 2015 and 2016 in the Sea of Galilee were between 10-15 °C (January 2015 daily records) and 12-18 °C (February 2016 daily records).

Statements that redclaw are unable to tolerate temperatures below 10 °C for a longer period, have been doubted in England, where it is suggested that the species is more tolerant to low temperatures (Soes & Koese 2010). Tolerance of temperatures down to 4 °C has been found in pond aquaculture (Karplus et al., 1998), and there is also a claim of a population in northern Germany (D. Holdich, pers. comm. Referred to in Soes & Koese [2010]). Other specimens found in northern European waters (England, Germany, and in Wageningen, Netherlands 2007; Soes & Koese 2010) probably represent deliberate or accidental releases from aquaria.

Kouba and colleagues (2014) reviewed the European distribution of the indigenous and non-indigenous freshwater crayfish in Europe. Apart from the non-confirmed observations mentioned above, only Lake Topla is listed as a European record of likely established redclaw.

An experimental test was recently conducted on the ability of four warm-water crayfish species to survive winter conditions in the temperate zone of Europe (Vesely et al., 2015). These authors simulated a 40-day acclimatization period, in which temperatures dropped from 25 °C to 4 °C, winter conditions with temperatures at 2-3 °C for 90 days, and spring conditions in which temperatures gradually increased from 2-3 °C to 10 °C over 60 days. Among the 15 specimens of redclaw tested, all died during the onset of winter conditions, between days 41 and 52 when the temperature declined to 2-3 °C. Feeding activity of these individuals stopped after 28 days, i.e., during the acclimatization period when temperatures were dropping (Vesely et al., 2015). It was concluded that these results indicated that redclaw does not pose a risk to the European temperate zone.

The warmest winter temperatures in Norway occur in the southern region. In the River Imsa (and The Norwegian Institute for Nature Research Ims Research Station), the temperature in the inlet water is registered daily. Recent temperature records show the following from spring 2015 to spring 2016:

- Temperatures were below 2.5 °C from 7 January to 29 January 2016.
- Temperatures were above 5 °C from 6 April 2015 to 2 January 2016, and again from 29 March 2016
- Temperatures were above 10 °C from 18 May to 16 October 2015 and again from 6 May 2016
- Temperatures were above 20 °C from 8 to 9 June and from 3 to 6 July 2015.

Winter temperatures in southeastern Norway are expected to increase from 2.4 to 3.2 °C by 2066 (Table 3.2-1). This suggests shorter winter conditions in winter-warm localities like the River Imsa. Survival of redclaw may be possible in such locations under a warmer climate, whereas in most Norwegian waters the low-temperature periods will probably be so long that survival will be very limited if any.

These current and future temperature scenarios, and *low* and *potentially high propagule pressure* scenarios, are kept in mind in the ecological risk assessment in the next two sub-chapters.

3.3 Initial screening using AS-ISK

3.3.1 Climate matching

Prior to employing the AS-ISK risk tool, an evaluation of the climate match between the redclaw's natural dispersion range and the recipient area (RA) were made using the

Australian «CLIMATCH» tool (http://data.daff.gov.au:8080/Climatch/climatch.jsp). Selecting the redclaw's natural range : (http://www.fishfiles.com.au/knowing/species/crustaceans/Pages/Redclaw.aspx), 70 stations in Northern Australia and Papua New Guinea were chosen. These were compared with 30 stations in the RA (Southern Norway up to Trondheim). The "Climatch" tool assigned class 0 score (the lowest of 10 match classes) to all sites within the RA. As the Australian tool does not have a module for temperatures within the climate change, a comparison between the climate in the natural dispersion range and southern Europe was made. The alternative RA was represented by 383 stations from the Iberian Peninsula, France (north to Bordeaux), Southern Switzerland, and Austria, Hungary, Bulgaria, Romania, The Balkans, Greece and Italy. Most of the Southern Europe stations showed a poor climatic match, with only 5 of the stations in the southernmost part of the alternative RA showing moderate climate matching (class 4 out of 10).

3.3.2 Invasion potential

High growth rates and tolerance to wide variations in water quality make redclaw suitable for cultivation (Anson and Rouse 1994). In areas where this species has been introduced, it may impact native fauna directly through direct competition, predation, or habitat modification, or indirectly by spreading previously unknown pathogens into native populations (Ahyong and Yeo, 2007). Redclaw has a rapid growth rate under favourable conditions, a life history trait that is typical of invasive species. However, as Jones (2005) noted: "It has developed abundant, self-sustaining populations in many large, man-made reservoirs and has been stocked to aquaculture developments within many catchments in which it is not native. Despite the opportunity for it to establish itself in the rivers and streams adjacent to the reservoirs or farms, there are no reports of it having done so. It would appear, that it is easily predated and/or competitively excluded to the extent that it is not able to colonise these areas. From that perspective, it can be considered a non-invasive species."

Together with the poor climatic match, these observations result in a BRA (Basic Risk Assessment) score of 2.5 for the biological, biogeographical and historical questions (see summary below).

3.3.3 Ecological effects

As the climate match (between Norway and redclaw's natural distribution range) is poor, the effects on recipient ecosystems in the RA would in general be temporary. If the aquaculture of redclaw is assumed to increase to large-scale, and it is also assumed that the farming technology/practices are not strictly monitored, repeated escapes may occur (previously called "Potentially high propagule pressure"). However, the direct effects on the recipient ecosystems are still likely to be small (given that the species, as adults, is basically a detritivore).

3.3.4 Summary

The questions and the responses are listed in Appendix II. Our screening analysis using the AS-ISK tool (Copp et al., 2015) gave a BRA score of 2,5 which is in the lower range of "medium risk" (scale from – 20 – (+)65). The CCA (climate-change adjusted) score was 12.5 which is in the upper half of "**medium risk**" ranging from ≥1 to < 19. The major contribution to the (positive) risk scores for redclaw is the species' role as host for crustacean pathogens and parasites. This is addressed in chapter 3.7.

A risk assessment has been conducted for redclaw in the Czech Republic (Patoka et al. 2014), but using the FI-ISK tool (Tricarico et al, 2010). The score derived was 14, which is in the upper range of "medium risk", ranging from ≥ 1 to < 19.

3.4 Ecological risk assessment by the NBIC-system

3.4.1 Invasion potential

Redclaw is considered an invasive alien species in the tropical region, both within Australia, and in other tropical regions outside its natural range; Mexico, Jamaica, Singapore, and South Africa. This may be related to its wide environmental tolerance (in warm-water conditions), and its natural tendency to migrate upstream.

In Norway, redclaw should be considered to show a Low invasion potential under most conditions. In the NBIC system, the invasion potential is a combined evaluation of the *population median lifetime* (in years) and the *range expansion rate* (in km/year). Alternatively, invasion potential can be evaluated from a *proportion of the colonized area* of a special habitat type (e.g., lowland freshwater lakes).

Criterion A. Population median lifetime

Under most scenarios, redclaw will not survive winter conditions in Norway, because winter temperatures, even in the winter-warm lakes and rivers of southern Norway, fall to 4 °C or lower for a considerable period during the winter. Most lakes and rivers in Norway are *dimictic* (Wetzel 1983), meaning that they circulate at 4 °C twice a year and are directly stratified in summer and inversely stratified in winter when ice covered. In these waters, surface temperatures are close to 0 °C during winter, whereas the deeper parts of lakes experience temperatures at or near 4 °C between the periods of autumn and spring circulation. Some lakes in southern Norway, or some very deep lakes, may be *warm monomictic* (Wetzel 1983), meaning that temperatures circulate at or near 4 °C during the winter and are directly stratified in summer.

Experiments and experience from aquaculture suggests that redclaw may be able to tolerate temperatures down to 2-3 °C for a period of a few days (Vesely et al., 2015), provided that the temperatures increase rapidly following the cold period. However, winter conditions in Norway last for weeks in the warmest locations and for months in most locations, meaning that much longer periods will experience temperatures that are too low for feeding activity in redclaw (Vesely et al., 2015). These considerations suggest that redclaw are unlikely to survive winter conditions in Norwegian watercourses today. Hence, the population median lifetime (should they escape) will be less than 1 year. In Figure 3.4.1-1 temperature records for a winter-warm location in southern Norway are shown (blue line) for summer 2015 to summer 2016.

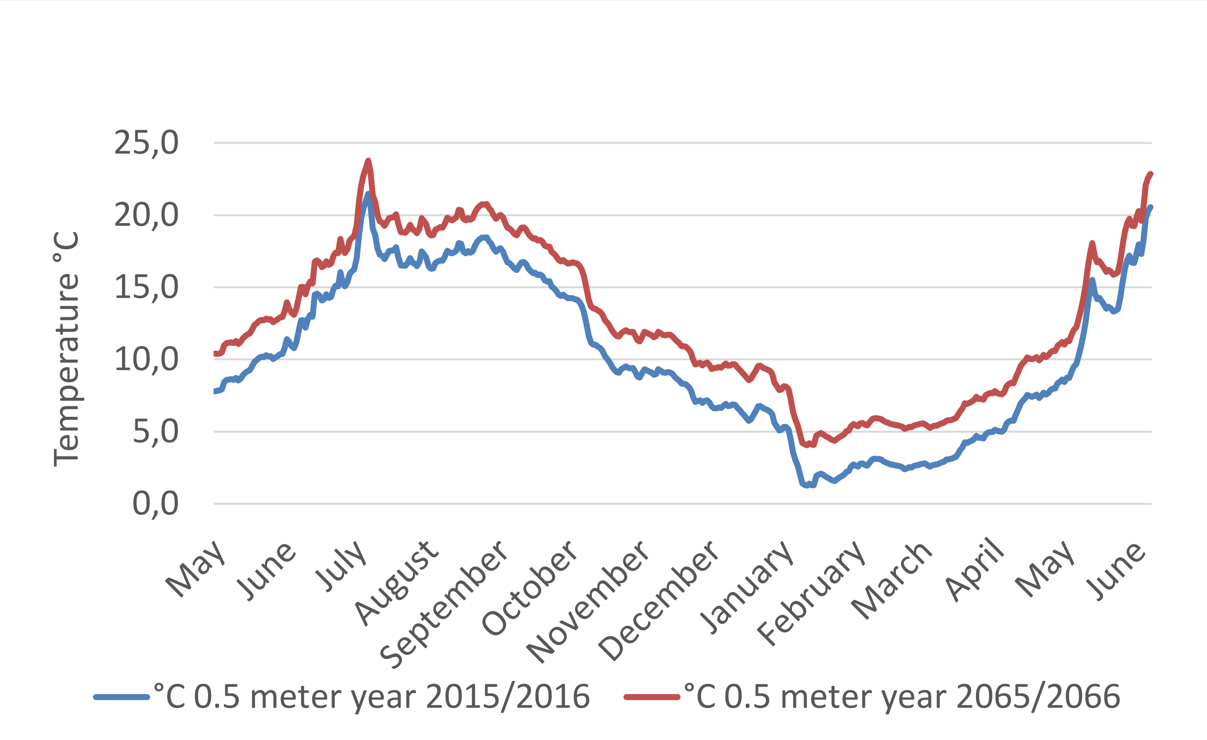


Figure 3.4.1-1. Water temperature at 0.5 metre depth at Lake Liavatnet in Rogaland County, southwestern Norway from 1 May 2015 to 6 June 2016 (blue line). A second temperature curve (orange line) represents the same temperature profile with a temperature increase at 2.3 °C during three summer months, 2.8 °C during three winter months, and an average of these during spring and autumn. These temperature increases were derived from projected temperature increases in southern Norway 50 years ahead (cf. Table 3.2-2).

The likelihood of successful reproduction of redclaw in Norwegian fresh waters is also low, because the known temperature range for reproduction in redclaw is 23 – 31 °C, which is higher than temperatures usually reached in Norwegian fresh waters. Although 23 °C is reached in some water bodies during warm summers, such temperatures usually do not last for more than days to a few weeks, which may not be long enough for egg maturation and incubation of eggs/hatchlings in redclaw. The female redclaw broods her eggs for 6-10 weeks, depending on temperature. In one experiment in which survival of hatchlings for 10 weeks was monitored, hatchling survival was zero at 15 °C (by six weeks), 33 % at 20 °C, and 83 % at 25 and 30 °C (King 1994). Furthermore, no hatchling growth was observed at 15 °C and the daily growth rate at 25 °C was more than double that which was observed at 20 °C. In another experiment, eggs did not hatch unless the temperature was above 22 °C

(King 1993). This suggests that successful reproduction in redclaw may require temperatures at or near 20 °C for several weeks.

In a future (2066) climate scenario in southern Norway, winter temperatures are expected to increase by between 2.4 and 3.2 °C, respectively, based on the RCP 4.5 and RCP 8.5 temperature projections for 2066, and summer temperatures are expected to increase by between 1.9 and 2.6 °C (Table 3.2-2). For the winter conditions, many lakes will still be *dimictic* and ice-covered during the winter (with water temperatures between 4 °C in the deep parts and 0 °C at the surface), but the time period between autumn and spring circulation will be shorter than today. These locations may still not provide high enough temperatures for redclaw survival. For some *warm monomictic* locations, however, that are not ice-covered today and for which periods at or below 4 °C are short (the Imsa watercourse being one example), a winter climate that is warmer by 2.4 to 3.2 °C may provide winter conditions in which redclaw are able to survive. Nevertheless, these conditions remain unfavourable for redclaw, so that should they survive, there will still be a winter period in which growth (and may be feeding and other activities) is unlikely. This is illustrated by the orange line in Figure 3.4.1-1.

Regarding reproduction, it seems likely that a future (2066) climate scenario in southern Norway, with summer temperatures increasing by 1.9 to 2.6 °C, may provide temperature conditions that allow reproduction of redclaw in the warmest fresh waters. This means maximum temperatures of 23 °C and a prolonged period at or near 20 °C that enables survival and growth of hatchlings. These conditions are, however, unlikely to be met in all freshwater localities in southern Norway, as those with a large part of their catchment area in the mountains usually do not experience summer temperatures near 20 °C today.

Criterion B. Expansion rate

Redclaw has a natural tendency to migrate upstream within their natural range, so, theoretically, should also be able to disperse and expand their range when introduced. The (geographical) expansion rate of redclaw that escape to the environment, will, however, be affected by their ability to survive, grow, and reproduce, so temperature considerations must also be taken into account when estimating expansion rate. Thus, in the conditions provided by Norwegian watercourses today, this expansion is likely limited to how far sub-adult and adult redclaw may disperse during the months when temperatures are 10 °C and above (given that the introduced specimens do not survive winter).

In a future climate (2066), both winter survival and reproduction may be likely in the warmest water bodies. From these, expansion may take place over one generation or more. In this case, it is possible that redclaw may disperse to utilize accessible habitats that offer the same high-temperature conditions, but be limited from expanding across rivers/lakes that belong to watercourses with colder temperatures. Spread of redclaw between watercourses may be possible where the outlet of rivers belong to the same estuaries, provided that these estuaries offer brackish conditions (0.5-10 Practical salinity units (PSU)) and not full seawater (35 PSU).

So far, only a *low propagule pressure* scenario has been considered, where expansion rate will be limited by spread to natural waters in the immediate neighbourhood of one or a few aquaculture facilities, and perhaps along transportation routes for live animals. Under the *low propagule pressure* scenario, the specimens that escape to the wild will form temporary assemblages rather than populations.

Under the *potentially high propagule pressure* scenario, the expansion rate of redclaw is determined by the growth of a successful aquaculture industry, rather than by range expansion of escaped redclaw. A widely distributed aquaculture industry may lead to escapes of redclaw from many locations and at several time points. This could be similar to several introductions taking place throughout the year, and, although each introduction might only lead to a temporary assemblage of individuals, the total effect on the environment might not be very different from a self-reproducing population of redclaw, should the number of escape events be high enough. One environmental limitation for expansion of the industry (if successful), may be access to heated water as this is necessary for efficient production of cultured redclaw.

A natural range expansion of redclaw can only be expected to take place if they survive the winter, and if summer temperatures exceed 23 °C (for reproduction). We consider this to be likely only under a future (2066) climate regime, and limited to naturally winter-warm localities in southernmost Norway. Under the *potentially high propagule pressure* scenario a future (2066) climate regime might provide conditions that could lead to a higher rate of expansion, as this could be a combination of several points of entry into the environment, and local conditions that are sufficient to allow a natural range expansion.

<u>*Criterion C. Colonised area of a particular habitat*</u>

As the expansion rate of redclaw is considered to be limited under most environmental conditions considered here, the proportional colonization of Norwegian lakes and rivers will be limited. One particular habitat, however, needs to be considered more closely. Redclaw aquaculture in Norway is unlikely to take place in locations other than those with access to considerable volumes of heated water. From these locations, effluent water will either be discharged into the sea or into fresh water, and, in the latter case, the heated water may create pockets of elevated temperatures that may allow survival, growth, and reproduction of redclaw, even where the natural environmental conditions do not.

<u>*Conclusion on invasion potential*</u>

Redclaw is considered to show a <u>Low invasion potential</u> under most environmental conditions. Current temperature conditions in Norway are unlikely to allow winter survival and reproduction to take place, so escaped individuals are likely to be present for less than one year at or near their point of entry into the environment.

Conditions for meeting the criteria that the NBIC system describes for <u>Limited invasion potential</u> or <u>Moderate invasion potential</u> are unlikely to be found in Norway, unless a successful aquaculture industry (leading to a *potentially high propagule pressure*) is accompanied by accidental releases to the environment, and this occurs in a future (2066) climate with projected temperature increases of 1.9-3.2 °C that could allow survival and reproduction of redclaw in Norwegian watercourses.

3.4.2 Ecological effect

A global meta-analysis of the ecological impacts of non-native crayfish has the following conclusion: "*The consistent and general negative effects of nonnative crayfish warrant efforts to discourage their introduction beyond native ranges*" (Twardochleb et al., 2013). This conclusion was based on findings of strong, but variable, negative ecological impacts of non-native crayfish, with consistent effects among introduced species. Non-native crayfish typically reduce the abundances of aquatic macrophytes and invertebrates, such as snails and insect larvae, and reduce the abundances and growth of amphibians and fish. Non-native crayfish tend to have larger positive effects on the growth of algae and larger negative effects on invertebrates and fish than native crayfish. The findings of direct and indirect effects of non-native crayfish on several trophic levels are consistent with the knowledge that crayfish are strong interactors in food webs, via their multi-trophic, generalist feeding habits (Twardochleb et al., 2013).

To perform their meta-analysis in a systematic way, (Twardochleb et al., (2013) included only manipulative experimental studies, and only those crayfish species that have the longest and most widespread history in invasion studies: *Procambarus clarkii*, *Pacifastacus leniusculus*, *Orconectes rusticus*, and *O. vitilis*. Thus, the strong conclusions reached in the meta-analysis are not derived from results obtained by studies of introduced redclaw (Twardochleb et al., 2013)*.* However, due to the consistent ecological results obtained from four other crayfish species, they may be relevant to extrapolate to other species, including redclaw.

Knowledge of redclaw in environments that resemble Norwegian environmental conditions is non-existent, and therefore, the general findings from such meta-analytic studies are currently our best knowledge about ecological effects. In addition, the negative effects of introduced redclaw in other environments, like in South Africa (de Preez & Smit 2013), support the general statements made in the meta-analysis.

