HORIZON SCANNING FOR INVASIVE ALIEN SPECIES ON THE ISLAND OF IRELAND

IDENTIFICATION OF EMERGING INVASIVE ALIEN SPECIES WITH THE POTENTIAL TO THREATEN BIODIVERSITY

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Contents

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INTRODUCTION

Biodiversity is under pressure from a suite of different drivers of change, one of the most significant of which is Invasive Alien Species (IAS) (Blackburn et al., 2014). Others include climate change, deforestation, eutrophication, and increased population load. It is the complex interaction between all these elements that leads to serious environmental damage, and it is difficult to mitigate against such broadly-based environmental degradation. The rate of biological invasions worldwide has not slowed over the past decade or so, and may actually be increasing (Seebens et al., 2017). IAS management has cost the combined taxpayers of the Republic of Ireland and Northern Ireland €261,517,445 annually (Kelly et al., 2013).

Essential to the judicious management of IAS is the prioritisation of the species that are most likely to arrive on our shores in the coming years. The process by which we prioritise these species, in an essentially unpredictable space, is through horizon scanning, whereby individual species (not yet established in the jurisdiction) are systematically assessed with regard to their potential threat to native biodiversity (Roy, Peyton and Aldridge, 2014). Not every IAS that establishes itself in our environment has the same level of impact on biodiversity. Some of the species that are most likely to arrive here through obvious pathways are not the most deleterious to native biodiversity, and so the potential impacts of each species must be taken into consideration when prioritising species for management (Jeschke et al., 2014).

In 2015, the EU Regulation on the prevention and management of the introduction and spread on invasive alien species (IAS) was enacted (EU 1143/2014). This legislation put the responsibility on Member States (MS) to review their status with regard to IAS, and specifically to undergo a risk assessment exercise to identify which new species were most likely to establish themselves as IAS. This horizon scanning exercise provides a scientific basis for the choice of IAS which will be subjected to a risk assessment (Booy et al., 2017).

Ireland, being an island, has fewer native species than mainland Europe and, therefore, the potential impacts of damage to biodiversity by IAS is greater than in a mainland MS. (Stokes, O Neill and Mcdonald, 2006) Historically, the majority of our invasions have been from Britain as a result of frequent movement of goods and people between the two countries. It is, therefore, appropriate that we take direction from a Horizon Scanning exercise that was completed in the UK in 2014 (Roy et al., 2014).

WHAT IS HORIZON SCANNING?

Horizon Scanning is the systematic process of conducting a search for potential threats and opportunities that are currently poorly recognised, to inform future decisions and policies. The systematic approach is what differentiates Horizon Scanning from other, less robust, processes (Sutherland and Woodroof, 2009). Relevant and credible evidence is obtained, and used, to prioritise the future response to the threats identified. A Horizon Scanning exercise consists of several distinct phases, and when effectively undertaken, it provides decision-makers with information on which to base reliable but flexible strategies and plans for future environmental management (Sutherland and Woodroof, 2009)

Horizon scanning for the island of Ireland

The workshop "Identification of emerging Invasive Alien Species with the potential to threaten biodiversity in Ireland" was held on 19th April 2017 at the Institute of Technology, Sligo, Ireland, supported by the Irish Environmental Protection Agency. The workshop applied a Horizon Scanning process to forecast Invasive Alien Species (IAS) arrival, establishment and impact for the island of Ireland (both jurisdictions) and was attended by experts from the Republic of Ireland, Northern Ireland and Great Britain (Appendix 1). These advisors were selected from a range of disciplines (scientific researchers, practitioners and responsible authorities) in order to provide a balance of expertise throughout terrestrial, freshwater and marine taxa. This Horizon Scanning exercise was vital to informing developing commitment to the new EU Regulation on Invasive Species (EU1143/2014).

In this Horizon Scanning exercise, undertaken for IAS on the island of Ireland, the same model was used as was employed for Britain in 2014 (Roy et al., 2014), albeit with some minor adjustments to reflect the different environmental and social context of Ireland. The exercise consisted of two distinct phases:

1. Deriving lists of ranked potential IAS with reference to previously generated lists, and through consultation with experts in three different biomes (Terrestrial, Freshwater and Marine).
2. Consensus-building amongst experts to rank the generated lists in a sensible manner, so that the final product reflected the true opinions of the expert group.

The final list that emerges from such a horizon scanning exercise can provide a basis for further risk-assessment work and gives any subsequent risk assessment a solid, scientifically robust, basis (Booy et al., 2017).

AIMS AND OBJECTIVES

The workshop aimed to contribute to Ireland's obligations under the EU Invasive Alien Species Regulation (EU, 2014) by completing a Horizon Scanning exercise aimed at identifying "door-knocker" species that pose a future threat to Ireland's biodiversity.
The primary objectives of the workshop were to identify the top IAS likely to arrive, establish and impact on native biodiversity in the subsequent ten years (2017-2027).

MATERIALS AND METHODS

We used an adapted version of the consensus method (Sutherland et al., 2011; Roy, Peyton and Aldridge, 2014). The process involves two distinct phases.

PHASE 1 (PRE-WORKSHOP):

a) Lists of potential IAS, with reference to previously generated lists, were generated. This preparatory work was completed by Colette O'Flynn, National Biodiversity Data Centre.
b) These potential IAS were ranking by each of the individual experts in the three different biomes [Terrestrial, Freshwater and Marine (Appendix 2)], using the template and guidelines provided.

