Risk assessment of live bait

Searching for alien species in live bait used by anglers in the Netherlands

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Bureau Waardenburg bv
Ecologie & landschap

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Report

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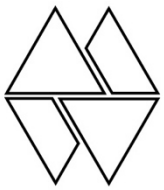

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Preface

Angling is one of the commonest forms of water recreation in the Netherlands with about 11 million fresh water fishing trips per year, including 800.000 trips to coastal waters. Anglers use live bait such as worms, insect larvae and plants to hook fish. In particular sea anglers use marine worms, which are commercially harvested in coastal wetlands, farmed in closed systems or collected from the wild by the anglers themselves. In Europe an increasing amount of marine worms is imported from other continents, in particular Asia, which has resulted in several successful introductions of invasive alien species. It is unknown if non-native invertebrates are also imported to the Netherlands.

Drs. A.A.J. Smolders (Invasive Alien Species Team, Bureau Risk Assessment & Research of the Ministry of Economic Affairs) commissioned Bureau Waardenburg bv to carry out a risk assessment of alien species in live bait used by anglers in the Netherlands. This analysis includes all invertebrate species used in fresh and salt water and one plant species, the Tigernut sedge *Cyperus esculentus*, frequently used by carp fishermen.

The project team of Bureau Waardenburg consisted of Tom van der Have, Arie Kersbergen and Pieter-Bas Broeckx.

Karin Didderen, Sander Smolders (BuRO), Remko Verspui and Jan Willem Wijnstroom (Sportvisserij Nederland) provided comments on previous versions of this manuscript.

The authors thank everyone who has contributed to this report.

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Summary

Aim and background
The substantial and increasing global trade in live bait used for recreational angling and the related risks of introductions of invasive alien species motivated the BuRO (NVWA, Ministry of Economic Affairs) to investigate if alien species are used as live bait in the Netherlands. The aim of this study is to carry out a risk assessment of the alien species, which are used as live bait by anglers in both fresh and salt water. Risk is usually expressed as impact weighted with the probability of occurrence, therefore, the risk assessment includes (1) an estimation of the probability of introduction: including a) which alien species are used as live bait by anglers in both fresh and salt water and b) which alien species could become established in natural areas in the Netherlands now or in the future as a result of climate change, and (2) an estimation of the ecological impact they will have on native biodiversity.

The following questions are addressed: How many companies are involved in the farming and trade of live bait? How many anglers use live bait? Which alien species of invertebrates are used as live bait? What is the ecological impact of the alien species used as live bait on biodiversity?

This study is limited to invertebrates used as live bait, because the use of fish as live bait is not allowed in the Netherlands. The focus is on species that are traded globally and are alien species in the Netherlands. This group includes predominantly marine, polychaete worms, for several reasons: these species are able to survive for long periods if stored in suitable wet substrate at low temperatures and as a result can be transported by air globally. They are attractive bait for larger fish species, highly suitable for angling in coastal waters and therefore popular with coastal anglers. Consequently, they have become a valuable commodity and the high prices are the main driver of the intercontinental trade.

The invertebrates used by freshwater anglers are predominantly native annelid worms and insect larvae of either native species (maggots of fly species) or species adapted to high temperatures (mealworms). This group of live bait will be briefly discussed.

One plant species, the tiger nut (*C. esculentus* var. *sativus*, an important crop species) or Chufa, is included in the study, because it is increasingly used as bait by carp anglers. It is often confused with the Yellow nutsedge (*Cyperus esculentus*), also known as one of the most damaging weeds in agriculture.

Approach in this study
We conducted first a web survey of shops and webshops offering live bait in the Netherlands. A selection of shops and one web shop was made to order live bait, in particular marine worms. The scientific names as published in peer-reviewed, scientific articles were used as much as possible throughout this report. Names used

in grey literature were checked with the World Register of Marine Species (WoRMS) website and only accepted names were used. Scientific names are not frequently used in trade and if mentioned they were treated with care. The common names used in trade and by anglers have been linked to the most likely scientific names as much as possible. The ISEIA-protocol has been used for the assessment of ecological risks.

Supply of saltwater live bait

In 2015 marine polychaete worms were offered for sale in 67 shops, one farm (Topsy Bait) and one webshop in the Netherlands. In July 2015 worms were bought alive from a selection of eleven shops and one webshop and these included five different species: lugworms species (*Arenicola marina* and *A. defodiens*), ragworms (*Alitta virens*), *Hediste diversicolor* ("slikzagers") and *Nephtys caeca* ("witjes"). No alien species other than the already established *A. virens* were found in the samples.

Marine worms global trade: species groups

In the global live bait trade over twenty species of marine worms are involved of two major taxonomic groups, Polychaeta (bristle worms) and Sipuncula (peanut worms). The bristle worms used as live bait include predatory worms with well-developed jaws (*Alitta, Perinereis, Namalycastis* and Onuphid tube worms *Diopatra*) and lugworms (*Arenicola*), which are deposit feeders (small organic material) living in burrows in the sediment. Peanut worms (Sipunculus) are also deposit feeders living in burrows in the sediment. Species identification, however, is in many cases unconfirmed or absent and scientific names given to traded worms should be treated with care. Several recent papers give up to date information on species status and taxonomy, including the description of new species. Some traded species are not yet formally described. The common names (in English and Dutch) used in trade and the angling community are given to ease cross-reference.

Marine worms: source areas

Marine worms are harvested and farmed in three major source areas: Europe, Atlantic North-America and Southeast Asia. The highest demand is in areas where there is limited or no harvest from natural areas, including Pacific North-America, Southern Europe and Japan. Currently there are no imports of marine worms from sources outside Europe to the Netherlands, but there is a potential risk that invasive alien species of marine worms are imported in the Netherlands from North-America or Southeast Asia if the local supply of marine worms would strongly decrease in the future. Most lugworms are harvested mechanically in natural areas. If the licence holders would stop their harvest, there will be no alternative supply in the Netherlands, because the licenses are not transferable. In addition, all farmed rag worms are produced by one farm in the Netherlands. If a disease or other calamity would stop this production, imports of rag worms is the only alternative.

Risk assessment fresh water live bait

Insect larvae (often called maggots or worms, including fly, beetle and moth larvae) and annelid worms are commonly used as live bait in fresh water angling. Several

species of grasshoppers and crickets are also used in angling, but excluded from this overview because they are used on a relatively small scale in trout ponds. Most insect species are also farmed to provide food for pets, like fish, reptiles and birds and commonly available in pet shops and angler shops. All groups (flies, beetles, moths and annelid worms) include alien species usually of subtropical to tropical origin, which are more suitable for storage and transport at room temperature. The ecological risks for aquatic ecosystems are absent and low for terrestrial ecosystems.

The tiger nuts used as bait for carp (after being boiled) are the crop variety (*C. esculentus* var. *sativus*, not known to be invasive), which is often confused with the invasive weed Yellow nut sedge (*C. esculentus*). The ecological risks for native biodiversity are therefore considered to be low.

Risk assessment saltwater live bait

Hitchhiking species
In the Netherlands most worms are transported in seawater, sediment, sea turf or just wet paper and the risk of larger hitchhiking organisms is considered to be low. Microorganisms, such as viruses, bacteria and fungi could be hitchhiking in the sediment or in the transported species. Parasites also occur in marine worms (e.g., ciliates in *Perinereis linea*), but are outside the scope of this report.

Directly introduced species
Over twenty species of polychaete worms of at least nine different genera are traded globally including several genera with native species (*Arenicola, Nereis, Nephtys*). *Alitta virens* is an invasive alien species, which has become established in many areas worldwide and in the Netherlands since 1915. A risk assessment is therefore not relevant.

The peanut worm *Sipunculus nudus* was until recently considered a cosmopolitan species and native to the Netherlands, but new genetic studies have shown that it consists of at least five different cryptic species. Therefore, it is recommended that imported "*Sipunculus nudus*" worms from outside Europe be considered as alien species.

The following genera include one or more species, which are not native in Europe and the Netherlands: *Alitta, Diopatra, Glycera, Marphysa, Namalycastis* and *Perinereis* and include species from temperate, subtropical and tropical climate zones.

The species from subtropical and tropical climates fell in the low risk category, because the probability of establishment is low (several species of *Diopatra, Marphysa* and all *Namalycastis* species). Several species from temperate climate zone fell in the medium risk category, including the predatory worms *Diopatra biscayensis* ("tubeworms"), *Glycera dibranchiata* ("bloodworms"), *Perinereis aibuhitensis* and *Perinereis linea* ("ragworms"). They are able to colonise soft

sediments, an abundant habitat in most marine Natura 2000 areas in the Netherlands, and could compete with native predatory, polychaete worms, which are important components of the food web.

Management options

If invasive alien species used as live bait would be imported to the Netherlands, like elsewhere in Europe, then there are several management options available to reduce the risks. Raising public awareness among anglers can motivate them not to discard live bait after fishing. Another option is to include the problem of invasive alien species in the Dutch Code of Conduct Sea Angling. In addition, Natura 2000 management plans could also give more attention to this potential pathway of invasive alien species. To safeguard the supply of live bait from Dutch sources, including sustainable harvest and farming, is also an important measure to prevent imports of alien species. Finally, if these measures would have insufficient impact, an import ban could be considered in the framework of the new EU Regulation 1143/2014 on Invasive Alien Species.

Figure 1, Bristle worms are a very popular live bait among sea anglers

Nederlandse samenvatting

Doel en achtergrond
Sportvisserij is een van de meest algemene vormen van waterrecreatie in Nederland en hierbij worden grote aantallen levend aas gebruikt. Dit betreft vooral ongewervelde dieren, zoals wormen, insectenlarven en schelpdieren, en zaden en delen van planten, omdat het gebruik van levende gewervelde dieren zoals vissen bij de wet is verboden. De aanzienlijke toename in de wereldwijde handel in levend aas en de risico's van introductie van invasieve exoten hebben het BuRO (NVWA, Ministerie van Economische Zaken) gemotiveerd om te onderzoeken of exoten ook in Nederland als levend aas gebruikt worden.

Het doel van dit onderzoek is om een risicobeoordeling uit te voeren van de exoten (geïntroduceerde uitheemse soorten) die mogelijk als levend aas gebruikt worden door sportvissers in zoet en zout water. Risico wordt meestal uitgedrukt als impact gewogen met de kans op voorkomen. Deze risicobeoordeling omvat daarom (1) een inschatting van de kans op introductie – a) welke exoten worden gebruikt in zoet en zout water en b) welke exoten zich zouden kunnen vestigen in natuurgebieden in Nederland nu of in de toekomst als gevolg van klimaatverandering, en (2) een schatting van de ecologische impact op inheemse biodiversiteit van deze exoten na eventuele vestiging en spreiding.

De volgende vragen worden behandeld: Hoeveel bedrijven zijn actief in de handel en kweek van levend aas? Hoeveel sportvissers gebruiken levend aas? Welke ongewervelde exoten worden gebruikt als levend aas? Wat is de ecologische impact van deze exoten, als die zich zouden vestigen in Nederland?

Dit onderzoek beperkt zicht tot ongewervelde dieren die door sportvissers als levend aas worden gebruikt. Gewervelde dieren, zoals vissen, mogen in Nederland niet als levend aas gebruikt worden. De focus is op soorten die wereldwijd verhandeld worden, niet voorkomen in Nederland en derhalve na introductie, vestiging en uitbreiding invasieve exoten genoemd zouden worden. Deze groep ongewervelde dieren omvat voornamelijk mariene, borstelwormen (polychaete wormen). Deze wormen zijn in staat lange perioden te overleven als ze bij lage temperatuur worden opgeslagen in geschikt, vochtig substraat. Door deze eigenschappen kunnen ze wereldwijd met het vliegtuig vervoerd worden. Mariene wormen zijn een aantrekkelijk aas voor grotere vissen, zijn zeer geschikt voor sportvisserij in kustwateren en daarom zeer gewild bij sportvissers in kustwateren. Door de grote vraag zijn de prijzen hoog en zijn internationale transporten voor de handel profijtelijk.

In zoet water gebruiken sportvissers voornamelijk gelede wormen en insectenlarven van inheemse soorten (vliegen maden) of soorten aangepast aan hogere temperaturen (meelwormen). Deze categorie van levend aas wordt alleen beknopt besproken.