Criterion D. Documented or likely effect on red-listed or keystone species

Crayfish are among the largest freshwater invertebrates, and are considered keystone species due to their feeding behaviour at several trophic levels. The only native freshwater crayfish in Norway, the noble crayfish, is a red-listed species. Should redclaw escape to freshwater environments where noble crayfish are present the impact of redclaw is likely to include effects on noble crayfish.

The potentially largest ecological effects of redclaw introduction to Norway are through the possibility that it can act as a vector of disease agents. In such cases, effects on the noble crayfish are a likely outcome. In addition, there is a possibility that another group of red-listed species may be affected. Signal crayfish have been shown to be a carrier of the fungus *Batrachochytrium dendrobatidis (BD),* which is implicated in the demise of several amphibian species worldwide (Berger et al., 2016). *BD* is present in amphibian populations in Australia and it is not known whether redclaw may be a carrier. If redclaw should introduce *BD* to Norway, two red-listed amphibians may be affected (*Triturus cristatus* and *Rana lessonae*).

As there is no information on interactions between redclaw and noble crayfish in Europe or elsewhere, speculations on potential ecological effects has to be based upon the general literature on crayfish introductions, and on the known effects of other introduced crayfish on the noble crayfish (Twardochleb et al., 2013, Ercoli 2014).

Given the higher growth rate of redclaw under favourable growth conditions, they are likely to outcompete noble crayfish when the water temperatures are very high, but not under most environmental conditions experienced in fresh water in Norway. Noble crayfish are likely show higher activity than redclaw under most temperature conditions, and redclaw might stop feeding and become inactive at temperatures in the range between 4-10 °C.

The most important predators of freshwater crayfish in Norway are eels (*Anguilla anguilla*) (Svärdson 1972), and probably pike (*Esox lucius*) and perch (*Perca fluviatilis*) in eastern Norway. Given a high growth rate under favourable conditions (high temperature), redclaw may be less vulnerable to fish predators than noble crayfish as they may rapidly achieve body sizes that make them less vulnerable to predation (the same may hold true if they escape at a large body size). However, under most environmental conditions in Norway, redclaw may show very little growth, and even inactivity, because of sub-optimal temperatures, and it seems probable that they will be more vulnerable to predation than the noble crayfish.

Criterion E. Documented or likely effect on other species

Juvenile redclaw feed on zooplankton, probably those occurring in the littoral zone or in drift. Adult redclaw feed on several trophic levels, but are mostly detritivores. Unless temperature conditions allow self-sustaining and relatively dense redclaw populations, their effects on the littoral zooplankton and benthic microbial communities are likely to be modest and temporary. A high number of escapes of various life stages to the environment might, in some respects, resemble the ecological effects of a self-sustaining population.

Criterion F. Documented or likely effect on rare habitat types

Should they escape, redclaw are likely to affect freshwater lakes and slow-flowing rivers that have water temperatures in the high end of that is found in Norway. Since no redclaw is known from freshwater habitats that resemble the environmental conditions in Norway, it is difficult to judge whether there are rare habitat types that are vulnerable from redclaw introductions – except those locations that have a natural temperature regime that is rare in relation to what is found in Norway.

Criterion G. Documented or likely effect on other habitats

Given favourable conditions (high temperatures), redclaw are likely to affect littoral benthic communities and both littoral and profundal soft-bottom habitats that are rich in organic matter and which, at the same time, harbour a microbial community offering good opportunities for growth. The effect of redclaw on these habitats is likely to be proportional to the number and body size of the redclaw present. Under most temperature conditions in Norway today, these effects are likely temporary.

Criterion H. Documented or likely transfer of genetic material to local species

To our knowledge, nothing is known about the possibility of interbreeding between redclaw and noble crayfish. Interbreeding between signal crayfish and noble crayfish is possible and has been reported to be detrimental for the latter. Interspecific hybrids between the two species are sterile, so when the more aggressive signal crayfish males outcompete noble crayfish males and interbreed with noble crayfish females, the noble crayfish may become locally extinct (Marren 1986).

We consider interbreeding between redclaw and noble crayfish to be much less likely than between signal crayfish and noble crayfish. First, they belong to phylogenetic groups that diverged 185 million years ago (Lodge et al. 2012), and may have developed incompatible reproductive biologies during the time of separation. Secondly, the low-end of environmental requirements for reproduction in redclaw are at the very high end of the environmental requirements for reproduction in noble crayfish (Table 1.1-1). Thus, on our opinion, there are both innate and environmental differences that mean that interbreeding between these two species is unlikely.

Criterion I. Documented or likely transfer of parasites or pathogens

Transfer of parasites or pathogens from redclaw to other organisms differs from the other potential ecological and genetic effects in one important aspect: whereas these other effects depend on redclaw escaping from aquaculture, the transfer of parasites and pathogens can occur without the escape of redclaw. Also, whereas the magnitude of ecological and genetic effects often depends on the number of specimens escaping, the magnitude of effects caused by a disease agent does not necessarily depend on the number transferred.

The transfer of parasites or pathogens is addressed in greater detail in sections 3.6 and 3.7.

Conclusion on ecological effects

In Norway, given the limited invasion potential of redclaw and the temporary nature of populations (groups of individuals) that escape to the environment, in our opinion the ecological effects listed here must be characterized in the NBIC system as Small effect for criterion D (weak and local effect on noble crayfish), and No known effect for criterion E (weak effect on other species), criterion F (unlikely effect on rare habitats) and criterion G (less than 5 % of other habitats affected). For criterion H, it is our opinion that transfer of genetic material is unlikely, for which the NBIC categorization suggests No known effect; however, the absence of experimental data should be emphasized.

In regard to criterion I (the potential spread of parasites or other disease agents), the conclusion of section 2.3 (summary of hazard identification) must be taken into account. Four pathogenic agents are identified as hazards; *Cherax quadricarinatus* bacilliform virus (CqBV), White spot syndrome virus (WSSV), *Aphanomyces astaci* and *Batracochytrium dedrobaditis (BD).* These agents are all likely to be imported with redclaw, and could have detrimental effect on native fauna, including red-listed species. The conclusion of ecological effect for criterion I is therefore: Large effect. The pathogens listed as potential hazards are further dealt with in sections 3.5 (mitigation measures), 3.6 and 3.7 (health risk assessment) and finally in chapter 4 (Answers to the NFSA terms of reference.

When combining the two-axis system for ecological risk assessment of the Norwegian Biodiversity Information Centre (Sandvik et al. 2015), the combination of a Low invasion potential and a Major effect (criterion I; the potential spread of parasites and other disease agents) leads to the risk category **Potential High risk** (PH) for importing redclaw for Norwegian aquaculture.

It is further important to note that the likelihood of transfer of a detrimental disease agent will increase under the conditions described as *potentially high propagule pressure* (expansion of the industry), and will likely be higher in a future (2066) climate than now because of the possibilities for natural spread of the animal and possibilities of stronger interactions with the natural fauna in Norway. However, even in a warmer future climate and an expansion of redclaw aquaculture (potentially high propagule pressure), there will likely still be a Low or Limited invasive potential for redclaw in Norway. In the latter situation, the risk category will change to **High risk** (HI) when combined with a Large effect (criterion I) on the effects axis.

3.5 Mitigation measures to reduce impact on biodiversity

One of the largest possible sources and vectors for pathogens from redclaw are the specimens sold for consumption (for which there is no control of location, or possible contact with waterbodies). A ban on distributing and selling live redclaw would reduce this risk considerably.

The risk from accompanying pathogens/parasites can be reduced by following quarantine procedures developed for aquaculture. ICES (The International Council for the Exploration of the Seas) has developed a "Code of Practice on the Introduction and Transfer of Marine Organisms" that may be applicable: See: https://www.nobanis.org/globalassets/ices-code-of-practice.pdf (for an overview) and http://www.ices.dk/publications/Documents/Miscellaneous%20pubs/ICES%20ITMO%20CoP%202005%20appendix%20revised.pdf (for a more elaborate outline).

Should culture of Australian redclaw be permitted, a number of risk-reducing actions could be implemented. As the temperature requirements for redclaw are quite different from the RA, the steps to avoid the introduction of pathogens with imported animals are the most important and are described in chapter 3.6. Should undetected pathogens be imported with redclaw, other measures may contribute towards reducing the overall risk. The facility may have multi-step water treatment processes (employing different technologies) to prevent animals or pathogens from escaping (e.g., ultraviolet (UV) radiation and filtration). As the main concern would be transfer of pathogens to the Norwegian noble crayfish (and, to some extent, to other crustaceans), the location of facilities may affect the risk. As reports on the survival rates for warm-water adapted pathogens in temperate conditions were not found, the self-cleaning capacity of natural running water (e.g., with regards to faecal coliform bacteria) could be a useful model. Thus: facilities could be established in areas where the noble crayfish is absent; closed water systems could be used minimizing runoff, and runoff could be channelled through the plant's own multi-step treatment system, or to a municipal chemical / biological treatment facility, or into a river system with high self-cleaning capacity. Finally, a substantial distance to the marine environment (allowing self-cleaning to operate) reduces the risk of impact on biodiversity.

3.6 Health risk assessment: general considerations

Elements which are common to all hazards are presented in this section, whereas agent-specific considerations are addressed in subsequent sections.

3.6.1 Entry assessment

Pathogenic agents (hazards) may be introduced into Norway if they are present in the export population, the consignment is imported, and there is failure to detect the hazards before the consignment is released from quarantine.

Prevalence of infection in the exporting farm

The likelihood that imported redclaw will carry pathogenic agents increases with the proportion of redclaw farms with infection (farm prevalence) at the time of export.

The real prevalence is often higher than reported prevalence due to lack of diagnosis or to under-reporting. Diseases with major clinical outcomes are relatively likely to be detected, whereas agents that cause milder symptoms may spread without the spread being recognized. Thus pathogens with low clinical impacts in an endemic country may still represent a major risk for disease-free countries.

Agents may lead to very different clinical outcomes in different species, depending on the host susceptibility and the pathogenicity of the strains/subtypes of the relevant agents. Due to lack of knowledge about the transmission of most agents between redclaw and other species, there might be a risk that agents that do not cause major clinical outcomes in redclaw may cause severe clinical outcomes in other susceptible species.

Limited data are available on the prevalence of infection with redclaw pathogens in wild or farmed redclaws, and a high level of uncertainty will usually be present.

The absence of a disease from a region is an important consideration for entry assessment. However, this assessment is generic in nature, and its scope includes import of redclaws from all countries. In order to accommodate this generic scope, the release assessment assumes that the pathogenic agents of concern are present in the source country.

Country or zone freedom from particular pathogenic agents of concern is an important risk management measure at this step.

Detection of infection in exporting farms

The likelihood that an infection remains undetected in a farm is related to the level of surveillance. The length of the incubation period, the clinical picture, the available diagnostic tools, and the awareness and knowledge of the farmer and/or authorities are also of importance. The length of the delay period between clinical examination/testing and import is of importance whenever there is a risk of introducing agents into a farm during this delay.

Likelihood that imported redclaw are infected, or the accompanying material contaminated

If an exporting farm is infected, the likelihood that a particular consignment to be imported is also infected is related to the proportion of infected individuals within the farm (intra-farm prevalence). In the absence of knowledge about intra-farm infection prevalence, the exact number of animals imported, and assuming a high likelihood of spread within a farm, it should be assumed that this likelihood is high.

Import procedures that may detect infection/contamination

Clinical examination, testing, and quarantine may identify infection in imported animals, depending on the quality and availability of diagnostic tools, and on the requirements at importation. Measures may be implemented prior to export or during quarantine. Current national regulations require a 40-day quarantine period for crustaceans, which might be insufficient to observe clinical signs of disease. In addition, some agents might not cause clinical disease, indicating the need for pathogen-specific screening.

Import conditions that may inactivate infection/contamination

This risk assessment addresses the importation of live animals. Some treatments may be used to inactivate some of the hazards. The availability of such treatments depends on various factors, including, among others, the agent.

Conclusion of the entry assessment

The conclusion of the entry assessment depends on the agent considered, and these will be discussed in agent-specific sections.

3.6.2 Exposure assessment

Existence of susceptible species in Norway

Decapoda (decapods) is an order of crustaceans, with more than 8500 species described worldwide. Most species of commercial interest in Norway are marine species (*Homarus gammarus, Nephrops norvegicus, Pandalus borealis, Paralithodes camtschaticus,* and *Cancer pagurus*). Noble crayfish (*Astacus astacus*) is the only indigenous species of freshwater crayfish in Norway, and other freshwater decapods include the brackish water shrimp *Palaemonetes varians* and the black-listed alien signal crayfish (*Pacifastacus leniusculus*). The remaining species diversity among decapods in Norway comprises approximately 35 species of marine shrimps, 30 species of marine crabs, and two indigenous species of marine lobsters.

Pathways for direct exposure to pathogens from the farm

In our opinion, the following pathways are the most important:

1. Release via water. Water may pose a high risk for spread of pathogenic agents from farm to the environment or vice versa. There are legal regulations in place in Norway regarding the pre-treatment and disinfection of water that is used for aquaculture activities (both intake and effluents) (FOR-1997-02-20-192 Forskrift om desinfeksjon av inntaksvann til og avløpsvann fra akvakulturrelatert virksomhet). Most of these treatments are based on chemical processes, UV radiation treatment, or filtration (detailed information on approved methods and agents for disinfection, and the requirements to obtain approval, are available from the Norwegian Veterinary Institute: (http://www.vetinst.no/fagområder/desinfeksjon/veileder-metoder-godkjent-for-desinfeksjon-av-vann-til-fra-akvakulturrelatert-virksomhet and http://www.vetinst.no/fagområder/desinfeksjon/veileder-orientering-om-godkjenningsordningen-for-desinfeksjonsanlegg-etter-vannbehandlingsforskriften).

Considering that, due to water temperature requirements, redclaw would always need closed, land-based production facilities, and would be considered an exotic species, the law

(FOR-1997-02-20-192) sets the following requirements regarding intake and effluents in articles 9 and 10.4, 10.6 and 10.7:

- §9 Inlet water and wastewater shall be pre-filtered through a sieving device prior to further processing. Inlet water for aquaculture should be filtered through a filter system / sieving device with pore size ≤ 0.3 mm.
- §10 (4) Section 10 (4) For wastewater from land-based aquaculture facilities that are authorized to conduct trials referred to in § 10.3 and, in addition, one or more of the following categories a) infectious agent that is listed on disease list as group A, b) exotic infectious agents, c) exotic species of aquatic organisms, and / or d) unknown disease agents, it is required that that the method should, through recognized scientific evidence under relevant experimental conditions (water quality, temperature, etc.), show a minimum of 5 $\log_{10}$ (99.999%) inactivation of infectious pancreatic necrosis virus.
- §10 (6) For wastewater from aquaculture facilities that keep imported aquatic organisms quarantined for resale to the consumer, § 10.4 applies.
- §10 (7) For wastewater from aquaculture facilities that are authorized to operate farming of exotic species of aquatic organisms, § 10.4 applies.

Furthermore the methods approved to fulfil the criteria set on §10 (4,6,7) for treatment of effluents are:

Temperature treatment of effluent water (outlet water) according to the following temperature/time combinations set-up:

80 °C for at least 4 minutes
85 °C for at least 3 minutes
90 °C for at least 2 minutes
95 °C for at least 1 minutes
100 °C for at least 30 seconds

These are described by the Norwegian Veterinary Institute (http://www.vetinst.no/fagomr%C3%A5der/desinfeksjon/veileder-metoder-godkjent-for-desinfeksjon-av-vann-til-fra-akvakulturrelatert-virksomhet). For discharge of effluent water to fresh water, a chlorine treatment should also be performed, resulting in a residual chlorine of ≥ 25 mg/l after a holding time of ≥ 30 minutes.

Based on the information available on the different agents described in Section 2 (for which the information is often limited), the correct implementation of the guidelines (combination of temperature treatment and chlorine) should prevent the direct spread of pathogens from a farm to the environment through effluent water. However, it should be noted that for many agents we do not possess detailed information regarding their temperature and chlorine susceptibilities, although it could be assumed that these might be similar to those of other viruses, bacteria, fungi, parasites etc., for which this information is known.

The likelihood that effluent water contains pathogens when released from an infected redclaw farm after correct disinfection is therefore considered **negligible**.

2. Release via live animals. The filteration of effluent waters from land-based facilities should ensure that the risk of accidental release of redclaw into the environment is minimal. Accidental defects in filter systems may, however, occur, although are considered rare. The likelihood of exposure through live animals is therefore considered to be **extremely low.**

3. Release via dead or sick animals. If dead or sick animals are not disposed of safely, pathogens may reach the aquatic environment, and thus come into contact with local crustacean species. According to regulation FOR-2008-06-17-822 (Akvakulturdriftsforskriften § 16. Slakting og håndtering av døde akvakulturdyr), dead animals must be removed daily, and kept in closed containers, without leakage to the environment. Dead fish must be minced and treated at pH below 4, but such requirements for other aquaculture species are lacking.

According to § 13. Helsekontroll og varsling, the NFSA must be warned if there is any suspicion of listed diseases or increased mortality at an aquaculture facility or farm. Identification of infection and appropriate control measures may then be implemented. However, mild diseases may not be detected and will remain undiagnosed, and regulations regarding the disposal of sick crayfish appear to be lacking.

The EC Regulation 1069/2009 lays down health rules, with regards to animal by-products and derived products not intended for human consumption (implemented by EU regulation 142/2011), and transposed into the Norwegian regulation FOR-2016-09-14-1064 (Forskrift om animalske biprodukter som ikke er beregnet på konsum –animaliebiproduktforskriften). This regulation seems to have a broader scope, in terms of the type of animal by-products that can include dead/sick animals (crustaceans not excluded) or parts of these (under Categories 2 or 3, depending on circumstances). In such cases, additional measures for the disposal of these byproducts are required.

Correct implementation of these measures may contribute for risk reduction.

The likelihood of release with sick or dead crayfish may therefore be considered as **moderate**.

4. Release via contaminated fomites. Contaminated tools that are used both inside and outside the farm without appropriate cleaning and disinfection may reach the aquatic environment, and thus come into contact with local crustacean species. According to regulation FOR-2008-06-17-822 (Akvakulturdriftsforskriften § 11.*Smittehygiene),* appropriate measures should be implemented to prevent disease spread through fomites. A list of approved agents for disinfection of materials and transport vehicles are available from the Norwegian Food Safety Authority (http://www.mattilsynet.no/fisk_og_akvakultur/akvakultur/desinfeksjon/godkjente_desinfeksjonsmidler_i_akvakultur.802). There is limited information on the susceptibility of the agents described in Chapter 2 to the approved disinfection methods, although it could be assumed that the susceptibilities of these pathogens to the approved methods might be similar to those of other viruses, bacteria, fungi, parasites etc., for which this information is known.

The incorrect implementation of such protocols may increase the risk of accidental spread, as many of the hazardous agents described have moderate to long survival capacity in a variety of fomites.

The likelihood of spread of hazards through fomites is therefore considered to be **very low**, with some uncertainty.