PHASE 2 (DURING WORKSHOP):

Consensus was achieved amongst experts, thus ranking the generated lists in a sensible manner, so that the final product reflected the true opinions of the full expert group. This was achieved through:
a) preliminary consultation between groups of experts in Terrestrial, Freshwater and Marine species;
b) consensus-building within expert groups to provide a ranked list of species for each biome; and
c) consensus-building between expert groups to provide an overall ranked list of species for the island of Ireland as a whole.

PHASE 1: PRELIMINARY CONSULTATION (IN ADVANCE OF WORKSHOP)

Twenty-three freshwater, terrestrial and marine species experts were selected from the island of Ireland (from both jurisdictions, i.e. Republic of Ireland and Northern Ireland). Each group was comprised of between 7-8 experts and was constituted by a group leader, co-leader/rapporteur and the core group. Each group was constituted according to complimentary expertise across taxa in each of the respective terrestrial, freshwater and marine environments.

Each expert was given an IAS list relevant to his/her group. This comprised 160 species that had been previously identified as High Risk in the following: a) the GB Horizon scanning for invasive alien species (Roy, Peyton and Aldridge, 2014), b) the previous Invasive Species Ireland horizon scan (Minchin 2014), c) NAPRA Ireland major risk species, and also d) species not currently established in Ireland pursuant with the 37 species named in the EU Regulation (EU) 2016/1141. The terrestrial list for this exercise comprised of 96 species, the freshwater list contained 44 species and the marine list included 20 species.

Experts were also provided with extra species lists, for consideration only, and invited to use these or alternative sources to put forward other IAS that could be likely to arrive, establish and impact on native biodiversity within the next decade. Supporting evidence (generally peer-reviewed publications but also grey literature where the former was lacking) would be required with any additional IAS. Participants were provided with relevant reference sources (MFSD 2012; Kelly et al. 2013; Non-native Species Risk Assessment for Ireland (NAPRA) Ireland 2014; Minchin 2014; Roy et al. 2014, Roy et al. 2015) and databases (e.g. DAISIE, NOBANIS, EASIN, GISID, CABI, EPPO). Participants were also asked to review and, if necessary, supplement the lists using other literature sources and their own and others' expert opinion. Where experts added species to the assessment, the group leaders communicated the added species to their group by sending full collated species lists prior to workshop, highlighting any new species and providing an opportunity to respond with their own assessment of any supplementary species. Each expert group was provided with a spreadsheet template to ensure consistency in the collated information. The grid had the following headings: species, taxonomic group, functional group, native range, likely pathway of arrival, uncertainty, comments and references. Uncertainty can be due to the natural unpredictability of a species and/or can arise due to a lack of evidence or information on a particular species. The approach taken here is to account for uncertainty in both information available and the uncertainty in the assessment made. For more information on uncertainty see Kelly et al. (2013) .

Guidance notes were provided on how to complete the grid. Functional groups were classified as primary producer, herbivore, omnivore, predator and parasite. Pathways of arrival were defined following IUCN classification. Each group standardized the assessment of the threat by scoring each of the likelihood of arrival, likelihood of establishment and likelihood of impact on biodiversity from 1 (very unlikely) to 5 (very likely). Impact on biodiversity was assessed by considering the following parameters adapted from Branquart (2007):

1. Dispersal potential
2. Colonization of high conservation value habitats
3. Adverse impacts on native species:
a) Predation/herbivory
b) Competition
c) Transmission of pathogens and parasites to native species
d) Genetic effects
4. Alteration of ecosystem functions:
a) Modification to nutrient cycling
b) Physical modifications to the habitat
c) Modifications of natural successions
e) Disruption of food webs

This preliminary consultation phase [combining elements of literature review, rapid risk assessment and consensus methods (within groups)] was conducted over three weeks. The scores were only used to provide guidance for ranking the species, enabling a starting point from which experts, across groups, could engage in debate leading to modification of the score in some cases. For transparency, we retained the original scores.

PHASE 2: CONSENSUS-BUILDING METHODS EMPLOYED DURING THE WORKSHOP

Consensus-building across the expert groups took place at a workshop held at the Institute of Technology, Sligo, Republic of Ireland (19th and 20th April 2017). The group leaders attended the first session on Day 1, prior to the arrival of the main group, and provided an overview of the species within their lists, with particular emphasis on justification of scores. The aim of this exercise was both to review the lists and to ensure standardization of approach to the overall scores derived within groups through the preliminary consultation.
The workshop was chaired by Dr. Matthew Jebb, Office of Public Works (OPW), with support from two technical facilitators [Professor Helen Roy (CEH) and Dr. Olaf Booy (GB-NNSS)]. Representatives from the EPA, DAERA, Department for Housing, Planning and Local Government and the GB Non-Native Species Secretariat were invited to observe the process and contribute to methodological discussion.

CONSENSUS-BUILDING WITHIN EXPERT GROUPS

In the second session on Day 1, group leaders were joined by all expert group participants. This began with a plenary session explaining the workshop process. Participants then divided into their expert groups to discuss and further refine the scores of the species within their lists. The discussions enabled participants to review available information and consider uncertainty in preparation for the final session. The list of IAS for each biome was reviewed, and expert opinion was used to further refine the ranking.

