

The Marine Biosecurity Porthole – a web-based information system on non-indigenous marine species in New Zealand

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Abstract

The Marine Biosecurity Porthole was created in 2010 as a collaboration between New Zealand's Ministry for Primary Industries (MPI) and the National Institute for Water and Atmospheric Research (NIWA) to provide greater public access to information and data on non-indigenous marine species (NIMS) in New Zealand. The porthole is primarily an interactive mapping application that allows verified observations on the distribution of NIMS within New Zealand to be displayed. It draws upon data compiled from a range of funded surveys for NIMS, including a series of port biological baseline surveys and a continuing programme of targeted surveillance for high risk marine pests in major shipping ports and marinas. The data also include records from specimens reported via the passive surveillance system and identified through the Marine Invasives Taxonomic Service (MITS), a taxonomic clearing house service for suspect marine organisms, and observations of NIMS made through taxonomic and ecological research undertaken by NIWA. It currently contains information for over 3,600 native, cryptogenic and non-indigenous marine species with links to over 155,000 individual distribution records. Additional features include a searchable catalogue of relevant reports, papers and information about NIMS and on the surveys undertaken to obtain the data. The design and functionality of the portal have been refreshed to provide a better overall experience for users. New features will allow greater filtering and selection of distribution data, more content on NIMS within New Zealand, and connections to social media.

Key words: alien, biosecurity, data portal, marine surveillance, invasive species management, data management

Introduction

Effective management of invasive species depends on being able to source accurate intelligence on the identity of suspect organisms and on changes in the distribution, abundance and virulence of harmful species in a timely manner (Binns et al. 2000). Such information can be gleaned from a range of sources, including from unsolicited reports by members of the public and news media ("passive surveillance"), and through planned scientific surveys ("active surveillance").

Over the past decade, the New Zealand Government has funded a range of passive and active surveillance activities to increase knowledge,

awareness and reporting of non-indigenous marine species (NIMS) within New Zealand. These have included a national series of baseline, early detection and delimiting surveys for NIMS, and measures to enhance awareness and vigilance of the general public and key sectoral groups. Each activity has been funded separately by the Ministry for Primary Industries (MPI; formerly Ministry of Agriculture and Forestry Biosecurity New Zealand), with data collection and management undertaken on a project-by-project basis. As a provider of many of these and, through its own biosystematics and biosecurity research, the National Institute of Water and Atmospheric Research Ltd (NIWA), assumed a *de facto*

curatorial role for much of the national data on NIMS within New Zealand.

In 2010, MPI and NIWA, in association with web developers, SilverStripe, launched an initiative to consolidate the existing data holdings on NIMS in New Zealand and make them more accessible to the general public. This followed a national review of all biosecurity surveillance programmes within New Zealand that highlighted the dispersed nature of data holdings and the restricted access to those data for stakeholders affected by and responsible for management of invasive species (MAF Biosecurity New Zealand 2008). The review and the subsequent New Zealand Biosecurity Surveillance Strategy 2020 (MAF Biosecurity New Zealand 2009) recommended increasing the utility of national surveillance data through consolidation, better analysis and dissemination to a broader range of stakeholders.

The Marine Biosecurity Porthole (<http://www.marinebiosecurity.org.nz>) is a web portal with a searchable mapping application that allows display of New Zealand distribution records for marine species recorded in national biosecurity surveillance programmes. It also provides a gateway to information on important unwanted marine organisms and to resources and information on biosecurity surveillance and research within New Zealand. Its aims are to:

- provide greater access to up-to-date information on the distribution and status of non-indigenous marine species in New Zealand,
- increase public awareness of MPI's marine surveillance programmes and other marine biosecurity activities, and
- encourage greater engagement of affected stakeholders and tangata whenua (New Zealand's indigenous Māori people) in biosecurity surveillance.

Data contained in the portal

Data displayed on the portal are derived from several principal sources.