Overall, the likelihood that pathogens will be released from an infected farm is considered **moderate.** The following estimates were made for the likelihood of direct exposure of susceptible species to agents released from the farm, wherever there are susceptible individuals in the vicinity of the farm:

Pathway of exposure	Likelihood	Comments
1. Water	Negligible	Assuming correct implementation of disinfection measures related to farms with exotic species
2. Live animals	Extremely low	Provided that filter systems are place
3. Dead or sick redclaw	Moderate	Few requirements in regulation of waste treatment
4. Fomites	Very low	May increase if strict disinfection protocols are not followed.

Pathways and likelihood for exposure after redclaw have been sold by the farm

Live redclaw may be sold to restaurants, or for stocking private aquaria or ponds. From these places, they might be released into the aquatic environment, thus allowing for direct transmission of disease agents to local crustacean species. Even if the redclaw themselves are not released, the ambient water may be released untreated, with the associated risk of spreading infectious agents should the redclaw be infected. Given the lack of regulation and lack of knowledge about the regulation, the likelihood that redclaw will be released into the environment over time, along with any pathogenic agents that they may carry, is estimated as **high**. Illegal release of American signal crayfish has been documented six times in Norway, which provides an indication that this could happen with redclaw as well. Efficient risk communication may decrease the likelihood of such a pathway.

Dead crayfish or their remains or products, when disposed of in an environment with susceptible species, may also spread disease agents. For agents that are resistant to freezing, such as most viruses, this is also true for frozen individuals or products. The effect of heat treatment also should be assessed for each specific agent.

Conclusion on the exposure assessment

The likelihood that susceptible species will be exposed to pathogens if they are introduced into Norway with imported redclaw, is estimated as

- **Moderate** through direct exposure from the farm, if susceptible individuals are present in the vicinity of the farm. The most likely route for spread is assessed as being from the disposal of dead or sick redclaws, due to the lack of specific regulations. Effluent waters are considered to be relatively safe, providing that existing regulations related to farms with exotic species are implemented.
- **High** through indirect exposure from the farm, through the sale of live individuals or products that may be released into the environment.

For some pathogens, this estimate has a high level of uncertainty related to the lack of knowledge regarding the susceptibility of Norwegian crustaceans to these pathogens.

3.6.3 Consequence assessment

Health effects, assuming that exposure occurs, vary between hazards. Therefore, whenever possible, these are described in the pathogen-specific text in Section 3.7.

Possibility of establishment and spread in the Norwegian population

Most disease agents introduced into an aquatic environment will be able to spread locally into the water system, as has been seen with crayfish plague. The likelihood that the disease agent will establish depends on host density and susceptibility, as well as on the characteristics of the agent itself, such as its ability to replicate or reproduce at local temperatures, its survival capacity outside a host, and its impact on local host populations.

Although redclaw is unlikely to establish itself on a long-term basis in Norway, due to temperature restrictions, an occasional release, e.g., during summer months, might allow sufficient time for these animals to transmit pathogens that are harmful to the native aquatic fauna in Norway. Thus, whereas the risk of establishment of redclaw itself in Norway is assessed as being **extremely low**, the establishment and spread of pathogens introduced with imported redclaw can be considered to be **higher**. This requires specific risk assessments.

Possibilities for detection and control

The capacity of detecting spillovers of pathogens from redclaw to other aquatic organisms in Norway is limited due to three factors: firstly, the uncertainty regarding which pathogens redclaw may host (especially those that are asymptomatic in redclaw); secondly, the lack of diagnostic tools/methods to detect several of these agents; and thirdly, the reduced health control/surveillance of crustacean species in Norway, with only a single surveillance programme (for crayfish plague) in place.

Based on these three factors, it would be reasonable to assume that there is only a very limited possibility, if any, for timely detection of most of the pathogens presented in Chapter 2. Control measures for spillovers of these pathogens could also be considered to be limited and very difficult or impossible to implement.

3.7 Health risk assessment: hazard-specific considerations

The assessment presented her builds on the general considerations and conclusions from the previous section.

3.7.1 *Cherax quadricarinatus* bacilliform virus (CqBV)

3.7.1.1 Entry assessment

Prevalence of infection in exporting countries

CqBV is present in Australia, USA, Chile and Ecuador (Anderson and Prior, 1992; Edgerton and Owens, 1999; Groff et al., 1993; Hauck et al., 2001; Romero and Jiménez, 2002). The virus has never been reported in Europe. Tto our knowledge, no specific management measures are in place against this virus in Australia or elsewhere, so the exact prevalence of infected farms is unknown.

Detection of infection in exporting farms

Several studies have found high prevalence of CqBV, despite lack of clinical disease, reviewed by Saoud and colleagues (2013). Detection would therefore require testing of a sample of sufficient size and standardization of diagnostic methods for CqBV, as to our knowledge, a standardized internationally accepted method for CqBV detection is lacking. Testing is likely to detect infection, as the intra-farm prevalence is generally high.

Likelihood that imported redclaw are infected, or the accompanying material contaminated

Intra-farm prevalence can be high, as reported in several studies (Saoud et al. 2013), and thus the likelihood of importing undiagnosed CqBV-infected redclaw is elevated.

Import procedures that may detect infection/contamination

Several studies have found high prevalences of CqBV, despite lack of clinical disease (Saoud et al. 2013). It is therefore unlikely that CqBV would be detected without specific tests being conducted before or during quarantine. To our knowledge commercial screening kits for this virus are not available, and a standardized, internationally accepted method for CqBV detection is lacking.

Import conditions that may inactivate infection/contamination

There is no treatment against CqBV. Appropriate treatment of water used for/during transport may help to reduce the risk spread of CqBV.

Conclusion on the entry assessment

The likelihood of entry of CqBV with the importation of redclaw depends on the infectious status of the exporting farm. The prevalence of infected farms is unknown, so the likelihood of entry ranges from low to high when imported from an endemic country, with some uncertainty. If imported from an infected farm, the likelihood of entry of CqBV is **high,** in the absence of specific screening**.**

Risk-reducing measures include specific testing of the farm of origin and/or the consignment during quarantine, and appropriate treatment of transport/used waters.

3.7.1.2 Exposure assessment

Existence of susceptible species in Norway

To our knowledge, there have been no reports on CqBV transmission to other crustacean species, although that possibility has been raised by Hauck et al. (2001). However, there should be awareness that there is a variety of closely related bacilliform viruses, and the possibility that these are able to cross-infect closely related crustacean species (e.g., *Cancer pagerus* bacilliform virus CpBV). As redclaw has been spread to several countries without causing epidemics of CqBV in new species, we consider it unlikely that Norwegian species would react differently. The susceptibility of Norwegian species is therefore considered as very low/unlikely, but with some uncertainty due to the lack of specific studies.

Specific elements regarding exposure pathways

Exposure may occur if excreted virus or infected redclaw are released into aquatic environments. Water treatment of effluents, if performed according to the Norwegian regulations for aquaculture of exotic species, is probably sufficient to inactivate the virus. Redclaw can, however, remain infected for prolonged periods. The capacity of CqBV to survive/persist in fomites is unknown.

Conclusion of the exposure assessment

There is a **very low likelihood** that susceptible species exist in Norway. The likelihood of exposure of susceptible species outside the farm is therefore considered to be **very low, with some uncertainty**.

3.7.1.3 Consequence assessment

There are contradictory reports on the impact of this virus on redclaw, with some studies referring to a lack of mortality or clinical disease (Anderson and Prior, 1992; Romero and Jiménez, 2002) and others referring to slow growth and low mortalities, although without macroscopic lesions (Edgerton et al., 2002; Groff et al., 1993).

Direct health effects on other aquatic organisms

It is unknown if whether CqBV may exhibit different pathogenicities in other species. As redclaw has been spread to several countries without causing epidemics of CqBV in new species, we consider it unlikely that Norwegian species would react differently.

Possibility of establishment and spread in the Norwegian population

It is unknown whether the virus may infect other species in Norway. The lack of detection of CqBV in other species in other countries may be due to lack of testing, low asymptomatic transmission, or actual lack of capacity of CqBV to cross-infect other species. There is no reason to assume that a different scenario would occur in Norway and therefore the possibility of establishment and spread in the Norwegian population is assessed as being very low or unlikely (with some uncertainty).

Possibilities for detection and control

If the virus is specific to redclaw, stamping out at the farm level would eliminate the disease as redclaw is not part of the Norwegian wild fauna. Successful detection is dependent on the development of sensitive and specific methods for the detection of CqBV in redclaw, water effluents, and fomites.

Conclusion of the consequence assessment

The consequences of exposure of susceptible species are considered **minor or unlikely to be discernible**, with uncertainty related to the absence of specific studies on crustacean species present in Norway.

3.7.1.4 Risk estimation

CqBV occurs in various areas of the world, but has not been identified in other areas. It is possible that it is present, but has not been detected in the absence of high mortality or clinical symptoms.

The likelihood of entry of CqBV with redclaw imported from infected farms may be considered as high in the absence of specific screening. The likelihood of exposure of susceptible species outside the farm is considered as very low, with some uncertainty.

The likelihood of entry and exposure of susceptible species outside the farm is considered very low with some uncertainty.

The consequences of exposure are considered as minor or unlikely to be discernible, with some uncertainty related to the absence of specific studies on crustacean species present in Norway and the lack of specific diagnostic methods for CqBV.

The overall risk associated with the introduction of CqBV with imported redclaw is therefore assessed as extremely low, with some uncertainty related mainly to the susceptibility of Norwegian crustaceans to the disease being unknown, although unlikely.

3.7.2 White spot syndrome virus (WSSV)

3.7.2.1 Entry assessment

Prevalence of infection in exporting countries

WSSV is widely considered to be the most serious viral pathogen in cultured penaeid shrimps, as well as being associated with epizootic mortalities in prawn aquaculture. Following its discovery in Southeast Asia in 1992, WSSV has spread around the world and now occurs in all shrimp-growing regions, except Australia. While all decapod crustaceans are reported to be susceptible to WSSV (OIE, 2009), it was not until 2011 and 2012 that studies finally demonstrated that redclaw can be infected by, and transmit, WSSV (Soowannayan and Phanthura, 2011; Wang et al., 2012). Because WSSV has probably not been considered as a pathogen in redclaw, and its pathogenicity in this species might be less severe than in shrimps, the possibility that WSSV in present in redclaw, especially in countries where this virus is already present in other crustaceans, must be considered. Mrugala and colleagues (Mrugała et al., 2015) screened ornamental crayfish for several diseases and WSSV was identified by PCR in Australian redclaw in two different locations in Germany. However, the prevalence of WSSV in redclaw farms is mostly unknown.

Detection of infection in exporting farms

Little is known about the pathogenicity of WSSV infections in redclaw, nor about any clinical signs that it may cause. Detection would require testing a sample of sufficient size, which might be difficult to estimate given the unknown intra-farm prevalence. The possibility of persistent infections with viral loads that are so low that they are below the level of detection of diagnostic tests may further complicate the chance of detection of WSSV in farms.

Likelihood that imported redclaw are infected, or the accompanying material contaminated, given that the exporting farm is infected

If a farm is infected with WSSV, the infection can spread rapidly, even if asymptomatically. The likelihood that imported redclaw are infected may therefore be considered as high in this situation.

Import procedures that may detect infection/contamination

Studies to date have not found severe pathology in redclaw infected with WSSV. It is therefore unlikely that the agent would be detected, unless tested for specifically before or during quarantine. Detailed OIE-approved diagnostic tests and commercial kits for detection of WSSV are available. OIE lists a number of recommendations for importing live crayfish, including redclaw. The recommendations include either importing from a country or zone that has been declared free from WSSV, or implementation of a strict procedure including risk assessment, testing, quarantine, and other biosecurity measures.

Conclusion on the entry assessment

The likelihood of entry of WSSV with the importation of redclaw is difficult to estimate due to the lack of knowledge about the exact prevalence of the disease and the variability of the distribution of the agent in redclaw. If imported from an infected farm, the likelihood of entry of WSSV is **high** in the absence of additional measures. If the OIE recommendations are followed, the likelihood of entry is considered **extremely low**.

3.7.2.2 Exposure assessment.

Existence of susceptible species in Norway

All decapod crustaceans are reported to be susceptible to WSSV (OIE, 2009), and, in the absence of scientific evidence indicating otherwise, susceptible species should be considered to be widespread in Norway.

Specific elements regarding exposure pathways

Exposure may occur if excreted WSSV or infected redclaw are released into aquatic environments. Treatment of effluents, if performed according to the Norwegian regulations for aquaculture of exotic species, is probably sufficient to inactivate WSSV. Redclaw can probably remain infected for a long period as a carrier. The capacity of WSSV to persist and survive in fomites is unknown.

Conclusion of the exposure assessment

The likelihood that susceptible species will be exposed to WSSV, should this pathogen be introduced into Norway with imported redclaw and is undetected at the farm, is estimated as being:

- **Negligible** through direct exposure from the farm, in regions without decapod crustaceans.
- **Moderate** through direct exposure from the farm, in regions with decapod crustaceans. The most likely route for spread is assessed as being the disposal of dead or sick redclaws, for which specific regulations are lacking. Effluent waters are considered to be safe, provided that existing regulations related to discharge of effluents from farms with exotic species are implemented.
- **High** through indirect exposure from the farm, through the sale of live individuals or products that may be released into the environment.

3.7.2.3 Consequence assessment

Direct health effects on aquatic organisms

WSSV is widely considered to be the most serious viral pathogen in penaeid shrimp and prawn aquaculture, with rapidly developing clinical symptoms and high mortalities. Redclaw is found in several countries where WSSV has been diagnosed, but there is limited information regarding whether redclaw is, for example, in contact with known susceptible species. Freshwater crayfish, including noble crayfish, are susceptible to WSSV and show high mortalities in experimental infections, but only at water temperatures above 20 °C (Jiravanichpaisal et al., 2004). It has been suggested that crayfish might act as carriers of WSSV at low water temperatures and could develop white spot disease should the water temperature rise (Jiravanichpaisal et al., 2004). It is unknown whether WSSV may cause different pathogenicities in other species, and therefore the health effects of WSSV for several crustacean species are currently mostly unknown.

Possibility of establishment and spread in the Norwegian population

All decapod crustaceans are susceptible to WSSV (OIE, 2009), including freshwater crayfish (Bateman et al. 2012). At low water temperatures, crayfish might act as carriers of WSSV, enabling further spread of the disease (Jiravanichpaisal et al. 2004), and succumbing to the disease only when water temperature rises above 20 °C. Thus, the possibility of WSSV establishing in other crustacean species in Norway, following introduction with redclaw, is very high should this introduction occur in areas with crustacean populations.

Possibilities for detection and control

WSSV can be detected by several methods (internationally described and recognized). However, surveillance must be active, as clinical signs may not be present at low temperatures or in resistant species. Stamping out would eliminate the disease from infected farms, but when spread into the environment, this would probably not be possible and the agent would probably never be eradicated.

Conclusion of the consequence assessment

The consequences of exposure of susceptible species are assessed as being **highly significant**, as the agent could not be eradicated from the environment, and could cause significant mortalities in penaeid shrimps and prawns, both of which are important fisheries resources.

Some uncertainty remains, mainly related to the effect of water temperature. The consequences of exposure are difficult to predict for species other than shrimp and prawns due to the absence of specific studies on susceptibility to WSSV.

3.7.2.4 Risk estimation

WSSV is widely spread globally, with serious impacts on both shrimp and prawn aquaculture where it has caused mass mortalities in some areas. It has not been identified in other areas, but could have been overlooked in the absence of high mortality or clinical symptoms.

The likelihood of entry of WSSV with redclaw imported from infected farms may be considered as **high** in the absence of additional screening, and also because redclaw may act as asymptomatic carriers with WSSV below the level of detection of current diagnostic methods. The likelihood of entry is considered **extremely low** if OIE recommendations for importing live crayfish are followed.

The likelihood that susceptible species will be exposed to WSSV, should this pathogen be introduced to Norway with imported redclaw and is undetected in the farm, is estimated as being:

- **Negligible** through direct exposure from the farm, in regions without decapods crustaceans.
- **Moderate** through direct exposure from the farm, in regions with decapod crustaceans. The most likely route for spread is assessed as being the disposal of dead or sick redclaws, for which specific regulations are lacking. Effluent waters are considered to be safe, provided that existing regulations related to discharge of effluents from farms with exotic species are implemented.
- **High** through indirect exposure from the farm, through the sale of live individuals or products that may be released into the environment.

The total risk associated with introduction of WSSV through imported redclaw from an endemic country can be regarded as **high**, with some uncertainty related to the effect of WSSV on Norwegian shrimp and prawns under natural water temperature conditions.

The risk can be reduced by following OIE recommendations.

3.7.3 *Aphanomyces astaci*

3.7.3.1 Entry assessment

Prevalence of infection in exporting countries

Aphanomyces astaci is known to be present in USA, Europe, and has recently also been reported in Asia (Taiwan and Japan). It can be expected to be present in all countries where various species of American crayfish (including signal crayfish) have been introduced. In Europe, the carrier prevalence in populations of American crayfish varies from not detected to 100 %. The prevalence of *A. astaci* in redclaw farms is largely unknown. However, if present in the farm it can be expected that the pathogen will spread rapidly between individuals, and eventually result in clinical signs and mortalities.

Detection of infection in exporting farms

Cherax species, including redclaw, are regarded as susceptible species to *A. astaci*, but are reported as being more resistant than European crayfish species as the incubation period before mortalities occurs has been shown to be longer (Unestam, 1969b; Mrugala et al 2016a). Furthermore, infections may remain largely undetected at higher temperatures due to reduced pathogen virulence or infection success (Marino et al., 2014). This is of particular relevance for aquaculture of redclaw, which requires a higher water temperature than Norwegian species of crayfish. Given the presence of infection in a farm of redclaw, the likelihood of detecting the agent depends on the surveillance system in place. Screening of tank water is not usually implemented, but may increase the chance of detecting the agent in the farm.

Likelihood that imported redclaw are infected, or the accompanying material contaminated

Given that a farm is infected, the infection may spread rapidly, increasing the intra-farm prevalence. The likelihood that imported redclaw are infected when imported from an infected farm may be considered as high, unless very few individuals are imported.

Import procedures that may detect infection/contamination

OIE lists a number of recommendations for importing live crayfish of the family Parastacidae, including redclaw.

The recommendations include either importing from a country or zone declared free from crayfish plague, or implementation of a strict procedure including risk assessment, testing, quarantine, and other biosecurity measures. If these recommendations are followed, the likelihood of importing infected redclaw is assessed as being extremely low.

Conclusion on the entry assessment

The likelihood of entry of *A. astaci* with the importation of redclaw is estimated as **high** if the redclaw are imported from an infected farm.

The prevalence of *A. astaci* in redclaw farms is largely unknown, but infected farms may be expected to be detected at some point, espeically if colder periods of the year affect farm water temperatures.