Using the individual scoring sheets from each of the experts (prepared in advance of the workshop), an overall score for each species was determined as the sum of the scores for likelihood of arrival, establishment and impact (maximum score = 15). The overall scores were used to rank the species within the expert groups into categories of low, medium and high risk in preparation for the next phase of the exercise. Participants reviewed and amended scores of the IAS within their group to produce an agreed ranked list of species within each group.

The processes of collaborative review and consensus-building were repeated until the entire group had converged on a ranked list. Throughout the discussions, the group provided expert opinion to support the decision-making process and the scores were used only as guidance for this process. Discussions were further informed by information on uncertainty, which can be used in the event of a tie.

Table 1: Species numbers for assessment, consideration and total counts.

Group	For assessment	For consideration	Total count
Terrestrial	96	85	181
Freshwater	44	43	87
Marine	20	60	80
Total	**160**	**188**	**348**

Only species considered to have a medium or high likelihood (scores of 3 or above) in all categories (arrival, establishment and impact) were taken forward to the next phase of the process (consensus-building across expert groups); hence, the resultant initial lists varied in length across groups. Subsequent discussions between group leaders enabled the moderation of group scores, to create an aggregated, ranked list of species from all groups.

At the end of Day 1 the group leaders and co-leaders met with the chair, technical facilitators and observers to review the ranking among the groups.

CONSENSUS-BUILDING ACROSS EXPERT GROUPS

All participants reconvened within their groups on Day 2 to review and refine the compiled and ranked multi-taxon list of IAS. Ultimately, consensus was reached on the basis of expert opinion provided through open discussion (a transparent process in which questions were openly asked and defences were given, or opinions were modified) and majority voting. Discussions were most detailed for species ranked as high impact (with a high degree of certainty) within the aggregated list. A plenary synthesis session determined the top ranked 30 species likely to arrive, establish and impact on native biodiversity in the next ten years.

RESULTS

Results of the Top Ten and the Top 40 IAS that were objectively selected during the Horizon Scanning exercise are presented in Table 2. The freshwater signal crayfish, Pacifastacus leniusculus, was the Number 1 species nominated most likely to arrive on the island of Ireland, followed in order by the roe deer Capreolus capreolus, the killer shrimp Dikerogammarus villosus, the salmon fluke Gyrodactylus salaris, and the quagga mussel Dreissena rostriformis bugensis. In addition to the scores given in Table 2 for risk of introduction, risk of establishment and level of impact on biodiversity of all 40 species, the invasion ecology of the ten top species is outlined in Appendix 1.

It is now 16 months since the Horizon Scanning workshop took place. Although none of the species listed have, as yet, been confirmed present on the island of Ireland, there is little doubt that one or more will be discovered as an established IAS here before too long.

Table 2. The Top 40 Horizon Scan IAS for Ireland to 2027.

Rank	Species	Common name	Environment	Risk of Introduction	Risk of Establishment	Level of Impact on biodiversity	Total	Product	Uncertainty
No. 1	*Pacifastacus leniusculus*	Signal crayfish	Freshwater	5	5	5	15	125	Low
No. 2	*Capreolus capreolus*	Roe deer	Terrestrial	5	4	5	14	100	Low
No. 3	*Dikerogammarus villosus*	Killer shrimp	Freshwater	5	4	5	14	100	Low
No. 4	*Gyrodactylus salaris*	Salmon fluke	Freshwater	4	5	5	14	100	Low
No. 5	*Dreissena rostriformis bugensis*	Quagga mussel	Freshwater	4	4	5	13	80	Low
No. 6	*Eriocheir sinensis*	Chinese mitten crab	Freshwater	5	3	5	13	75	Low
No. 7	*Caulacanthus okamurae*	Pom-pom weed	Marine	5	5	3	13	75	Low
No. 8	*Hesperibalanus fallax*	Warm-water barnacle	Marine	5	5	3	14	75	Medium
No. 9	*Ondatra zibethicus*	Muskrat	Terrestrial	5	5	3	13	75	Medium
No. 10	*Pseudorasbora parva*	Topmouth gudgeon; Stone moroko	Freshwater	3	5	5	13	75	Medium

Table 2. The Top 40 Horizon Scan IAS for Ireland to 2027.

Rank	Species	Common name	Environment	Risk of Introduction	Risk of Establishment	Level of Impact on biodiversity	Total	Product	Uncertainty
Top 40	*Orconectes limosus*	Spinycheek crayfish	Freshwater	4	3	5	12	60	Medium
Top 40	*Onchoryhnchus mykiss*	Rainbow Trout	Freshwater	5	3	4	12	60	Medium
Top 40	*Psittacula krameri*	Ring-Necked parakeet	Terrestrial	5	4	3	12	60	Medium
Top 40	*Dikerogammarus haemobaphes*	Demon shrimp	Freshwater	5	4	3	12	60	Medium
Top 40	*Agrilus planipennis*	Emerald ash borer	Terrestrial	4	3	4	11	48	High
Top 40	*Agrilus anxius*	Birch borer	Terrestrial	4	3	4	11	48	High
Top 40	*Ludwigia grandiflora (+species)*	Water primrose	Freshwater	4	3	4	11	48	Low
Top 40	*Procyon lotor*	Raccoon	Terrestrial	4	3	4	11	48	Medium
Top 40	*Sander lucioperca*	Zander; Pikeperch	Freshwater	4	3	4	11	48	Medium
Top 40	*Orconectes virilis*	Virile crayfish	Freshwater	4	3	4	11	48	Medium
Top 40	*Ensis directus*	American razor-clam	Marine	5	5	2	12	50	Medium
Top 40	*Mnemiopsis leidyi*	Warty comb-jelly	Marine	3	4	4	10	48	Medium
Top 40	*Myriophyllum heterophyllum*	American water-milfoil	Terrestrial	3	4	4	11	48	High

Table 2. The Top 40 Horizon Scan IAS for Ireland to 2027.