De tijgernoot is ook in dit onderzoek betrokken, omdat deze steeds meer gebruikt wordt door sportvissers als aas voor karper (*Cyprinus carpio*). Dit betreft het belangrijke landbouwgewas chufa ook wel tijgernoot genoemd (*C. esculentus* var. *sativus*, en niet bekend als invasieve exoot). Dit gewas wordt vaak verward met de aardamandel (*Cyperus esculentus*) een van de meest schadelijke onkruiden in de landbouw.

Opzet van deze studie

Eerst is een web survey uitgevoerd van de winkels en web shops die levend aas aanbieden in Nederland. Vervolgens zijn voor determinatie bij een selectie van winkels en een webwinkel mariene wormen gekocht die als levend aas voor de kustvisserij werden aangeboden. In dit rapport zijn zoveel mogelijk de wetenschappelijke namen gebruikt zoals die in peer-reviewed wetenschappelijk artikelen zijn gepubliceerd. De namen die gehanteerd worden in de grijze literatuur zijn gecheckt met de website van het World Register of Marine Species (WoRMS) en alleen geaccepteerde namen zijn gebruikt. De soorten die met gewone namen in de handel en door sportvissers worden aangegeven zijn zoveel mogelijk gekoppeld aan de meest waarschijnlijke wetenschappelijke soortnamen. Het ISEIA-protocol is toegepast voor de beoordeling van de ecologische risico's.

Aanbod levend aas zout water

In 2015 boden in Nederland 67 winkels, een webwinkel en één kwekerij (TopsyBait, Zeeland) mariene wormen aan. In juli 2015 zijn levende mariene wormen gekocht in een selectie van 11 winkels en een webwinkel. In totaal werden vijf soorten wormen gedetermineerd. De meeste winkels verkochten twee soorten wadpieren (*A. marina* en *A. defodiens*) en zagers (groene zeeduizendpoot, *A. virens*). Sommige winkels bieden ook veelkleurige zeeduizendpoot (*Hediste diversicolor*) en zandzager ("witjes", *Nephtys caeca*). Slechts een exoot, de groene zeeduizendpoot *A. virens,* is in de monsters aangetroffen. Deze is in Nederland al lang gevestigd en algemeen in de kustwateren aanwezig,

Wereldwijde handel in mariene wormen

Bij de wereldwijde handel in levend aas zijn meer dan twintig soorten mariene wormen betrokken. Deze behoren tot twee groepen, de borstelwormen (Polychaeta) en pindawormen (Sipuncula). De borstelwormen die als levend aas worden gebruikt, zijn roofwormen met stevige kaken (*Alitta, Perinereis, Namalycastis* en onuphide kokerwormen, *Diopatra*) en wadpieren (*Arenicola*). Wadpieren zijn *deposit feeders* (eten fijn organisch materiaal), die gangen maken in het sediment. Pindawormen zijn ook *deposit feeders* en bewonen ook gangen in het sediment. De soortnamen die in de handel worden gebruikt zijn in vele gevallen niet door deskundigen bevestigd of zelfs helemaal afwezig. De wetenschappelijke namen die in de handel aan wormen worden gegeven zijn niet meer dan een indicatie. Sommige verhandelde soorten zijn zelfs nog niet formeel door de wetenschap beschreven.

Mariene wormen: herkomstgebieden

Mariene wormen worden geoogst en gekweekt worden in Europa, Atlantisch Noord-Amerika en Zuidoost Azië, vooral in China, Korea, Taiwan en Vietnam). De grootste vraag naar levend aas bestaat in gebieden waar de oogst in kustgebieden beperkt is, zoals langs de westkust van Noord-Amerika, in Zuid Europa en Japan. Momenteel vinden geen importen plaats van exotische wormen naar Nederland. Echter, als de oogst en kweek van mariene wormen in Nederland sterk zou afnemen, dan is de kans groot dat door importen vanuit buiten Europa aan de grote vraag zal worden voldaan. De meeste wadpieren worden in Nederland mechanisch geoogst in de Waddenzee. Als de vergunninghouders zouden stoppen met hun activiteit zijn er weinig alternatieven voor de grote vraag naar wadpieren, omdat de vergunningen niet overdraagbaar zijn. De meeste zagers die in Nederland worden gebruikt als levend aas zijn afkomstig van één kweekbedrijf in Zeeland. Als door een calamiteit dit bedrijf niet kan produceren, dan zijn er in Nederland geen alternatieven beschikbaar om aan de grote vraag naar zagers te voldoen.

Risicobeoordeling zoetwater levend aas

In zoetwater gebruiken sportvissers insectenlarven (vaak wormen genoemd, zoals larven van vliegen, kevers en motten) en gelede wormen als levend aas. Een aantal soorten sprinkhanen en krekels worden gebruikt bij het vissen op forel. Dit gebeurt op kleine schaal (forellenvijvers) en daarom zijn ze niet opgenomen in deze studie. Veel insecten worden gekweekt als voer voor huisdieren, en algemeen beschikbaar in dierenwinkels en hengelsportwinkels. Het gebruik van nieuwe soorten aas en ook levend aas is voortdurend in ontwikkeling. Dit overzicht beoogt daarom niet volledig te zijn. Alle groepen vliegen, kevers, wormen, omvatten ook exoten die gewoonlijk uit subtropische of tropische gebieden afkomstig zijn. Deze zijn meer geschikt voor opslag en transport bij kamertemperatuur, omdat ze aan hogere temperaturen zijn aangepast. Bij kamertemperatuur is hun activiteit en ontwikkelingssnelheid lager dan soorten die meer aan een koud klimaat zijn aangepast en blijven ze geschikt als levend aas.

De tijgernoten die gebruikt worden als aas voor karpers worden altijd gekookt voor gebruik en behoren bovendien tot het landbouwgewas (chufa, *C. esculentus* var. *sativus*) en niet tot de invasieve soort *C. esculentus,* die eveneens bekend is als tijgernoot. De ecologische risico's voor inheemse biodiversiteit worden daarom als laag ingeschat.

Risicobeoordeling mariene wormen

Meelifters

In Nederland worden de meeste mariene wormen na de oogst, in de winkel en voor gebruik verpakt in nat papier, zeeturf, of zeewater. Zeewier wordt zelden gebruikt als verpakkingsmateriaal en het risico van het introduceren van met de verpakking "meeliftende" organismen is waarschijnlijk laag. Micro-organismen, zoals virussen, bacteriën en schimmels kunnen meekomen in aanhangend water of sediment. Parasieten kunnen ook met mariene wormen meekomen (e.g., ciliaten in Koreaanse wormen *Perinereis linea*), maar vallen buiten de scope van dit rapport.

Rechtstreeks geïntroduceerde soorten

Wereldwijd worden tenminste twintig soorten mariene wormen verhandeld van negen verschillende genera. Een deel van deze genera omvatten ook inheemse soorten (*Arenicola, Hediste* en *Nephtys*) waarvoor een risicobeoordeling niet nodig is. De zager of groene zeeduizendpoot *A. virens* is een invasieve exoot die wereldwijd in veel gebieden is gevestigd en sinds 1915 algemeen voorkomt in Nederland. Ook voor deze soort is een risicobeoordeling niet relevant.

De pindaworm *Sipunculus nudus* werd tot voor kort als een kosmopolitische soort beschouwd, die ook in Nederland voorkomt. Echter, nieuwe genetische studies laten zien dat deze soort uit tenminste vijf verschillende soorten bestaat, waarvoor nog geen formele taxonomische beschrijvingen zijn gemaakt. Dit betekent dat pindawormen die van buiten Europa worden geïmporteerd als exoten moeten worden aangemerkt.

De volgende genera bevatten een of meer soorten die niet inheems zijn in Europa en Nederland: *Alitta, Diopatra, Glycera, Marphysa, Namalycastis* en *Perinereis*. Dit zijn soorten van gematigde, subtropische en tropische klimaatzones. Het genus *Arenicola* betreft ook de zwarte wadpier of Franse tap *A. defodiens* die in Nederland geoogst wordt en ook ingevroren geïmporteerd wordt uit Frankrijk en België.

De soorten uit subtropische en tropische klimaatzones vallen in de lage risico-categorie, doordat de kans op vestiging als laag is beoordeeld (diverse soorten in *Diopatra, Marphysa* en alle soorten *Namalycastis*). Een aantal soorten uit gematigde klimaatzones vallen in de categorie "matig risico", waaronder de roofwormen *Diopatra biscayensis* ("kokerwormen"), *Glycera dibranchiata* ("bloedwormen"), *Perinereis aibuhitensis* en *P. linea* ("slikzagers"). Deze soorten zijn in staat zacht sediment te koloniseren. Dit biotoop is algemeen en kenmerkend voor de meeste mariene Natura 2000 gebieden in Nederland. Daarnaast kunnen ze concurreren met inheemse roofwormen, die een belangrijke component vormen van de voedselwebben in het zachte sediment. Deze soorten kunnen zich na vestiging ontwikkelen tot invasieve exoten.

Management opties

Diverse management opties kunnen het risico van invasieve exoten, die als levend aas kunnen worden gebruikt, beperken of voorkomen. Het onder de aandacht brengen en vergroten van de bewustwording van sportvissers is een effectieve manier om het weggooien in de natuur van overgebleven aas te voorkomen. Daarnaast kan het probleem van de invasieve exoten genoemd worden in de Gedragscode voor Zeevisserij. Ook is het mogelijk dat de Natura 2000 beheerplannen expliciet aandacht geven aan het mogelijke gebruik van invasieve exoten als levend aas in de kustwateren. Verder is het van belang om de binnenlandse aanvoer van mariene wormen op peil te houden door duurzame oogst of kweek om zo importen van exotische wormen te voorkomen. Indien de implementatie van deze maatregelen te weinig effect heeft kan een importverbod overwogen worden in het kader van de nieuwe EU-verordening 1143/2014 voor preventie en beheer van invasieve exoten.

Figuur 2, Sportvisserij is een van de meest algemene vormen van waterrecreatie in Nederland.

1 Introduction

1.1 Background

Angling is one of the most popular forms of water recreation in the Netherlands. About two million anglers, including 650.000 in coastal waters, regularly go fishing (Smit *et al.,* 2004; website Sportvisserij NL). These anglers make a total of 11 million fishing trips each year, including 800.000 in coastal waters (van der Hammen & de Graaf, 2012, 2015). Assuming that on average 50 worms are used for each trip, and that half of the worms are bought in (web-) shops, which costs € 10 – 20 in total per trip, then around 40 million marine worms are used annually with a total market value of 8 - 16 million euros. These species usually include lugworms *Arenicola marin*a and ragworms *Alitta virens*, which are both harvested and farmed in the Netherlands. In addition, the global trade in marine worms is increasing and has a substantial risk of introducing invasive alien species either directly as bait species or through other invertebrates and algae as hitchhikers in seaweed packaging (Weigle *et al.,* 2005).

As became clear recently, species of marine worms are regularly imported from Belgium and France, including black lugworms *Arenicola defodiens* and “sandworms or slikzagers” *Nereis diversicolor* and “witjes” *Nephtys* sp. (Seys, 2001). Other species are also mentioned by webshops like “bloedzager” (species unknown). Additionally North-American species (bloodworms *Glycera dibranchiata*) and tubeworms *Diopatra* have been suggested to have farming potential.

Live insect larvae and earthworms are commonly used as bait by freshwater anglers. In recent years carp fishermen have discovered the attraction of the cooked tubers of Tiger nut sedge or Yellow nut sedge *Cyperus esculentus*, which is also known as an invasive alien species and globally one of the 20 worst weeds in the world (e.g., Bryson & Carter, 2008).

The substantial and increasing global trade in live bait and the related risks of introductions of invasive alien species in the Netherlands prompted the Ministry of Economic Affairs to initiate this study.

1.2 Aim

The aim of this study is to carry out a risk assessment of alien species, which are used as live bait by anglers in both fresh and salt water. The risk assessment includes (1) an estimation of the probability of introduction, a) which alien species are used and b) which alien species could become established in natural areas in the Netherlands now or in the future as a result of climate change, and (2) an estimation of the ecological impact they will have on biodiversity in the Netherlands.