New Zealand Port Biological Baseline Surveys (PBBS)

Between 2001 and 2007 a nationwide programme of marine biological surveys was undertaken in shipping ports and marinas throughout New Zealand. The purpose of the surveys was to gather baseline information on marine biodiversity within the ports, with a particular emphasis on determining the presence and distribution of

NIMS already extant within the country. The surveys were based on protocols developed in Australia by the CSIRO Centre for Research on Introduced Marine Pests (CRIMP) that have since been applied in more than 15 countries worldwide (Hewitt and Martin 1996, 2001; Campbell et al. 2007). The PBBS are best described as “generalised pest surveys” (Wittenberg and Cock 2001), as they are broad-based investigations whose primary purpose was to identify and inventory the range of species (non-indigenous and indigenous) present in each port. They were taxonomically intensive surveys, in which all specimens collected were identified by recognised experts to the lowest taxonomic unit (LTU) possible and a voucher collection was established for the programme. In total, 43 separate PBBS were completed of shipping ports and marinas within New Zealand (Figure 1), comprising repeated surveys of 13 international shipping ports and three marinas of first entry for cruising yachts and single surveys of an additional nine secondary (“domestic”) ports and two marinas. Data from the PBBS include >60,000 sample records and >2,900 species, including 109 NIMS, 24 of which had not previously been recorded in New Zealand. PDF copies of reports on these surveys can be downloaded from the portal.

Marine High Risk Site Surveillance (MHRSS)

The national Marine High-Risk Site Surveillance (MHRSS) is a programme of surveys that are targeted at the early detection of particular high-risk NIMS. Currently (2014), this list comprises five species that are not known to be present in New Zealand: the Northern Pacific seastar, *Asterias amurensis* Lutken, 1871, the European shore crab, *Carcinus maenas* (Linnaeus, 1758), the invasive aquarium weed, *Caulerpa taxifolia* (M.Vahl) C.Agardh, 1817, the Chinese mitten crab, *Eriocheir sinensis* H. Milne Edwards, 1853 and the Asian Clam, *Potamocorbula amurensis* (Schrenck, 1861). The MHRSS also has two secondary objectives, which are (i) to detect incursions of NIMS not previously recorded in New Zealand, and (ii) to detect range extensions by NIMS that are already established in New Zealand waters.

The MHRSS has been in place since 2002. Surveys are currently undertaken every six months at 11 harbours throughout New Zealand that contain international shipping ports and marinas of first entry (“High Risk Sites”, Figure 2). As their purpose is detection rather than enumeration,