Rank	Species	Common name	Environment	Risk of Introduction	Risk of Establishment	Level of Impact on biodiversity	Total	Product	Uncertainty
Top 40	*Salvelinus fontinalis*	Brook trout; Brook charr; Sea trout	Freshwater	3	4	4	11	48	High
Top 40	*Astacus astacus*	Noble Crayfish; Broad-fingered crayfish	Freshwater	4	3	4	11	48	High
Top 40	*Squalius cephalus*	Chub	Freshwater	4	4	3	11	48	Low
Top 40	*Microtus agrestis*	Field vole	Terrestrial	4	4	3	11	48	Medium
Top 40	*Hemigrapsus takanoi*	Brush-clawed shore crab	Marine	4	4	3	11	48	Medium
Top 40	*Barbus barbus*	Barbel	Freshwater	4	4	3	11	48	Medium
Top 40	*Hylastes ater*	Black pine bark beetle	Terrestrial	4	4	3	11	48	High
Top 40	*Celtodoryx ciocalyptoides*	sponge	Marine	4	4	3	11	48	Very high
Top 40	*Hemigrapsus sanguineus*	Asian shore crab	Marine	4	4	3	11	48	May already be present
Top 40	*Tamias sibiricus*	Siberian chipmunk	Terrestrial	5	3	3	11	45	Medium
Top 40	*Obama nungara*	Flatworm	Terrestrial	5	3	3	11	45	High
Top 40	*Thymallus thymallus*	Grayling	Freshwater	2	5	4	11	40	Medium
Top 40	*Microtus arvalis*	Orkney vole	Terrestrial	3	4	3	10	36	Medium
Top 40	*Threskiornis aethiopicus*	Sacred Ibis; African Sacred Ibis	Terrestrial	4	3	3	10	36	Medium

1. AMERICAN SIGNAL CRAYFISH

Pacifastacus leniusculus

PHOTO CREDIT:LORNE GILL/SCOTTISH NATURAL HERITAGE; PACIFASTACUS LENIUSCULUS 2.JPG, © MDE AT WIKIMEDIA COMMONS, CC-BY-SA 3.0

Pacifastacus leniusculus (North American signal crayfish) is the most widespread alien crayfish in Europe (29 invaded territories, UK included), introduced for stocking and aquaculture purposes. It is omnivorous, highly prolific (up to 400 eggs per female) and is adaptable to a wide range of environments. It can live up to 20 years, being sexually mature at the age of 2-3 years. It carries the crayfish plague (Aphanomyces astaci), lethal for native crayfish. Ireland has an important native population of Austropotamobius pallipes (Whiteclawed crayfish), which has a 100% mortality rate with crayfish plague. Its feeding habits, burrowing activity, reproductive rate and aggressiveness has a highly destructive effect on invaded ecosystems, outcompeting native crayfish, reducing local biodiversity and stability of river banks. Its management is challenging (an integrated approach is recommended), thus prevention of its introduction is recommended as the most practical approach.

- � **LIKELIHOOD OF INTRODUCTION -5**
  � **LIKELIHOOD OF ESTABLISHMENT -5**
  � **LIKELY IMPACT ON BIODIVERSITY -5**
  � **LEVEL OF UNCERTAINTY –LOW**

Current distribution (www.cabi.org)

- � **NATIVE RANGE - NORTH AMERICA**
  � **PATHWAY – ANGLING**
  � **VECTORS - CONTAMINATED EQUIPMENT**

2. ROE DEER

Capreolus capreolus

PHOTO CREDIT:MANXBIRDPHOTOGRAPHY.CO.UK

- � LIKELIHOOD OF INTRODUCTION -5
  � LIKELIHOOD OF ESTABLISHMENT -4
  � LIKELY IMPACT ON BIODIVERSITY -5
  � LEVEL OF UNCERTAINTY -LOW

Capreolus capreolus (Roe Deer) was heavily debated when it came in as the highest risk species in the terrestrial group. Previously introduced breeding populations of Roe deer (Lissadell Estate and environs, Co. Sligo) were eradicated around 1905 (Stokes, O Neill and McDonald, 2006). Roe deer are currently held in captivity in Wicklow and have produced young in the last 5 years (J. Dick pers obs; NPWS pers obs). They are very widespread in the UK, with their range expanding by a compound rate of 2.3% between 1972 and 2002 (Ward, 2005). The similarity between habitat type in the UK and Ireland implies that they would be equally successful here. New, less stressful forms of sedation are now available, increasing the risk that deliberate introductions for hunting purposes could establish themselves successfully here.