Research questions

The overall question is: “what are the ecological risks of the alien species used as live bait for native species and areas in the Netherlands?” Since risk is expressed as impact weighed with the probability of occurrence the following related questions are therefore addressed.

Probability of introduction in the Netherlands:

- How many Dutch companies are involved in the farming and trade of live bait?
- How many Dutch anglers use live bait?
- How and when do anglers use live bait?
- Which alien species of invertebrates are used as live bait?
- What is the probability of introduction and establishment of these alien species in the Netherlands?

Ecological impact:

- What is the ecological impact of the alien species used as live bait on biodiversity in the Netherlands?

2 Materials and methods

2.1 General approach

Species selection

This study will be limited to invertebrates used as live bait, because the use of fish as live bait is not permitted in the Netherlands. Although live bait used by anglers both in inland and coastal waters is addressed in the study, the focus is on species, which are traded globally and are actually or potentially alien species in the Netherlands. This group includes predominantly marine, polychaete worms, for several reasons. These species are able to survive for long periods if stored in suitable substrate at low temperatures and as a result can be transported by air globally. They are attractive bait for larger fish species, highly suitable for angling in coastal waters and therefore in high demand by coastal anglers. Consequently, they have become a valuable commodity and the high prices are the main driver of the intercontinental trade (Cohen *et al.,* 2001; Cohen, 2012).

The invertebrates used by freshwater anglers are predominantly native annelid worms and insect larvae of either native species (maggots of fly species) or species adapted to high temperatures (mealworms). This group of live bait will be briefly discussed.

One plant species, the Yellow nutsedge *Cyperus esculentus*, which is known as a crop, tiger nut (*C. esculentus* var. *sativus*, de Vries, 1991) or Chufa (Pascual *et al.,* 2000), is included in the study, because it is also known as one of the most damaging weeds in agriculture (Holm *et al.,* 1977) and increasingly used as bait by carp anglers (e.g., Niesar *et al.,* 2004).

General survey method

Our approach was as follows.

- We first conducted a web survey of shops and websites offering live bait in the Netherlands.

- A selection of shops and one web shop was made to order live bait, in particular marine worms. Live bait was bought without informing the seller about the aim of project to avoid any interference.

- The samples were conserved for reference in ethanol (70%) and identified in our laboratory. Live bait not used for identification was frozen and discarded.

- The scientific names as published in peer-reviewed, scientific articles (Arias & Paxton, 2015; Arias *et al.,* 2013; Berke *et al.,* 2010; Kawauchi & Giribet, 2014; Luttikhuizen & Dekker, 2010; Saito *et al.,* 2014; Wijnhoven & Dekker, 2010) were

used as much as possible throughout this report. Names used in grey literature were checked with the World Register of Marine Species (WoRMS) website and only accepted names were used. Scientific names are not frequently used in trade and if mentioned they were treated with care. The common names have been linked to the most likely scientific names if possible.

Risk Analysis method

The ISEIA-protocol (Branquart, 2009) has been used for the assessment of ecological risks.

Sanitary and veterinary risks have been described for live bait, including cholera *Vibrio* sp. found in ragworm samples imported from Vietnam (Mullady *et al.,* 2000) and viruses found in live fish bait (Goodwin *et al.,* 2004). However, microorganisms, including pathogens and parasites, and vertebrates are not part of the assignment and not included in the analysis, but briefly addressed in the discussion.

2.2 Web survey trading shops

The web survey has been limited to shops and web shops offering saltwater live bait for several reasons. The number of shops selling bait for coarse fishing in the Netherlands is very large, probably several hundred, and also includes many pet shops. In addition, there is a substantial turnover in shop and the information would not be valid for a long time. A selection of websites of larger shops or web shops was checked for the species offered for sale. The number of shops selling saltwater live bait is less than hundred and all available websites were checked for the supply of saltwater live bait.

2.3 Literature research and web survey species

The risks of invasive alien species introductions in relation to local and international transports of marine live bait have received some attention in the scientific literature. As a result, mainly scientific papers have been used for the risk analysis of marine invasive alien species used as live bait. In the Netherlands the trade and transports include almost exclusively marine, polychaete worms. Only invertebrate species are allowed as live bait in the Netherlands, in contrast to North-America, where bait buckets are used for a variety of fish species and weeds is used as package material for invertebrate bait species such as molluscs, crayfish and others. For these species between basin transports of bait buckets have shown to be repeatedly the cause of introductions of alien species of pathogens, parasites, plankton, weeds, invertebrates and fish species (Anderson *et al.,* 2014; Keller *et al.,* 2007; Kilian *et al.,* 2012; Nathan *et al.,* 2014).

Most invertebrates used as live bait in freshwater are commercially farmed and include both native and alien species. The latter species originate mainly from subtropical to tropical areas and are unlikely to become established and spread in temperate climates like Western Europe. Hardly any scientific papers were found on this subject. All information is therefore derived from a variety of web-sources, including specialised websites for coarse fishing and web-shop sites.
New types of bait are constantly developed for commercial use and may include the use of live organisms. The overview presented in this report, therefore, is not aimed to be complete.

All taxonomic names have been checked with the World Register of Marine Species (WoRMS) website.

Scientific publications were searched with Scholar Google (search terms included live bait, marine worms, harvest, and genus or species name of live bait) and by following the citations of relevant publications. Open access publications were downloaded or retrieved through ResearchGate.

2.4 Ecological risk assessment

Risk is expressed as impact weighted with the probability of occurrence. The probability of introduction and establishment is evaluated first. The probability of spread and ecological impact is evaluated separately with the ISEIA-protocol (Branquart, 2009). Although several species have become established in introduction areas (e.g., *Perinereis linea* in Portugal, Arias *et al.,* 2013), no studies are available yet on the ecological impact. Therefore, the scores are based on expert judgement.

Probability of introduction
The probability of introduction is related to angler behaviour such as the release of unused bait (Anderson *et al.,* 2014; Arias *et al.,* 2013; Haska *et al.,* 2012; Keller *et al.,* 2007; Kilian *et al.,* 2012; Nathan *et al.,* 2014). This aspect will be briefly discussed, but a large survey to quantify the probability was not part of this study.

Probability of establishment
A general climate match analysis will be included based on distribution and/or thermal tolerance if data are available. The average monthly seawater temperatures in Dutch coastal waters vary between 0 °C in February and 20 °C in August (OSPAR, 2000). The salinity tolerance varies between live bait species and ranges from euryhaline species to stenohaline species and the latter category include species adapted to oligohaline (brackish water) to polyhaline (seawater) ecosystems (Saito *et al.,* 2014).

Ecological impact

There are two types of potential impact involved in this pathway: (1) the ecological impact of the directly imported alien species (Branquart, 2009); (2) the ecological impact of alien species hitchhiking in the transports, such as in the sediment or weeds used for packaging the live bait (Kilian *et al.,* 2012). Both types of impact will be addressed, but only the impact of the directly imported species will be scored with the ISEIA-protocol (Branquart, 2009).

For each species four aspects or parameters are evaluated: invasive potential, potential spread in vulnerable habitats, ecological impact on species and ecological impact on the ecosystem (Branquart, 2009). Each aspect gets an impact score (low=1, medium=2, high=3) provided that suitable ecological information is available. If the parameter is poorly documented there are two possible impact scores (impact is unlikely=1, or likely=2) and no score is given if no data are available (DD= data deficient). Each of the parameters is equally weighted. The global ISEIA-score is the sum of risk rating scores for the four parameters and is used to allocate species to different risk categories. Scores 4 at 8 indicate low risk, 9-10 medium risk and 11-12 high risk of negative ecological impact.

All brackish, estuarine and marine Natura 2000 areas in the Netherlands (Figure 3) were identified as “vulnerable habitats” in the sense of the ISEIA-protocol. These areas consist mainly of soft-sediment communities with salinities varying from oligohaline (brackish), estuarine (mesohaline) and marine (polyhaline). Therefore, salinity tolerance of an alien species is not very informative, as a “vulnerable habitat” with a suitable salinity is readily available in the Dutch coastal and marine waters.

If no data are available for the assessment, then a species is assigned to the low risk category. This implies that the precautionary principle is not applied in this risk assessment protocol. In other risk assessment protocols (e.g., Bomford, 2002) data deficient species are ranked in the high-risk category.

Figure 3. Map of Natura 2000 areas in the Netherlands in 2012, which includes all coastal Natura 2000 areas designated under the EU Habitat Directive (orange), EU Bird Directive (blue) or both (green)
(Source: www.compendiumvoordeleefomgeving.nl).

3 Bait supply and species

3.1 Supply of live bait: shops and websites

3.1.1 Shops and websites in the Netherlands

In 2015 marine polychaete worms were for sale in 67 shops, one farm and one webshop in the Netherlands (Appendix 1). In July 2015 worms were bought alive in a selection of eleven shops and one webshop (Table 1). The webshop sent the live bait by post in special insulated styrene boxes. Many shops, including the webshop, also offer American razor clams *Ensis directus* ("mesheften") as live bait. This invasive alien species was probably introduced with ballast water (Wolff, 2005) and is now widely distributed in Dutch coastal waters and estuaries. Furthermore, only the meat is used as bait and hardly any clams survive after use as bait. For this reason the American razor clam is excluded from this study.

The majority of shops in Table 1 offered both lugworms (*Arenicola* sp.) and ragworms (*A. virens*) for sale on their websites. Some shops offered *N. diversicolor* ("slikzagers") and a few also *Nephtys caeca* ("witjes", means little white worms).

With respect to the worms bought, most shops indicated if the worms were harvested in the wild ("steekzagers") or farmed ("kweekzagers"). Five different species were identified: *Arenicola marina* (indicated as harvested "zeepier"), *A. defodiens* ("Franse tap"), *Alitta virens* ("zager, steekzager, kweekzager"), *Nereis diversicolor* ("slikzager") and *Nephtys caeca* ("witjes") (Table 1).

Several shops offered both common lugworm and black lugworm alive separately and indicated with separate names (shops 9 and 11). Two shops (3 and 4) offered lugworms without separation between common or black lugworms and the samples included both species (Table 1).

All species found in the samples included native species or established alien species (*A. virens*) and no other alien species.

3.1.2. Shops and websites outside the Netherlands

Most websites offering saltwater live bait for sale are situated in Southeast-Asia and available through websites like Alibaba and include exclusively wholesale companies, which do not deliver to individual anglers. They offer a large variety of marine worms (polychaetes and sipunculids), which are both harvested in the wild and farmed. Several websites were checked and these all mentioned exports to Europe. Other large companies exclusively offering bloodworms are located in North-America (e.g., MaineBait.com).

Sportvisserij Nederland provided information about recent imports of marine worms for live bait from Southeast Asia to the Netherlands. These imports were confirmed by two companies and involved ragworms similar to *Nereis diversicolor* ("slikzagers") from Korea in 2012. The worms were ordered from Normandie Appats, Ranville, which is a large firm trading in live bait in France (see also Figure 4). They probably included a *Perinereis* species (Table 2).

Table 1. List of species of polychaete worms sold in 12 different shops and websites in the Netherlands, July 2015, with reference number the list of live bait shops in Appendix 1.

