Marine Engineering Biosecurity

Eco-engineering in an urbanised marine environment - encouraging the return of native species

An ‘urbanised’ marine environment typified by man-made structures, chemical pollution and reduced water circulation can favour INNS through factors such as:

- Providing stepping stones for rapid spread of INNS.
- Providing substrates of a physical and chemical nature that favour INNS over native species.
- Artificial surfaces are often vertically orientated and therefore shaded – favouring non-native fauna – especially those that have arrived on ship’s hulls.
- Water movement is often slowed and result in accumulation of INNS larvae or spores.
- Antifouling and polluting heavy metals facilitate INNS dominance over native species.
- Fast-growing or opportunistic INNS will establish on new artificial surfaces faster than native species.
- Lack of natural predators / grazers on artificial substrata encourages INNS dominance.

Eco-engineering can reverse some of these factors by providing more naturalised habitats that encourage the return of native species that then outcompete INNS. It has, however, not been tested globally and the results of eco-engineering trials from one region might not apply equally in others, but so far results are promising. Dafforn cites some encouraging values:

- Building with natural stone instead of artificial substrates can reduce space occupation by INNS up to 54% and increase native species by 45% over time.
- Building with specially formulated concrete (e.g. ECOncrete®) compared to standard concrete can reduce INNS richness by up to 50% and increase native species richness by ~ 43%.
- Building fixed rather than shallow, floating (e.g. pontoon) structures can reduce

INNS richness by 28%.

- Reducing shading (e.g. by building on a gentle gradient or adding light penetrating features ('skylights') to over-water structures) and design structures to mimic naturally complex habitats could reduce INNS dominance by 50–90%.
- Controlling metal contaminant inputs (e.g. storm water management, antifouling regulations) could increase native species richness by 34% and reduce INNS dominance (space occupation) by up to 29%.
- "Pre-seeding substrates" (i.e. rearing algae spores on substrates that are then planted on to man-made objects) with native fouling species (e.g. habitat forming algae) can reduce occupation by INNS by up to 33%). Restoration of threatened algal-dominated communities by pre-seeding is now shown to be successful.
- Increasing native predator abundance on artificial structures (e.g. by increasing connectivity to benthos) can reduce INNS dominance (e.g. ascidians) by ~ 50%.
- Improve flushing in marinas to reduce water retention.
- Use of non-toxic antifouling paints.
- Manage storm water runoff.
- Shift from hard defence structures to natural coastal protection.

The Sydney Metropolitan Catchment Management Authority and Department of Environment and Climate Change produced a Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries that illustrates eco-engineering and the benefit of discouraging INNS by the improvement in habitat complexity of man-made structures by building sea defences using natural materials and enhancing vertical harbour walls by adding boulders and more complex structures in front of them.

A seawall created in the Hawkesbury River estuary, which highlights a number of the design principles discussed, including gentle slopes and a variety of habitats.
Image courtesy of Danny Wiecek (DECC)

A seawall at McMahons Point, Sydney Harbour, purposely designed to include pools in the structure for habitat, and boulders at the toe for additional habitat.
Image courtesy of Danny Wiecek (DECC)

Images courtesy of Danny Wiecek (DECC)
http://www.environment.nsw.gov.au/research-and-publications/publications-search/environmentally-friendly-seawalls

Concrete 'Bioblocks', built to provide additional suitable habitats within a sea walls and breakwaters, are aimed at increasing the biodiversity of developed areas of shoreline. Small scale studies are underway in N Wales and may also result in a reduction in the proportions of INNS if such structures are used widely in sea defences. Part of the proposal for the development of the Swansea Bay tidal energy lagoon includes eco-friendly design and sourcing local natural materials (limestone) for creating the lagoon wall. This would potentially enhance biodiversity and at the same time reduce the opportunities for INNS to become invasive.

Images courtesy of Louise Firth, https://www.seacams.ac.uk/case-study/9/

Summary

In short, encouraging, supporting and even artificially establishing native species can facilitate the fight against invasive species. Although INNS are robust and adaptive they are also opportunistic – making the most of any vacancy that has been left when native flora and fauna are absent, for example on new infrastructure. By making sure these vacancies do not appear we can lessen the opportunities for INNS to get a foothold.

Ballast water treatment and handling

Large cargo vessels have to fill or partially empty their ballast tanks in order to maintain stability when underway. This is balanced against the amount of cargo they have on board by taking on water or pumping it overboard. Ballast water exchange at sea or in port has resulted in the unintentional transference of marine species thousands of miles outside their natural range. This has resulted in not only small planktonic animals and plants being shipped around the world, but also fish such as lion fish (*Pterois* spp.) and even pathogens such as cholera which once released can contaminate shellfish and be passed into the human food chain.