Current distribution

- � NATIVE RANGE - WIDESPREAD THROUGH EUROPE
  � PATHWAY – DELIBERATE INTRODUCTION
  � VECTORS - SPORT

3. KILLER SHRIMP

Dikerogammarus villosus

PHOTO CREDIT:ENVIRONMENT AGENCY(UK), GBNNSS

Dikerogammarus villosus (Killer shrimp) is present in the UK (MacNeil et al., 2010), listed officially as "Occasional or few reports" (Dodd et al., 2014), but widely acknowledged as being established in UK catchments. Native to the Black Sea and Caspian Sea, it is a relatively recent invader in Europe, but has now been recorded in all major European rivers (Devin and Beisel, 2006). The likelihood of introduction of this species into Ireland has been assessed as "high", with a low level of uncertainty. It has readily spread throughout mainland Europe, with the primary vector of spread over long distances being ballast water and the hulls of boats (MacNeil et al. 2010).
Dikerogammarus villosus is tolerant of a wide range of habitats, freshwater and brackish (Bruijs et al. 2001), both lentic and lotic systems, and has a high reproductive rate (Pockl 2007), making it highly likely to establish successfully on introduction. Its impact on biodiversity is high, showing extremely aggressive behaviour towards native invertebrate species and causing significant changes in food-web dynamics (Dick & Platvoet 2000; Dick et al. 2002).

- **� LIKELIHOOD OF INTRODUCTION -5**
  � LIKELIHOOD OF ESTABLISHMENT -4
  � LIKELY IMPACT ON BIODIVERSITY -5
  � LEVEL OF UNCERTAINTY -LOW

Current distribution (www.cabi.org)

- **� NATIVE RANGE - PONTO-CASPIAN**
  � PATHWAY – ANGLING
  � VECTORS - CONTAMINATED EQUIPMENT

4. SALMON FLUKE

Gyrodactalus salaris

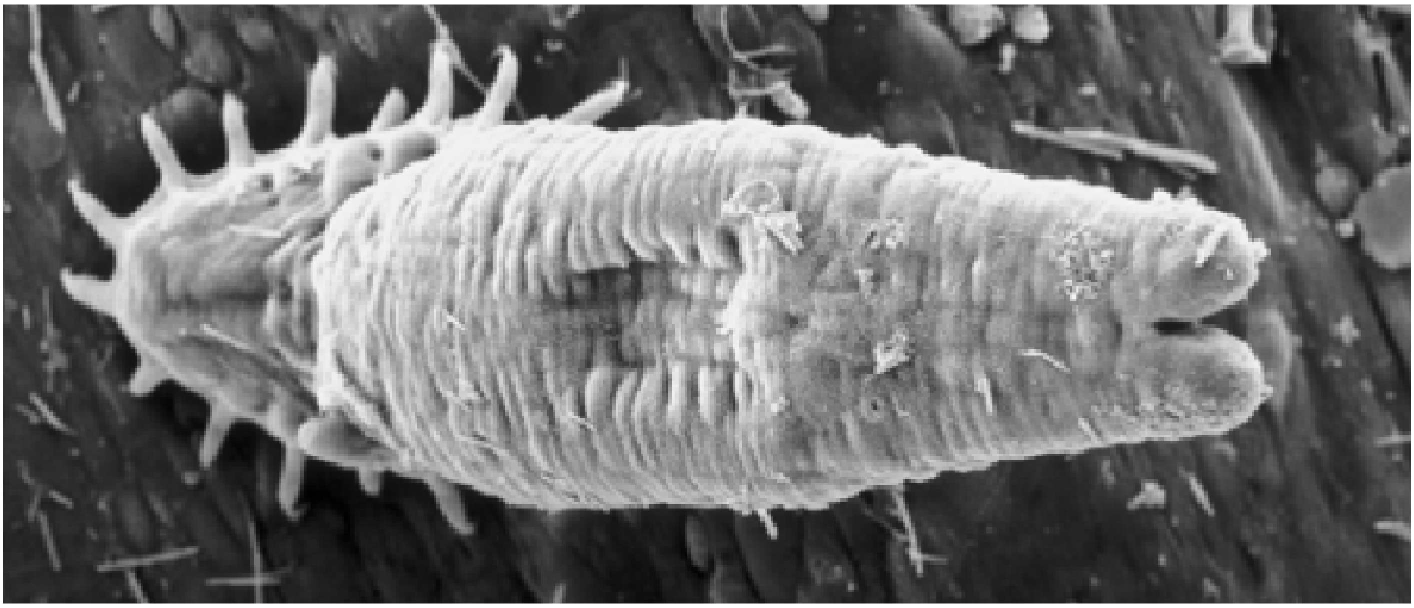


PHOTO CREDIT: KURT BUCHMANN AND JOSÉ BRESCIANI

Gyrodactylus salaris (Salmon fluke) is a small (<1mm) parasite that infects the skin, gills and fins of salmon, trout and some other species of freshwater fish. It causes gyrodactylosis, a serious notifiable disease that represents one of the biggest threats to the salmon population in Ireland. It is present in most countries of Europe and Scandinavia, although is currently absent from both Ireland and Great Britain. Based on experience in countries with Atlantic salmon populations that have become infected, if G. salaris establishes itself in Ireland, it could bring about a catastrophic collapse of the salmon stocks. It has several possible pathways of introduction, the most significant of which is the illegal importation of infected fish. Next in importance is the introduction of the parasite on contaminated fishing equipment. The parasite is very hardy and is capable of surviving for several days in damp conditions on wet angling equipment (e.g. wet landing nets, waders).