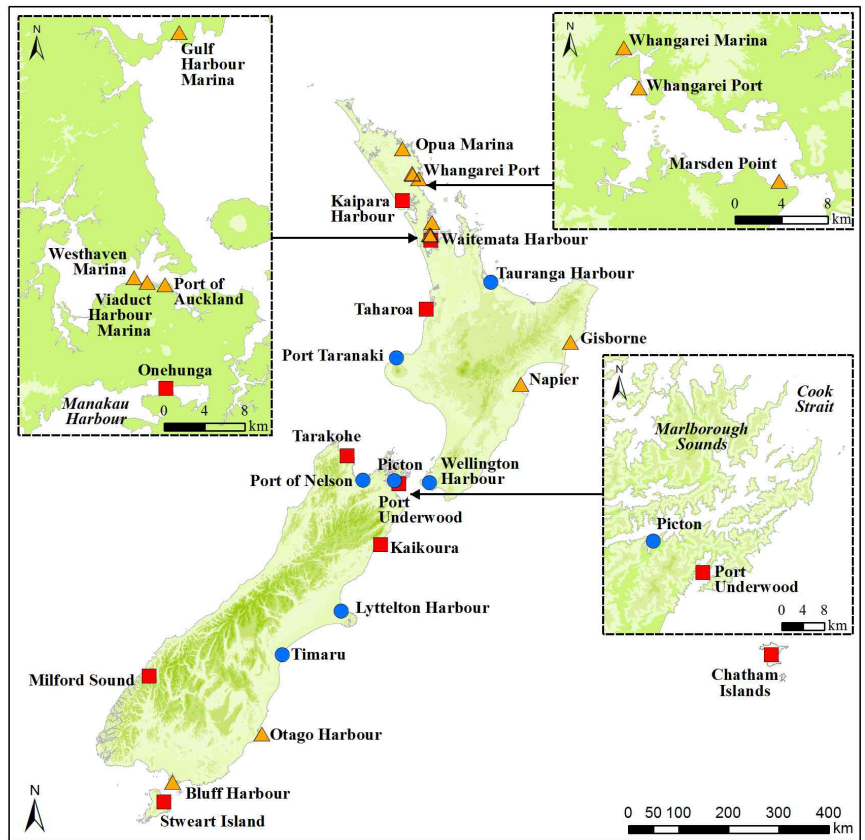


Figure 1. Commercial shipping ports and marinas in New Zealand where Port Biological Baseline Surveys (PBBS) were undertaken. Blue circles = locations surveyed in 2001/2002 and re-surveyed in 2004/2005. Orange triangles = locations surveyed in 2002/2003 and re-surveyed in 2005/2006. Red squares = locations surveyed only once between 2006 and 2007.

survey methods used in the MHRSS allow the presence or absence of the target species to be determined rapidly so that a large number of locations can be sampled on each survey. A risk-based stratification of environments within each harbour is used to prioritise allocation of sample effort based on the likely distribution of founding populations of the primary target species. Details of the sampling and processes used to prioritise survey sites can be found in Inglis et al. (2006) and Morrissey et al. (2012).

At the time of writing, >200 MHRSS surveys have been completed with observations made on >80,000 sample locations and >105,000 specimens. Since its inception, the MHRSS has detected one primary target pest species (the Mediterranean fanworm, *Sabella spallanzanii* Gmelin, 1791, in 2008), >16 non-indigenous species that were not previously known from New Zealand and numerous range extensions by other NIMS, including *S. spallanzanii*; the tunicates, *Styela clava* Herdman, 1881; and *Eudistoma elongatum* (Herdman, 1886),

the decapod crustaceans *Charybdis (Charybdis) japonica* (A. Milne-Edwards, 1961) and *Metapenaeus bennettiae* Racek and Dall, 1965; the Asian bag-mussel, *Arcuatula senhousia* (Benson in Cantor, 1842); and the algae *Undaria pinnatifida* (Harvey) Suringar, 1873 and *Grateloupia turuturu* Yamada, 1941.

Marine Invasives Taxonomic Service (MITS)

The Marine Invasives Taxonomic Service (MITS) was established in 2005, under contract, as a centralized identification and collection management service to support MPI's marine biosecurity programme. It provides expert taxonomic identification and curation of marine organisms (indigenous, cryptogenic, or non-indigenous) collected in all of MPI's marine surveillance, including the PBBS, MHRSS and other active and passive surveillance activities.

The latter include interceptions of marine organisms made by border control inspectors and