If OIE recommendations are followed, the likelihood of entry is considered **extremely low**

3.7.3.2 Exposure assessment

Existence of susceptible species in Norway

Noble crayfish (*Astacus astacus*) is highly susceptible to *A. astaci* (crayfish plague), which usually eradicates almost all crayfish in an infected population (Gherardi et al., 2009; Holdich et al., 2009; Vrålstad et al, 2014). North American crayfish, including signal crayfish, carry the oomycetes asymptomatically, but its distribution is restricted as it is on the black list of introduced species, and under an eradication programme. The distribution of populations of signal crayfish and noble crayfish in Norway is described in Fig. 1.3-1.

No other crustaceans or other aquatic organisms in Norway are known to be susceptible to *A. astaci*.

Specific elements regarding exposure pathways

Infection of crayfish with *A. astaci* relies on free-living motile zoospores (~10 µm in size). This infective unit is released into the water from living or dead susceptible infected carrier crayfish. The zoospores have a limited survival period in the absence of live host crayfish. Should effluent water be treated according to the legal regulations of aquaculture facilities (Söderhäll and Cerenius, 1999) for exotic species, the zoospores will be inactivated. Pathogen spread to susceptible species can occur if infected dead/sick redclaw are discarded into the environment without sufficient disinfection, or if sale of infected live redclaw results in release of live animals or remains containing zoospores into natural aquatic crayfish habitats, in particular in the Eastern part of Norway (Fig 1.3).

Conclusion of the exposure assessment

The likelihood that susceptible species will be exposed to *A. astaci* , should this pathogen be introduced to Norway with imported redclaw, and remain undetected in the farm, is estimated as being:
- **Negligible** through direct exposure from the farm, in regions without crayfish populations.
- **Moderate** through direct exposure from the farm, in regions with crayfish populations. The most likely route for spread is assessed as being the disposal of dead or sick redclaws, for which specific regulations are lacking. Effluent waters are considered to be safe, provided that existing regulations related to discharge of effluents from farms with exotic species are implemented.
- **High** through indirect exposure from the farm, through the sale of live individuals or products that may be released into the environment.

3.7.3.3 Consequence assessment

Direct health effects on redclaw

Redclaw is considered susceptible to *A. astaci*, but research indicates that redclaw and other *Cherax* species are only moderately susceptible (Unestam, 1969; Mrugala et al., 2015; 2016a). Redclaw mortality rates can be much lower than 100 %, in particular at high water temperatures. At low water temperatures, redclaw infected with *A. astaci* may suffer up to 100 % mortalities.

Direct health effects on other aquatic organisms

A. astaci is lethal to noble crayfish, causing up to 100 % mortality if spread to a population. No other crustaceans or other aquatic organisms in Norway are known to show any symptoms following exposure to *A. astaci*.

Possibility of establishment and spread in the Norwegian population

The possibility for establishment and spread of *A. astaci* is very high in regions with noble crayfish or signal crayfish (cf. *Fig. 1.3).* In regions without established populations of freshwater crayfish, the likelihood for establishment is negligible. If introduced signal crayfish are present, then this species can become infected and serve as a permanent reservoir. So far, six populations of illegally introduced signal crayfish have been found in Norway since 2007, distributed from Brevik to Nord-Trøndelag.

Possibilities for detection and control

Possibilities for detection of *A. astaci* are very good, both in infected animals (by applying OIE-recommended methods) and in water using molecular screening. If detected in the farm, stamping out and decontamination of the farm facilities would be possible control measures.

If discovered in the wild, NFSA creates zone regulations and limits the activity and risk for further spread of the infection in the area through prohibitions and instructions. Thereafter, the infection will, in best case, “burn out” after the disease outbreak as the pathogen will die in the absence of live crayfish. The method can only be considered to be likely to be successful in the absence of signal crayfish hosts. If present, these will be able to pick up the pathogen and serve as permanent infection reservoirs. Unless chemical eradication of carrier crayfish is performed, the pathogen will then be established in the ecosystem.

Conclusion of the consequence assessment

The consequence of exposure of susceptible species to *A. astaci* is estimated to be **significant**, as it will lead to 100 % mortality in the exposed populations of noble crayfish, with a high risk of further spread. Nevertheless, the situation may be reversible, as it is limited to the freshwater environment and to only a few susceptible species.

3.7.3.4 Risk estimation

The likelihood of entry of *A. astaci* with imported redclaw is considered as **high** if redclaw are imported from an infected farm. The prevalence of redclaw farms is largely unknown in endemic areas. The likelihood of entry is considered **extremely low** if OIE recommendations for importing live crayfish are followed.

The likelihood that susceptible species will be exposed to *A. astaci* should this pathogen be introduced to Norway with imported redclaw, and remain undetected at the farm, is estimated as being:

- **Negligible** through direct exposure from the farm, in regions without crayfish populations.
- **Moderate** through direct exposure from the farm, in regions with crayfish populations. The most likely route for spread is assessed as being the disposal of dead or sick redclaws, for which specific regulations are lacking. Effluent waters are considered to be safe, provided that existing regulations related to discharge of effluence from farms with exotic species are implemented.
- **High** through indirect exposure from the farm, through the sale of live individuals or products that may be released into the environment.

The consequence of exposure of susceptible species to *A. astaci* is estimated to be **significant**, as it will lead to 100 % mortality in the exposed noble crayfish populations, with a high risk of further spread. Nevertheless, the situation may be reversible, as it is limited to the freshwater environment and to few susceptible species.

The total risk can be regarded as **high.**

Possible management measures include

1) Following OIE recommendations
2) Implementation of testing during quarantine.

3.7.4 *Batrachochytrium dendrobatidis*

3.7.4.1 Entry assessment

Prevalence of infection in exporting countries

Batrachochytrium dendrobatidis (BD) is present in amphibian populations in Africa, Asia, Australia, USA, and Europe, but not Norway. Recent findings in America have confirmed *BD* infections in American crayfish, raising the concern that American crayfish in particular, but also crayfish in general, may be carriers of this serious amphibian disease. The prevalence of *BD* in redclaw farms is unknown.

Detection of infection in exporting farms

It is not known if redclaw can act as carriers of *BD*. Given the presence of infection in a farm of redclaw, the likelihood of detecting the agent depends on the surveillance system in place. Unless specifically requested by an importing country, it is unlikely that exporting countries would screen for *BD* because it does not affect crayfish health.

Likelihood that imported redclaw are infected, or the accompanying material contaminated

Given that a farm is infected, and that redclaw can act as carriers of this pathogen, the likelihood that imported redclaw are infected may be considered as **high,** unless very few individuals are imported.

Import procedures that may detect infection/contamination

OIE has recommendations and diagnostic methods for *BD*, but the recommendations do not apply for import of live crayfish.

Unless requested from the competent authorities, it is unlikely that exporting and/or importing countries will implement procedures to substantiate the absence of *BD* in crayfish. Quarantine will not reveal *BD* infections/carrier status unless the crayfish are sacrificed and screened with specific diagnostic tests for *BD*.

Conclusion on the entry assessment

The likelihood of entry of *BD* with the import of redclaw from an infected farm is assessed as being **high, with some uncertainty**, related to the carrier status of redclaw.

The prevalence of infected redclaw farms in endemic areas is unknown. Quarantine will not reveal infection, unless crayfish are screened for *BD* with appropriate methods.

3.7.4.2 Exposure assessment

Existence of susceptible species in Norway

All amphibians in Norway can be regarded as being highly susceptible to *BD*. This includes six species: *Rana temporaria, Rana arvalis, Rana lessonae (or Pelophylax lessonae), Bufo bufo, Lissotriton vulgaris* and *Triturus cristatus,* some of which are red-listed.

Crayfish have been shown to be susceptible to *BD* and could act as healthy carriers. However, challenge experiments have shown an association of *BD* with mortality of American crayfish.

As far as we know, no other species have been shown to be susceptible to *BD* to date.

Specific elements regarding exposure pathways

Infection of amphibians with *BD* relies on free-living motile zoospores (~3-5 µm in size). This infective unit is released into the water from infected animals (crayfish or amphibians). If effluents from infected farms are treated in accordance with the Norwegian regulations for discharge of effluents from aquaculture facilities for exotic species, the zoospores will be inactivated.

Conclusion of the exposure assessment

The likelihood that susceptible species will be exposed to *BD*, should this pathogen be introduced to Norway with imported redclaw, and it remains undetected in the farm, is estimated as being:
- **Negligible** through direct exposure from the farm, in regions without susceptible

populations.
- **Moderate** through direct exposure from the farm, in regions with susceptible populations. The most likely route for spread is assessed as being the disposal of dead or sick redclaws, for which specific regulations are lacking. Effluent waters are considered to be safe, provided that existing regulations related to discharge of effluent from farms with exotic species are implemented.
- **High** through indirect exposure from the farm, through the sale of live individuals or products that may be released into the environment. The existence of healthy carriers such as crayfish increase the likelihood of exposure

3.7.4.3 Consequence assessment

Direct health effects on redclaw

There are no reports of direct health effects of *BD* on redclaw.

Direct health effects on other aquatic organisms

BD has led to global declines and extinctions of amphibians, making *BD* one of the most devastating emerging wildlife pathogens ever known. According to OIE, most, if not all, anurans (frogs) and urodeles (adult-tailed amphibians such as newts) are susceptible to *BD* infection. Morbidity and mortality varies among species, and mortality in tadpoles has not yet been reported.

BD has been associated with mortalities of American freshwater crayfish in challenge experiments. Whether the pathogen also adversely affects freshwater crayfish that are carriers of the pathogen in nature or in crayfish farms is not known,

No other aquatic organisms are known to be affected.

Possibility of establishment and spread in the Norwegian population

The possibility for establishment and spread of *BD* is very high in all aquatic environments hosting amphibians. Furthermore, freshwater crayfish may also pick up the infection and act as carriers.

Possibilities for detection and control

Possibilities for detection of *BD* are good, both in amphibians and crayfish. OIE-recommended methods are available, but these were originally validated for amphibians.

If detected in a redclaw farm, destruction and decontamination would be necessary control measures.

Detection and control in the wild is challenging. Although notifiable in OIE, this disease is no longer listed in Norway. Thus, regulations and control measures from the authorities are not in place. The consequences might be severe for amphibian wildlife in Norway.

Conclusion of the consequence assessment

BD has led to global declines and extinctions of amphibians, making *BD* one of the most devastating emerging wildlife pathogens ever known. Introduction of *BD* to Norway may have very serious consequences on amphibian populations, some of which are red-listed. Once *BD* has been introduced, eradication may be impossible. Consequences of exposure of susceptible species to *BD* are therefore considered **highly significant**.

3.7.4.4 Risk estimation

BD occurs all over Australia and Asia, and has also reached Africa, America and parts of Europe, but has still not been reported in Norway (http://www.bd-maps.net/). Amphibian species are declining at an alarming rate, with over 200 species reported as becoming extinct due to *BD*, and many more threatened with extinction. Although not yet present in Norway, the pathogen has reached Denmark; it is vital to Norwegian amphibian wildlife to avoid introduction of *BD*.

The likelihood of entry of *BD* with the importation of redclaw from an infected farm is assessed as being **high, with some uncertainty**, related to the carrier status of redclaw. The prevalence of infected redclaw farms in endemic areas is unknown. Quarantine will not reveal infection, unless crayfish are screened for *BD* with appropriate methods.

The likelihood that susceptible species will be exposed to *BD*, should the pathogen be introduced to Norway with imported redclaw, and is undetected in the farm, is estimated as being:
- **Negligible** through direct exposure from the farm, in regions without amphibians or crayfish populations.
- **Moderate** through direct exposure from the farm, in regions with amphibian or/and crayfish populations. The most likely route for spread is assessed as being the disposal of dead or sick redclaws, for which specific regulations are lacking. Effluent waters are considered to be safe, provided that existing regulations related to discharge of effluent from farms with exotic species are implemented.
- **High** through indirect exposure from the farm, through the sale of live individuals or products that may be released into the environment.

The consequence of exposure of susceptible species is **highly significant**.

The total risk can be regarded as **high.**

Possible management measures include:

1) *BD* risk assessment and screening prior to import
2) Compulsory implementation of biosecurity measures to prevent spread from live, sick, and dead animals
3) Exhaustive diagnostic surveillance during quarantine

3.8 Summary of risk assessment

- The screening method and the full risk assessment method methods require a number of non-identical questions to be answered, although the themes (e.g., for the queries) are similar. The AS-ISK screening method classified redclaw as "**medium risk**", and thus a full risk assessment was necessary.
- Based on the full risk assessment using the NBIC method, the overall risk classification of redclaw is "**potential high risk**" (scenario 1) and "**high risk**" (scenario 2/future climate with increased temperature).
- At the current climatic regime, the risk for establishment of redclaw in Norwegian ecosystems is evaluated as low. This evaluation is reached with high confidence. For future (50 years) climate projections, the AS-ISK assesses the risk for establishment of redclaw as being moderate, but this estimate is given with moderate confidence.
- Temperature was identified as a key factor in identifying ecological risks upon introducing redclaw. Redclaw requires 23 ^{o}C or higher for reproduction, which is only occasionally reached in Norway. The species cannot survive current winter temperatures in Norwegian waters.
-
- Under the conditions of the projected climate change, the chances for reproduction of redclaw will increase.
- The introduction of hitchhiker organisms with redclaw may significantly affect the health of aquatic organisms in Norway.
- Four disease-causing agents were identified as potential hazards when importing live redclaw to Norway from endemic areas. Hazard identification was not possible for a number of agents due to lack of scientific information, and the risks associated with these other agents remains unknown.
- The risk of introducing *Cherax quadricarinatus* Bacilloform Virus (CqBV) was considered as being **extremely low**, due to the likely absence of susceptible species in Norway. The risks of introducing White Spot Syndrome Virus (WSSV), the oomycete *Aphanomyces astaci* and the fungus *Batrachochytrium dendrobatidis* (*BD*) were considered as being **high**.
- The likelihood of introducing pathogenic agents with redclaw is generally difficult to assess because data on the prevalence of infection in wild or farmed redclaws are limited, and there is usually a high level of associated uncertainty. Specific screening in exporting farms and/or in quarantine or other diagnostic approaches may decrease the likelihood of entry.
- Once introduced into Norway, the most likely route of exposure of susceptible native species to the disease agents is considered to be the distribution of live or raw individuals to the market, due to the lack of regulation. The likelihood of direct

exposure from the farm through disposal of dead or sick individuals was considered as being moderate, whereas exposure through waste water was considered negligible provided that existing regulations related to discharge of effluent from farms with exotic species are followed. Ordinary wastewater treatment would be insufficient to eliminate the risk.

- The consequences of exposure of native species were considered as minor or unlikely to be discernible for CqBV, significant for *A. astaci*, and highly significant for BD and WSSV. Whereas *A. astaci* could remain local, *BD* and WSSV would probably spread widely and be impossible to eradicate.
- OIE recommendations exist for WSSV and crayfish plague, (caused by *A. astaci*) and may reduce the risk to extremely low. Specific measures need to be developed for *BD*, as OIE recommendations do not include carrier species. Possible management measures to avoid the entry of known pathogens include quarantine in both exporting and importing countries, and the use of specific screening tools if available. If introduced into a farm, the direct exposure of susceptible species from the farm will be reduced by the mandatory treatment of wastewater as described in the regulations related to discharge of effluent from farms with exotic species. Additional biosecurity measures are necessary to avoid the spread through the disposal of sick or dead animals, and through the distribution of live or raw redclaw to the market.

4 Answers to the NFSA Terms of reference

a. Which pathogens could potentially be transferred in relation to the import of red claw crayfish to Norway? What is the risk of disease outbreaks amongst Norwegian native fauna caused by such pathogens? The risk is to be assessed regardless of exporting country.

Two viruses were identified as potential hazards, *Cherax quadricarinatus* bacilloform virus (CqBV) and White Spot Syndrome Virus (WSSV), that could be translocated to Norway with the import of redclaw. For CqBV the risk of disease outbreaks in susceptible crustaceans or other aquatic species amongst Norwegian native fauna is considered extremely low, but with some uncertainty due to the absence of specific studies on the susceptibilities of the Norwegian fauna. All decapod crustaceans can be infected by WSSV. Cultured penaeid shrimps and prawns are particularly prone to developing WSD if infected, resulting in high mortalities. Freshwater crayfish species can act as carriers at lower water temperatures and may develop disease symptoms if the water temperature rises. The risk of impacting native fauna is either negligible in areas lacking decapod crustaceans, or ranging from moderate to high in areas with crustacean populations.

The oomycete *Aphanomyces astaci*, which is the agent of crayfish plague, and the fungus *Batrachochytrium dendrobatidis* (*BD*), which is the agent of amphibian chytridiomycosis, were also identified as hazards that can be introduced to Norwegian native fauna. Crayfish plague is already established in a few areas in Norway, following introduction of infected signal crayfish. However, new strains *of A. astaci* may be introduced to Norway through the import of redclaw or already existing strains may be transferred to plague-free areas. The noble crayfish is extremely susceptible to *A. astaci*, usually resulting in total extinction among entire populations. No other crustaceans or aquatic organisms in Norway are known to be susceptible to this pathogen. With regards to the noble crayfish in Norway, the risk of disease outbreaks is considered high, should redclaw be imported from an infected farm.

It is extremely important to keep track of *BD*, as it causes chytridiomycosis with alarmingly high mortality rates. Freshwater amphibian species are highly susceptible to *BD*. Freshwater crayfish can be infected and act as carriers of this pathogen, although redclaw has not been specifically tested for this carrier trait. With the exception of amphibians, no other aquatic organisms are known to be susceptible to *BD*. The risk of *BD* triggering disease outbreaks in amphibians is regarded as high.

Overall, the risk of these pathogens entering Norway and causing disease outbreaks depends on whether the exporting country/farm is infected and the availability of specific screening tools. These risks can be reduced to some extent by ensuring that OIE recommendations are followed. Details are provided in the core of this risk assessment report.

In addition, a number of agents present in redclaw could not be defined as hazards due to the lack of scientific information. These include, among others, a range of parasitic worms (platyhelminths, nematodes, and acanthocephelans), ciliates, apicomplexan crayfish parasites, *Psorospermium*, microsporidian crayfish parasites, and CqPV. The risk associated with their introduction are highly uncertain.

b. What is the risk of infection among Norwegian native fauna given that the farmed animals are set in quarantine before being released within the aquaculture facility?

The definition of quarantine adopted here is that of the World Organisation for Animal Health (formerly the Office International des Épizooties, OIE), as given in the Aquatic Animal Health Code (OIE, 2006a):

"Quarantine means maintaining a group of aquatic animals in isolation with no direct or indirect contact with other aquatic animals, in order to undergo observation for a specified length of time and, if appropriate, testing and treatment, including proper treatment of the effluent waters."

Norwegian law describes several requirements and timeframes for quarantine of aquatic animals in Norway. Quarantine of aquatic animals is used to minimize the risk of introducing potential pathogens. Quarantine will not exclude the risk of introduction. This is especially true for pathogens with an asymptomatic carrier status in the imported species. Quarantine will not reveal unknown pathogens that are being carried asymptomatically in the introduced animal species and that might lead to new emerging diseases in specific groups of aquatic animals. Likewise, quarantine might not reveal pathogens that may require long periods of incubation before clinical signs of disease are observed. The likelihood of detecting a potential pathogen can be increased by: co-cultivation with susceptible species (sentinel species), increased quarantine time period, cultivation at optimum conditions for disease manifestation in susceptible species, and increased sensitivity of the detection method, including analysis of theholding water for pathogens. Thus, it is not possible to specify a general risk level.

c. What is the risk of infection for Norwegian native fauna stemming from the import of Australian red claw given that the crayfish is released into aquaculture facilities that:

i. Filter and drain the wastewater through a public wastewater facility.

