

A checklist of alien and cryptogenic aquatic species in Ireland

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Received 14 May 2007; accepted in revised form 27 October 2007

Abstract

One-hundred-and-twelve alien species are recorded for marine, brackish and freshwater environments in Ireland, of these sixty-eight are thought to be established. Their arrival has been mainly due to shipping, aquaculture and the ornamental industries. There are almost thirty species considered to be invasive and some that have arrived recently may have significant future impact. The majority of recorded alien species will have arrived since 1950. Usually these species appear in Britain or Northern Europe before occurring in Ireland. The majority of the marine species will have originated from the North Pacific Ocean whilst most of the freshwater species will have originally been sourced from North America. The sixty-three cryptogenic species arise out of the uncertainty of their origin or as to how they will have arrived. Ireland being a recently deglaciated island and separated from the continental land mass will have acquired the majority of its biota since the last glacial retreat making distinction between native and alien species more difficult.

Key words: Ireland, Celtic Sea, aquatic species, introductions, alien, freshwater, marine, invasive, population status

Introduction

The spread of alien species arises out of centuries of human mobility aided by increased trade over progressively greater areas via new vector transmissions and further and more rapid routes for dispersal (Minchin 2006a, 2007a). Trade in Ireland up till the early 1900s was mainly confined to Britain, Northern Europe, and the eastern coast of North America. Today links exist with all continental regions and aliens may be directed through Northern Europe or Britain and then subsequently spread as a result of natural range extensions and/or by human transmissions to Ireland.

There have been compilations of alien species for Ireland for some taxonomic groups (Hayden 2002, Reynolds 2002), environments (O'Riordan 2002) or as a result of specific industries

(Minchin 1996, 2004). No previous attempt has been made to include all known alien aquatic species from the freshwater, brackish (transitional) and marine environments of Ireland or to separate them according to alien and cryptogenic components. However, a full list of aquatic aliens is unlikely to be achieved as this requires specific taxonomic knowledge, regular monitoring to reveal them and many are either or both rare or cryptic and remain undiscovered. Those that become recognised are normally because they are either conspicuous or result in some recognised impact. Alien species are defined here as those species that will have been spread intentionally or unintentionally by humans to areas outside of their natural range. Any subsequent movements may either involve humans or natural spread or combinations of both. While many can be recognised as aliens there is a significant component whose means of arrival, or whose native origin, is unclear or

unknown. These are termed cryptogenic species (Carlton 1996). In time the origin and history of some of the cryptogenic component will be clarified through forensic biogeography. Very often species that arrive in Ireland will have been recorded at an earlier time in Britain (Minchin and Eno 2002) or elsewhere in northern Europe. Shipping, aquaculture and the trade in ornamentals has enabled the spread of species over greater distances, and from different geographical provinces. The extent and reduced durations of long-distance transport have greatly aided opportunities for the dispersal of species (Minchin 2006a, Minchin 2007a). In concert with this increased trade and mobility there are many well studied regions of the world showing an increase in the frequency of alien species arrivals in recent decades (Hewitt et al. 1999, Cohen and Carlton 1998, Leppäkoski et al. 2002, Wonham and Carlton 2005, Leppäkoski and Olenin 2000).

This account summarises the occurrence of those aquatic species that have been recorded in Ireland to June of 2007. The list ranges from single records of species, some of which are unlikely to survive or become established in Irish waters, to those that are invasive and spreading. The account does not provide a full record of alien microbiota and disease organisms. Similar recent European accounts have been compiled for Belgium (Kerckhof et al. 2007), Denmark (Jensen and Knudsen 2005), Germany (Gollasch and Nehring 2006), The Netherlands (Wolff 2005), the Baltic States (Olenin 2005) and the Ukraine (Alexandrov et al. 2007).

Methods

A register of alien and cryptogenic species was developed from literature searches through journals, reports, unpublished records and from recent field and taxonomic studies.

There are different levels of certainty as to how a species arrives (Minchin 2007a). In cases where there is direct evidence for an arrival the activity responsible for the arrival is known. Likely arrivals are those associated with a vector activity in an area adjacent to where a species is presumed to have arrived and where there is also evidence for the species being associated with the same mode of entry elsewhere. Written accounts that relate to early introductions are also considered. In many cases direct evidence is lacking and no single likely mode can be

ascribed. Possible modes for an entry, where several activities may be responsible for an introduction, are not considered in assessments of the role of human activities in the introduction of species except in a group analysis of all possible entry modes.

Species living adjacent to aquatic environments without a dependency on water immersion are not considered in this account, such as riverbank plants and mammals (with one exception) and all birds. Neither are vagrant species arriving as a result of climate or ocean currents such as plant disseminules (Nelson 2000), however, some molluscs arriving on drifting man-made objects have been included.

Cryptogenic species are tabled separately (Annex 2). Over time the status of some of these is expected to change and so may be removed due to improved knowledge of natural dispersal mechanisms or of transport from their origin.

Results

One-hundred-and-twelve alien species were found in Ireland (Annex 1) and sixty-three cryptogenic species (Annex 2). The numbers obtained show an increase of both marine and freshwater species recorded for recent decades (Figure 1). The most notable increase is from the 1950s to the present day. While there are fewer cryptogenic species these generally show a similar trend except over the last seventeen-year period (Figure 2). The arrival of eighteen species prior to 1850 can not be truly ascribed as being native or alien either due to imperfect knowledge of their native distributions or as to how they arrived.

The great majority of marine species originate from the North Pacific and if extended to include the Indo-Pacific would make up more than half of all records (Figure 3). Among these are deliberate introductions for aquaculture made-up of five cultivated molluscs and a fish making up ~10% of this total. Over twenty percent of the brackish and marine species are from the north-west Atlantic arriving as a result of the close trading connection between the east coast of North America and Britain and Ireland. This same historical link, over the last few hundred years, could explain the large proportion of freshwater biota, of more than one third, arriving from North America (Figure 4). As far as can be reasonably determined the great majority of species will have arrived with aquaculture, trade

in ornamental species and with commercial and leisure vessels (Figure 5) with most arriving within the last fifty years. Natural spread of aliens will have involved either the spread of molluscs attached to buoys and other human-made flotsam or from spread from an

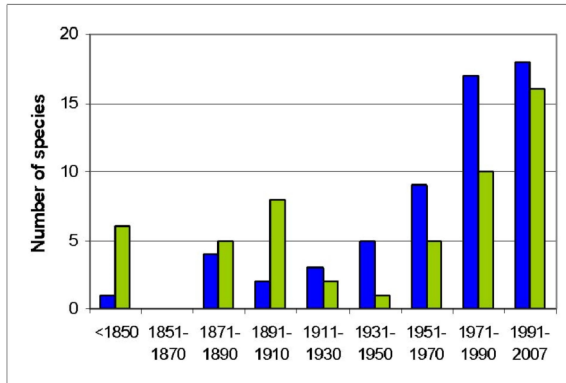


Figure 1. Periods of first known Irish records for alien aquatic species occurring in freshwater (green) brackish and marine environments (blue). Note: These may not be the real arrival dates

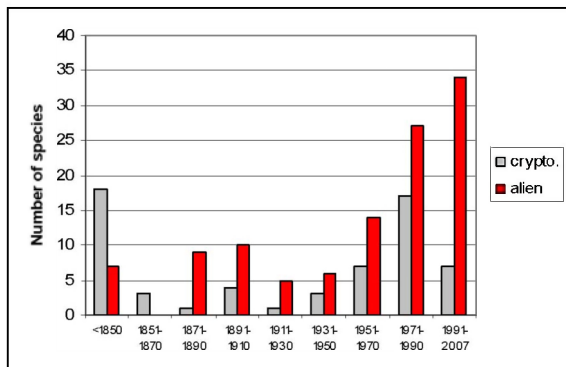


Figure 2. Periods for all first known Irish records for alien aquatic species (red) and cryptogenic species (grey). Note: These may not be the real arrival dates

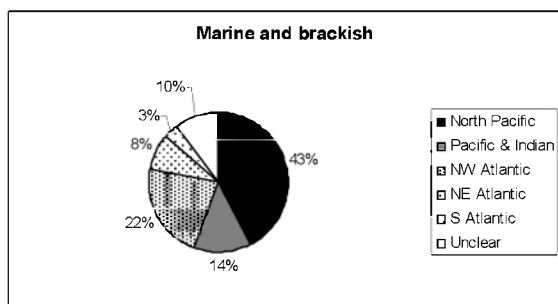


Figure 3. Native origin of alien brackish and marine species occurring on Irish coasts

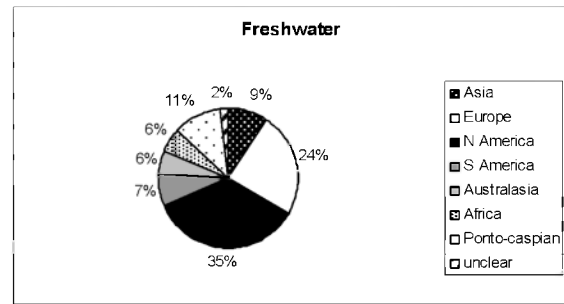


Figure 4. Native origin of aquatic species occurring in Irish inland waters

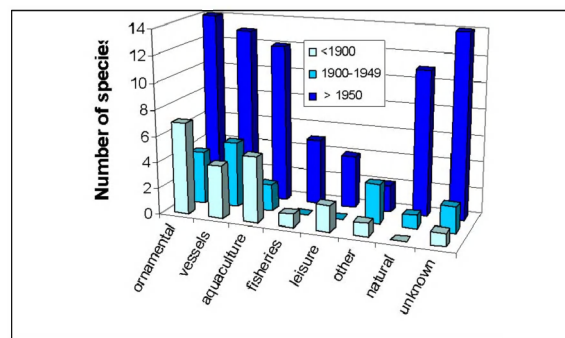


Figure 5. The numbers of aquatic alien species introductions associated with human activities over different time periods where there is direct evidence, or where it is likely that a particular human activity is involved in an arrival to Ireland

introduction that took place elsewhere within Europe. All other activities range from less than a quarter to a half of any of these principal modes of transmission. However, there is a large component of species whose mode of arrival remains unknown. All of the ornamental species will have been released to freshwater environments and the majority of the brackish and marine species will have arrived with shipping or aqua-culture activities.

Table 1. Relative distributions of alien species considered to be established in Irish aquatic environments

Recent Distributions	Freshwater	Brackish/ Marine
Single locality	6	5
Localities	16	12
Regional	8	3
Widespread	7	11

Table 2. Status of alien species in Irish aquatic environments. From this list the numbers in cultivation are also indicated

Population Status	Freshwater	Brackish/ Marine
Abundant	6	6
Common	20	18
Rare	11	7
No further records/ extinct	8	16
unknown	8	5
<i>cultivated</i>	15	7

Many of the aliens in both the freshwater and brackish and marine environments have similar patterns for distribution (Table 1) and their status (Table 2).

Discussion

A-hundred-and-twelve alien species have been recognised as occurring in Ireland, and sixty-three cryptogenic species, up to the end of June 2007. Further species have almost certainly yet to be revealed or reported and it is likely that there will be additions from disparate sources not found in this exercise. The high preponderance of aliens recorded from one or more localities (Table 1) suggests there are future opportunities for these species to expand. The larger numbers of species known to be common or abundant (Table 2) may merely reflect findings of species more easily observed while those that are rare and less significant are overlooked. Costello et al. (1996) indicated that there are many more species yet to be described as new to science from British and Irish waters but the numbers will vary according to each taxonomic group and depend on available expertise, their size and distinctiveness.

Islands off continents have a reduced diversity due to the different levels of separation caused by linear distance, strength and direction of water and wind currents and intervening depths. Rare or occasional events that inoculate islands may be important in the establishment and colonisation of islands to form a native biota. However, in recent decades the efficient, diverse and far-ranging extent of transport modes has

enabled access to a greater diversity of species from all world regions. Nevertheless many arrivals to islands can be predicted on account of their appearance and spread on nearby landmasses. This provides managers with an advantage by providing an advanced warning of some impacting species.

Some species may be difficult to classify as alien or cryptogenic, as in the case of expansions in the ranges of the plants *Hottonia palustris*, *Stratiotes aloides* and snails *Planorbis cornuta* and *Viviparus viviparus*. These will be considered by some to have confined 'native' populations but different populations from overseas may have been imported which might explain their recent vigorous spread in the wild. Classifying a species moved from one nearby region in Ireland to another, for example *Groenlandia densa*, is likely to rely on different definitions on the scale of the extended range to different bays or catchments and/or to different administrative/political regions. Consequently the opinions as to the status of a species may vary.

The natterjack toad *Bufo calamita*, according to a Whilde (1993) might have been introduced with sand ballast; and until the recent work by Rowe et al (2006) would have been classified as cryptogenic. Their study of toad populations throughout its European range, using mitochondrial DNA, found the Irish population to be distinct and so considered it to be native to Ireland. Normally an alien species will have a known range that exists outside of Ireland. However, some such as the wasting disease of the eel-grass *Labrynthula zosterae* is almost certainly introduced to Ireland although its origin remains unknown.

Of particular interest to managers are those alien species that are recognised as having some impact. The Irish Environmental Protection Agency (EPA, 2004) and the Environment and Heritage Service of Northern Ireland (Anon, 2005) undertook alien species risk analyses in accordance with Article 5 of the Water Framework Directive (WFD) (EU 2000) (apart from microbiota and parasites). The two agencies listed nine aquatic species present in Ireland of management priority: *Azolla filiculoides*, *Crassula helmsii* (Figure 6), *Hydrocotyle ranunculoides*, *Elodea nuttallii* (Figure 7), *Myriophyllum aquaticum*, *Sargassum muticum*, *Spartina anglica*, *Dreissena polymorpha* (Figure 8) and *Leuciscus leuciscus*.