- � **LIKELIHOOD OF INTRODUCTION -4**
  � **LIKELIHOOD OF ESTABLISHMENT -5**
  � **LIKELY IMPACT ON BIODIVERSITY -5**
  � **LEVEL OF UNCERTAINTY - LOW**

Current distribution (www.cabi.org)

- � **PATHWAY – ANGLING**
  � **VECTORS - CONTAMINATED EQUIPMENT**

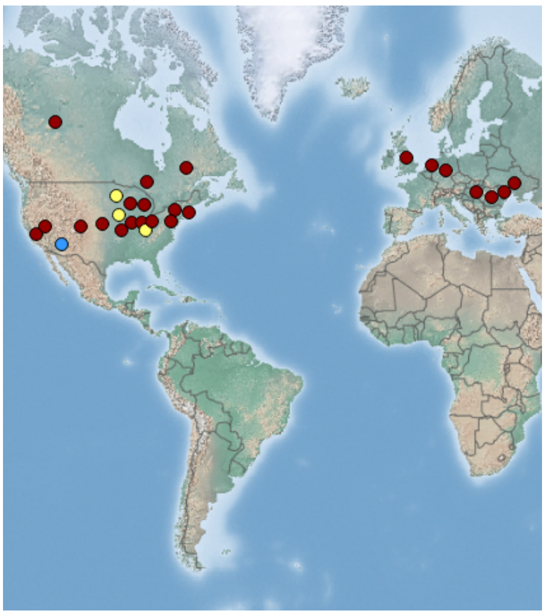
5. QUAGGA MUSSEL

Dreissena rostriformis bugensis

PHOTO CREDIT: SERGEY E. MASTITSKY; NATALIE MUTH, UTAH DIVISION OF WILDLIFE RESOURCES

Dreissena rostriformis bugensis (Quagga mussel) is a bivalve mollusc, native to the Ponto-Caspian region. It was first discovered in Britain in 2014 (Aldridge et al. 2014) and is continuing to spread rapidly. Pathways for spread include the construction of canals, discharge of ballast water and overland transport in association with recreational boat traffic and angling. Its invasion success is reflected in the fact that a mature quagga mussel can produce up to one million eggs per year. In addition to blocking water pipes and carpeting boats' hulls, quagga mussel can significantly reduce native plant, invertebrate and fish populations; it can also outcompete sensitive unionid molluscs (Aldridge et al. 2014).

- **� LIKELIHOOD OF INTRODUCTION - 4**
  � LIKELIHOOD OF ESTABLISHMENT - 4
  � LIKELY IMPACT ON BIODIVERSITY - 5
  � LEVEL OF UNCERTAINTY - LOW



Current distribution (www.cabi.org)

- **� NATIVE RANGE - PONTO-CASPIAN**
  � PATHWAY – ANGLING
  � VECTORS - CONTAMINATED EQUIPMENT�

6. CHINESE MITTEN CRAB

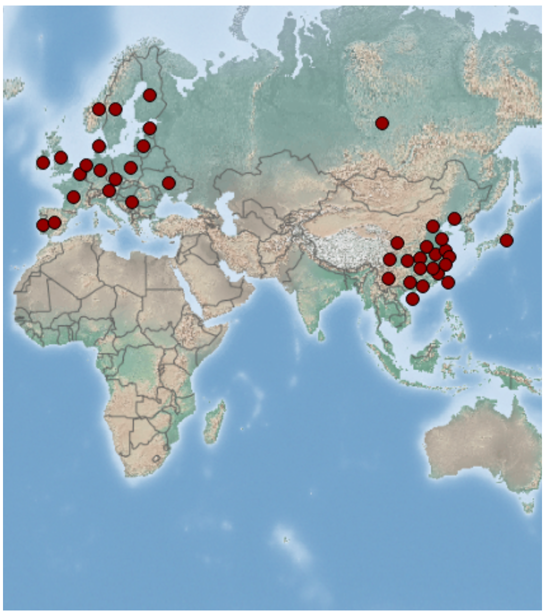
Eriocheir sinensis

PHOTO CREDIT: SHUTTERSTOCK

Eriocheir sinensis (Chinese mitten crab) is a large migrating crab with dense mats of hair (mittens) on it white-tipped claws. It is native to Eastern Asia and was first recorded in Ireland (Waterford estuary) in 2005, although viable populations never established in Irish rivers (J. Caffrey pers. comm.). It has the potential to cause significant economic and environmental damage where it becomes established. Migrating upstream from breeding grounds in brackish water, these large crabs can alter the morphological features of rivers and increase the amount of fine sediment in the watercourse through their burrowing activity, resulting in a threat to riverbank stability and land loss (Rosewarne et al. 2016). This species predates voraciously on a wide variety of aquatic invertebrates and fish eggs, and could outcompete native invertebrates (e.g. white-clawed crayfish) for food and space.