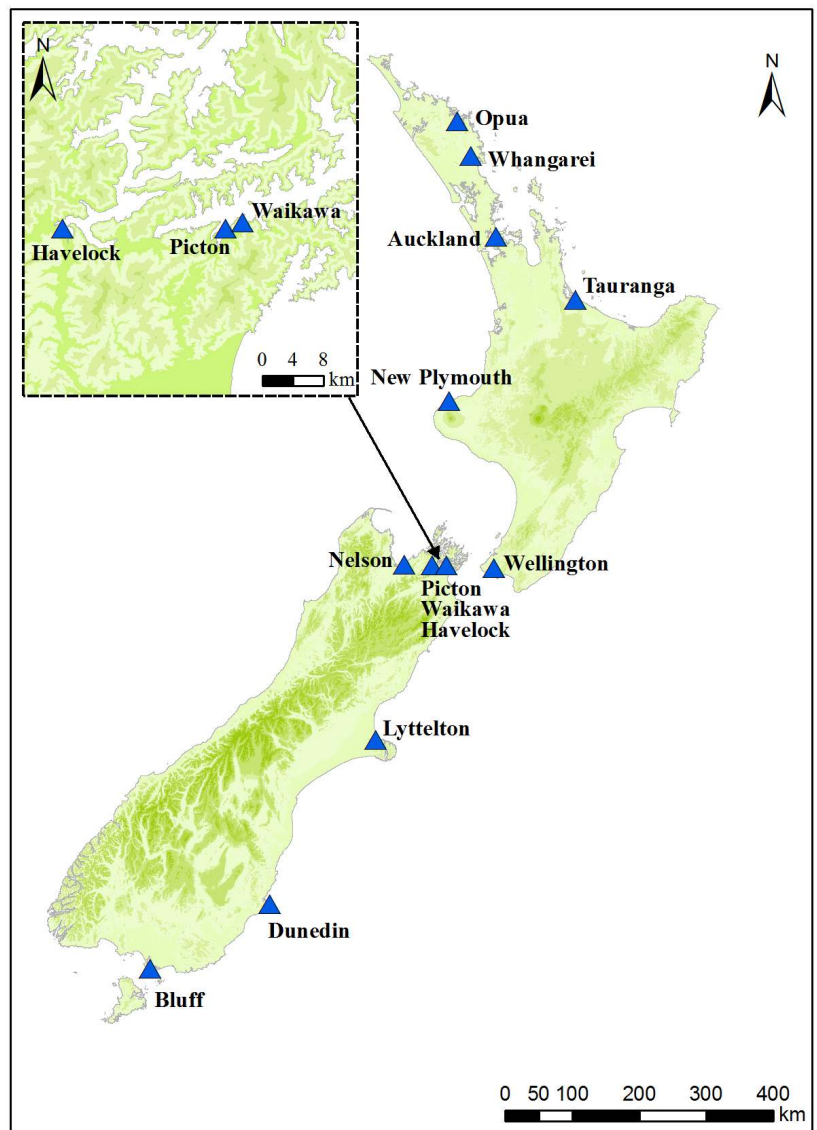


Figure 2. The 11 surveyed locations (where Picton, Havelock and Waikawa are surveyed as one location) in which the Marine High Risk Site Surveillance (MHRSS) is undertaken at six-monthly intervals.

submissions made through MPI's 'Pests and Diseases Hotline'. In addition to specimens identified in the PBBS and MHRSS since 2005, MITS records include >6,500 specimens from surveys of vessel biofouling and >1600 specimens from other submissions.

Other verified observations of non-indigenous marine organisms

As elsewhere, observations of new or unusual species are also made by scientists in the course of other systematic or ecological research and by

members of the public who regularly spend time in or on coastal waters (e.g., fishers, aquaculturalists, divers, Māori, etc). Over 130 NIMS were collected and verified through these observations. In 1998, a team of New Zealand marine scientists published a consolidated inventory of all non-indigenous and cryptogenic species that had been recorded at that time from New Zealand marine environments (Cranfield et al. 1998). The report reviewed existing published records and museum holdings and provided basic information for each taxon about the dates and probable means of introduction to New Zealand and their regional distributions

(although often not specific geographic coordinates). That exercise was repeated in 2010 to incorporate records that had been collected over the intervening 12 years (Kospartov et al. 2010). Both reviews included NIMS that had been reported from New Zealand, but which were not known to have established self-sustaining populations within New Zealand's coastal marine environments. These include, for example, species that were introduced deliberately, but which failed to naturalise (e.g., *Homarus gammarus* (Linnaeus, 1758) and *Cancer pagurus* Linnaeus, 1758 (Cranfield et al. 1998)) and those described from the hulls of visiting vessels or offshore oil platforms (Foster and Willian 1979; Inglis et al. 2010). To date, more than 720 non-indigenous and cryptogenic marine species known to have been recorded from New Zealand waters. Data on all these species have been included in the portal.

Because geospatial information on many historical records of NIMS were not always specific enough to allocate a geographic coordinate to a record, we also implemented a bioregional classification to display the distribution of these species. The bioregions were based on Francis (1996) and were regions of New Zealand's coastal seas within which hydrological conditions, coastal type, indentation and exposure to weather were relatively homogenous and/or which reflected known or suspected biogeographical discontinuities in species distributions (Francis 1996). Classification of a species as being present within a bioregion indicates that it was recorded at one or more locations within the bioregion. It does not imply that it is present throughout the whole bioregion. This caused some confusion among some users for species that are known to have a very restricted distribution within a region.