Figure 6. The ornamental plant *Crassula helmsii* in clay pits on the Ards Peninsula, Northern Ireland, June 2006. Photo: Dan Minchin



Figure 8. Settlement of spat of the zebra mussel *Dreissena polymorpha* on an older shell at a time of rapid expansion in Lough Derg, June 1998. Photo: Dan Minchin



Figure 7. The ornamental plant *Elodea nuttallii* from Lough Derg, June 2005. Photo: Dan Minchin



Figure 9. The ornamental plant *Lagarosiphon major* from Lough Corrib in the west of Ireland. Photo: Dan Minchin

Certainly in Ireland the zebra mussel has had important impacts (Minchin et al. 2006) and is likely to continue to spread over decades (Karatayev et al. 2006). To this list three further aquatic species have become notable since these accounts were assembled, the Chinese mitten crab *Eriocheir sinensis*, the South African pondweed *Lagarosiphon major* (Figure 9) and the colonial tunicate *Didemnum* sp. (Figure 10).

Specimens of the Chinese mitten crab have only recently appeared in the Waterford Estuary on the Irish south coast but it has the potential to expand its range throughout much of Ireland because many of the main river basins are connected by canals (Minchin 2006b). The South African pondweed has become dominant in a large area of one lake (J Caffrey pers. comm.) and there is a risk this species will spread. The

origin of the *Didemnum* sp. is unknown and is classed here as being cryptogenic although all indications suggest it is an alien species. This marine tunicate has not yet been fully identified due to the small number of anatomical features, which can be variable. However, its growth and often pendulous appearance is similar to *D. vexillum* described from New Zealand (Kott 2002) and *D. vestum* described from the east coast of North America (Kott 2004) where invasive forms have been noted (Pannell and Coutts 2007; Valentine 2007a, 2007b). There are no previous records to the findings of Minchin and Sides (2006) in Irish waters who between them will have had over fifty years diving experience. It is true that some species are likely to have been recorded many years after an arrival, likely to be the case for *Clymenella*

torquata. This annelid was most probably introduced to Ireland during the late 1800s or early 1900s with imports of half-grown North American oyster *C. virginica* for on-growing. Due to its abundance and form it is very unlikely that the *Didemnum* sp. would have been overlooked in the same way.

There are several diseases and parasites, and some, such as the crayfish plague *Aphanomyces astaci* and the shell disease of oysters *Ostracoblabe implexa*, are no longer thought to remain in Ireland. However, there are two parasites causing significant impact: the haplosporidian *Bonamia ostreae* a blood parasite of the native oyster *Ostrea edulis* and the nematode parasite of eels *Anguillicola crassus* (Figure 11). *B. ostreae* may have originated in California (Elston et al. 1986) arriving with transfers of the European native oyster *Ostrea edulis* to France from where the disease is thought to have spread to Ireland. Although reduced densities and suspended culture result in lower mortalities there have been considerable declines in affected wild fisheries and a change to culturing of the Pacific oyster *Crassostrea gigas* (Héral 1989). The Oriental eel parasite *Anguillicola crassus* arrived with a consignment of the Pacific eel *Anguilla japonica* from Taiwan in an European aquaculture trial. This nematode resides beneath the air bladder feeding on the blood supplied to it (Kennedy and Fitch 1990) and causes damage to other internal organs (Lefebvre et al. 2004) and eels entering the winter have reduced levels of fat (DW Evans pers. comm.) and is likely to result in an inability to regulate their buoyancy and have sufficient reserves for the spawning migration. Unfortunately this species is beyond any control on account of the large number of paratenic hosts that can include aquatic insects (Moravec and Škoríková 1998). Other impacting diseases of fish in Britain such as the rosette-like agent (Gozlan et al. 2005) could gain access to Ireland with aquarium fish imports or releases of sport fishes.

Species likely to be of consequence, and yet to be recorded in Ireland, will be among those already recognised as causing impacts in Britain or northern Europe. Advanced targeting of these may enable eradication or reduction of their spread should they arrive. Early intervention using a regular rapid assessment surveys as developed by Ashton et al (2006) and Minchin (2007b) provides practical information for managers by revealing sites of alien species arrivals and range extensions of species already present.



Figure 10. The cryptogenic tunicate *Didemnum* sp. overgrowing mussels and removed from a floating pontoon in the Malahide Estuary on the Irish east coast. June 2006. Photo. Dan Minchin



Figure 11. *Anguillicola crassus* a nematode parasite of the European eel, Lough Derg 2006. Photo. Dan Minchin

It has not been possible to determine the human activities responsible for all of the introductions; but almost three-quarters of all known entries involve deliberate and purposeful

trade to Ireland, albeit some of these introductions will have been misguided or associated with traded species. Some will have initially been confined but subsequently became released or escaped. For several species their arrival can not be related to a single human activity. Yet when all of the possible modes of entry are pooled a similar trend emerges (Figure 12). Should there have been fore-knowledge of the nine priority species (under Article 5 of the WFD, see above) eight could have been 'prevented' on the basis of risk assessments; and of the three additional species of concern, one. However, such foresight was acquired only after an introduction was made as in the case of the deliberate plantings of *Spartina anglica* used to accrete land (Cummins 1930) but was later found to result in ecological impacts (McCorry and Otte 2000).

The large number of ornamental plants appearing in new localities in the wild is of concern and there are also several aquarium species, other than plants, on sale that may become introduced to the wild that include freshwater snails, crabs, crayfish, fish (such as sturgeon and pumpkinseed) and terrapins. It is possible that some of these will be found in the wild over the coming decades.

The incomplete knowledge of Ireland's native assemblages and of human species transmissions after the last glacial period makes it difficult to evaluate what is native and what is introduced. For example, the appearance of the soft-shelled clam *Mya arenaria* may have resulted from early Viking exploration from North America during about the 1300s (Strasser 1999), or perhaps from a late and natural northward re-expansion. Similarly the 'shipworm' *Teredo navalis* may have arrived in the hulls of wooden ships, yet drifting tree parts must have been a frequent form of flotsam at a time when there were extensive forests.

On account of the poor knowledge of the mechanisms of natural dispersal many species have been classified as cryptogenic. While some may be spread after an arrival following human activities their subsequent dispersal may occur with different combinations of natural and human spread. Remote appearances are often deduced as being due to human activities but might also be due to the transmission of a specific stage by natural means. Without a better knowledge of natural dispersal mechanisms there will continue to be some confusion on the status of some species. Knowledge of the natural

mechanisms of dispersal are important to deduce, not only to classify their status correctly, but because efforts by management spent in control of some aliens may be rendered ineffective because of efficient natural spreading mechanisms.

Birds have the capability of spreading species inadvertently on the body, in the gut or tissues as parasites. Some may equally have arrived with fish introductions, i.e. freshwater fish eye-flukes. The hydroid *Cordylophora caspia* appears in widely separated Irish lagoons frequented by birds that might have transmitted the resting menont stage. However, *C. caspia* is generally considered to be alien in many parts of Europe; but their transmission elsewhere in Europe may also have been with bird movements. The semi-tropical aquatic macrophyte *Hydrilla verticillata*, listed as one of the worlds most invasive species (ISSG 2007), according to Preston et al. (2002) is considered to be native. It occurs in two remote western Irish lakes and may have been carried there with migrating waterfowl. Scannell and Webb (1976) found it produced an abundance of all-female flowers under greenhouse conditions indicating the plant does not enjoy optimal conditions in Ireland. Invasive plants only known to propagate vegetatively may not be native (i.e. *Hottonia palustris*, *Hydrilla verticillata*, *Stratiotes aloides*), and a species occurring with only one sex present may not be native, an argument used by Cook and Urmikönig (1983). The appearance of the aquatic macrophyte *Ceratophyllum submersum* in lakes or coastal lagoons might also be explained by the presence of wildfowl. Meteorological events may even cause some species to be carried to Ireland. This may have happened with the arrival of the once established insect *Microvelia pygmaea* to Lough Gur in the southern midlands of Ireland (Walton 1985).

Conditions following the last deglaciation will have enabled anadromous and catadromous fishes access to Ireland's river catchments. There is a presumption that those intolerant of marine conditions will all have been introduced. Giralduus Cambrensis on visits to Ireland 1183 and 1185 referred to an absence of several fishes by name such as the pike (Went 1957) and cyprinids as being absent (Moriarty and Fitzmaurice, 2000). Such reported absence has not been considered to be sufficient evidence in this account to include them as aliens unless there are records of an introduction since then. Some fishes might have survived in refugia and

subsequently expanded their range from areas now inundated by the sea (Ménot et al 2006). Yet it is possible that some fishes and a crustacean, the white-clawed crayfish *Austropotomobius pallipes*, were introduced during monastic times to Ireland (Gouin et al. 2003).

Recognised invaders can be prevented entry by using pre-border management measures. Managers have the capability of controlling deliberate introductions by legislation and by monitoring of imported ornamental products and by applying precautionary measures in relation to aquaculture stock imports that may have associated pests, parasites and diseases (ICES 2005). Yet large bulk transmissions, although inspected, could carry unwanted introductions as happened with the introduction of associated species with imports of half-grown Pacific oysters from France (Holmes and Minchin 1995; Minchin et al. 1993). Such imports could include cysts contained in shell spaces or in the molluscan gut (Dijkema 1992) or otherwise attach to the shells of oysters (Mineur 2007a). Controls on ships' ballast water are confronted with problems of scale for effective treatment (IMO 2004) and presently mid-ocean exchanges are only suitable in reducing primary inoculations over large distances whereas short sea-going journeys have insufficient time for such an exchange process. Consequently secondary spread by shipping is likely to continue until some practical sterilisation approach is generally employed. Despite any of these measures it is difficult to see how microbial pathogens can be controlled (Drake et al. 2007). The usage of less-effective antifouling paint applications, of lower toxicity, on ship-hull are likely to result in further alien expansions worldwide (Minchin and Gollasch 2003). Hull fouling by ships (Gollasch 2002, Mineur 2007b) continues to be a significant problem and leisure craft also have the capability of inoculating the many bays and inlets that ships do not visit (Floerl 2002, Minchin et al. 2006b). Impacts can be reduced with specific forms of boat harbour design (Floerl and Inglis 2003).

The general changes in weather patterns with warmer over-wintering water temperatures, most probably resulting from an alteration of overall current flow in the north-east Atlantic and in the Polar Sea (Greene and Pershing 2007) allow species with poor lower temperature tolerances to survive and enhance the opportunities for the spread of aliens (Stachowitz et al. 2002). Those requiring higher temperatures for reproduction

may now colonise after being introduced. For example the layings of hatchery produced Pacific oysters have over the last decade produced small settling numbers in different Irish bays (Boelens et al. 2005). Vagrants may also establish themselves and the distinction of these from those introduced by human activities is likely to lead to additions to the cryptogenic list for Ireland.

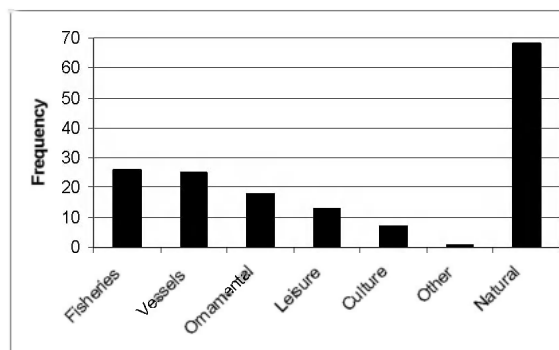


Figure 12. Accumulated frequency of possible modes of arrival for an alien species to Ireland

With expansion of the European Union to include eastern European countries further risks of transmissions of alien species arise with the policy of an open market (Howarth and McGillivray 1994). The Ponto-caspian bioprovince has a separate and distinct biota which has already made advances across Europe (Bij de Vaate et al 2002) and small numbers of these will have recently arrived in Ireland, such as the zebra mussel *D. polymorpha*, and its commensals, and the amphipod *Chelicorophium curvispinum*. It is likely that the spread of further species from this region will continue along the inland navigation network (Panov et al. 2007; Galil and Minchin 2006; Minchin et al 2006c). Some of these may be expected to arrive in Ireland as a result of different human activities.

Conclusion

One-hundred-and-twelve species are considered to be introduced to Ireland of which sixty-eight are considered to be established and sixty-three cryptogenic species have been identified. Many other species have almost certainly yet to be revealed. Fourteen species have been considered to be of high impact and continue to expand their

ranges in Ireland. The high degree of human mobility and the expansion of the European trading block as well as continued trade will result in further species becoming introduced from Britain and Northern Europe. Some pathways pose special risks and management may more effectively apply controls on specific species known to result in ecological and economic impacts that may, for example, be imported as, or with, ornamentals and those involved in aquaculture. With a policy of open trade and expansion of the European Union further species are likely to be inadvertently or deliberately brought to Ireland. More emphatic controls to protect Ireland's aquatic ecosystems are needed if further high impacting species are to be prevented from arriving. Such pre-border management is a cheaper and easier option and will involve a shared responsibility with different user groups.

Acknowledgements

The account was supported under the European Union 6th Programme funded projects ALARM (GOCE-CT-2003-506675) and DAISIE (SSPI-CT-2003-511202). Other investigations involving support since 2000 were from The Marine Institute, Environment and Heritage Service of Northern Ireland, Irish Wildlife Service, Regional Fisheries Boards, Shannon River Basin District programme of the Department of the Environment and the Environmental Protection Agency. My thanks to the following who either provided information, guided me in my searches of the literature, aided in confirmations of identity or provided field assistance over the years: R Anderson, G Ashton, J Bishop, P Boaden, R Boelens, J Caffrey, P. Casburn, E Cook, MJ Costello, DCF Cotton, E Cusack, G Day, M Davis, J Dick, CB Duggan, DW Evans, NC Folino-Rorem, FA Gibson, MD Guiry, JMC Holmes, E Horgan, F Igoe, K Jazdzewski, M Jebb, CR Kennedy, S Kraan, G Lambert, J Lucey, FE Lucy, J. McArdle, C McCarthy, C Maguire, TK McCarthy, B MacGabhain, D McGrath, T Mackie, CA Maggs, F Marnell, T McMahon, A Minchin, B Minchin, E Moorkens, O Morton, J Nunn, M O' Cinneide, F O'Beirn, G Oliver, B Ottway, D Quigley, J Reynolds, SCP Reynolds, E Sides, J Silke, M Sullivan, P Sweeney, E Thompson, P Treacy, C Trowbridge, P Whelan, N Wilkins and J Williams.