Apart from preventing redclaw from escaping, filtering and draining wastewater through public facilities has little effect regarding inactivation of viruses and fungi. More precautionary measures, such as use of heat and chemical treatment of water, are necessary to reduce the risk of infection. Use of recirculating systems with minimal wastewater, which, in turn, is subject to disinfection procedures, is thus recommended.

In addition, there will be a risk of spread through other pathways of exposure, such as the sale of live or raw animals, the disposal of dead and sick redclaw, and the use of contaminated tools outside the farm.

ii. Fulfils the requirements for disinfecting intake water and effluent water stated by the regulation relating to cleaning and disinfection of intake water to, and effluent water from aquaculture-related operations.

Given that redclaw is an exotic species preferring higher temperatures, we assume that the putative aquaculture facility is a closed, land-based recirculating system. Should adequate disinfection procedures be followed, the likelihood that pathogens will be released from or introduced to a farm through water inlet/outlet is assessed as being negligible. Other pathways of exposure, such as the sale of live or raw animals, the disposal of dead and sick redclaw, and the use of contaminated tools outside the farm, increases the risk of infection to native fauna.

d. In addition to the measures stated in c, are there further measures that may reduce the risk of infection or are there methods for treating the wastewater of an aquaculture facility, that may be better suited to reducing the risk of pathogen transfer to native fauna stemming from the import of Australian red claw?

The risk can theoretically be reduced by minimizing the likelihood that agents are introduced into the facility, are spread from the facility, and/or reach susceptible species. Once susceptible species are infected, the impact can be reduced by implementing a rapid control programme.

The following measures are suggested:

- Ensure that OIE recommendations for import are followed.
- Use closed recirculating systems with minimal wastewater.
- Treat wastewater according to the regulationss for farming of exotic species.
- Prohibit, sale of live or raw individual animals and ensure secured transport of live or raw individual animals.
- Implement strict biosecurity measures regarding the disposal of dead or sick individual animals.
- Implement strict biosecurity measures regarding fomites.
- Implement regulations on exotic species.
- Increased awareness and surveillance in aquaculture facilities and in zones at risk of exposure to introduced pathogens; sentinel species may be part of the surveillance system.

5 Answers to the NEA Terms of reference

a. The Norwegian Environment Agency requests the Norwegian Scientific Committee for Food Safety (VKM) to undertake an assessment of the risks of adverse impacts on biodiversity in Norway stemming from the import and keeping of Australian red claw crayfish (*Cherax quadricarinatus*) for aquaculture purposes. Possible risks caused by the introduction of harmful "hitchhiker organisms" should be included in the assessment.

The Australian redclaw crayfish is a tropical species with a temperature requirement for reproduction at or above 23°C. This is rarely met in Norwegian freshwater habitats today. The sparse scientific information indicates that although the species may survive shorter periods (from days to a few weeks) at temperatures below 5 °C, it will not survive prolonged periods of low temperatures as occurs during Norwegian winter. With the possible exception of heated plumes from industrial activities and a few winter-warm localities in southern Norway, it is unlikely that all the species' temperature requirements (annual (for growth), summer (for reproduction), and winter (for survival)) will be met in Norwegian freshwater systems within a 50-year's perspective.

Escaped redclaw in natural waters will be temporary assemblages in most cases, without any establishment. The ecological impact of the species itself will therefore largely be determined by the number and timing of individuals escaping from aquaculture facilities. A meta-analysis of alien crayfish species by Twardochleb and colleagues (2013) suggest that they generally have strong, but variable, negative ecological impacts. This experimentally-based knowledge does not include studies of redclaw, and features of their biology suggest that they may have smaller impacts than alien crayfish in general.

The temperature requirements for natural reproduction of redclaw at above 23 °C is at the very high end of the temperatures that are currently registered in Norwegian freshwater localities. This temperature is reached only for a period of a few days or weeks in a few localities in southern Norway, and may not be reached on an annual basis. The likelihood of reproduction, and thus establishment, of the redclaw in Norwegian ecosystems is therefore assessed as being low.

There is, however, a risk of introducing harmful hitchhiking organisms via the import of redclaw to Norway. The potential impacts of these pathogenic agents and risk of such impacts occurring are addressed in chapter 3.7. In short, the viruses *Cherax quadricarinatus* bacilloform virus (CqBV) and White Spot Syndrome Virus (WSSV) could both cause disease in native crustaceans. *Aphanomyces astaci* is the agent of crayfish plague, and while this disease is already present in Norway, new strains of *A. astaci* may be introduced. In addition, the plague may spread to new and plague-free areas. Such events may have detrimental effects on the red-listed noble crayfish. *Batrachochytrium dendrobatidis* (*BD*), is the agent of amphibian chytridiomycosis and could have detrimental effects on native amphibians, included the two red-listed amphibian species (*Triturus cristatus* and *Rana lessonae*).

Based on the NBIC method and taking into account the possible introduction of harmful hitchhiking organisms, the conclusions of the ecological risk assessments are:

Scenario 1 low propagule pressure: Potentiallyl high impact (PH) = (Low invasion potential*Major effect) is considered the most appropriate (best) risk category under environmental conditions, as well as under a future climate (projected to 2066).

Scenario 2 high propagule pressure: Potentially high impact PH = (Low invasion potential*Major effect) is considered the best risk category under current environmental conditions, whereas there may be a possibility that under a future climate (projected to 2066) the invasion potential could increase to Limited invasion potential, which would then lead to a **High risk** (HI) category.

b. VKM should consider whether precautionary measures, such as quarantine and/or treatment of wastewater from aquaculture related activities, would influence on the risk of adverse impacts on biodiversity. In addition, VKM should consider whether there are other measures that could be carried out to reduce the risk.

Redclaw may reach Norwegian waters should they escape during import, from the quarantine station, from the production facility, or during live transport from these facilities to restaurants and markets where the animals are sold for consumption.

Importing specimens from certified disease-free stocks /areas will lower the risks of a stealth import of pathogens. Holding imported specimen in a quarantine facility will both enable further evaluation of the disease-free status claim, and reduce the risks of inadvertently releasing pathogens into Norwegian water systems. A quarantine regime in which only the offspring of the imported specimen are allowed for production will reduce the risk of stealth horizontal infections.

Treatment of effluent water from the production facility by physical (e.g. filtering, UV irradiation, or temperature) or chemical (e.g. chlorine, ozone, or hydrogen peroxide) measures will reduce the probability of release of animals or pathogens into the environment. However, UV -irradiation is ineffective at killing pathogenic agents such as *A. astaci* and *BD*. Modern, high-performance UV -irradiation techniques may be more efficient as a treatment against most pathogenic microorganisms, although these have not been tested against *A. astaci* or against *BD* (Jones et al, 2014; Berger and Speare, 2004 and http://www.water-research.net/index.php/water-treatment/water-disinfection/uv-disinfection).

Using a closed on-growth system with low water effluent flux, the effluent treatment will be more efficient than for an open system (for which large water flow will depend on access to heated water). In the latter type of production facility, warm water plumes facilitating possible survival may occur around the facility.

Geographical restriction of where production units are sited could lower the risk for both release of the species (in a future warmer climate) and infection opportunities for associated pathogens.

c. The timeframe for the risk assessment of adverse impacts on biodiversity should be 50 years or 5 generations for organisms with a generation time of more than 10 years.

Although the temperature requirements for reproduction of redclaw may be met in some localities (occasionally, but probabøy not regularly) in a 50-year perspective, permanent establishment of the species also requires that the minimum temperature during winter is within the species survival requirements. Translating the climate forcing of the various IPCC scenarios into water temperatures in all freshwater bodies to which the species may have accesses is challenging. Based on the observation that the distribution of redclaw is restricted to the tropical and subtropical zones, both in its natural range (where it has had opportunity to spread during its evolutionary course) and in the known feral populations, the risk that redclaw will be able to establish reproductive populations within a 50-year perspective is assessed as being small.

6 Conclusions

- Redclaw is unlikely to become established in Norway under current environmental conditions. Temperature was identified as a key factor in identifying ecological risks from the introduction of redclaw. Redclaw requires water temperatures of 23 °C or higher for reproduction which are only occasionally reached in Norway. The species cannot survive current winter temperatures in Norwegian waters. The ecological risks following introduction of redclaw are therefore more likely to be related to the hitchhiker organisms associated with the imports, than the ecological effects of redclaw itself.
- Under the projected conditions of climate change, natural reproduction of redclaw may become possible in some locations in Norway, but winter survival is still unlikely in most locations, except in artificially heated effluents and in a small number of winter-warm locations, although probably not on a regular basis. Projected temperature increases will however, extend the period of survival for redclaw specimens, should they escape to the wild.
- An unknown assembly of hitchhiker organisms might be associate with the import of redclaw. If these are unintentionally transferred to natural environments, they may significantly affect the health of aquatic organisms in Norway.
- Four disease-causing agents were identified as potential hazards associated with importing live redclaw to Norway from endemic areas. Hazard identification was not possible for a number of agents due to lack of scientific information, and the risks associated with these agents remains unknown.
- The risk of introducing *Cherax quadricarinatus* Bacilloform Virus (CqBV) was assessed as being **extremely low**, due to probable absence of susceptible species in Norway. The risks of introducing White Spot Syndrome Virus (WSSV), the oomycete *Aphanomyces astaci* and the fungus *Batracochytrium dedrobaditis* (*BD*) were assessed as being **high**.
- The likelihood of introducing pathogenic agents with redclaw is in general difficult to assess because data on the prevalence of infection in wild or farmed redclaw are limited, and there is usually a high level of uncertainty. Specific screening in exporting farms and/or in quarantine or use of other diagnostic approaches may decrease the likelihood of entry.
- Once introduced into Norway, the most likely route of exposure of susceptible native species to the disease agents is assessed as being the distribution of live or raw individuals to the market, due to the lack of regulation. The likelihood of direct exposure from the farm through disposal of dead or sick individuals was assessed as being moderate, whereas exposure through wastewater was considered negligible provided that existing regulations related to discharge of effluent from farms with exotic species are followed. Ordinary wastewater treatment would be insufficient to eliminate eliminate the risk.

- The consequences of exposure of native species were assessed as being minor or unlikely to be discernible for CqBV, significant for *A. astaci*, and highly significant for *BD* and WSSV. Whereas *A. astaci* could remain local, *BD* and WSSV would probably spread widely and be impossible to eradicate.
- OIE recommendations for WSSV and crayfish plague are available, and their implementation may reduce the risk to extremely low. Specific measures need to be developed for *BD*, as OIE recommendations do not include carrier species. Possible management measures to avoid the entry of known pathogens include quarantine in both exporting and importing countries, and the use of specific screening tools if available. If introduced into a farm, the direct exposure of susceptible species from the farm will be reduced by ensuring that existing regulations related to discharge of effluent from farms with exotic species are followed. Additional biosecurity measures are necessary to avoid the spread through the disposal of sick or dead animals, and through the distribution of live or raw redclaw to the market.

7 Uncertainties and data gaps

An assessment of introducing redclaw to Norway meets challenges at several levels of biological inquiry.

- Ecological experiments involving redclaw reproduction, growth and survival in temperate environments are very scarce. The majority of studies are from aquaculture operations in tropical and sub-tropical conditions, and the most informative experiment with respect to redclaw survival in European winters was based on a single set of 15 individuals and one temperature regime (Vesely et al. 2015).
- To our knowledge, no experiments have been conducted on the reproductive and ecological interactions between redclaw and the only native crayfish in Norway, the noble crayfish.
- Information about the position of *C. quadricarinatus* in the food web of natural ecosystems is scarce and little is yet known about its possible negative impact on the environment, as well as on human activities and health.
- The survival, dispersal and infective status of some of the identified pathogens in Norwegian climate, water quality and fauna are not well studied. This applies from freshwater to seawater.
- We are invited to predict effects in a future climate, as well as under current environmental conditions.

These challenges make it difficult to make informed predictions of the consequences of introducing redclaw into Norway for aquacultural production.

However, freshwater crayfish are, in general a well-studied group of animals. The extent of biological knowledge of a large number of species is good, and the consequences of introducing crayfish species to new environments has been studied for a large number of species and environmental combinations. Recent meta-analyses suggest that some patterns of interactions are general across species and environments, and makes quite clear predictions about the likely consequences for novel combinations of species (Twardochleb et al. 2013). Finally, the noble crayfish is a well-studied species in Norway and in neighbouring countries, and also knowledge about the effects from introducing another crayfish species (the signal crayfish) is extensive.

Based on available information in literature, there are also a number of uncertainties and data gaps related to health risks:

- The infection status (depending on the situation).
- The prevalence of infection in potential exporting countries.
- The extent to which other aquatic organisms are susceptible to the relevant pathogens, in particular CqBV and BD.

- There may be more pathogenic agents that are potential hazards, but the lack of scientific knowledge prevents further risk assessment. More studies are needed.
- Quarantine time is insufficient and/or screening tools are not specific enough for detection in time.
- Clinical symptoms are masked or less severe in infected redclaw, creating a false sense of proper management procedures.

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Appendix I

Aliens Species Invasiveness Screening Kit (AS-ISK)

A. Biogeography / Historical	
1. Domestication/Cultivation	
1	Has the taxon been the subject of domestication (or cultivation) for at least 20 generations?
2	Is the taxon harvested in the wild and likely to be sold or used in its live form?
3	Does the taxon have invasive races, varieties, sub-taxa or congeners?
2. Climate, distribution and introduction risk	
4	How similar are the climatic conditions of the RA area and the taxon's native range?
5	What is the quality of the climate matching data?
6	Is the taxon already present outside of captivity in the RA area?
7	How many potential pathways could the taxon use to enter in the RA area?
8	Is the taxon currently found in close proximity to, and likely to enter into, the RA area in the near future (e.g. unintentional and intentional introductions)?
3. Invasive elsewhere	
9	Has the taxon become naturalised (established viable populations) outside its native range?
10	In the taxon's introduced range, are there known adverse impacts to wild stocks or commercial taxa?
11	In the taxon's introduced range, are there known adverse impacts to aquaculture?
12	In the taxon's introduced range, are there known adverse impacts to ecosystem services?
13	In the taxon's introduced range, are there known adverse socio-economic impacts?
B. Biology / Ecology	
4. Undesirable (or persistence) traits	
14	Is it likely that the taxon will be poisonous or pose other risks to human health?

15	Is it likely that the taxon will smother one or more native taxa (that are not threatened or protected)?
16	Are there threatened or protected taxa that the non-native taxon would parasitise in the RA area?
17	Is the taxon adaptable in terms of climatic and other environmental conditions, thus enhancing its potential persistence if it has invaded or could invade the RA area?
18	Is the taxon likely to disrupt food-web structure/function in aquatic ecosystems it has or is likely to invade in the RA area?
19	Is the taxon likely to exert adverse impacts on ecosystem services in the RA area?
20	Is it likely that the taxon will host, and/or act as a vector for, recognised pests and infectious agents that are endemic in the RA area?
21	Is it likely that the taxon will host, and/or act as a vector for, recognised pests and infectious agents that are absent from (novel to) the RA area?
22	Is it likely that the taxon will achieve a body size that will make it more likely to be released from captivity?
23	Is the taxon capable of sustaining itself in a range of water velocity conditions (e.g. versatile in habitat use)?
24	Is it likely that the taxon's mode of existence (e.g. excretion of by-products) or behaviours (e.g. feeding) will reduce habitat quality for native taxa?
25	Is the taxon likely to maintain a viable population even when present in low densities (or persisting in adverse conditions by way of a dormant form)?
5. Resource exploitation	
26	Is the taxon likely to consume threatened or protected native taxa in RA area?
27	Is the taxon likely to sequester food resources (including nutrients) to the detriment of native taxa in the RA area?
6. Reproduction	
28	Is the taxon likely to exhibit parental care and/or to reduce age-at-maturity in response to environmental conditions?
29	Is the taxon likely to produce viable gametes or propagules (in the RA area)?
30	Is the taxon likely to hybridize naturally with native taxa?
31	Is the taxon likely to be hermaphroditic or to display asexual reproduction?
32	Is the taxon dependent on the presence of another taxon (or specific habitat features) to complete its life cycle?
33	Is the taxon known (or likely) to produce a large number of propagules or offspring within a short time span (e.g. <1 year)?

34	How many time units (days, months, years) does the taxon require to reach the age-at-first-reproduction? [In the Justification field, indicate the relevant time unit being used.]
7. Dispersal mechanisms	
35	How many potential internal pathways could the taxon use to disperse within the RA area (with suitable habitats nearby)?
36	Will any of these pathways bring the taxon in close proximity to one or more protected areas (e.g. MCZ, MPA, SSSI)?
37	Does the taxon have a means of actively attaching itself to hard substrata (e.g. ship hulls, pilings, buoys) such that it enhances the likelihood of dispersal?
38	Is natural dispersal of the taxon likely to occur as eggs (for animals) or as propagules (for plants: seeds, spores) in the RA area?
39	Is natural dispersal of the taxon likely to occur as larvae/juveniles (for animals) or as fragments/seedlings (for plants) in the RA area?
40	Are older life stages of the taxon likely to migrate in the RA area for reproduction?
41	Are propagules or eggs of the taxon likely to be dispersed in the RA area by other animals?
42	Is dispersal of the taxon along any of the pathways mentioned in the previous seven questions (7.01–7.07; i.e. both unintentional or intentional) likely to be rapid?
43	Is dispersal of the taxon density dependent?
8. Tolerance attributes	
44	Is the taxon able to withstand being out of water for extended periods (e.g. minimum of one or more hours) at some stage of its life cycle?
45	Is the taxon tolerant of a wide range of water quality conditions relevant to that taxon? [In the Justification field, indicate the relevant water quality variable(s) being considered.]
46	Can the taxon be controlled or eradicated in the wild with chemical, biological, or other agents/means?
47	Is the taxon likely to tolerate or benefit from environmental/human disturbance?
48	Is the taxon able to tolerate salinity levels that are higher or lower than those found in its usual environment?
49	Are there effective natural enemies (predators) of the taxon present in the RA area?
C. Climate change	
9. Climate change	
50	Under the predicted future climatic conditions, are the risks of entry into the RA area posed by the taxon likely to increase, decrease or not change?
51	Under the predicted future climatic conditions, are the risks of establishment posed by the taxon likely to increase, decrease or not change?

52	Under the predicted future climatic conditions, are the risks of dispersal within the RA area posed by the taxon likely to increase, decrease or not change?
53	Under the predicted future climatic conditions, what is the likely magnitude of future potential impacts on biodiversity and/or ecological integrity/status?
54	Under the predicted future climatic conditions, what is the likely magnitude of future potential impacts on ecosystem structure and/or function?
55	Under the predicted future climatic conditions, what is the likely magnitude of future potential impacts on ecosystem services/socio-economic factors?

Appendix II

SECTION 9.

DISEASES OF CRUSTACEANS

CHAPTER 9.1.