The Ballast Water Management Convention aims to 'prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments'. In practice this is achieved by a variety of on-board treatments such as filtration combined with UV light, chemical or heat treatment and ensuring water is exchanged mid-ocean where coastal species are far less likely to survive. Dock-side ballast water treatment facilities, working to IMO guidelines, are also available in some ports that process ballast water using similar filtration and decontamination equipment before returning it to the sea. For more information on the Ballast Water Convention click here. The Globallast programme did a lot to forward our understanding of ballast water treatment.

Boat hulls and marina structures – removing INNS and decontamination

Hull cleaning and inspection

Targeted removal of INNS by hand from boat hulls and marina components by divers and snorkelers has been attempted and may visibly reduce the amount of INNS but its long term effectiveness is questionable unless a species is reasonably easy to identify and handle, such as a starfish, for example. Handling less substantial species or colonies can either cause break up of colonies into viable fragments that can re-establish nearby or stimulates larval or spore release that disperses the target species further. For the same reasons in-water hull cleaning by hand scrubbing or mechanical means should be avoided, unless the debris can be prevented from dispersing into the surrounding water (deposits to the seabed, including those from hull fouling, require a licence in England). In-water hull scrubbing can also disperse toxic antifouling paint fragments that can weaken native species and actually encourage some INNS, for example some bryozoans are tolerant of copper and other toxins used in antifouling coatings.

Diver-operated hull cleaning system

Image courtesy of WA Marine http://www.wamarine.co.uk/

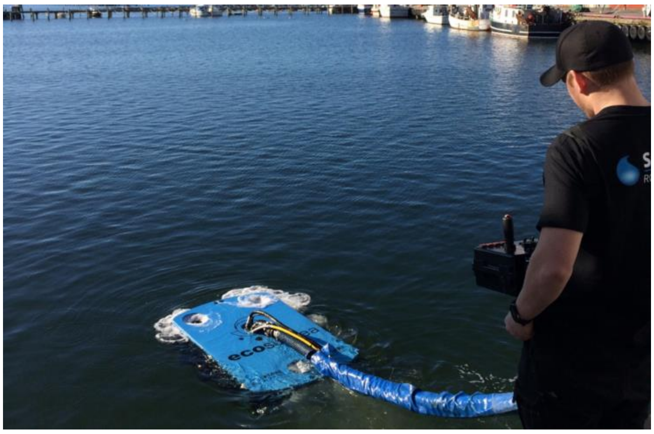
Methods for hull inspection vary around the world. In Australia and New Zealand, divers are used to inspect hulls for INNS. Where this is not suitable for example because of the size of the vessel, and dry docks is also not an option, Remotely Operated Vehicles (ROVs) are used to inspect larger ships and endoscopes used to examine obscured spaces in pipes and seachests. This technique is also used in the UK.

Cleaning of hulls is done most effectively out of the water; however, this is not always possible, particularly for larger vessels and so a number of in-water cleaning devices have been developed.

A device for the ‘clean’ removal of fouling organisms from large ship hulls has been developed by Ecosubsea based in Southampton and Norway. Their system is remotely operated rather than controlled by divers in situ and is highly efficient at the collection of 97.5% of fouling organisms and debris with minimal contamination of the surrounding water. This approach has been welcomed by the sector in the UK and it is expected that this will be rolled out further in future.

The Ecosubsea hull cleaning system is designed for large ship hulls and is operated remotely from a containerised module.

Image courtesy of Ecosubsea
https://www.ecosubsea.com/



The Ecosubsea system is operated remotely from the surface.