References

- Alexandrov B, Boltachev A, Kharchenko T, Lyashenko A, Son M, Tsarenko P and Zukinsky V (2007) Trends of aquatic alien species invasions in Ukraine. *Aquatic Invasions* 2 (3): 215-242
- Anderson R (1977) Mapping non-marine mollusca in north-east Ireland. *Irish Naturalists' Journal* 19(2): 33-37
- Anderson R (1983) Mapping non-marine mollusca in north-west Ireland. *Irish Naturalists' Journal* 21(2): 59-61
- Anderson R (1996) *Physa gyrina* (Say), a North American freshwater gastropod new to Ireland, with a key to the British Isles Physidae. *Irish Naturalists' Journal* 25(7): 248-253
- Anderson R (2001) *Physa (Physella) gyrina* (Say) (Mollusca: Pulmonata) in Lough Eske, East Donegal. *Irish Naturalists' Journal* 26(11): 429
- Anderson R (2003a) *Dugesia tigrina* (Girard) (Tricladida: Paludicola) new to Ireland. *Irish Naturalists' Journal* 27: 236-237
- Anderson R (2003b) *Physella (Costatella) acuta* Draparnaud in Britain and Ireland - its taxonomy, origins and relationships to other introduced physidae. *Journal of Conchology* 38: 7-22
- Anderson R (2004) *Physella gyrina* (Say)(Mollusca: Gastropoda) in the Quoile pondage, Co Down. *Irish Naturalists' Journal* 27: 482-483
- Anon. (2005) Water Framework Summary report of the characterisation and impact analyses required by Article 5, Northern Ireland. March 2005, 60pp. <http://www.ehsni.gov.uk/pubs/publications/article5report.pdf>
- Arnold (1960) Occurrence of the slipper limpet *Crepidula fornicata* L. in Ireland. *Nature* 180: 95
- Ashton G, Boos K, Shucksmith R and Cook E (2006) Rapid assessment of the distribution of marine non-native species in marinas in Scotland. *Aquatic Invasions* 1(4): 209-213
- Astanev J, Gosling E, Wilson J and Powell E (2005) Genetic variability and phylogeography of the invasive zebra mussel, *Dreissena polymorpha* (Pallas). *Molecular Ecology* 14: 1655-1666
- Bean CW and Winfield IJ (1989) Biological and ecological effects of a *Ligula intestinalis* (L.) infestation of the gudgeon, *Gobio gobio* (L.), in Lough Neagh, Northern Ireland. *Journal of Fish Biology* 34: 135-147
- Beard DM (1957) Occurrence of *Elminius modestus* Darwin in Ireland. *Nature* 180: 1145
- Bij de Vaate A, Jazdzewski K, Ketelaars HAM, Gollasch S and Van der Velde G (2002) Geographical patterns in range extension of Ponto-caspian macroinvertebrate species in Europe. *Canadian Journal of Fisheries and Aquatic Sciences* 59: 1159-1174
- Black T (1978) *Acanthocephala anguillae* (Muller, 1780) from bronze bream *Abramis brama* for the first time in Britain and Ireland together with some additional records of intestinal parasites in *A. brama*. *Irish Naturalists' Journal* 19(7): 251
- Boaden PJS (1995) The adventive seaweed *Sargassum muticum* (Yendo) Fensholt in Strangford Lough, Northern Ireland. *Irish Naturalists' Journal* 25: 111-113
- Boelens R, Minchin D and O'Sullivan G (2005) Climate Change: Implications for Ireland's marine environment and Resources. Marine Foresight Series No 2, Marine Institute, Oranmore, Co Galway 40pp.
- Breeman AM, Meulenhoff EJS and Guiry MD (1988) Life history regulation and phenology of the red alga

- Bonnemaisonia hamifera*. Helgoländer Meeresuntersuchungen 42: 535-551
- Briggs R (1973) *Lichomolgus actinae* D.V. an associated copepod new to Irish waters. Irish Naturalists' Journal 17 (12): 423-424
- Burlakova LE, Padilla DK, Karatayev AY and Minchin D (2006) Endosymbionts of *Dreissena polymorpha* in Ireland: evidence for the introduction of adult mussels. Journal of Molluscan Studies 72: 207-210
- Carlton JT (1996) Biological invasions and cryptogenic species. Ecology 77(6): 1653-1655
- Cohen AN and Carlton JT (1998) Accelerating invasion rate in a highly invaded estuary. Science 279: 555-558
- Cole HA and Hancock DA (1956) Progress in oyster research in Britain 1949-1954, with special reference to the control of pests and diseases. Proceedings pour verbaux 1956: 24-29
- Cook CDK and Urmi-König K (1983) A revision of the genus *Stratiotes* (Hydrocharitaceae). Aquatic Botany 16: 213-249
- Copely L and McCarthy TK (2001) The first record of the monogenean gill fluke *Pseudodactylogyrus bini* (Kikuchi 1929) in Ireland, with observations on other ectoparasites of River Erne eels. Irish Naturalists' Journal 26: 405-413
- Costello MJ (1993) Biogeography of alien amphipods occurring in Ireland and interactions with native species. Crustaceana 65: 287-299
- Costello MJ, Embrow CS and Picton BE (1996) Long term trends in the discovery of marine species new to science which occur in Britain and Ireland. Journal of the Marine Biological Association of the United Kingdom 76: 255-257
- Cotton DCF (1996) First Irish record of a living population of the river snail *Viviparus viviparus* (L.) (Gastropoda: Prosobranchia) in the Shannon catchment, Co Leitrim. Irish Naturalists' Journal 25(8): 278-280
- Cotton DCF (1999) Least duckweed *Lemna minuta* Kunth, in Ireland. Irish Naturalists' Journal 26(5/6) 199-200
- Cotton D and Caffrey J (2000) Curly waterweed *Lagarosiphon major* (Ridley) Moss, in Ireland. Irish Naturalists' Journal 26(9): 327-328
- Crowley M (1972) The parasitology of Irish mussels. Department of Agriculture and Fisheries, Fishery leaflet No 35, 12pp
- Cullinane J and Whelan P (1981) Ecology, distribution and spread of *Cryptonemia hibernica* Guiry et Irvine on the south coast. Proceedings of the International Seaweed Symposium 10: 259-264
- Cullinane J, Maguire D and Whelan P (1984) The importance of substrate type in colonization by *Cryptonemia hibernica* Guiry et Irvine and its associated algae. Hydrobiologia 116-117: 438-442
- Cullinane JP and Whelan PM (1984) Marine algal records from the south coast of Ireland. Irish Naturalists' Journal 21(7): 302-304
- Culloty SC and Mulcahy MF (1996) Season-, age-, and sex-related variation in the prevalence of bonamiasis in flat oysters (*Ostrea edulis* L.) on the south coast of Ireland. Aquaculture 144: 53-63
- Culloty SC and Mulcahy MF (2007) *Bonamia ostreae* in the native oyster *Ostrea edulis*, a review. Marine Environment and Health Series No 29, 36pp. Marine Institute, Oranmore, Galway.
- Culloty SC, Novoa B, Pernas M, Longshaw M, Mulcahy MF, Feist SW and Figueras A (1999) Susceptibility of a number of bivalve species to the protozoan parasite *Bonamia ostreae* and their ability to act as vectors for this parasite. Diseases of Aquatic Organisms 37: 73-80
- Cummins HA (1930) Experiments on the establishment of rice grass (*Spartina townsendii*) in the estuary of the Lee. The Economic Proceedings of the Royal Dublin Society 2. No 26, 419-421
- Curtis TGF and Sheehy-Skeffington (1998) The salt marshes of Ireland: an inventory and account of their geographic variation. Biology and Environment: Proceedings of the Royal Irish Academy 98B: No 2, 87-104
- Day GV (2003) A report for Co Down (vc H38) 2003. Irish Botanical News 14: 31-34
- Day G (2004) *Hydrocotyle ranunculoides* L. f., an invasive aquatic plant, in Cos Down (H38) and Antrim (H39). Irish Naturalists' Journal 27: 400
- De Grave S, Moore SJ and Burnell G (1998) Changes in benthic macrofauna associated with intertidal oyster, *Crassostrea gigas* (Thunberg) culture. Journal of Shellfish Research 17: 1137-1142
- De Grave S and Wilkins HKA (1994) *Corophium multisetosum* (Crustacea), an amphipod new to Ireland. Irish Naturalists' Journal 24 (9): 366-367
- DeValera M (1942) A red algae new to Ireland: *Asparagopsis armata* Harv. on the west coast. Irish Naturalists' Journal 8: 30-34
- Dijkema R (1992) The risk of provoking toxic dinoflagellate blooms in the Dutch coastal waters through immersion of imported bivalves, originating from red tide areas. ICES Shellfish Committee CM 1992/K:48, 11pp
- Dromey M (1991) *Groenlandia densa* (L.) Fourr in the Royal Canal, Dublin. Irish Naturalists' Journal 23: 383-384
- Drake L, Doblin MA and Dobbs FC (2007) Potential microbial bioinvasion via ships' ballast water, sediment and biofilm. Marine Pollution Bulletin 55: 333-341
- Edwards M, John AWG, Johns DG and Reid PC (2001) Case history and persistence of the non-indigenous diatom *Coscinodiscus wailesii* in the north-east Atlantic. Journal of the Marine Biological Association of the United Kingdom 81: 207-211
- Elston RA, Farley CA and Kent ML (1986) Occurrence and significance of bonamiasis in European flat oysters *Ostrea edulis* in North America. Diseases of Aquatic Organisms 2: 49-54
- El-Toumi F and McCarthy TK (1990) *Tylodelphys podicipina* Kozicka and Niewiadomska (Digenea: Diplostomatidae), new to Ireland. Irish Naturalists' Journal 23 (8): 341
- EPA (2004) Alien Species Risk assessment (Republic of Ireland). Guidance for the assessment of pressures and impacts in accordance with Article 5 of the Water Framework Directive. Environmental Protection Agency, Kilkenny, 37pp
- EU (2000) Directive 2000/60/EC of the European parliament and the Council, 23 October 2000
- Evans DW and Mathews MA (1999) *Anguillicola crassus* (Nematoda, Dracunculoidea); first documented record of this swimbladder parasite of eels in Ireland. Journal of Fish Biology. 55: 665-668
- Fairley J (1982) The muskrat in Ireland. Irish Naturalists' Journal 20: 405-411
- Fairley J. (2001) A basket of weasels. Privately published, Belfast 384pp
- Floerl O (2002) Intracoastal spread of fouling organisms by recreational vessels. PhD Dissertation, James Cook University, Townsville, 293pp
- Floerl O and Inglis GJ (2003) Boat harbour design can exacerbate hull fouling. Austral Ecology 28: 116-127
- Forbes RS (2000) Assessing the status of *Stratiotes aloides* L. (Water-soldier) in Co Fermanagh, Northern Ireland (v.c. H33). Watsonia 23: 179-196