CRAYFISH PLAGUE

(*APHANOMYCES ASTACI*)

Article 9.1.1.

For the purposes of the *Aquatic Code*, crayfish plague means *infection* with *Aphanomyces astaci* Schikora. This organism is a member of a group commonly known as the water moulds (the *Oomycetida*). Common synonyms are listed in the corresponding chapter of the *Aquatic Manual*.

Information on methods for *diagnosis* are provided in the *Aquatic Manual*.

Article 9.1.2.

Scope

The recommendations in this chapter apply to all species of crayfish in all three crayfish families (*Cambaridae*, *Astacidae* and *Parastacidae*). These recommendations also apply to any other *susceptible species* referred to in the *Aquatic Manual* when traded internationally.

Article 9.1.3.

Importation or transit of aquatic animals and aquatic animal products for any purpose regardless of the crayfish plague status of the exporting country, zone or compartment

1) *Competent Authorities* should not require any conditions related to crayfish plague, regardless of the crayfish plague status of the *exporting country*, *zone* or *compartment*, when authorising the importation or transit of the following *aquatic animal products* from the species referred to in Article 9.1.2. which are intended for any purpose and which comply with Article 5.4.1.:

a) heat sterilised hermetically sealed crayfish products (i.e. a heat treatment at 121°C for at least 3.6 minutes or any time/temperature equivalent);

b) cooked crayfish products that have been subjected to heat treatment at 100°C for at least one minute (or any time/temperature equivalent which has been demonstrated to inactivate *A. astaci*);

c) pasteurised crayfish products that have been subjected to heat treatment at 90°C for at least ten minutes (or any time/temperature equivalent which has been demonstrated to inactivate *A. astaci*);

d) frozen crayfish products that have been subjected to minus 20°C or lower temperatures for at least 72 hours;

e) crayfish oil;

f) crayfish *meal*;

g) chemically extracted chitin.

2) When authorising the importation or transit of *aquatic animals* and *aquatic animal products* of a species referred to in Article 9.1.2., other than those referred to in point 1 of Article 9.1.3., *Competent Authorities* should require the conditions prescribed in Articles 9.1.7. to 9.1.11. relevant to the crayfish plague status of the *exporting country*, *zone* or *compartment*.

3) When considering the importation or transit of *aquatic animals* and *aquatic animal products* of a species not covered in Article 9.1.2. but which could reasonably be expected to pose a *risk* of spread of crayfish plague, the *Competent Authority* should conduct a *risk analysis* in accordance with the recommendations in Chapter 2.1. The *Competent Authority* of the *exporting country* should be informed of the outcome of this assessment.

Article 9.1.4.

Country free from crayfish plague

If a country shares a *zone* with one or more other countries, it can only make a *self-declaration of freedom* from crayfish plague if all the areas covered by the shared water bodies are declared countries or *zones* free from crayfish plague (see Article 9.1.5.).

As described in Article 1.4.6., a country may make a *self-declaration of freedom* from crayfish plague if:

1) none of the *susceptible species* referred to in Article 9.1.2. are present and *basic biosecurity conditions* have been

continuously met for at least the last two years;

OR

2) any of the *susceptible species* referred to in Article 9.1.2. are present and the following conditions have been met:

> *a)* there has been no observed occurrence of the *disease* for at least the last 25 years despite conditions that are conducive to its clinical expression (as described in the corresponding chapter of the *Aquatic Manual*); and
>
> *b) basic biosecurity conditions* have been continuously met for at least the last 10 years;

OR

3) the disease status prior to *targeted surveillance* is unknown but the following conditions have been met:

> *a) basic biosecurity conditions* have been continuously met for at least the last five years; and
>
> *b) targeted surveillance*, as described in Chapter 1.4., has been in place for at least the last five years without detection of crayfish plague;

OR

4) it previously made a *self-declaration of freedom* from crayfish plague and subsequently lost its *disease* free status due to the detection of crayfish plague but the following conditions have been met:

> *a)* on detection of the *disease*, the affected area was declared an *infected zone* and a *protection zone* was established; and
>
> *b)* infected populations have been destroyed or removed from the *infected zone* by means that minimise the *risk* of further spread of the *disease*, and the appropriate *disinfection* procedures (as described in Chapter 4.3.) have been completed; and
>
> *c)* previously existing *basic biosecurity conditions* have been reviewed and modified as necessary and have continuously been in place since eradication of the *disease*; and
>
> *d) targeted surveillance*, as described in Chapter 1.4., has been in place for at least the last five years without detection of crayfish plague.

In the meantime, part or all of the non-affected area may be declared a free *zone* provided that such a part meets the conditions in point 3 of Article 9.1.5.

Article 9.1.5.

Zone or compartment free from crayfish plague

If a *zone* or *compartment* extends over more than one country, it can only be declared a *zone* or *compartment* free from crayfish plague if all the relevant *Competent Authorities* confirm that all relevant conditions have been met. As described in Article 1.4.6., a *zone* or *compartment* within the *territory* of one or more countries not declared free from crayfish plague may be declared free by the *Competent Authority(ies)* of the country(ies) concerned if:

1) none of the *susceptible species* referred to in Article 9.1.2. are present in the *zone* or *compartment* and *basic biosecurity conditions* have been continuously met for at least the last two years;

OR

2) any of the *susceptible species* referred to in Article 9.1.2. are present in the *zone* or *compartment* and the following conditions have been met:

> *a)* there has not been any observed occurrence of the *disease* for at least the last 25 years despite conditions that are conducive to its clinical expression (as described in the corresponding chapter of the *Aquatic Manual*); and
>
> *b) basic biosecurity conditions* have been continuously met for at least the last 10 years;

OR

3) the disease status prior to *targeted surveillance* is unknown but the following conditions have been met:

> *a) basic biosecurity conditions* have been continuously met for at least the last five years; and
>
> *b) targeted surveillance*, as described in Chapter 1.4., has been in place, in the *zone* or *compartment*, for at least the last five years without detection of crayfish plague;

OR

4) it previously made a *self-declaration of freedom* for a *zone* from crayfish plague and subsequently lost its *disease* free status due to the detection of crayfish plague in the *zone* but the following conditions have been met:

a) on detection of the *disease*, the affected area was declared an *infected zone* and a *protection zone* was established; and

b) infected populations have been destroyed or removed from the *infected zone* by means that minimise the *risk* of further spread of the *disease*, and the appropriate *disinfection* procedures (as described in Chapter 4.3.) have been completed; and

c) previously existing *basic biosecurity conditions* have been reviewed and modified as necessary and have continuously been in place since eradication of the *disease*; and

d) targeted surveillance, as described in Chapter 1.4., has been in place for at least the last five years without detection of crayfish plague.

Article 9.1.6.

Maintenance of free status

A country, *zone* or *compartment* that is declared free from crayfish plague following the provisions of points 1 or 2 of Articles 9.1.4. or 9.1.5. (as relevant) may maintain its status as free from crayfish plague provided that *basic biosecurity conditions* are continuously maintained.

A country, *zone* or *compartment* that is declared free from crayfish plague following the provisions of point 3 of Articles 9.1.4. or 9.1.5. (as relevant) may discontinue *targeted surveillance* and maintain its status as free from crayfish plague provided that conditions that are conducive to clinical expression of crayfish plague, as described in the corresponding chapter of the *Aquatic Manual*, exist, and *basic biosecurity conditions* are continuously maintained.

However, for declared free *zones* or *compartments* in infected countries and in all cases where conditions are not conducive to clinical expression of crayfish plague, *targeted surveillance* needs to be continued at a level determined by the *Aquatic Animal Health Service* on the basis of the likelihood of *infection*.

Article 9.1.7.

Importation of aquatic animals and aquatic animal products from a country, zone or compartment declared free from crayfish plague

When importing *aquatic animals* and *aquatic animal products* of species referred to in Article 9.1.2. from a country, *zone* or *compartment* declared free from crayfish plague, the

Competent Authority of the *importing country* should require that the consignment be accompanied by an *international aquatic animal health certificate* issued by the *Competent Authority* of the *exporting country* or a *certifying official* approved by the *importing country* certifying that, on the basis of the procedures described in Articles 9.1.4. or 9.1.5. (as applicable) and 9.1.6., the place of production of the *aquatic animals* and *aquatic animal products* is a country, *zone* or *compartment* declared free from crayfish plague.

The *certificate* should be in accordance with the Model Certificate in Chapter 5.11.

This Article does not apply to *commodities* listed in point 1 of Article 9.1.3.

Article 9.1.8.

Importation of live aquatic animals for aquaculture from a country, zone or compartment not declared free from crayfish plague

1) When importing, for *aquaculture*, live *aquatic animals* of species referred to in Article 9.1.2. from a country, *zone* or *compartment* not declared free from crayfish plague, the *Competent Authority* of the *importing country* should assess the *risk* and, if justified, apply the following *risk* mitigation measures:

a) the direct delivery to and lifelong holding of the consignment in biosecure facilities for continuous isolation from the local environment; and

b) the treatment of water used in transport and of all effluent and waste materials in a manner that ensures inactivation of *A. astaci*.

2) If the intention of the introduction is the establishment of a new stock, relevant aspects of the Code of Practice on the Introductions and Transfers of Marine Organisms of the International Council for the Exploration of the Seas (ICES) should be considered.

3) For the purposes of the *Aquatic Code*, relevant aspects of the ICES Code (full version see:

http://www.ices.dk/publications/our-publications/Pages/Miscellaneous.aspx) may be summarised to the following points:

a) identify stock of interest (cultured or wild) in its current location;

b) evaluate stock health and disease history;

c) take and test samples for *A. astaci*, pests and general health/disease status;

d) import of a founder (F-0) population and quarantine in a secure facility;

e) produce F-1 generation from the F-0 stock in *quarantine*;

f) culture F-1 stock and at critical times in its development (life cycle) sample and test for *A. astaci* and perform general examinations for pests and general health/disease status;

g) if *A. astaci* is not detected, pests are not present, and the general health/disease status of the stock is considered to meet the *basic biosecurity conditions* of the *importing country*, *zone* or *compartment*, the F-1 stock may be defined as crayfish plague free or specific pathogen free (SPF) for *A. astaci*;

h) release SPF F-1 stock from *quarantine* for *aquaculture* or stocking purposes in the country, *zone* or *compartment*.

4) With respect to point 3 *e)*, *quarantine* conditions should be conducive to multiplication of the pathogen and eventually to clinical expression. If *quarantine* conditions are not suitable for pathogen multiplication and development, the recommended diagnostic approach might not be sensitive enough to detect low *infection* level.

This Article does not apply to *aquatic animals* listed in point 1 of Article 9.1.3.

Article 9.1.9.

Importation of aquatic animals and aquatic animal products for processing for human consumption from a country,

zone or compartment not declared free from crayfish plague

When importing, for processing for human consumption, *aquatic animals* or *aquatic animal products* of species referred to in Article 9.1.2. from a country, *zone* or *compartment* not declared free from crayfish plague, the *Competent Authority* of the *importing country* should assess the *risk* and, if justified, require that:

1) the consignment is delivered directly to and held in *quarantine* or containment facilities until processing into one of the products referred to in point 1 of Article 9.1.3., or products described in point 1 of Article 9.1.11., or other products authorised by the *Competent Authority*; and

2) water used in transport and all effluent and waste materials from the processing are treated in a manner that ensures inactivation of *A. astaci* or is disposed in a manner that prevents contact of waste with *susceptible species*. For these *commodities* Member Countries may wish to consider introducing internal measures to address the *risks* associated with the *commodity* being used for any purpose other than for human consumption.

Article 9.1.10.

Importation of live aquatic animals intended for use in animal feed, or for agricultural, industrial or pharmaceutical use, from a country, zone or compartment not declared free from crayfish plague

When importing, for use in animal *feed* or for agricultural, industrial or pharmaceutical use, live *aquatic animals* of species referred to in Article 9.1.2. from a country, *zone* or *compartment* not declared free from crayfish plague, the *Competent Authority* of the *importing country* should require that:

1) the consignment is delivered directly to, and held in, *quarantine* facilities for slaughter and processing into products authorised by the *Competent Authority*; and

2) water used in transport and all effluent and waste materials from the processing are treated in a manner that ensures inactivation of *A. astaci*.

This Article does not apply to *commodities* referred to in point 1 of Article 9.1.3.

Article 9.1.11.

Importation of aquatic animals and aquatic animal products for retail trade for human consumption from a country, zone or compartment not declared free from crayfish plague

1) *Competent Authorities* should not require any conditions related to crayfish plague, regardless of the crayfish plague status of the *exporting country*, *zone* or *compartment*, when authorising the importation or transit of the following *commodities* which have been prepared and packaged for retail trade and which comply with Article 5.4.2.:

– no *commodities* listed.

2) When importing *aquatic animals* or *aquatic animal products*, other than those referred to in point 1 above, of species referred to in Article 9.1.2. from a country, *zone* or *compartment* not declared free from crayfish plague, the *Competent Authority* of the *importing country* should assess the *risk* and apply appropriate *risk* mitigation measures.

CHAPTER 9.2.

INFECTION WITH YELLOW HEAD VIRUS GENOTYPE 1

Article 9.2.1.

For the purposes of the *Aquatic Code*, infection with yellow head virus genotype 1 means *infection* with yellow head virus genotype 1 (YHV1) of the Genus *Okavirus* in the Family *Roniviridae* and the Order *Nidovirales*.

Information on methods for *diagnosis* are provided in the *Aquatic Manual*.

Article 9.2.2.

Scope

The recommendations in this chapter apply to the following *susceptible species* which meet the criteria for listing species as susceptible in Chapter 1.5.: giant tiger prawn *(Penaeus monodon)*, white leg shrimp *(Penaeus vannamei)*, blue shrimp *(Penaeus stylirostris)*, dagger blade grass shrimp *(Palaemonetes pugio)* and Jinga shrimp *(Metapenaeus affinis)*.

Article 9.2.3.

Importation or transit of aquatic animals and aquatic animal products for any purpose regardless of the infection with YHV1 status of the exporting country, zone or compartment

1) *Competent Authorities* should not require any conditions related to infection with YHV1, regardless of the infection with YHV1 status of the *exporting country*, *zone* or *compartment*, when authorising the importation or transit of the following *aquatic animal products* from the species referred to in Article 9.2.2. which are intended for any purpose and which comply with Article 5.4.1.:

a) heat sterilised hermetically sealed crustacean products (i.e. a heat treatment at 121°C for at least 3.6 minutes or equivalent);

b) cooked crustacean products that have been subjected to heat treatment at 60°C for at least 15 minutes (or any time/temperature equivalent which has been demonstrated to inactivate YHV1);

c) pasteurised crustacean products that have been subjected to heat treatment at 90°C for at least ten minutes (or any time/temperature equivalent which has been demonstrated to inactivate YHV1);

d) crustacean oil;

e) crustacean *meal*;

f) chemically extracted chitin.

2) When authorising the importation or transit of *aquatic animals* and *aquatic animal products* of a species referred to in Article 9.2.2., other than those referred to in point 1 of Article 9.2.3., *Competent Authorities* should require the conditions prescribed in Articles 9.2.7. to 9.2.11. relevant to the infection with YHV1 status of the *exporting country*, *zone* or *compartment*.

3) When considering the importation or transit of *aquatic animals* and *aquatic animal products* of a species not covered in Article 9.2.2. but which could reasonably be expected to pose a *risk* of infection with YHV1, the *Competent Authority* should conduct a *risk analysis* in accordance with the recommendations in Chapter 2.1. The *Competent Authority* of the *exporting country* should be informed of the outcome of this assessment.

Article 9.2.4.

Country free from infection with yellow head virus genotype 1

If a country shares a *zone* with one or more other countries, it can only make a *self-declaration of freedom* from infection with YHV1 if all the areas covered by the shared water bodies are declared countries or *zones* free from infection with YHV1 (see Article 9.2.5.).

As described in Article 1.4.6., a country may make a *self-declaration of freedom* from infection with YHV1 if:

1) none of the *susceptible species* referred to in Article 9.2.2. are present and *basic biosecurity conditions* have been continuously met for at least the last two years;

OR

2) any of the *susceptible species* referred to in Article 9.2.2. are present and the following conditions have been met:

a) there has been no observed occurrence of the *disease* for at least the last ten years despite conditions that are conducive to its clinical expression, as described in the corresponding chapter of the *Aquatic Manual*; and

b) basic biosecurity conditions have been continuously met for at least the last two years;

OR

3) the disease status prior to *targeted surveillance* is unknown but the following conditions have been met:

a) basic biosecurity conditions have been continuously met for at least the last two years; and

b) targeted surveillance, as described in Chapter 1.4., has been in place for at least the last two years without detection of infection with YHV1;

OR

4) it previously made a *self-declaration of freedom* from infection with YHV1 and subsequently lost its *disease* free status due to the detection of infection with YHV1 but the following conditions have been met:

a) on detection of the *disease*, the affected area was declared an *infected zone* and a *protection zone* was established; and

b) infected populations have been destroyed or removed from the *infected zone* by means that minimise the likelihood of further spread of the *disease*, and the appropriate *disinfection* procedures (as described in Chapter 4.3.) have been completed; and

c) previously existing *basic biosecurity conditions* have been reviewed and modified as necessary and have continuously been in place since eradication of the *disease*; and

d) targeted surveillance, as described in Chapter 1.4., has been in place for at least the last two years without detection of infection with YHV1.

In the meantime, part or all of the non-affected area may be declared a free *zone* provided that such a part meets the conditions in point 3 of Article 9.2.5.

Article 9.2.5.

Zone or compartment free from infection with yellow head virus genotype 1

If a *zone* or *compartment* extends over more than one country, it can only be declared a *zone* or *compartment* free from infection with YHV1 if all the relevant *Competent Authorities* confirm that all relevant conditions have been met.

As described in Article 1.4.6., a *zone* or *compartment* within the *territory* of one or more countries not declared free from infection with YHV1 may be declared free by the *Competent Authority* of the country concerned if:

1) none of the *susceptible species* referred to in Article 9.2.2. are present in the *zone* or *compartment* and *basic biosecurity conditions* have been continuously met for at least the last two years;

OR

2) any of the *susceptible species* referred to in Article 9.2.2. are present in the *zone* or *compartment* and the following conditions have been met:

> *a)* there has not been any observed occurrence of the *disease* for at least the last ten years despite conditions that are conducive to its clinical expression (as described in the corresponding chapter of the *Aquatic Manual*); and
>
> *b) basic biosecurity conditions* have been continuously met for at least the last two years;

OR

3) the disease status prior to *targeted surveillance* is unknown but the following conditions have been met:

> *a) basic biosecurity conditions* have been continuously met for at least the last two years; and
>
> *b) targeted surveillance*, as described in Chapter 1.4., has been in place, in the *zone* or *compartment*, for at least the last two years without detection of infection with YHV1;

OR

4) it previously made a *self-declaration of freedom* from infection with YHV1 for a *zone* and subsequently lost its disease status due to the detection of infection with YHV1 in the *zone* but the following conditions have been met:

> *a)* on detection of the *disease*, the affected area was declared an *infected zone* and a *protection zone* was established; and
>
> *b)* infected populations have been destroyed or removed from the *infected zone* by means that minimise the likelihood of further spread of the *disease*, and the

appropriate *disinfection* procedures (as described in Chapter 4.3.) have been completed; and

c) previously existing *basic biosecurity conditions* have been reviewed and modified as necessary and have continuously been in place since eradication of the *disease*; and

d) targeted surveillance, as described in Chapter 1.4., has been in place for at least the last two years without detection of infection with YHV1.