Species	Company	Description seller (Dutch)
Alitta virens	Albatros hengelsport, Scheveningen	Zagers
Alitta virens	Avicentra, Oostvoorne	Zagers 1
Alitta virens	Brouwers, Bergen op Zoom	Kweekzagers
Alitta virens	Eagle, Rotterdam	Kweekzagers
Alitta virens	Goedkopervissen.nl, Ijmuiden	Zagers
Alitta virens	Hengelsport Rik, Beverwijk	Zagers 2
Alitta virens	Hengelsport Rik, Beverwijk	Zagers 3
Alitta virens	Herman's Marine, IJmuiden	Kweekzagers
Alitta virens	Jan Peter, Vlissingen	Zagers
Alitta virens	Tofaas.nl, Oud-Vossemeer	Kweekzagers
Alitta virens	W. v. Leeuwen, Vlaardingen	Steekzagers
Alitta virens	W. v. Leeuwen, Vlaardingen	Kweekzagers (Topsy)
Alitta virens	t Zeepiertje, Yerseke	Kweekzagers
Alitta virens	Zagersenzeepieren.nl	Zagers
Arencola defodiens	Tofaas.nl, Oud-Vossemeer	Franse tap
Arenicola defodiens	Brouwers, Bergen op Zoom	Zeepier (steek)
Arenicola defodiens	Eagle, Rotterdam	Zeepier (steek)
Arenicola defodiens	t Zeepiertje, Yerseke	Franse tap
Arenicola marina	Avicentra, Oostvoorne	Zeepier
Arenicola marina	Brouwers, Bergen op Zoom	Zeepier (steek)
Arenicola marina	Eagle, Rotterdam	Zeepier (steek)
Arenicola marina	Jan Peter, Vlissingen	Zeepier
Arenicola marina	t Zeepiertje, Yerseke	Zeepier
Nephtys caeca	Zagersenzeepieren.nl	Witjes
Nereis diversicolor	Avicentra, Oostvoorne	Zagers 2
Nereis diversicolor	Brouwers, Bergen op Zoom	Slikzagers (kweek)
Nereis diversicolor	Goedkopervissen.nl, IJmuiden	Slikzagers
Nereis diversicolor	Hengelsport Rik, Beverwijk	Zagers 1
Nereis diversicolor	Tofaas.nl, Oud-Vossemeer	Slikzagers

Figure 4. Twelve different species, including several alien species of marine worms offered by Normandie Appats, Ranville, France (Source: website Normandie Appats). The scientific names of the species possibly involved are given in Appendix 1.

3.2 Demand and supply of marine live bait in the Netherlands

The annual demand of live bait by recreational fishers depends on the number of anglers and the annual number of fishing trips. This has been surveyed in 2003 - 2004 (Smit *et al.*, 2004) and nearly annually since 2009 (V§an der Hammen & de Graaf, 2013, 2015). The number of fishermen and number of fishing trips was estimated by panel surveys conducted by a commercial marketing company TNS-NIPO and included Online Screening Surveys and Random Digit Dialling (RDD) Phone Surveys. The recent surveys are due to the EU obligations to report the catch numbers of cod, eel, sharks and rays (Van der Hammen & de Graaf, 2013, 2015).

In December 2013 and January 2014 the estimates for the total number of anglers in the Netherlands were 1 million (RDD) and 1,3 million (Screening Survey, Van der Hammer & de Graaf, 2015)). The estimates for total number of sea anglers varied between 290.000 (RDD) and 504.000 (Screening Survey).

Van der Hammen & de Graaf (2013) estimated that sea anglers make on average 1.6 fishing trips per year. The number of 504.000 sea anglers estimated by the Screening Survey leads to 806.000 fishing trips each year. If 40 to 50 live bait items are used for each trip, then the total number of live bait items used annually by sea anglers is in the range of 32 to 40 million items. This corresponds to a total weight of 190.000 to 240.000 kg if all live bait items were lugworms. This estimate is in the same order of magnitude of 31 to 39 million lugworms *A. marina* (200.000 to 250.000 kg) and 30.000 kg (2-3 million worms) of farmed ragworms used as live bait by sea anglers in 2004 (Smit et al., 2004).

The web and shop survey showed that more species are offered and used as live bait by sea anglers, including *N. diversicolor* (slikzagers), *Nephtys caeca* (witjes) and *Ensis directus* (Amerikaanse zwaardschede, mesheften). However, there are no data available yet of the numbers involved in trade and during fishing trips.

In the Netherlands three companies (one in the Oosterschelde, two in the Wadden Sea) harvest lugworms commercially by dredging (75 % of the total lugworm supply in 1997, 50% in 2004, Smit et al., 2004). Commercial hand-digging takes place in various areas in the Wadden Sea and Oosterschelde to supply retail shops with fresh bait. Most ragworms used as live bait in the Netherlands originate from the only ragworm farm in the Netherlands In Zeeland. Sea anglers in the Wadden Sea dig their own bait on a regular basis. In the Oosterschelde lugworm digging is regulated through an annual permit that is included in the sea fishing licence (ZeeVISpas).

Currently the high demand for marine worms for use as live bait in coastal areas is completely met by commercial and recreational harvest of lugworms and ragworms and one ragworm farm. However, no new licenses for mechanical digging for lugworms in the Wadden Sea will be issued and therefore this activity will be ended on the long term. In addition, the supply of ragworms depends now on only one

company in the Netherlands. If for some reason this supply would become unavailable, then it cannot be excluded that marine worms would be imported on a large scale from outside Europe.

3.3 Overview of traded species worldwide

3.3.1 Marine worms

Species groups

Over twenty species of marine worms are involved in the live bait trade, belonging to two major taxonomic groups: Polychaeta (bristle worms and annelids) and Sipuncula (peanut worms) (Table 2). The bristle worms used as live bait include predatory worms with well-developed jaws (*Alitta, Perinereis, Namalycastis* and onuphid tube worms *Diopatra*) and lugworms (*Arenicola)*, which are deposit feeders (small organic material) living in burrows in the sediment. Peanut worms (*Sipunculus*) are also deposit feeders living in burrows in the sediment. Species identification, however, is in many cases unconfirmed or absent and scientific names given to traded worms should be treated with care. Several recent papers give up to date information on species status and taxonomy, including the description of new species (Arias & Paxton, 2015; Arias *et al.,* 2013; Berke *et al.,* 2010; Kawauchi & Giribet, 2014; Luttikhuizen & Dekker, 2010; Saito *et al.,* 2014; Wijnhoven & Dekker, 2010; and references in these publications. The common names (in English and Dutch) used in trade and the angling community are presented in Table 2.

Polychaeta

Polychaete worms used for live bait like ragworms and peanut worms are relatively robust worms (in particular in comparison to the soft lugworms *Arenicola*) and able to survive in wet, sea turf or oxygenated water for many days to several weeks at low temperatures. As a result, worldwide trade is possible and sealed and cooled containers are used for transport. *Alitta virens* is farmed on a relatively large scale in the UK (Seabait Ltd.; Olive, 1999) and the Netherlands (TopsyBaits, Wilhelminadorp, Zeeland) and exported worldwide as live bait for anglers and locally as food for cultured Sole (*Solea solea*). An increasing number of worm species are farmed in Australasia including *Diopatra* – species (Austasia Aquaculture Magazine, Vol. 21.4 Summer 2007-2008), and *Perinereis* cf. *nuntia* (Poltana *et al.,* 2007).

Lugworms (*Arenicola marina)* are less robust and survive for only a few days outside their natural habitat. They are harvested by hand (Delta and Wadden Sea) and mechanically (Wadden Sea) and sold only locally. Recently a sibling species of the common lugworm was newly described in 1993, the black lugworm *Arenicola defodiens* (in Dutch “Franse tap”) (Luttikhuizen & Dekker, 2010; Seys, 2001).
This species is larger (20-30 cm) and darker than *A. marina* (15-20 cm), lives in a J-shaped burrow with only one entrance/exit and occurs in deeper, sandier and more exposed areas up to the lowest parts of the intertidal area. Black lugworms are mainly harvested in France and Belgium and imported, usually frozen, to the Netherlands

(Het Visblad, 2014). This species was identified for the first time in the Netherlands in 2005 (Luttikhuizen & Dekker, 2010). It is also harvested in the Netherlands, but an overview of the harvest localities and the numbers of worms involved is currently lacking.

Source areas

There are three major source areas where marine worms are harvested and farmed: Europe (harvested in West- and South-Europe and farmed in the Netherlands and UK), Atlantic North-America (harvested) and Southeast-Asia (harvested and farmed, mainly in China, Korea, Taiwan, Vietnam) (Table 2). The highest demand is in areas where there is limited or no harvest from natural areas, including Pacific North-America, South-Europe (Mediterranean) and Japan (Cohen *et al.,* 2001; Passerelli, 2010; Saito *et al.,* 2014).

Figure 5. Marine worms.

Table 2. List of worm species globally traded for live bait with scientific name, source population, markets (available=offered but specific market unclear), references and remarks.

Species	Common name	Sources	Markets	References
Alitta virens	pileworm	Netherlands	Japan	Saito *et al*. 2014
Alitta virens	pileworm	Atl. N-America	Pacific USA, Italy, France	Gambi *et al*. 1994
Alitta virens	pileworm	Ireland,	UK, Spain, Italy	Gambi *et al*. 1994
Alitta virens	pileworm	Netherlands	UK, France, Spain, Italy	Olive 1994
Alitta virens	pileworm	Atl. N-America	Pacific USA (California)	Passarelli 2010
Arenicola defodiens	black lugworm	France, Belgium	Netherlands	this paper
Arenicola marina	lugworm	West-Europe	Europe	Olive 1994
Arenicola sp.	lugworm	China, Vietnam	available	Cohen 2012
Diopatra bilobata[2]	bloodworm	China	available	Cohen 2012
Glycera dibranchiata	bloodworm	Atl. N-America	Pacific USA, Italy	Gambi *et a*l. 1994
Glycera dibranchiata	bloodworm	Atl. N-America	Pacific USA (California)	Passarelli 2010
Glycera nicobarica	bloodworm	China	Japan	Saito *et al*. 2014
Glycera sp.[3]	bloodworm	China	available	Cohen 2012
Hediste versicolor	sand worm	France	Italy	Gambi *et a*l. 1994
Marphysa sanguinea	bloodworm	USA	Italy	Gambi *et a*l. 1994
Marphysa sanguinea	bloodworm	Korea	Japan, USA, France, Italy	Gambi *et a*l. 1994
Marphysa sanguinea	bloodworm	Italy	Southern Europe	Olive 1994
Marphysa sanguinea	bloodworm	China, Korea	available	Cohen 2012
Marphysa sp.[6]	bloodworm	Vietnam	available	Cohen 2012
Namalycastis abiuma[4]	nuclear worm	Vietnam	Atlantic USA	Mullady *et al*., 2000
Namalycastis abium[4]	nuclear worm	SE-Asia	Japan, Korea, Australia, Europe, Pacific USA	Cohen *et al*. 2001
Namalycastis sp.[4]	nuclear worm	Vietnam	Pacific USA (California)	Passarelli 2010
Nereis oxyopoda [5]	pileworm	China	available	Cohen 2012
Perinereis aibuhitensis	Korean lugworm	SE-Asia	Italy	Gambi *et a*l. 1994
Perinereis aibuhitensis	Korean lugworm	China, Korea	available	Cohen 2012
Perinereis brevicirris	Korean lugworm	Korea, Taiwan	USA, Europe	Olive 1994
Perinereis brevicirris	Korean lugworm	Taiwan	Japan	Saito *et al*. 2014
Perinereis cultrifera	Korean lugworm	France	Italy	Gambi *et a*l. 1994
Perinereis linea	Korean lugworm	NW-Pacific	Europe, Japan	Arias *et al*. 2013
Perinereis linea	Korean lugworm	China	Japan	Saito *et al*. 2014
Perinereis n. vallata[6]	Korean lugworm	China	available	Cohen 2012
Perinereis n. vallata[6]	Korean lugworm	Japan	Italy	Gambi *et a*l. 1994
Perinereis sp.	Korean lugworm	South-Korea	Pacific USA (California)	Passarelli 2010
Perinereis vancaurica	Korean lugworm	Korea	Italy	Gambi *et a*l. 1994
Sipunculus nudus[1]	peanut worm	Cosmopolitan	Europe	Fidalgo E Costa *et al*. 2006
Sipunculus nudus[1]	peanut worm	China	Japan	Saito *et al*. 2014

Notes to Table 1: [1]Includes over five cryptic species, Kawauchi & Giribet, 2014), [2] refers to *D. sukogai* (Saito *et al.,* 2014), [3] refers to *G. nicobarica* (Saito *et al.,* 2014), [4] refers to *N. rhodochore* (Saito *et al.,* 2014), [5] synonym with *N. succinea*, [6] refers to *P. wilsoni* (Saito *et al.,* 2014).

Table 3. List of commercially available marine polychaete worms is given with scientific name, common names in English and Dutch, geographical origin and status in the Netherlands. Only the alien species, which are not established and widespread in the Netherlands, are included in the risk assessment. For references see Table 2.