- Fryer G (1985) The ecology and distribution of the genus *Daphnia*. *Journal of Natural History* 19: 97-128
- Galil BS and Minchin D (2006) Snakes and ladders: navigable waterways as invasion corridors. John Davenport and Julia L. Davenport, (eds.) *The Ecology of Transportation: Managing Mobility for the Environment*, 71-75, Springer, The Netherlands
- Gibson CE, McCall RD and Dymond A (1993) *Skeletonema subsalsum* in a freshwater lake. *Diatom Research*. 8: 65-71
- Gibson FA (1961) *Gaffkaemia* in stored lobsters. ICES Shellfish Committee CM No 58
- Gibson FA (1970) Introduction of the American hard shelled clam *Mercenaria mercenaria* into Ireland. *Irish Naturalists' Journal* 16: 281-282
- Gollasch S (2002) The importance of ship hull fouling as a vector of species introductions to the North Sea. *Biofouling* 18: 105-121
- Gollasch S and Nehring S (2006) National checklist for aquatic alien species in Germany. *Aquatic Invasions* 1(4): 245-269
- Gouin N, Grandjean F, Pain S, Souty-Grosset C and Reynolds J. (2003) Origin and colonisation history of the white-clawed crayfish, *Austropotamobius pallipes*, in Ireland. *Heredity* 91: 70-77
- Gozlan RE, St-Hilaire S, Feist SW, Martin P and Kent ML (2005) Disease threat to European fish. *Nature* 435: 1046
- Grainger JNR (1951) Notes on the biology of the copepod *Mytilicola intestinalis* Steuer. *Parasitology* 41 (3/4): 135-142
- Greene CH and Pershing AJ (2007) Climate drives sea change. *Science* 315: 1084-1085
- Grizel H (1985) *Mytilicola orientalis* Mori, parasitism. Fische No 20. Fiches d'identification des maladies et parasites des poissons, crustacéens et mollusques. ICES, Copenhagen, 4pp
- Guiry GM and Guiry MD (1973) Spread of an introduced ascidian to Ireland. *Marine Pollution Bulletin* 4: 127
- Guiry MD and Ni Donnachada E (2001) *Algaebase*. www.algaebase.com
- Hammond MER and Cooper A (2002) *Spartina anglica* eradication and inter-tidal recovery in Northern Ireland estuaries. In: Veith CR and Clout MN (eds) *Turning the tide: the eradication of invasive species*. IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK, 124-131
- Hayden TJ (2002) The assembly of Ireland's freshwater fish, amphibia, reptiles and mammals: tempo and mode. In: C Moriarty, D Murray (eds) *Biological Invaders: the impact of exotic species*. Dublin, Royal Irish Academy, 13-29
- Healy A (1956) Roach and dace in the Cork Blackwater. Fisheries Division, Department of Lands, Report on the Sea and Inland Fisheries 1956, 3-14
- Healy B, Bates R and McGrath D (1982) Marine fauna of County Wexford. 5. Lady's Island Lake. *Irish Naturalists' Journal* 20(12):510-526
- Héral M (1989) Traditional oyster culture in France. In: Barnabé, G. (Ed.), *Aquaculture* 1. Lavoisier, Paris, 342-387
- Hewitt CL, Campbell ML, Thresher RE, Martin RB, Boyd S, Cohen BF, Currie DR, Gomon MF, Keough MJ, Lewis J, Lockett MM, Mays N, McArthur MA, O'Hara TD, Poore GCB, Ross DJ, Storey MJ, Watson JE and Wislon RS (2004) Introduced and cryptogenic species in Port Phillip Bay, Victoria, Australia. *Marine Biology* 144: 183-202
- Holdich DM, Rogers WD and Reynolds JD (1999) Native and alien crayfish in the British Isles. In: Gherardi F and Holdich DM (eds) *Crayfish in Europe as alien species: how to make the best of a bad situation*. AA Balkema, Rotterdam, 221-235
- Holmes JMC (1991) Crustacean records from Lough Hyne (Ine) Co Cork Ireland: Part V. *Bulletin of the Irish Biogeographical Society* 14: 73-84
- Holmes JMC (1996) Crustacean records from Lough Hyne (Ine) Co Cork, Ireland. *Bulletin of the Irish Biogeographical Society* 19: 139-147
- Holmes JMC (1998) A checklist of the Siphonostomatoidea (Crustacea: Copepoda) of Ireland. *Bulletin of the Irish Biogeographical Society* 22: 194-228
- Holmes JMC and Gotto RV (2000) A checklist of the Cyclopoida (Crustacea: Copepoda) of Ireland. *Bulletin of the Irish Biogeographical Society* 24: 1-42
- Holmes JMC and Minchin D (1991) A new species of *Herrmannella* (Copepoda, Poecilostomatoidea, Sabelliphilidae) associated with the oyster *Ostrea edulis* L. *Crustaceana* 60: 258-269
- Holmes JMC and Minchin D (1995a) Two exotic copepods imported into Ireland with the Pacific oyster *Crassostrea gigas* (Thunberg). *Irish Naturalists' Journal* 25: 17-20
- Holmes JMC and Minchin D (1995b) Parasitic copepoda associated with teleosts in Killary Harbour, Ireland *Bulletin of the Irish Biogeographical Society* 18: 13-18
- Holland CV and Kennedy CR (1997) A checklist of parasitic helminth and crustacean species recorded in freshwater fish from Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy* 97B: 225-243
- Howarth W and McGillivray D (1994) Regulating fish movements in the single European market: the scope for more restrictive measures under national law. *Fisheries Management and Ecology* 1: 193-203
- ICES (2005) ICES Code of Practice on the Introductions and Transfers of Marine Organisms (<www.ices.dk>).
- IMO (2004) International Convention for the Control and Management of Ships' Ballast Water and Sediments. International Maritime Organization. <http://www.imo.org>
- Ingle RW (1980) *British Crabs*. British Museum of Natural History London 222pp
- ISSG (2007) *Hydrilla verticillata* <http://www.issg.org/database/species/ecology.asp?si=272&fr=1&sts=&ver=print&prflag=false> (accessed 13 May 2007)
- Jensen KR and Knudsen J (2005) A summary of alien marine benthic invertebrates in Danish waters. *Oceanological and Hydrobiological Studies* 34: Supplement 1, 137-162
- Juhel G, Culloty SC, O'Riordan RM, O'Connor J, de Faoite L and McNamara R (2003) A histological study of the gametogenic cycle of the freshwater mussel *Dreissena polymorpha* (Pallas, 1771) in Lough Derg, Ireland. *Journal of Molluscan Studies* 69: 365-373
- Karatayev AY, Padilla DK, Minchin D, Boltovskoy D and Burlakova LE (2006) Changes in global economies and trade: the potential spread of exotic freshwater bivalves. *Biological Invasions*. 9: 161-180
- Kelly DW and Dick JT (2005) Introduction and the non-indigenous amphipod *Gammarus pulex* alters population dynamics and diet of juvenile trout *Salmo trutta*. *Freshwater Biology* 50:127-139
- Kennedy CR (1966) Helminth parasites of some Irish freshwater fish. *Irish Naturalists' Journal*. 15 (7): 196-199
- Kennedy CR (1993) Introductions, spread and colonisation of new localities by fish helminth and crustacean parasites in the British Isles: a perspective and appraisal. *Journal of Fish Biology*. 43: 287-301
- Kennedy CR, Bates RM and Brown AF (1989) Discontinuous distributions of the fish acanthocephalans *Pompho-*

- rhynchus laevis* and *Acanthocephalus anguillae* in Britain and Ireland: an hypothesis. *Journal of Fish Biology* 34: 607-619
- Kennedy CR and Fitch DJ (1990) Colonisation, larval survival and epidemiology of the nematode *Anguillicola crassus*, parasite in the eel *Anguilla anguilla* in Britain. *Journal of Fish Biology* 36: 117-131
- Kerckhof F, Haelters J and Gollasch S (2007) Alien species in the marine and brackish ecosystem: the situation in Belgian waters. *Aquatic Invasions* 2(3): 243-257
- Kilty GM and Guiry MD (1973) *Mercierella enigmatica* Fauvel (Polychaeta Serpulidae) from Cork Harbour. *Irish Naturalists' Journal* 17: 379-381
- Kirk RS (2003) The impact of *Anguillicola crassus* on European eels. *Fisheries Management and Ecology* 10(6): 385
- Knight-Jones P and Knight-Jones EW (1977) Taxonomy and ecology of British spirorhynchids (Polychaeta). *Journal of the Marine Biological Association of the United Kingdom* 57(2): 453-499
- Kott P (2002) A complex didemnid ascidian from Whangamata, New Zealand. *Journal of the Marine Biological Society of the United Kingdom* 82(4): 127-137
- Kott P (2004) A new species of *Didemnum* (Ascidiacea, Tunicata) from the Atlantic coast of North America. *Zootaxa* 732: 1-10
- Kraan S and Barrington KA (2005) Commercial farming of *Asparagopsis armata* (Bonnemaisoniaceae, Rhodophyta) in Ireland, maintenance of an introduced species? *Journal of Applied Phycology* 17: 103-110
- Lefebvre F, Mounaix B, Poizat G and Crivelli AJ (2004) Impacts on the swimbladder nematode *Anguillicola crassus* on *Anguilla anguilla*: variations in liver and spleen mass. *Journal of Fish Biology* 64: 435-447
- Leppäkoski E, Gollasch S, Gruszka P, Ojaveer H, Olenin S and Panov V (2002) The Baltic – a sea of invaders. *Canadian Journal of Fisheries and Aquatic Sciences* 59: 1175-1188
- Leppäkoski E and Olenin S (2000) Non-native species and rates of spread: lessons from the brackish Baltic Sea. *Biological Invasions* 2: 151-163
- Loughnane C and Stengel D (2002) Attached *Sargassum muticum* (Yendo) Fensholt found on the west coast of Ireland. *Irish Naturalists' Journal* 27(2): 70-72
- Lucey J (2003) *Lemna minuta* Kunth (least duckweed) in E. Cork (vc H5). *Irish Botanical News* 13: 5-8
- Lucey J and Nolan K (1996) Natural Heritage. In: Stapleton (ed) *State of the Environment in Ireland*, Wexford: Environmental Protection Agency, 160-183
- Lucy F, Minchin D, Holmes JMC and Sullivan M (2004) First records of the Ponto-caspian amphipod *Chelicorophium curvispinum* (Sars, 1895) in Ireland. *Irish Naturalists' Journal* 27: 461-464
- Lyons R and Kelly-Quinn M (2003) An investigation into the disappearance of *Austropotamobius pallipes* (Lereboullet) populations in the headwaters of the Nore River, Ireland, and the correlation to water quality. *Bulletin France Pêche Pisciculture* 370-371: 139-150
- Maggs CA and Hommersand MH (1993) *Seaweeds of the British Isles*. Volume 1: Rhodophyta. Part 3A: Ceramiales. London, HMSO for Natural History Museum
- Maguire C and Gibson C (2005) Ecological change in Lough Erne: influence of catchment changes and species invasions. *Freshwater Forum* 24: 38-58
- Massey AL (1903) New locality for *Paludestrina jenkinsi*. *Irish Naturalist* 11: 19
- Matthews M. and Reynolds JD (1992) Ecological impact of crayfish plague in Ireland. *Hydrobiologia* 234: 1-6
- McArdle JF, McKiernan F, Foley H and Hugh-Jones D (1991) The current status of *Bonamia* disease in Ireland. *Aquaculture* 93: 273-278
- McCarthy DT (1981) The roach problem. *Fishery Handbook* No 1. Department of Fisheries and Forestry, Dublin. 5pp
- McCarthy TK (1973) A note on the occurrence in Ireland of the flatworm *Bdellocephalata punctata* (Pallas), (Tricladida: Dendrocoelidae). *Irish Naturalists' Journal* 17 (12): 419-420
- McCarthy TK (1974) A note on two interesting freshwater oligochaetes occurring in Ireland, *Chaetogaster limnaei* Von Baer (Naididae) and *Branchiura sowerbyi* Beddard (Tubificidae). *Irish Naturalists' Journal* 18: 46-48
- McCarthy TK (1986) Biogeographical aspects of Ireland's invertebrate fauna. In: *Proceedings of the Postglacial Colonisation Conference*. DP. Sleeman, RJ Devoy, PC Woodman. Occasional Publications of the Irish Biogeographical Society No 1. 88pp
- McCarthy TK (2002) The leech *Erpobdella testacea* (Savigny, 1920) in Ireland. *Irish Naturalists' Journal* 27: 123
- McCarthy TK and Rita SD (1991) The occurrence of the monogenean *Pseudodactylogyris anguillae* (Yin & Sproston) on migrating silver eels in western Ireland. *Irish Naturalists' Journal* 23: 473-477
- McCloughlin TJJ and Irwin SWB (1991) The occurrence of eye flukes in fish from the Erne catchment area. *Irish Naturalists' Journal* 23(10): 409-414
- McCorry MJ and Otte ML (2000) Ecological effects of *Spartina anglica* on the macro-invertebrate infauna of the mud flats at Bull Islands, Dublin Bay, Ireland. *Web Ecology* 2: 71-73
- McGrath D and King P (1992) The immigrant barnacle, *Elminius modestus* Darwin, in Galway Bay, Ireland. *Bulletin of the Irish Biogeographical Society* 15: 63-67
- McKinney ESA, Gibson CE, Stewart BM. 1997. Planktonic diatoms in the north-west Irish Sea: a study by automatic sampler. *Biology and Environment: Proceedings of the Royal Irish Academy* 97B (3): 197-202
- McMahon T, Raine R and Silke J (1998) Oceanographic control of harmful phytoplankton blooms around south-western Ireland. In: Blanco RB, Fernández J and Wyatt T (1998) *Harmful Algae*, Xunta de Galicia and Inter-governmental Oceanographic Commission of UNESCO, 128130
- McMillan N and Zeissler H (1990) Recent and fossil mollusca of the rivers Barrow, Nore and Suir, south-east Ireland. *Bulletin of the Irish Biogeographical Society* 13: 189-199
- McNeill WI (2003) Interesting plants from Co Tyrone (vc H36) 2000-2003. *Irish Botanical News* 14: 28
- Marnell F (1998) The distribution of the smooth newt (*Triturus vulgaris* L.) in Ireland. *Bulletin of the Irish Biogeographical Society* 22: 84-96
- Marnell F (1999) The distribution of the common frog *Rana temporaria* L. in Ireland. *Bulletin of the Irish Biogeographical Society* 23: 60 – 70
- Ménot C, Bard E, Rostek F, Weijers JWH, Hopmans EC, Schouten S and Sinninghe Damste JS (2006) Early reactivation of European rivers during the last deglaciation. *Science* 313: 1623-1625
- Mgaya YD and Mercer JP (1994) A review of the biology, ecology and mariculture of the European abalone *Haliotis tuberculata* Linnaeus 1758 (Gastropoda: Haliotidae). *Biology and Environment, Proceedings of the Royal Irish Academy* 94B: 285-304
- Minchin A (1991) Further distributional records of the adventive marine brown alga *Colpomenia peregrina* (Phaeophyta) in Ireland. *Irish Naturalists' Journal* 23: 38-381