Article 9.2.6.

Maintenance of free status

A country, *zone* or *compartment* that is declared free from infection with YHV1 following the provisions of points 1 or 2 of Articles 9.2.4. or 9.2.5. (as relevant) may maintain its status as free from infection with YHV1 provided that *basic biosecurity conditions* are continuously maintained.

A country, *zone* or *compartment* that is declared free from infection with YHV1 following the provisions of point 3 of Articles 9.2.4. or 9.2.5. (as relevant) may discontinue *targeted surveillance* and maintain its status as free from infection with YHV1 provided that conditions that are conducive to clinical expression of infection with YHV1, as described in the corresponding chapter of the *Aquatic Manual*, exist, and *basic biosecurity conditions* are continuously maintained.

However, for declared free *zones* or *compartments* in infected countries and in all cases where conditions are not conducive to clinical expression of infection with YHV1, *targeted surveillance* needs to be continued at a level determined by the *Aquatic Animal Health Service* on the basis of the likelihood of *infection*.

Article 9.2.7.

Importation of aquatic animals and aquatic animal products from a country, zone or compartment declared free from infection with yellow head virus genotype 1

When importing *aquatic animals* and *aquatic animal products* of species referred to in Article 9.2.2. from a country, *zone* or *compartment* declared free from infection with YHV1, the *Competent Authority* of the *importing country* should require that the consignment be accompanied by an *international aquatic animal health certificate* issued by the *Competent*

Authority of the *exporting country* or a *certifying official* approved by the *importing country* certifying that, on the basis of the procedures described in Articles 9.2.4. or 9.2.5. (as applicable) and 9.2.6., the place of production of the *aquatic animals* and *aquatic animal products* is a country, *zone* or *compartment* declared free from infection with YHV1.

The *certificate* should be in accordance with the Model Certificate in Chapter 5.11.

This Article does not apply to *commodities* listed in point 1 of Article 9.2.3.

Article 9.2.8.

Importation of live aquatic animals for aquaculture from a country, zone or compartment not declared free from infection with yellow head virus genotype 1

1) When importing, for *aquaculture*, live *aquatic animals* of species referred to in Article 9.2.2. from a country, *zone* or *compartment* not declared free from infection with YHV1, the *Competent Authority* of the *importing country* should assess the *risk* and, if justified, apply the following *risk* mitigation measures:

a) the direct delivery to and lifelong holding of the consignment in biosecure facilities for continuous isolation from the local environment; and

b) the treatment of water used in transport and all effluent and waste materials in a manner that ensures inactivation of YHV1.

2) If the intention of the introduction is the establishment of a new stock, relevant aspects of the Code of Practice on the Introductions and Transfers of Marine Organisms of the International Council for the Exploration of the Seas (ICES) should be considered.

3) For the purposes of the *Aquatic Code*, relevant aspects of the ICES Code (full version see: http://www.ices.dk/publications/our-publications/Pages/Miscellaneous.aspx) may be summarised to the following points:

a) identify stock of interest (cultured or wild) in its current location;

b) evaluate stock health and disease history;

c) take and test samples for YHV1, pests and general health/disease status;

d) import of a founder (F-0) population and quarantine in a secure facility;

e) produce F-1 generation from the F-0 stock in *quarantine*;

f) culture F-1 stock and at critical times in its development (life cycle) sample and test for YHV1 and perform general examinations for pests and general health/disease status;

g) if YHV1 is not detected, pests are not present, and the general health/disease status of the stock is considered to meet the *basic biosecurity conditions* of the *importing country*, *zone* or *compartment*, the F-1 stock may be defined as free from infection with YHV1 or specific pathogen free (SPF) for infection with YHV1;

h) release SPF F-1 stock from *quarantine* for *aquaculture* or stocking purposes in the country, *zone* or *compartment*.

4) With respect to point 3 *e)*, *quarantine* conditions should be conducive to multiplication of the pathogen and eventually to clinical expression. If *quarantine* conditions are not suitable for pathogen multiplication and development, the recommended diagnostic approach might not be sensitive enough to detect low *infection* level.

This Article does not apply to *aquatic animals* listed in point 1 of Article 9.2.3.

Article 9.2.9.

Importation of aquatic animals and aquatic animal products for processing for human consumption from a country, zone or compartment not declared free from infection with yellow head virus genotype 1

When importing, for processing for human consumption, *aquatic animals* or *aquatic animal products* of species referred to in Article 9.2.2. from a country, *zone* or *compartment* not declared free from infection with YHV1, the *Competent Authority* of the *importing country* should assess the *risk* and, if justified, require that:

1) the consignment is delivered directly to and held in *quarantine* or containment facilities until processing into one of the products referred to in point 1 of Article 9.2.3., or products described in point 1 of Article 9.2.11., or other products authorised by the *Competent Authority*; and

2) water used in transport and all effluent and waste materials from the processing are treated in a manner that ensures inactivation of YHV1 or is disposed in a manner that prevents contact of waste with *susceptible species*.

For these *commodities* Member Countries may wish to consider introducing internal measures to address the *risks* associated with the *commodity* being used for any purpose other than for human consumption.

Article 9.2.10.

Importation of live aquatic animals intended for use in animal feed, or for agricultural, industrial or pharmaceutical use, from a country, zone or compartment not declared free from infection with yellow head virus genotype 1

When importing, for use in animal *feed* or for agricultural, industrial or pharmaceutical use, live *aquatic animals* of species referred to in Article 9.2.2. from a country, *zone* or *compartment* not declared free from infection with YHV1, the *Competent Authority* of the *importing country* should require that:

1) the consignment is delivered directly to, and held in, *quarantine* facilities for slaughter and processing into products authorised by the *Competent Authority*; and

2) water used in transport and all effluent and waste materials from the processing are treated in a manner that ensures inactivation of YHV1.

This Article does not apply to *commodities* referred to in point 1 of Article 9.2.3.

Article 9.2.11.

Importation of aquatic animals and aquatic animal products for retail trade for human consumption from a country, zone or compartment not declared free from infection with yellow head virus genotype 1

1) *Competent Authorities* should not require any conditions related to infection with YHV1, regardless of the infection with YHV1 status of the *exporting country*, *zone* or *compartment*, when authorising the importation or transit of frozen peeled shrimp or decapod crustacea (shell off, head off) which have been prepared and packaged for retail trade and which comply with Article 5.4.2.

Certain assumptions have been made in assessing the safety of the *aquatic animal products* mentioned above. Member Countries should refer to these assumptions at Article 5.4.2. and consider whether the assumptions apply to their conditions.

For these *commodities* Member Countries may wish to consider introducing internal measures to address the *risks* associated with the *commodity* being used for any purpose other than for human consumption.

2) When importing *aquatic animals* or *aquatic animal products*, other than those referred to in point 1 above, of species referred to in Article 9.2.2. from a country, *zone* or *compartment* not declared free from infection with YHV1, the *Competent Authority* of the *importing country* should assess the *risk* and apply appropriate *risk* mitigation measures.

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CHAPTER 9.7.

WHITESPOT DISEASE

Article 9.7.1.

For the purposes of the *Aquatic Code*, white spot disease (WSD) means *infection* with white spot syndrome virus (WSSV). White spot syndrome virus 1 is classified as a species in the genus *Whispovirus* of the family *Nimaviridae*. Common synonyms are listed in the corresponding chapter of the *Aquatic Manual*.

Information on methods for *diagnosis* are provided in the *Aquatic Manual*.

Article 9.7.2.

Scope

The recommendations in this chapter apply to all decapod (order *Decapoda*) crustaceans from marine, brackish and freshwater sources. These recommendations also apply to any other *susceptible species* referred to in the *Aquatic Manual* when traded internationally.

For the purposes of this chapter, the terms shrimp and prawn are used interchangeably.

Article 9.7.3.

Importation or transit of aquatic animals and aquatic animal products for any purpose regardless of the white spot disease status of the exporting country, zone or compartment

1) *Competent Authorities* should not require any conditions related to WSD, regardless of the WSD status of the *exporting country*, *zone* or *compartment*, when authorising the importation or transit of the following *aquatic animal products* from the species referred to in Article 9.7.2. which are intended for any purpose and which comply with Article 5.4.1.:

a) heat sterilised hermetically sealed crustacean products (i.e. a heat treatment at 121°C for at least 3.6 minutes or any time/temperature equivalent);

b) cooked crustacean products that have been subjected to heat treatment at 60°C for at least one minute (or any time/temperature equivalent which has been demonstrated to inactivate WSSV);

c) pasteurised crustacean products that have been subjected to heat treatment at 90°C for at least ten minutes (or any time/temperature equivalent which has been demonstrated to inactivate WSSV);

d) crustacean oil;

e) crustacean *meal*;

f) chemically extracted chitin.

2) When authorising the importation or transit of *aquatic animals* and *aquatic animal products* of a species referred to in Article 9.7.2., other than those referred to in point 1 of Article 9.7.3., *Competent Authorities* should require the conditions prescribed in Articles 9.7.7. to 9.7.11. relevant to the WSD status of the *exporting country*, *zone* or *compartment*.

3) When considering the importation or transit of *aquatic animals* and *aquatic animal products* of a species not covered in Article 9.7.2. but which could reasonably be expected to pose a *risk* of spread of WSD, the *Competent Authority* should conduct a *risk analysis* in accordance with the recommendations in Chapter 2.1. The *Competent Authority* of the *exporting country* should be informed of the outcome of this assessment.

Article 9.7.4.

Country free from white spot disease

If a country shares a *zone* with one or more other countries, it can only make a *self-declaration of freedom* from WSD if all the areas covered by the shared water bodies are declared countries or *zones* free from WSD (see Article 9.7.5.).

As described in Article 1.4.6., a country may make a *self-declaration of freedom* from WSD if:

1) none of the *susceptible species* referred to in Article 9.7.2. are present and *basic biosecurity conditions* have been continuously met for at least the last two years;

OR

2) any of the *susceptible species* referred to in Article 9.7.2. are present and the following conditions have been met:

a) there has been no observed occurrence of the *disease* for at least the last ten years despite conditions that are conducive to its clinical expression (as described in the corresponding chapter of the *Aquatic Manual*); and

b) basic biosecurity conditions have been continuously met for at least the last two years;

OR

3) the disease status prior to *targeted surveillance* is unknown but the following conditions have been met:

a) basic biosecurity conditions have been continuously met for at least the last two years; and

b) targeted surveillance, as described in Chapter 1.4., has been in place for at least the last two years without detection of WSD;

OR

4) it previously made a *self-declaration of freedom* from WSD and subsequently lost its *disease* free status due to the detection of WSD but the following conditions have been met:

a) on detection of the *disease*, the affected area was declared an *infected zone* and a *protection zone* was established; and

b) infected populations have been destroyed or removed from the *infected zone* by means that minimise the *risk* of further spread of the *disease*, and the appropriate *disinfection* procedures (as described in Chapter 4.3.) have been completed; and

c) previously existing *basic biosecurity conditions* have been reviewed and modified as necessary and have continuously been in place since eradication of the *disease*; and

d) targeted surveillance, as described in Chapter 1.4., has been in place for at least the last two years without detection of WSD.

In the meantime, part or all of the non-affected area may be declared a free *zone* provided that such a part meets the conditions in point 3 of Article 9.7.5.

Article 9.7.5.

Zone or compartment free from white spot disease

If a *zone* or *compartment* extends over more than one country, it can only be declared a WSD free *zone* or *compartment* if all the relevant *Competent Authorities* confirm that all relevant conditions have been met.

As described in Article 1.4.6., a *zone* or *compartment* within the *territory* of one or more countries not declared free from WSD may be declared free by the *Competent Authority(ies)* of the country(ies) concerned if:

1) none of the *susceptible species* referred to in Article 9.7.2. are present in the *zone* or *compartment* and *basic biosecurity conditions* have been continuously met for at least the last two years;

OR

2) any of the *susceptible species* referred to in Article 9.7.2. are present in the *zone* or *compartment* and the following conditions have been met:

> *a)* there has not been any observed occurrence of the *disease* for at least the last ten years despite conditions that are conducive to its clinical expression (as described in the corresponding chapter of the *Aquatic Manual*); and
>
> *b) basic biosecurity conditions* have been continuously met for at least the last two years;

OR

3) the disease status prior to *targeted surveillance* is unknown but the following conditions have been met:

> *a) basic biosecurity conditions* have been continuously met for at least the last two years; and
>
> *b) targeted surveillance*, as described in Chapter 1.4., has been in place, in the *zone* or *compartment*, for at least the last two years without detection of WSD;

OR

4) it previously made a *self-declaration of freedom* for a *zone* from WSD and subsequently lost its *disease* free status due to the detection of WSD in the *zone* but the following conditions have been met:

> *a)* on detection of the *disease*, the affected area was declared an *infected zone* and a *protection zone* was established; and
>
> *b)* infected populations have been destroyed or removed from the *infected zone* by means that minimise the *risk* of further spread of the *disease*, and the appropriate *disinfection* procedures (as described in Chapter 4.3.) have been completed; and

c) previously existing *basic biosecurity conditions* have been reviewed and modified as necessary and have continuously been in place since eradication of the *disease*; and

d) targeted surveillance, as described in Chapter 1.4., has been in place for at least the last two years without detection of WSD.

Article 9.7.6.

Maintenance of free status

A country, *zone* or *compartment* that is declared free from WSD following the provisions of points 1 or 2 of Articles 9.7.4. or 9.7.5. (as relevant) may maintain its status as free from WSD provided that *basic biosecurity conditions* are continuously maintained.

A country, *zone* or *compartment* that is declared free from WSD following the provisions of point 3 of Articles 9.7.4. or 9.7.5. (as relevant) may discontinue *targeted surveillance* and maintain its status as free from WSD provided that conditions that are conducive to clinical expression of WSD, as described in the corresponding chapter of the *Aquatic Manual*, exist, and *basic biosecurity conditions* are continuously maintained.

However, for declared free *zones* or *compartments* in infected countries and in all cases where conditions are not conducive to clinical expression of WSD, *targeted surveillance* needs to be continued at a level determined by the *Aquatic Animal Health Service* on the basis of the likelihood of *infection*.

Article 9.7.7.

Importation of aquatic animals and aquatic animal products from a country, zone or compartment declared free from white spot disease

When importing *aquatic animals* and *aquatic animal products* of species referred to in Article 9.7.2. from a country, *zone* or *compartment* declared free from WSD, the *Competent Authority* of the *importing country* should require that the consignment be accompanied by an *international aquatic animal health certificate* issued by the *Competent Authority* of the *exporting country* or a *certifying official* approved by the *importing country* certifying that, on the basis of the procedures described in Articles 9.7.4. or 9.7.5. (as applicable) and 9.7.6., the place of production of the *aquatic animals* and *aquatic animal products* is a country, *zone* or *compartment* declared free from WSD.

The *certificate* should be in accordance with the Model Certificate in Chapter 5.11.

This Article does not apply to *commodities* listed in point 1 of Article 9.7.3.

Article 9.7.8.

Importation of live aquatic animals for aquaculture from a country, zone or compartment not declared free from white spot disease

1) When importing, for *aquaculture*, live *aquatic animals* of species referred to in Article 9.7.2. from a country, *zone* or *compartment* not declared free from WSD, the *Competent Authority* of the *importing country* should assess the *risk* and, if justified, apply the following *risk* mitigation measures:

a) the direct delivery to and lifelong holding of the consignment in biosecure facilities for continuous isolation from the local environment; and

b) the treatment of water used in transport and of all effluent and waste materials in a manner that ensures inactivation of WSSV.

2) If the intention of the introduction is the establishment of a new stock, relevant aspects of the Code of Practice on the Introductions and Transfers of Marine Organisms of the International Council for the Exploration of the Seas (ICES) should be considered.

3) For the purposes of the *Aquatic Code*, relevant aspects of the ICES Code (full version see: http://www.ices.dk/publications/our-publications/Pages/Miscellaneous.aspx) may be summarised to the following points:

a) identify stock of interest (cultured or wild) in its current location;

b) evaluate stock health and disease history;

c) take and test samples for WSSV, pests and general health/disease status;

d) import of a founder (F-0) population and quarantine in a secure facility;

e) produce F-1 generation from the F-0 stock in *quarantine*;

f) culture F-1 stock and at critical times in its development (life cycle) sample and test for WSSV and perform general examinations for pests and general health/disease status;

g) if WSSV is not detected, pests are not present, and the general health/disease status of the stock is considered to meet the *basic biosecurity conditions* of the *importing country*, *zone* or *compartment*, the F-1 stock may be defined as WSD free or specific pathogen free (SPF) for WSSV;

h) release SPF F-1 stock from *quarantine* for *aquaculture* or stocking purposes in the country, *zone* or *compartment*.

4) With respect to point 3 *e)*, *quarantine* conditions should be conducive to multiplication of the pathogen and eventually to clinical expression. If *quarantine* conditions are not suitable for pathogen multiplication and development, the recommended diagnostic approach might not be sensitive enough to detect low *infection* level.

This Article does not apply to *aquatic animals* listed in point 1 of Article 9.7.3.

Article 9.7.9.

Importation of aquatic animals and aquatic animal products for processing for human consumption from a country, zone or compartment not declared free from white spot disease

When importing, for processing for human consumption, *aquatic animals* or *aquatic animal products* of species referred to in Article 9.7.2. from a country, *zone* or *compartment* not declared free from WSD, the *Competent Authority* of the *importing country* should assess the *risk* and, if justified, require that:

1) the consignment is delivered directly to and held in *quarantine* or containment facilities until processing into one of the products referred to in point 1 of Article 9.7.3., or products described in point 1 of Article 9.7.11., or other products authorised by the *Competent Authority*; and

2) water used in transport and all effluent and waste materials from the processing are treated in a manner that ensures inactivation of WSSV or is disposed in a manner that prevents contact of waste with *susceptible species*.

For these *commodities* Member Countries may wish to consider introducing internal measures to address the *risks* associated with the *commodity* being used for any purpose other than for human consumption.

Article 9.7.10.

Importation of live aquatic animals intended for use in animal feed, or for agricultural, industrial or pharmaceutical use, from a country, zone or compartment not declared free from white spot disease

When importing, for use in animal *feed* or for agricultural, industrial or pharmaceutical use, live *aquatic animals* of species referred to in Article 9.7.2. from a country, *zone* or *compartment* not declared free from WSD, the *Competent Authority* of the *importing country* should require that:

1) the consignment is delivered directly to, and held in, *quarantine* facilities for slaughter and processing into products authorised by the *Competent Authority*; and

2) water used in transport and all effluent and waste materials from the processing are treated in a manner that ensures inactivation of WSDV.

This Article does not apply to *commodities* referred to in point 1 of Article 9.7.3.

Article 9.7.11.