Features of the portal

The mapping functions of the portal were designed primarily as a means to display the distributions of species collected by the programmes listed above. As such, the portal does not necessarily provide a complete or necessarily up-to-date picture on the geographical distribution of all invasive species. However, the portal is the most comprehensive, publicly available and regularly updated data source on the subject in New Zealand. The records within each programme are searchable by location and by approved taxonomic name. Once an individual species is selected, the user is able to display a range of other metadata

about the species (e.g., its taxonomic hierarchy and its status as native, non-indigenous or cryptogenic within New Zealand) and the sample (e.g., date of collection, sample method, sample station and survey code). A searchable catalogue of reports and other information associated with the PBBS and MHRSS is provided on the site. Most of the reports are available to be downloaded as PDF copies.

The biosecurity status classification used by the portal to reflect the known or suspected geographic origin of a species contains some features that are unique to New Zealand. Understanding this classification is important for evaluating the relevance of the information associated with discovery of a new suspect organism. Our system uses five categories that reflect the occasional uncertainty in assigning a native geographic range to some species: native, non-indigenous, two classes of cryptogenesis and indeterminate taxa (Table 1). Cryptogenic species are not demonstrably native or non-indigenous (sensu Carlton 1996). Cryptogenesis can arise because the species has a cosmopolitan range and was possibly spread by humans before scientific descriptions of marine flora and fauna began in earnest (i.e., historical introductions) or because the species was discovered relatively recently and there is insufficient biogeographic information to determine its true native range (Table 1). Our classification includes two forms of cryptogenesis to reflect these differences. The portal also includes some records of specimens that could not be reliably identified to species ("Indeterminate species"). This was often because the specimen lacked distinguishing morphological features because it was damaged, immature or part of a cryptic complex.

Delivery of the web services

The portal was built to be compliant with the New Zealand e-Government Interoperability Framework Programme (States Services Commission 2008). It uses Open Source tools that are compliant with Open Geospatial Consortium (OGC) standards for web mapping, data distribution and data management. These enable interoperability and compatibility with a wide range of web and desktop GIS and mapping applications. The underlying Relational Database Management System (RDMS) uses Postgres, a powerful OpenSource RDBMS that has an extensive global user base. It supports PostGIS (<http://refractions.net/products/postgis/>), an OGC compliant extension that allows geometric

Table 1. Definitions used on the biosecurity status of organisms within the Marine Biosecurity Porthole.

Status	Definition
Native	Species that occurred within the New Zealand biogeographical region historically and have not been introduced to coastal waters by human mediated transport.
Non-indigenous	Species known or suspected of being introduced to the New Zealand biogeographical region as a result of human mediated transport. Criteria established by Chapman and Carlton (1994) were used to evaluate the likelihood that the species is non-indigenous. These are: <ol style="list-style-type: none"> 1. Has the species suddenly appeared locally where it has not been found before? 2. Has the species spread subsequently? 3. Is the species' distribution associated with human mechanisms of dispersal? 4. Is the species associated with, or dependent on, other non-indigenous species? 5. Is the species prevalent in, or restricted to, new or artificial environments? 6. Is the species' distribution restricted compared to natives? <p>The global distribution of the species was evaluated against a further three criteria:</p> <ol style="list-style-type: none"> 7. Does the species have a disjunctive worldwide distribution? 8. Are dispersal mechanisms of the species inadequate to reach New Zealand, and is passive dispersal in ocean currents unlikely to bridge ocean gaps to reach New Zealand? 9. Is the species isolated from the genetically and morphologically most similar species elsewhere in the world?
Cryptogenic 1	Species previously recorded from New Zealand whose identity as either native or non-indigenous is ambiguous. This uncertainty may be because the species was spread globally in the era of sailing vessels, prior to scientific investigation such that it is no longer possible to determine their original native distribution. Also included in this category are recently described species that exhibited invasive behaviour in New Zealand (Criteria 1 and 2 above), but for which there are no known records outside the New Zealand region.
Cryptogenic 2	Species that have recently been discovered but for which there is insufficient systematic or biogeographic information to determine whether New Zealand lies within their native range. This category includes previously undescribed species that are new to New Zealand and/or science.
Indeterminate taxa	Specimens that could not be reliably identified to species. This group includes: <ol style="list-style-type: none"> 1. Organisms that were damaged, immature or belonged to species complexes that contain multiple cryptic species and which lacked morphological characteristics necessary for identification, and 2. Taxa for which there is not sufficient taxonomic or systematic information available to allow identification to species.