- Minchin D (1996) Management of the introduction and transfer of marine molluscs. *Aquatic Conservation: Marine and Freshwater Ecosystems* 6: 229-244
- Minchin D (2000) Modes of introduction of exotic animals into Irish waters. In: *Biodiversity: the Irish dimension*. (ed) BS Rushton, Dublin, Royal Irish Academy, 147-155
- Minchin D (2004) Aquatic transport and the spread of aquatic species: challenges for management. In: John Davenport and Julia L. Davenport (eds) *The effects of human transport on ecosystems: cars and planes, boats and trains*. Dublin, Royal Irish Academy, 244-265
- Minchin D (2006a) The transport and spread of living aquatic species. John Davenport and Julia L. Davenport, (eds) *The Ecology of Transportation: Managing Mobility for the Environment*. Springer, The Netherlands, 77-97
- Minchin D (2006b) First Irish record of the Chinese-mitten crab *Eriocheir sinensis* (Milne-Edwards, 1854) (Decapoda: Crustacea). *Irish Naturalists' Journal* 28(7): 303-304
- Minchin D (2007a) Aquaculture and transport in a changing environment: overlap and links in the spread of alien biota. *Marine Pollution Bulletin* 55: 302-313
- Minchin D (2007b) Rapid coastal survey for targeted alien species associated with floating pontoons in Ireland. *Aquatic Invasions* 2(1): 63-70
- Minchin D and Boelens R (2005) *Hottonia palustris* L. (Water-violet) established in Lough Derg, N Tipperary (H10). *Irish Naturalists' Journal* 28(3): 136-137
- Minchin D and Boelens R (2007) Investigation into the distribution and abundance of alien biota in Lough Derg: an assessment of impacts 2005-6. A report to the Shannon River basin District Steering Group. Lough Derg Science Group 18 February 2007, 37pp
- Minchin D, Davis MH and Davis ME (2006a) Spread of the Asian tunicate *Styela clava* Herdman, 1882 to the east and south-west coasts of Ireland. *Aquatic Invasions* 1(2): 91-96
- Minchin D, Dodd D, Lucy F and Levine I (1998) Is *Viviparus viviparus* (Linnaeus) (Gastropoda: Prosobranchia) a native species to Ireland? *Bulletin of the Irish Biogeographical Society* 22: 229-234
- Minchin D, Duggan CB, Holmes JMC and Neiland S (1993) Introduction of exotic species associated with Pacific oyster transfers from France to Ireland. International Council for the Exploration of the Sea C.M 1993/F27
- Minchin D and Eno C (2002) Exotics of coastal and inland waters of Ireland and Britain. In: *Invasive aquatic species of Europe: distribution, impacts and management*. (eds) E. Leppakoski, S Gollasch, S. Olenin. Kluwer Academic Publishers Dordrecht, pp 267-275
- Minchin D, Floerl O, Savini D and Occhipinti-Ambrogi A (2006b) Small craft and the spread of exotic species. John Davenport and Julia L. Davenport, (eds.) *The Ecology of Transportation: Managing Mobility for the Environment*. 77-97, Springer, The Netherlands, 77-97
- Minchin D, Galil BS, David M, Gollasch S and Olenin S. (2006c). Overall introduction. In: Gollasch S, Galil, B.S., Cohen, A.N. (eds) *Bridging divides: maritime canals as invasion corridors*. Springer, The Netherlands
- Minchin D and Gollasch S (2003) Fouling and ships' hulls: how changing circumstances and spawning events may result in the spread of exotic species. *Biofouling* 19 (Suppliment) 111-122
- Minchin D and Holmes JMC (2007) The first record of *Caprella mutica* Schurin, 1935 (Crustacea: Amphipoda) from the east coast of Ireland. *Irish Naturalists Journal* 28(8): 321-326
- Minchin D, Lucy F, Sullivan M. (2002) Zebra mussel: impacts and spread. In: *Invasive aquatic species of Europe*. E Leppakoski, S Gollasch, S Olenin (eds) Kluwer Academic Publishers, The Netherlands pp 135-146
- Minchin D, Lucy F and Sullivan M (2006d). Ireland: a new frontier for the zebra mussel *Dreissena polymorpha* (Pallas). *Oceanological and Hydrobiological Studies* 34 (Supplement 1): 19-30
- Minchin D, McGrath D and Duggan CB (1987) *Calyptraea chinensis* (Mollusca: Gastropoda) on the west coast of Ireland: a case of accidental introduction? *Journal of Conchology* 32(5): 297-301
- Minchin D, McGrath D and Duggan CB (1995) The slipper limpet *Crepidula fornicata* (L.) in Irish waters with a review of its occurrence in the north-eastern Atlantic. *Journal of Conchology* 35: 247-254
- Minchin D and Nunn JD (2006) Further range extensions of the marine gastropod *Calyptraea chinensis* (L.) in Ireland. *Irish Naturalists' Journal* 28(5): 200-203
- Minchin D and Rosenthal H (2002) Exotics for stocking and aquaculture, making correct decisions. In: *Invasive aquatic species of Europe: distribution, impacts and management*. (eds) E. Leppakoski, S Gollasch, S. Olenin. Kluwer Academic Publishers Dordrecht, pp 206-216
- Minchin D and Sides E (2006) Appearance of a cryptogenic tunicate, a *Didemnum* sp. fouling marina pontoons and leisure craft in Ireland. *Aquatic Invasions* 1(3): 143-147
- Mineur F, Belsher T, Johnson MP, Maggs CA and Verlaque M (2007a) Experimental assessment of oyster transfers as a vector for macroalgal introductions. *Biological Conservation* 137(2): 237-247
- Mineur F, Johnson MP, Maggs CA and Stegenga H (2007b) Hull fouling on commercial ships as a vector of macroalgal introduction. *Marine Biology* 151(4): 1299-1307
- Moorkens EA (2007) Survey of *Vertigo moulinsiana* in the Shannon Basin. Unpublished Report to National Parks and Wildlife Service, Dublin.
- Moravec F and Škoriková B (1998) Amphibians and larvae of aquatic insects as new paratenic hosts of *Anguillicola crassus* (Nematoda: Dracunculoidea) a swimbladder parasite of eels. *Diseases of Aquatic Organisms* 34: 217-222
- Moriarty C (1982) Midwinter migration of bream *Abramis brama* (L.). *Irish Naturalists' Journal* 20(11): 505
- Moriarty C and Fitzmaurice P (2000) Origin and diversity of freshwater fish in Ireland. *Verhandlungen internationale Vereinigung für Theoretische und Angewandte Limnologie* 27: 128-130
- Morrissey J, Kraan S and Guiry M (2001) A guide to commercially important seaweeds on the Irish coast. An Bord Iascaigh Mhara, Dun Laoghaire, Co Dublin. 66pp
- Murphy DF and Holmes JMC (1990) *Heterolaophonte hamondi* Hicks (Crustacea: Copepoda: Harpacticoida) new to Ireland. *Irish Naturalists' Journal* 23 (5/6) 225
- Murray DA (2000) First record of *Telmatogeton japonicus* Tokunaga (Dipt., Chironomidae) from the British Isles and additional records of halobiontic Chironomidae. *Entomologist's Monthly Magazine* 136: 157-159
- Murray PJ (1972) The occurrence of *Mytilicola intestinalis* Steuer on the coasts of counties Galway and Clare. *Irish Naturalists' Journal* 17: 198-199
- Nelson C (2000) Seabeans and nickarnuts: a handbook of exotic seeds and fruits stranded on beaches in north-western Europe. Botanical Society of the British Isles, London, 156pp
- Nichols AR (1900) A list of the marine mollusca of Ireland. *Proceedings of the Royal Irish Academy Series 3: 5* (28): 477-662

- O'Mahony EM, Bradley DG, Kennedy CR and Holland CV (2004) Evidence for the hypothesis of strain formation in *Pomphorhynchus laevis* (Acanthocephala): an investigation using mitochondrial DNA sequences. *Parasitology* 129: 341-347
- O'Malley J (1996) New plant records for South Kerry (H1) and North Kerry (H2). *Irish Naturalists' Journal* 25(8): 298-299
- O'Connor JP, O'Connor MA and Holmes JMC (1991) Ornamental plants and the distribution of exotic amphipods (crustacea) in Ireland. *Irish Naturalists' Journal* 23(12): 490-492
- Olenin S (2005) Invasive aquatic species in the Baltic States. Klaipeda University, Coastal Research and Planning Institute, 42pp
- Oliver GA, McGrath D and Healy B (2007) The amphipod *Corophium insidiosum* Crawford in Ireland. *Irish Naturalists' Journal* 28(8): 324-326
- O'Riordan CE (1967) Cirripedes in Ireland (Irish cirripedes in the collections of the National Museum of Ireland and in the literature). *Proceedings of the Royal Irish Academy* 65B: 285-296
- O'Riordan CE and Holmes JMC (1978) Marine fauna notes from the National Museum of Ireland V. passengers on the North Atlantic currents. *Irish Naturalists' Journal* 19(5): 152-153
- O'Riordan RM (1996) The current status and distribution of the Australian barnacle *Elminius modestus* Darwin in Ireland. In: *Proceedings of the Irish Marine Science Symposium 1995* (eds) Keegan BF and R O'Connor, Galway University Press, Galway, 207-218
- O'Riordan RM (2002) The accidental introduction of marine animals into Ireland. In: C Moriarty and DA Murray (eds) *Biological Invaders: the impact of exotic species*. Royal Irish Academy, Dublin pp 96-106
- O'Sullivan G (1983) The intertidal fauna of Aughinish Island, Shannon, Co Limerick. *Irish Naturalists' Journal* 21(2) 62-68
- Ottway B, Parker M, McGrath D and Crowley M (1979) Observations on a bloom of *Gyrodinium aureolum* Hulbert on the south coast of Ireland, summer 1976, associated with mortalities of littoral and sub-littoral organisms. *Irish Fisheries Investigations Series B* No 18, 9pp
- Pannell A and Coutts DM (2007) Treatment methods used to manage *Didemnum vexillum* in New Zealand. *Biosecurity New Zealand*, March 2007, 38pp
- Panov V, Dgebuadze YY, Shiganova TA, Filippov AA and Minchin D (2007) A risk assessment of biological invasions in the inland waterways of Europe: the northern invasion corridor case study pp 639-656 In: Gherardi F (ed) *Biological Invaders of Inland Waters*. Springer
- Parker LE, Culloty S, O'Riordan R, Kelleher B, Steele S and Van der Velde G (1999). Preliminary study on the gonad development of the exotic ascidian *Styela clava* in Cork Harbour, Ireland. *Journal of the Marine Biological Association of the United Kingdom* 79: 1141-1142
- Parkes HM (1975) Records of *Codium* species in Ireland. *Proceedings of the Royal Irish Academy* B75: 125-134
- Partridge JK (1977) Littoral and benthic investigations on the west coast of Ireland - VI (Section A Faunistic and ecological studies). Annotated bibliographies of the genus *Tapes* (Bivalvia: veneridae): Part II *Tapes semidecussatus*. *Proceedings of the Royal Irish Academy* 77B: 1-64
- Pollux B, Minchin D, Van der Velde G, Van Allen T, Moon-Van der Staay SY and Hackstein J (2003) Zebra mussels (*Dreissena polymorpha*) in Ireland, AFLP- fingerprinting and boat traffic both suggest an origin from Britain. *Freshwater Biology* 48: 1127-1138
- Preston CD and Croft JM (1997) *Aquatic plants in Britain and Ireland*. Harley Books, Colchester
- Preston CD, Pearman DA and Dines TD (2002) *New atlas of the British and Irish flora. An atlas of the vascular plants of Britain, Ireland, the Isle of Man and the Channel Islands*. Oxford University Press, 910pp
- Pybus C (1977) A list of algae found on artificial substrata in Galway Bay. *Irish Naturalists' Journal* 19(3): 72-75
- Pybus C (1980) Observations on a *Gyrodinium aureolum* (Dinophyta) bloom off the south coast of Ireland. *Journal of the Marine Biological Association of the United Kingdom* 60: 661-674
- Raine R, O'Boyle S, O'Higgins T, White M, Patching J, Cahill B and McMahon T (2001) A satellite and field portrait of a *Karenia mikimotoi* (Hulbert) bloom off the south coast of Ireland, August 1998. *Hydrobiologia* 465: 187-193
- Renouf LPW (1939) *Colpomenia sinuosa* (Mert) Derb et Sol., and *Zostera* disease on the coasts of Ireland. *Irish Naturalists' Journal* 7: 272
- Reynolds JD (1988) Extinctions and crayfish plague in Ireland. *Biological Conservation* 45: 279-285
- Reynolds JD (1997) The present status of freshwater crayfish in Ireland. *Bulletin France Pêche et Pisciculture* 347: 693-700
- Reynolds SCP (2002) A catalogue of alien plants in Ireland. National Botanic Gardens, Glasnevin, Dublin, 414pp
- Reynolds SCP (2006) *Azolla* to *Zostera*: a report on field work in Co Limerick. *Irish Botanical News* 16: 30-39
- Rich TCG, Kay GM and Kirschner J (1995) Floating water-plantain *Luronium natans* (L.) RAF. (Alismataceae) present in Ireland. *Irish Naturalists' Journal* 25 (4): 140-145
- Roden C (2005) A new station for *Hydrilla verticillata* (L.f.) Royle in Connemara (H16). *Irish Naturalists' Journal* 28(3): 138-139
- Ross HCG (1984) A catalogue of the land and freshwater mollusca of the British Isles in the Ulster Museum. Ulster Museum, Belfast, 160pp
- Rowe R, Harris DJ, Beebee TJC (2006) Lusitania revisited: a phylogeographic analysis of the natterjack toad *Bufo calamita* across its entire biogeographical range. *Molecular Phylogenetics and Evolution* 39: 335-346
- Ryan JT (1993) The soft shelled clam *Mya arenaria* (L.) in Irish waters. MSc Thesis, Dundalk Regional Technical College, Dundalk, 165pp
- Ryland JS and Nelson-Smith A (1975) Littoral and benthic investigations on the west coast of Ireland - IV (Section A: faunistic and ecological studies) Some shores in counties Clare and Galway. *Proceedings of the Royal Irish Academy* 75B: 245-266
- Scannell MJP and Jebb M. (2000) Flora of Connemara and the Burren. *Records from 1984*. *Glasra* 4(1): 7-45
- Scannell MJP and Webb DA (1976) The identity of the Renvyle *Hydrilla*. *Irish Naturalists' Journal* 18(12): 327-331
- Scharff RF (1900) Attempted introduction of the American shad into Irish waters. *Irish Naturalist* 9: 185
- Simkanin CM (2004) The invasive seaweed *Sargassum muticum* (Yendo) Fensholt in Lough Hyne Marine Nature Reserve, Co Cork. *Irish Naturalists' Journal* 27(12): 481-482
- Simpson D (1985) *Elodea nuttallii* (Planch.) St John in Ireland. *Irish Naturalists' Journal* 21 (11): 497-498