- � NATIVE RANGE - CHINA/KOREAN PENINSULA
  � PATHWAY – DELIBERATE RELEASE
  � VECTORS - CONTAMINATED EQUIPMENT

- � LIKELIHOOD OF INTRODUCTION - 5
  � LIKELIHOOD OF ESTABLISHMENT - 3
  � LIKELY IMPACT ON BIODIVERSITY - 5
  � LEVEL OF UNCERTAINTY - LOW



Current distribution (www.cabi.org)

7. POMPOM WEED

Caulacanthus okamurae

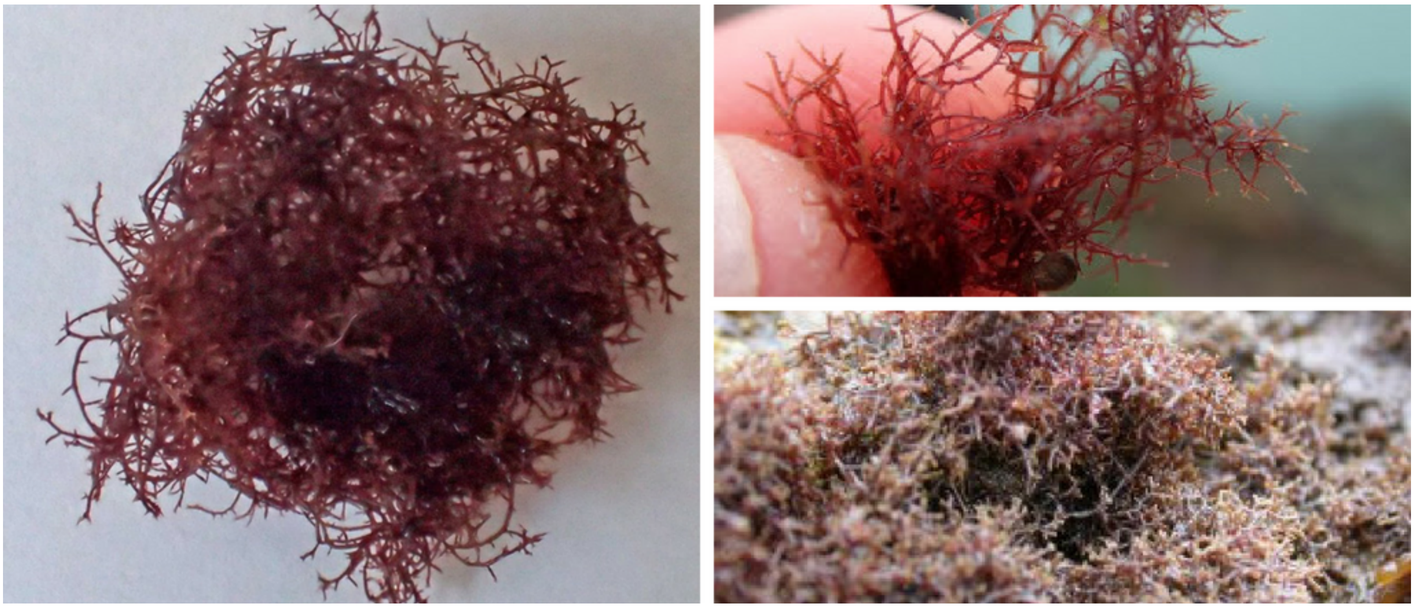


PHOTO CREDIT: BISHOP GROUP MBA (TWITTER); , BRYONY CHAPMAN; BRAD SCOTT

Caulacanthus ustulatus is a turf-forming dark purple to brown, profusely and irregularly branched alga with a hornlike appearance at branched tips. It does not generally grow longer than 30 mm and is attached to the substrate by creeping stolons. It generally occupies rocky, intertidal and exposed habitats. Caulacanthus ustulatus was introduced from Asia to southern California in 1999 but has since been recorded in France and SW Britain. Caulacanthus appears to displace macro-invertebrates, such as barnacles, limpets, and periwinkles, in the high intertidal zone. while facilitating a more diverse array of small invertebrates and macroalgae (Smith et al. 2014). This is likely due to the formation of a turf habitat in the upper zone where turfs are uncommon.

- � **LIKELIHOOD OF INTRODUCTION - 5**
  � **LIKELIHOOD OF ESTABLISHMENT - 5**
  � **LIKELY IMPACT ON BIODIVERSITY - 3**
  � **LEVEL OF UNCERTAINTY - LOW**

Current distribution (www.cabi.org)

- � **NATIVE RANGE - FAR EAST**
  � **PATHWAY – MARINE TRAFFIC**
  � **VECTORS - SHIPPING**

8. BARNACLE

Hesperibalanus fallax

PHOTO CREDIT: DAVIDFENWICK WWWAPHOTOMARINE.COM; D. MINCHIN.

Hesperibalanus fallax (Broch, 1927: Family Archaeobalanidae; synonym Solidobalanus fallax) is a warm water sessile thoracican barnacle native to most of West Africa, Morocco and Algeria (see Southward 2008 for identification details). With one exception, H. fallax was unrecorded in Europe before 1980, but has since been found in SW England, Wales, the Iberian peninsula, the Atlantic and English Channel coast of France, in the Southern North Sea, as well as on a lobster pot bought in Guernsey (Southward et al. 2004). Its habitat ranges from 15 m to 220 m depth, and it can occur on a range of biological and man-made substrata, but not on rocks or harbour walls (Southward et al. 2004). Its occurrence on the sea-fan Eucinella verrucosa may adversely impact populations and there is concern that H. fallax might become a serious fouler of fish cages and other sea-farming structures (Southward et al. 2004).