data types (points, lines and polygons) to be displayed and functions/operators for working with them.

Initial development of the architecture and tools used to create the portal were based on an existing project developed by NIWA to display data from a series of coastal marine surveys; the Ocean 20/20 Bay of Islands Coastal Survey Project (<http://www.os2020.org.nz>).

The software applications used to build the portal include:

- Linux as the underlying operating system on the servers supporting the portal, web mapping and most database servers. <http://www.linux.com>
- Apache as the web server application supporting the portal server and web map server. <http://www.apache.org>
- PostGIS as the spatial database used to manage the data underlying most map layers. <http://www.postgis.org>

- SilverStripe as the CMS used to run the portal. <http://www.silverstripe.org>
- OpenLayers as the embedded web mapping client. <http://www.openlayers.org>
- UMN Mapserver as the WMS/WFS server application providing map layers to the portal. <http://www.mapserver.org>
- Atlas as the image (photograph) management tool providing access to photographic datasets. <http://www.atlasmd.com>
- ESRI ArcServer to manage and supply bathymetry data to the portal (via mapserver). <http://www.esri.com>.

The database that supports the layers being displayed was created specifically for the portal. This involved converting all project information initially stored in several Microsoft Access 2014 databases and one Specify database (<http://specifysoftware.org/>) for use in a PostGIS system. Some technical issues arose around consolidation of

the data as some records were initially duplicated across the multiple databases that fed into the portal. Amalgamation of the separate datasets allowed this replication to be removed and created a more universal repository that can be queried for species distribution information. All data collected during the separate surveillance programmes have gone through several rounds of quality control. In most cases, data collected in the field in hard copy format were transcribed into MS Excel templates and checked for accuracy and completeness by nominated project members and managers prior to import into the database. Species records were verified using experts in each taxonomic field. The record and all sample locations collected in the field were converted into New Zealand Transverse Mercator 2000 (Land Information New Zealand 2007) and their accuracy examined using ArcGIS software (ESRI 2014) before being released to the portal.

Because of the QA/QC procedures implemented in the survey programmes, data displayed in the portal are accurate records of a species' presence in a location. However, the portal does not necessarily contain all available data on a NIMS in New Zealand. Distribution data collected during incursion response activities (including delimiting surveys), or by other research programmes, regional authorities, and other end-users are not necessarily included.

The source databases are still in use in their original capacity as they each had a different purpose and scope and are used to feed into the combined PostGIS database. As the data are regularly updated with new records from the most recent MHRSS surveys and submissions to MITS (on average over 5600 species and sample records are loaded every 6 months), the portal provides a platform to track and display changes in the distribution of NIMS through time at local (within an embayment) and national scales.

Current and future directions

The creation of the Marine Biosecurity Porthole has allowed greater access to and visibility of distribution information on NIMS within New Zealand. Stakeholder engagement with the MHRSS surveys and MPI's biosecurity surveillance activities appears to have increased as the results from the surveys have become more available and visible. As use of the site has increased, so have requests from stakeholders for greater functionality and more information on the site,

including more immediate access to recently collected data. At the time that this manuscript was prepared, MPI and NIWA, in association with web designers, Stripe-the-Web, were refreshing the design and content of the portal and adding new features that will make the site more interactive and allow greater access to data. The new features include updates via a regular news section, more information about active research programmes, connections to social media, better access to meta-data and reports, improved facilities for download of data queries and more options for searching within the datasets using a wider range of metadata. The new features are scheduled for re-launch in early 2015.

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