Scientific name	Common names (English)	Common names (NL)	Geographical origin	Status NL
Alitta virens	Ragworm, pileworm	zager, steekzager, kweekzager	France, Belgium, NL	alien
Arenicola defodiens	Black lugworm	Franse tap	France, Belgium, NL	native
Arenicola marina	Common lugworm, blow lug, red lug	zeepier, wadpier	France, Belgium, NL	native
Diopatra bilobata	Tube worm	n.a.	Japan	alien
Diopatra neonapolitana	Tube worm	n.a.	Portugal	alien
Diopatra biscayensis[1]	Tube worm	n.a.	Spain, France	alien
Diopatra marocensis	Tube worm	n.a.	Morocco	alien
Glycera dibranchiata	Bloodworm	n.a.	North America	alien
Glycera nicobarica	Bloodworm	n.a.	China	alien
Marphysa sanguinea	Bloodworm	bloedworm	Southeast Asia	alien
Namalycastis abiuma[2]	Nuclear worm	n.a.	Vietnam	alien
Nephtys sp.	Sandworm	witjes	France, Belgium, NL	native
Nereis diversicolor	Sandworm, pileworm	strandzager	France, Belgium, NL	native
Nereis oxyopoda	ragworm	n.a.		alien
Perinereis aibuhitensis	Korean ragworm	Koreaanse zager	SE Asia	alien
Perinereis brevicirris	Korean ragworm	Koreaanse zager	SE Asia	alien
Perinereis cultrifera	Korean ragworm	Koreaanse zager	SE Asia	alien
Perinereis linea	Korean ragworm	Koreaanse zager	SE Asia	alien
Perinereis nuntia	Korean ragworm	Koreaanse zager	SE Asia	alien
Perinereis vancaurica	Korean ragworm	Koreaanse zager	SE Asia	alien
Sipunculus nudus[3]	Peanut worm	pindaworm	Europe, SE Asia	native/ alien

[1] Recently described species (Berke *et al.,* 2010).

[2] Is probably another species, *Namalycastis rhodochore* (Saito *et al.,* 2014).

[3] Includes over five cryptic species (Kawauchi et Giribet, 2013).

3.3.2 Freshwater bait

Two groups of invertebrates are commonly used as live bait in freshwater angling: insect larvae (often called worms or maggots, including fly, beetle and moth larvae) and annelid worms (Tables 4 & 5). Several species of grasshoppers and crickets are also used in angling, for example trout fishing, but excluded from this overview because they are used on a relatively small scale in commercial trout ponds (c 50 are present in the Netherlands, http://www.vis-vakanties.nl/forelvijvers). Most insect species are also farmed to provide food for pets, like fish, reptiles and birds and commonly available in pet shops and angler shops. All groups (flies, beetles, moths and annelid worms) include alien species usually of subtropical to tropical origin, which are considered more suitable for storage and transport at room temperature than native species. Fly larvae (excluding black soldier fly) and annelid worms are most commonly used by most anglers in coarse fishing in public waters, beetle larvae and wax moths are mainly used in privately owned trout ponds (Remko Verspui, pers. comm.).

Table 4. List of 12 invertebrate species offered as live bait for freshwater angling with scientific name, common names and taxonomy.

Scientific name	Common names (English)	Common name larvae or alternative names	Common names (NL)	Phyllum
Hermetia illucens	Black soldier fly	calciworms	Zwarte wapenvlieg	Arthropoda
Lucilia sericata	Common greenbottle fly	maggots	Groene vleesvlieg	Arthropoda
Calliphora vomitoria	Bluebottle fly	maggots	Blauwe bromvlieg	Arthropoda
Tenebrio molitor	Mealworm	mealworm	Meeltor	Arthropoda
Zoophobas morio	Darkling beetle	superworm, zoophobas	Morio	Arthropoda
Galleria mellonella	Greater wax moth	waxies	Grote wasmot	Arthropoda
Achroia grisella	Lesser wfax moth	waxies	Kleine wasmot	Arthropoda
Eisenia hortensis / Dendrobaena veneta	European nightcrawlers	Dutch nightcrawler	Vissersworm	Annelida
Eisenia fetida	Redworm		Mestworm	Annelida
Eudrillus eugeniae	African nightcrawler		Mestworm	Annelida
Lumbricus terrestris	Common earthworm	lob worm, nightcrawler	Dauwworm	Annelida

Fly larvae

Two native species of fly larvae (maggots) are traditionally used as live bait, Common greenbottle fly (*Lucilia sericat a*) and Bluebottle fly (*Calliphora vomitoria*) (Tables 4 & 5). The larvae are commonly used as maggots (colour pale ivory white) or as pupae (colour brown) and known as casters. They are commercially farmed and distributed to shops and web-shops. The maggots are attached to the hook and both maggots and casters are also mixed with ground bait. At room temperatures the larvae quickly develop into pupae and adult flies and less suitable for angling. Cooling is therefore necessary during storage in shops and at home.

Recently, the larvae of the Black soldier fly (*Hermetia illucens*) have become commercially available as pet food and sometimes suggested as fishing bait, but are not used by anglers because of their low mobility at lower temperatures. This species originates from warm temperate parts of North-America and the larvae need higher temperatures for development. The larvae are somewhat larger than maggots and at room temperature development is relatively slow, which makes the species more suitable for commercial trade. The larvae feed on plant material, such as fallen vegetation and fruits, compost heaps and manure.

Beetle larvae

The larvae of two beetle species are used as live bait: mealworm (*Tenebrio molitor*) and Darkling beetle (*Zophobas morio*) (Tables 4 & 5). The first is cosmopolitan nuisance species and lives mainly indoor in dry places with room temperature on flour, grains and cereals. Darkling beetles have a subtropical to tropical origin and need higher temperatures for development. The larvae are larger than mealworms and at room temperatures the larvae develop more slowly, which makes them more suitable for commercial purposes (e.g., Leung et al., 2012).

Wax moths

Two species of wax moths are used as live bait: Greater wax moth (*Galleria mellonella*) and Lesser wax moth (*Achroia grisella*) (Tables 4 & 5). The caterpillars of wax moths live in beehives and consume wax. Greater wax moth is a native species, Lesser wax moth is a cosmopolitan species and both are a nuisance species in apiculture. The larvae are commonly farmed for commercial trade as food for pets and live bait and do not need to be stored at low temperatures as they develop rather slowly at room temperatures (e.g., Stairs, 1978).

Annelid worms

Several species of annelid worms are used as live bait, including three native species (*Eisenia hortensis (also known as Dendrobaena veneta), E. fetida, Lumbricus terrestris*) and one non-native (*Eudrillus eugeniae*). All species are farmed to meet the considerable demand almost exclusively for recreational fishing. The former three species have been introduced in North-America, where they are now widespread invasive alien species with a considerable impact on biodiversity, in particular in deciduous forests (bron). Apparently, Common earthworms (*Lumbricus terrestris*) can grow to larger sizes in Canada compared to Europe and are now imported to the Netherlands (see website baitshop.nl, also known as Canadian nightcrawlers).

Tiger nuts

Self-hooking systems with solid, artificial baits (“boillies”) have become very popular in carp fishing (e.g., Niesar *et al.,* 2005). Recently, tiger nuts, the tubers of Chufa (*Cyperus esculentus* var. *sativus*)*,* have become commercially available and are now widely used as bait for carp fishing (e.g., Ezeh *et al.,* 2014), as they are nutritious, tasty and similarly sized as artificial carp baits. These tubers always have to be soaked in water for 24 hours and then boiled for at least 20 minutes until they are

tender and fully expanded. Some anglers leave the tubers to ferment for 1 – 2 days to enhance the attractiveness and effectiveness as bait. If the tubers are not properly prepared, they can be very toxic to the carp.

Yellow nutsedge (*C. esculentus*) is also known as an invasive alien species and a persistent weed in agriculture, in particular in potato and cornfields (de Vries, 1991; Holm *et al.,* 1977) and has been recorded in the Netherlands as well (Rotteveel, 1993). When used in large quantities by anglers, there is a possibility that "leftovers" of uncooked tiger nuts are disposed in gardens or natural areas (cf. marine and freshwater bait, Anderson *et al.,* 2014; Keller *et al.,* 2007; Kilian *et al.,* 2012; Nathan *et al.,* 2014) or are introduced in gardens, agricultural and natural areas as a result of spillage during handling.

Table 5. List of 12 invertebrate species offered as live bait to freshwater anglers with origin, status in the Netherlands, size and natural habitat.

Scientific name	Common names (English)	origin	Status NL	Remarks	Size	Habitat
Hermetia illucens	Black soldier fly	warm temperate	alien	not yet recorded NL, established South-Europe	3-19 mm	soil (detrivore)
Lucilia sericata	Common greenbottle fly	temperate	native		10 mm	carrion
Calliphora vomitoria	Bluebottle fly	temperate	native		10 mm	carrion
Tenebrio molitor	Mealworm	cosmopolitan	native	cosmopolitan	1-5 cm	seeds in soil or litter
Zoophobas morio	Darkling beetle	tropical south - middle America	alien		5 cm	seeds in soil or litter
Galleria mellonella	Greater wax moth	Eurasia	native	IAS in North-America, nuisance species in bee hives	20 mm	bee colonies
Achroia grisella	Lesser wax moth	cosmopolitan	native	nuisance species in bee hives	13-16 mm	bee colonies
Eisenia hortensis / Dendrobaena veneta	European nightcrawlers	Europe	native	IAS North-America	5 cm	soil
Eisenia fetida	Redworm	Europe	native	IAS North-America	5 cm	soil
Eudrillus eugeniae	African nightcrawler	West Africa	alien	established South-Europe	5 cm	soil
Lumbricus terrestris	Common earthworm	Europe	native	IAS North-America, imported to Europe	12-15 cm	soil

4 Ecological Risk Assessment

4.1 Risk assessment of marine worms

Five species of marine polychaete worms are offered for sale, which originate from natural harvest and one worm farm in the Netherlands (*A. defodiens* is a native species but also harvested in and imported from Belgium and France) and used as live bait in the Netherlands (Table 1). Over twenty species of polychaete worms of at least nine different genera are traded globally and reported in the scientific literature (Tables 2 & 3). These include several genera with native species (*Arenicola, Nereis, Nephtys*), which are also offered for sale in the Netherlands and for which a risk assessment is not necessary (Table 3). This also applies to *Alitta virens,* an invasive alien species, which has become established in many areas worldwide and in the Netherlands since 1915 (Didderen *et al.,* 2015).

The peanut worm *Sipunculus nudus* was until recently considered a cosmopolitan species, which is also native to the Netherlands. However, new genetic studies have shown that it consists of at least five different cryptic species (Kamauchi & Giribet, 2014), which have not yet received formal taxonomic names. Therefore, imports of "*Sipunculus nudus*" worms from outside Europe should be considered as alien species (Table 3).

The following genera include one or more species, which are not native in Europe and the Netherlands: *Alitta*, *Diopatra, Glycera, Marphysa, Namalycastis* and *Perinereis* (Table 3) and include species from temperate, subtropical and tropical climate zones (Table 6). The genus *Arenicola* includes *A. defodiens*, which is harvested in the Netherlands, but also imported from France and Belgium.

4.1.1 Probability of introduction

A substantial number of studies have shown that the introduction of alien species in aquatic ecosystems has been caused by the release of certain baits (e.g., Carlton, 1992; Ludwig & Leitch, 1996, Weigle *et al.,* 2005). The release occurs mainly by emptying bait buckets after fishing sessions, which occurs according several studies in a substantial proportion of fishing sessions (Anderson *et al.,* 2014; Arias *et al.,* 2013; Keller *et al.,* 2007; Kilian *et al.,* 2012; Nathan *et al.,* 2014). Considering the large number of fishing sessions in the Netherlands (§ 3.2) the overall introduction risk of bait species, disregarding which species are involved, is considered to be substantial.

4.1.2 Probability of establishment

The thermal environment determines to a large extent if an introduced species can become established in a new area. Winter temperatures generally determine winter survival, the highest seawater temperature during August generally determines if a species can reproduce. The salinity tolerance, determines if a species can occur in brackish, estuarine or marine environments but is not included in Table 6 for the following reason. The Dutch coastal and marine Natura 2000 areas include the whole salinity range and, therefore, salinity tolerance is not very informative about the probability of establishment in coastal and marine Natura 2000 areas. In addition, many polychaete worm species have a relatively broad salinity tolerance range.