A checklist of alien aquatic species in Ireland

- Smith SJ and Wolfe-Murphy SA (1991) *Ceratophyllum submersum* L. soft hornwort, a species new to Ireland. Irish Naturalists' Journal 23: 374-376
- Smith T (1994) The distribution of freshwater bryozoa in Ireland. Bulletin of the Irish Biogeographical Society 17: 9-22
- Spicer JJ (1923) The slipper limpet, an enemy of the oyster. Fisheries Technical Report, Dublin 4pp
- Stachowicz JJ, Terwin JR, Whitlatch RB and Osman RW (2002) Linking climate change and biological invasions: ocean warming facilitates nonindigenous species invasions. PNAS 99(24): 15497-15500
- Stranock SD (1979) Occurrence of the gill parasite *Diplozoon paradoxum* Nordmann (Trematoda: Monogenea) on fish from the Fairywater, Co Tyrone, Northern Ireland. Irish Naturalists' Journal 19(9): 311-315
- Strasser M (1999) *Mya arenaria* – an ancient invader of the North Sea coast. Helgoländer Meeresuntersuchungen 52: 309-324
- Sweeney P (in press) Distribution of estuarine Naididae and Tubificidae (Oligochaeta) in Munster, Ireland.
- Sweeney P, Trodd W and Kelly Quinn M (2003) Two Ponto-Caspian freshwater oligochaetes new to Irish rivers. Irish Naturalists' Journal 27: 319-320
- Sykes ER (1905) The molluscs and brachiopods of Ballinakill and Bofin harbours, Co Galway, and the deep water off the west and south-west coasts of Ireland. Annual Report for Fisheries, Ireland 1902-03, Part 2: 53-92
- Thompson W (1856) The Natural History of Ireland 4. Bohn, London
- Tierney TD, Kane F, Naughton O, Kennedy S, O'Donohue P, Copley L and Jackson D (2004) On the occurrence of the caprellid amphipod, *Caprella mutica* Schurin 1935, in Ireland. Irish Naturalists' Journal 27(11): 437-439
- Trowbridge CD (1998) Ecology of the green macroalga *Codium fragile* (Suringar) Hariot 1889: invasive and non-invasive subspecies. Oceanography and Marine Biology: an annual review 36: 1-64
- Tylor TJM, Lewis J and Heaney SI (1995) A survey of *Alexandrium* sp cysts in Belfast Lough, 1992. In Lassus P, Arzul G, Erard E, Gentian P and Marcaillou C. Harmful Algal Blooms. Lavoisier, Intercept Ltd, 835-840
- Valentine PC, Carman MR, Blackwood DS and Heffron EJ (2007b) Ecological observations on the colonial ascidian *Didemnum* sp. in a New England tidepool habitat. Journal of Experimental Marine Biology and Ecology 342: 109-121
- Valentine PC, Collie JS, Reid RN, Asch RG, Guida VG and Blackwood DS (2007a) The occurrence of the colonial ascidian *Didemnum* sp. on Georges Bank gravel habitat – Ecological observations and potential effects on groundfish and scallop fisheries. Journal of Experimental Marine Biology and Ecology 342: 179-181
- Vandermeulen H and DeWreede RE (1986) The phenology, mortality, dispersal and canopy species interaction of *Colpomenia peregrina* (Sauv.) Hamel in British Columbia. Journal of Experimental Marine Biology and Ecology 99: 31-47
- Walton GA (1985) *Microvelia pygmaea* (Durfour) (Hemiptera: Velidae) in Ireland. Irish Naturalists' Journal 21: 493-495
- Wallentinus I (2002) Introduced marine algae and vascular plants in European aquatic environments. In: Invasive aquatic species of Europe. Distribution, Impacts and Management. E. Leppäkoski, S. Gollasch and S. Olenin (eds). Kluwer Academic Publishers, Dordrecht, 27-52
- Went AEJ (1950) Notes on the introduction of some freshwater fish into Ireland. Journal of the Department of Agriculture, Dublin 47: 3-7
- Went AEJ (1957) The pike in Ireland. Irish Naturalists' Journal 12: 1-5
- Went AEJ (1974) Some interesting fishes taken in Irish waters in 1973. Irish Naturalists' Journal 18 (3): 57-56
- West AB and O'Riordan CE (1984) *Dendrostea frons* (L.) (Ostreidae: Lophinae): a record from flotsam in Co Mayo. Irish Naturalists' Journal 21(6): 278-279
- Weyl R and Hackney P (1988) *Crassula helmsii* (T. Kirk) Cockayne: new to Ireland. Irish Naturalists' Journal 22 (2): 536
- Whelan PM and Cullinane JP (1987) The occurrence of 'wasting disease' of *Zostera* in Ireland in the 1930's. Aquatic Botany 27: 285-289
- Whilde A (1993) Threatened mammals, birds amphibians and fish in Ireland. Irish red data book 2. Vertebrates. HMSO, Belfast
- Wilkins NP (1989) Ponds, passes and parcs: aquaculture in Victorian Ireland. Glendale Press, Sandycove, Co Dublin, 352pp
- Wolff WJ (2005) Non-indigenous marine and estuarine species in The Netherlands. Zoologische Mededelingen, Leiden 79: 1-116
- Wonham MJ and Carlton JT (2005) Trends in marine biological invasions at local and regional scales: the Northeast Pacific Ocean as a model system. Biological Invasions 7: 369-392
- Wyse Jackson PS (1988) *Groenlandia densa* (L.) Fourn. In Dublin. Irish Naturalists' Journal 22 (10): 457
- www.fishbase.org (accessed 10 January 2006)

Annex 1

List of alien species in inland waters, coastal and sea areas of Ireland

Species	Year of first record and recipient zone			Native origin	Known or likely spread	Current status	Impact in Ireland	References
	Fresh waters <1psu	Brackish waters 1-30psu	Marine waters >30psu					
Firmicutes, Bacilli								
Aerococcaceae								
<i>Aerococcus viridans</i> Williams et al. 1953*			1961	NW Atlantic	with <i>Homarus americanus</i> imports	no further records	mortality in lobsters	Gibson 1961
Oomycota, Oomycetes								
Saprolegniaceae								
<i>Aphanomyces astaci</i> Schikora 1906*	1987			N America	fishing equipment	no recent records	mortality in <i>A. pallipes</i>	Reynolds 1988, Mathews & Reynolds 1992, Lyons & Kelly-Quinn 2003
<i>Ostracoblabe implexa</i> Bornet & Fiahault*		1951	1951	unknown	oyster imports	extinct	shell blisters on native oysters	Cole & Hancock 1956, CB Duggan pers. comm.
Labyrinthulomorpha, Labyrinthulomycetes								
Labyrinthulidae								
<i>Labyrinthula zosterae</i> Porter & Muehlstein 1989*		1926	1926	unknown	ships ballast water	no recent records	die-off of sea grass, <i>Zostera marina</i>	Renouf 1939, Whelan & Cullinane 1987
Haplosporidia								
Haplosporididae								
<i>Bonamia ostreae</i> Pichot et al. 1980*		1988	1988	NE Pacific	aquaculture, shipping	established	native oyster mortalities	McArdle et al. 1991, Culloty & Mulcahy 1996, Culloty et al. 1999, Culloty et al. 2007
Ciliophora, Ciliata								
Ophryoglenidae								
<i>Ophryoglena hemophaga</i> Molloy et al. 2005*	2004			Ponto-caspian	leisure craft hull fouling	established	symbiont of <i>Dreissena polymorpha</i>	Burlakova et al. 2006
Conchophthiridae								
<i>Conchophthirus acuminatus</i> Claparède & Lachman*	2004			Ponto-caspian	leisure craft hull fouling	established	symbiont of <i>Dreissena polymorpha</i>	Burlakova et al. 2006
Dinophyta, Dinophyceae								
Gymnodiniaceae								
<i>Karenia mikimotoi</i> (Miyake et Kominami ex Oda) G Hansen et Ø Moestrup, 2000			1976	N Pacific	alongshore drift	established	sporadic blooms, ichthyotoxins, invertebrate mortalities	Ottway et al, 1979; Pybus 1980, McMahon et al. 1998, Raine et al. 2001
Ochrophyta, Coscinodiscophyceae								
Coscinodiscaceae								
<i>Coscinodiscus walesii</i> Gran & Angst 1931			1979	Indo-Pacific	alongshore drift	established	bloom forming	Edwards et al. 2001
<i>Odontella sinensis</i> (Granville) Grunow 1884			<1997	N Pacific	alongshore drift	established	bloom forming	McKinney et al. 1997
Skeletonemataceae	1980			Baltic Sea	unknown	no recent records, probably established	unknown	Gibson et al. 1993
<i>Skeletonema subsalsum</i> (A Cleve-Euler) Bethge 1928								
Haptophyta, Haptophyceae								
<i>Isochrysis</i> aff. <i>galbana</i> 'Tahitian isolate'			1970s	Pacific	aquaculture	unknown	cultured for feeding bivalves	Minchin 2006, B Ottway pers. comm.

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	Fresh waters <1psu	Brackish waters 1-30psu	Marine waters >30psu					
Ocrophyta, Phaeophyceae								
Scytosiphonaceae								
<i>Colpomenia peregrina</i> (Sauvageau) Hamel 1927			1935	Pacific	surface drift aquaculture	established	possible competition	Vandermeulen & deWreede 1986, Minchin 1991
Sargassaceae								
<i>Sargassum muticum</i> (Yendo) Fensholt 1955			1995	N Pacific	aquaculture, drift	established	competition, habitat modification, affecting navigation	Boaden 1995, Loughnane & Stengel 2002, Simkanin 2004
Rhodophyta, Florideophyceae								
Bonnemaisoniaceae								
<i>Bonnemaisonia hamifera</i> Hariot, 1891			1911	N Pacific	unknown	established	competition	Breeman et al 1988, Guiry & Ni Donnachada 2001
Dasyaceae								
<i>Asparagopsis armata</i> Harvey 1855			1939	Australasia	shipping	established, S & W coasts	cultivated	DeValera 1942, Morrissey et al. 2001, Kraan & Barrington 2005 S Kraan pers. comm
<i>Heterosiphonia japonica</i> Yendo 1920			2002	NW Pacific	unknown	established	competition	
Rhodomeliaceae								
<i>Neosiphonia harveyi</i> (J Bailey) M-S Kirr, H-G Choi, Guiry & GW Saunders 2001			1970s	N Pacific	unknown	established	unknown	Maggs & Hommersand 1993
<i>Polysiphonia subtileissima</i> Montagne 1940			2006	West Indies	unknown	one locality established	unknown	C. Maggs, pers. comm.
Ceramiaceae								
<i>Antithamnionella spirographidis</i> (Schiffner) Wollaston 1968			1973	N Pacific	shipping, leisure craft or aquaculture	rare, established	unknown	Pybus 1977
Halymeniaceae								
<i>Cryptonema hibernica</i> Guiry & L Irvine 1974			1971	S Atlantic?	shipping	local, established	unknown	Cullinane & Whelan 1981 ; Cullinane et al. 1984
Chlorophyta, Bryopsidophyta								
Codiaceae								
<i>Codium fragile tomentosoides</i> (van Goor) Silva, 1955			1950	N Pacific	unknown	established	competition	Parkes 1975, Trowbridge 1998
<i>Codium fragile atlanticum</i> (Cotton) P Sinva 1955			1808	NW Pacific ?	unknown	established	competition	Parkes 1975
Chlorophyta, Ulvophyceae								
Ulvaceae								
<i>Ulva californica</i> Wille 1889		<2007		E Pacific	vessels	local	unknown	C A Maggs pers. comm.
Pteridiophyta, Filicopsida								
Azollaceae								
<i>Azolla filiculoides</i> Lam.	1893			West N & S America	ornamental	locally abundant, established	dense surface growths, deoxygenation of water column	Reynolds 2002
Magnoliophyta, Liliopsida								
Pontederiaceae								
<i>Pontederia cordata</i> L.	1958			N America E	ornamental	one locality, established	unknown	Reynolds 2002
Alismataceae								
<i>Sagittaria rigida</i> Pursh.	1999			N America E	ornamental	local, established	unknown	Reynolds 2002

Species	Year of first record and recipient zone			Native origin	Known or likely spread	Current status	Impact in Ireland	References
	Fresh waters <1psu	Brackish waters 1-30psu	Marine waters >30psu					
Poaceae								
<i>Spartina anglica</i> CE Hubb		1925	1925	N Europe	habitat management	established	competition, accumulation of sediments	Curtis & Sheehy-Skeffington 1998, Hammond & Cooper 2002, Reynolds 2002
<i>Spartina pectinata</i> Link	~1910			N. America	ornamental	one locality, established	unknown	Scannell & Jebb 2000
<i>Spartina x townsendii</i> H & J Groves Roman		1933		hybrid	habitat management	rare, declining	unknown	Reynolds 2002
Acoridae								
<i>Acorus calamus</i> Linnaeus 1753	1744			N.America Asia	ornamental	local and widespread	unknown	Reynolds 2002
Aponogetonaceae								
<i>Aponogeton distachyos</i> L.f.	1900s			S Africa	ornamental	one locality	unknown	Reynolds 2002
Hydrocharitaceae								
<i>Egeria densa</i> Planch.	1988			S America	ornamental	rare	unknown	Reynolds 2002
<i>Elodea canadensis</i> Michx.	~1836			N America	ornamental	widespread, established	competition	Reynolds 2002
<i>Elodea nuttallii</i> (Planch.) H St John	1984			N America	ornamental, aquaria	locally abundant, established, expanding	competition, affecting navigation	Simpson 1985, Minchin & Boelens 2007
<i>Lagarosiphon major</i> (Ridley) Moss	1966			S Africa	ornamental, fishing	locally abundant, established, expanding	dense growth, affecting navigation, competition	Cotton & Caffrey 2000, Reynolds 2002
Juncaceae								
<i>Juncus planifolius</i> R. Br	1971			Australasia, S America	unknown	locally established	unknown	Reynolds 2002
Araceae								
<i>Lemna minuta</i> Kunth	1993			Americas	ornamental	widespread, established, expanding	local competition, affects abstraction	Cotton 1999, Lucey 2003, Preston & Croft 1997
<i>Lysichiton americanus</i> Hultén & St John	~1930			N America	ornamental	locally common, established	unknown	O' Malley 1996, Reynolds 2002
Magnoliophyta, Magnoliopsida								
Primulaceae								
<i>Hottotia palustris</i> L.	1898?			Europe	ornamental	locally abundant, established, expanding	competition, affecting navigation	Minchin & Boelens 2005, 2007
Apiaceae								
<i>Hydrocotyle ranunculoides</i> L. f.	2002			N America	ornamental, aquaria	locally established	competition	Day 2004
Haloragaceae								
<i>Myriophyllum aquaticum</i> (Velloso) Verdc.	1990			S America	ornamental, water purification	locally abundant, established	competition, surface growths	Reynolds 2002
Nymphaeaceae								
<i>Nuphar pumila</i> (Timm.) DC	1898			Europe, N Asia	ornamental	local, established	competition	Reynolds 2002
Menyanthaceae								
<i>Nymphoides peltata</i> (S.G. Gmel.) Kuntze	1850			Europe	ornamental	local, established	competition	Reynolds 2002
Crassulaceae								
<i>Crassula helmsii</i> (Kirk) Cockayne	1985			Australasia	ornamental	locally abundant, established	dense surface growths	Weyl & Hackney 1988, Day 2004