Image courtesy of Ecosubsea
https://www.ecosubsea.com/

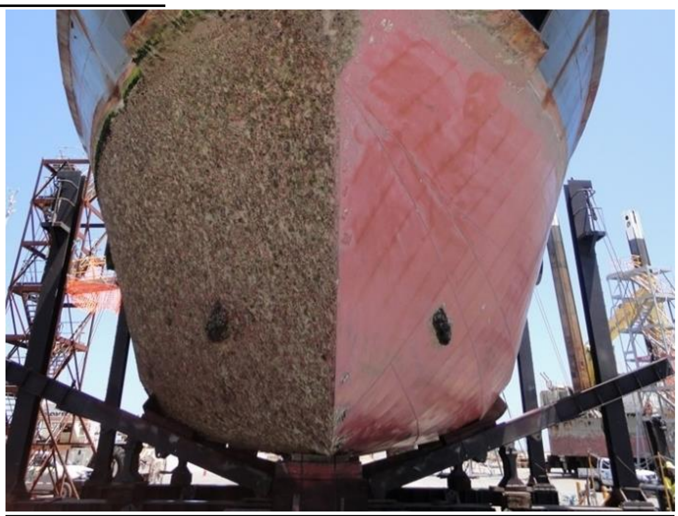
A similar system for difficult to retrieve vessels (e.g. larger vessels or where facilities do not exist) called Envirocart that either uses rotating blades, for cleaning steel, hulls or brushes, for GRP hulls, has been developed in Western Australia by Franmarine. All debris is pumped aboard and passed through a filtration system before the water is discharged. The system has various specialist cleaning tools to deal with anodes and water intake gratings.

Envirocart cleaning vessel hull. Image courtesy of Envirocart
https://www.grdfranmarine.com.au/

On deck filtration system
Image courtesy of Envirocart
https://www.grdfranmarine.com.au/

The blade tool head of the Envirocart. Image courtesy of Envirocart
https://www.grdfranmarine.com.au/

50:50 cleaned hull
Image courtesy of Envirocart
https://www.grdfranmarine.com.au/

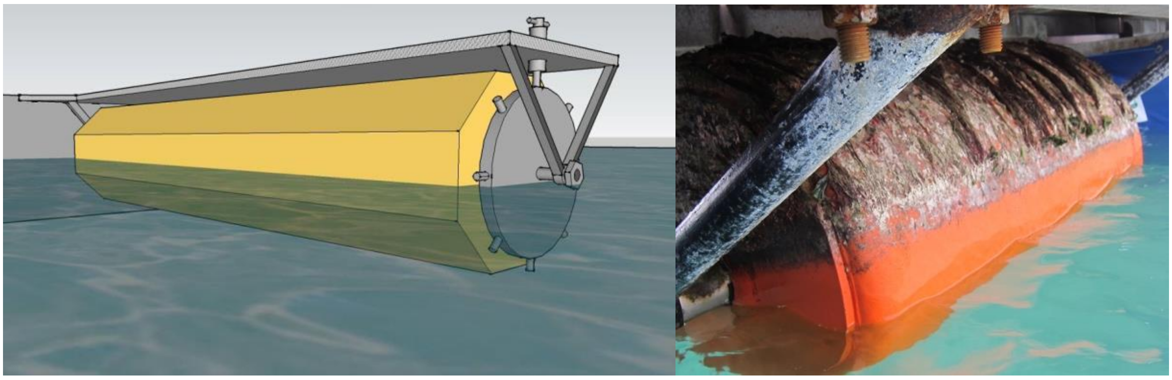


Air drying

Probably the most effective and least damaging approach to removing marine fouling organisms is to dry the structures by removing them from the water. This is most cost effective for smaller vessels such as recreational boats. Complete mortality can be achieved within a few days in dry, hot (or very cold) conditions, although species normally adapted to survive in the intertidal or in sediment can survive in dark crevices, or mud adhering to the hull, for longer if the weather is damp and cool. For this reason drying moorings, used by many recreational boats, offer some protection against INNS but are not 100% effective.

If boats and marina structures can be removed from the water seasonally, over winter or when not in use for example, this is sufficient to kill off all attached marine growth. Many marinas now offer a 'dry stack' service where smaller craft can be retrieved and launched when the customer requests. Modular marina pontoons have also been designed to make components easy to disassemble and swap on a rotational basis (e.g. every 6-9 months). To improve biosecurity, this should be designed into new developments, however, on established developments, alternative engineering solutions may be available.

As part of an eradication attempt of the invasive carpet sea-squirt *Didemnum vexillum* in Holyhead marina (Holt and Cordingly 2011), a prototype cylindrical float on an axel was tested and shown to work effectively in place of conventional box-shaped floats. Rotating the submerged 'fouled' portion of the float through 180º into the air killed off any marine growth and presented a clean surface into the water. The principle requires the building of an axle with a float of sufficient buoyancy to support the walkway deck and at the same time keep the axle just above the water surface. The float should be rotatable but lock in position where required. Although more expensive to build than conventional floats, savings could be made through minimising fouling, and therefore the need to clean, in the long-term.