- **� LIKELIHOOD OF INTRODUCTION - 5**
  � LIKELIHOOD OF ESTABLISHMENT - 5
  � LIKELY IMPACT ON BIODIVERSITY - 3
  � LEVEL OF UNCERTAINTY - MEDIUM

Current distribution (www.cabi.org)

- **� NATIVE RANGE - ANGOLA THROUGH WEST AFRICA AND MOROCCO TO ALGERIA**
  � PATHWAY – MARINE TRAFFIC
  � VECTORS - SHIPPING

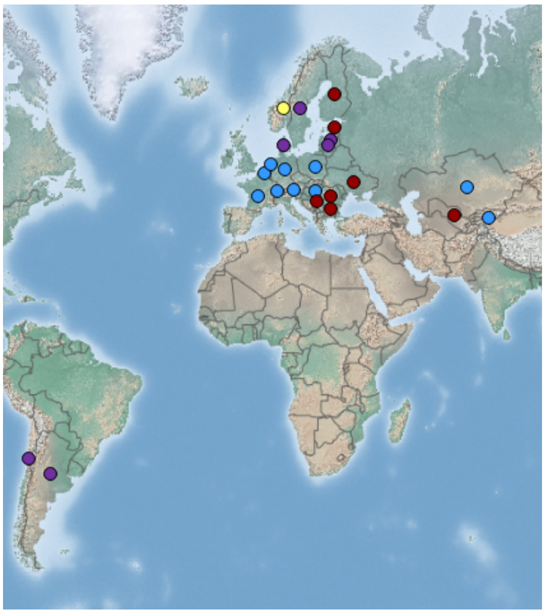
9. MUSKRAT

Ondatra zibethicus

PHOTO CREDIT: IRINAV - DREAMSTIME.COM; ;JOHN CANCALOSI

Ondatra zibethicus (muskrat) is an amphibious rodent which grows to a length of between 46-67 cm and a height of 20-27 cm. It has long been bred for its dense, waterproof fur. Native to the United States of America, Canada and parts of Mexico, it has been introduced to Europe, where it has spread widely. Muskrats are territorial, building burrows and lodges at very regular intervals. Their population density is dependent on food supply, up to 30 pairs per ha. They reach breeding maturity between five and seven months, and each breeding female is capable of producing between two and six litters per year, each containing six to seven young. Muskrat burrows destabilise riverbanks and contribute to flooding. They have serious impacts on agriculture production and environmental quality. Their high rate of reproduction makes the population very difficult to control. (Valenzuela et al. 2014; Stokes et al. 2004; Shine et al. 2010; Triplet P, 2009)

- **� LIKELIHOOD OF INTRODUCTION -5**
  � LIKELIHOOD OF ESTABLISHMENT -5
  � LIKELY IMPACT ON BIODIVERSITY -3
  � LEVEL OF UNCERTAINTY -MEDIUM



Current distribution (www.cabi.org)

- **� NATIVE RANGE -NORTH AMERICA**
  � PATHWAY – HITCH-HIKER
  � VECTORS - SHIPPING

10. TOPMOUTH GUDGEON

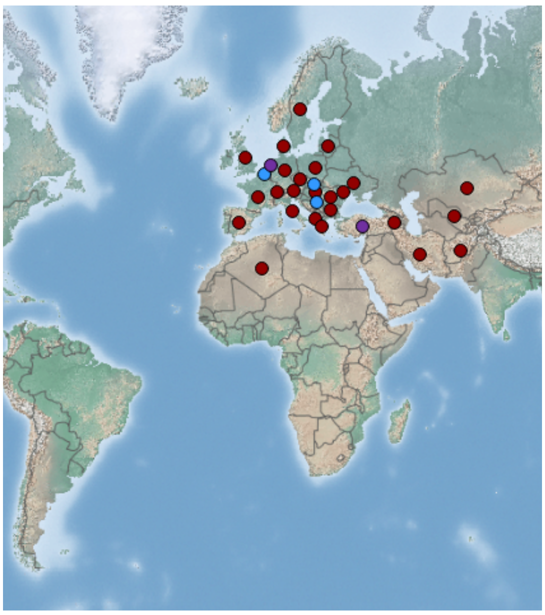
Pseudorasbora parva

PHOTO CREDIT:SEOTARO (WIKICOMMONS); GB NNSS

Pseudorasbora parva (Topmouth gudgeon: synonyms Stone moroko and False harlequin) is a small-bodied fish (< 10 cm) of the Cyprinidae family originating from East Asia (Gozlan et al. 2010). It arrived accidentally into Eastern Europe in the 1960s via the aquaculture trade and has since been transported all around Europe in the same manner. In addition, natural dispersal from aquaculture sites has resulted in their widespread invasion of many European countries (Gozlan et al. 2010). Pseudorasbora parva have shown a high phenotypic plasticity in life history characteristics, such as somatic growth rates and reproductive traits, which has greatly facilitated their capacity to colonise new waters (Britton et al. 2013). Whilst there is some concern over their negative ecological interactions with native fishes (Tran et al. 2015), the primary concern of their invasion is their potential transmission of the novel pathogen rosette agent Sphaerothecum destruens that can potentially impacts native fishes (Sana et al. 2018).

- **� NATIVE RANGE -EAST ASIA, INCLUDING JAPAN AND KOREA**
  � PATHWAY – COMMERCIAL FISHERIES
  � VECTORS - CONTAMINATED FISH-STOCKS

- **� LIKELIHOOD OF INTRODUCTION - 3**
  � LIKELIHOOD OF ESTABLISHMENT - 5
  � LIKELY IMPACT ON BIODIVERSITY - 5
  � LEVEL OF UNCERTAINTY - MEDIUM



Current distribution (www.cabi.org)

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