Table 6. List of species of polychaete worms presented with native range, introduction areas and areas of establishment, thermal range , with reference (1= Saito et al., 2014, 2=EoL) and remarks on taxonomy (including accepted or most likely names).

Species	Native range	Introduction range	Established	Thermal range (°C)	Ref	Remarks
Alitta virens	Netherlands	Japan	Japan	mei-30	1	
Alitta virens	America, Europe	America, Europe	America, Europe	03-dec	2	
Arenicola defodiens	Europe	Europe	n.a.			
Arenicola marina	Europe	Europe	n.a.	-14	2	
Arenicola sp.	China, Vietnam	available	n.a.			
Diopatra bilobata	China	available	n.a.			*D. sugokai*
Diopatra biscayensis	Spain, Portugal, France	?	?			spreading northward
Diopatra cuprea	Atlantic N-America	?	?	jul-28	2	
Diopatra marocensis	Morocco	Portugal	Portugal			
Glycera dibranchiata	Atlantic N-America	Europe	?	jul-24	2	
Glycera nicobarica	China	Japan	Japan	mei-30	1	
Glycera sp.	China	available	n.a.			*G. nicobarica*
Hediste versicolor	France	Italy	?			
Marphysa sanguinea	Atlantic, Pacific, Indian Ocean, Red Sea,	Japan, USA, Europe	Japan, USA, Europe			
Marphysa sanguinea	China, Korea	available	n.a.	mei-30	1	
Marphysa sp.	Vietnam	available	n.a.	20-35	1	*M. cf mossambica*
Namalycastis abiuma	SE Asia	USA, Australia, Europe	?	20-35	1	*N. rhodochore*
Nephtys sp.	Europe	Europe	n.a.	jun-20	2	
Nereis diversicolor	Europe	Europe	n.a.	07-dec	2	
Nereis oxyopoda	China	available	n.a.	feb-28	2	*N. succinea*
Perinereis aibuhitensis	SE Asia	Europe	?			Valid species
Perinereis aibuhitensis	China, Korea	available	n.a.			
Perinereis brevicirris	SE Asia	Japan, USA, Europe	?			
Perinereis cultrifera	Europe	Europe	?			
Perinereis linea	NW-Pacific	Europe	Spain	mei-30	1	
Perinereis linea	China	Japan	Japan			
Perinereis nuntia	Pacific, Indian Ocean	Eastern Mediterranean	Eastern Mediterranean			Lessepsian migrant
Perinereis nuntia vallata	Japan	Italy	?			*P. wilsoni*
Perinereis nuntia vallata	China	available	n.a.			*P. wilsoni*
Perinereis spp.	Korea	Japan, France	?			
Perinereis vancaurica	Indian Ocean	Italy	?			*P. linea*
Sipunculus nudus	Cosmopolitan	Europe	n.a.	sep-24	2	>5 species
Sipunculus sp.	China	Japan	Japan			>5 species

4.1.3 Ecological impact

Following the risk assessment ISEIA-protocol (Branquart, 2009) four aspects are evaluated for each species: invasive potential, potential spread in vulnerable habitats (e.g., Natura 2000 areas), ecological impact on species and ecological impact on the ecosystem. Only the ecological impact of directly imported species has been assessed, the possible impact of hitchhiking alien species in the transports is only briefly addressed.

Table 7. Ecological impact of alien species of marine polychaete worms according to the ISEIA-protocol (Branquart, 2009). For an explanation of the parameters and scores, see method section. Species with low risk are marked green, with medium risk are marked orange and data deficient species (DD) are not marked.

species	climate match	ISEIA					reference
		invasive potential	vulnerable habitats	impact species	impact ecosystem	total ISEA score	
Diopatra biscayensis	2	2	3	2	3	10	Cohen 2012
Diopatra marocensis	1	DD	DD	DD	DD	4	Berke *et al.* 2010
Glycera dibranchiata	3	3	3	2	2	10	Gambi *et al.* 1994
Glycera nicobarica	3	3	3	1	1	8	Saito *et al.* 2014
Glycera sp.[1]	3	3	3	1	1	8	Cohen 2012
Marphysa sanguinea	3	3	3	1	3	10	Cohen 2012
Marphysa sp.[2]	1	3	3	1	3	10	Cohen 2012
Namalycastis rhodochore	1	1	1	1	1	4	Cohen *et al.* 2001
Perinereis aibuhitensis	3	3	3	2	2	10	Cohen 2012
Perinereis brevicirris	3	DD	DD	DD	DD	4	Olive 1994
Perinereis cultrifera	3	DD	DD	DD	DD	4	Gambi *et al.* 1994
Perinereis linea	3	3	3	2	2	10	Arias *et al.* 2013
Perinereis nuntia	3	DD	DD	DD	DD	4	Olive 1994
Perinereis nuntia vallata	3	DD	DD	DD	DD	4	Cohen 2012
Perinereis vancaurica	3	DD	DD	DD	DD	4	Gambi *et al.* 1994
Sipunculus nudus[3]	3	3	3	1	1	8	Fidalgo E Costa *et al.* 2006
Sipunculus sp.[3]	3	3	3	1	1	8	Saito *et al.* 2014

[1] *Glycera nicobarica* (Saito *et al.,* 2014)

[2] *Marphysa* cf. *mossambica* (Saito *et al.,* 2014)

[3] Includes over five cryptic species (Kawauchi & Gilibert, 2014)

Alitta *A. virens* is a large, predatory worm, and considered an alien species, which has become established in the Netherlands since 1915. The company farms this species in large numbers and they supply many shops, which sell ragworms in the Netherlands and over 14 countries worldwide (Cohen *et al.,* 2001; Cohen, 2012; Passerelli, 2010; Saito *et al.,* 2014, (see also section 3.1). The ISEIA-score is not relevant, because it is an established species. *A. oxypoda (synonym of Nereis succinea*) is smaller sized (usually smaller than 15 cm) than *A. virens* and the Glycerid and Ophunid worms and it is expected that the ecological impact could be less in comparison. The overall ISEIA-score is (8 = low risk).

Arenicola The black lugworm *Arenicola defodiens* (in Dutch "Franse tap") was discovered in 1993 as a new, sibling species of the common lugworm (Cadman & Nelson-Smith, 1993; see also Luttikhuizen & Dekker, 2010; Seys, 2001). This species is larger (20-30 cm) and darker than *A. marina* (15-20 cm), lives in a deep (up to 75 cm), J-shaped burrow with only one entrance/exit and occurs in deeper, sandier and more exposed areas up to the lowest parts of the intertidal. Black lugworms are harvested in France and Belgium and imported, mainly in a frozen state, to the Netherlands (Het Visblad, 2014). This species was identified for the first time in the Netherlands in 2005, but its exact distribution and abundance and commercial harvest is still relatively unknown (Luttikhuizen & Dekker, 2010).

Diopatra Ophunid tubeworms are predatory polychaete worms that build large, emergent tube structures in tropical and temperate marine sediments worldwide. Several species are internationally traded as live bait, including *D. sukogai* from Southeast Asia (Saito *et al.,* 2014). *D. neopolitana* is harvested in Portugal for the local market (Cunha *et al.,* 2005). In Australia the farming of *D. aciculata* has been started to supply locally recreational fishermen and aquaculture (Austasia Aquaculture Magazine, Vol. 21.4 Summer 2007-2008).

In Western Europe, *Diopatra biscayensis* is undergoing a range expansion of over 350 km along the Atlantic coast of France in a period of 80 years (Berke *et al.,* 2010). This species was recently described and is considered to be native to Western Europe (Arias & Paxton, 2015). *D. biscayensis* is an ecosystem engineer, which causes the sediment to stabilize and is able to invade habitats dominated by bioturbating common lugworms *A. marina* and may become the dominant species itself. As a result, the estuarine soft-sediment ecosystem will switch from a dynamic to a more stable state with more macroalgae and higher algal biomass (Berke *et al.,* 2010). Woodin *et al.* (2014) argue that mussel transports have contributed more to the northward expansion than larval dispersal, in particular to the most recent settlements within the Normano-Breton Gulf in the English Channel.

Diopatra marocensis is a native species in Morocco and was recently found along the Atlantic coast of France as result of an introduction, but the pathway was unknown (Berke *et al.,* 2010).

The ecosystem changes resulting from invasion of *D. biscayensis* leads to a relatively high ISEIA-score (10=medium risk), if this species or other *Diopatra* tubeworm species from temperate climate zone would be introduced in Natura 2000 areas in the Netherlands as a result of live bait imports or otherwise (Table 7).

Glycera Glycerid worms (bloodworms) are predatory, polychaete worms, which live in intertidal to subtidal soft sediments in temperate to subtropical regions. The largest numbers of bloodworms (*Glycera dibranchiata*) are harvested in Atlantic North-America, which are shipped to Pacific North-America and Europe (Table 1, Cohen *et al.,* 2001; Cohen, 2012; Passerelli, 2010). Smaller numbers of *G. nicobarica* are

harvested in Southeast Asia (mainly China) to Japan (Saito *et al.,* 2014) and could potentially exported to Europe and North-America (Cohen, 2012). Both species have a moderate to good climate match. As they potentially can become established in estuarine Natura 2000 areas and as a large, predatory species have a substantial impact on the food web, they received a relatively high ISEIA-score (10=medium risk).

Nereis This genus includes the native species *Nereis diversicolor* (accepted name *Hediste diversicolor*), which is sold as live bait in the Netherlands (Table 1) and exported from France to Italy (Cohen *et al.,* 2001). Formerly it included also *Nereis (Alitta) oxypoda* (accepted name: Alitta (*Nereis) succinea)*, also known as clamworm, Table 5), which is offered on Southeast Asian websites (Cohen, 2012). The latter species could potentially be exported to Europe and North-America (Cohen, 2012). There is a good climate match (Table 5) and it is likely that this species will become established in vulnerable Natura 2000 areas in the Netherlands. However, recently it was found to be a synonym of *Alitta succinea*, which is a native species in the Netherlands (reference in WoRMS). The ISEIA-score is therefore not relevant.

Marphysa This genus includes the temperate zone species *Marphysa sanguinea*, which has been introduced to the sandy to muddy intertidal areas of the Oosterschelde (Wijnhoven & Dekker, 2010). Other *Marphysa* species occur in subtropical to tropical areas including *M*. cf. *mossambica*, which is used as live bait in Japan (Saito *et al.,* 2014). Both species are harvested and traded worldwide as live bait (Cohen *et al.,* 2001; Cohen, 2012; Gambi *et al.,* 1994; Saito *et al.,* 2014). *M. sanguinea* has become established as an invasive alien species in many countries worldwide (references in Wijnhoven & Dekker, 2010) as a result of the live bait trade, but also in relation to mollusc transports in aquaculture. *M. sanguinea* is a relatively large (over 30 cm), predatory worm with a reddish colour and therefore is also called bloodworm in the live bait trade, similar to the unrelated *Glycera dibranchiata*. The situation has become more complex as *Marphysa sanguinea* was recently found to consist of several cryptic species (references in Wijnhoven & Dekker, 2010). *Marphysa* species imported from Southeast Asia (for example available at Normandie Appat as “Mouron”) might include other species than *M. sanguinea*. As *M. sanguinea* has already has become established in estuarine Natura 2000 areas and as a large, predatory species can have a substantial impact on the food web, it received a relatively high ISEIA-score (10=medium risk). This will also apply to other *Marphysa* species from temperate areas like China or Korea.