Experimental rotating pontoon developed in Holyhead marina. Conceptual diagram (left) and working prototype that has just been rotated 180º (right). Images courtesy of Rohan Holt, Natural Resources Wales

Boat lifts such as the "Hydrohoist" system are designed to keep boat hulls out of the water without needing to remove the boat to hard standing minimising the need for hull cleaning and antifouling. This also results in improving fuel efficiency, reduced corrosion, improved biosecurity and minimised leaching of antifouling compounds into the water. The system comprises of a cradle supported on floodable pontoon floats that lift the boat out of the water when air-filled via a small compressor and re-flooded to launch the boat. The operational size of the boat lift/vessel is limited by physical size of the boat, the minimum depth of water below its position, and a suitable secure pontoon side for anchorage/mooring for the lift.

Sunstream boat lift supporting a rigid hulled inflatable at Deganwy marina, Conwy.
Image courtesy of Rohan Holt, Natural Resources Wales

Sunlift systems adopt the same principle of keeping the boat's hull suspended above the water when not in use but make use of hydraulic legs attached to the seabed (more often lake bed). The system is suitable for areas that have little, or no, intertidal range.

Sunlift systems to use in freshwater or marine situations with small tidal ranges.

Images courtesy of Sunstream Boat Lifts and Cover Systems
http://sunstreamcorp.com/

The biosecurity benefits are mainly gained through reducing the risk of transporting an invasive species that might already be established in a marina. While the boat lift itself is colonised, the hull fouling on the boat is minimised, and therefore potential to spread the INNS is significantly reduced.

Jet washing on hard standing and closed loop wash-down systems

Routine hull cleaning and re-application of antifouling coatings will remove virtually all growth from vessel hulls and can be completed, for typical leisure yachts and power boats, in less than a day. Most boatyards have facilities to crane/hoist a boat onto a cradle or trailer positioned on hard standing well away from the shoreline. Pressure washing run-off should not be allowed to enter drains or back into the harbour. All debris, which can contain a mixture of live material and antifouling, should be collected and disposed of as contaminated waste.

A heavily fouled yacht brought ashore by mobile crane for jet washing. The location is suitably isolated from the marina to prevent any accidental re-introduction of live material back into the harbour.

Image courtesy of Rohan Holt, NRW

Operating on the same principle as the Hydrohoist described above the Sealift system and the drive in boat wash are useful hull cleaning services. Vessels can drive on to the adjustable cradle and be brought above the waterline for rapid jet washing and antifouling treatment. It is important that such systems have an on-board water treatment plant to capture jet washings and avoid any living or contaminated material being washed back into the sea.

Images courtesy of Sealift
http://sealift3.com/

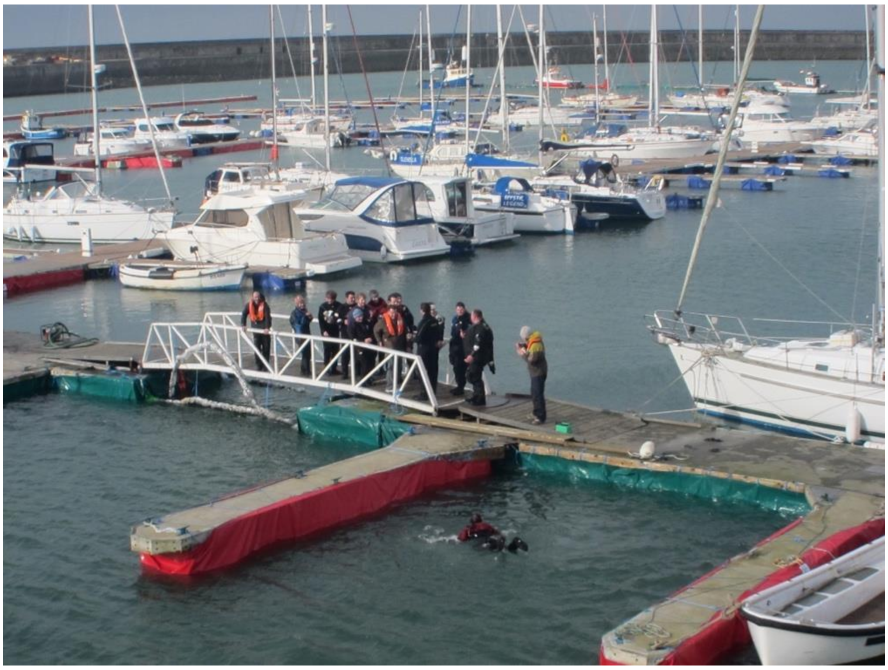
Further information on boat hull cleaning systems can be found in the RYA The Green Blue's *Green Guide to Boat Washdown Systems* that details various hull jet-washing systems with water recycling / filtration and disposal. The Green Blue also has a factsheet documenting the whereabouts of closed loop washdown systems in the UK.