Importation of aquatic animals and aquatic animal products for retail trade for human consumption from a country, zone or compartment not declared free from white spot disease

1) *Competent Authorities* should not require any conditions related to WSD, regardless of the WSD status of the *exporting country*, *zone* or *compartment*, when authorising the importation or transit of frozen peeled shrimp or decapod crustacea (shell off, head off) which have been prepared and packaged for retail trade and which comply with Article 5.4.2.

Certain assumptions have been made in assessing the safety of the *aquatic animal products* mentioned above. Member Countries should refer to these assumptions at Article 5.4.2. and consider whether the assumptions apply to their conditions.

For these *commodities* Member Countries may wish to consider introducing internal measures to address the *risks* associated with the *commodity* being used for any purpose other than for human consumption.

2) When importing *aquatic animals* or *aquatic animal products*, other than those referred to in point 1 above, of species referred to in Article 9.7.2. from a country, *zone* or *compartment* not declared free from WSD, the *Competent Authority* of the *importing country* should assess the *risk* and apply appropriate *risk* mitigation measures.

CHAPTER 9.8.

WHITE TAIL DISEASE

Article 9.8.1.

For the purposes of the *Aquatic Code*, white tail disease (WTD) means *infection* with macrobrachium nodavirus (MrNV). This virus has yet to be formally classified.

Information on methods for *diagnosis* are provided in the *Aquatic Manual*.

Article 9.8.2.

Scope

The recommendations in this chapter apply to: the giant fresh water prawn *(Macrobrachium rosenbergii)*. Other common names are listed in the *Aquatic Manual*. These recommendations also apply to any other *susceptible species* referred to in the *Aquatic Manual* when traded internationally.

For the purposes of this chapter, the terms shrimp and prawn are used interchangeably.

Article 9.8.3.

Importation or transit of aquatic animals and aquatic animal products for any purpose regardless of the white tail disease status of the exporting country, zone or compartment

1) *Competent Authorities* should not require any conditions related to WTD, regardless of the WTD status of the *exporting country*, *zone* or *compartment*, when authorising the importation or transit of the following *aquatic animal products* from the species referred to in Article 9.8.2. which are intended for any purpose and which comply with Article 5.4.1.:

a) heat sterilised hermetically sealed crustacean products (i.e. a heat treatment at 121°C for at least 3.6 minutes or any time/temperature equivalent);

b) cooked crustacean products that have been subjected to heat treatment at 60°C for at least 60 minutes (or any time/temperature equivalent which has been demonstrated to inactivate MrNV);

c) pasteurised crustacean products that have been subjected to heat treatment at 90°C for at least ten minutes (or any time/temperature equivalent that has been shown to inactivate MrNV);

d) crustacean oil;

e) crustacean *meal*;

f) chemically extracted chitin.

2) When authorising the importation or transit of *aquatic animals* and *aquatic animal products* of a species referred to in Article 9.8.2., other than those referred to in point 1 of Article 9.8.3., *Competent Authorities* should require the conditions prescribed in Articles 9.8.7. to 9.8.11. relevant to the WTD status of the *exporting country*, *zone* or *compartment*.

3) When considering the importation or transit of *aquatic animals* and *aquatic animal products* of a species not covered in Article 9.8.2. but which could reasonably be expected to pose a *risk* of spread of WTD, the *Competent Authority* should conduct a *risk analysis* in accordance with the recommendations in Chapter 2.1. The *Competent Authority* of the *exporting country* should be informed of the outcome of this assessment.

Article 9.8.4.

Country free from white tail disease

If a country shares a *zone* with one or more other countries, it can only make a *self-declaration of freedom* from WTD if all the areas covered by the shared water bodies are declared countries or *zones* free from WTD (see Article 9.8.5.).

As described in Article 1.4.6., a country may make a *self-declaration of freedom* from WTD if:

1) none of the *susceptible species* referred to in Article 9.8.2. are present and *basic biosecurity conditions* have been continuously met for at least the last two years;

OR

2) any of the *susceptible species* referred to in Article 9.8.2. are present and the following conditions have been met:

a) there has been no observed occurrence of the *disease* for at least the last ten years despite conditions that are conducive to its clinical expression (as described in the corresponding chapter of the *Aquatic Manual*); and

b) *basic biosecurity conditions* have been continuously met for at least the last two years;

OR

3) the disease status prior to *targeted surveillance* is unknown but the following conditions have been met:

a) *basic biosecurity conditions* have been continuously met for at least the last two years; and

b) *targeted surveillance*, as described in Chapter 1.4., has been in place for at least the last two years without detection of WTD;

OR

4) it previously made a *self-declaration of freedom* from WTD and subsequently lost its *disease* free status due to the detection of WTD but the following conditions have been met:

a) on detection of the *disease*, the affected area was declared an *infected zone* and a *protection zone* was established; and

b) infected populations have been destroyed or removed from the *infected zone* by means that minimise the *risk* of further spread of the *disease*, and the appropriate *disinfection* procedures (as described in Chapter 4.3.) have been completed; and

c) previously existing *basic biosecurity conditions* have been reviewed and modified as necessary and have continuously been in place since eradication of the *disease*; and

d) *targeted surveillance*, as described in Chapter 1.4., has been in place for at least the last two years without detection of WTD.

In the meantime, part or all of the non-affected area may be declared a free *zone* provided that such a part meets the conditions in point 3 of Article 9.8.5.

Article 9.8.5.

Zone or compartment free from white tail disease

If a *zone* or *compartment* extends over more than one country, it can only be declared a WTD free *zone* or *compartment* if all the relevant *Competent Authorities* confirm that all relevant conditions have been met.

As described in Article 1.4.6., a *zone* or *compartment* within the *territory* of one or more countries not declared free from WTD may be declared free by the *Competent Authority(ies)* of the country(ies) concerned if:

1) none of the *susceptible species* referred to in Article 9.8.2. are present in the *zone* or *compartment* and *basic biosecurity conditions* have been continuously met for at least the last two years;

OR

2) any of the *susceptible species* referred to in Article 9.8.2. are present in the *zone* or *compartment* and the following conditions have been met:

a) there has not been any observed occurrence of the *disease* for at least the last ten years despite conditions that are conducive to its clinical expression (as described in the corresponding chapter of the *Aquatic Manual*); and

b) *basic biosecurity conditions* have been continuously met for at least the last two years;

OR

3) the disease status prior to *targeted surveillance* is unknown but the following conditions have been met:

a) *basic biosecurity conditions* have been continuously met for at least the last two years; and

b) *targeted surveillance*, as described in Chapter 1.4., has been in place, in the *zone* or *compartment*, for at least the last two years without detection of WTD;

OR

4) it previously made a *self-declaration of freedom* for a *zone* from WTD and subsequently lost its *disease* free status due to the detection of WTD in the *zone* but the following conditions have been met:

a) on detection of the *disease*, the affected area was declared an *infected zone* and a *protection zone* was established; and

b) infected populations have been destroyed or removed from the *infected zone* by means that minimise the *risk* of further spread of the *disease*, and the appropriate *disinfection* procedures (as described in Chapter 4.3.) have been completed; and

c) previously existing *basic biosecurity conditions* have been reviewed and modified as necessary and have continuously been in place since eradication of the *disease*; and

d) *targeted surveillance*, as described in Chapter 1.4., has been in place for at least the last two years without detection of WTD.

Article 9.8.6.

Maintenance of free status

A country, *zone* or *compartment* that is declared free from WTD following the provisions of points 1 or 2 of Articles 9.8.4. or 9.8.5. (as relevant) may maintain its status as free from WTD provided that *basic biosecurity conditions* are continuously maintained.

A country, *zone* or *compartment* that is declared free from WTD following the provisions of point 3 of Articles 9.8.4. or 9.8.5. (as relevant) may discontinue *targeted surveillance* and maintain its status as free from WTD provided that conditions that are conducive to clinical expression of WTD, as described in the corresponding chapter of the *Aquatic Manual*, exist, and *basic biosecurity conditions* are continuously maintained.

However, for declared free *zones* or *compartments* in infected countries and in all cases where conditions are not conducive to clinical expression of WTD, *targeted surveillance* needs to be continued at a level determined by the *Aquatic Animal Health Service* on the basis of the likelihood of *infection*

Article 9.8.7.

Importation of aquatic animals and aquatic animal products from a country, zone or compartment declared free from white tail disease

When importing *aquatic animals* and *aquatic animal products* of species referred to in Article 9.8.2. from a country, *zone* or *compartment* declared free from WTD, the *Competent Authority* of the *importing country* should require that the consignment be accompanied by an *international aquatic animal health certificate* issued by the *Competent Authority* of the *exporting country* or a *certifying official* approved by the *importing country* certifying that, on the basis of the procedures described in Articles 9.8.4. or 9.8.5. (as applicable) and 9.8.6., the place of production of the *aquatic animals* and *aquatic animal products* is a country, *zone* or *compartment* declared free from WTD.

The *certificate* should be in accordance with the Model Certificate in Chapter 5.11.

This Article does not apply to *commodities* listed in point 1 of Article 9.8.3.

Article 9.8.8.

Importation of live aquatic animals for aquaculture from a country, zone or compartment not declared free from white tail disease

1) When importing, for *aquaculture*, live *aquatic animals* of species referred to in Article 9.8.2. from a country, *zone* or *compartment* not declared free from WTD, the *Competent Authority* of the *importing country* should assess the *risk* and, if justified, apply the following *risk* mitigation measures:

a) the direct delivery to and lifelong holding of the consignment in biosecure facilities for continuous isolation from the local environment; and

b) the treatment of water used in transport and of all effluent and waste materials in a manner that ensures inactivation of WTDV.

2) If the intention of the introduction is the establishment of a new stock, relevant aspects of the Code of Practice on the Introductions and Transfers of Marine Organisms of the International Council for the Exploration of the Seas (ICES) should be considered.

3) For the purposes of the *Aquatic Code*, relevant aspects of the ICES Code (full version see: http://www.ices.dk/publications/our-publications/Pages/Miscellaneous.aspx) may be summarised to the following points:

a) identify stock of interest (cultured or wild) in its current location;

b) evaluate stock health and disease history;

c) take and test samples for WTDV, pests and general health/disease status;

d) import of a founder (F-0) population and quarantine in a secure facility;

e) produce F-1 generation from the F-0 stock in *quarantine*;

f) culture F-1 stock and at critical times in its development (life cycle) sample and test for WTD and perform general examinations for pests and general health/disease status;

g) if WTDV is not detected, pests are not present, and the general health/disease status of the stock is considered to meet the *basic biosecurity conditions* of the *importing country*, *zone* or *compartment*, the F-1 stock may be defined as WTD free or specific pathogen free (SPF) for WTDV;

h) release SPF F-1 stock from *quarantine* for *aquaculture* or stocking purposes in the country, *zone* or *compartment*.

4) With respect to point 3 *e)*, *quarantine* conditions should be conducive to multiplication of the pathogen and eventually to clinical expression. If *quarantine* conditions are not suitable for pathogen multiplication and development, the recommended diagnostic approach might not be sensitive enough to detect low *infection* level.

This Article does not apply to *aquatic animals* listed in point 1 of Article 9.8.3.

Article 9.8.9.

Importation of aquatic animals and aquatic animal products for processing for human consumption from a country, zone or compartment not declared free from white tail disease

When importing, for processing for human consumption, *aquatic animals* or *aquatic animal products* of species referred to in Article 9.8.2. from a country, *zone* or *compartment* not declared free from WTD, the *Competent Authority* of the *importing country* should assess the *risk* and, if justified, require that:

1) the consignment is delivered directly to and held in *quarantine* or containment facilities until processing into one of the products referred to in point 1 of Article 9.8.3., or products described in point 1 of Article 9.8.11., or other products authorised by the *Competent Authority*; and

2) water used in transport and all effluent and waste materials from the processing are treated in a manner that ensures inactivation of WTDV or is disposed in a manner that prevents contact of waste with *susceptible species*.

For these *commodities* Member Countries may wish to consider introducing internal measures to address the *risks* associated with the *commodity* being used for any purpose other than for human consumption.

Article 9.8.10.

Importation of live aquatic animals intended for use in animal feed, or for agricultural, industrial or pharmaceutical use, from a country, zone or compartment not declared free from white tail disease

When importing, for use in animal *feed* or for agricultural, industrial or pharmaceutical use, live *aquatic animals* of species referred to in Article 9.8.2. from a country, *zone* or *compartment* not declared free from WTD, the *Competent Authority* of the *importing country* should require that:

1) the consignment is delivered directly to, and held in, *quarantine* facilities for slaughter and processing into products authorised by the *Competent Authority*; and

2) water used in transport and all effluent and waste materials from the processing are treated in a manner that ensures inactivation of WTDV.

This Article does not apply to *commodities* referred to in point 1 of Article 9.8.3.

Article 9.8.11.

Importation of aquatic animals and aquatic animal products for retail trade for human consumption from a country, zone or compartment not declared free from white tail disease

1) *Competent Authorities* should not require any conditions related to WTD, regardless of the WTD status of the *exporting country*, *zone* or *compartment*, when authorising the importation or transit of frozen peeled shrimp (shell off, head off) which have been prepared and packaged for retail trade and which comply with Article 5.4.2.

Certain assumptions have been made in assessing the safety of the *aquatic animal products* mentioned above. Member Countries should refer to these assumptions at Article 5.4.2. and consider whether the assumptions apply to their conditions.

For these *commodities* Member Countries may wish to consider introducing internal measures to address the *risks* associated with the *commodity* being used for any purpose other than for human consumption.

2) When importing *aquatic animals* or *aquatic animal products*, other than those referred to in point 1 above, of species referred to in Article 9.8.2. from a country, *zone* or *compartment* not declared free from WTD, the *Competent Authority* of the *importing country* should assess the *risk* and apply appropriate *risk* mitigation measures.

Appendix III

Regelverk for import, etablering og drift av akvakulturanlegg for eksotiske krepsdyr som Mattilsynet forvalter

Nedenfor beskrives regler for import, etablering og drift av akvakulturanlegg for eksotiske krepsdyr som Mattilsynet forvalter. Vi gjør oppmerksom at Fiskeridirektoratet og Miljødirektoratet forvalter også andre regler som er relevante i denne sammenheng. Disse nevnes ikke her.

Import av eksotiske krepsdyr for akvakultur

Omsetnings- og sykdomsforskriften

Forskrifter implementerer direktive 2006/88/EF (Fiskehelsedirektive). Forskriften omfatter fisk, bløtdyr og krepsdyr (tifotkreps) til og fra et akvakulturanlegg. Den omfatter ikke akvariedyr i private akvarier.

Alle tifotkrepsarter er listeført som mottakelig for hvitflekksykdom (liste 2) og Norge har uavklart helsestatus for denne sykdommen. Redclaw er ikke listeført som vektorarter av andre listeførte sykdommer.

Hvis krepsen kommer fra land innenfor EØS, regnes det som omsetning og kap. 4 i omsetning- og sykdomsforskriften gjelder. Hvis krepsen importeres fra land utenfor EØS (tredjesatser), gjelder kap. 5 i forskriften.

Regler for omsetning (§§ 10-23)

De generelle regler for omsetning av akvakulturdyr er at dyrene er kliniske friske og ikke kommer fra et akvakulturanlegg med forøket dødelighet.

Akvakulturdyr som omsettes følges av et dyrehelsesertifikat og skal meldes inn i TRACES.

Regler for import (§§ 24-25)

§24. Generelle vilkår ved import og transitt av akvakulturdyr og produkter av akvakulturdyr

Akvakulturdyr skal innføres fra godkjente tredjestater eller godkjente områder i tredjestater i henhold til tid gjeldende liste over tredjesatser og områder i tredjestater knyttet til de aktuelle akvakulturdyrene.

Krepsdyr som er ment til akvakulturanlegg kan bare importeres fra USA per dagsdato. Se forordning 1252/2008.

§ 25. Helsesertifikatet.

Akvakulturdyr som importeres skal følges av et helsesertifikat og skal oppfylle kravene som er fastsatt i forskrift om ytterligere krav til transport, omsetning og import av akvakulturdyr og produkter av disse.

Forskrift om ytterligere krav til transport, omsetning og import av akvakulturdyr og produkter av disse

Krepsdyr beregnet på oppdrett skal ledsages av et helsesertifikat utfyll med modellen i del A i vedlegg IV og de forklarende merknadene i vedlegg V. Vedleggene finnes her: https://lovdata.no/static/SF/sf-20110118-0060-01-06.pdf?timestamp=1460689261000

Etablering av akvakulturanlegg

For å drive oppdrettsvirksomhet må virksomheten ha offentlig tillatelse. Fylkeskommunene har ansvaret for å avgjøre akvakultursøknader etter akvakulturloven. Fylkeskommunen kontrollerer søknader og sender søknadene videre til relevante sektormyndigheter og lokaliseringskommunen.
Mattilsynets oppgave ved behandling av søknader er å vurdere anlegget og lokaliseringens egnethet ut fra hensyn til fiskehelse og fiskevelferd. Blant annet vurderer vi faren for smittespredning til og fra anlegget. Dette er hjemlet i etableringsforskriften.

Forskrift om etablering og utvidelse av akvakulturanlegg

§ 5. Krav om godkjenning
Etablering av akvakulturanlegg skal være godkjent av Mattilsynet. Søknaden skal inneholde bla. en beredskapsplan, et internkontrollsystem og dokumentasjon på lokalitetens egenhet til å sikre fisk og tifotkreps en god velferd.

§ 7.Forhold som vurderes ved godkjenning
For at godkjenning skal kunne gis må etableringen av akvakulturanlegget, eller akvakulturområdet for bløtdyr, ikke innebære uakseptabel risiko for spredning av smitte, herunder smitte inn til akvakulturanlegget eller akvakulturområdet for bløtdyr og dets omkringliggende miljø (...).

Mattilsynet ønsker en vurdering fra VKM om risiko for spredning av smitte ved etablering av akvakulturanlegg for australsk redclaw. En del av vurderingen er knyttet til desinfeksjon av avløpsvann.

Forskrift om desinfeksjon av inntaksvann til og avløpsvann fra akvakulturrelatert virksomhet.

Mattilsynet kan bestemme at landbaserte akvakulturanlegg skal desinfisere avløpsvannet slik at faren for smittespredning reduseres.

§ 10. Krav til metoder for desinfeksjon

For avløpsvann fra akvakulturanlegg som har tillatelse til å drive oppdrett av eksotiske arter av akvatiske organismer gjelder at metoden gjennom anerkjent vitenskapelig dokumentasjon under relevante forsøksbetingelser (vannkvalitet, temperatur m.v.), skal vise minimum 5 log10 (99,999%) inaktivering av IPN-virus.

Transport av krepsdyr

Transportforskriften

For transport av krepsdyr til og fra akvakulturanlegg, gjelder følgene bestemmelser i transportforskriften:

- Kapittel 1., §§ 1-3.
- Kapittel 3. §§ 8, 9, 10 og 11.
- Kapittel 5. §§ 19- 24.
- Kapittel 6. §§ 25-28.

Drift av akvakulturanlegg

Akvakulturdriftsforskriften

For drift av akvakulturanlegg for krepsdyr, gjelder følgende bestemmelser:

- Kapittel 1.
- Kapittel 2.
- Kapittel 6. §§ 64, 65
- Kapittel 7.