Namalycastis This genus includes large (up to 1,5 -2 m), predatory worms, which mainly live in subtropical to tropical areas in Southeast Asia. They are harvested in several countries, in particular Vietnam, and exported to North-America and Europe to be used as live bait and sold as “Nuclear worms” or “Supercordelle” (Cohen *et al.,* 2001; Cohen, 2012; Miller *et al.,* 2004; Passerelli 2010; website Normandie Appats). In these publications is referred to *N. abiuma* or *Namalycastis* sp. Recently it was described as a new species *N. rhodochorde* (Glasby *et al.*, 2007) and used by Saito et al. (2014). *N. rhodochorde* is an euryhaline species (5 – 30 psu), which lives in

intertidal mudflats of estuaries with mangroves in Vietnam, Indonesia and Malaysia and has a temperature tolerance range of 20 – 35 °C. Miller et al. (2004) showed that imported *Namalycastis* sp. (most likely *N. rhodochorde*) from Vietnam was able to survive at lower temperatures (up to 13 °C). This implies that *N. rhodochorde* is not able to survive the temperate climate in the Netherlands (no climate match, Table 7) and the resulting ISEIA-score is (4=low risk).

Perinereis Several species are harvested in Southeast Asia (China, Japan, Korea) and imported in North-America, Europe and Japan as live bait often under the name "Korean ragworm" or "Korean lugworm" (Arias *et al.,* 2013; Cohen *et al.,* 2001; Cohen, 2012; Fidalgo E Costa *et al.,* 2006; Gambi *et al.,* 1994; Saito *et al.,* 2014). In the period 2002 – 2003 up to 15 million "Korean ragworms", which were identified as *P. aibuhitensis,* were transported annually through Lisbon Airport, mainly as transits to Spain (Fidalgo E Costa *et al.,* 2006). This species is a medium-sized (10-15 cm) predatory worm. It is thought to be able to compete with native polychaetes, for example, *Nereis (Hediste) diversicolor* lives in the intertidal, in the same range of salinity and similar spawning period, if it would become established (Fidalgo E Costa *et al.,* 2006). There is a good climate match with part of its distribution area (e.g., Korea) and the total ISEIA-score is (10-medium risk).

P. linea has become established in the Mar Menor Lagoon, near Murcia, Spain, as a result of introduction by the use as live bait (Arias et al., 2013). This shallow, soft-sediment lagoon is hypersaline with temperature range of 11 – 32 °C. *P. linea* has a wide distribution along the coasts of China and Korea and lives in estuarine areas with large fluctuations in temperature and salinity (Arias et al., 2013). The establishment of *P. linea* in the hypersaline Mar Menor Lagoon shows that this species is able to adapt to a wide range of conditions. The thermal range of 5 – 30 °C suggests that there is a good climate match, which also fits to its distribution range up to Korea and Japan (Saito et al., 2014). The total ISEIA-score is (10=medium risk).

Sipunculus Peanut worms *Sipunculus nudus* are medium-sized (up to 15 cm) worms, which live in muddy or sandy sediments in the intertidal and subtidal down to depths of 900 m (Kawauchi & Giribet, 2014; Murina, 1984). They are deposit feeders and inhabit shallow burrows. Peanut worms are harvested in China and Vietnam (but also Europe) and exported to Europe and North-America and Japan to be used as saltwater live bait and known as "Bibi" (Cohen et al., 2001; Cohen, 2012; Fidalgo E Costa et al., 2006; Gambi et al., 1994; Saito et al., 2014).

This cosmopolitan species was recently identified to consist of at least five cryptic species (Hsu et al., 2013; Kawauchi & Giribet, 2014). Therefore, imports from Southeast Asia should be treated as alien species, different from the native *S. nudus,* although they have not received separate scientific names yet. Although the thermal tolerance range of the Asiatic species is not yet known, there is probably a good climate match with the peanut worms imported from China. If one of these species would become established in the Netherlands, the ecological impact is expected to be

small, because of its position in the food web and relatively low densities of the native species. This results in an ISEIA-score of (8=low risk).

4.2 Risk assessment freshwater bait

Table 8. Ecological risks of alien freshwater bait species (fly, beetle and moth larvae and annelid worms) if spilled in terrestrial habitats. Parameter scores are according to the ISEIA protocol (low=1, medium=2, high=3), total score is the sum of the four parameter scores. The alien species with low risks are indicated in green.

			ISEIA					
Species	**origin**	**status**	**climate match**	**invasive potential**	**vulnerable habitats**	**impact species**	**impact ecosystem**	**total score**
Hermetia illucens	warm temperate	alien	low	1	1	1	1	4
Zoophobas morio	tropical south - middle America	alien	low	1	1	1	1	4
Eudrillus eugeniae	West Africa	alien	low	1	1	1	1	4
Lumbricus terrestris	Europe/ Canada	native	high	*3*	*1*	*1*	*1*	*6*

Tiger nuts

Tiger nuts (*C. esculentus* var. *sativus*) is an ancient crop and grown globally in nearly all continents (de Vries, 1991; Ezeh *et al.,* 2014). It is often confused with the closely related weed Yellow nutsedge (*C. esculentus*), which is one of the worst weeds in the world (Holm *et al.,* 1977). We assume that most tiger nuts used in the Netherlands as bait for carp fishing have been produced as a crop most likely in Spain (e.g., tigernuts.com) and does not include the weed Yellow nutsedge. In addition, tiger nuts used as carp bait are always boiled, because the raw tubers contain substances, which are toxic for carp. Although tubers could be potentially introduced in natural and agricultural areas by spillage during handling of raw tubers, the risk for biodiversity and agriculture is considered to be low because it concerns the crop variety and not the invasive alien weed. Therefore, no further inquiries were made with respect to the introduction risk.

Fish

Because fish are not permitted as live bait in the Netherlands and the transport of baitfish with bait buckets does not occur on a large geographical scale we believe it does not lead to ecological risks.

Invertebrates

Probability of introduction and establishment

Spillage of live bait during transport and after use by anglers has been an important source of introductions of invasive alien species, in particular annelid worms (Keller et al. 2007; Hale *et al.,* 2005; Hendrix *et al.,* 2008). However, only two alien species are used as live bait for coarse fishing in the Netherlands: African nightcrawler (*Eudrillus eugeniae)* and Darkling beetle (*Zoophobas morio*) (Table 6). As these species originate from subtropical to tropical areas the probability of establishment is considered to be low in natural, terrestrial areas in the Netherlands.

Ecological impact
Virtually all invertebrate species used as freshwater bait are terrestrial species and therefore do not impose any ecological risks to the biodiversity of freshwater in the Netherlands.

The African night crawler *Eudrillus eugeniae* originates from West-Africa and is globally used for vermicomposting and as live bait (Tomlin, 1983). Although it is cultured in the Netherlands mainly for vermicomposting, it has not been recorded yet in the wild.

A special case is *Lumbricus terrestris,* which has been introduced to North-America (Hale *et al.,* 2005; Hendrix et al. 2008) where it developed into an invasive alien species. It is has become so common on Canadian golf courses that they are commercially harvested and exported to North-America and Europe, including the Netherlands. Here it is sold as live bait, because of its size, which is larger than the worms farmed and harvested in the Netherlands (e.g., baitshop.nl). Although DNA barcoding has revealed cryptic diversity in this species and is now considered to be two species *L. terrestris* and *L. herculeus*, only *L. terrestris* has been found in North-America (James *et al.,* 2010). It is unknown if alien pathogens and parasites could be introduced in the Netherlands with these imports.

4.3 Additional risks

Hitchhiking species
In the Netherlands most worms are transported in seawater, sediment, sea turf or just wet paper (pers. obs.). Weeds are rarely used as package material and the risk of larger hitchhiking organisms is considered to be low.

Pathogens and parasites
Microorganisms, such as viruses, bacteria and fungi could be hitchhiking in the sediment (Mulladi *et al.,* 2000; Cohen *et al.,* 2001) or in the transported species (Olive, 1994). Parasites also occur in marine worms (e.g., ciliates in *Perinereis linea*, Arias *et al.,* 2013), but are outside the scope of this report.

Allergic reactions
Several large, predatory worms (e.g., *Glycera dibranchiata* and *Alitta virens*) have large jaws and will bite anglers during handling, which occasionally can cause allergic reactions (Félix-Toledo *et al.*, 2005). Several species of worms use as live bait evoke allergic reactions in particular after prolonged use (*Glycera dibranchiata, Perinereis cultrifera, Marphysa sanguinea, Nereis diversicolor, Sipunculus nudus*, Félix-Toledo *et al.,* 2005 and references therein).

4.4 Management options

4.4.1 Code of Conduct or Practice for Sea Angling

Sportvisserij Nederland has published a Code of Conduct Sea Angling (Gedragscode Zeehengelsport) on her website (www.sportvisserijnederland.nl). Two articles are relevant for the risk of introducing alien species through the use of live bait: article 4 – Environmental friendly angling and 8 – Follow the rules for bait harvest. Article 4 advised anglers to take home all waste, which is produced during a day of fishing. Article 8 is limited to the local harvest of live bait. In both articles the potential risk of introducing alien species by the use of imported live bait is not mentioned.

The FAO European Inland Fisheries and Aquaculture Advisory Commission (EIFAC) has adopted a Code of Practice for Recreational Fisheries (EIFAC, 2008) and includes an article about the risk of introducing alien species by the use of live bait. Under Article 8 Recreational fishing practices is stated:
"*8.11 do not stock, introduce or transfer live fish or other aquatic organisms within or between catchments without permission from the authorities. This applies particularly to non-native organisms*;"

The Bern Convention has recently published the European Code of Conduct on Recreational Fishing and Invasive Alien Species (Owen, 2013). Under 3.2 Fisheries Management is stated that recreational fisheries should:
"*Prevent, the release, spread and translocation of invasive alien species that have impacts on native fish populations or the environment*" and "*Use bait, particularly live bait, only in agreement with local or national regulations and use aquatic organisms only in the water body from which these were collected; never transfer aquatic live bait from one water body to another*".

These articles are not yet implemented in the current Dutch Code of Conduct Sea Angling.

4.4.2 Increasing public awareness

In North-America there is much attention to the problem of alien species introductions resulting from the use of live bait and hitchhiking species in bait buckets (Anderson *et al.*, 2014; Haska *et al*., 2012; Keller *et al.*, 2007; Nathan *et al*., 2014). Several studies have shown that this increase in public awareness stimulates anglers to avoid

discarding bait buckets in natural areas and helps to reduce the risk of alien species introductions (Nathan *et al*., 2014)

4.4.3 Management plans Natura 2000 area

Large parts of the coastal areas of the Netherlands are protected under the EU Habitat Directive and designated as Natura 2000 sites (Vlakte van de Raan, Voordelta, Westerschelde, Oosterschelde, Grevelingen, Haringvliet, Noordzee-kustzone, Waddenzee en Eems-Dollard. A management plan has been implemented for each Natura 2000 area. As part of the Oosterschelde and Wadden Sea management plans special areas have been designated for common lugworm *Arenicola marina* harvest under licence by anglers (Oosterschelde) and bait harvest companies (Oosterschelde, Wadden Sea). The risk of introducing alien species by the use of live bait is not addressed in these management plans, neither in any other coastal Natura 2000 area management plan.

5 Conclusions and discussion

5.1 Live bait trade and ecological risks

The use of live bait in salt water is very different compared to fresh water. Saltwater live bait includes only marine species, such as worms and shellfish, while in fresh water mainly terrestrial insect larvae, annelids worms and plant tubers or seeds are used. In general, the risks of introducing alien species with live bait in fresh water habitats are very low, as terrestrial species do not survive in water. This is very different to the marine species used as live bait in salt water, which generally have a high survival rate if discarded alive. Therefore, in this study most attention has been given to marine species. The ecological risk of alien species is generally determined by the probability of introduction, establishment and spread weighted by the ecological impact on native species and ecosystems. These components have been estimated by inspection of the supply in a selection of shops in the Netherlands and through a web search in combination with a literature review with respect to probability of establishment and spread and ecological impacts.

Supply of live bait

In the Netherlands the considerable demand of salt water live bait is currently completely met by the commercial and recreational harvest of lugworms and ragworms in coastal areas and one ragworm farm in Zeeland. American Razor clams are also used as live bait, but are widely established in the Dutch coastal waters and therefore not included in this study. In 2015 five species of worms were found to be for sale in a selection of 11 shops (out of 67 shops and one webshop in total). These included the native species *Arenicola marina, A. defodiens, Nephtys caeca* and *Hediste (Nereis) diversicolor*, and one alien species *Alitta virens*. The latter species is already established and widespread in the Netherlands.