In-water encapsulation, chemical treatment and decontamination

Encapsulation has been used as an emergency measure to isolate and eradicate invasive species in marinas, on moorings and boat hulls. It is a labour-intensive, non-routine action usually targeted against a specific INNS such as *Didemnum vexillum* where, for example, its occurrence in New Zealand and the UK has threatened natural marine biodiversity and commercial shellfish stocks.

The process involves firstly isolating the invasive species by enclosing it and the surface it is growing on inside a waterproof barrier (e.g. PVC coated polyester bags or sheet polythene) to prevent any water exchange. This also halts dispersal of propagules and viable fragments and also initiates a stagnation reaction that, over time, causes anoxia and kills the contents of the enclosures. The process can be accelerated using a biocide such as calcium hypochlorite ('swimming pool chlorine') or acetic acid and results in 100% mortality of all marine life in a few days. Ideally the process should be initiated when the target species, *Didemnum vexillum* for example, is 'dormant' or at least not in a state where the process might initiate larvae or spore production – which for *D. vexillum* is mid to late winter when the sea temperature is at its lowest. Re-infestation often occurs as any fragments left can re-attach and reproduce, so checks and multiple treatments are often required.

Small finger pontoon floats covered by PVC coated polyester bags.
Image courtesy of Rohan Holt, NRW



All floating pontoons, chains, service cables and pipes plus moored contaminated vessel hulls treated simultaneously.
Image courtesy of Rohan Holt, NRW

Moored vessels' hulls, too large (more than 30 m) to be craned out using local facilities, and can be treated in a similar manner using larger versions of the enclosures used to treat marina pontoon floats. Chains and ropes anchoring the marina pontoons in place, plus chains and ropes on swinging moorings can also be treated by wrapping in sheet polythene plastic, cable-tied in place. Hypochlorite granules can also be introduced to the plastic wrap in porous cloth 'socks'.

Larger vessels, found to be colonised by D vexillum were treated in situ at Holyhead, if they could not be 'slipped' ashore for biocide treatment at low water.

Image courtesy of Rohan Holt, NRW

The same principles have been applied to designing a 'decontamination berth' intended for more routine use in marinas and harbours that are dealing with an invasive species incursion or are aiming to prevent one arriving. Vessels suspected of harbouring an unwanted species on their hull moor inside the berth for a few hours while the chemical treatment is introduced. Once completed, the biocide is pumped back out into a reservoir for re-use, and the vessel leaves.

A prototype in-water boat encapsulation system was developed in response to the introduction of the ascidian *Didemnum vexillum* in Wales, UK (Roche et al 2014). The 'decontamination berth' comprised a hull-shaped PVC coated canvas bag, suspended under air-filled floatation chambers, into which a recreational vessel could be driven without the need to remove it from the water. Once the rear skirt of the bag was drawn above the water line, excess water was pumped out and replaced by a suitable chemical / biocide stored in a separate flexible floating chamber adjacent to the berth. Laboratory tests of treatment chemicals showed that acetic acid and sodium hypochlorite were equally effective in reducing *D. vexillum* growth following exposures of 30 minutes. It should be noted that any chemical treatments are likely to require a licence to undertake them and should only be undertaken under close supervision by experts to prevent unintended consequences for both the marine environment and workers.

The inflatable bladders supporting the decontamination berth. This prototype could treat vessels of approximately 10m length.
Image courtesy of Rohan Holt, NRW

A small vessel being driven into the berth – the rear flap is brought above the waterline once the boat is inside the berth.

Image courtesy of Rohan Holt, NRW

Smothering sediment habitats to clear INNS

The technique of smothering has been used mainly in the aquaculture setting but there is potential for wider application should the species and the infested environment suit the method.

The slipper limpet *Crepidula fornicata* was found amongst the mussel lays in the Menai Strait, N Wales in 2006. It was thought to have been introduced there accidentally with imported seed mussels from the south coast of England. 'Wanted – Dead or Alive' posters were issued by Countryside Council for Wales, but the most effective way to eradicate it was by removing the mussels and associated material with dredgers then re-burying the area with a thick layer of native mussels and sediment from nearby uncontaminated seabed. Monitoring surveys in the area have not recorded slipper limpets in the area since (Wilson and Smith, 2008).