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Species	Year of first record and recipient zone			Native origin	Known or likely spread	Current status	Impact in Ireland	References
	Fresh waters <1psu	Brackish waters 1-30psu	Marine waters >30psu					
Cnidaria, Anthozoa								
Diadumenidae								
<i>Diadumene lineata</i> (Verrill 1869)		1974	1974	NW Pacific	aquaculture hull fouling	local	unknown	Ryland & Nelson-Smith 1975
Nematoda, Dracunculoidea								
Anguillicolidae								
<i>Anguillicola crassus</i> Kuwahara, Niimi & Itagaki 1974*	1998			E Asia	eel transport shipping	widespread, established	endoparasite of <i>Anguilla anguilla</i>	Kennedy & Fitch 1990, Evans & Mathews 1999, Kirk 2003
Platyhelminthes, Trematoda								
Pseudodactylogyridae								
<i>Pseudodactylogyrus anguillae</i> (Yin & Sprosten 1948)*	1988			Asia	eel transport	present	ectoparasite of <i>A. anguilla</i>	McCarthy & Rita 1991
<i>Pseudodactylogyrus bini</i> (Kikuchi 1929)*	1996			Asia	unknown	present	ectoparasite of <i>A. anguilla</i>	Copley & McCarthy 2001
Dactylogyridae								
<i>Dactylogyrus vastator</i> (Nybelin 1924)*	1960s			Europe	leisure	no recent record	unknown	Kennedy 1993
Dugesiiidae								
<i>Dugesia tigrina</i> (Girard)	2001			N America	ornamental	local	unknown	Anderson 2003a
Annelida, Hirudinea								
Hirudinidae								
<i>Hirudo medicinalis</i> Linnaeus 1758	<1900			Europe	medical treatment	extinct	none	McCarthy 1986
Annelida, Polychaeta								
Serpulidae								
<i>Ficopomatus enigmaticus</i> (Fauvel 1923)		1971	1971	Indo-Pacific	hull fouling	locally abundant established	fouling organism	Kilty & Guiry 1973
Maldanidae								
<i>Clymenella torquata</i> (Leidy, 1855)			2006*	NW Atlantic	aquaculture	established	unknown	T Mackie pers. comm.
Terebellidae								
<i>Terebella lapidaria</i> (Linnaeus 1767)			1993	continental Europe	aquaculture	no recent record	unknown	Minchin et al. 1993
Annelida, Clitellata								
Tubificidae								
<i>Potamothenis moldaviensis</i> Vejdovsky & Mrázek 1903	2002			Ponto-caspian	unknown, ?ships	probably established	unknown	Sweeney et al. 2003, Sweeney in press
<i>Potamothenis vejdovskyi</i> (Hrabe 1941)	2002			Ponto-caspian	unknown, ?ships	probably established	unknown	Sweeney et al. 2003, Sweeney in press
<i>Branchiura sowerbyi</i> Beddard 1892	1909			Asia	ornamental	no recent record	unknown	McCarthy 1974
Mollusca: Gastropoda								
Pseudococciidae								
<i>Ferrisia wautieri</i> Mirolli 1960	2006			N Africa	ornamental	established	unknown	Moorkens 2007
Hydrobiidae								
<i>Potamopyrgus antipodarum</i> (JE Gray 1843)	<1900	<1900		Australasia	shipping	widespread & abundant, established	competition	Massey 1903
Physidae								
<i>Physella acuta</i> Draparnaud 1805	1909			N America	ornamental	established	unknown	Anderson 2003b
<i>Physella gyrina</i> (Say 1816)	1995			N America	ornamental	established	unknown	Anderson 1996, 2001, 2004

Species	Year of first record and recipient zone			Native origin	Known or likely spread	Current status	Impact in Ireland	References
	Fresh waters <1psu	Brackish waters 1-30psu	Marine waters >30psu					
Calyptraeidae								
<i>Crepidula formicata</i> (Linnaeus 1758)		1902	1902	NW Atlantic	aquaculture	no known population, individuals	none	Sykes 1905, Spicer 1923, Arnold 1960, Minchin et al. 1995
<i>Calyptraea chinensis</i> Linnaeus 1758			1962	Europe	fisheries	established spreading	unknown	Minchin et al. 1987, Minchin & Nunn 2006
Haliotidae								
<i>Haliotis discus hannai</i> Ino 1953			1985	NW Pacific	aquaculture	hatchery production	cultivated	Minchin 1996
<i>Haliotis tuberculata</i> Linnaeus 1758			1978	Continental W Europe	aquaculture	hatchery production	cultivated	Mgaya & Mercer 1994
Mollusca : Bivalvia								
Teredinidae								
<i>Bankia fimbriata</i> (Moll & Roch 1931)			<1847	circum-tropical	ship's hull	not established, individual	none	Nichols 1900
Mytilida								
<i>Brachidontes exustus</i> Linnaeus 1758			1977	W Atlantic	flotsam (metal bouy)	not established, individuals	none	O'Riordan & Holmes 1978
Isognomonidae								
<i>Isognomon radiata</i> Antón 1839			1996	W Atlantic	flotsam (brush)	not established, individual	none	Minchin pers. ob.
Ostreidae								
<i>Ostrea equestris</i> Say 1834			1995	W Atlantic	flotsam (float)	not established, individuals	none	Minchin pers. ob.
<i>Crassostrea angulata</i> (Lamarck 1819) ‡		1877	1877	W Europe, + <i>C. gigas</i>	aquaculture	not established	none, once cultivated	Wilkins 1989
<i>Crassostrea gigas</i> (Thunberg 1793)		1969	1969	N Pacific	aquaculture	some recruitment	widely cultivated	De Grave et al. 1998
<i>Crassostrea virginica</i> (Gmelin 1791)		1875	1875	NW Atlantic	aquaculture	no longer present	none, once cultivated	Minchin et al. 1995
<i>Dendroostrea frons</i> (Linnaeus 1758)			1983	W Atlantic	flotsam (float)	not established, individuals	none	West & O'Riordan 1984
Chamidae								
<i>Chama</i> sp.			1989	W Atlantic	flotsam (rope)	not established, individuals	individuals	P Casburn pers. comm.
Dreissenidae								
<i>Dreissena polymorpha</i> (Pallas 1771)	1993	1993		Ponto-caspian	fouling on leisure craft	abundant, established, expanding	competitor, blockages to abstraction, piping, fouling organism	Pollox et al. 2003, Juhel et al 2003, Astane et al 2005, Maguire & Gibson 2005, Minchin et al. 2002, 2006d
Pectinidae								
<i>Patinopecten yessoensis</i> Jay 1857			1988	NW Pacific	aquaculture	no longer present	once cultivated	Minchin & Rosenthal 2002
Veneridae								
<i>Mercenaria mercenaria</i> (Linnaeus 1758)			1969	NW Atlantic	aquaculture	no known populations	once cultivated	Gibson 1970
<i>Venerupis philippinarum</i> (Adams & Reeve 1850)			1973	Pacific	aquaculture	hatchery production	cultivated	Partridge 1977
Arthropoda, Maxillopoda, Copepoda								
Myicolidae								
<i>Myicola ostreae</i> Hoshina & Sugiura 1953*		1993	1993	NW Pacific	oyster movements	local, no recent records	symbiont, no known impact	Holmes & Minchin 1995a
Mytilicolidae								
<i>Mytilicola orientalis</i> Mori 1935*		1993	1993	NW Pacific	oyster movements	local population	endoparasite of <i>C. gigas</i>	Grizel 1985, Minchin 2004

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Species	Year of first record and recipient zone			Native origin	Known or likely spread	Current status	Impact in Ireland	References
	Fresh waters	Brackish waters	Marine waters					
	<1psu	1-30psu	>30psu					
Arthropoda: Maxillopoda, Cirripedia								
Archeobalanidae								
<i>Elminius modestus</i> Darwin 1854		1957	1957	S Pacific	hull fouling	abundant established	competition, fouling organism	Beard 1957, McGrath & King 1992, O’Riordan 1996
Balanidae								
<i>Balanus amphitrite</i> Darwin 1854			1966	circum-tropical	hull fouling	not-established	fouling organism	Minchin 2000
<i>Balanus improvisus</i> Darwin 1854		<1950		S America	hull fouling	locally abundant, established	fouling organism	O’Sullivan 1983, Minchin 2004
<i>Megabalanus tintinnabulum</i> (Linnaeus 1758)			<1900	Sub-tropical cosmopolitan	hull fouling	Individual records, not established	fouling organism	O’Riordan 1967
Arthropoda, Malacostraca, Amphipoda								
Caprellidae								
<i>Caprella mutica</i> Schurin 1935			2003	NW Pacific	hull fouling	locally abundant, established	fouling organism	Tierney et al. 2004, Minchin & Holmes 2007
Corophiidae								
<i>Chelicorophium curvispinum</i> (Sars 1895)	2000			Ponto-caspian	unknown	established	unknown	Lucey et al. 2004
Crangonyetidae								
<i>Crangonyx pseudogracilis</i> Bousfield 1958	1969			N America	ornamental	established	competition	O’Connor et al. 1991
Gammaridae								
<i>Gammarus pulex</i> (Linnaeus 1758)	1958			Europe	stocked from Britain	established	competition	Kelly & Dick 2005
<i>Gammarus tigrinus</i> Sexton 1939	1931			N America	vessels	established	competition	Costello 1993
Arthropoda, Malacostraca, Decapoda								
Grapsidae								
<i>Eriocheir sinensis</i> (H Milne-Edwards 1853)		2006	2006	E Asia	shipping ?	individuals present	unknown	Minchin 2006b
Geryonidae								
<i>Pilumnoides inglei</i> Guinot & MacPherson 1987			<1900	E Pacific	hull fouling	individuals, no recent records	unknown	Ingle 1980
Penaeidae								
<i>Marsupenaeus japonicus</i> (Bate 1888)			2007	Indo-Pacific	aquaculture escape	individuals, not thought to be established	unknown	D Quigley pers. comm..
Homaridae								
<i>Homarus americanus</i> Herrick 1895			1961	NW Atlantic	live food trade	not considered to be established	possible hybridisation	Gibson 1961
Arthropoda, Insecta, Diptera								
Chironomidae								
<i>Telmatogeton japonicus</i> Tokunaga 1933		1999	1999	N Pacific	unknown	no more recent records	unknown	Murray 2000
Chordata, Ascidiacea								
Botryllidae								
<i>Botrylloides violaceus</i> Oka 1927			2006	NW Pacific	shipping	locally established	fouling organism	Minchin 2007
Corellidae								
<i>Corella eumyota</i> Traustedt 1882			2005	circum sub-Antarctic	shipping	locally established	fouling organism	Minchin 2007
Molgulidae								
<i>Molgula manhattensis</i> (De Kay 1843) †			1998	NW Atlantic	unknown	present, may be more frequent	fouling organism	Holmes & Gotto 2000

Species	Year of first record and recipient zone			Native origin	Known or likely spread	Current status	Impact in Ireland	References
	Fresh waters <1psu	Brackish waters 1-30psu	Marine waters >30psu					
Styelidae								
<i>Styela clava</i> Herdman 1882		1971	1971	NW Pacific	shipping aquaculture	locally established	fouling organism	Guiry & Guiry 1973, Parker et al 1999, Minchin et al. 2006a, Minchin 2007
Chordata : Pisces								
Salmonidae								
<i>Oncorhynchus gorbuscha</i> (Walbaum 1792)			1973	N Pacific	vagrant from stocking	individuals, not present	none	Went 1974
<i>Oncorhynchus mykiss</i> (Walbaum 1792)	1899	1899	1899	NE Pacific	aquaculture	populations, hatchery production	cultivated	Moriarty & Fitzmaurice 2002
<i>Hucho hucho</i> (Linnaeus 1758)	1993			Europe	unapproved stocking	extinct	unknown	Lucy & Nolan 1996
Clupeidae								
<i>Alosa sapidissima</i> (Wilson 1811)	1900			N America	stocking attempt	extinct	none	Scharff 1900
Ictaluridae								
<i>Ictalurus catus</i> (Linnaeus 1758)	1889			N America	ornamental	no recent record	none	Holmes pers. comm.
<i>Ameiurus melas</i> (Rafinesque 1820)	2001			N America	ornamental	no recent record	none	www.fishbase.org
Cyprinidae								
<i>Cyprinus carpio</i> Linnaeus 1758	1634			Asia	stocked ponds	local populations	unknown	Went 1950, Moriarty & Fitzmaurice 2002
<i>Leuciscus leuciscus</i> (Linnaeus 1758)	1889			Europe	live angling bait	established	competitor	Healy 1956
<i>Rutilus rutilus</i> (Linnaeus 1758)	1889			Europe	angling bait	established	competition	Healy 1956, McCarthy 1981
<i>Leuciscus cephalus</i> (Linnaeus 1758)	2004			Europe	unapproved stocking	present, may be established	competition	J Caffrey pers. comm.
<i>Tinca tinca</i>	~1634			Europe	stocked ponds	widely distributed	unknown	Went 1950, Moriarty & Fitzmaurice 2002;
Characidae								
<i>Serrasalmsis</i> sp.	1988			S America	human food discard?	not established	none	P Boaden pers comm..
Chordata, Mammalia								
Cricetidae								
<i>Ondatra zibethica</i> (Linnaeus 1766)	1929			N America	fur-farm escape	trapped to extinction	none	Fairley 1982, 2001