International trade in marine live bait has been made possible by storage at low temperature and transport by air. Our review of recent scientific literature showed that over twenty species of marine worms (including mainly bristle worms and peanut worms) are globally traded. These results are complicated by the general lack of accurate identification and occurrence of newly discovered cryptic species.

Source areas marine live bait

There are three major source areas where marine worms are harvested and farmed: Europe (harvested in Western and Southern Europe and farmed in the Netherlands and UK), Atlantic North-America (harvested) and Southeast Asia (harvested and farmed, mainly in China, Korea, Taiwan, Vietnam). Marine worms imported from Asia and North-America are, for example, offered by large firm in Northern France. If the local supply of marine worms would strongly decrease, then a scenario that marine worms would be imported to the Netherlands from outside Europe or through European retail shops seems likely.

Risk assessment saltwater live bait

Hitchhiking species
In the Netherlands worms are usually transported in seawater, sediment, sea turf or just wet paper. Seaweeds are rarely used as package material and the risk of larger hitchhiking organisms is considered to be low. Microorganisms, such as viruses, bacteria and fungi could be hitchhiking in the sediment or in the transported species. Parasites also occur in marine worms, in particular if they are imported from outside Europe (e.g., ciliates in *Perinereis linea*), but are outside the scope of this report.

Directly introduced species
Over twenty species of polychaete worms of at least nine different genera are traded globally and also available in Europe (e.g., Northern France). These include several genera with native species (*Arenicola, Nereis, Nephtys*) for which a risk assessment is not necessary. *Alitta virens* is an invasive alien species, which has become established in many areas worldwide and in the Netherlands since 1915. A risk assessment is therefore not relevant.

The peanut worm *Sipunculus nudus* was until recently considered a cosmopolitan species, which is also native to the Netherlands. However, new genetic studies have shown that it consists of at least five different cryptic species, which have not yet received formal taxonomic names. Therefore, it is recommended that imports of "*Sipunculus nudus*" worms from outside Europe be considered as alien species.

The following genera include one or more species, which are not native in Europe and the Netherlands: *Alitta*, *Diopatra, Glycera, Marphysa, Namalycastis* and *Perinereis* and include species from temperate, subtropical and tropical climate zones. The genus *Arenicola* includes *A. defodiens*, which is harvested in the Netherlands, but also imported from France and Belgium.

The species from subtropical and tropical climates fell in the low risk category, because the probability of establishment is low (several species of *Diopatra*, *Marphysa* and all *Namalycastis* species). Several species from temperate climate zone fell in the medium risk category, including the predatory worms *Diopatra biscayensis* ("tubeworms"), *Glycera dibranchiata* ("bloodworms"), *Perinereis aibuhitensis* and *Perinereis linea* ("ragworms"). They are able to colonise soft sediments, which are an abundant habitat in most Natura 2000 areas in the Netherlands and could compete with native predatory polychaete worms, which are important components of the food web.

Risk assessment fresh water live bait
Two groups of invertebrates are commonly used as live bait in fresh water angling: insect larvae (often called maggots or worms, including fly, beetle and moth larvae) and annelid worms. Several species of grasshoppers and crickets are also used in angling, for example trout fishing, but excluded from this overview because they are

used on a relatively small scale. New types of bait are constantly developed for commercial use and may include the use of live organisms. This overview, therefore, is not aimed to be complete.

Most insect species are also farmed to provide food for pets, like fish, reptiles and birds and commonly available in pet shops and angler shops. All groups (flies, beetles, moths and annelid worms) include alien species. These are usually of subtropical to tropical origin, which are more suitable for storage and transport at room temperature. Warm-adapted species tend to develop slower at low temperatures compared to cold-adapted species.

The ecological risks for aquatic ecosystems are absent because terrestrial species do not survive in water and low for terrestrial ecosystems as most alien species originate from subtropical to tropical areas and have a low probability of establishment.

The tiger nuts used as bait for carp (after being boiled) are the crop variety (*C. esculentus* var. *sativus*), which is often confused with the invasive weed Yellow nut sedge (*C. esculentus*). The ecological risks for native biodiversity are therefore considered to be low.

Management options
Several management options could reduce the risks of invasive alien species used as live bait, if they would be imported to the Netherlands, like in other EU member states (e.g., France, Portugal).

- Raising public awareness among anglers is an effective way to inform them about the risks and motivate them not to discard live bait after fishing.
- Include the problem of invasive alien species in the Dutch Code of Conduct Sea Angling.
- Natura 2000 management plans could also give more attention to this potential pathway of invasive alien species and governmental authorities could add more conditions to the use of live bait to the fishing permits.
- To safeguard the supply of marine worms from Dutch sources for the use as live bait and produced by sustainable harvest and farming, is also an important measure to prevent imports of alien species
- Finally, if these measures would have insufficient results, then an import ban in the framework of the new EU directive on Invasive Alien Species could be considered.

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Appendix 1. List of live bait sellers.

Table A1. with province (P), company name, address, website and sample number in Table 1 (Webshop, ** Farm).*

province	company	street	nr	town	website	sample
ZL	Zagers-zeepieren.nl *	Suzanna Maria Loncquestraat	20	Oosterland	Zagers-zeepieren.nl	12
ZL	Hengelsport JanPeter	Coosje Buskenstraat	200	Vlissingen		8
ZL	J. Bijl Zeeaas en Hengelsport	Molenstraat	16	St-Maartensdijk	bijlzeeaas.nl	
ZL	Topsy Baits **	Oosthavendijk	1A	Wilhelminadorp	topsybaits.nl	
ZL	Tofaas	Burg. Versluys	12	Oud-Vossemeer	tofaas.nl	9
ZL	JR Tackle	Dorpsstraat	11A	Breskens	jrtackle.nl	
ZL	Het Piertje	Zuidkerkstraat	40	Colijnsplaat	hetpiertje-colijnsplaat.nl	
ZL	SeaFarm BV	Jacobahaven	4	Kamperland	seafarm.nl	
ZL	Van Vossen Zeeaas & Hengelsport	Schoolstraat	21	Sint Annaland		
ZL	De Golfbreker	Batenburg	47	Vlissingen	golfbrekeraas.nl	
ZL	De Waal - Van Gilst	Pr. Wilhelminalaan	8	Bruinisse		
ZL	Van Gilst	Beatrixstraat	4	Bruinisse		
ZL	Dixhoorn	Burenpolderweg	4	Yerseke		
ZL	De Zeebaars	Boulevard de Wielingen	86	Cadzand-bad	dezeebaars.nl	
ZL	Van Der Sterren	Noordstraat	10	Poortvliet	van-der-sterren.nl	
ZL	t Zeeaasje - E.J. Dek	Walsoordensestraat	37a	Walsoorden		
ZL	Fam. Timmer	Steinstraat	1	Bruinisse		
ZL	Fam. v/d Hoek	Taaijersweg	14	Moriaanshoofd		
ZL	See-fish	Visstraat	12	Zierikzee		
ZL	Zeeaashandel Lewedorp	Maalweg	3	Lewedorp		
ZL	Fixet 's Gravenpolder	Spoorstraat	51	s Gravenpolder	fixetsgravenpolder.nl	
ZL	Van Bunderen Marc	Kwakkel	15	Zaamslag		
ZL	't Zeepiertje	Meerpaalweg		Yerseke	zeepiertje.nl	11
ZH	Hengelsport Wesdijk	Gouwe	9	Barendrecht	wesdijk.nl	
ZH	Avicentra Hengelsport	Goudhoekweg	6	Oostvoorne	avicentrahengelsport.nl	2
ZH	Hengelhuis Maassluis	Haven	21a	Maassluis	hengelhuismaassluis.nl	
ZH	Wout van Leeuwen	George Stephensonweg	21H	Vlaardingen	woutvanleeuwen.nl	10
ZH	Albatros Hengelsport	Dr. Lelykade	68-70	Scheveningen	albatroshengelsport.nl	1
ZH	Eagle Hengelsport	Pleinweg	184A	Rotterdam		4
ZH	Klaas van der Heijden Hengelsport	Loosduinse Hoofdstraat	90	Loosduinen		
ZH	Zeehengelsport Hoek	Havenweg	30	Ouddorp		
ZH	Rien Rothfusz Hengelsport	v.Lodensteynstraat	114	Delft		
ZH	Coöperatie "Westvoorn"	Mr. Snijderweg	7a	Stellendam	coopwv.nl	
ZH	Hengelsporthuis De Catfish	Oostzanddijk	12a	Hellevoetsluis	de-catfish.nl	
NH	Animal Attraction	Burgemeester fockstraat	53	Amsterdam	animalatraction.nl	
NH	HANDY FISH	KENNEMERSTRAATWEG	129	Heiloo	handyfish.nl	
NH	Hermans Marine	Middenhavenstraat	98	Ijmuiden	hermansmarine.nl	7
NH	Lagerweij hengelsport	J.J. Allanstraat	111	Westzaan	lagerweij-hengelsport.nl	
NH	C.V. Bakker - Klein	Hofstraat	77	Den Oever		
NH	Zeepieren groothandel Rotgans	Gemeenelandsweg	12	Hippolytushoef	zeeaas.nl	
NH	Gerk van Dijk	Schinkelkade	13	Amsterdam		

A1. Continued.

P	company	street	nr	town	website	sample
NH	Rik's Hengelsport	Baanstraat	80	Beverwijk		6
NH	Ten Broek Hengelsport	Heiligeweg	71	Krommenie		
NH	Wiggers hengelsport	Balweg 81	81	Breezand		
NH	Jorna hengelsport en botenverhuur	hofstraat	53	Den Oever		
NH	Meinetten hengelsport	hofstraat	63	Den Oever		
NH	Goedvolk hengelsport	Rijksstraatweg	161	Haarlem		
NH	Catch hengelsport	W.M. Dudokweg 22a	22a	Herhugowaard		
NH	Cees Bruijn	Heereweg	180	Schoorl		
NH	NIPRO hengelsport	Rijperweg	48	St. Maarten		
NH	Engelhart	Trompstraat	92	Ijmuiden		5
NH	AT hengelsport	Binnenhaven	57	Den Helder		
NH	Zorg hengelsport	Baljuwstraat	9	Den Helder		
NH	de Moel Wervershoof	Zijdwerk	5	Wervershoof		
NH	Hengelsport Volendam	Sportlaan	10	Volendam		
NB	Bestelzeeaas	Oude Huijbergsebaan	231	Bergen op Zoom	bestelzeeaas.nl	
NB	Mbrouwershengelsport	Oude Huijbergsebaan	231	Bergen op Zoom	Mbrouwershengelsport	
NB	Vriends Hengelsport	Achtmaalseweg	178A	Achtmaal		
NB	M. Brouwers Hengelsport	Oude Huijbergsebaan	231	Bergen op Zoom	www.mbrouwershengelsport.nl	3
NB	Hengelsport Jurgers	St.-Catharinaplein	16	Bergen op Zoom		
NB	WSV Zevenbergen	Hazeldonkse Zandweg	28a	Zevenbergen		
GR	Kuperus Hengelsport	De Dam	7	Leek		
GR	Cees Bisschop Hengelsport	Mennonietenkerkstraat	10	Uithuizen		
GR	Hengelsport Mekka	Hoofdweg	184	Paterswolde		
GR	Hengelsport Sappemeer	Noorderstraat	75	Sappemeer		
FR	Hengelsport Zurcih	Caspar de Roblesdijk	13	Zurich		
FR	BlueBlizz	Apolloweg 16	16	Leeuwarden		
FR	Baitshop	Eigenhaard	12a	Balk		
FR	Meomar Seafoods	Celcuisstraat	15	Harlingen		

Appendix 2. Baits offered by Normandie Appats, France.

Table A2. Possible scientific names of twelve different species of marine worms offered by Normandie Appats (see Figure 4).

Trade name	Scientific name (indication
Demi-dure	?
Super DD	?
Dure	?
Jumbo	*Namalycastis sp.*
Saltarelle	*Perinereis cultrifera*
Rag	*Alitta virens*
Mouron	*Marphysa sanguinea*
Américain	*Glycera dibranchiata*
Bibi	*"Sipunculus nudus"*
Chalut	*Halla parthenopeida*
Sabloon	?
Super Cordelle	*Namalycastis sp.*