[Wilson, J. and K. Smith. 2008. Code of good practice for mussel seed movements. Bangor Mussel Growers Association. 26pp]

Emergency Situations

Scuttling of oil rig to prevent INNS incursions to Tristan da Cunha, South Atlantic

The extraordinary loss and subsequent grounding of the oil production platform *A Turtle* on the coast of the South Atlantic island Tristan da Cunha occurred in 2006. A biological survey of the platform revealed at least 20 INNS associated with the structure, including various attached corals, sponges, urchins, barnacles, bivalves and three species of fish that 'followed' the rig as it drifted across the Atlantic since it became separated from its tug off the coast of Brazil four months earlier.

Not all the species were physiologically capable of colonising the new habitat, but many were regarded as potentially high risk to the fragile marine ecosystem and the Tristan spiny lobster fishery on the island. As complete salvage of the now damaged rig was impracticable at this remote location, and the biosecurity risk very high, the decision was made, in these extreme circumstances, to re-float the grounded rig and tow it into deep water (3400 m) and sink it. This took place, after the vessel had been drained of toxic fluids and made as safe as possible, around 7 months after the rig ran aground. At least one fish species porgy *Diplodus argenteus argenteus* settled in Tristan waters and is steadily increasing in numbers.

[Report for Tristan da Cunha government by Enviro-Fish (Pty) Ltd. 2007. Environmental observations and risk assessment: removal of the stranded production platform "A Turtle" Tristan da Cunha.]

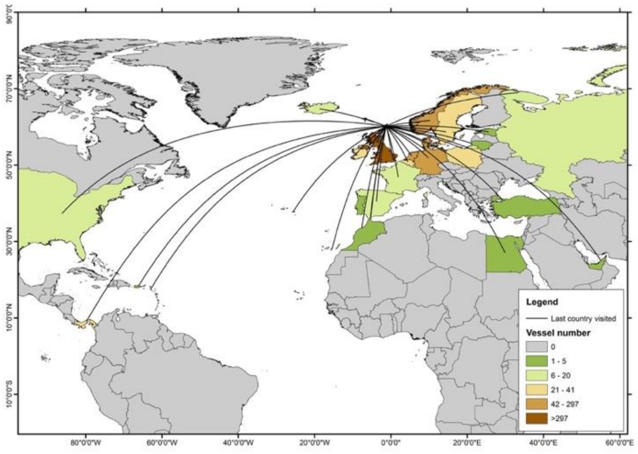
The rig "A Turtle" grounded at Trypot Bay, Tristan, September 2006. (Photo: Jodi Brobhy)

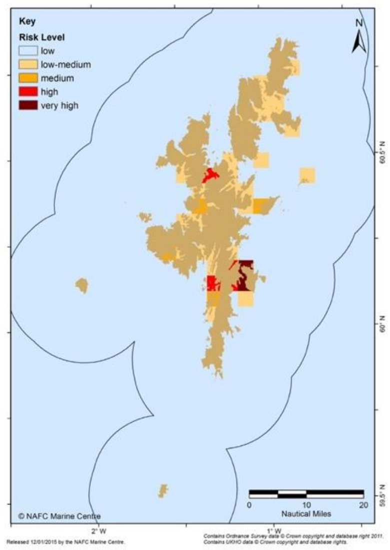
Use of electronic surveillance for biosecurity risk management (AIS)

International transportation by large vessels is a major vector for spreading INNS but keeping track of vessel movements is now possible using Automatic Identification Systems (AIS) which is fitted to all marine vessels over 300 gross tonnage on an international voyage, all cargo vessels greater than 500 gross tonnage, all EU fishing vessels over 15 m in length, and all commercial passenger vessels.

By tracking their movements, the number of vessels travelling through or docking in any port in the World can be assessed complete with information on their previous ports of call, their route and the type of vessel. This information is helpful for risk assessment when undertaking biosecurity planning, for example it was used to good effect in Shetland, however it is difficult to use on each and every vessel for a large port or marina. Remote and relatively isolated ports and harbours can also use it to help them risk assess and verify new arrivals.

By mapping these data, the cumulative risk of a INNS introduction to an area can be assessed, for example, the Shetland Islands has identified that Lerwick harbour area as 'very high' risk and Sullom Voe and Scalloway harbour have been identified as 'high' risk in their Biosecurity Plan for the Shetland Islands.





Images courtesy of Richard Shelmerdine, NAFC Marine Centre