Notes: * diseases, parasites or commensals; † difficult to separate from *M. socialis*; ‡ now considered to be *C. gigas*

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Annex 2

List of cryptogenic species occurring in inland waters, coastal and sea areas of Ireland. Early dates are suggested for arrivals of vertebrates or their parasites

Species	Year of first record and recipient zone			Native origin	Known or likely spread	Current status	Impact in Ireland	References
	Fresh waters <1psu	Brackish waters 1-30psu	Marine waters >30psu					
Pyrophyta, Dinophyceae								
Goniodonadaceae								
<i>Alexandrium tamarense</i> (Lebour) Balech 1985			1986	World-wide	oysters, shipping, native	established, local	sporadic blooms	Taylor et al. 1995, Minchin 2004
Ochrophyta, Raphidophyceae								
Chattonellaceae								
<i>Heterosigma akashiwo</i> (Y Hada) Y Hada ex Y Hare & M Chihara 1967			1970	Pacific?	aquaculture shipping	established	sporadic blooms, cultured fish kills	T. McMahon pers. comm..
Rhodophyta, Rhodophyceae								
Ceramiaceae								
<i>Antithamnion densum</i> (Suhr) MA Howe 1914			1991	Indo-Pacific?	unknown	rare, no recent record	unknown	Wallentinus 2002
<i>Antithamnionella ternifolia</i> (JD Hooker & Harvey) Lyle 1922			1930	Europe	unknown	widespread, established	unknown	Pybus 1977
Gigartinales								
<i>Iridaea</i> sp.			1972	Pacific	unknown	rare	single record	Cullinane & Whelan 1984
Gracilariaceae								
<i>Gracilaria multipartata</i> (Clemente y Rubio) Harvey 1846			1977		unknown, drift	local, no recent record	unknown	Cullinane & Whelan 1984
Magnoliophyta, Liliopsida								
Potamogetonaceae								
<i>Groenlandia densa</i> (L.) Fourn	1866			Europe	turf barges	Established, spread within Ireland	unknown	Dromey 1991, Wyse-Jackson 1988
Hydrocharitaceae								
<i>Hydrilla verticillata</i> (L.f.) Royle	1935			S Africa?	ornamental	local	unknown	Roden 2005
<i>Stratiotes aloides</i> L.	1750			Europe, W Asia	original introduction unknown, ornamental	established, spreading	unknown	Forbes 2000
Alismataceae								
<i>Luronium latans</i> (L.) Rafn.	1900			Europe, N Africa	unknown	local	unknown	Rich et al. 1995
Juncaceae								
<i>Juncus compressus</i> Kit.	1968			Europe, N America	leisure (anglers footwear)	local	unknown	Reynolds 2002
Magnoliophyta, Magnoliopsida								
Ceratophyllaceae								
<i>Ceratophyllum submersum</i> L.	1989	1989		Europe	ornamental, birds	local, spreading	fouling	Smith & Wolfe-Murphy 1991, McNeill 2003, Reynolds 2006
Cnidaria, Hydrozoa								
Clavidae								
<i>Cordylophora caspia</i> (Pallas 1771)	1979	1979		Ponto-caspian	vessels birds	local	unknown	Healy et al. 1982
Acanthocephala, Palaecanthocephala								
Pomphorynchidae								
<i>Pomphorhynchus laevis</i> Muller 1776*	~1700 ?			Europe	fisheries	local established	fish parasite	Kennedy et al. 1989, O'Mahony et al. 2004

Species	Year of first record and recipient zone			Native origin	Known or likely spread	Current status	Impact in Ireland	References
	Fresh waters <1psu	Brackish waters 1-30psu	Marine waters >30psu					
Echinorhynchidae								
<i>Acanthocephalus anguillae</i> (Müller 1790)*	~1700 ?			Europe	stocking	local, established	fish parasite	Black 1978, Kennedy et al. 1989
<i>Acanthocephalus lucii</i> (Müller 1776)*	~1700 ?			Europe	stocking	established	fish parasite	Holland & Kennedy, 1997
Plathelminthes, Trematoda								
Diplostomatidae								
<i>Posthodiplostomum cuticola</i> (Nordmann 1832)*	<1960s			Europe	fisheries, birds	established	fish parasite	Holland & Kennedy 2003
<i>Tetracotyle percafluviatilis</i> (Linstow 1856)*	~1700s			Europe	fisheries birds	no recent record	fish parasite	Holland & Kennedy 1998
<i>Tylodelphys clavata</i> (Nordmann 1832)*	1980s			Europe	fisheries, birds	established	fish parasite	McLoughlin & Irwin 1991
<i>Tylodelphys podicipina</i> (Kozicka & Niewiadomska 1960)*	1990			Europe	Fisheries, birds	local, no recent record	fish parasite	El-Toumi & McCarthy 1990
Discocotylidae								
<i>Diplozoon paradoxum</i> von Nordman 1832*	1950s			Europe	leisure, fisheries	unknown	fish parasite	Stranock 1979, Holland & Kennedy 1998
Dendrocoelidae								
<i>Bdellocephala punctata</i> (Pallas 1774)*	1972			Europe	unknown	no recent records	fish parasite	McCarthy 1973
Caryophyllaeidae								
<i>Caryophyllaeides fennica</i> (Schneider 1902)*	~1700?			Europe	fisheries, leisure	local, unknown	fish parasite	Kennedy 1966
<i>Caryophyllaeus laticeps</i> (Pallas 1781)*	~1700?			Europe	fisheries, leisure	local, unknown	fish parasite	Holland & Kennedy 1998
Diphyllobothriidae								
<i>Ligula intestinalis</i> (Linnaeus 1758)*	~1973			Europe	leisure, birds	widespread, established	fish parasite	Bean & Winfield 1989
Platyhelminthes, Cestoda								
Diphyllobothridae								
<i>Diphyllobothrium latum</i> (Linnaeus 1758)*	<1945			Europe	leisure fisheries birds	local	fish parasite	Holland & Kennedy 1998
Annelida								
Hirudinidae								
<i>Erpobdella testacea</i> (Savigny 1820)	1900s			Europe	unknown	local, established	unknown	McCarthy 2002
Serpulidae								
<i>Paralaeospira malardi</i> Caullery & Mesnil 1897		<1977		S. hemisphere?	vessels	local, no recent record	unknown	Knight-Jones & Knight-Jones 1977
Spirorbidae								
<i>Pileolaria militaris</i> Claparède 1868		<1977		warm and tropical seas	vessels	local, no recent record	unknown	Knight-Jones & Knight-Jones 1977
Mollusca: Gastropoda								
Planorbidae								
<i>Planorbarius cornuta</i> (Linnaeus 1758)	1895			Europe	ornamental	established	unknown	Anderson 1977, 1983
Viviparidae								
<i>Viviparus viviparus</i> (Linnaeus 1758)	1990s			Europe	leisure, ornamental	established, local	unknown	McMillan & Zeissler 1990, Cotton INJ, Minchin et al. 1998
Mollusca: Bivalvia								
Myidae								
<i>Mya arenaria</i> (Linnaeus 1758)		<1900	<1900	N. America	live food, vessels, larval drift	widespread established	unknown	Ryan 1993

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Species	Year of first record and recipient zone			Native origin	Known or likely spread	Current status	Impact in Ireland	References
	Fresh waters <1psu	Brackish waters 1-30psu	Marine waters >30psu					
Pholadidae								
<i>Martesia striata</i> (Linnaeus 1758)			1871	circum-tropical	in timber	not established	none	J Nunn pers.com.
Teredinidae								
<i>Teredo navalis</i> Linnaeus 1758		1845	1845	SE Asia?	vessels	probably established, no recent records	damaging timber piles	Minchin 2004
Arthropoda: Amphipoda								
Corophiidae								
<i>Monocorophium sextonae</i> Crawford 1937			1982	S. hemisphere?	vessels	widespread, established	competition	Costello 1993
<i>Monocorophium insidiosum</i> Crawford 1937	2002	2002		N Atlantic	unknown	local	unknown	Oliver et al 2007
<i>Corophium multisetosum</i> Stock 1952	1993			Europe	vessels	local, established	unknown	De Grave & Wilkins 1994
Arthropoda: Copepoda								
Caligidae								
<i>Caligus pageti</i> Russel 1925*			1986	Mediterranean	vessels	local, may be established	unknown,	Holmes 1998
Mytilicolidae								
<i>Mytilicola intestinalis</i> Steuer 1902*			1948	Mediterranean	vessels, aquaculture	local, established	gut parasite of mussels	Grainger 1951, Crowley 1972, Murray 1972
Sabelliphilidae								
<i>Herrmannella duggani</i> Holmes & Minchin 1991*			1982	unknown	vessels, aquaculture	South and west coasts, no recent records	may damage oyster <i>Ostrea edulis</i> gills	Holmes & Minchin 1991
Lichomolgidae								
<i>Critomolga actinae</i> D.V.*			1973	Europe	vessels	established	unknown	Briggs 1973
Cyclopinidae								
<i>Muceddina multispinosa</i> Jaume & Boxshall 1996			1982	Mediterranean, eastern Atlantic islands	vessels	rare, no recent record	unknown	Holmes & Gotto 2000
Taeniacanthidae								
<i>Taeniastrotos sp.*</i>			1993	Indo-Pacific?	vessels	local, no recent record	unknown	Holmes & Minchin 1985b
Ergasilidae								
<i>Ergasilus gibbus</i> (Nordmann 1832)*	1969			Europe	leisure, fisheries	local established	unknown	Kennedy 1993
Porcellidiidae								
<i>Porcellidum ovatum</i> Haller 1879			1991	Pacific?	vessels, aquaculture	established, local	unknown	Holmes 1991
Laophontidae								
<i>Heterolaophonte hamondi</i> Hicks 1975			1986	unknown	vessels	no recent record	unknown	Murphy & Holmes 1990
Arthropoda: Isopoda								
Limnoriidae								
<i>Limnoria quadripunctata</i> (Holthuis 1949)			1995	unknown	vessels, drift wood	no recent record	unknown	Holmes 1996
Arthropoda: Cirripedia								
Scalpellidae								
<i>Pollicipes pollicipes</i> (Gmelin 1769)			1900	E N Atlantic	vessels	individuals, no recent record	unknown	Thompson 1856
Arthropoda: Decapoda								
Astacidae								
<i>Austropotamobius pallipes</i> (Lereboullet 1858)	1100s?			W Europe	fisheries, stocking	established, widespread	not studied	Reynolds 1997, Holdich et al. 1999, Gouin et al 2003
Arthropoda: Cladocera								
Daphniidae								
<i>Daphnia atkinsoni</i> Baird 1859	1970			Europe	ornamental, birds	no recent record	unknown	Fryer 1985

Species	Year of first record and recipient zone			Native origin	Known or likely spread	Current status	Impact in Ireland	References
	Fresh waters <1psu	Brackish waters 1-30psu	Marine waters >30psu					
Bryozoa, Phylactolaemata								
Lophopodidae								
<i>Lophopus crystallinus</i> (Pallas 1768)	1856			Europe	ornamental	no recent record	unknown	Smith 1994
Chordata: Ascidiacea								
Didemnidae								
<i>Didemnum sp.</i>			2005	unknown	vessels	established two localities	overgrows benthos	Minchin & Sides 2006
Ascidiidae								
<i>Phallusia mamillata</i> (Cuvier 1815)			<1979	Europe	vessels	one bay established	unknown	Minchin 2000
Chordata: Pisces								
Cyprinidae								
<i>Abramis brama</i> (Linnaeus 1758)	1600s			Europe	fisheries	established	hybridises	Moriarty 1982, Hayden 2002
<i>Gobio gobio</i> (Linnaeus 1758)	1600s			Europe	unknown	established	unknown	Hayden 2002
<i>Phoxinus phoxinus</i> (Linnaeus 1758)	1600s			Europe	ornamental	established	unknown	Hayden 2002
<i>Scardinius erythrophthalmus</i> (Linnaeus 1758)	1600s			Europe	fisheries	established	hybridises	Went 1950
Esocidae								
<i>Esox lucius</i> Linnaeus 1758	<1682			Europe	fisheries	widely distributed	predator	Went 1957
Cobitidae								
<i>Barbatula barbatula</i> (Linnaeus 1758)	1600s			Europe	ornamental	established	unknown	Hayden 2002
Percidae								
<i>Perca fluviatilis</i> Linnaeus 1758	1600s			Europe	fisheries	established	competitor	Hayden 2002
Gasterosteidae								
<i>Pungitius pungitius</i> Linnaeus 1758	1856			Europe	unknown, ornamental	established	unknown	Hayden 2002
Chordata, Amphibia								
Ranidae								
<i>Rana temporaria</i> Linnaeus 1758	1700s			Europe	unknown, ornamental	established	unknown	Hayden 2002, Marnell 1998
Salamandridae								
<i>Triturus vulgaris</i> (Linnaeus 1758)	not known			Europe	ornamental	established, local	unknown	Hayden 2002, Marnell 1999

NOTES: * parasites and commensals